SREE VAAGESWARI EDUCATIONAL SOCIETY
VAAGESWARI COLLEGE OF ENGINEERING
(Affiliated to JNTUH, Hyderabad.)
(Approved by AICTE New Delhi & Recognised by the Govt. of Telangana State)

COURSE FILE FOR

CONCRETE TECHNOLOGY

PREPARED BY

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DEPARTMENT OF CIVIL ENGINEERING

COURSE FILE

SUBJECT	: CONCRETE TECHNOLOGY
NAME	: RAJESH K
DESIGNATION	: ASST. PROFESSOR
REGULATION	: R 18
COURSE CODE	: CE511PE
YEAR / SEMESTER	: III / I
DEPARTMENT	: CIVIL ENGINEERING
ACADEMIC YEAR	: 2020-2021

Principal
Vardhaman College of Engineering
KONDAPUR-501 182.

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1. Vision, Mission, PEO's, PO's & PSOs

a).Vision of Civil Engineering Department

• To give the world new age civil engineers who can transform the society with their creative vibe for the sustainable development by instilling scientific temper with ethical human outlook.

b). Mission of Civil Engineering Department

- To make the department a Centre of excellence in the field of civil engineering and allied research
- To promote innovative and original thinking in the minds of budding engineers to face the challenges of future.

c). Program Educational Objectives of Civil Engineering Department

PEO1	Graduates will utilize the foundation in Engineering and Science to improve lives and livelihoods through a successful career in Civil Engineering or other fields
PEO2	Graduates will become effective collaborators and innovators, leading or participating in efforts to address Social, Technical and Business Challenges
PEO3	Graduates will engage in Life-Long Learning and professional development through Self-Study, continuing education or graduate and professional studies in engineering & Business

d) Program Outcomes of Civil Engineering Department

PO1	**Fundamental engineering analysis skills:** An ability to apply knowledge of computing, mathematical foundations, algorithmic principles, and civil engineering theory in the modelling and design of to civil engineering problems.
PO2	**Information retrieval skills:** An ability to design and conduct experiments, as well as to analyze and interpret data.

PO3	**Creative skills:** An ability to design, implement, and evaluate a system, process, component, or program to meet desired needs, within realistic constraints such as economic, environmental, social, political, health and safety, manufacturability, and sustainability. Graduates have design the competence.
PO4	**Teamwork:** An ability to function effectively on multi-disciplinary teams.
PO5	**Engineering problem solving skills**: An ability to analyze a problem, and identify, formulate and use the appropriate computing and engineering requirements for obtaining its solution.
PO6	**Professional integrity**: An understanding of professional, ethical, legal, security and social issues and responsibilities. Graduates must understand the principles of ethical decision making and can interpret the ASCE Code of Ethics. Graduates will understand the proper use of the work of others (e.g., plagiarism, copyrights, and patents). Graduates will understand the special duty they owe to protect the public's health, safety and welfare by virtue of their professional status as engineers in society.
PO7	**Speaking / writing skills**: An ability to communicate effectively, both in writing and orally. Graduates are able to produce engineering reports using written, oral and graphic methods of communication.
PO8	**Engineering impact assessment skills:** The broad education necessary to analyze the local and global impact of computing and engineering solutions on individuals, organizations, and society.
PO9	**Social awareness:** Knowledge of contemporary issues. Students are aware of emerging technologies and current professional issues.
PO10	**Practical engineering analysis skills**: An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.
PO11	**Software hardware interface:** An ability to apply design and development principles in the construction of software and hardware systems of varying complexity.
PO12	**Successful career and immediate employment:** An ability to recognize the importance of professional development by pursuing postgraduate studies or face competitive examinations that offer challenging and rewarding careers in Civil Engineering

e). Program Specific Outcomes (PSO'S)

PSO	DESCRIPTION
PSO1	Educating students with fundamental mathematical, scientific, and engineering knowledge to have a significant and positive long-term impact on the field of Civil Engineering.
PSO 2	Emphasizing the importance of working in a team effectively and to communicate properly within the team to achieve the desired outcome.
PSO 3	Motivate students in learning to learn and the ability to keep learning for a life-time to increase their professionalism, update and deepen their knowledge through the development of the profession.

2. SYLLABUS UNIVERSITY COPY

CE511PE: CONCRETE TECHNOLOGY (Professional Elective – I)

B.Tech. III Year I Sem.

L	T/P/D	C
3	0/0/0	3

Pre-Requisites: Building Materials

Course Objectives: The objectives of the course are to

- **Know** different types of cement as per their properties for different field applications.
- **Understand Design** economic concrete mix proportion for different exposure conditions and intended purposes.
- **Know** field and laboratory **tests** on concrete in plastic and hardened stage.

Course Outcomes: After the completion of the course student should be able to

- **Determine** the properties of concrete ingredients i.e. cement, sand, coarse aggregate by conducting different tests. Recognize the effects of the rheology and early age properties of concrete on its long-term behavior.
- **Apply** the use of various chemical admixtures and mineral additives to design cement-based materials with tailor-made properties
- **Use** advanced laboratory techniques to characterize cement-based materials.
- **Perform** mix design and engineering properties of special concretes such as high-performance concrete, self-compacting concrete, and fibre reinforced concrete.

UNIT I

Cement: Portland cement – chemical composition – Hydration, Setting of cement – Structure of hydrated cement – Tests on physical properties – Different grades of cement. Admixtures: Types of admixtures – mineral and chemical admixtures.

UNIT - II

Aggregates: Classification of aggregate – Particle shape & texture – Bond, strength & other mechanical properties of aggregate – Specific gravity, Bulk density, porosity, adsorption & moisture content of aggregate – Bulking of sand – Deleterious substance in aggregate – Soundness of aggregate – Alkali aggregate reaction – Thermal properties – Sieve analysis – Fineness modulus – Grading curves – Grading of fine, Manufactured sand and coarse Aggregates – Gap graded aggregate – Maximum aggregate size- Properties Recycled aggregate.

UNIT – III

Fresh Concrete: Workability – Factors affecting workability – Measurement of workability by different tests – Setting times of concrete – Effect of time and temperature on workability – Segregation & bleeding – Mixing, vibration and revibration of concrete – Steps in manufacture of concrete – Quality of mixing water.

UNIT - IV

Hardened Concrete: Water / Cement ratio – Abram's Law – Gel/space ratio – Gain of strength of concrete – Maturity concept – Strength in tension and compression – Factors affecting strength – Relation between compression and tensile strength - Curing.

Testing of Hardened Concrete: Compression tests – Tension tests – Factors affecting strength – Flexure tests – Splitting tests – Pull-out test, Non-destructive testing methods – codal provisions for NDT.

ELASTICITY, CREEP & SHRINKAGE – Modulus of elasticity – Dynamic modulus of elasticity – Posisson's ratio – Creep of concrete – Factors influencing creep – Relation between creep & time – Nature of creep – Effects of creep – Shrinkage – types of shrinkage.

UNIT – V

Mix Design: Factors in the choice of mix proportions – Durability of concrete – Quality Control of concrete – Statistical methods – Acceptance criteria – Proportioning of concrete mixes by various methods – BIS method of mix design.

Special Concretes: Introduction to Light weight concrete – Cellular concrete – No-fines concrete – High density concrete – Fibre reinforced concrete – Polymer concrete – High performance concrete – Self compacting concrete.

TEXT BOOKS:

1. Concrete Technology by M.S. Shetty. – S. Chand & Co.; 2004
2. Concrete Technology by A.R. Santhakumar, 2nd Edition, Oxford university Press, New Delhi
3. Concrete Technology by M. L. Gambhir. – Tata Mc. Graw Hill Publishers, New Delhi

REFERENCE BOOKS:

1. Properties of Concrete by A. M. Neville – Low priced Edition – 4th edition
2. Concrete: Micro structure, Properties and Materials – P.K. Mehta and J.M. Monteiro, Mc-Graw Hill Publishers

IS Codes:

IS 383
IS 516
IS 10262 - 2009

3. COURSE OBJECTIVES, COURSE OUTCOMES AND TOPIC OUTCOMES

a). COURSE OBJECTIVES

(i) Student should be able to differentiate the materials that can be effectively used for preparing concrete.

(ii) Student should be able to design, prepare and work with the concrete

(iii) The mechanism of hydration and potential hydration with the concrete heat of hydration kinetic. Shrinkage and its potential to generate cracks in concrete, including chemical, autogen, drying, and carbonation shrinkage.

(iv) The basic principles of mix designing various types of concrete as well as curing technology required for each of the following types.

(v) High performance concrete, ultra high strength concrete, self-compacting concrete, under water.

b). COURSE OUTCOMES

CO1: Identify Quality Control tests on concrete making materials

CO2: Understand the durability requirements of fresh concrete

CO3: Identify Quality Control tests hardened concrete

CO4: Design concrete mixes as per IS and ACI codes

CO5: Understand the need for special concretes

c). TOPIC OUTCOMES

S. No.	Topic to be covered	Topic Outcome (At the end of this topic student will be able to)
L1	**UNIT-I: Cement** Introduction on concrete technology course.	Define cement, aggregates and water.
L2	History of port land cement and Manufacturing process of Portland cement	Various methods and stages of cement manufacturing.
L3	Chemical composition & Bogies' compounds of Portland cement	Various chemical composition and compounds.
L4	Hydration of cement, Structure of hydrate cement and setting time of cement	Illustrate cement hydration and consistency of cement
L5	Test on physical properties of cement.	Explain physical properties test of

S. No.	Topic to be covered	Topic Outcome (At the end of this topic student will be able to)
		cement
L6	Different grades of cement.	Describe the cement grades.
L7	Admixtures and types of admixtures, mineral and chemical admixtures	Define admixture, Classify the admixture types – List out the different types of mineral and chemical admixtures
L8	**UNIT-II: Aggregates** Introduction on Aggregates and Classification of aggregate, Particle shape and texture, Bond strength.	Define aggregates- Classify aggregates based on their particle shape and texture, bond strength
L9	Mechanical properties of aggregate: Specific gravity, Bulk density, porosity, absorption and moisture content of aggregate.	Define specific gravity, bulk density and porosity. Conclude its importance in mix design. aggregate mechanical properties
L10	Bulking of aggregate and Soundness of aggregate	Demonstrate bulking of sand. Explain soundness of aggregate
L11	Alkali aggregate reaction, Thermal properties	Discuss deleterious substances in aggregates and its effect on properties of concrete. Define and alkali aggregate reaction and its effect on concrete properties. Explain thermal properties of aggregates
L12	Sieve analysis, Fineness modulus, Grading curves,	Demonstrate sieve analysis of aggregates and discuss importance of maximum size of aggregates. Determine fineness modulus, Prepare grading curves to make aggregates correction in design mix.
L13	Grading of fine and coarse Aggregates, Gap graded aggregate, Maximum aggregate size	Examine grading of fine and coarse aggregates; discuss gap graded and maximum aggregate sizes.
L14	**UNIT-III: Fresh Concrete** Introduction of workability and factors affecting workability	Explain properties of concrete define workability and list out factors effecting of workability.
L15	Measurement of workability by different tests, Setting time of concrete	Demonstrate workability test to measure it.
L16	Effect of time and temperature on workability	Define concrete setting, discuss about time and temperature effect on workability.

S. No.	Topic to be covered	Topic Outcome (At the end of this topic student will be able to)
L17	Segregation and bleeding of concrete	Define segregation & bleeding, Demonstrate concrete mixing and vibration.
L18	Steps in manufacture of concrete, Mixing and vibration of concrete	List out concrete manufacturing steps; describe the water quality and its importance in quality of concrete.
L19	Quality of mixing water	Quality of mixing water in concrete.
	MID EXAMINATION-II	
L20	**UNIT-IV: Hardened Concrete** Introduction on hardened concrete, water/cement ratio, Abram's law	Define Water/Cement ratio, Abram's law.
L21	Gel space ratio, nature of strength of concrete	Calculate gel-space ratio to predict concrete strength.
L22	Maturity concept in concrete and problems	Explain concrete strength natures and discuss maturity of concrete to calculate concrete strength.
L23	Strength in tension and compression, factors affecting strength	List out factors effecting concrete strength.
L24	Relation between compression and tensile strength, curing	Distinguish between concrete compressive and tensile strength
L25	Testing of hardened concrete-compression test and tensile strength	Demonstrate compression and tension test of concrete.
L26	Flexural test and splitting test	Explain flexure, splitting tensile and pull out test of concrete.
L27	NDT methods and codal provisions	Explain Non-destructive testing, Name it with codal provisions.
L28	Modulus of elasticity, dynamic modulus of elasticity and poisons ratio	Define elasticity, creep and shrinkage of concrete. Explain experimental process to determine modulus of elasticity.
L29	Creep of concrete, factors influencing creep of concrete, relation between creep and time	Define dynamic modulus of elasticity; differentiate static and dynamic modulus of elasticity. Show the relation between creep and time, list out the effects of creep on concrete strength.
L30	Nature of creep, effects of creep	Explain concrete creep and list out factors effecting on concrete creep.
L31	Shrinkage and types of shrinkage	Define shrinkage and list out types of shrinkages.

L32	**Unit-V: Mix Design & Special Concrete** Factors in the choice of mix proportion	Define mix design and its importance in concrete strength. List out the factors to choose the mix proportions.
L33	Durability of concrete	Define concrete durability.
L34	Quality control of concrete, Statistical quality control of concrete	Explain concrete quality control; demonstrate statistical quality control and acceptance criteria.
L35	Proportioning of concrete mix by normal concretes by BIS method	Select concrete mix proportions for normal concrete.
L36	Normal Mix design problem	Design a mix design as per BIS method and conclude the concrete mix proportions.
L37	Normal Mix design problem	Design a M20 or M25 concrete mix for local available materials.
L38	Proportioning of concrete mix by pump able concretes by BIS method	Select concrete mix proportions for pump able concrete.
L39	Pumpable Mix design problem	Design a mix design as per BIS method and conclude the concrete mix proportions.
L40	Proportioning of concrete mix by pump able concretes by ACI method	Select concrete mix proportions for pump able concrete.
L41	ACI mix design problem	Select concrete mix proportions for ACI Method.
L42	Introduction to Light weight concrete	Define special concretes. Explain light weight concrete and list out the merits and demerits of it.
L43	Cellular concretes	Define cellular concrete. Explain preparation produce of cellular and its applications in construction industry.
L44	No fines concrete	Define no fine concrete. Explain preparation produce of no fines concrete and its applications in construction industry.
L45	Fiber reinforced concrete	Define fiber reinforced concrete. Explain the ingredient of its importance in FRC.
L46	Polymer concrete and types of polymer concrete	Define polymer concrete. Explain the ingredient of its importance in polymer concrete
L47	Self-compacting concrete	Demonstration of self-compacting concrete, list out the test to conclude self-compacting concrete.
L48	High density concrete	Demonstration high density concrete, list out the test to conclude high density concrete

4. COURSE PRE–REQUISITES

1. Ingredients of concrete
2. Elements of building components
3. Characteristics of cement, fine aggregate and coarse aggregates

5. COURSE INFORMATION SHEET

5 a).COURSE DESCRIPTION:

PROGRAMME: B. Tech. (Civil Engineering)	DEGREE: BTECH
COURSE: CONCRETE TECHNOLOGY	YEAR: III SEM: I CREDITS: 4
COURSE CODE: CE511PE REGULATION: R18	COURSE TYPE: CORE
COURSE AREA/DOMAIN: Theory	CONTACT HOURS: 4+0 (L+T)) hours/Week.
CORRESPONDING LAB COURSE CODE (IF ANY): YES	LAB COURSE NAME: CONCRETE TECHNOLOGY LAB

5. b). SYLLABUS:

Unit	Details	Hours
I	**Cement:**Portland cement – chemical composition – Hydration, Setting of cement – Structure of hydrate cement – Test on physical properties – Different grades of cement. Admixtures: Types of admixtures – mineral and chemicaladmixtures	7
II	**Aggregate:**Classification of aggregate – Particle shape & texture –, strength & other mechanical properties of aggregate – Specific gravity, Bulk density, porosity, adsorption & moisture content of aggregate – Bulking of sand – Deleterious substance in aggregate – Soundness of aggregate – Alkali aggregate reaction – Thermal properties – Sieve analysis – Fineness modulus – Grading curves – Grading of fine & coarse Aggregates – Gap graded aggregate – Maximum aggregate size	8
III	**Fresh Concrete:** Workability – Factors affecting workability – Measurement of workability bydifferenttests–Settingtimesofconcrete–Effectoftimeandtemperatureonworkability– Segregation & bleeding – Mixing and vibration of concrete – Steps in manufacture of concrete – Quality of mixing Water	7
IV	**Hardened Concrete** : Water / Cement ratio – Abram's Law – Gel/space ratio – Nature of strength of concrete – Maturity concept – Strength in tension & compression – Factors affecting strength – Relation between compressive & tensile strength - Curing. **Testing of Hardened Concrete:** Compression tests – Tension tests– Flexure tests – Splitting tests – Pull-out test, Non-destructive testing methods – codal provisions for NDT. Elasticity. Creep & Shrinkage – Modulus of elasticity – Dynamic modulus of elasticity – Poisson's ratio – Creep of concrete – Factors influencing creep – Relation between creep & time – Nature of creep – Effects of creep – Shrinkage –types of shrinkage	12

V	**Mix Design:** Factors in the choice of mix proportions – Durability of concrete – Quality Control of concrete – Statistical methods – Acceptance criteria – Proportioning of concrete mixes by– BIS method and ACI mix design. **Special Concretes:** Introduction to light weight concrete – Cellular concrete – No-fines concrete – High density concrete – Fibre reinforced concrete – Polymer concrete – High performance concrete – Self compacting concrete.	18
	Contact classes for syllabus coverage	52
	Total No. of classes	52

5.c). GAPS IN THE SYLLABUS - TO MEET INDUSTRY/PROFESSION REQUIREMENTS:

NIL

5.d). TOPICS BEYOND SYLLABUS/ ADVANCED TOPICS:

NIL

5. e). WEB SOURCE REFERENCES:

Sl. No	Name of book/ website
a.	nptel.ac.in/courses/112104121/1
b.	https://www.youtube.com/watch?v=cx5gPKp9CEc&list=PLbMVogVj5nJQU7M0LdA77p_XaaWBJniNc
c.	http://www.civilenggforall.com/2015/09/concrete-technology-theory-and-practice-by-ms-shetty-free-download-pdf-civilenggforall.html

5. f). DELIVERY/INSTRUCTIONAL METHODOLOGIES:

☑ CHALK & TALK	☑ STUD. ASSIGNMENT	☑ WEB RESOURCES
☑ LCD/SMART BOARDS	☑ STUD. SEMINARS	☐ ADD-ON COURSES

5.g). ASSESSMENT METHODOLOGIES-DIRECT

☑ ASSIGNMENTS	☑ STUD. SEMINARS	☑ TESTS/MODEL EXAMS	☑ UNIV. EXAMINATION
☐ STUD. LAB PRACTICES	☐ STUD. VIVA	☐ MINI/MAJOR PROJECTS	☐ CERTIFICATIONS
☐ ADD-ON COURSES	☐ OTHERS		

5.h). ASSESSMENT METHODOLOGIES - INDIRECT

☑ ASSESSMENT OF COURSE OUTCOMES (BY FEEDBACK, ONCE)	☑ STUDENT FEEDBACK ON FACULTY (TWICE)
☐ ASSESSMENT OF MINI/MAJOR PROJECTS BY EXT. EXPERTS	☐ OTHERS

5.i). TEXT / REFERENCE BOOKS:

T/R	BOOK TITLE/AUTHORS/PUBLICATION
Text Book	Properties of concrete / A.M.Neville / Pearson 5th edition
Text Book	Concrete technology / M.S.Shetty / S.Chand&co
Text Book	Concrete technology / Job Thomas / Cengage Learning
Reference Book	Concrete technology / M.L Gmbhir / Tata Mc.Grawhill
Reference Book	Concrete: Micro structure, Properties and materials/P.K.Mehta and J.M. Monteiro, McGraw Hill Publishers.

6. TEACHING SCHEDULE

Subject	CONCRETE TECHNOLOGY					
	Text Books (to be purchased by the Students)					
Book 1	Concrete Technology by M.S. Shetty					
Book 2	Properties of concrete by A.M. Neville					
	Reference Books					
Book 3	Concrete technology / Job Thomas / Cengage Learning					
Book 4	Concrete Technology by M.L Gambhir					
Unit	Topic	Chapters Nos				No of classes
		Book 1	Book 2	Book 3	Book 4	

I	Introduction on concrete technology course.	1	1	4	2	
	History of port land cement and Manufacturing of process of Portland cement	1	1	4	2	
	Chemical composition & Bogies' compounds of Portland cement	1	1	4	2	
	Hydration of cement, Structure of hydrate cement and setting time of cement	1	1	4	2	
	Test on physical properties of cement.	1	2	4	2	
	Test on physical properties of cement.	1	2	4	2	
	Different grades of cement.	1	2	4	2	
	Admixtures and types of admixtures,	5	5	5	5	
	mineral and chemical admixtures	5	5	5	5	
II	Introduction on Aggregates and Classification of aggregate, Particle shape and texture, Bond strength.	3	3	4	3	
	Mechanical properties of aggregate: Specific gravity, Bulk density, porosity, absorption and moisture content of aggregate.	3	3	4	3	
	Bulking of aggregate and Soundness of aggregate	3	3	4	3	

	Alkali aggregate reaction, Thermal properties	3	3	4	3	
	Sieve analysis, Fineness modulus, Gradingcurves,	3	3	4	3	
	Grading of fine and coarse Aggregates, Gap graded aggregate, Maximum aggregate size	3	3	4	3	
III	Introduction of workability and factors affecting workability	6	4	6	6	
	Measurement of workability by different tests, Setting time of concrete	6	4	6	6	
	Effect of time and temperature on workability	6	8	6	6	
	Segregation and bleeding of concrete	6	4	6	6	
	Steps in manufacture of concrete, Mixing and vibration of concrete	6	4	6	11	
	Quality of mixing water	5	4	-	6	
IV	Introduction on hardened concrete, water/cement ratio, Abram's law	7	6	2	8	
	Gel space ratio, nature of strength of concrete	7	6	2	8	
	Maturity concept in concrete and problems	7	6	2	8	
	Strength in tension and compression, factors affecting strength	7	6	2	8	
	Relation between compression and tensile strength, curing	7	6	2	8	
	Testing of hardened concrete-compression test and tensile strength	10	12	5	8	
	Testing of hardened concrete-Flexural test and splitting test	10	12	5	8	
	NDT methods and codal provisions	7	12	5	8	

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	Modulus of elasticity, dynamic modulus of elasticity and poisons ratio	8	9	3	8	
	Creep of concrete, factors influencing creep of concrete, relation between creep and time	8	9	3	8	
	Nature of creep, effects of creep	8	9	3	8	
	Shrinkage and types of shrinkage	8	9	3	8	
	Factors in the choice of mix proportion	11	14	7	10	
	Durability of concrete	11	10	7	10	
	Quality control of concrete, Statistical quality control of concrete	-	14	7	9	
	Proportioning of concrete mix by normal concretes by BIS method	11	14	11to15	10	
	Normal Mix design problem	11	14	11to15	10	
	Normal Mix design problem	11	14	11to15	10	
	Proportioning of concrete mix by pump able concretes by BIS method	11	14	11to15	10	
V	Pumpable Mix design problem	11	14	11to15	10	
	Proportioning of concrete mix by pump able concretes by ACI method	11	14	11to15	10	
	ACI mix design problem	11	14	11to15	10	
	Introduction to Light weight concrete	12	14	11to15	14	
	Cellular concretes	12	13	11to15	14	
	No fines concrete	12	13	11to15	14	
	Fibre reinforced concrete	12	13	11to15	14	
	Polymer concrete	12	13	11to15	14	

	Self-compacting concrete	12	13	11to15	14	
	High density concrete	12	13	11to15	14	
Contact classes for syllabus coverage					60	
Total No. of classes					60	

7. UNIT WISE HAND WRITTEN NOTES

UNIT-I

CEMENTS & ADMIXTURES

HISTORY OF PORTLAND CEMENT :-

-> The history of cementing materials is as old as the history of engineering construction.

-> Some kind of cementing materials were used by egyptians, Romans and indians in their ancient constructions.

-> Egyptians mostly used cementitious objects obtained by burning gypsum

-> Analysis of mortar from Great pyramid showed that it contained 81.5% calcium sulphate and only 9.5% carbonate.

-> The early Greeks and Romans used cementing materials obtained by burning limestones.

-> The Greeks and Romans later became aware of the fact that certain volcanic ash, which mixed with lime and sand yields mortar. possessing superior strength and better durability in fresh or salt water.

-> Roman writers used volcanic ash found near to Pozzuoli village near in Italy. The volcanic ash is siliceous in nature thus acquired the name pozzolanas, later on the name pozzolana was applied to any other material natural or artificial having nearly the same composition as that of volcanic ash found at pozzuoli.

-> In India burnt brick mixed surkhi has been used in the Indian practice through mixing and long continued pounding of lime mortar with or without the addition of surkhi yielded strong and impervious mortar which confirmed the secret of superiority of Roman mortar.

→ Roman added blood lime to [illegible] mortar for better workability. Hemoglobin is a powerful air entraining agent and plasticizer, which perhaps is yet another reason for the durability of Roman construction.

→ When we come to more recent times, the most important advance in the knowledge of cements, prior to the discovery and manufacture of all modern cements is undoubtedly the investigations carried out by John Smeaton. When he was called upon the rebuild the Eddystone Lighthouse in 1756, he made extensive enquiries into the state of an existing in those days and also conducted experiments with a view of find out the best material to withstand the severe action of clayey water yielded better lime possessing superior hydraulic properties.

→ In spite of the success of this experiment, the use of hydraulic lime made little progress and the old practice of mixture of lime and pozzolana remained popular in long period.

→ The story of the investigation of portland cement is however attributed to Joseph Aspdin, a Leeds builder and brick layer, even though similar procedures had been adopted by other inventors.

→ In early period cement was used for making mortar only. Later the use of cement was extended for making concrete.

→ In India, portland cement was first manufactured in 1904 near Madras by the South India Industries Ltd. But this venture failed. Later Indian cement Co. Ltd, was established at Porbandar the company was able to deliver about 1000 tons of portland cement.

→ During the first five year plan cement production from India rise from 2.69 million to 4.6 millions tons.

MANUFACTURING OF PORTLAND CEMENT :-

→ The raw materials required for manufacture of portland cement are calcareous materials such as limestone, chalk and argillaceous materials such as shale or clay.

→ The process of manufacture of cement consists of grinding the raw materials, mixing them intimately in certain portion depending upon their purity and composition and burning them in a kiln at a temperature of about 1300 to 1500°C at which temperature the materials sinter and partially fuse to form nodular clinker.

→ The clinker is cooled and ground to fine powder with addition of about 3 to 5% of gypsum. The product formed by using this procedure is portland cement.

→ There are two process known as "wet" and "dry" process depending upon whether the mixing and grinding of raw materials is done in wet or dry conditions.

→ With a little change in the above process we have the semi-dry process also where the raw materials are ground dry and then mixed with about 10-14% of water and further burnt to clinkering temperature.

→ For many years the wet process remained popular because of the possibility of more accurate control in the mixing of raw materials.

→ The dry process requires much less fuel as the materials are already in a dry state. whereas in the wet process the slurry contains about 35-50% of water.

WET PROCESS

→ In wet process the limestone brought from the quarries is first crushed to smaller fragments.

→ Then it is taken to a ball or tube mill where it is mixed with clay or shale or the case may be ground to a fine consistency of slurry with addition of water.

→ The slurry is a liquid of creamy consistency with water content of about 35-50% where in particles crushed to the fineness of Indian standard sieve number, are held in suspension.

→ The slurry is pumped to slurry tanks or basins where it is kept in an agitated condition by means of rotating arms with chains or blowing compressed air from the bottom to prevent settling of lime stone and clay particles.

→ The composition of slurry is tested to give the required chemical composition and corrected periodically in the tube mill and also in the slurry tank by blending slurry from different storage tanks.

→ Finally the corrected slurry is stored in storage tanks and kept in homogeneous condition by agitation of slurry.

→ The corrected slurry is sprayed on to the upper end of rotary kiln against hot moving heating chains.

→ The rotary kiln is an important component of cement factory. It is a steel cylinder of diameter anything from 3m to 8m lined with refractory materials. Mounted on roller bearings capable of rotating about its own axis at a specified speed.

→ The length of rotary kiln may vary from 30 to 150 mm.

→ The slurry on being sprayed against a hot surface of flexible chains loses moisture and become flakes.

→ The flakes feed offhand fall on the floor. The rotation of rotary kiln causes the flakes to move from the upper end towards the lower end of the kiln and higher temperature.

→ The kilns fired from the lower end. The fuel is either powered coal oil or natural gas. In the time the material downs to the lower end of rotary kiln, the dry materials undergoes a series of chemical reactions. Until finally in the hottest part of the kiln where the temperature is in order of 1500°C about 20 to 30% of the material get fused.

→ Lime silica and alumina get recombined. The fused materials into nodular form of size 3mm to 20mm known as clinker.

→ The clinker drops into a rotary cooler where it is cooled under controlled conditions.

→ The clinker is stored in silos or bins. The clinker weighs about 1100 to 1300 gms per litre. The litre weight of clinker indicates the quality of clinker.

→ The cooled clinker is then ground in a ball mill with the addition of 3-5% of gypsum in orders to prevent flash ~~setting~~ of cement.

→ A ball mill consists of several compartments filled with progressively smaller hardened steel balls. The particles are crushed to the required fineness & separated by current of air and taken to storage silos from where

the cement is bagged [illegible] into [illegible] supply.

WET PROCESS

Clay ← water

Clay → Wash Mill → Storage basins → wet grinding mills

Limestone → Crusher → Storage basins → wet grinding mills

wet grinding mills → Blending of slurry to correct composition

↓

Storage of corrected slurry

↓

Powdered coal / oil / gas → corrected slurry fed to rotary kiln

↓

Slurry is converted into clinker

↓

addition of 2-3% of gypsum. → clinker is ground in ball mill

↓

Cement silos

↓

packing plant

DRY PROCESS

→ In the dry and semi dry process the raw materials are crushed dry and fed in correct proportions into grinding mill where they are dried and reduced to a very fine powder.

→ The dry powder coming in the raw mill is then blended and corrected for its right composition and mixed by means of compressed air. The aerated powder tends to behave almost like liquid and in about one hour of aeration a uniform mixture is obtained.

→ The blended meal is further sieved and fed into a rotating disc called granulator. A quantity of water about 12% by weight is added to make the blended meal into pellets.

→ The equipment used in the dry process kilns is comparatively smaller. The process is quite economical. The total consumption of coal is this method is only about 100kg when compared to the requirement of about 350 kg for producing a ton of cement in the wet process.

→ During March 1998 in India there were 173 large plants operating, out of which 49 plants used wet process, 115 plants used dry process and 9 plants used semi-dry process.

→ The methods are commonly employed for direct control of quality of clinker. The first method involves reflected light optical microscopy of polished and etched section of clinker, followed by point count of areas occupied by various compounds.

→ For moderate cooling it is implied that from about 1300°C the clinker is brought to about 800°C in about 15 minutes and from the 800°C the temperature is brought down to normal atmospheric temperature in about 10 minutes.

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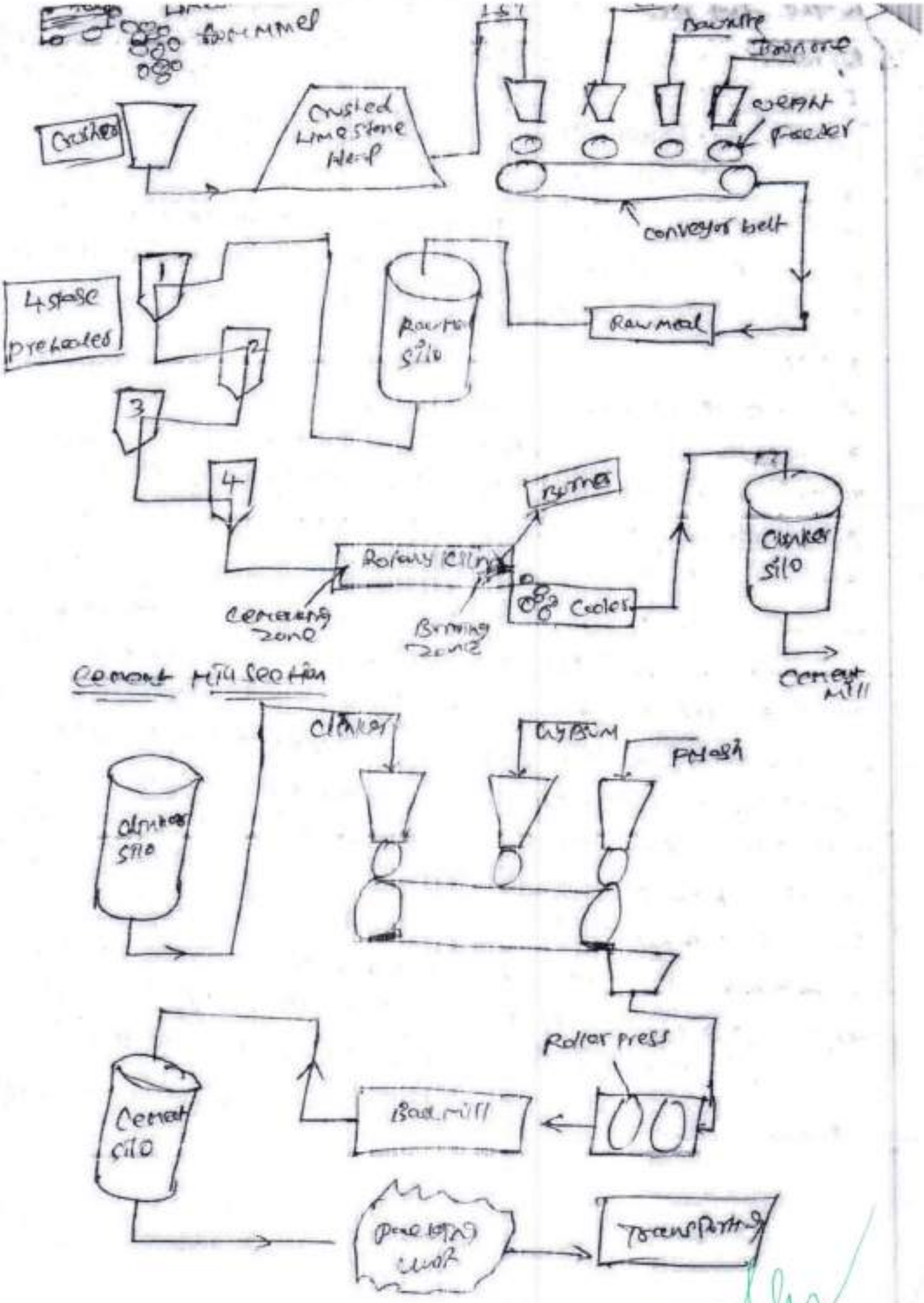

Hammer
Crusher
Crushed Limestone Heap
Bauxite
Iron ore
Sand
Feeder
conveyor belt
4 stage preheater
1
2
3
4
Raw mill
Raw meal silo
Rotary kiln
Burner
Cooler
Clinker silo
Cement mill
Cement mill section
Clinker
Gypsum
Flyash
Clinker silo
Roller press
Ball mill
Cement silo
Packing unit
Transporting

Chemical composition

→ The raw materials used for the manufacture of cement consists mainly of lime, silica, alumina and iron oxide. These oxides interacts with one another in the kiln at high temperature to form more complex compounds.

→ The relative composition of these oxides composition are responsible for influencing the various properties of cement.

Oxide	% Content
CaO	60-67
SiO_2	17-25
Al_2O_3	3-8
Fe_2O_3	0.5-6
MgO	0.1-4
Alkalies	0.4-1.3
SO_3	1.3-3.0

Approximate oxide composition limits of ordinary portland cement.

→ As mentioned earlier the oxides present in the raw materials when subjected to high temperature combine with each other to form complex compounds.

→ The identification of the major compound is largely based on Bogue's work and hence it is called Bogue's compounds. The four compounds ~~usually re-~~ ~~guarded~~ regarded as major compounds.

BOGUE'S COMPOUNDS

Name of compounds	Formula	Abbreviated Formula	%
Tricalcium silicate	$3CaO.SiO_2$	C_3S	54.1
Dicalcium silicate	$2CaO.SiO_2$	C_2S	16.6
Tricalcium Aluminate	$3CaO.Al_2O_3$	C_3A	10.8
Tetracalcium Aluminoferrite	$4CaO.Al_2O_3.Fe_2O_3$	C_4AF	9.1

→ Tricalcium silicate and dicalcium silicate are the most important compounds responsible for strength. Together constitute 70-80% of cement. The avg C_3S content in modern cement is about 45% and C_2S is about 25%. The sum of the contents of C_3A and C_4AF has decreased slightly in modern cements.

→ An increase in lime content beyond a certain value makes it difficult to combine with other compounds and free lime will exist in the clinker which causes unsoundness in cement.

→ An increase in silica content at the expense of the content of alumina and ferric oxide will make the cement difficult to fuse and form clinker.

→ Cements with a high (early) total alumina and high ferric oxide content is favourable to the production of early strength in cements.

→ Bogue's compounds C_3S, C_2S, C_3A, C_4AF are sometimes called as Alite, Belite, Celite, and Ferrite respectively.

HYDRATION OF CEMENT :

→ Anhydrous cement does not bind fine and coarse aggregate. It acquires adhesive property only when mixed with water.

→ The chemical reaction that take place between cement and water is referred as hydration of cement.

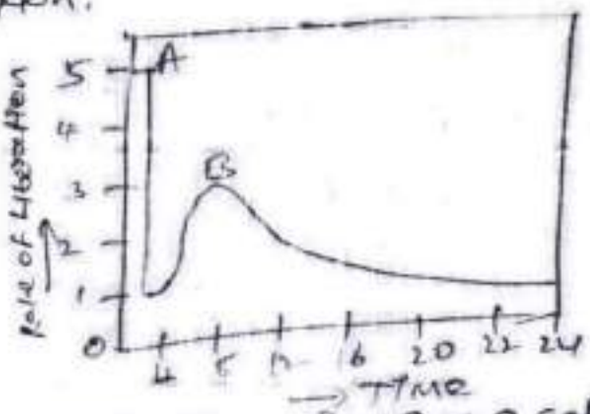
→ On account of hydration certain products are formed. These products are important because they have cementing or adhesive wave.

→ The hydration of cement is visualised in two ways the first is "through solution" mechanism. Instead cement compounds dissolve to produce a supersaturated solution from which different hydrated products get precipitate.

→ The second possibility is that water attacks cement compounds in the solid state converting the compounds into hydrated products starting from the surface and proceeds to the interior of the compound with time.

→ It is probable that both "through solution" and "solid state" type of mechanism may occur during the course of reactions between the cement and water.

→ The former mechanism is predominate in the early stages of hydration in view of large quantities of water and after and then later mechanism may operate during the later stages of hydration.



Heat liberated from a setting cement

STRUCTURE of HYDRATED CEMENT

→ To understand the behaviour of concrete is necessary to acquaint ourselves with structure of hydrated hardened cement paste.

→ If the concrete is considered to be as two phase material namely the paste phase and the aggregate phase, the understanding of the paste phase will become more important as it influences the behaviour of the concrete to a much greater extent.

→ The strength, permeability, durability, shrinkage, elastic properties the creep and volume change properties of the concrete are much influenced by the paste structure

→ So to understand the concrete it is important that we have a deep understanding of the structure of the hydrated hardened cement paste.

transition zone :

→ transition zone which represents the interfacial region between the particles of coarse aggregate and hardened cement paste.

→ Transition zone is generally a plane of weakness and therefore has far greater influence on the mechanical behaviour of concrete.

→ Although transition zone is composed of same bulk cement paste, the quality of paste in the transition zone is of poor quality. Firstly due to internal bleeding, water accumulation below elongated, flaky and large pieces of aggregates. This reduces the bond between paste and aggregate in general.

-> Due to drying shrinkage (or) temperature variation, the transition zone develops microcracks even before a structure is loaded. When structure is loaded at high stress level, these micro cracks propagate and ~~[illegible]~~ bigger cracks are formed resulting in failure. Hence transition zone, generally the weakest part of the chain is considered strength limiting phase in concrete.

-> The techniques used to study the structure of cement paste include measurements of setting time, compressive strength, quantity of heat of hydration evolved etc.

-> Measurements of heat evolved during the exothermic reactions also give valuable insight into the mechanism of hydration reactions, since approximately 50% of the total heat evolution occurs during 3 days of hydration, a continuous record of heat liberation during this time is extremely useful in understanding the degree of hydration and the resultant structure of hardening cement paste.

-> The mechanical properties of the hardened concrete depends more on the physical structure of the product of hydration than on the chemical composition of the cement.

-> For simplicity's sake we will consider only the structure of the paste phase. Fresh cement paste is a plastic mass consisting of water and cement. With the lapse of time, say one hour, the hardening paste consists of hydrates of various compounds, unhydrated cement particles and water. With further lapse of time the quantity of unhydrated cement left in the paste decreases and the hydrates of the various compounds increase

TEST ON PHYSICAL PROPERTIES

Testing of cement

testing of cement can be brought under two categories

1) Field testing
2) Laboratory testing

Field testing

→ It is sufficient to test the cement in field when it is used for minor works. The following are the field tests.

a) open the bag and take a good look at a cement. There should not be any visible lumps. The color of the cement should ~~not be~~ normally be greenish grey.

b) Thrust your hand into the cement bag it must give a cool feeling there should not be any lumps inside.

c) ~~take a~~ pinch of cement and feel like the fingers it should give a smooth and not gritty feeling.

d) Take a hand full of cement and throw it on a bucket full of water the particles should not float for sometimes before they sink.

Laboratory tests

The following tests are usually conducted in the lab

i) Fineness test
ii) setting time test
iii) Soundness test.
iv) Strength test.

i) Fineness test:-

→ The fineness of cement has an important bearing on the rate of hydration and hence on the rate of gain of strength and also on the rate of evolution of heat.

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→ Fineness cement offers greater surface area [illegible] and hence faster development of strength. The disadvantage of fine grinding is that it is susceptible to air set and early deterioration.

→ Max no of particles in a sample of cement should have a size less than 100 microns and the smallest particles may have a size about 1.5μ

→ Fineness of cement is tested by sieving.

Sieve test

→ weigh correctly 100 grams of cement and take it on a standard IS sieve No 9 (90 microns). Break down the ~~[illegible]~~ air-set lumps in the sample with fingers. Continuously sieve the sample giving circular and vertical motion for a period of 15 min. Mechanical sieving devices may also be used. Weigh the residue left on the sieve this weight should not exceed 10% of ordinary cement.

ii) Setting time test

→ An arbitrary division has been made for the setting time of cement as initial setting time and final setting time. It is difficult to draw a rigid line b/w these two arbitrary divisions. For convenience initial setting time is regarded as the time elapsed b/w the moment that the water is added to cement to the time that the paste starts losing its plasticity.

→ The final setting time is the time elapsed b/w the moment the water is added to cement and the time when the paste has completely lost its plasticity and attained sufficient firmness to resist certain definite pressure.

→ Initial setting time is normally 30 min and final setting time should not be more than 10 hrs.

→ For initial and final setting time test is tested by the Vicats apparatus.

Initial setting time

→ take about 500gms of cement sample and gauge it with 0.85 times the water required to produce cement paste of standard consistency 0.85 P.

→ The paste shall be gauged and filled into the vicat moulds in specific manner within 3-5 min.

→ start the stop watch the moment water is added to the cement.

→ lower the needle gently and bring it in contact with the surface of the test block and quickly release allow it to penetrate percentage into the test block.

→ In begining the needle will completely pierce through the test block. But after sometimes when the paste starts losing its plasticity, the needle will penetrate only to a depth of 33-35 mm from top.

→ The period elapsing b/w the time when water is added to the cement and the time at which the needle penetrates the test block to a depth equal to 33-35 mm from the top is taken as initial setting time.

Final setting time

→ replace the needle of the vicat apparatus by accessory attachment the cement shall be considered as finally set when upon lowering the attachment gently cover the surface of the test block, the centre needle makes an impression, while the circular cutting edge of the attachment fails to do so. In other words the paste has attained such hardness that the centre needle does not pierce through the paste more than 0.5 mm.

iii) Soundness test

→ It is very important that cement after setting shall not undergoes any appreciable change of volume. certain cement have been found to undergo a large expansion after setting causing distruption of the set and hardened mass.

→ The apparatus consist of small split cylinder of spring brass or other suitable metal. It is 30mm in diameter and 30mm high on either side of split are attached two indicator 30mm / 60mm long with a pointed ends.

→ cement is gauged with 0.85 times the water required for standard consistency 0.85P. in a standard manner and filled into the mould kept on a glass plate.

→ The mould is covered on the top with another glass plate. the whole assembly is immersed in water at a temp. of 27°C - 34°C and kept there for 24 hrs.

→ measure the distance b/w the indicator points. Submerge the mould again in water. Heat the water and bring to boiling point in about 25-30 min. keep it boiling for 3 hrs.

→ Remove the mould from the water allow it to cool and measure the distance b/w the indicator points.

→ The difference b/w these two measurements represents the expansion of cement this must not exceed 10mm for ordinary Portland cement. If in case the expansion is more than 10mm as stated above the cement is said to be unsound.

iv) Strength test

→ The compressive strength of hardened cement is the most important of all the properties

→ strength of cement is indirectly found on cement sand mortar in specific proportions

→ Take 555 gms of standard sand, 185 gms of cement (1:3) in a non porous enamel tray and mix them with a trowel for one minute. Then add water of quantity $\frac{P}{4}$ + 3 percent of combined weight of cement and sand and mix the three ingredients thoroughly until the mixture is of uniform colour.

→ The time of mixing should not be less than 3 minutes nor more than 4 minutes.

→ Immediately after mixing, the mortar is filled into a cube mould of size 7.06 cm. The area of the face of the cube will be equal to 50 sq cm. Compact the mortar either by hand compaction in standard specified manner (or) in the vibrating equipment for 2 minutes.

→ Keep the compacted cube in the mould at a temp of 27°C ± 2°C and at least 90% relative humidity for ~~the remaining~~ 24 hrs.

→ After 24 hrs the cubes are removed from the mould and immersed in clean fresh water until taken out for testing.

TYPES OF CEMENT (GRADES OF CEMENT)

1) Ordinary portland cement.
2) Rapid hardening cement
3) Extra rapid hardening cement
4) Sulphate resisting cement
5) Portland slag cement
6) Quick setting cement

7) super sulphated cement
8) Low heat cement
9) Portland pozzolana cement
10) Air entraining cement
11) coloured cement (white cement)
12) Hydrophobic cement
13) masonary cement
14) expansive cement
15) oil well cement
16) rediset cement
17) concrete sleeper grade cement
18) High alumina cement
19) very high strength cement

ADMIXTURES :

→ Admixture is defined as a material, other than cement, water and aggregates that is used as ingredient of concrete and is added to the batch immediately before (or) during mixing. Additive is a material which is added at the time of grinding cement clinker at the cementary.

→ These days concrete is using for wide varities of purposes to make it suitable in different condition. In these conditions ordinary (cement) concrete may fail to exhibit the required quality performance (or) durability in such cases, admixtures is used to modify the properties of ordinary concrete so as to make it more suitable for any situation.

→ A few type of admixtures called water reducers (or) High range water reducers, generally referred as plasticizers (or) super plasticizers.

TYPES OF ADMIXTURES

① Chemical Admixtures

1) Plasticizers (water reducers)

2) Super plasticizers

3) Retarders and retarding plasticizers

4) Accelerators and accelerating plasticizers

5) Air Entraining Admixtures

② MINERAL ADMIXTURES

6) Pozzolanic (or) Mineral admixtures

7) Damp-proofing and water proofing admixtures

8) Gas forming admixtures

9) Air detraining admixtures

10) Alkali aggregate expansion inhibiting admixtures.

11) Workability admixtures

12) Grouting admixtures

13) Corrosion inhibiting admixtures

14) Bonding admixtures

15) Colouring admixtures

CONSTRUCTION CHEMICALS

1) Concrete curing compounds

2) Polymer Bonding Agents

3) Mould Releasing Agents

4) Protective and Decorative Coatings

5) Installation Aids

6) Surface Retarders

7) Bond aid for proofing

8) Gunniting Aid.

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AGGREGATES :-

→ Aggregates are important constituents in concrete. They give bulk to the concrete, reduce shrinkage and effect economy.

→ They aggregates occupy 70-80% of volume of concrete, their impact on various characteristics and properties of concrete is undoubtedly considerable.

Classification of aggregates

→ Aggregates are classified as

1) Normal aggregates
2) Lightweight aggregates
3) Heavy weight aggregates.

→ In this chapter properties of normal aggregates will be discuss.

→ Normal weight aggregates further classified as natural and artificial aggregates

Natural	Artificial
Sand,	Broken brick,
Gravel,	Air cooled slag,
Crushed rock such as	sintered fly ash,
Granite, Quartzite, Basalt,	Bloated clay
Sand stone.	

→ aggregates can be classified on the basis of the size of the aggregates as coarse aggregates and fine aggregates

Particle shape & texture of aggregates

SHAPE:

→ The shape of aggregate is an important characteristic since it affects the workability of concrete. It is difficult to easily measure the shape of irregular body like concrete aggregates which are derived from various rocks.

→ One of the methods of expressing the angularity qualitatively is by a figure called angularity number.

→ This is based on % voids in the aggregate after compaction in a specified manner.

→ A quantity of single sized aggregates are ~~considered~~ is or ~~[illegible]~~ filled into metal cylinder of 3 lit capacity. The aggregates are compacted in a standard manner and % of voids is found out.

→ The void is found out can be knowing the sp. gravity of aggregates and bulk density (or) by pouring water to the cylinder to bring the level of water upto the brim. If the voids is 33% the angularity of such aggregates is considered zero. If the void is 44% the angularity no of such aggregate is considered 11.

→ The normal aggregates which are suitable for making the concrete may have angularity number continuing from 0 to 11.

→ Angularity number zero represents the most practicable rounded aggregates and the number 11 indicates the most angular aggregates that could be tolerated for making concrete not so unduly harsh and uneconomical.

TEXTURE:

→ Surface texture is that property the measure of which depends upon the relative degree to which particle surfaces are polished (or) dull smooth (or) rough.

→ Rough textured aggregates develops higher bond strength in tension than smooth textured aggregates

Strength of aggregate

→ When the cement paste is of good quality and its bond with the aggregate is satisfactory, then the mechanical properties of rock (or) aggregates will influence the strength of concrete.

→ The test for strength of aggregate is required to be made in the following situations.

i) For production of high strength & extra-high strength concrete.

ii) When contemplating to use aggregates manufacture from weathered rocks.

iii) Aggregates manufactured by industrial process.

Aggregate crushing value

→ Strength of rock is found out by making a test specimen of cylinder shape of size 25mm dia and 25mm height.

→ The cylinder is subjected to compressive stress different rock samples are found to give different compressive strength varying from a min of 45MPa – 545MPa.

→ As said earlier the compressive strength of parent rock does not exactly indicate the strength of aggregate in concrete. For this reason assessment of strength of the aggregate is made by using a sample of bulk aggregate in standardised manner. The test is known as "aggregate crushing value test".

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Aggregate impact value

-> With respect to concrete aggregates, toughness is usually considered the resistance of the material to failure by impact.

-> Several attempts to develop a method of test for aggregates impact value have been made.

-> The most successful is the one in which a sample of standard aggregates kept in a mould is subjected to 15 blows of a metal hammer of weight 14kgs falling from a height of 38cms.

-> The quantity of finer materials resulting from ~~potential~~ will indicate the toughness of the sample of aggregates.

-> The ratio of the fines formed to the weight of the total sample taken is expressed as a %.

Aggregate Abrasion value

-> Apart from testing aggregates with respect to crushing value, impact resistance & testing the aggregate with respect to its resistance to wear is an important test for aggregates to be used for road construction & pavement constr.

Modulus of elasticity

-> Modulus of elasticity of aggregate depends upon its composition, texture and structure. The modulus of elasticity of aggregate will influence the properties of concrete with respect to shrinkage and elastic behaviour and to very small extent of creep of concrete.

-> Elasticity of aggregate has a decided effect on the elastic property of concrete and that the relation of elasticity of aggregate that of the concrete is not a linear function, but may be expressed as an equation of exponential type.

Specific gravity

→ In concrete technology sp. gravity of aggregates is made use of in design calculation of concrete mixes. The specific gravity of the rock vary from 2.6 to 2.8

Bulk density

→ Bulk density shows how densely the aggregates is packed when filled in a standard manner.

→ The bulk density depends on the particle size distribution and shape the particles

Absorption and moisture content

→ Some of the aggregates are porous and absorptive. Porosity and absorption of aggregates will effect the w/c ratio and hence the durability of concrete.

→ The porosity of aggregates will also effect the durability of concrete when the concrete is subjected to freezing and thawing and also when the concrete is subjected to chemically aggresive fluids.

Bulking of aggregates

→ The free moisture content in fine aggregate results in bulking of volume

→ Free moisture forms a film around each particle. This film of moisture exerts what is known as surface tension which keeps the neighbouring particles away from it.

→ The extent of bulking can be estimated by a simple test. A sample of moist fine aggregate is filled into a measuring cylinder in the normal manner.

$$\% \text{ of bulking} = \frac{h_1 - h_2}{h_2} \times 100$$

h_1 = fine aggregate

h_2 = fine agregate with water.

Soundness of aggregate:

→ Soundness refers to the ability of aggregate to resist a marine changes in volume as a result of change in physical conditions

→ These physical conditions that affect the soundness of aggregate are the freezing and thawing variation in temperature, alternate wetting and drying under normal condition and drying & wetting in saltwater.

→ Aggregates which are porous, weak and containing any undesirable extraneous matter undergo excessive volume change when subjected to the above condition.

→ Aggregates which undergo more than specified amount of volume change is said to be unsound aggregates.

Alkali Aggregate:

→ For a long time aggregates have been considered as inert materials but later on people was clearly brought out that the aggregates are not fully inert. Some of the aggregates contain reactive silica, which reacts with alkalies present in cement. The sodium oxide and potassium oxide.

→ The reaction starts with attack on the reactive siliceous minerals in the aggregate by the alkaline hydroxide derived from the alkalies in cement.

→ As a result the alkali silicate gels of unlimited swelling type are formed. When the condition are congential, progressive manifestation by swelling take place, which results in disruption of concrete with spreading of pattern cracks and eventual failure of concrete structure

→ The rate of deterioration may be slow or fast depending upon the condition. There were cases where concrete has become unserviceable in about 2 years time.

THERMAL PROPERTIES:

→ Rock and aggregates possess 3 thermal properties which are significant in establishing the quality of aggregate for concrete construction they are

1) co-efficient of expansion 2) specific heat 3) Thermal conductivity

→ An avg value of the mean thermal co-efficient of expansion of concrete may be taken as $9.9 \times 10^{-6}/°C$ but the range may be from about $5.4 \times 10^{-6}/°C - 14 \times 10^{-6}/°C$ depending upon the type and quantities of the aggregates the mix proportions and other factors.

→ The range of co-efficient of thermal expansion for hydrated cement paste may vary from $10.8 \times 10^{-6}/°C$ to $16.2 \times 10^{-6}/°C$. For mortar it may range from $7.9 \times 10^{-6}/°C$ to $12 \times 10^{-6}/°C$.

→ For common rocks ranges from $0.9 \times 10^{-6}/°C$ to $16 \times 10^{-6}/°C$

SIEVE ANALYSIS

→ This is the name given to the operation of dividing a sample of aggregates into various fractions each consisting of particles of the same size.

→ The sieve analysis is conducted to determine the particle size distribution in a sample of aggregate which are called gradation.

→ The aggregates used for making concrete are normally of the maximum size 80mm, 40mm, 20mm, 10mm, 4.75mm, 2.36mm 600μ, 300μ, and 150μ.

→ The aggregates fraction from 80mm–4.75mm are termed as coarse aggregate and their fraction from 4.75mm–150μ are termed as fine aggregates.

→ The size 4.75mm is a common fraction appearing both in coarse aggregates and fine aggregates (CA & FA)

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→ The material retained on each sieve after shaking represents the fraction of aggregates coarser than the sieve in question and finer than the sieve above.

→ Sieving is done either manually or mechanically

→ In the manual operation the sieve is shaken giving movements in all possible direction to give chance to all particles for passing through the sieve. Operation should be continued till such time that almost no particle is passing through.

Fineness Modulus:

→ From the sieve analysis the particle size distribution in a sample of aggregates is found out. In this connection a term known as "Fineness Modulus"

→ Fineness Modulus is a ready index of coarseness (or) fineness of the material.

→ Fineness Modulus is an empirical factor obtained by adding the cumulative % of aggregates retained on each of the standard sieve ranging from 80-150mm microns and dividing this sum by an arbitrary number 100.

The following limits may be taken as guidance.

	FM
Fine sand	2.2 – 2.6
Medium sand	2.6 – 2.9
Coarse sand	2.9 – 3.2

→ A sand having a fineness modulus more than 3.2 will be unsuitable for making satisfactory concrete.

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Grading of Aggregates

→ Aggregate comprises about 55% of the volume of mortar and 85% volume of mass concrete.

→ Mortar contains aggregates of size upto 4.75mm and concrete contains aggregate upto a maximum size of 150mm.

→ It is well known that the strength of concrete is depend upon w/c ratio provided the concrete is workable.

→ One of the most important factor for producing workable concrete is good gradation of aggregates

→ Good grading implies that a sample of aggregates contains all standard fractions of aggregates in required proportion such that the sample contains minimum voids.

→ a sample of well graded aggregates containing minimum voids will require minimum paste to fill up the voids in aggregates

→ Minimum paste will be mean less quantity of water which will furthermore ~~less quantity of cement and less quantity of sand~~ increased economy higher strength, lower shrinkage and greater durability.

→ The advantage due to good grading of aggregates can also be viewed from another aspect. The concrete is viewed as a two phase material paste phase and aggregate phase. It is the paste phase which is vulnerable to all life of concrete.

→ Paste is weaker than avg aggregate in normal concrete with some exception when very soft aggregates are used.

→ The paste is more permeable than many of the mineral aggregates. It is the paste that is susceptible to deterioration by the attack of aggressive chemicals.

→ In short, it is the paste which is weak link in a mass of concrete. This objective can be achieved by having well graded aggregates. Hence the importance of good grading.

Gap Grading :

→ So far we discussed the grading pattern of aggregates in which all particle size are present in certain portion in a sample of aggregate. Such pattern of particle size distribution is also referred as continous grading.

→ Originally in the theory of continous grading, it was assumed that the voids present in the higher size of the aggregates are filled up by the next lower size of aggregate

→ Similarly the voids created by lower size are filled up by the lower than those particles and so on

→ It have been seen that the size of voids existing b/w a particular size of aggregate is of the order of 2 (or) 3 size lower than that of fraction. In other words the void size existing b/w 40mm aggregates is of the size equal to 10mm (or) possibly 4.75mm (or) the size of voids occurring when 20mm aggregate are used in order of say 1.18mm (or) so. ∴ along with 20mm aggregate only when 1.18mm aggregate size is used.

Advantages of gap graded concrete :

i) sand required will be of the order of about 26% as against about 40% in the case of continous grading.

ii) Specific surface area of the gap graded aggregate will be low because of high % of C.A & low % of F.A.

iii) Requires less cement and lower water/cement ratio.

iv) Because of point contact b/w C.A & C.A and also on account of lower cement and matrix content the drying shrinkage is reduced.

UNIT III

FRESH CONCRETE

→ Fresh concrete (or) plastic concrete is a freshly mixed material which can be moulded into any shape.

→ The relative quantities of cement, aggregates and water mixed together, control the properties of concrete in the wet state as well as in the hardened state.

Workability:

→ 100% compaction of concrete is an important parameter for contributing to the maximum strength. Lack of compaction will result in air voids whose detrimental effect on strength and durability is equally (or) more predominant than the presence of capillary cavities.

→ To enable the concrete to be fully compacted with given efforts, normally a higher water / cement ratio than that calculated by theoretical consideration may be required. That is to say the function of water is also to lubricate the concrete so that the concrete can be compacted with specified effort forth coming at the site work.

→ The word 'workability' (or) 'workable concrete' signifies much wider and deeper meaning than the other terminology "consistency" often used loosely for workability.

→ Consistency is a general term to indicate the degree of fluidity (or) the degree of mobility.

→ A concrete which has high consistency and which is more mobile, need not be of right workability for a particular job. Every job requires particular workability.

→ A concrete which is required workable for mass concrete for foundation is that not workable for concrete to be used in roof construction or even in roof construction. Concrete considered workable when vibrator is used is not workable when concrete is to be compacted by hand.

→ similarly concrete certain [illegible] section is not workable when required to be used in thin section. Therefore the word workability assumes full significance of the type of work, thickness of section, extent of reinforcement and mode of compaction.

→ workability is defined as property of concrete which determines the amount of useful internal work necessary to produce full compaction.

→ Another definition which envelopes a wider meaning is that it is defined as the ease with which concrete can be compacted 100% having regard to mode of compaction and place of deposition.

FACTORS AFFECTING WORKABILITY:

→ workable concrete is the one which exhibits very little internal friction between particle and particle which overcomes the frictional resistance offered by the form work surface and reinforcement contained in the concrete with full the amount of compacting efforts from coming

1) Water content
2) Mix proportion
3) size of aggregates
4) shape of aggregates
5) surface texture of aggregates
6) Grading of aggregates
7) use of admixtures.

→ The above are the factors affecting to the workability of concrete.

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MEASUREMENT OF WORKABILITY

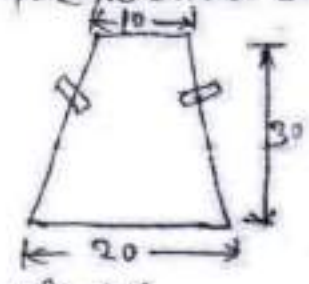
→ The following test are commonly employed to measure workability

1) Slump test
2) Compaction factor test
3) Flow test
4) Vee bee consistometer test.

1) Slump test

→ Slump test is the most commonly used method of measuring consistency of concrete which can be employed either in laboratory (or) at site of work.

→ The apparatus for conducting the slump test essentially consists of a metallic mould in the form of a frustum of a cone having the internal dimension under.



All in CM

Bottom diameter : 20CM
Top diameter : 10CM
Height : 30CM
Tamping rod : 16mm dia, 0.6m long

→ The mould is placed on a smooth horizontal, rigid and non absorbent surface. The mould is then filled in four layers, each approximately 1/4 of the height of the mould. Each layer is tamped 25 times by the tamping rod taking care to distribute the strokes evenly over the cross section.

→ After the top layer has been rodded the concrete is struck off level with a trowel and tamping rod.

→ The mould is removed immediately by raising it slowly and carefully in a vertical direction.

→ This allows the concrete to subside. The subsidence is referred as slump of concrete.

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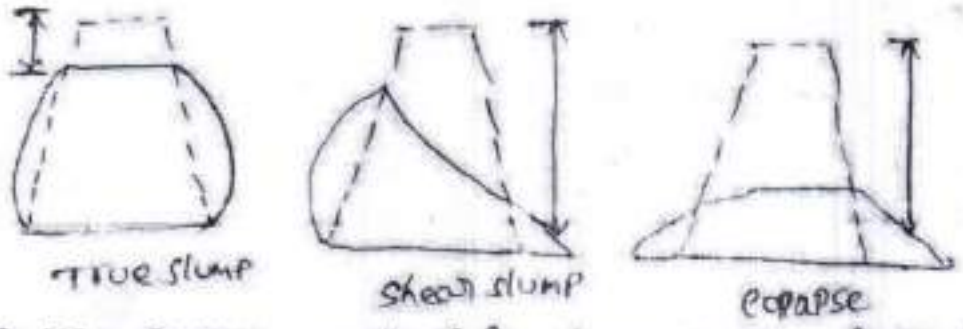

→ The pattern of slump is shown in fig. It indicates the characteristic of concrete in addition to the slump cone value.

→ If the concrete slumps evenly it is called true slump.

→ If one half of the cone slides down, it is called shear slump. It is also indicates the concrete is non-cohesive and shows the characteristic of segregation.

→ If the concrete slumps totally collapsed is called collapse.

→ It is seen that the slump test gives fairly good consistent results for a plastic mix. This test is not sensitive for a stiff mix. In case of dry mix, no variation can be detected between mixes of different workability.

Degree of workability	slump (mm)
Low	25-75
Medium	~~50-100~~ 50-100
High	100-150
Very high	—

2) Compacting factor test

→ The compacting factor test is designed primarily for use in the laboratory but it can also be used in the field.

→ It is more precise and sensitive than the slump test and is particularly useful for concrete mixes of very low workability as are normally used when concrete is to compacted by vibration

Dimension of the compacting factor apparatus

Upper Hopper A	Dimension (cm)
Top internal dia	25.4
Bottom internal dia	12.7
Internal height	27.9
Lower Hopper B	
Top internal dia	22.9
Bottom internal dia	12.7
Internal height	22.9
Cylinder C	
Internal dia	15.2
Internal height	30.5
Distance b/w Hopper	20.3

→ The sample of concrete to be tested is placed in the hopper upto the brim. The trap door is opened so that the concrete falls into the lower hopper. Then the trap door of the lower hopper is opened and the concrete is falls into the cylinder.

→ The excess of concrete remaining above the cylinder is then cut off with the help of plane blades supplied with the apparatus.

→ The outside of the cylinder is wiped clean. The concrete is filled up exactly upto the top level of the cylinder. It is weighed to the nearest 100 grams. This weight is known as "weight of partially compacted concrete"

→ The cylinder is emptied and then refilled with the concrete from the same sample in layers approximately 5cm deep. The layers are heavily rammed (or) vibrated as a full compaction. The top surface of the fully compacted concrete is then carefully struck off level with the top of the cylinder and weighed to the nearest 100 gm. This weight is known as "weight fully compacted concrete"

$$\text{Compaction factor} = \frac{\text{wt of partially compacted concrete}}{\text{wt of fully compacted concrete}}$$

3) Flow test:

→ This is a laboratory test which gives an indication of the quality of concrete with respect to consistency, cohesiveness and the proneness to segregation.

→ This apparatus consist of flow table about 76cm in diameter.

→ The mould made from smooth metal casting in the form of frustum of a cone is used with the following internal dimensions. The base is 25cm in dia, upper surface 17cm in dia. and height of the cone is 12cm.

→ The table top is cleaned of all gritty material and is wetted. The mould is kept on the centre of the table, firmly held and is filled in two layers. Each layer is rodded 25 times with a tamping rod 1.6cm in dia and 61cm long.

→ The top layer is rodded evenly the excess of concrete which has overflowed the mould is removed.

→ The mould is lifted vertically upward and the concrete stands on its own without support. The table is then raised and dropped 12.5mm 15 times in about 15 sec.

→ The diameter of spread concrete is measured in about 6 directions to the nearest 5mm and the avg spread is noted.

$$\text{Flow \%} = \frac{\text{spread dia in cm} - 25}{25} \times 100.$$

→ The value could range anything from 0 to 150%

4) Vee-Bee consistometer test:

→ This is good laboratory test to measure indirectly the workability of concrete. This test consists of a vibrating table, a metal pot, a sheet metal cone, a standard iron rod.

→ Slump test as described earlier is performed, placing the slump cone inside the sheet metal cylindrical pot of the consistometer.

→ The glass disc attached to the swivel arm is turned and placed on the top of the concrete in the pot.

→ The electrical vibrator is then switched on and simultaneously a stop watch started. The vibration is continued till such a time as the conical shape of the concrete disappears and the concrete assumes a cylindrical shape.

→ This can be judged by observing the glass disc from the top for disappearance of transparency. Immediately when the concrete is fully assumes a cylindrical shape the stop watch is switched off.

→ The time required for the shape of concrete to change from slump cone test to cylindrical shape in seconds is known as <u>vee-bee degree.</u>

SETTING TIME OF CONCRETE:

→ The setting time of concrete depends upon w/c ratio, temperature conditions, type of cement, use of mineral admixtures, use of plasticizers in particular retarding plasticizers.

→ The setting parameter of concrete is more of practical significance for site engineers than setting time of cement.

→ When retarding plasticizers are used, the increase in setting time, the duration upto which concrete remains in plastic condition is of special interest.

→ The setting time of concrete is found by penetrometer test.

→ The apparatus consist of container which should have minimum lateral dimension of 150mm and minimum depth of 150mm.

→ There are 6 penetration needles with bearing ~~area~~ areas of 645, 323, 161, 65, 32 and 16mm². Each needle stem is scribed circumferentially at a distance of 25mm from the bearing area.

→ The test procedure involves the collection of representative sample of concrete in sufficient quantity and sieve it through 4.75 mm sieve and the resulting mortar is filled in the container
→ compact the mortar by rodding, tapping, rocking or by vibrating
Level the surface and keep it covered to prevent the loss of moisture. Remove bleeding water, if any by mean of pipette.
→ insert a needle of appropriate size, depending upon the desire of setting of mortar in the following manner.
→ Bring the bearing surface of needle in contact with the mortar surface, gradually and uniformly apply a vertical force downward on the apparatus until the needle penetrates to a depth of 25 ± 1.5 mm, as indicated by the scribe mark.
→ The time taken to penetrate 25 mm depth could be about 10 sec. Record the force required to produce 25 mm penetration and the time of inserting from the time water is added to cement.
→ Calculate the penetration resistance by dividing the recorded force by the bearing area of the needle. This is the penetration resistance.
→ For the subsequent penetration avoid the area where the mortar has been disturbed. The clear distance should be two times the diameter of the bearing area. Needle is inserted at least 25 mm away from the wall of container.
→ Plot a graph of penetration resistance as ordinate and elapsed time as abscissa. Not less than six penetration resistance determination is made.
→ Continue tests until one penetration resistance of at least 27.6 MPa is reached. Connect the various point by a smooth curve.
→ Penetration resistance equal to 3.5 MPa draw a horizontal line. The point of intersection of this with the smooth curve. Read on the X axis which gives the initial setting time. By horizontal line is drawn from the penetration resistance of 27.6 MPa and perpendicular is cuts the smooth curve is read on the X axis which gives final setting time.

SEGREGATION :

→ segregation can be defined as the seperation of the constituent materials of concrete.

→ A good concrete is one in which all the ingredients are properly distributed to make a homogeneous mixture.

→ if a sample of concrete exhibits a tendency for seperation of coarse aggregate from the rest of the ingredients that sample is said to be showing the tendency for segregation. Such a concrete is not only going to be weak. lack of homogeneity is also going to induce all undesirable properties in the hardened concrete.

→ segregation may be of three types

* coarse aggregate seperating out and settling down from the rest of the matrix.
* the paste (or) matrix seperating from coarse aggregate and ~~[illegible]~~
* water seperating out from the rest of the material being a material of lowest specific gravity.

→ A well made concrete taking into consideration various parameters such as grading, size, shape and surface texture of aggregates with optimum quantity of water makes a cohesive mix. Such concrete will not exhibit any tendency for segregation

→ The conditions favourable for segregation are as can be seen from the above para. the badly proportioned mix where sufficient matrix is not there to bind and contain the aggregates. Insufficiently mixed concrete with excess water content shows a higher tendency for segregation.

→ drops of concrete from heights as in the case of placing concrete in column concreting will result in segregation.

→ Vibration of concrete is one of the important methods of compaction. It should be remembered that only comparatively dry mix should be vibrated. If a wet mix is excessively vibrated, it is likely that the concrete gets segregated.

→ In the recent time we use concrete with very high slump particularly in RMC. The slump value required at the batching point may be in the order of 150mm and at the pouring point the slump may be around 100mm.

→ While finishing concrete floors with a view to achieve a smooth surface masons are likely to work too much with the trowel, float (or) tamping rule immediately on placing concrete. This immediate working on the concrete on placing without any time interval is likely to press the coarse aggregate down which results in the movement of excess of mortar (or) paste to the surface. Segregation caused entirely account impairs the homogeneity and serviceability of concrete. The excess mortar at the top causes plastic shrinkage cracks.

→ Segregation is difficult to measure quantitatively but it can be easily observed at the time of compacting operation. The pattern of subsidence of concrete in slump test (or) the pattern of spread in the flow test gives a fair idea of the quality of concrete with respect to segregation.

BLEEDING:

→ Bleeding is sometimes referred as water gain. This a particular form of segregation, in which some of the water from the concrete comes out to be the surface of the concrete, being of the lowest specific gravity among all the ingredients of concrete.

→ Bleeding is predominantly observed in a highly wet mix, badly proportioned and insufficiently mixed concrete. In thin members like roof slabs (or) road slabs and when concrete is placed in sunny weather shows excessive bleeding.

→ due to bleeding water rises up and accumulates at the surface. sometimes along with this water, certain quantity of cement also comes to the surface.

→ when the surface is worked up with the trowel and floats the aggregates goes down and the cement and water comes up to top surface. This formation of cement paste at the surface is known as "Laitance".

→ In such a cases the top of slabs and pavements will not have good wearing quality. This laitance formed on roads produces dust in summer and mud in rainy season.

→ water while traversing from bottom to top, makes continous channels, if the water cement ratio is used more than 0.7 the bleeding channels will remain continous and unsegmented by the development of gel. This continous bleeding channels are often responsible for causing permeability of the concrete structures.

→ The bleeding water is likely to accumulate below the aggregates. This accumulation of water creates water voids and reduces the bond b/w the aggregates and the paste.

→ Bleeding rate increases with time up to about one hour or so and there after rate decreases but continues however less till the final setting time of cement.

→ Bleeding presents several serious problem when slip form paver is used for construction of concrete pavements. If too much of bleeding water accumulates on the surface of pavement slab the bleeding water flows out over the unsupported sides which causes collapsing of sides.

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Method of test for bleeding of concrete

→ This method covers determination of relative quantity of mixing water that will bleed from a sample of freshly mixed concrete.

→ A cylindrical container of approximately 0.01 m³ capacity, having an inside diameter of 250mm and inside height of 280mm is used. A tamping bar similar to the one used for slump test is used. A pipette for drawing off free water from the surface a graduated jar of 100cm³ capacity is required for test.

→ A sample of freshly mixed concrete is obtained. The concrete is filled in 50mm layer for a depth of 250 ± 3 mm (5 layers) and each layer is tamped by giving strokes, and top surface is made smooth by trowelling.

→ The test specimen is weighed and the weight of the concrete is noted. Knowing the total water content in 1 m³ of concrete quantity of water in the cylindrical container is also calculated.

→ The cylindrical container is kept in a level surface free from vibration at a temperature of 27°C ± 2°C. It is covered with a lid. Water accumulated at the top is drawn by means of pipette at 10 minutes interval for the first 40 min and at 30 min. interval subsequently till bleeding cease. To facilitate collection of bleeding water the container may be slightly tilted. All the bleeding water collected in a jar.

$$\text{Bleeding \%} = \frac{\text{Total quantity of bleeding water}}{\text{Total quantity of water in sample of concrete}} \times 100$$

STEPS IN MANUFACTURE OF CONCRETE.

→ The various steps of manufacture of concrete are.

1) Batching
2) Mixing
3) Transporting
4) Placing
5) Compacting
6) Curing
7) Finishing.

1) Batching:

→ The measurement of materials for making concrete is known as 'batching'.

→ There are two methods of batching.

i) Volume Batching (ii) Weight Batching.

i) Volume Batching:

→ Volume batching is not a good method for proportioning the material because of the difficulty it offers to measure granular material in terms of volume.

→ Cement is always measured by weight, it is never measured in volume. Generally for each batch mix one bag of cement is used. The volume of 1 bag of cement is taken by 35 litres.

→ Gauge boxes are used for measuring the fine and coarse aggregates. The volume of the box is made equal to the volume of 1 bag of cement i.e 35 litres

→ Gauge boxes are generally called forms. They can be made of timber (or) steel plates.

→ water is proportion either in litres or kg BECAUSE IN THIS case the two units are same as the density of water is one kg/litre. The quantity of water required is a product of water/cement ratio and the weight of cement.

→ For example if the water/cement ratio of 0.5 is specified the quantity of mixing water is required per bag of cement is 0.5×50 = 25 kg (or) litres

Batch volume of materials for mixes

Grade	cement (kg)	sand (lits)	aggregate (litres)
1:1:2 (M200)	50	35	70
1:1½:3 (M200)	50	52.5	105
1:2:3	50	70	105
1:2:4 (M150)	50	70	140
1:2½:5	50	87.5	175
1:3:6	50	105	210

ii) Weigh Batching:

→ Weigh batching is the correct method of measuring the materials. For important concrete weigh batching is adopted.

→ Use of weigh system in batching facilities accuracy, flexibility and simplicity. Different types of weigh batches are available.

→ The particular type to be used, depends upon the nature of the job. Large weigh batching plants have automatic weighing is one of sophistication and requires qualified and experienced engineers. In this further complication will come to adjust water content to water for the moisture content in the aggregates.

→ In small jobs cement is often measured in bags assuming the weight of the bag as 50 kg. In reality the cement bag is made of 50 kg at the factory due to transportation when the bags are used. In fact the weight of a cement bag at the site is considerably less. Some times the loss of weight becomes more than 5 kg. This is one of the sources of error in volume.

→ Batching and weigh batching when the cement is not actually weighed. But in important major concreting jobs, cement is also actually weighed and exact proportion as designed is maintained.

2) MIXING :

→ Through mixing of the material is essential for the production of uniform concrete. The mixing should ensure that the mass becomes homogeneous, uniform in colour and consistency.

→ There are two methods adopted for mixing concrete.

1) Hand mixing.
2) Machine mixing.

1) Hand mixing:

→ Hand mixing is practised for small scale unimportant concrete works.

→ As the mixing cannot be thorough and efficient it is desirable to add 10% more cement to water for the intended concrete produces by this method.

2) Machine mixing:

→ Mixing of concrete is almost invariably carried out by machine for reinforced concrete work and for medium (or) large scale mass concrete work.

→ Machine mixing is not only efficient but also economical when the quantity of concrete to produced is large.

3) Transporting:

→ The methods adopted for transportation of concrete.

i) Mortar pan (ii) Wheel barrow, Hand cart

iii) Crane, Bucket and rope way iv) Truck mixer & dumper

v) Belt conveyors vi) Chute.

vii) Skip and Hoist viii) Transit mixer

ix) Pump and pipeline x) Helicopter.

4) Placing of concrete:

→ It is not enough that a concrete mix correctly designed, batched mixed and transported, it is of of most importance that the concrete must be placed in symmetric manner to yield optimum results.

→ Concrete is invariably laid on foundation bed below the walls (or) columns. Before placing the concrete in the foundation, all the loose earth must be removed from the bed.

→ For the construction of road slabs, airfield slabs and ground floor slabs in buildings, concrete is placed in bays. The ground surface on which the concrete is placed must be free from loose earth, pool of water and other organic matters like grass, roots, leaves etc.

→ When concrete is laid in great thickness as in the case of concrete raft for a high rise building (or) in the construction of concrete pier for abutment (or) in the construction of mass concrete dam, concrete is placed in layers.

→ Before placing the concrete the surface of the previous lift is cleaned thoroughly with water jet and scrubbing by wire brush.

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5) Compaction :

→ Compaction of concrete is the process adopted for expelling the entrapped air from the concrete. In process of mixing, transporting and placing of concrete air is likely to get entrapped in the concrete.

Methods of compaction:

i) Hand compaction

a) Rodding b) Ramming c) Tempping

ii) Compaction by vibration

a) Internal vibrator

b) Formwork vibrator

c) Table vibrator

d) Platform vibrator

e) Surface vibrator

f) Vibratory roller

iii) Compaction by pressure and jarring

iv) Compaction by spinning.

6) Curing :

→ Curing can also be described as keeping the concrete moist and warm enough so that the hydration of cement can continue. More elaborately it can be described as the process of maintaining a satisfactory moisture content and a favourable temp. in concrete during the period immediately following placement, so that hydration of cement may continue until the desired properties are developed to a sufficient degree to meet the requirement of service.

→ A quick surface drying of concrete results in the movement of moisture from the interior to the surface.

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CURING METHODS:

a) Water curing → Immersion, Ponding, Spraying, Wet covering

b) Membrane curing — Steam curing, Electrical, Infra-red radiation

c) Application of heat —

7) FINISHING:

→ Finishing operation is the last operation in making concrete. Finishing in real sense does not apply to all concrete operations

→ For a beam concreting, finishing may not be applicable, Road pavement, airfield pavement, domestic buildings, careful finishing is of great importance.

EFFECT OF TIME & TEMPERATURE ON WORKABILITY:

→ Concrete mixers are generally designed to run at a speed of 15–20 revolutions per minute.

→ For proper mixing it is seen that about 25–30 revolutions are required in a well designed mixer.

→ In the site the normal tendency is to speed up the out-turn of concrete by reducing the mixing time. This results in poor quality of concrete. On the other hand, if the concrete is mixed for a comparatively longer time, it is uneconomical from the point of view of rate of production of concrete and fuel consumption therefore it is of importance to mix the concrete for such a duration which will secure optimum benefit.

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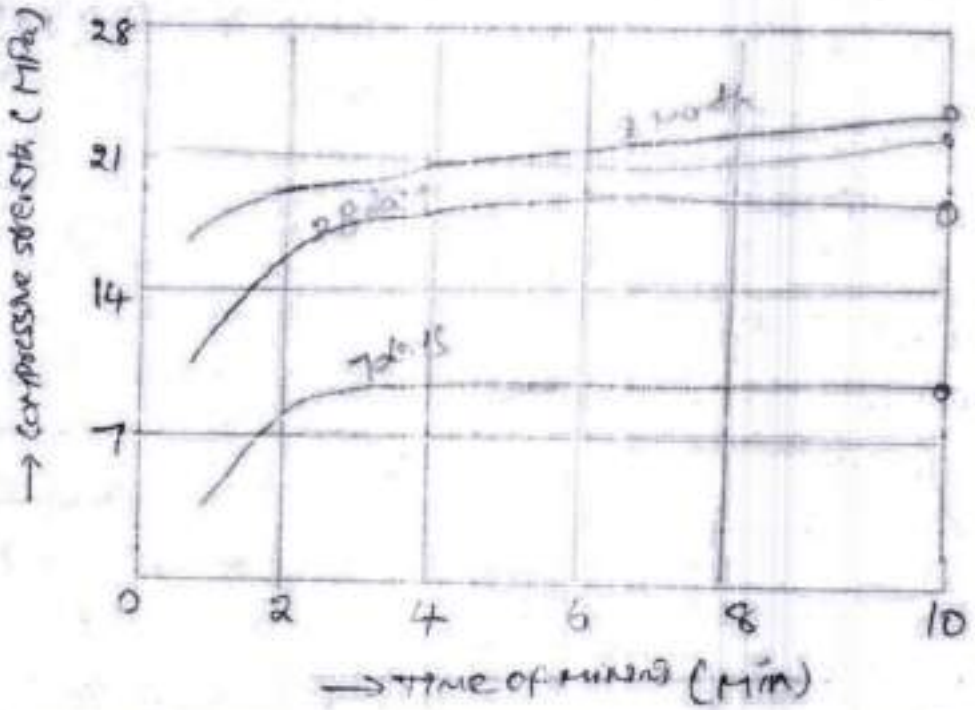

→ It is seen from the experiment that the quality of concrete in terms of compressive strength will increased with the increase in time of mixing but for mixing time beyond two min the improvement in compressive strength is not very significant. The graph shows the effect of mixing time on strength of concrete.

→ Concrete mixer is not a simple apparatus lot of considerations have gone as input in the design of the mixer. Shape of drum, the number of blades, inclination of blades with respect to drum surface. The length of blades, the depth of blades, the space b/w the drum and the blades, the space b/w the metal strips of blades and speed of rotation etc. are important to give uniform mixing quality and optimum time of mixing.

→ Generally mixing time is related to the capacity of mixer. The mixing time varies b/w 1° to 2° minutes. Bigger the capacity of drum more is the mixing time. However modern high speed pan mixer used in RMC, mixes the concrete in about 15-30 secs. one cubic meter (1m³) capacity high speed pan mixer takes only about 2 min. for batching and mixing. The batching plant takes about 12 min. to load a transit mixer of 6m³ capacity.

→ Some times, at some work concrete may run → discharged from the drum and concrete may be kept rotating in the drum for long time, as for instance when some trouble/(or) dispute takes place with the workers (or) when an unanticipated repair (or) modification is required to be done on form work and reinforcement.

→ Long time mixing of concrete will generally result in increase of compressive strength of concrete within limits. Due to mixing over periods the effective water/cement ratio gets reduced.

→ The evaporation of water and formation of excess fines may reduce the workability and hence bring about reduction in strength. The excess of fines may also cause greater shrinkage.

RETEMPERING OF CONCRETE:

→ The process of restoring of concrete if necessary with addition of just the required quantity of water is known as "Retempering of concrete". Sometimes a small quantity of extra cement also added while retempering. Many specifications do not permit mortar regaining renewed mixing with (or) without addition of cement + aggregate (or) water.

→ The production of concrete of excessive slump (or) adding water in excess of designed water cement ratio to compensate for slump loss resulting from delays in delivery should be prohibited.

→ Retempering of concrete is too wet and at a delay of about one hour as an increase in compressive strength of 2 to 15%.

Quality of Mixing Water

→ Concrete is a chemically combined mass which is manufactured from binding materials such their material with water.

Functions of water in concrete:-

→ To wet the surface of aggregate to develop adhesion because the cement paste adheres quick and satisfactory to the surface of the aggregates than to any surface.

→ To make a plastic mixture of the various ingredients and to impart workability to concrete to facilitate placing in the desired position

→ Water is also needed for the hydration of the cementing material to set and harden during the period of curing

→ Quantity of water in the mix plays a vital role on the strength of the concrete, some waters which have adverse effect on hardened concrete, sometimes may not be harmless (or) even beneficial during mixing.

→ The effect on concreting for different types of contamination impurities are described below-

1) Suspended solids:

→ Mixing water with high content of suspended solids should be allowed to stand in a settling tank before use as it undesirable to introduce large quantities of clay and silt into the concrete.

2) Acidity & Alkalinity:

→ Natural water that is slightly acidic are harmless, but presence of humic (or) other organic acids may result

adverse effect over the hardening of concrete. Waters which are highly alkaline should also be tested.

3) Algae:-

→ The presence of algae in mixing water causes air entrainment with a consequent loss of strength. The green (or) brown slime forming algae should be regarded with suspicion and such water should be tested carefully.

4) Sea water:-

→ Sea water contains a total salinity of about 3.5% (78% of the dissolved solids being NaCl and 15% MgCl2 and MgSO4) which produces a slightly higher early strength but a lower long term strength.

→ The loss of strength is usually limited 15% and consequently be tolerated. Sea water reduces the initial setting time of cement but do not effect final setting time.

5) Chloride:-

→ Water containing large amount tends to cause persistant dampness and surface efflorence.

→ The presence of chlorides in concrete containing embedded steel can lead to its corrosion.

6) Moisture content of Aggregate:-

→ Aggregates usually contains some surface moisture. Coarse aggregate rearly contains more than 1% of surface moisture but fine aggregate can contain in excess of 10%.

→ This water can represent a substantial proportion of the total mixing water indicating a significant importance in the quality of water that contributes surface moisture in aggregate.

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UNIT IX

HARDENED CONCRETE

→ The compressive strength of concrete is one of the most important and useful properties of concrete.

→ compressive strength is also used a qualitative measure for other properties of hardened concrete.

→ no exact quantitative relationship b/w compressive strength and flexural strength, tensile strength, modulus of elasticity, wear resistance fire resistance or permeability.

→ The compressive strength of concrete is generally determined by testing cubes when concrete fails under a compressive load the failure is essentially a mixture of crushing and shear failure.

→ The modern version of original water/cement ratio rule can be given as follows.

1) Ratio of cement to mixing water
2) Ratio of cement to aggregates.
3) Grading, surface texture, shape, strength and stiffness of aggregates.
4) Maximum size of aggregate.

Water/cement ratio:

→ strength of concrete primarily depends upon the strength of cement paste. It has been depends upon the dilution of paste

→ The strength of paste increases with cement content and decreases with air and water content

$$S = \frac{A}{B^x}.$$

x = water cement ratio by volume and for 28 days results the constant A & B are 1000 kg/cm and 7 respectively.

→ Abrams w/c ratio law states that the strength of concrete is only dependent upon w/c ratio provided the mixes consist

→ According to the strength of concrete depends and concrete in terms of volume fraction of the constituents by the equation

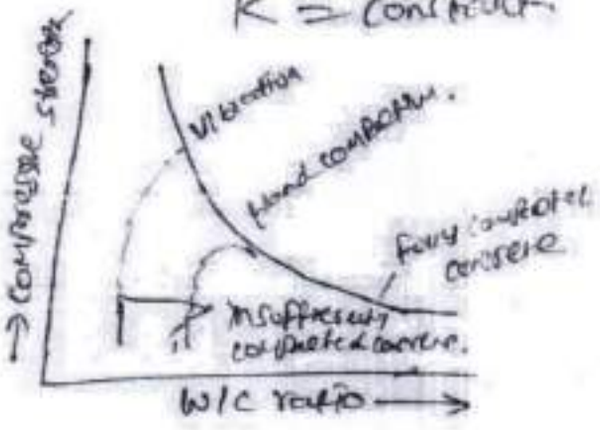
$$S = K\left(\frac{c}{c+e+a}\right)^2$$

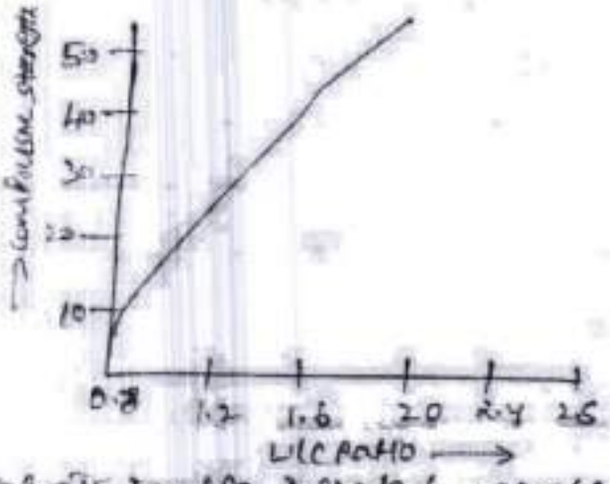
where,

S = strength of concrete

c, e and a = volume of cement, water and air

K = constant





→ In this expression the volume of air is also included because it is not only the water/cement ratio but also the degree of compaction. which indirectly means the volume of air filled voids in the concrete is taken into account in estimating the strength of concrete.

→ It can be seen that lower water/cement ratio could be used when the concrete is vibrated to achieve higher strength, whereas comparatively higher water/cement ratio is required when concrete is hand compacted. In both cases when the water/cement ratio is below the practical limit the strength of concrete falls rapidly due to introduction of air voids.

→ The graph showing the relationship b/w the strength and water/cement ratio is approximately hyperbolic in shape. Sometimes it's difficult to interpolate the intermediate value.

Gel/space ratio:

→ Instead of relating the strength to w/c ratio, the strength can be more related to the solid products of hydration of cement to the space available for formation of this product.

→ Gel/space ratio is defined as the ratio of the volume of the hydrated cement space to the sum of the volumes of the hydrated cement and of the capillary pores.

→ Power experiment showed that the strength of concrete has a specific relationship with the gel/space ratio. He found the relationship to be $240x^3$, where x is the gel/space ratio and 240 represents the intrinsic strength of gel in MPa for the type of cement and specimen used.

→ The relationship b/w the strength and water/cement ratio will hold good primarily for 28 days strength for fully compacted concrete, whereas the relationship b/w the strength and gel/space ratio is independent of age.

→ Gel space ratio can be calculated at any age and for any fraction of cement.

→ The following example show how to calculate gel/space ratio

Calculation of gel/space ratio for complete hydration:

C = weight of cement in gm

V_c = specific volume of cement = 0.319 ml/gm

W_0 = volume of mixing water in (ml)

Assuming that 1ml of cement on hydration will produce 2.06ml of gel

Volume of gel = $C \times 0.319 \times 2.06$

space available = $C \times 0.319 + W_0$

$\therefore$ Gel/space ratio $= \dfrac{\text{vol of gel}}{\text{space available}}$

$$X = \frac{0.657C}{0.319C + W_0}$$

Calculation of gel/space ratio for Partial Hydration:

α = Fraction of cement that has hydrated

Volume of gel $= C \times \alpha \times 0.319 \times 2.06$

Total space available $= C V_c \alpha + W_0$

$\therefore$ Gel/space Ratio $= X = \dfrac{2.06 \times 0.319 \times C\alpha}{0.319 C\alpha + W_0} = \dfrac{0.657\alpha}{0.319\alpha + W_0}$

Ex:

Calculate the Gel/space ratio and the theoretical strength of a sample of concrete made with 500 gm. of cement with 0.5 W/C ratio, on fully hydration & at 60% hydration

Ans

Gel/space ratio $= \dfrac{0.657C}{0.319C + W_0}$ $\left[\begin{array}{l} W_0 = 0.5 \times 500 \\ W_0 = 250 \end{array}\right]$

$$X = \frac{0.657 \times 500}{0.319 \times 500 + 250}$$

$X = 0.8$

$\therefore$ Theoretical strength of concrete $= 240 \times (0.8)^3$

$= 123$ MPa.

Gel/space ratio for 60% hydration $\alpha = 0.6$

$$X = \frac{0.657C\alpha}{0.319C\alpha + W_0}$$

$$X = \frac{0.657 \times 500 \times 0.6}{0.319 \times 500 \times 0.6 + 250}$$

$X = 0.57$

$\therefore$ Theoretical strength of concrete $= 240 \times (0.57)^3$

$= 44.4$ MPa.

Maturity concept of concrete:

→ strength development of concrete depends on both time and temperature. It can be said that strength is a function of summation of product of time and temperature. This summation is called maturity of concrete.

$$\therefore \text{Maturity} = \Sigma (\text{time} \times \text{temp.})$$

→ The datum line for computing maturity is $-11°C$.

→ Maturity is measured in °C-H (or) °C (Degree centigrade)

→ A sample of concrete cured at 18°C for 28 days taken as fully matured concrete.

$$\text{Maturity} = 28 \times 24 \times (18-(-11)).$$
$$= 19488 °C.h.$$

→ In standard calculations the maturity of fully cured concrete is taken as 19,800°C.h.

→ Maturity concept is useful for estimating the strength of concrete at any other maturity as a percentage of strength of concrete of known maturity.

Strength at any maturity as a % of strength of maturity 19,800 C.h $= A + B \log_{10} \frac{(\text{maturity})}{10^3}$

Plowman's coefficient for maturity eqn.

Strength after 28 days at 18°C (MPa)	coefficient	
	A	B
< 17.5	10	68
17.5 – 35.0	21	61
35.0 – 52.5	32	54
52.5 – 70.0	42	46.5

Ex 1)

The strength of a sample of fully matured concrete is found to be 40 MPa find the strength of identical concrete at the age of 7 day when cured at an avg. temp. during day time at 20°C and night time 10°C.

Sol

maturity of concrete

at 7 days $= \Sigma(\text{time} \times \text{temp})$

$= 7 \times 12 \times (20-(-11)) + 7 \times 12 \times (10-(-11))$

$= 4368\,°C\,h.$

∴ strength range of this concrete falls in zone II

∴ $A = 32$, $B = 54$.

% strength of concrete

$$\text{maturity of } 4368\,°C\,h = A + B \log_{10} \frac{(\text{maturity})}{10^3}$$

$$= 32 + 54 \log_{10} \frac{(4368)}{10^3}$$

$$= 66.5\,\%$$

$$\therefore \text{strength at 7 days} = 40 \times \frac{66.5}{100}$$

$$= 26.5 \text{ MPa.}$$

Ex 2 Laboratory experiments conducted at Pune on a particular mix showed a strength of 32.5 MPa for fully matured concrete. Find whether formwork can be removed for an identical concrete placed at Srinagar at the age 15 days when the avg temp. is 15°C. The concrete is likely to sustain a stripping stress of 25 MPa.

Sol maturity of concrete at 15 days $= 15 \times 24 \times (5-(-11))$

$= 5760\,°C\,h.$

Concrete falls in $A = 21$, $B = 61$. zone II.

% strength of concrete $= 21 + 61 \log_{10} \frac{(5760)}{10^3}$

$= 67.38\,\%$

$$\therefore \text{strength at 15 days} = 32.5 \times \frac{67.38}{100}$$

$$= 21.9 \text{ MPa.}$$

Nature of strength factor:

→ The paramount influence of voids in concrete on its strength has been repeatedly mentioned and it should be possible to relate this factor to the actual mechanism of failure.

→ For this purpose concrete is considered to be a brittle material even though it exhibits a small amount of plastic action as fracture under static loading takes place at moderately low total strain

→ a strain of 0.001 to 0.005 at failure has been suggested as the limit of brittle behavior.

→ High strength concrete is more brittle than normal strength concrete but there is no quantitative method of expressing the brittleness of concrete whose behavior in practice falls b/w the brittle and the ductile types.

Fracture & failure:

→ Concrete specimens subjected to any state of stress can support loads of upto 40-50% of ultimate without any apparent signs of distress.

→ Below this level any sustained load results in creep strain which is proportional to the applied stress and can be defined in terms of specific creep. Also concrete is below the fatigue limit.

→ Also the load increased above this level soft but distinct noises of internal disruption can be heard until about 70-90% of ultimate small fissures (or) cracks appear on the surface. At this stage sustained loads result in eventual failure.

Strength in tension & compression:

1) Compressive strength:

→ It is tested in a standard manner which includes full compaction and wet curing for a specified period give results representing the potential quality of the concrete.

→ There are three types of loading in compression test.

i) Uniaxial loading
ii) Biaxial loading
iii) Triaxial loading

→ The uniaxial loading case represents the most conservative system and yields the lowest values in compression.

→ There are three types of failure in compression test.

i) Tension failure (splitting)
ii) Shear failure (sliding)
iii) Combined failure (tension & shear)

2) Tension strength:

→ Although concrete is not normally designed to resist direct tension, the knowledge of tensile strength is of value in estimate the load under which cracking will develop.

→ The absence of cracking is considerable importance in maintaining the continuity of a concrete structure and in many cases in the prevention of corrosion of reinforcement.

→ There are two types of test for strength in tension test.

i) Direct tension test ii) Splitting tensile strength test

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Relation B/W compressive and tensile strength:

→ In reinforced concrete construction the strength of the concrete in compression is only taken into consideration.

→ The tensile strength of concrete is generally not taken into consideration but the design of concrete pavement slab is often based on the flexural strength of concrete.

→ As measurements and control of compressive strength in field are easier and more convinient, it has been customary to find out the compressive strength for different conditions and to correlate this compressive strength to flexural strength.

→ It is seen that strength of concrete in compression and tension are closely related, but the relationship is not the type of direct proportionality.

→ The two ratios of the strength depends on general level of strength of concrete. For higher compressive strength concrete shows higher tensile strength, but the ratio of increase of tensile strength is of decreasing order.

→ The type of coarse aggregate influences this relationship. Crushed aggregate gives relatively higher flexural strength than compressive strength.

→ The tensile strength of concrete as compared to its compressive strength is more sensitive to improper curing.

→ The use of pozzolanic material increased the tensile strength of concrete.

→ Following statical relation b/w tensile and compressive strength

i) $Y = 15.3X - 9.00$ for 20mm max. size aggregate.

ii) $Y = 14.1X - 10.4$ for 20mm max. size natural gravel

iii) $Y = 9.9X - 0.55$ for 40mm max. size crushed aggregate

iv) $Y = 9.8X - 2.52$ for 40mm max. size natural gravel

where, Y = compressive strength of concrete (MPa)

X = flexural strength of concrete (MPa)

→ There are number of empirical relationships b/w tensile strength and compressive strength of concrete.

$$\text{Tensile strength} = K(\text{compressive strength})^n$$

$K = 6.2$ for gravels

$K = 10.4$ crushed rock

$n = 1/2$ to $3/4$

→ Indian standard IS 456-2000 gives the following relationship b/w the compressive strength and flexural strength

$$\text{Flexural strength} = 0.7\sqrt{f_{ck}}$$

f_{ck} = characteristic compressive strength of concrete in N/mm^2.

CURING:

→ The test specimens are stored in place from vibration, in moist air of at least 90% relative humidity and at a temp. of $27° \pm 2°C$ for 24 hours $\pm$ 1/2 hour from the time of addition of water to the dry ingredients.

→ After this period the specimen are removed and removed from the moulds and unless required for test within 24 hours, immediately submerged in clean fresh water or saturated lime solution and kept there until taken out just prior to test.

→ The water or solution in which the specimen are submerged, are renewed every seven days and are maintained at a temp. of $27°C \pm 2°C$. The specimens are not to be allowed to become dry at any time until they have been tested.

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FLEXURAL STRENGTH OF CONCRETE:

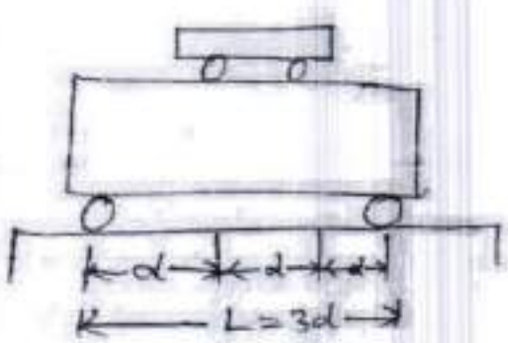
→ Concrete as we know is relatively strong in compression and weak in tension. In reinforced concrete members, little independence is placed on the tensile strength of concrete.

Determination of tensile strength:

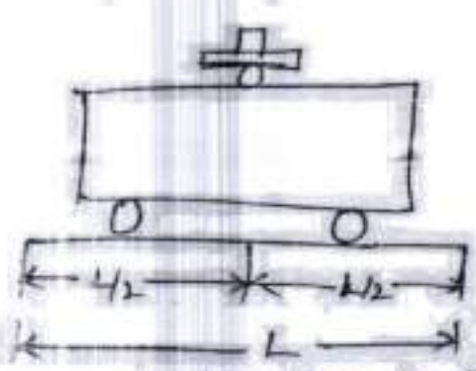
→ Direct measurement of tensile strength of concrete is difficult. Neither specimens nor testing apparatus have been designed which assure uniform distribution of the pull applied to the concrete.

→ The value of the modulus of rupture depends on the dimension of the beam and manner of loading. The system of loading used in finding out the flexural tension are central point loading and third point loading.

→ In central point loading maximum fibre stress will come below the point of loading where the bending moment is maximum. In case of symmetrical two point loading the critical crack may appear at any section, not strong enough to resist the stress within the middle third, where the bending moment is maximum.



Third-point loading



Centre-point loading.

→ The standard size of specimen are 15×15×70 cm. Alternatively if the largest nominal size of the aggregate does not exceed 80 mm, specimen 10×10×50 cm may be used.

SPLIT TENSILE TEST :

→ This is also called as cylinder splitting tension test (or) "Brazilian test"

→ This test is carried out by placing cylindrical specimen horizontally between the loading surface of a compression testing machine and the load is applied until failure of the cylinder, along the vertical diameter.

→ When the load is applied along the generatrix an element on the vertical diameter of the cylinder is subjected to a vertical compressive stress of.

$$\frac{2P}{\pi LD}\left[\frac{D^2}{r(D-r)}-1\right]$$

and a horizontal stress of $\frac{2P}{\pi LD}$

P = compressive load
L = length of cylinder
D = diameter.

→ The loading condition produces a high compressive stress immediately below the two generators to which the load is applied. But the larger portion corresponding to depth is subjected to a uniform tensile stress acting horizontally. It is estimated that the compressive stress is acting for about 1/6 depth and remaining 5/6 depth is subjected to tension.

→ In order to reduce the magnitude of the high compression stresses near the points of application of the load, narrow packing strips of suitable material such as plywood are placed b/w the specimen and loading platens of the testing machine. The packing strips should be soft enough to allow distribution of load over a reasonable area, yet narrow and thin enough to prevent large contact area. Normally a plywood strip of 25mm wide, 3mm thick, 30cm long used.

→ The main advantage of this method is that same type of specimen and the same testing machine as are used for the compression test

→ The splitting test is simple to perform and gives more uniform results than other tension tests.

NON-DESTRUCTIVE TESTING METHODS:

→ In this method is now a powerful method for evaluating existing concrete structures with regard their strength and durability apart from assessment and control of quality of hardened concrete.

→ Though non-destructive testing methods are relatively simple to perform, the analysis and interpretation of test results are not so easy. The special knowledge is required to analyse the hardened properties of concrete.

NDT METHODS

1) Schmidt's Rebound hammer
2) Penetration techniques
3) Pullout test
4) Dynamic (or) vibration methods
5) Pulse velocity method.
6) Radioactive & nuclear methods
7) Magnetic & electrical methods

1) Schmidt's Rebound hammer:

→ It is one of the most commonly adopted equipments for measuring the surface hardness.

→ It consist of a spring control hammer that slides on a plunger within a tubular housing. When the plunger is pressed against the surface of concrete, the mass rebound from the plunger. It retracts against the force of the spring.

→ The hammer impacts against the concrete and the spring control mass rebounds, taking the slider with it along the guide scale.

→ The distance travelled by the mass is called the rebound number. It is indicated by the slider moving along a graduated

→ The test has conducted by horizontally, vertically – upwards (or) downwards (or) at any intermediate angle.

→ At each angle the rebound number will be different for the same concrete and will require seperate calibration (or) correction chart.

Limitations:

* smoothness of surface under test
* size, shape & rigidity of specimen.
* Age of specimen.
* Surface and internal moisture condition of concrete.
* type of coarse aggregate.
* type of cement
* type of mould
* carbonation of concrete surface.

2) Penetration techniques

→ The measurement of hardness by probing techniques was first reported during 1954. Two techniques were used.

→ In one case a hammer known as "Simi" was used to perforate concrete and the depth of borehole was correlated to compressive strength of concrete cubes.

→ In other technique the probing of concrete was achieved by blasting with spit pins and the depth of penetration of the pins was correlated with compressive strength of concrete.

→ The accuracy of this test was found to be ± 25%. However it is further seen that 'simi' and 'spit pins' were more effected by the arrangement of coarse aggregate, than the tests using rebound hammers.

3) Pullout test:

→ A pullout test measures the force required to pull out from the concrete a specially shaped rod whose enlarged end has been cast into that concrete.

→ The stronger the concrete the more is the force required to pullout the. Ideal way to use pullout test in the field would be to incorporate assemblies into the structure.

→ This standard specimen could then be pulled out at any point of time.

→ The force required denotes the strength of concrete. Another way to use pullout test in the field would be to cast one (or) two base blocks of concrete incorporating pullout assemblies.

→ Pullout test could then be performed to assess the strength of concrete.

4) Dynamic (or) Vibration Method:

→ This is the important non destructive method in testing concrete strength and other properties.

→ The fundamental principle on which the dynamic (or) vibration methods are based is velocity of sound through a material.

→ A mathematical relationship could be established b/w the velocity of sound through specimen and its resonant frequency and the relationship of these two to the modulus of elasticity of the material.

→ The relationship which are derived for solid mediums considered to be homogeneous, isotropic and perfectly elastic but they may be applied to heterogeneous materials like concrete.

→ The velocity of sound in a solid can be measured by determining the resonant frequency of specimen (or) by recording the time of travel of short pulses of vibration passing through the samples.

→ In NDT of concrete either resonance method (or) pulse velocity techniques could be adopted.

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5) Pulse velocity method:

→ This can be of two methods

i) Mechanical sonic pulse velocity

ii) Ultrasonic pulse velocity.

i) Mechanical sonic pulse velocity:

→ Out of these two ultrasonic pulse velocity method has gained considerable popularity all over the world.

→ When mechanical impulses are applied to a solid mass, three different kinds of waves are generated.

→ These are generally known as longitudinal waves, shear waves and surface waves. These three waves travel at different speeds.

→ The longitudinal (or) compressional waves travel about twice as fast as the other two types. Shear (or) transverse waves are not so fast, the surface waves are the slowest.

→ The pulses can be generated either by hammer blows (or) by the use of an electro acoustic transducer. Electro acoustic transducers are preferred as they provide better control on the type and frequency of pulses generated. The instrument used is called "Sonic scope".

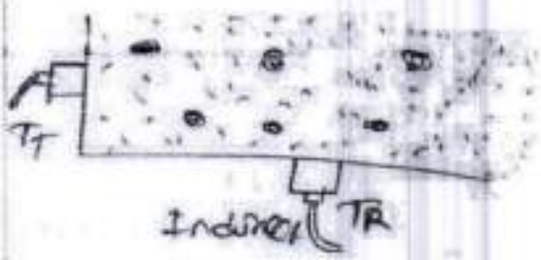
ii) Ultrasonic pulse velocity:

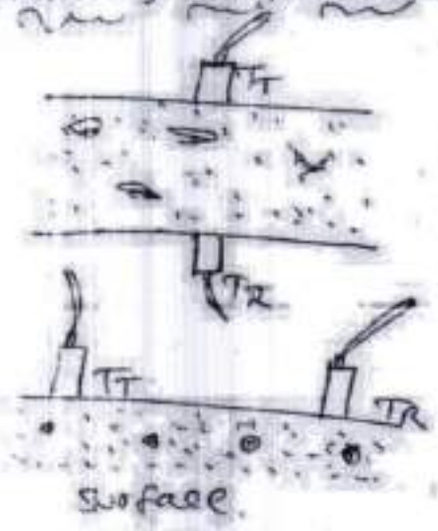
→ This method consists of measuring the time of travel of an ultrasonic pulse, passing through the concrete to be tested. The pulse generator circuit consists of electronic circuit for generating pulses and a transducers for transforming these electronic pulses into mechanical energy having vibration frequencies in the range of 15 to 50 kHz.

→ The time of travel b/w initial onset and the reception of the pulses is measured electronically. The path length b/w transducer divided by the time of travel gives the avg velocity of wave propagation.

Techniques of measuring pulse velocity through concrete:

a) Direct transmission
b) Indirect transmission
c) Surface transmission





T_T = T_R = Transducer transmitters.

Factors affecting the measurement of pulse velocity:

→ The measurement of pulse velocity is affected by another of factors regardless of the properties of concrete.

i) Smoothness of contact surface under test.
ii) Influence of path length on pulse velocity.
iii) Temperature of concrete.
iv) Moisture condition of concrete.
v) Presence of reinforcing steel.

6) Radioactive & Nuclear Methods:

i)
→ The use of X-ray and gamma rays as non destructive method for testing properties of concrete is relatively new. X-ray and γ-ray both components of high energy region on the electromagnetic spectrum penetrate concrete but undergo attenuation in the process.

→ The degree of attenuation depends on the kind of matter traversed its thickness and the wavelength of the radiation.

→ The intensity of incident γ-rays and the emerging γ-rays after passing through the specimens are measured. These two values use for calculating density of structural concrete the most.

γ-rays transmission method has been used to measure the thickness of concrete slabs of known density. γ-radiation sources of known intensity is made to pass and penetrate through the concrete. The intensity at the other face is measured to measure thickness of the concrete is calculated.

ii) → Use of nuclear methods for non destructive measurement of some properties of concrete is of recent region.

→ Two techniques have been reported, namely neutron scattering methods for determining the moisture content of concrete and neutron activation analysis for the determination of cement content. These methods are not suitable for finding out the strength of concrete.

7) Magnetic & Electrical Method:

i) → Battery operated magnetic devices that can measure the depth of reinforcement covers in concrete and detect the position of reinforcement bars are now available. The apparatus is known as cover meter.

ii) → Electrical resistivity methods have seen used to find out the thickness of concrete pavements.

→ The method is based on the principle that the material offers resistance to the passage of an electric current.

→ A concrete pavement has resistivity characteristic that is different from that of the underlying subgrade layers.

→ A change in the slope of the resistivity (vs) depth curve is used to estimate the depth of concrete pavement.

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MODULUS OF ELASTICITY :

→ The stress in steel is 'm' times the stress in concrete. where 'm' is the ratio b/w the modulus of elasticity of steel and concrete. known as modular ratio.

→ The modulus of elasticity can also be determined by subjecting a concrete cube (or) cylinder specimen to uniaxial compression and measuring the deformation by means of dial gauges fixed b/w the certain gauge length.

→ Total gauge reading divided by gauge length will give the strain and load applied divided by area of cross section will give the stress.

→ The modulus of elasticity can also be determined by subjecting a concrete beam to bending and then using the formulae for deflection and substituting other parameters. The modulus of elasticity so found out from actual loading is called static modulus of elasticity.

→ Modulus of elasticity may be measured in tension, compression (or) shear.

→ The modulus in tension is equal to modulus in compression.

→ Modulus of elasticity of concrete increases approximately with the square root of the strength.

Modulus of elasticity as $E_c = 5000\sqrt{f_{ck}}$.

→ The modulus of elasticity of light weight concrete is usually between 40 to 80% of the modulus of elasticity of ordinary concrete of the same strength.

→ The relation b/w the modulus of elasticity and strength is not much effected by temperature upto about 230°C since both the properties vary with temperature in approximately the same manner. Steam cured concrete shows a slightly lower modulus than water-cured concrete of the same strength.

DYNAMIC MODULUS OF ELASTICITY.

→ The value of E is found out by actual loading of concrete. i.e. the static modulus of elasticity does not truly represent the elastic behaviour of concrete due to the phenomenon of creep. The elastic modulus of elasticity will get affected more seriously at higher stresses when the effect of creep is more pronounced.

→ The modulus of elasticity can be determined by subjecting the concrete member to longitudinal vibration at their natural frequency.

→ Modulus of elasticity can be calculated from the following relationship

$$E_d = Kn^2L^2\rho$$

E_d = Dynamic modulus of elasticity.
K = constant
n = resonant frequency.
L = length of specimen.
ρ = density of concrete.

$$E_d = 4\times10^{-5}\, n^2L^2\rho \text{ GPa.}$$

→ The value of E found out in this method by the velocity of sound (or) frequency of sound is referred as dynamic modulus of elasticity, in contrast to the value of E found out by actual loading of the specimen and from stress-strain relationship which is known as static modulus of elasticity.

→ The value of dynamic modulus of elasticity computed from ultrasonic pulse velocity method is somewhat higher than those determined by static method.

→ This is because the modulus of elasticity as determined by dynamic modulus is unaffected by creep. The creep also doesnot significantly effect the initial tangent modulus in the static method.

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→ The value of dynamic modulus and the value of initial tangent modulus ~~of~~ to be more or less agree with each other. Approximate relationship b/w the two modulai expressed in CNI/mm is given by

$$E_c = 1.25\, E_d - 19$$

E_c & E_d are static and dynamic modulus of elasticity

→ For 1:2:4 mixture concrete the relationship is

$$E_c = 1.04\, E_d - 14$$

Poisson's Ratio:

→ Poissons ratio is the ratio b/w lateral strain to the longitudinal strain. It is denoted by 'μ'

→ For normal concrete $\mu = 0.15$ to 0.20

→ Poissons ratio can be determined from ultrasonic pulse velocity method and by finding out the fundamental resonant frequency of longitudinal vibration of concrete beam.

$$\left(\frac{V^2}{2nL}\right)^2 = \frac{1-\mu}{(1+\mu)(1-2\mu)}$$

V = pulse velocity
n = resonant frequency
L = length of beam
μ = 0.2 to 0.25

→ Dynamic modulus of elasticity can also be found out from following eqn.

$$E_d = \rho V^2 \frac{(1+\mu)(1-2\mu)}{(1-\mu)}$$

V = pulse velocity
ρ = density
μ = poissons ratio.

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CREEP:

→ Creep can be defined as the "time-dependent" part of the strain resulting from stress.

→ The gradual increase in strain, without increase in stress, with the time is due to creep. From this explanation creep can also be defined as the increase in strain under sustained stress.

→ Creep of concrete is approximately linear function of stress upto 30 to 40% of its strength.

Measurement of Creep:

→ Creep is usually determined by measuring the change with time in the strain of specimen subjected to constant stress and stored under appropriate condition.

→ It is generally assumed that the creep continues to assume a limiting value after an infinite time under load. It is estimated that 80% of the 20 years creep occurs in 2 years. 55% of 20 years creep occurs in 3 months and 76% of 20 years creep occurs in one year.

→ If creep after one year is taken as unity, then the avg value of creep at later ages are.

1.14 after 2 years
1.20 after 5 years
1.26 after 10 years
1.33 after 20 years
1.36 after 30 years.

→ The relation b/w creep (C) and time (t) is

$$C = \frac{t}{a+bt}$$

$$a = 1/C$$

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FACTORS AFFECTING CREEP:

i) Influence of aggregate:

→ Aggregate undergoes very little creep. It is really the paste which is responsible for the creep. However the aggregates influences the creep of concrete through a restraining effect on the magnitude of creep.

→ The grading, the shape, the maximum size of aggregate have been suggested as factors affecting creep.

→ The Modulus of elasticity of aggregate is one of the important factors influencing creep. It can be easily imagined that the higher the modulus of elasticity the less is the creep.

ii) Influence of mix proportion:

→ The amount of paste content and its quality is one of the most important factors influencing creep.

→ A poorer paste content structure undergoes higher creep. Therefore it can be said that creep increases in water/cement ratio.

→ In other words creep is inversely proportional to strength of concrete.

iii) Influence of Age:

→ Age at which concrete members is loaded will have a predominant effect on the magnitude of creep. This can be easily understood from the fact that the quality of gel improves with time. Such gel creeps less, whereas a young gel under load being not so stronger creeps more.

iv) Effects of Creep:

→ Magnitude of creep is dependent on many factors the main factors being time and level of stress. In reinforced concrete beams, creep increases the deflection with time and may be a critical consideration in design.

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SHRINKAGE:

→ The volume change on account of inherent properties of concrete is known as "shrinkage".

→ One of the most objectionable defects in concrete is the presence of cracks, particularly in floors and pavements due to the shrinkage.

→ It is difficult to make concrete which does not shrink and crack. It is only a question of magnitude.

TYPES OF SHRINKAGE:

1) Plastic shrinkage
2) Drying shrinkage
3) Autogeneous shrinkage
4) Carbonation shrinkage.

1) Plastic shrinkage:

→ Loss of water by evaporation from the surface of concrete (or) by the absorption by aggregate (or) substrate is believed to be the reason of plastic shrinkage.

→ The loss of water results in the reduction volume. The aggregate particles (or) the reinforcement acts in the way of subsidence due to which cracks may appear at the surface (or) internally around the aggregate (or) reinforcement.

→ In case of floors and pavements where the surface area exposed to drying is large as compared to vertic, when that large surface is exposed to hot sun and drying wind the surface of concrete dries very fast which results in plastic shrinkage.

→ Plastic shrinkage can be reduced mainly by preventing the rapid loss of water from surface. This can be done by covering the surface with polyethylene sheets immediately on finishing operation

→ Monomolecular coatings by fog spray that keeps the surface moist.

→ Working at night is an effective method of reducing shrinkage.

2) **DRYING SHRINKAGE:**

→ The drying shrinkage is a long over lasting process when concrete is subjected to drying conditions.

→ The drying shrinkage of concrete is analogous to the mechanism of drying of hardened specimen. The loss of water contained in hardened concrete does not result in any appreciable dimension change.

→ Cement paste shrinks more than mortar and mortar shrinks more than concrete.

→ The rate of shrinkage decreases rapidly with time. It is observed that 14-34% of the 20 years shrinkage occurs in 2 weeks, 40-80% of the 20 year shrinkage occurs in 3 months, 60-85% of the 20 year shrinkage occurs in one year.

→ The volume fraction of aggregate will have some influence on the total shrinkage. The ratio of shrinkage of concrete (S_c) to shrinkage of neat paste (S_p) depends on the aggregate content in the concrete.

$$S_c = S_p (1-a)^n$$

$$n = 1.2 \text{ to } 1.7$$

→ The property of swelling when placed in wet condition and shrinking when placed in drying condition is referred as moisture movement in concrete.

3) **Autogeneous shrinkage:**

→ In a conservative system i.e. where no moisture movement to (or) from the paste is permitted when temperature is constant some shrinkage may occur. The shrinkage of such a conservative system is known as autogeneous shrinkage.

→ Autogeneous shrinkage is of minor importance and is not applicable in practice to many situations except that of mass of concrete in the interior of concrete dam.

→ The magnitude of autogeneous shrinkage is 100×10^{-6}.

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4) Carbonation shrinkage

→ Carbonation shrinkage is a phenomenon very recently recognised. Carbon dioxide present in the atmosphere reacts in the presence of water with hydrated cement.

→ Calcium hydroxide ($Ca(OH)_2$) gets converted to calcium carbonate ($CaCO_3$) and also some other cement compounds are decomposed. Such a complete decomposition of calcium compound in hydrated cement is chemically possible even at the low pressure of carbon dioxide in normal atmosphere. Carbonation penetrates beyond the exposed surface of concrete only very slowly.

→ The rate of penetration of carbon dioxide depends upon the moisture content of the concrete and the relative humidity of the ambient medium.

→ Carbonation of concrete also results in increased strength and reduced permeability.

UNIT-III

MIX DESIGN

FACTORS AFFECTING THE CHOICE OF MIX PROPORTIONS:

1) Compressive strength
2) Workability
3) Durability
4) Max. nominal size of aggregate
5) Fineness modulus & zone of aggregate
6) Quality control

① **Compressive strength:**

→ The compressive strength of any material is defined as the resistance to failure under the action of compressive forces. Especially for concrete, compressive strength is an important parameter to determine the performance of the material during service conditions

→ Concrete mix can be designated (or) proportioned to obtain the required engineering and durability properties as required by the design engineer.

→ Some of the other engineering properties of hardened concrete include elastic modulus, tensile strength, creep co-efficient, density, co-efficient of thermal expansion etc.

Compressive strength of concrete:

→ Concrete specimens are a cast and tested under the action of compressive loads to determine the strength of concrete

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→ Compressive strength is calculated by dividing the failure load by the area of application load, usually after 28 days of curing.

→ The strength of concrete is controlled by the proportioning of cement coarse and fine aggregates, water and various admixtures.

→ The ratio of the water to cement is the chief factor for determining concrete strength. The lower the water-cement ratio the higher is the compressive strength.

→ In normal field the concrete strength can vary from 10MPa to 60MPa.

→ For structures the concrete mixes can be designed to obtain very high compressive strength capacity in the range of 500MPa.

→ The compressive strength of concrete is given in terms of the characteristic compressive strength of 150mm size cubes tested at 28 days.

→ The characteristic strength is defined as the strength of the concrete below which not more than 5% of the test results are expected to fall.

PROCEDURE:

→ Specimen stored in water shall be tested immediately on removal from the water and while they are still in the wet condition.

→ Take the dimension of the specimen to the nearest 0.2mm.

→ Clean the bearing surface of the testing machine.

→ Place the specimen in the machine in such a manner that the load shall be applied to the opposite sides of the specimen.

→ Apply the load gradually without shock & continuously at the rate of 40 kg/cm²/min. till the specimen fails.

→ Record the max. load and note any unusual features in the type of failure.

2) Workability of concrete:

→ "Workability represents consistency and cohesiveness of concrete.

General consideration for workability

i) Water content:

→ The higher the water content, the higher will be the fluidity of concrete, which is one of the important factors affecting workability.

ii) aggregate/cement ratio:

→ The higher the a/c ratio, the leaner is the concrete.

→ In lean concrete, less quantity of paste is available for lubrication per unit surface area of aggregate and hence the mobility reduce.

→ In case of rich concrete with lower aggregate/cement ratio, more paste is available to make the mix cohesive and fatty to give better workability.

iii) size of aggregate:

→ The bigger the size of aggregate, the less the surface area hence, less water is required for wetting the surface and paste is required for lubricating the surface to reduce internal friction.

→ For a given quantity of water and paste bigger size of aggregate will give higher workability.

iv) shape of aggregate:

→ Angular, elongated (or) flaky aggregate makes the concrete very harsh when compared to rounded aggregate (or) cubical shaped aggregates.

→ Round round in shape the frictional resistance is also greatly reduced.

v) surface texture:

→ Total surface area of rough textured aggregate is more than the surface area of smooth rounded aggregate of same volume.

→ Rough textured aggregate will show poor workability and smooth (or) glassy textured aggregate will give better workability.

vi) Grading of aggregates:

→ Better the grading, the less is the void content and higher the workability.

→ When the total voids are less, excess paste is available to give better lubricating effect

vii) Use of Admixtures:

→ Use of air entraining agent being surface-active reduces the internal friction between the particles.

→ Plasticizers and super-plasticizers greatly improve the workability many folds.

3) Durability of concrete:

→ Durability of concrete may be defined as the ability of concrete to resist weathering action, chemical attack, and abrasion while maintaining its desired engineering properties.

→ It is normally refers to the duration of life span of trouble free performance.

Concrete will remain durable if:

→ The cement paste structure is dense and of low permeability

→ Under extreme condition, it has entrained air to resist freeze-thaw cycle.

→ It is made with graded aggregate that are strong and tough

→ The ingredients in the mix contain minimum impurities such as alkalis, chlorides, sulphates and silt.

Factors affecting Durability:

i) Cement content:

→ Mix must be designed to ensure cohesion and prevent segregation and bleeding. If cement is reduced than at fixed w/c ratio the workability will be reduced leading to inadequate compaction

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→ Also even if water is added to improve workability, water cement ratio increases and resulting in highly permeable material.

ii) Compaction:

→ The concrete as a whole contain voids can be caused by inadequate compaction. Usually this being governed by compaction equipments used type of formwork, and density of the steel work.

iii) Curing:

→ It is very important to permit proper strength development and moisture retention and to ensure hydration process occur completely.

iv) Cover:

→ Thickness of concrete cover must follow the limits set in codes.

v) Permeability:

→ The higher permeability usually caused by higher porosity.

→ A proper curing, sufficient cement, proper compaction and suitable concrete cover would provide a low permeability concrete.

Types of Durability of Concrete:

1. Physical durability
2. Chemical durability

1. Physical durability:

→ Freezing and thawing action
→ Percolation / Permeability of water
→ Temperatures stresses.

2. Chemical durability:

→ Alkali aggregate reaction.
→ Sulphate attack
→ Chloride ingress
→ Corrosion of reinforcement.

Causes of durability

1. External causes
2. Internal causes

1. External causes

→ Extreme weathering conditions
→ Extreme temperature.
→ Extreme humidity
→ Abrasion
→ Electrolytic action.

2. Internal causes

→ Physical → Frost action
→ Chemical → Alkali aggregate reaction and
→ Corrosion of steel.

4) Max. nominal size of coarse aggregate:

→ The max. nominal size of the coarse aggregate is determined by sieve analysis and is determined by the sieve size higher than the largest size on which 15% or more of the aggregate is retained.
→ The max. nominal size of the aggregate to be used in concrete is governed by the size of the section and spacing of the reinforcement.
→ According to IS: 456-2000 and IS: 1343-1980, the maximum nominal size of the aggregate should not be more than 1/4th of the max. thickness of the member, and it should be restricted to 5mm less than min. clear distance b/w main bars of 5mm not less than min. clear cover to the reinforcement.
→ The nominal max. size of aggregate, smaller ~~[illegible]~~ ~~[illegible]~~ ~~[illegible]~~ be as large as possible, because for the max. size of the aggregate, smaller is the cement requirement for a particular water/cement ratio.
→ The workability also increases increase in max. size aggregate

→ For the concrete with higher w/c ratio the larger max size of aggregate may be beneficial whereas for high strength concrete 10-20 mm size of aggregate is preferable.

5) Quality control:

→ The strength of concrete varies from batch to batch over a period of time.

→ The source of variability in the strength of concrete may be considered due to variation in the quality of the constituent materials, variations in mix proportions due to batching process, variations in the quality of batching and mixing equipment available, the quality of supervision and workmanship.

→ Controlling the variation is important in lowering the difference b/w minimum strength and characteristic mean strength of the mix and hence reducing the cement content. The factor controlling the difference is quality control.

→ The degree of control is ultimately evaluated by the variation in test results usually expressed in terms of "co-efficient of variation"

→ Most of the mix design procedures are primarily based on the water-cement ratio law and absolute volume system of calculating the amount of materials.

→ According to Abram's law, the strength of fully compacted hardened concrete is approximately inversely proportional to the water content per cubic meter of cement.

$$\text{Absolute volume} = \frac{\text{Mass of loose dry material}}{\text{Sp. Gravity} \times \text{Mass of unit of volume of water.}}$$

Statical Quality control of concrete :-

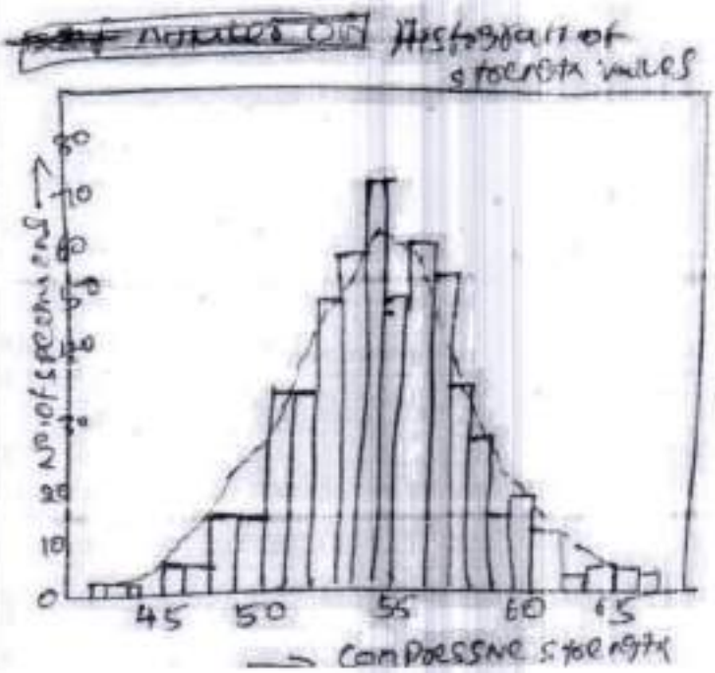
-> The aim of quality control is to limit the variability of much as practicable. Statical quality control method provides a scientific approach to the concrete designer to understand the realistic variability of the materials so as to lay down design specifications with proper tolerance to cater for unavoidable variations.

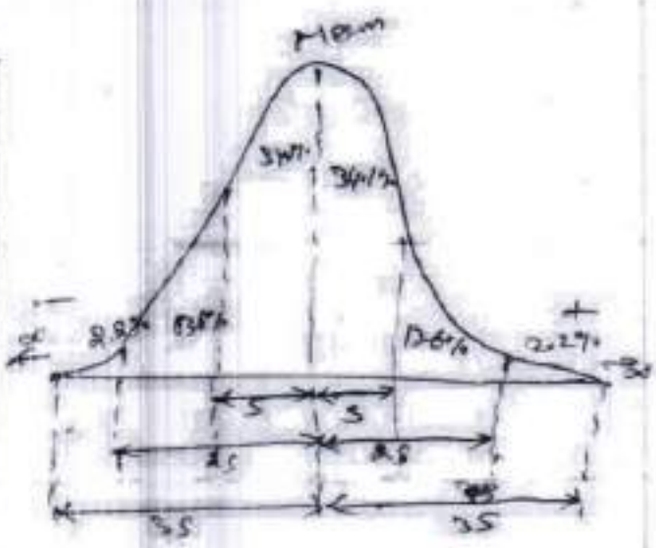
-> The acceptance criteria are based on statical evaluation on the test result of samples taken at random during execution.

-> The method provides a scientific basis of acceptance which is not only realistic but also relatives as required by the design requirements for the concrete construction.

-> The quality of concrete will be of immense value for large contracts where the specifications insist on certain minimum requirements. The effort put in will be more than repaid by resulting savings in the overall concreting operations.

-> The compressive strength test comes from random sampling of a mix, exhibit variations, which are inherent in the various operations involved in the making and testing of concrete.





→ If a number of cube test result are plotted on histogram, the results are found to follow a bell shaped curve known as "normal distribution curve".

→ The results are said to follow a normal distribution curve if they are equally spaced about the mean value and if the largest number of the cubes have a strength closer to the mean value, the few number of results with much greater (or) less value than the mean value.

→ The arithmatic mean (or) the average value of the number of test result gives no indication of the extent of variation of strength. This can be ascertained by relating the individual strength to mean strength and determining the variation from the mean with the help of the properties of normal distribution curve.

Common terminologies:

i) Mean strength:

→ The avg strength obtained by dividing the sum of strength of all the cubes by the number of cubes

$$\bar{x} = \frac{\Sigma x}{n}$$

ii) Variance:

→ This is the measure of variability (or) difference b/w any single observed data from the mean strength.

iii) Standard deviation:

→ This is the root mean square deviation of all the results. (σ)

$$\sigma = \sqrt{\frac{\Sigma (x-\bar{x})^2}{n-1}}$$

iv) Co-efficient of variation:

→ It is an alternative method of expressing the variation of results. This non dimensional measure of variation obtained by dividing the standard deviation by the arithmatic mean.

$$V = \frac{\Sigma}{\bar{x}} \times 100.$$

Various Methods of proportioning mix design.

1) Arbitrary proportion
2) Fineness Modulus Method.
3) Maximum Density method
4) Surface area Method.
5) Indian Road congress, IRC 44 Method.
6) High strength concrete mix design.
7) Mix design based on flexural strength.
8) Road note No 4.
9) ACI comitee 211 method.
10) DOE Method.
11) Mix design for pumpable concrete.
12) Indian standard recommended Method IS 10262-82

→ out of the above methods, some of them are not very widely used these days because of some difficulties (or) drawbacks in the procedures for arriving at the satisfactory proportions.

→ The ACI comitee 211 method, the DOE Method and Indian standard recommended methods are commly used.

→ Since concrete is very commonly placed by pumping these days method of mix design of pumpable concrete has become important.

→ Before we deal with some of the important methods of concrete mix design, it is necessary to get acquainted with statical quality control methods, which are common to all the methods of mix design.

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PROCEDURE FOR CONCRETE MIX DESIGN

1. Determine the mean target strength (f_t) from the specified characteristic compressive strength at 28 days f_{ck} and the level of quality control.

$$f_t = f_{ck} + 1.65\,S$$

S = standard deviation.

2. Obtain the water cement ratio for the desired mean ~~strength~~ target using the empirical relationship b/w compressive strength and water cement ratio so choosen is checked against the limiting w/c ratio.

3. Estimate the amount of entrapped air for maximum nominal size of the aggregate from the table.

4. Select the water content for the required workability and maximum size of aggregates from table.

5. Determine the % of fine aggregates in total aggregate by absolute volume from table for the concrete using crushed coarse aggregate.

6. Adjust the value of water content and % of sand as provided in the table for any difference in workability water cement ratio, grading of fine aggregate and for rounded aggregate the values are given in table.

7. Calculate the cement content from the water-cement ratio and the final water content as arrived after adjustment. Check the cement against the minimum cement content from the requirements of the durability and greater of the two values is adopted.

8. From the quantities of [illegible] of concrete and the % of sand already determined in step 6 and step 7 above, calculate the content of coarse and fine aggregates per unit volume of concrete from the following relation.

$$V = \left[W + \frac{C}{Sc} + \frac{1}{P} \frac{Fa}{Sfa} \right] \times \frac{1}{1000}$$

$$V = \left[W + \frac{C}{Sc} + \frac{1}{1-P} \cdot \frac{Ca}{Sca} \right] \times \frac{1}{1000}$$

V = absolute volume of concrete = gross volume (m³) − volume of entrapped air

Sc = sp. gravity of cement

W = mass of water per cubic metre of concrete, kg.

C = mass of cement per cubic metre of concrete, kg

P = ratio of fine aggregates to total aggregates by absolute volume.

Ca = total masses of fine and coarse aggregates, kg

Sfa, Sca = sp. gravities of saturated surface dry fine and coarse aggregates.

9. Determine the concrete mix proportions for the first trial mix.

10. Prepare the concrete using the calculated proportions and cast three cubes of 150mm size and test them at 28 days after moist curing and check for the strength.

11. Prepare trial mixes with suitable adjustments till the final mix proportions are arrived at.

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PROBLEM

Q). CONCRETE MIX DESIGN - M50 GRADE CONCRETE

Grade Designation = M50

Type of cement = OPC-43 Grade

Brand of cement = ULTRATECH

Admixture = silica

fine aggregate = zone - II

Sp. Gravity

cement = 2.15

fine aggregate = 2.61

C.A (20mm) = 2.65

C.A (10mm) = 2.66

Min. cement = 400 kg/m3

water/cement Ratio = 0.45.

MIX CALCULATION:

1) Target Mean Strength:-

$f_t = f_{ck} + 1.65S$

$f_t = 50 + (1.65 \times 5)$

$f_t = 58.25$ MPa.

2) W/C ratio:-

(IS 10262-2009)

Assume W/C = 0.35

3) calculation of water:-

Approximate water content for 20mm max. size of aggregate = 180 kg/m3 (table No 5, IS 10262)

As plasticizers is proposed we can reduce water content by 20%

100 - 20 = 80% = 0.8

water content = 180 × 0.8 = 144 kg/m3

Calculation of cement content :-

W/C ratio = 0.35

water content / m3 of concrete = 144 kg

cement content = $\frac{144}{0.35}$ = 411.4 kg/m3

cement content = 412 kg/m3 (As per control Min. cement content 400 kg/m3)

Hence OK.

5) Calculation for C.A & F.A :-

Volume of concrete = 1 m3

volume of cement = $\frac{412}{(3.15 \times 1000)}$ = 0.1308 m3

Volume of water = $\frac{144}{1 \times 1000}$ = 0.1440 m3

Volume of admixture = $\frac{4.944}{(1.145 \times 1000)}$ = 0.0043 m3

Total vol of materials except C.A = 0.1308 + 0.1440 + 0.0043 = 0.2791

Volume of CA & F.A = 1 − 0.2791 = 0.7209 m3.

Volume of F.A = 0.7209 × 0.33 = 0.2379 m3 (Assume 33% by volume of total aggregate)

Volume of C.A = 0.7209 − 0.2379 = 0.4830 m3.

weight of F.A = 0.2379 × 2.61 × 1000 = 1282.365 kg/m3 = 620.9178 kg/m3

say weight of C.A = 1284 kg/m3.

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considering 20mm : 10mm = 0.55 : 0.45

... 20mm = 706 kg
10mm = 578 kg.

Hence mix details / m3

increasing cement, water, admixture by 2.5% for mix specimens.

cement = 422 x 1.025 = 432 kg.

water = 144 x 1.025 = 147.8 kg

F.A = 621 kg

C.A 20mm = 706 kg.

C.A 10mm = 578 kg

Admixture = 1.2% by weight of cement = 5.064 kg.

water : cement = F.A : CA = 0.35 : 1 : 1.472 : 5.043.

Observations from concrete mix designs—

A. Mix was cohesive & homogeneous

B. Slump = 120mm

C. No. of cube cast = 9 nos.

7 days avg compressive strength = 52.07 MPa

28 days avg compressive strength = 62.52 MPa.

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UNIT - V

SPECIAL CONCRETE

LIGHT WEIGHT CONCRETE:

-> one of the disadvantages of conventional concrete is the high self weight of concrete.

-> density of normal concrete is in the order of 2200 to 2400 kg/m3. This heavy self weight will make it to some extent an uneconomical structural material.

-> Attempts have been made in the past to reduce the self weight of concrete to increase the efficiency of concrete as structural material.

-> The light weight concrete as we call is a concrete whose density varies from 300 to 1850 kg/m3.

-> There are many advantages of having low density. It helps in reduction of dead load, increases the progress of building, and lowers haulage and handling costs.

-> The weight of a building on the foundation is an important factor in design, particularly in the case of weak soil and tall structures.

-> In framed structures, the beams and columns have to carry load of floors and walls. This are made up of light-weight concrete it will result in considerable economy.

-> Another most important characteristic of light weight concrete is the relatively low thermal conductivity, a property which improves with decreasing density.

-> In extreme climatic conditions and also in case of buildings where air conditioning is to be installed, the use of light weight concrete with low thermal conductivity will be of considerable advantage from the point of view of thermal comforts and lower power consumption.

-> The adoption of light weight concrete gives an outlet for industrial wastes such as clinker, flyash, slag etc.

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→ Basically there is only two methods of making concrete light.
i.e by the inclusion of air in concrete.
i) By replacing the usual mineral aggregates by cellular porous (or) light weight aggregates.
ii) By introducing gas (or) air bubbles in mortar. This is known as aerated concrete.
iii) By omitting sand fraction from the aggregate. This is called no-fines concrete.

→ A particular type of light-weight concrete called structural light weight concrete is one which is comparatively lighter than conventional concrete but at the same time strong enough to be used for structural purposes.

LIGHT WEIGHT AGGREGATE CONCRETE:

→ very often light-weight concrete is made by the use of light weight aggregates. we have seen that different light-weight aggregates have different densities.

→ naturally when this aggregate used, concrete of different densities are obtained. By using expanded perlite (or) vermiculite, a concrete of density as low as 300 kg/m³ can be produced, and by the use of expanded slag, sintered fly ash, bloated clay etc. a concrete of density 1900 kg/m³ can be obtained.

→ The strength of the light weight concrete may also vary from about 0.3 N/mm² to 40 N/mm². A cement content of 200 kg/m³ to about 500 kg/m³ may be used.

→ Strength of light weight concrete depends on the density of concrete. Less porous aggregates which are heavier in weight produces stronger concrete particularly with higher cement content.

→ The grading of aggregate, the water/cement ratio, the degree of compaction also effect the strength of concrete.

→ Most of the light-weight aggregate with the exception of bloated clay and sintered fly ash are angular in shape and rough in texture they produce harsh mix.

→ The strength of aggregate will also be influenced by the type of fine aggregates. For increasing the strength, for improving the workability and for reducing the water requirements, some times natural sand is used instead of crushed sand made out of light-weight aggregate.

→ Most of the light weight aggregates have a high and rapid absorption quality. This is one of the important difficulties in applying the normal mix design procedure to the light weight concrete.

→ Light weight concrete being comparatively porous when used for reinforced concrete, reinforcement may become prone to corrosion. Either the reinforcement must be coated with anticorrosive compound (or) the concrete must be plastered at the surface by normal mortar to inhibit the penetration of air and moisture inside.

Design :

→ Mix design methods applying to normal weight concrete are generally difficult to use with light weight aggregate concrete. The lack of accurate value of absorption, specific gravity, and free moisture content in the aggregate make it difficult to apply the water/cement ratio accurately for mix proportioning.

→ Light weight concrete mix design is usually established by trial mixes. The proportion of fine to coarse aggregate and the cement and water requirement are estimated based on the previous experience with particular aggregate.

→ Sometimes the aggregate is saturated before mixing so that it doesn't take up the water used for mixing.

→ The quality of concrete does not get altered on account of absorption by aggregate. It has been seen that the strength

of the resulting concrete is about 5 to 10 % lower than when only aggregate is used for the same content and workability.

Mixing Procedure:

→ Mixing procedure for light weight concretes may vary with different types of aggregates. The general practice for structural light weight concrete is to mix the aggregates and about 2/3 of the mixing water for a period upto one minute prior to the addition of cement and the balance mixing water.

→ Mixing is done continously as required for homogeneity. Usually 2 or 3 more minutes are required to get uniform mixing. In case of some insulating concrete the aggregate is added at the end of mixing to minimize degradation.

Aerated concrete / cellular concrete:

→ Aerated concrete is made by introducing air (or) gas into slurry composed of portland cement (or) lime and finely crushed siliceous fiver so that when the mix sets and hardens, a cellular structure is formed. Though it is called aerated concrete it is not a concrete in the correct sense of the word. It is mixture of water, cement and finely crushed sand.

→ Aerated concrete is also referred as gas concrete, foam concrete, cellular concrete.

→ There are several ways in which aerated concrete can be manufactured.

(a) By the formation of gas by chemical reaction within the mass during liquid (or) plastic state.

(b) By mixing performed stable foam with the slurry.

(c) By using finely powdered metal.

-> Powdered zinc may also be added in place of aluminium powder. Hydrogen peroxide and bleaching powder have also been used instead of metal powder. But this practice is not widely followed at present.

(b)
-> In the stable foam is mixed with cement and crushed sand slurry thus casting the cellular structure when this gets set and hardened.

-> However this method cannot be employed for decreasing the density of the concrete beyond a certain point and as such the use of air entrainment is not often practised for making aerated concrete.

(a)
-> Gasification method is most widely adopted method using aluminium powder for such other similar material. This method is adopted in the large scale manufacture of aerated concrete in the factory where in the whole process is mechanised and the product is subjected to high pressure steam curing i.e. the products are autoclaved.

NO FINES CONCRETE :

-> No fines concrete as the term implies is a kind of concrete from which the fine aggregate fraction had been omitted. This concrete made up of only coarse aggregate, cement and water.

-> Very often only single sized coarse aggregate of size passing through 20mm retained on 10mm is used.

-> No fines concrete is becoming popular because of some of the advantages it posses over the conventional concrete.

-> This single sized aggregates take a good no fines concrete, which in addition to having more voids and hence light in weight also offers an architectural attractive look.

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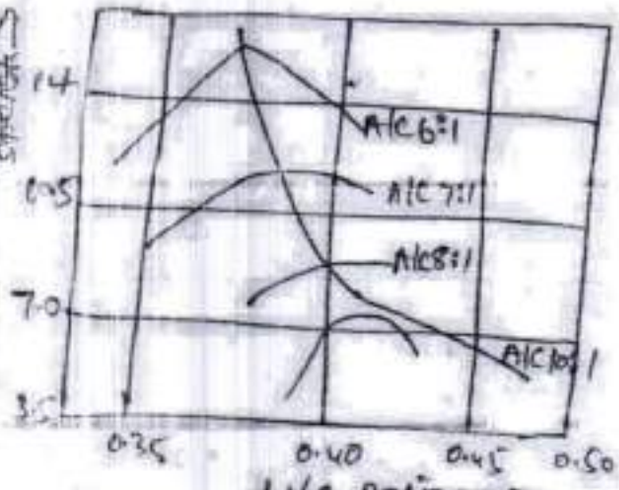
Mix Proportion:

→ No fines concrete is generally made with the aggregate/cement ratio from 6:1 to 10:1.

→ Aggregates are used normally of size passing through 20mm and retained on 10mm unlike the conventional concrete, in which strength is primarily controlled by the water/cement ratio the strength of fines concrete is dependent on the water/cement ratio, aggregate cement ratio and unit weight of concrete.

→ The w/c ratio for satisfactory consistency will vary b/w a narrow range of 0.35 and 0.52

→ If too low w/c ratio is adopted the paste will be so dry that aggregates does not get properly coated with paste which result in insufficient.



→ On the other hand if the w/c ratio is too high, the paste flows to the bottom of the concrete, particularly when vibrated and fills up the voids b/w the aggregates at the bottom and make that portion dense.

→ No standard method is available, like slump test (or) compacting factor test for measuring the consistency of no-fines concrete.

→ No fines concrete when conventional aggregates are used, may show a density of about 1600 to 1900 kg/m³, but when no-fines concrete is made by using light weight aggregate, the density may come to about 300 kg/m³.

→ The bond strength of no fines concrete is very low and therefore reinforcement is not used in conjunction with no fines concrete. However if reinforcement is required to be used in no fines concrete, it is advisable to smear the RC with cement paste to improve the bond and also to protect it from rusting.

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HIGH DENSITY CONCRETE:

→ Density of normal concrete is in the order of about 2400 kg/m³

→ The density of light weight concrete will be less than about density 1900 kg/m³.

→ To call the concrete, as high density concrete it must have unit weight varying from about 3360 kg/m³ — 3640 kg/m³, which is about 50% higher than the unit weight of conventional concrete.

→ The advent of the nuclear energy industry presents a considerable demand on the concrete technologists.

→ Large scale production of penetrating radiation and radioactive materials are as a result of the use of nuclear reactors, particle accelerator, industrial radiography, and X-ray, γ-ray therapy, require the need of shielding material for the protection of operating personnel against the biological hazards such radiation.

→ Concrete both high density and normal density are effective and economic construction material for permanent shielding purposes.

Types of Radiation and Hazards:

→ There are two general classes of radiation.

1) Electromagnetic waves
2) Nuclear particles

→ Electromagnetic waves the high energy, high frequency waves known as X- and γ-rays are only types which require shielding for the protection of personnel. They are similar to light rays but of higher energy greater penetrating power.

→ Nuclear particles consist of nuclei of atoms or fragments thereof. They include neutrons, protons, alpha and beta particles of these all neutrons possess an electric charge.

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FIBRE REINFORCED CONCRETE :

→ Fibre reinforced concrete can be defined as a composite material consisting of mixtures of cement, mortar or concrete and discontinuous, discrete, uniformly dispersed suitable fibres. continuous meshes, woven fabrics and long wires or rods are not considered to be discrete.

→ Fibre is a small piece of reinforcing material possessing certain characteristics properties. It may be circular or flat.

→ The fibre is often described by a convenient parameter called 'aspect ratio' i.e ratio of its length to its diameter. The ratio ranges from 30 to 150.

TYPES OF F.R.C

→ Although every type of the fibre has been tried out in cement and concrete, not all of them can be effectively and economically used. Each types of fibre has its characteristic properties and limitations.

→ Some of the fibres could be used are

1) Steel fibres
2) Polypropylene fibres
3) nylons fibres
4) asbestos fibre
5) coir fibre
6) Glass fibre
7) Carbon fibre

1) Steel fibre :

→ It is one of the most commonly used fibre. Generally round fibres are used.

→ They diameter may vary from 0.25 to 0.75 mm. The steel fibre is likely to get rusted and lose some of its strengths. But investigations have shown that the rusting of fibres takes place only at the surface.

2) Polypropylene & nylon fibres :-

→ This fibres are found to be suitable to increase the impact strength. They posses very high tensile strength, but their low modulus of elasticity and higher elongation do not contribute to the flexural strength.

b) Asbestos fibre :-

→ Asbestos is a mineral fibre and has proved to be most successful of all fibres as it can be mixed with portland cement.

→ Tensile strength of asbestos varies b/w 560 to 980 N/mm². The composite product called asbestos cement has considerably higher flexural strength than the portland cement paste.

→ For unimportant fibre concrete, organic fibres like coir, jute, canesplits are also used.

5) Glass fibre :

→ It is a recent introduction in making fibre concrete. It has very high tensile strength 1020 – 4080 N/mm².

→ Glass fibres which is originally used in construction with cement and found to be affected by alkaline condition of cement.

→ Therefore alkali-resistant glass fibre by trade name "CEM-FIL" have been developed and used. The alkali resistant fibre reinforced concrete shows considerable improvements in durability to the conventional E-Glass fibre.

6) Carbon fibre :

→ Carbon fibre posses very high tensile strength 2110 to 2815 N/mm² and Young's modulus. It has been reported that cement composite made with carbon fibre as reinforcement will have very high modulus of elasticity and flexural strength.

→ The use of carbon fibres for structures like cladings, panels, and shells will have promising future.

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FACTORS AFFECTING PROPERTIES OF FRC.

→ F.R.C reinforced concrete is the composite material containing fibres in the cement matrix in an orderly manner (or) randomly distributed manner.

→ Its properties would obviously depend upon the efficient transfer of stresses between matrix and the fibres, which is largely dependent on the type of fibre, fibre geometry, fibre content, orientation and distribution of the fibres, mixing and compaction techniques of concrete, and size and shape of the aggregate.

1) Relative fibre matrix stiffness:-

→ The modulus of elasticity of matrix must be much lower than that of fibre for efficient stress transfer. Low modulus of fibres such as nylons and polypropylene are therefore unlikely to give strength improvement, but they help in the absorption of large energy and therefore impart greater degree of toughness and resistance to impact.

→ High modulus fibres such as steel, glass and carbon impart strength and stiffness to the composite.

→ A good bond is essential for improving tensile strength of the composite.

→ The interfacial bond could be improved by larger area of contact improving the frictional properties and degree of gripping and by treating the steel fibres with sodium hydroxide (or) acetone.

2) Volume of fibres:-

→ The strength of the composite largely depends on the quantity of fibres used. If use of higher percentage of fibres is likely to cause segregation and harshness of concrete and mortar.

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Vel Tech Dr. RR & Dr. SR Engineering College
Avadi, Chennai-600 062.

3) Aspect ratio of Fibre :-

→ Another important factor which influences the properties and behaviour of the composite is the aspect ratio of the fibre. It has been reported that upto aspect ratio of 75, increase in the aspect ratio increases the ultimate strength of the concrete linearly. Beyond 75 relative strength and toughness is reduced.

4) Orientation of Fibres :

→ One of the differences b/w conventional reinforcement and fibre reinforcement is that in conventional reinforcement, bars are oriented in the direction desired while fibres are randomly oriented.

→ To see the effect of randomness, model specimens reinforced with 0.5 % volume of fibres were tested.

5) Workability and compaction of concrete :-

→ Incorporation of steel fibre decreases the workability considerably. This situation adversely affects the condition of fresh mix. Even prolonged external vibration fails to compact the concrete.

→ The fibre volume which this situation is reached depends on the length and diameter of the fibre.

→ Another consequence of poor workability is non-uniform distribution of the fibres. Generally the workability and compaction standard of the mix is improved through increase w/c ratio.

6) Size of coarse aggregate :-

→ Several investigations recommended that the max. size of the coarse aggregate should be restricted to 10mm, to avoid appreciable reduction in strength of the composite.

7) Mixing :-

→ Mixing of fibre reinforced concrete needs careful conditions to avoid balling of fibres, segregation and in general the difficulty of mixing the materials uniformly.

→ Increase in the aspect ratio, volume % and size and quantity of coarse aggregate intensify the difficulties and balling tendencies.

→ A steel fibre content in excess of 2% by volume and an aspect ratio of more than 100 are difficult to mix.

→ The typical proportions for fibre reinforced concrete is

Cement content : 325 – 550 kg/m³

W/C ratio : 0.4 to 0.6

% of sand to total aggregate : 50 to 100%

Max. Aggregate size : 10 mm.

Air content : 6 – 9 %

Fibre content : 0.5 – 2.5%

: Steel – 1 % – 78 kg/m³

Glass – 1% – 25 kg/m³

Nylon – 1 % – 11 kg/m³

Applications :

→ Fibre reinforced concrete is increasingly used on account of the advantages of increased static and dynamic tensile strength, energy absorbing characteristics and better fatigue strength.

→ The uniform dispersion of fibres throughout the concrete provides isotropic properties not common to conventionally reinforced concrete.

→ F.R.C has been used on overlays of air field, road pavements, industrial floorings, bridge decks, canal lining, explosive resistant structures, refractory linings etc.

→ F.R.C concrete can also be used for the fabrication of precast pipes, boats, beams, stair case steps, wall panels, roof panels, manhole covers etc.

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POLYMER CONCRETE :-

→ continous research by concrete technologists to understand improve and develop the properties of concrete has resulted in a new type of concrete known as "Polymer Concrete".

→ The porosity is due to air voids, water voids (or) due to the inherent porosity of gel structure itself. on account of the porosity, the strength of concrete is naturally reduced. It is conceived by many research workers that reduction of porosity results in increase of strength of concrete.

→ Therefore process like vibration, pressure application spinning etc. have been practiced mainly to reduce porosity. All these methods have been found to be helpful to a great extent, but none of these methods could really help to reduce the water voids and the inherent porosity of gel which is estimated to be about 28%.

→ The development of concrete-polymer composite material is directed at producing a new material by combining the current technology of cement concrete with the modern technology of polymer chemistry.

TYPES OF POLYMER CONCRETE :

① Polymer impregnated concrete: is one of the widely used polymer composite. It is nothing but a pre cast conventional concrete, cured and dried in oven, (or) by dielectric heating from which the air and dried in the open cell is removed by vaccum. Then a low viscosity monomer is diffused through the open cell and polymerised by using radiation, application of heat (or) by chemical initiation.

→ Mainly the following types of monomer are used.

a) Methylmethacrylate
b) Styrene
c) Acrylonitrile
d) t-butyl styrene.
e) other thermoplastic monomers.

→ The amount of monomer that can be loaded into a concrete specimen is limited by the amount of water and air that

has occurred the [illegible] state.

→ It is necessary to know the concentration of water and air void in the system to determine the rate of monomer penetration. However the main research effort has been towards obtaining a maximum monomer loading in concrete by the removal of water and air from the concrete by vacuum (or) thermal drying, the latter being more practicable for water removal because of its rapidity.

2) Polymer cement concrete (PCC)

→ Polymer cement concrete is made by mixing cement, aggregates, water and monomer. Such plastic mixture is cast in moulds, cured, dried and polymerised. The monomers that are used in PCC are.

a) Polyster-styrene
b) Epoxy-styrene
c) furans
d) vinylidene chloride.

→ However the results in obtained by the production of PCC in this way have been disappointing and have shown relatively modest improvement of strength and durability. In many cases, materials poorer than ordinary concrete are obtained.

→ This behaviour is explained by the fact that organic materials are incompatible with aqueous system and sometimes interfere with the alkaline cement hydration process.

3) Polymer concrete :-

→ Polymer concrete is an aggregate bound with a polymer binder instead of portland cement as in conventional concrete.

→ The main technique in producing PC is to minimise void volume in the aggregate mass so as to reduce the quantity of polymer needed for binding the aggregates.

→ This is achieved by properly grading and mixing the aggregates to attain the maximum density and minimum void volume.

→ The graded aggregates are prepacked and vibrated in a mould. Monomer is then diffused up through the aggregates and polymerisation is initiated by radiation (or) chemical means.

→ An important reason for the development of this material is the advantage it offers over conventional concrete where the alkaline portland cement on curing, forms internal voids water can be entrapped in these voids which on freezing can readily crack the concrete.

→ Polymer concretes tend to be brittle and it is reported that dispersion of fibre reinforcement would improve the toughness and tensile strength of the material.

→ The use of fibrous polyester concrete (FPC) in the compressive strength of reinforced concrete beams provides a rich strength, ductile concrete at reasonable cost.

4) Partially impregnated and surface coated concrete:

→ Partial impregnation may be sufficient in situations where the major equipment is surface resistance against chemical and mechanical attack in addition to strength increase.

→ Even with only partial impregnation, significant increases in the strength of original concrete has been obtained.

→ The depth of monomer penetration is dependent upon following.

1) Pore structure of hardened and dried concrete.

2) The duration of soaking.

3) viscosity of the monomer.

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Application of polymer impregnated concrete:

1) Prefabricated structural elements.
2) prestressed concrete
3) Marine works
4) Desalination plants
5) Nuclear power plants
6) sewage works - pipe & storage work.
7) ferrocement products
(0) water proofing structures
11) Industrial applications.

SELF COMPACTING CONCRETE:

→ Modern application of self compacting concrete (SCC) is focussed on high performance, better and more reliable and uniform quality.
→ self compacting concrete has been described as "the most revolutionary development in concrete construction for several decades"
→ Originally developed in Japan to offset a growing shortage of skilled labour, it has proved to be beneficial from the following points.

1) faster construction
2) Reduction to site manpower
3) Better surface finish
4) faster placing
5) Improved durability
6) Greater freedom in design
7) Thinner concrete sections
8) Reduced noise level
9) safer working environment

Material for SCC

Cement: ordinary portland cement, 43 to 53 grades can be used.

Aggregates:

→ The maximum size of aggregate is generally limited to 20mm. Aggregate of size 10to12mm is desirable for structures having congested reinforcement. Possible size of aggregate higher than 20mm could also be used.

Mixing water:

→ water quality must be stabilised on the same line as that for using reinforced concrete or prestressed concrete.

Chemical admixtures:

→ super plasticizers are an essential component of SCC to provide necessary workability. The new generation super plasticizers formed poly-carboxylated ethers (PCE) is particularly useful for SCC.

Mineral admixtures:

a) Fly ash
b) GGBFS
c) Silica fume
d) Stone powder
e) Fibres.

TYPES OF SSC

→ There are three types of SSC

i) Powder type:

→ This is proportioned to give the required self compactability by reducing the water-powder ratio and provide adequate segregation resistance.

→ powdered type SSC made by increasing powder content

ii) Viscosity modifying admixtures:

→ by the use of viscosity SSC by the use of viscosity modifying admixtures to avoid segregation

~~→ increasing powder content and using VMA.~~

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iii) Combined type :-

-> reduce the water powder ratio.
-> It is made by increasing powder content and using VMA.

MIX DESIGN:

1) Determine the desired air content.
2) Determine the coarse aggregate volume.
3) Determine the sand content
4) Design the paste composition.
5) Determine the optimum water/powder ratio & superplasticizer dosage in mortar.

TESTS ON CONCRETE:

-> The concrete composition is now determined and the super-plasticizer dosage is finally selected on the basis of tests on concrete

Guidelines for mix composition:

Coarse aggregate <50%
Water/powder ratio = 0.8 to 1.0
Total powder content = 400-600 kg/m3.
Sand content = < 40% of the mortar.
Sand < 50% of paste volume.
Sand > 50% weight of total aggregate.
Free water < 200 litres
Paste > 40% of the volume of the mix.

SREE VAAGESWARI EDUCATIONAL SOCIETY
VAAGESWARI COLLEGE OF ENGINEERING
(Affiliated to JNTUH, Hyderabad.)
(Approved by AICTE New Delhi & Recognised by the Govt. of Telangana State)

COURSE FILE FOR

CONCRETE TECHNOLOGY

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DEPARTMENT OF CIVIL ENGINEERING

COURSE FILE

SUBJECT	: CONCRETE TECHNOLOGY
NAME	: RAJESH K
DESIGNATION	: ASST. PROFESSOR
REGULATION	: R 18
COURSE CODE	: CE511PE
YEAR / SEMESTER	: III / I
DEPARTMENT	: CIVIL ENGINEERING
ACADEMIC YEAR	: 2020-2021

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COURSE FILE CONTENTS

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	a). Vision
	b). Mission
	c). Program Educational Objectives (PEO'S)
	d). Program Outcomes (PO'S)
	e). Program Specific Outcomes (PSO'S)
2	CT Syllabus (University Copy) FOR THE ACADEMIC YEAR 2020-2021
3	Course Objectives, Course Outcomes And Topic Outcomes
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	c). Topic Outcomes
4	Course Prerequisites
5	Course Information Sheet (CIS)
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	b). Syllabus
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6	Teaching Schedule
7	Unit Wise Hand Written notes
8	OHP/LCD SHEETS /CDS/DVDS/PPT (Soft/Hard copies)
9	University Previous Question papers
10	MID exam Descriptive Question Papers
11	Assignment topics with materials
12	Tutorial topics and Questions
13	Unit wise-Question bank
	1 Two marks question with answers — 5 questions
	2 Three marks question with answers — 5 questions
	3 Five marks question with answers — 5 questions
	4 Objective question with answers — 10 questions
	5 Fill in the blanks question with answers — 10 questions
14	Course Attainment
15	CO-PO Mapping

1. Vision, Mission, PEO's, PO's & PSOs

a).Vision of Civil Engineering Department

• To give the world new age civil engineers who can transform the society with their creative vibe for the sustainable development by instilling scientific temper with ethical human outlook.

b). Mission of Civil Engineering Department

- To make the department a Centre of excellence in the field of civil engineering and allied research
- To promote innovative and original thinking in the minds of budding engineers to face the challenges of future.

c). Program Educational Objectives of Civil Engineering Department

PEO1	Graduates will utilize the foundation in Engineering and Science to improve lives and livelihoods through a successful career in Civil Engineering or other fields
PEO2	Graduates will become effective collaborators and innovators, leading or participating in efforts to address Social, Technical and Business Challenges
PEO3	Graduates will engage in Life-Long Learning and professional development through Self-Study, continuing education or graduate and professional studies in engineering & Business

d) Program Outcomes of Civil Engineering Department

PO1	**Fundamental engineering analysis skills:** An ability to apply knowledge of computing, mathematical foundations, algorithmic principles, and civil engineering theory in the modelling and design of to civil engineering problems.
PO2	**Information retrieval skills:** An ability to design and conduct experiments, as well as to analyze and interpret data.

PO3	**Creative skills:** An ability to design, implement, and evaluate a system, process, component, or program to meet desired needs, within realistic constraints such as economic, environmental, social, political, health and safety, manufacturability, and sustainability. Graduates have design the competence.
PO4	**Teamwork:** An ability to function effectively on multi-disciplinary teams.
PO5	**Engineering problem solving skills**: An ability to analyze a problem, and identify, formulate and use the appropriate computing and engineering requirements for obtaining its solution.
PO6	**Professional integrity**: An understanding of professional, ethical, legal, security and social issues and responsibilities. Graduates must understand the principles of ethical decision making and can interpret the ASCE Code of Ethics. Graduates will understand the proper use of the work of others (e.g., plagiarism, copyrights, and patents). Graduates will understand the special duty they owe to protect the public's health, safety and welfare by virtue of their professional status as engineers in society.
PO7	**Speaking / writing skills**: An ability to communicate effectively, both in writing and orally. Graduates are able to produce engineering reports using written, oral and graphic methods of communication.
PO8	**Engineering impact assessment skills:** The broad education necessary to analyze the local and global impact of computing and engineering solutions on individuals, organizations, and society.
PO9	**Social awareness:** Knowledge of contemporary issues. Students are aware of emerging technologies and current professional issues.
PO10	**Practical engineering analysis skills**: An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.
PO11	**Software hardware interface:** An ability to apply design and development principles in the construction of software and hardware systems of varying complexity.
PO12	**Successful career and immediate employment:** An ability to recognize the importance of professional development by pursuing postgraduate studies or face competitive examinations that offer challenging and rewarding careers in Civil Engineering

e). Program Specific Outcomes (PSO'S)

PSO	DESCRIPTION
PSO1	Educating students with fundamental mathematical, scientific, and engineering knowledge to have a significant and positive long-term impact on the field of Civil Engineering.
PSO 2	Emphasizing the importance of working in a team effectively and to communicate properly within the team to achieve the desired outcome.
PSO 3	Motivate students in learning to learn and the ability to keep learning for a life-time to increase their professionalism, update and deepen their knowledge through the development of the profession.

2. SYLLABUS UNIVERSITY COPY

CE511PE: CONCRETE TECHNOLOGY (Professional Elective – I)

B.Tech. III Year I Sem.

L	T/P/D	C
3	0/0/0	3

Pre-Requisites: Building Materials

Course Objectives: The objectives of the course are to

- **Know** different types of cement as per their properties for different field applications.
- **Understand Design** economic concrete mix proportion for different exposure conditions and intended purposes.
- **Know** field and laboratory **tests** on concrete in plastic and hardened stage.

Course Outcomes: After the completion of the course student should be able to

- **Determine** the properties of concrete ingredients i.e. cement, sand, coarse aggregate by conducting different tests. Recognize the effects of the rheology and early age properties of concrete on its long-term behavior.
- **Apply** the use of various chemical admixtures and mineral additives to design cement-based materials with tailor-made properties
- **Use** advanced laboratory techniques to characterize cement-based materials.
- **Perform** mix design and engineering properties of special concretes such as high-performance concrete, self-compacting concrete, and fibre reinforced concrete.

UNIT I

Cement: Portland cement – chemical composition – Hydration, Setting of cement – Structure of hydrated cement – Tests on physical properties – Different grades of cement. Admixtures: Types of admixtures – mineral and chemical admixtures.

UNIT - II

Aggregates: Classification of aggregate – Particle shape & texture – Bond, strength & other mechanical properties of aggregate – Specific gravity, Bulk density, porosity, adsorption & moisture content of aggregate – Bulking of sand – Deleterious substance in aggregate – Soundness of aggregate – Alkali aggregate reaction – Thermal properties – Sieve analysis – Fineness modulus – Grading curves – Grading of fine, Manufactured sand and coarse Aggregates – Gap graded aggregate – Maximum aggregate size- Properties Recycled aggregate.

UNIT – III

Fresh Concrete: Workability – Factors affecting workability – Measurement of workability by different tests – Setting times of concrete – Effect of time and temperature on workability – Segregation & bleeding – Mixing, vibration and revibration of concrete – Steps in manufacture of concrete – Quality of mixing water.

UNIT - IV

Hardened Concrete: Water / Cement ratio – Abram's Law – Gel/space ratio – Gain of strength of concrete – Maturity concept – Strength in tension and compression – Factors affecting strength – Relation between compression and tensile strength - Curing.

Testing of Hardened Concrete: Compression tests – Tension tests – Factors affecting strength – Flexure tests – Splitting tests – Pull-out test, Non-destructive testing methods – codal provisions for NDT.

ELASTICITY, CREEP & SHRINKAGE – Modulus of elasticity – Dynamic modulus of elasticity – Posisson's ratio – Creep of concrete – Factors influencing creep – Relation between creep & time – Nature of creep – Effects of creep – Shrinkage – types of shrinkage.

UNIT – V

Mix Design: Factors in the choice of mix proportions – Durability of concrete – Quality Control of concrete – Statistical methods – Acceptance criteria – Proportioning of concrete mixes by various methods – BIS method of mix design.

Special Concretes: Introduction to Light weight concrete – Cellular concrete – No-fines concrete – High density concrete – Fibre reinforced concrete – Polymer concrete – High performance concrete – Self compacting concrete.

TEXT BOOKS:

1. Concrete Technology by M.S. Shetty. – S. Chand & Co.; 2004
2. Concrete Technology by A.R. Santhakumar, 2nd Edition, Oxford university Press, New Delhi
3. Concrete Technology by M. L. Gambhir. – Tata Mc. Graw Hill Publishers, New Delhi

REFERENCE BOOKS:

1. Properties of Concrete by A. M. Neville – Low priced Edition – 4th edition
2. Concrete: Micro structure, Properties and Materials – P.K. Mehta and J.M. Monteiro, Mc-Graw Hill Publishers

IS Codes:

IS 383
IS 516
IS 10262 - 2009

3. COURSE OBJECTIVES, COURSE OUTCOMES AND TOPIC OUTCOMES

a). COURSE OBJECTIVES

(i) Student should be able to differentiate the materials that can be effectively used for preparing concrete.

(ii) Student should be able to design, prepare and work with the concrete

(iii) The mechanism of hydration and potential hydration with the concrete heat of hydration kinetic. Shrinkage and its potential to generate cracks in concrete, including chemical, autogen, drying, and carbonation shrinkage.

(iv) The basic principles of mix designing various types of concrete as well as curing technology required for each of the following types.

(v) High performance concrete, ultra high strength concrete, self-compacting concrete, under water.

b). COURSE OUTCOMES

CO1: Identify Quality Control tests on concrete making materials

CO2: Understand the durability requirements of fresh concrete

CO3: Identify Quality Control tests hardened concrete

CO4: Design concrete mixes as per IS and ACI codes

CO5: Understand the need for special concretes

c). TOPIC OUTCOMES

S. No.	Topic to be covered	Topic Outcome (At the end of this topic student will be able to)
L1	**UNIT-I: Cement** Introduction on concrete technology course.	Define cement, aggregates and water.
L2	History of port land cement and Manufacturing process of Portland cement	Various methods and stages of cement manufacturing.
L3	Chemical composition & Bogies' compounds of Portland cement	Various chemical composition and compounds.
L4	Hydration of cement, Structure of hydrate cement and setting time of cement	Illustrate cement hydration and consistency of cement
L5	Test on physical properties of cement.	Explain physical properties test of

S. No.	Topic to be covered	Topic Outcome (At the end of this topic student will be able to)
		cement
L6	Different grades of cement.	Describe the cement grades.
L7	Admixtures and types of admixtures, mineral and chemical admixtures	Define admixture, Classify the admixture types – List out the different types of mineral and chemical admixtures
L8	**UNIT-II: Aggregates** Introduction on Aggregates and Classification of aggregate, Particle shape and texture, Bond strength.	Define aggregates- Classify aggregates based on their particle shape and texture, bond strength
L9	Mechanical properties of aggregate: Specific gravity, Bulk density, porosity, absorption and moisture content of aggregate.	Define specific gravity, bulk density and porosity. Conclude its importance in mix design. aggregate mechanical properties
L10	Bulking of aggregate and Soundness of aggregate	Demonstrate bulking of sand. Explain soundness of aggregate
L11	Alkali aggregate reaction, Thermal properties	Discuss deleterious substances in aggregates and its effect on properties of concrete. Define and alkali aggregate reaction and its effect on concrete properties. Explain thermal properties of aggregates
L12	Sieve analysis, Fineness modulus, Grading curves,	Demonstrate sieve analysis of aggregates and discuss importance of maximum size of aggregates. Determine fineness modulus, Prepare grading curves to make aggregates correction in design mix.
L13	Grading of fine and coarse Aggregates, Gap graded aggregate, Maximum aggregate size	Examine grading of fine and coarse aggregates; discuss gap graded and maximum aggregate sizes.
L14	**UNIT-III: Fresh Concrete** Introduction of workability and factors affecting workability	Explain properties of concrete define workability and list out factors effecting of workability.
L15	Measurement of workability by different tests, Setting time of concrete	Demonstrate workability test to measure it.
L16	Effect of time and temperature on workability	Define concrete setting, discuss about time and temperature effect on workability.

S. No.	Topic to be covered	Topic Outcome (At the end of this topic student will be able to)
L17	Segregation and bleeding of concrete	Define segregation & bleeding, Demonstrate concrete mixing and vibration.
L18	Steps in manufacture of concrete, Mixing and vibration of concrete	List out concrete manufacturing steps; describe the water quality and its importance in quality of concrete.
L19	Quality of mixing water	Quality of mixing water in concrete.
	MID EXAMINATION-II	
L20	**UNIT-IV: Hardened Concrete** Introduction on hardened concrete, water/cement ratio, Abram's law	Define Water/Cement ratio, Abram's law.
L21	Gel space ratio, nature of strength of concrete	Calculate gel-space ratio to predict concrete strength.
L22	Maturity concept in concrete and problems	Explain concrete strength natures and discuss maturity of concrete to calculate concrete strength.
L23	Strength in tension and compression, factors affecting strength	List out factors effecting concrete strength.
L24	Relation between compression and tensile strength, curing	Distinguish between concrete compressive and tensile strength
L25	Testing of hardened concrete-compression test and tensile strength	Demonstrate compression and tension test of concrete.
L26	Flexural test and splitting test	Explain flexure, splitting tensile and pull out test of concrete.
L27	NDT methods and codal provisions	Explain Non-destructive testing, Name it with codal provisions.
L28	Modulus of elasticity, dynamic modulus of elasticity and poisons ratio	Define elasticity, creep and shrinkage of concrete. Explain experimental process to determine modulus of elasticity.
L29	Creep of concrete, factors influencing creep of concrete, relation between creep and time	Define dynamic modulus of elasticity; differentiate static and dynamic modulus of elasticity. Show the relation between creep and time, list out the effects of creep on concrete strength.
L30	Nature of creep, effects of creep	Explain concrete creep and list out factors effecting on concrete creep.
L31	Shrinkage and types of shrinkage	Define shrinkage and list out types of shrinkages.

L32	**Unit-V: Mix Design & Special Concrete** Factors in the choice of mix proportion	Define mix design and its importance in concrete strength. List out the factors to choose the mix proportions.
L33	Durability of concrete	Define concrete durability.
L34	Quality control of concrete, Statistical quality control of concrete	Explain concrete quality control; demonstrate statistical quality control and acceptance criteria.
L35	Proportioning of concrete mix by normal concretes by BIS method	Select concrete mix proportions for normal concrete.
L36	Normal Mix design problem	Design a mix design as per BIS method and conclude the concrete mix proportions.
L37	Normal Mix design problem	Design a M20 or M25 concrete mix for local available materials.
L38	Proportioning of concrete mix by pump able concretes by BIS method	Select concrete mix proportions for pump able concrete.
L39	Pumpable Mix design problem	Design a mix design as per BIS method and conclude the concrete mix proportions.
L40	Proportioning of concrete mix by pump able concretes by ACI method	Select concrete mix proportions for pump able concrete.
L41	ACI mix design problem	Select concrete mix proportions for ACI Method.
L42	Introduction to Light weight concrete	Define special concretes. Explain light weight concrete and list out the merits and demerits of it.
L43	Cellular concretes	Define cellular concrete. Explain preparation produce of cellular and its applications in construction industry.
L44	No fines concrete	Define no fine concrete. Explain preparation produce of no fines concrete and its applications in construction industry.
L45	Fiber reinforced concrete	Define fiber reinforced concrete. Explain the ingredient of its importance in FRC.
L46	Polymer concrete and types of polymer concrete	Define polymer concrete. Explain the ingredient of its importance in polymer concrete
L47	Self-compacting concrete	Demonstration of self-compacting concrete, list out the test to conclude self-compacting concrete.
L48	High density concrete	Demonstration high density concrete, list out the test to conclude high density concrete

4. COURSE PRE–REQUISITES

1. Ingredients of concrete
2. Elements of building components
3. Characteristics of cement, fine aggregate and coarse aggregates

5. COURSE INFORMATION SHEET

5 a).COURSE DESCRIPTION:

PROGRAMME: B. Tech. (Civil Engineering)	DEGREE: BTECH
COURSE: CONCRETE TECHNOLOGY	YEAR: III SEM: I CREDITS: 4
COURSE CODE: CE511PE REGULATION: R18	COURSE TYPE: CORE
COURSE AREA/DOMAIN: Theory	CONTACT HOURS: 4+0 (L+T)) hours/Week.
CORRESPONDING LAB COURSE CODE (IF ANY): YES	LAB COURSE NAME: CONCRETE TECHNOLOGY LAB

5. b). SYLLABUS:

Unit	Details	Hours
I	**Cement:**Portland cement – chemical composition – Hydration, Setting of cement – Structure of hydrate cement – Test on physical properties – Different grades of cement. Admixtures: Types of admixtures – mineral and chemicaladmixtures	7
II	**Aggregate:**Classification of aggregate – Particle shape & texture –, strength & other mechanical properties of aggregate – Specific gravity, Bulk density, porosity, adsorption & moisture content of aggregate – Bulking of sand – Deleterious substance in aggregate – Soundness of aggregate – Alkali aggregate reaction – Thermal properties – Sieve analysis – Fineness modulus – Grading curves – Grading of fine & coarse Aggregates – Gap graded aggregate – Maximum aggregate size	8
III	**Fresh Concrete:** Workability – Factors affecting workability – Measurement of workability bydifferenttests–Settingtimesofconcrete–Effectoftimeandtemperatureonworkability– Segregation & bleeding – Mixing and vibration of concrete – Steps in manufacture of concrete – Quality of mixing Water	7
IV	**Hardened Concrete** : Water / Cement ratio – Abram's Law – Gel/space ratio – Nature of strength of concrete – Maturity concept – Strength in tension & compression – Factors affecting strength – Relation between compressive & tensile strength - Curing. **Testing of Hardened Concrete:** Compression tests – Tension tests– Flexure tests – Splitting tests – Pull-out test, Non-destructive testing methods – codal provisions for NDT. Elasticity. Creep & Shrinkage – Modulus of elasticity – Dynamic modulus of elasticity – Poisson's ratio – Creep of concrete – Factors influencing creep – Relation between creep & time – Nature of creep – Effects of creep – Shrinkage –types of shrinkage	12

V	**Mix Design:** Factors in the choice of mix proportions – Durability of concrete – Quality Control of concrete – Statistical methods – Acceptance criteria – Proportioning of concrete mixes by– BIS method and ACI mix design. **Special Concretes:** Introduction to light weight concrete – Cellular concrete – No-fines concrete – High density concrete – Fibre reinforced concrete – Polymer concrete – High performance concrete – Self compacting concrete.	18
	Contact classes for syllabus coverage	52
	Total No. of classes	52

5.c). GAPS IN THE SYLLABUS - TO MEET INDUSTRY/PROFESSION REQUIREMENTS:

NIL

5.d). TOPICS BEYOND SYLLABUS/ ADVANCED TOPICS:

NIL

5. e). WEB SOURCE REFERENCES:

Sl. No	Name of book/ website
a.	nptel.ac.in/courses/112104121/1
b.	https://www.youtube.com/watch?v=cx5gPKp9CEc&list=PLbMVogVj5nJQU7M0LdA77p_XaaWBJniNc
c.	http://www.civilenggforall.com/2015/09/concrete-technology-theory-and-practice-by-ms-shetty-free-download-pdf-civilenggforall.html

5. f). DELIVERY/INSTRUCTIONAL METHODOLOGIES:

☑ CHALK & TALK	☑ STUD. ASSIGNMENT	☑ WEB RESOURCES
☑ LCD/SMART BOARDS	☑ STUD. SEMINARS	☐ ADD-ON COURSES

5.g). ASSESSMENT METHODOLOGIES-DIRECT

☑ ASSIGNMENTS	☑ STUD. SEMINARS	☑ TESTS/MODEL EXAMS	☑ UNIV. EXAMINATION
☐ STUD. LAB PRACTICES	☐ STUD. VIVA	☐ MINI/MAJOR PROJECTS	☐ CERTIFICATIONS
☐ ADD-ON COURSES	☐ OTHERS		

5.h). ASSESSMENT METHODOLOGIES - INDIRECT

☑ ASSESSMENT OF COURSE OUTCOMES (BY FEEDBACK, ONCE)	☑ STUDENT FEEDBACK ON FACULTY (TWICE)
☐ ASSESSMENT OF MINI/MAJOR PROJECTS BY EXT. EXPERTS	☐ OTHERS

5.i). TEXT / REFERENCE BOOKS:

T/R	BOOK TITLE/AUTHORS/PUBLICATION
Text Book	Properties of concrete / A.M.Neville / Pearson 5th edition
Text Book	Concrete technology / M.S.Shetty / S.Chand&co
Text Book	Concrete technology / Job Thomas / Cengage Learning
Reference Book	Concrete technology / M.L Gmbhir / Tata Mc.Grawhill
Reference Book	Concrete: Micro structure, Properties and materials/P.K.Mehta and J.M. Monteiro, McGraw Hill Publishers.

6. TEACHING SCHEDULE

Subject	CONCRETE TECHNOLOGY					
	Text Books (to be purchased by the Students)					
Book 1	Concrete Technology by M.S. Shetty					
Book 2	Properties of concrete by A.M. Neville					
	Reference Books					
Book 3	Concrete technology / Job Thomas / Cengage Learning					
Book 4	Concrete Technology by M.L Gambhir					
Unit	Topic	Chapters Nos				No of classes
		Book 1	Book 2	Book 3	Book 4	

I	Introduction on concrete technology course.	1	1	4	2	
	History of port land cement and Manufacturing of process of Portland cement	1	1	4	2	
	Chemical composition & Bogies' compounds of Portland cement	1	1	4	2	
	Hydration of cement, Structure of hydrate cement and setting time of cement	1	1	4	2	
	Test on physical properties of cement.	1	2	4	2	
	Test on physical properties of cement.	1	2	4	2	
	Different grades of cement.	1	2	4	2	
	Admixtures and types of admixtures,	5	5	5	5	
	mineral and chemical admixtures	5	5	5	5	
II	Introduction on Aggregates and Classification of aggregate, Particle shape and texture, Bond strength.	3	3	4	3	
	Mechanical properties of aggregate: Specific gravity, Bulk density, porosity, absorption and moisture content of aggregate.	3	3	4	3	
	Bulking of aggregate and Soundness of aggregate	3	3	4	3	

	Alkali aggregate reaction, Thermal properties	3	3	4	3	
	Sieve analysis, Fineness modulus, Gradingcurves,	3	3	4	3	
	Grading of fine and coarse Aggregates, Gap graded aggregate, Maximum aggregate size	3	3	4	3	
III	Introduction of workability and factors affecting workability	6	4	6	6	
	Measurement of workability by different tests, Setting time of concrete	6	4	6	6	
	Effect of time and temperature on workability	6	8	6	6	
	Segregation and bleeding of concrete	6	4	6	6	
	Steps in manufacture of concrete, Mixing and vibration of concrete	6	4	6	11	
	Quality of mixing water	5	4	-	6	
IV	Introduction on hardened concrete, water/cement ratio, Abram's law	7	6	2	8	
	Gel space ratio, nature of strength of concrete	7	6	2	8	
	Maturity concept in concrete and problems	7	6	2	8	
	Strength in tension and compression, factors affecting strength	7	6	2	8	
	Relation between compression and tensile strength, curing	7	6	2	8	
	Testing of hardened concrete-compression test and tensile strength	10	12	5	8	
	Testing of hardened concrete-Flexural test and splitting test	10	12	5	8	
	NDT methods and codal provisions	7	12	5	8	

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	Modulus of elasticity, dynamic modulus of elasticity and poisons ratio	8	9	3	8	
	Creep of concrete, factors influencing creep of concrete, relation between creep and time	8	9	3	8	
	Nature of creep, effects of creep	8	9	3	8	
	Shrinkage and types of shrinkage	8	9	3	8	
	Factors in the choice of mix proportion	11	14	7	10	
	Durability of concrete	11	10	7	10	
	Quality control of concrete, Statistical quality control of concrete	-	14	7	9	
	Proportioning of concrete mix by normal concretes by BIS method	11	14	11to15	10	
	Normal Mix design problem	11	14	11to15	10	
	Normal Mix design problem	11	14	11to15	10	
	Proportioning of concrete mix by pump able concretes by BIS method	11	14	11to15	10	
V	Pumpable Mix design problem	11	14	11to15	10	
	Proportioning of concrete mix by pump able concretes by ACI method	11	14	11to15	10	
	ACI mix design problem	11	14	11to15	10	
	Introduction to Light weight concrete	12	14	11to15	14	
	Cellular concretes	12	13	11to15	14	
	No fines concrete	12	13	11to15	14	
	Fibre reinforced concrete	12	13	11to15	14	
	Polymer concrete	12	13	11to15	14	

	Self-compacting concrete	12	13	11to15	14	
	High density concrete	12	13	11to15	14	
Contact classes for syllabus coverage					60	
Total No. of classes					60	

7. UNIT WISE HAND WRITTEN NOTES

UNIT-I

CEMENTS & ADMIXTURES

HISTORY OF PORTLAND CEMENT :-

-> The history of cementing materials is as old as the history of engineering construction.

-> Some kind of cementing materials were used by egyptians, Romans and indians in their ancient constructions.

-> Egyptians mostly used cementitious objects obtained by burning gypsum

-> Analysis of mortar from Great pyramid showed that it contained 81.5% calcium sulphate and only 9.5% carbonate.

-> The early Greeks and Romans used cementing materials obtained by burning limestones.

-> The Greeks and Romans later became aware of the fact that certain volcanic ash, which mixed with lime and sand yields mortar. possessing superior strength and better durability in fresh or salt water.

-> Roman writers used volcanic ash found near to Pozzuoli village near in Italy. The volcanic ash is siliceous in nature thus acquired the name pozzolanas, later on the name pozzolana was applied to any other material natural or artificial having nearly the same composition as that of volcanic ash found at pozzuoli.

-> In India burnt brick mixed surkhi has been used in the Indian practice through mixing and long continued pounding of lime mortar with or without the addition of surkhi yielded strong and impervious mortar which confirmed the secret of superiority of Roman mortar.

→ Roman added blood lime to [illegible] mortar for better workability. Hemoglobin is a powerful air entraining agent and plasticizer, which perhaps is yet another reason for the durability of Roman construction.

→ When we come to more recent times, the most important advance in the knowledge of cements, prior to the discovery and manufacture of all modern cements is undoubtedly the investigations carried out by John Smeaton. When he was called upon the rebuild the Eddystone Lighthouse in 1756, he made extensive enquiries into the state of an existing in those days and also conducted experiments with a view of find out the best material to withstand the severe action of clayey water yielded better lime possessing superior hydraulic properties.

→ In spite of the success of this experiment, the use of hydraulic lime made little progress and the old practice of mixture of lime and pozzolana remained popular in long period.

→ The story of the investigation of portland cement is however attributed to Joseph Aspdin, a Leeds builder and brick layer, even though similar procedures had been adopted by other inventors.

→ In early period cement was used for making mortar only. Later the use of cement was extended for making concrete.

→ In India, portland cement was first manufactured in 1904 near Madras by the South India Industries Ltd. But this venture failed. Later Indian cement Co. Ltd, was established at Porbandar the company was able to deliver about 1000 tons of portland cement.

→ During the first five year plan cement production from India rise from 2.69 million to 4.6 millions tons.

MANUFACTURING OF PORTLAND CEMENT :-

→ The raw materials required for manufacture of portland cement are calcareous materials such as limestone, chalk and argillaceous materials such as shale or clay.

→ The process of manufacture of cement consists of grinding the raw materials, mixing them intimately in certain portion depending upon their purity and composition and burning them in a kiln at a temperature of about 1300 to 1500°C at which temperature the materials sinter and partially fuse to form nodular clinker.

→ The clinker is cooled and ground to fine powder with addition of about 3 to 5% of gypsum. The product formed by using this procedure is portland cement.

→ There are two process known as "wet" and "dry" process depending upon whether the mixing and grinding of raw materials is done in wet or dry conditions.

→ With a little change in the above process we have the semi-dry process also where the raw materials are ground dry and then mixed with about 10-14% of water and further burnt to clinkering temperature.

→ For many years the wet process remained popular because of the possibility of more accurate control in the mixing of raw materials.

→ The dry process requires much less fuel as the materials are already in a dry state. whereas in the wet process the slurry contains about 35-50% of water.

WET PROCESS

→ In wet process the limestone brought from the quarries is first crushed to smaller fragments.

→ Then it is taken to a ball or tube mill where it is mixed with clay or shale or the case may be ground to a fine consistency of slurry with addition of water.

→ The slurry is a liquid of creamy consistency with water content of about 35-50% where in particles crushed to the fineness of Indian standard sieve number, are held in suspension.

→ The slurry is pumped to slurry tanks or basins where it is kept in an agitated condition by means of rotating arms with chains or blowing compressed air from the bottom to prevent settling of lime stone and clay particles.

→ The composition of slurry is tested to give the required chemical composition and corrected periodically in the tube mill and also in the slurry tank by blending slurry from different storage tanks.

→ Finally the corrected slurry is stored in storage tanks and kept in homogeneous condition by agitation of slurry.

→ The corrected slurry is sprayed on to the upper end of rotary kiln against hot moving heating chains.

→ The rotary kiln is an important component of cement factory. It is a steel cylinder of diameter anything from 3m to 8m lined with refractory materials. Mounted on roller bearings capable of rotating about its own axis at a specified speed.

→ The length of rotary kiln may vary from 30 to 150 mm.

→ The slurry on being sprayed against a hot surface of flexible chains loses moisture and become flakes.

→ The flakes feed offhand fall on the floor. The rotation of rotary kiln causes the flakes to move from the upper end towards the lower end of the kiln and higher temperature.

→ The kilns fired from the lower end. The fuel is either powered coal oil or natural gas. In the time the material downs to the lower end of rotary kiln, the dry materials undergoes a series of chemical reactions. Until finally in the hottest part of the kiln where the temperature is in order of 1500°C about 20 to 30% of the material get fused.

→ Lime silica and alumina get recombined. The fused materials into nodular form of size 3mm to 20mm known as clinker.

→ The clinker drops into a rotary cooler where it is cooled under controlled conditions.

→ The clinker is stored in silos or bins. The clinker weighs about 1100 to 1300 gms per litre. The litre weight of clinker indicates the quality of clinker.

→ The cooled clinker is then ground in a ball mill with the addition of 3-5% of gypsum in orders to prevent flash ~~setting~~ of cement.

→ A ball mill consists of several compartments filled with progressively smaller hardened steel balls. The particles are crushed to the required fineness & separated by current of air and taken to storage silos from where

the cement is bagged [illegible] into [illegible] supply.

WET PROCESS

Clay ← water

Clay → Wash Mill → Storage basins → wet grinding mills

Limestone → Crusher → Storage basins → wet grinding mills

wet grinding mills → Blending of slurry to correct composition

↓

Storage of corrected slurry

↓

Powdered coal / oil / gas → corrected slurry fed to rotary kiln

↓

Slurry is converted into clinker

↓

addition of 2-3% of gypsum. → clinker is ground in ball mill

↓

Cement silos

↓

packing plant

DRY PROCESS

→ In the dry and semi dry process the raw materials are crushed dry and fed in correct proportions into grinding mill where they are dried and reduced to a very fine powder.

→ The dry powder coming in the raw mill is then blended and corrected for its right composition and mixed by means of compressed air. The aerated powder tends to behave almost like liquid and in about one hour of aeration a uniform mixture is obtained.

→ The blended meal is further sieved and fed into a rotating disc called granulator. A quantity of water about 12% by weight is added to make the blended meal into pellets.

→ The equipment used in the dry process kilns is comparatively smaller. The process is quite economical. The total consumption of coal is this method is only about 100kg when compared to the requirement of about 350 kg for producing a ton of cement in the wet process.

→ During March 1998 in India there were 173 large plants operating, out of which 49 plants used wet process, 115 plants used dry process and 9 plants used semi-dry process.

→ The methods are commonly employed for direct control of quality of clinker. The first method involves reflected light optical microscopy of polished and etched section of clinker, followed by point count of areas occupied by various compounds.

→ For moderate cooling it is implied that from about 1300°C the clinker is brought to about 800°C in about 15 minutes and from the 800°C the temperature is brought down to normal atmospheric temperature in about 10 minutes.

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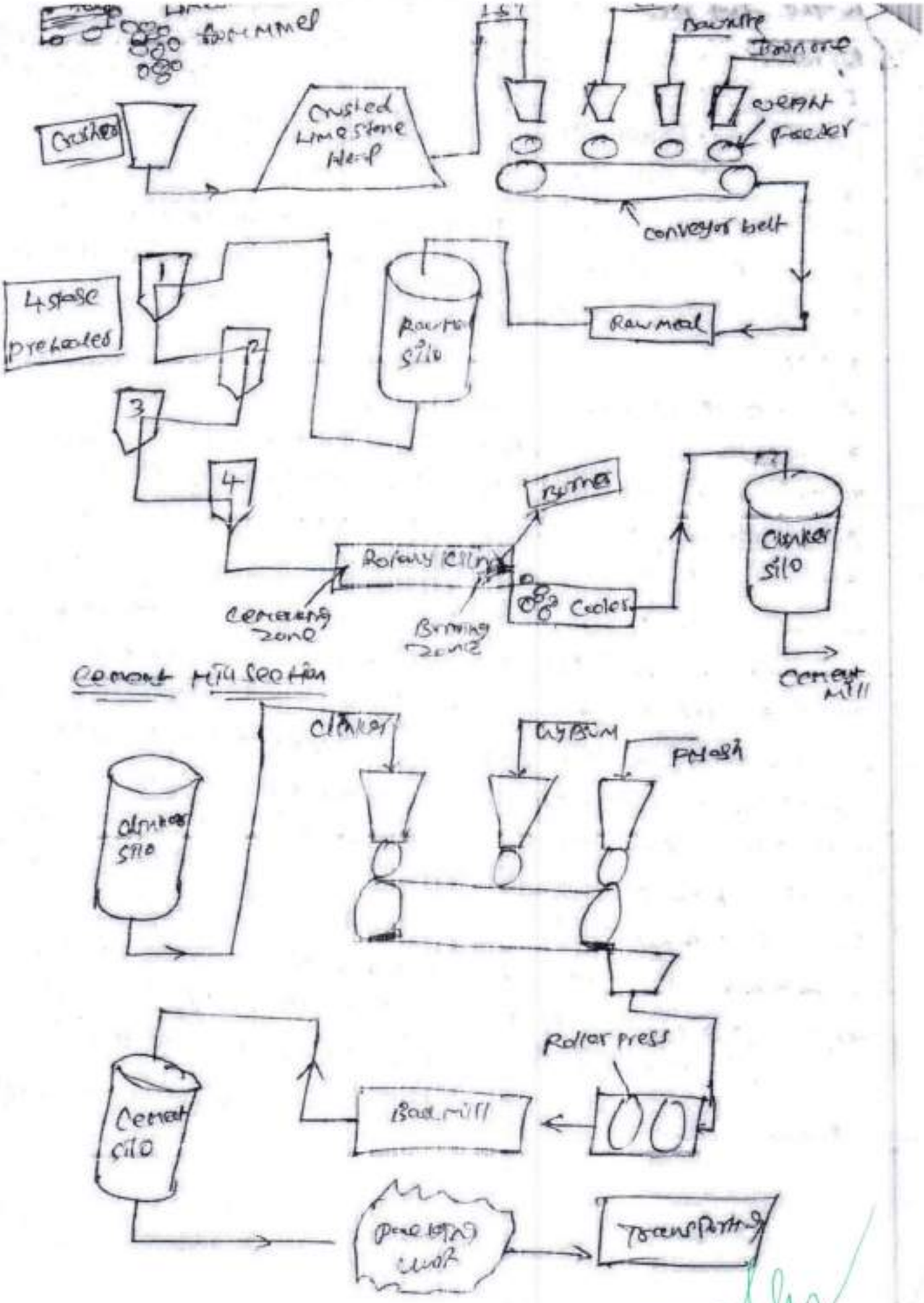
Hammer
Crusher
Crushed Limestone Heap
Bauxite
Iron ore
Sand
Feeder
conveyor belt
4 stage preheater
1
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Raw mill
Raw meal silo
Rotary kiln
Burner
Cooler
Clinker silo
Cement mill
Cement mill section
Clinker
Gypsum
Flyash
Clinker silo
Roller press
Ball mill
Cement silo
Packing unit
Transporting

Chemical composition

→ The raw materials used for the manufacture of cement consists mainly of lime, silica, alumina and iron oxide. These oxides interacts with one another in the kiln at high temperature to form more complex compounds.

→ The relative composition of these oxides composition are responsible for influencing the various properties of cement.

Oxide	% Content
CaO	60-67
SiO_2	17-25
Al_2O_3	3-8
Fe_2O_3	0.5-6
MgO	0.1-4
Alkalies	0.4-1.3
SO_3	1.3-3.0

Approximate oxide composition limits of ordinary portland cement.

→ As mentioned earlier the oxides present in the raw materials when subjected to high temperature combine with each other to form complex compounds.

→ The identification of the major compound is largely based on Bogue's work and hence it is called Bogue's compounds. The four compounds ~~usually re-~~ ~~guarded~~ regarded as major compounds.

BOGUE'S COMPOUNDS

Name of compounds	Formula	Abbreviated Formula	%
Tricalcium silicate	$3CaO.SiO_2$	C_3S	54.1
Dicalcium silicate	$2CaO.SiO_2$	C_2S	16.6
Tricalcium Aluminate	$3CaO.Al_2O_3$	C_3A	10.8
Tetracalcium Aluminoferrite	$4CaO.Al_2O_3.Fe_2O_3$	C_4AF	9.1

→ Tricalcium silicate and dicalcium silicate are the most important compounds responsible for strength. Together constitute 70-80% of cement. The avg C_3S content in modern cement is about 45% and C_2S is about 25%. The sum of the contents of C_3A and C_4AF has decreased slightly in modern cements.

→ An increase in lime content beyond a certain value makes it difficult to combine with other compounds and free lime will exist in the clinker which causes unsoundness in cement.

→ An increase in silica content at the expense of the content of alumina and ferric oxide will make the cement difficult to fuse and form clinker.

→ Cements with a high (early) total alumina and high ferric oxide content is favourable to the production of early strength in cements.

→ Bogue's compounds C_3S, C_2S, C_3A, C_4AF are sometimes called as Alite, Belite, Celite, and Ferrite respectively.

HYDRATION OF CEMENT :

→ Anhydrous cement does not bind fine and coarse aggregate. It acquires adhesive property only when mixed with water.

→ The chemical reaction that take place between cement and water is referred as hydration of cement.

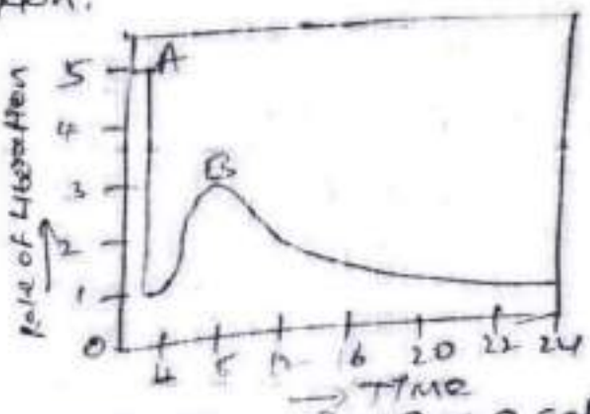
→ On account of hydration certain products are formed. These products are important because they have cementing or adhesive wave.

→ The hydration of cement is visualised in two ways the first is "through solution" mechanism. Instead cement compounds dissolve to produce a supersaturated solution from which different hydrated products get precipitate.

→ The second possibility is that water attacks cement compounds in the solid state converting the compounds into hydrated products starting from the surface and proceeds to the interior of the compound with time.

→ It is probable that both "through solution" and "solid state" type of mechanism may occur during the course of reactions between the cement and water.

→ The former mechanism is predominate in the early stages of hydration in view of large quantities of water and after and then later mechanism may operate during the later stages of hydration.



Heat liberated from a setting cement

STRUCTURE of HYDRATED CEMENT

→ To understand the behaviour of concrete is necessary to acquaint ourselves with structure of hydrated hardened cement paste.

→ If the concrete is considered to be as two phase material namely the paste phase and the aggregate phase, the understanding of the paste phase will become more important as it influences the behaviour of the concrete to a much greater extent.

→ The strength, permeability, durability, shrinkage, elastic properties the creep and volume change properties of the concrete are much influenced by the paste structure

→ So to understand the concrete it is important that we have a deep understanding of the structure of the hydrated hardened cement paste.

transition zone :

→ transition zone which represents the interfacial region between the particles of coarse aggregate and hardened cement paste.

→ Transition zone is generally a plane of weakness and therefore has far greater influence on the mechanical behaviour of concrete.

→ Although transition zone is composed of same bulk cement paste, the quality of paste in the transition zone is of poor quality. Firstly due to internal bleeding, water accumulation below elongated, flaky and large pieces of aggregates. This reduces the bond between paste and aggregate in general.

-> Due to drying shrinkage (or) temperature variation, the transition zone develops microcracks even before a structure is loaded. When structure is loaded at high stress level, these micro cracks propagate and ~~[illegible]~~ bigger cracks are formed resulting in failure. Hence transition zone, generally the weakest part of the chain is considered strength limiting phase in concrete.

-> The techniques used to study the structure of cement paste include measurements of setting time, compressive strength, quantity of heat of hydration evolved etc.

-> Measurements of heat evolved during the exothermic reactions also give valuable insight into the mechanism of hydration reactions, since approximately 50% of the total heat evolution occurs during 3 days of hydration, a continuous record of heat liberation during this time is extremely useful in understanding the degree of hydration and the resultant structure of hardening cement paste.

-> The mechanical properties of the hardened concrete depends more on the physical structure of the product of hydration than on the chemical composition of the cement.

-> For simplicity's sake we will consider only the structure of the paste phase. Fresh cement paste is a plastic mass consisting of water and cement. With the lapse of time, say one hour, the hardening paste consists of hydrates of various compounds, unhydrated cement particles and water. With further lapse of time the quantity of unhydrated cement left in the paste decreases and the hydrates of the various compounds increase

TEST ON PHYSICAL PROPERTIES

Testing of cement

testing of cement can be brought under two categories

1) Field testing
2) Laboratory testing

Field testing

→ It is sufficient to test the cement in field when it is used for minor works. The following are the field tests.

a) open the bag and take a good look at a cement. There should not be any visible lumps. The color of the cement should ~~not be~~ normally be greenish grey.

b) Thrust your hand into the cement bag it must give a cool feeling there should not be any lumps inside.

c) ~~take a~~ pinch of cement and feel like the fingers it should give a smooth and not gritty feeling.

d) Take a hand full of cement and throw it on a bucket full of water the particles should not float for sometimes before they sink.

Laboratory tests

The following tests are usually conducted in the lab

i) Fineness test
ii) setting time test
iii) Soundness test.
iv) Strength test.

i) Fineness test:-

→ The fineness of cement has an important bearing on the rate of hydration and hence on the rate of gain of strength and also on the rate of evolution of heat.

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→ Fineness cement offers greater surface area [illegible] and hence faster development of strength. The disadvantage of fine grinding is that it is susceptible to air set and early deterioration.

→ Max no of particles in a sample of cement should have a size less than 100 microns and the smallest particles may have a size about 1.5μ

→ Fineness of cement is tested by sieving.

Sieve test

→ weigh correctly 100 grams of cement and take it on a standard IS sieve No 9 (90 microns). Break down the ~~[illegible]~~ air-set lumps in the sample with fingers. Continuously sieve the sample giving circular and vertical motion for a period of 15 min. Mechanical sieving devices may also be used. Weigh the residue left on the sieve this weight should not exceed 10% of ordinary cement.

ii) Setting time test

→ An arbitrary division has been made for the setting time of cement as initial setting time and final setting time. It is difficult to draw a rigid line b/w these two arbitrary divisions. For convenience initial setting time is regarded as the time elapsed b/w the moment that the water is added to cement to the time that the paste starts losing its plasticity.

→ The final setting time is the time elapsed b/w the moment the water is added to cement and the time when the paste has completely lost its plasticity and attained sufficient firmness to resist certain definite pressure.

→ Initial setting time is normally 30 min and final setting time should not be more than 10 hrs.

→ For initial and final setting time test is tested by the Vicats apparatus.

Initial setting time

→ take about 500gms of cement sample and gauge it with 0.85 times the water required to produce cement paste of standard consistency 0.85 P.

→ The paste shall be gauged and filled into the vicat moulds in specific manner within 3-5 min.

→ start the stop watch the moment water is added to the cement.

→ lower the needle gently and bring it in contact with the surface of the test block and quickly release allow it to penetrate percentage into the test block.

→ In begining the needle will completely pierce through the test block. But after sometimes when the paste starts losing its plasticity, the needle will penetrate only to a depth of 33-35 mm from top.

→ The period elapsing b/w the time when water is added to the cement and the time at which the needle penetrates the test block to a depth equal to 33-35 mm from the top is taken as initial setting time.

Final setting time

→ replace the needle of the vicat apparatus by accessory attachment the cement shall be considered as finally set when upon lowering the attachment gently cover the surface of the test block, the centre needle makes an impression, while the circular cutting edge of the attachment fails to do so. In other words the paste has attained such hardness that the centre needle does not pierce through the paste more than 0.5 mm.

iii) Soundness test

→ It is very important that cement after setting shall not undergoes any appreciable change of volume. certain cement have been found to undergo a large expansion after setting causing distruption of the set and hardened mass.

→ The apparatus consist of small split cylinder of spring brass or other suitable metal. It is 30mm in diameter and 30mm high on either side of split are attached two indicator 30mm / 60mm long with a pointed ends.

→ cement is gauged with 0.85 times the water required for standard consistency 0.85P. in a standard manner and filled into the mould kept on a glass plate.

→ The mould is covered on the top with another glass plate. the whole assembly is immersed in water at a temp. of 27°C - 34°C and kept there for 24 hrs.

→ measure the distance b/w the indicator points. Submerge the mould again in water. Heat the water and bring to boiling point in about 25-30 min. keep it boiling for 3 hrs.

→ Remove the mould from the water allow it to cool and measure the distance b/w the indicator points.

→ The difference b/w these two measurements represents the expansion of cement this must not exceed 10mm for ordinary Portland cement. If in case the expansion is more than 10mm as stated above the cement is said to be unsound.

iv) Strength test

→ The compressive strength of hardened cement is the most important of all the properties

→ strength of cement is indirectly found on cement sand mortar in specific proportions

→ Take 555 gms of standard sand, 185 gms of cement (1:3) in a non porous enamel tray and mix them with a trowel for one minute. Then add water of quantity $\frac{P}{4}$ + 3 percent of combined weight of cement and sand and mix the three ingredients thoroughly until the mixture is of uniform colour.

→ The time of mixing should not be less than 3 minutes nor more than 4 minutes.

→ Immediately after mixing, the mortar is filled into a cube mould of size 7.06 cm. The area of the face of the cube will be equal to 50 sq cm. Compact the mortar either by hand compaction in standard specified manner (or) in the vibrating equipment for 2 minutes.

→ Keep the compacted cube in the mould at a temp of 27°C ± 2°C and at least 90% relative humidity for ~~the remaining~~ 24 hrs.

→ After 24 hrs the cubes are removed from the mould and immersed in clean fresh water until taken out for testing.

TYPES OF CEMENT (GRADES OF CEMENT)

1) Ordinary portland cement.
2) Rapid hardening cement
3) Extra rapid hardening cement
4) Sulphate resisting cement
5) Portland slag cement
6) Quick setting cement

7) super sulphated cement
8) Low heat cement
9) Portland pozzolana cement
10) Air entraining cement
11) coloured cement (white cement)
12) Hydrophobic cement
13) masonary cement
14) expansive cement
15) oil well cement
16) rediset cement
17) concrete sleeper grade cement
18) High alumina cement
19) very high strength cement

ADMIXTURES :

→ Admixture is defined as a material, other than cement, water and aggregates that is used as ingredient of concrete and is added to the batch immediately before (or) during mixing. Additive is a material which is added at the time of grinding cement clinker at the cementary.

→ These days concrete is using for wide varities of purposes to make it suitable in different condition. In these conditions ordinary (cement) concrete may fail to exhibit the required quality performance (or) durability in such cases, admixtures is used to modify the properties of ordinary concrete so as to make it more suitable for any situation.

→ A few type of admixtures called water reducers (or) High range water reducers, generally referred as plasticizers (or) super plasticizers.

TYPES OF ADMIXTURES

① Chemical Admixtures

1) Plasticizers (water reducers)

2) Super plasticizers

3) Retarders and retarding plasticizers

4) Accelerators and accelerating plasticizers

5) Air Entraining Admixtures

② MINERAL ADMIXTURES

6) Pozzolanic (or) Mineral admixtures

7) Damp-proofing and water proofing admixtures

8) Gas forming admixtures

9) Air detraining admixtures

10) Alkali aggregate expansion inhibiting admixtures.

11) Workability admixtures

12) Grouting admixtures

13) Corrosion inhibiting admixtures

14) Bonding admixtures

15) Colouring admixtures

CONSTRUCTION CHEMICALS

1) Concrete curing compounds

2) Polymer Bonding Agents

3) Mould Releasing Agents

4) Protective and Decorative Coatings

5) Installation Aids

6) Surface Retarders

7) Bond aid for proofing

8) Gunniting Aid.

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AGGREGATES :-

→ Aggregates are important constituents in concrete. They give bulk to the concrete, reduce shrinkage and effect economy.

→ They aggregates occupy 70-80% of volume of concrete, their impact on various characteristics and properties of concrete is undoubtedly considerable.

Classification of aggregates

→ Aggregates are classified as

1) Normal aggregates
2) Lightweight aggregates
3) Heavy weight aggregates.

→ In this chapter properties of normal aggregates will be discuss.

→ Normal weight aggregates further classified as natural and artificial aggregates

Natural	Artificial
Sand,	Broken brick,
Gravel,	Air cooled slag,
Crushed rock such as	sintered fly ash,
Granite, Quartzite, Basalt,	Bloated clay
Sand stone.	

→ aggregates can be classified on the basis of the size of the aggregates as coarse aggregates and fine aggregates

Particle shape & texture of aggregates

SHAPE:

→ The shape of aggregate is an important characteristic since it affects the workability of concrete. It is difficult to easily measure the shape of irregular body like concrete aggregates which are derived from various rocks.

→ One of the methods of expressing the angularity qualitatively is by a figure called angularity number.

→ This is based on % voids in the aggregate after compaction in a specified manner.

→ A quantity of single sized aggregates are ~~considered~~ is or ~~[illegible]~~ filled into metal cylinder of 3 lit capacity. The aggregates are compacted in a standard manner and % of voids is found out.

→ The void is found out can be knowing the sp. gravity of aggregates and bulk density (or) by pouring water to the cylinder to bring the level of water upto the brim. If the voids is 33% the angularity of such aggregates is considered zero. If the void is 44% the angularity no of such aggregate is considered 11.

→ The normal aggregates which are suitable for making the concrete may have angularity number continuing from 0 to 11.

→ Angularity number zero represents the most practicable rounded aggregates and the number 11 indicates the most angular aggregates that could be tolerated for making concrete not so unduly harsh and uneconomical.

TEXTURE:

→ Surface texture is that property the measure of which depends upon the relative degree to which particle surfaces are polished (or) dull smooth (or) rough.

→ Rough textured aggregates develops higher bond strength in tension than smooth textured aggregates

Strength of aggregate

→ When the cement paste is of good quality and its bond with the aggregate is satisfactory, then the mechanical properties of rock (or) aggregates will influence the strength of concrete.

→ The test for strength of aggregate is required to be made in the following situations.

i) For production of high strength & extra-high strength concrete.

ii) When contemplating to use aggregates manufacture from weathered rocks.

iii) Aggregates manufactured by industrial process.

Aggregate crushing value

→ Strength of rock is found out by making a test specimen of cylinder shape of size 25mm dia and 25mm height.

→ The cylinder is subjected to compressive stress different rock samples are found to give different compressive strength varying from a min of 45MPa – 545MPa.

→ As said earlier the compressive strength of parent rock does not exactly indicate the strength of aggregate in concrete. For this reason assessment of strength of the aggregate is made by using a sample of bulk aggregate in standardised manner. The test is known as "aggregate crushing value test".

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Aggregate impact value

-> With respect to concrete aggregates, toughness is usually considered the resistance of the material to failure by impact.

-> Several attempts to develop a method of test for aggregates impact value have been made.

-> The most successful is the one in which a sample of standard aggregates kept in a mould is subjected to 15 blows of a metal hammer of weight 14kgs falling from a height of 38cms.

-> The quantity of finer materials resulting from ~~potential~~ will indicate the toughness of the sample of aggregates.

-> The ratio of the fines formed to the weight of the total sample taken is expressed as a %.

Aggregate Abrasion value

-> Apart from testing aggregates with respect to crushing value, impact resistance & testing the aggregate with respect to its resistance to wear is an important test for aggregates to be used for road construction & pavement constr.

Modulus of elasticity

-> Modulus of elasticity of aggregate depends upon its composition, texture and structure. The modulus of elasticity of aggregate will influence the properties of concrete with respect to shrinkage and elastic behaviour and to very small extent of creep of concrete.

-> Elasticity of aggregate has a decided effect on the elastic property of concrete and that the relation of elasticity of aggregate that of the concrete is not a linear function, but may be expressed as an equation of exponential type.

Specific gravity

→ In concrete technology sp. gravity of aggregates is made use of in design calculation of concrete mixes. The specific gravity of the rock vary from 2.6 to 2.8

Bulk density

→ Bulk density shows how densely the aggregates is packed when filled in a standard manner.

→ The bulk density depends on the particle size distribution and shape the particles

Absorption and moisture content

→ Some of the aggregates are porous and absorptive. Porosity and absorption of aggregates will effect the w/c ratio and hence the durability of concrete.

→ The porosity of aggregates will also effect the durability of concrete when the concrete is subjected to freezing and thawing and also when the concrete is subjected to chemically aggresive fluids.

Bulking of aggregates

→ The free moisture content in fine aggregate results in bulking of volume

→ Free moisture forms a film around each particle. This film of moisture exerts what is known as surface tension which keeps the neighbouring particles away from it.

→ The extent of bulking can be estimated by a simple test. A sample of moist fine aggregate is filled into a measuring cylinder in the normal manner.

$$\% \text{ of bulking} = \frac{h_1 - h_2}{h_2} \times 100$$

h_1 = fine aggregate

h_2 = fine agregate with water.

Soundness of aggregate:

→ Soundness refers to the ability of aggregate to resist a marine changes in volume as a result of change in physical conditions

→ These physical conditions that affect the soundness of aggregate are the freezing and thawing variation in temperature, alternate wetting and drying under normal condition and drying & wetting in saltwater.

→ Aggregates which are porous, weak and containing any undesirable extraneous matter undergo excessive volume change when subjected to the above condition.

→ Aggregates which undergo more than specified amount of volume change is said to be unsound aggregates.

Alkali Aggregate:

→ For a long time aggregates have been considered as inert materials but later on people was clearly brought out that the aggregates are not fully inert. Some of the aggregates contain reactive silica, which reacts with alkalies present in cement. The sodium oxide and potassium oxide.

→ The reaction starts with attack on the reactive siliceous minerals in the aggregate by the alkaline hydroxide derived from the alkalies in cement.

→ As a result the alkali silicate gels of unlimited swelling type are formed. When the condition are congential, progressive manifestation by swelling take place, which results in disruption of concrete with spreading of pattern cracks and eventual failure of concrete structure

→ The rate of deterioration may be slow or fast depending upon the condition. There were cases where concrete has become unserviceable in about 2 years time.

THERMAL PROPERTIES:

→ Rock and aggregates possess 3 thermal properties which are significant in establishing the quality of aggregate for concrete construction they are

1) co-efficient of expansion 2) specific heat 3) Thermal conductivity

→ An avg value of the mean thermal co-efficient of expansion of concrete may be taken as $9.9 \times 10^{-6}/°C$ but the range may be from about $5.4 \times 10^{-6}/°C - 14 \times 10^{-6}/°C$ depending upon the type and quantities of the aggregates the mix proportions and other factors.

→ The range of co-efficient of thermal expansion for hydrated cement paste may vary from $10.8 \times 10^{-6}/°C$ to $16.2 \times 10^{-6}/°C$. For mortar it may range from $7.9 \times 10^{-6}/°C$ to $12 \times 10^{-6}/°C$.

→ For common rocks ranges from $0.9 \times 10^{-6}/°C$ to $16 \times 10^{-6}/°C$

SIEVE ANALYSIS

→ This is the name given to the operation of dividing a sample of aggregates into various fractions each consisting of particles of the same size.

→ The sieve analysis is conducted to determine the particle size distribution in a sample of aggregate which are called gradation.

→ The aggregates used for making concrete are normally of the maximum size 80mm, 40mm, 20mm, 10mm, 4.75mm, 2.36mm 600μ, 300μ, and 150μ.

→ The aggregates fraction from 80mm–4.75mm are termed as coarse aggregate and their fraction from 4.75mm–150μ are termed as fine aggregates.

→ The size 4.75mm is a common fraction appearing both in coarse aggregates and fine aggregates (CA & FA)

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→ The material retained on each sieve after shaking represents the fraction of aggregates coarser than the sieve in question and finer than the sieve above.

→ Sieving is done either manually or mechanically

→ In the manual operation the sieve is shaken giving movements in all possible direction to give chance to all particles for passing through the sieve. Operation should be continued till such time that almost no particle is passing through.

Fineness Modulus:

→ From the sieve analysis the particle size distribution in a sample of aggregates is found out. In this connection a term known as "Fineness Modulus"

→ Fineness Modulus is a ready index of coarseness (or) fineness of the material.

→ Fineness Modulus is an empirical factor obtained by adding the cumulative % of aggregates retained on each of the standard sieve ranging from 80-150mm microns and dividing this sum by an arbitrary number 100.

The following limits may be taken as guidance.

	FM
Fine sand	2.2 – 2.6
Medium sand	2.6 – 2.9
Coarse sand	2.9 – 3.2

→ A sand having a fineness modulus more than 3.2 will be unsuitable for making satisfactory concrete.

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Grading of Aggregates

→ Aggregate comprises about 55% of the volume of mortar and 85% volume of mass concrete.

→ Mortar contains aggregates of size upto 4.75mm and concrete contains aggregate upto a maximum size of 150mm.

→ It is well known that the strength of concrete is depend upon w/c ratio provided the concrete is workable.

→ One of the most important factor for producing workable concrete is good gradation of aggregates

→ Good grading implies that a sample of aggregates contains all standard fractions of aggregates in required proportion such that the sample contains minimum voids.

→ a sample of well graded aggregates containing minimum voids will require minimum paste to fill up the voids in aggregates

→ Minimum paste will be mean less quantity of water which will furthermore ~~less quantity of cement and less quantity of sand~~ increased economy higher strength, lower shrinkage and greater durability.

→ The advantage due to good grading of aggregates can also be viewed from another aspect. The concrete is viewed as a two phase material paste phase and aggregate phase. It is the paste phase which is vulnerable to all life of concrete.

→ Paste is weaker than avg aggregate in normal concrete with some exception when very soft aggregates are used.

→ The paste is more permeable than many of the mineral aggregates. It is the paste that is susceptible to deterioration by the attack of aggressive chemicals.

→ In short, it is the paste which is weak link in a mass of concrete. This objective can be achieved by having well graded aggregates. Hence the importance of good grading.

Gap Grading :

→ So far we discussed the grading pattern of aggregates in which all particle size are present in certain portion in a sample of aggregate. Such pattern of particle size distribution is also referred as continous grading.

→ Originally in the theory of continous grading, it was assumed that the voids present in the higher size of the aggregates are filled up by the next lower size of aggregate

→ Similarly the voids created by lower size are filled up by the lower than those particles and so on

→ It have been seen that the size of voids existing b/w a particular size of aggregate is of the order of 2 (or) 3 size lower than that of fraction. In other words the void size existing b/w 40mm aggregates is of the size equal to 10mm (or) possibly 4.75mm (or) the size of voids occurring when 20mm aggregate are used in order of say 1.18mm (or) so. ∴ along with 20mm aggregate only when 1.18mm aggregate size is used.

Advantages of gap graded concrete :

i) sand required will be of the order of about 26% as against about 40% in the case of continous grading.

ii) Specific surface area of the gap graded aggregate will be low because of high % of C.A & low % of F.A.

iii) Requires less cement and lower water/cement ratio.

iv) Because of point contact b/w C.A & C.A and also on account of lower cement and matrix content the drying shrinkage is reduced.

UNIT III

FRESH CONCRETE

→ Fresh concrete (or) plastic concrete is a freshly mixed material which can be moulded into any shape.

→ The relative quantities of cement, aggregates and water mixed together, control the properties of concrete in the wet state as well as in the hardened state.

Workability:

→ 100% compaction of concrete is an important parameter for contributing to the maximum strength. Lack of compaction will result in air voids whose detrimental effect on strength and durability is equally (or) more predominant than the presence of capillary cavities.

→ To enable the concrete to be fully compacted with given efforts, normally a higher water / cement ratio than that calculated by theoretical consideration may be required. That is to say the function of water is also to lubricate the concrete so that the concrete can be compacted with specified effort forth coming at the site work.

→ The word 'workability' (or) 'workable concrete' signifies much wider and deeper meaning than the other terminology "consistency" often used loosely for workability.

→ Consistency is a general term to indicate the degree of fluidity (or) the degree of mobility.

→ A concrete which has high consistency and which is more mobile, need not be of right workability for a particular job. Every job requires particular workability.

→ A concrete which is required workable for mass concrete for foundation is that not workable for concrete to be used in roof construction or even in roof construction. Concrete considered workable when vibrator is used is not workable when concrete is to be compacted by hand.

→ similarly concrete certain [illegible] section is not workable when required to be used in thin section. Therefore the word workability assumes full significance of the type of work, thickness of section, extent of reinforcement and mode of compaction.

→ workability is defined as property of concrete which determines the amount of useful internal work necessary to produce full compaction.

→ Another definition which envelopes a wider meaning is that it is defined as the ease with which concrete can be compacted 100% having regard to mode of compaction and place of deposition.

FACTORS AFFECTING WORKABILITY:

→ workable concrete is the one which exhibits very little internal friction between particle and particle which overcomes the frictional resistance offered by the form work surface and reinforcement contained in the concrete with full the amount of compacting efforts from coming

1) Water content
2) Mix proportion
3) size of aggregates
4) shape of aggregates
5) surface texture of aggregates
6) Grading of aggregates
7) use of admixtures.

→ The above are the factors affecting to the workability of concrete.

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MEASUREMENT OF WORKABILITY

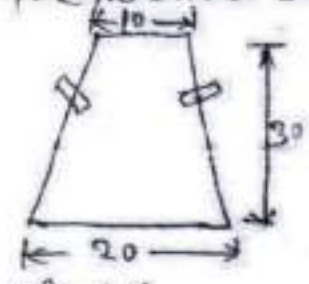
→ The following test are commonly employed to measure workability

1) Slump test
2) Compaction factor test
3) Flow test
4) Vee bee consistometer test.

1) Slump test

→ Slump test is the most commonly used method of measuring consistency of concrete which can be employed either in laboratory (or) at site of work.

→ The apparatus for conducting the slump test essentially consists of a metallic mould in the form of a frustum of a cone having the internal dimension under.



All in CM

Bottom diameter : 20CM
Top diameter : 10CM
Height : 30CM
Tamping rod : 16mm dia, 0.6m long

→ The mould is placed on a smooth horizontal, rigid and non absorbent surface. The mould is then filled in four layers, each approximately 1/4 of the height of the mould. Each layer is tamped 25 times by the tamping rod taking care to distribute the strokes evenly over the cross section.

→ After the top layer has been rodded the concrete is struck off level with a trowel and tamping rod.

→ The mould is removed immediately by raising it slowly and carefully in a vertical direction.

→ This allows the concrete to subside. The subsidence is referred as slump of concrete.

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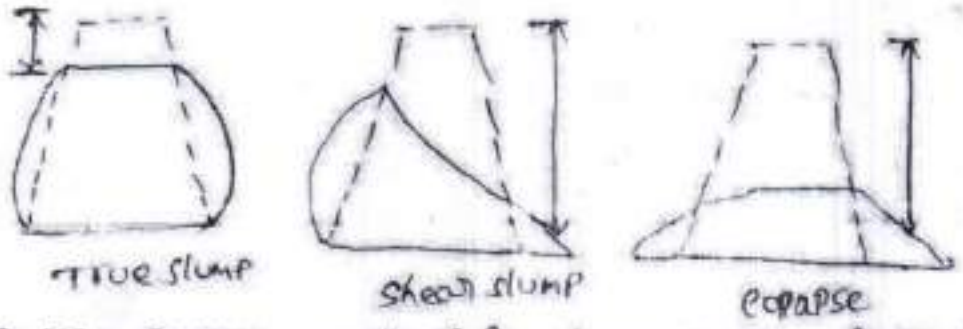

→ The pattern of slump is shown in fig. It indicates the characteristic of concrete in addition to the slump cone value.

→ If the concrete slumps evenly it is called true slump.

→ If one half of the cone slides down, it is called shear slump. It is also indicates the concrete is non-cohesive and shows the characteristic of segregation.

→ If the concrete slumps totally collapsed is called collapse.

→ It is seen that the slump test gives fairly good consistent results for a plastic mix. This test is not sensitive for a stiff mix. In case of dry mix, no variation can be detected between mixes of different workability.

Degree of workability	slump (mm)
Low	25-75
Medium	~~50-100~~ 50-100
High	100-150
Very high	—

2) Compacting factor test

→ The compacting factor test is designed primarily for use in the laboratory but it can also be used in the field.

→ It is more precise and sensitive than the slump test and is particularly useful for concrete mixes of very low workability as are normally used when concrete is to compacted by vibration

Dimension of the compacting factor apparatus

Upper Hopper A	Dimension (cm)
Top internal dia	25.4
Bottom internal dia	12.7
Internal height	27.9
Lower Hopper B	
Top internal dia	22.9
Bottom internal dia	12.7
Internal height	22.9
Cylinder C	
Internal dia	15.2
Internal height	30.5
Distance b/w Hopper	20.3

→ The sample of concrete to be tested is placed in the hopper upto the brim. The trap door is opened so that the concrete falls into the lower hopper. Then the trap door of the lower hopper is opened and the concrete is falls into the cylinder.

→ The excess of concrete remaining above the cylinder is then cut off with the help of plane blades supplied with the apparatus.

→ The outside of the cylinder is wiped clean. The concrete is filled up exactly upto the top level of the cylinder. It is weighed to the nearest 100 grams. This weight is known as "weight of partially compacted concrete"

→ The cylinder is emptied and then refilled with the concrete from the same sample in layers approximately 5cm deep. The layers are heavily rammed (or) vibrated as a full compaction. The top surface of the fully compacted concrete is then carefully struck off level with the top of the cylinder and weighed to the nearest 100 gm. This weight is known as "weight fully compacted concrete"

$$\text{Compaction factor} = \frac{\text{wt of partially compacted concrete}}{\text{wt of fully compacted concrete}}$$

3) Flow test:

→ This is a laboratory test which gives an indication of the quality of concrete with respect to consistency, cohesiveness and the proneness to segregation.

→ This apparatus consist of flow table about 76cm in diameter.

→ The mould made from smooth metal casting in the form of frustum of a cone is used with the following internal dimensions. The base is 25cm in dia, upper surface 17cm in dia. and height of the cone is 12cm.

→ The table top is cleaned of all gritty material and is wetted. The mould is kept on the centre of the table, firmly held and is filled in two layers. Each layer is rodded 25 times with a tamping rod 1.6cm in dia and 61cm long.

→ The top layer is rodded evenly the excess of concrete which has overflowed the mould is removed.

→ The mould is lifted vertically upward and the concrete stands on its own without support. The table is then raised and dropped 12.5mm 15 times in about 15 sec.

→ The diameter of spread concrete is measured in about 6 directions to the nearest 5mm and the avg spread is noted.

$$\text{Flow \%} = \frac{\text{spread dia in cm} - 25}{25} \times 100.$$

→ The value could range anything from 0 to 150%

4) Vee-Bee consistometer test:

→ This is good laboratory test to measure indirectly the workability of concrete. This test consists of a vibrating table, a metal pot, a sheet metal cone, a standard iron rod.

→ Slump test as described earlier is performed, placing the slump cone inside the sheet metal cylindrical pot of the consistometer.

→ The glass disc attached to the swivel arm is turned and placed on the top of the concrete in the pot.

→ The electrical vibrator is then switched on and simultaneously a stop watch started. The vibration is continued till such a time as the conical shape of the concrete disappears and the concrete assumes a cylindrical shape.

→ This can be judged by observing the glass disc from the top for disappearance of transparency. Immediately when the concrete is fully assumes a cylindrical shape the stop watch is switched off.

→ The time required for the shape of concrete to change from slump cone test to cylindrical shape in seconds is known as <u>vee-bee degree.</u>

SETTING TIME OF CONCRETE:

→ The setting time of concrete depends upon w/c ratio, temperature conditions, type of cement, use of mineral admixtures, use of plasticizers in particular retarding plasticizers.

→ The setting parameter of concrete is more of practical significance for site engineers than setting time of cement.

→ When retarding plasticizers are used, the increase in setting time, the duration upto which concrete remains in plastic condition is of special interest.

→ The setting time of concrete is found by penetrometer test.

→ The apparatus consist of container which should have minimum lateral dimension of 150mm and minimum depth of 150mm.

→ There are 6 penetration needles with bearing ~~area~~ areas of 645, 323, 161, 65, 32 and 16mm². Each needle stem is scribed circumferentially at a distance of 25mm from the bearing area.

→ The test procedure involves the collection of representative sample of concrete in sufficient quantity and sieve it through 4.75 mm sieve and the resulting mortar is filled in the container
→ compact the mortar by rodding, tapping, rocking or by vibrating
Level the surface and keep it covered to prevent the loss of moisture. Remove bleeding water, if any by mean of pipette.
→ insert a needle of appropriate size, depending upon the desire of setting of mortar in the following manner.
→ Bring the bearing surface of needle in contact with the mortar surface, gradually and uniformly apply a vertical force downward on the apparatus until the needle penetrates to a depth of 25 ± 1.5 mm, as indicated by the scribe mark.
→ The time taken to penetrate 25 mm depth could be about 10 sec. Record the force required to produce 25 mm penetration and the time of inserting from the time water is added to cement.
→ Calculate the penetration resistance by dividing the recorded force by the bearing area of the needle. This is the penetration resistance.
→ For the subsequent penetration avoid the area where the mortar has been disturbed. The clear distance should be two times the diameter of the bearing area. Needle is inserted at least 25 mm away from the wall of container.
→ Plot a graph of penetration resistance as ordinate and elapsed time as abscissa. Not less than six penetration resistance determination is made.
→ Continue tests until one penetration resistance of at least 27.6 MPa is reached. Connect the various point by a smooth curve.
→ Penetration resistance equal to 3.5 MPa draw a horizontal line. The point of intersection of this with the smooth curve. Read on the X axis which gives the initial setting time. By horizontal line is drawn from the penetration resistance of 27.6 MPa and perpendicular is cuts the smooth curve is read on the X axis which gives final setting time.

SEGREGATION :

→ segregation can be defined as the seperation of the constituent materials of concrete.

→ A good concrete is one in which all the ingredients are properly distributed to make a homogeneous mixture.

→ if a sample of concrete exhibits a tendency for seperation of coarse aggregate from the rest of the ingredients that sample is said to be showing the tendency for segregation. Such a concrete is not only going to be weak. lack of homogeneity is also going to induce all undesirable properties in the hardened concrete.

→ segregation may be of three types

* coarse aggregate seperating out and settling down from the rest of the matrix.
* the paste (or) matrix seperating from coarse aggregate and ~~[illegible]~~
* water seperating out from the rest of the material being a material of lowest specific gravity.

→ A well made concrete taking into consideration various parameters such as grading, size, shape and surface texture of aggregates with optimum quantity of water makes a cohesive mix. Such concrete will not exhibit any tendency for segregation

→ The conditions favourable for segregation are as can be seen from the above para. the badly proportioned mix where sufficient matrix is not there to bind and contain the aggregates. Insufficiently mixed concrete with excess water content shows a higher tendency for segregation.

→ drops of concrete from heights as in the case of placing concrete in column concreting will result in segregation.

→ Vibration of concrete is one of the important methods of compaction. It should be remembered that only comparatively dry mix should be vibrated. If a wet mix is excessively vibrated, it is likely that the concrete gets segregated.

→ In the recent time we use concrete with very high slump particularly in RMC. The slump value required at the batching point may be in the order of 150mm and at the pouring point the slump may be around 100mm.

→ While finishing concrete floors with a view to achieve a smooth surface masons are likely to work too much with the trowel, float (or) tamping rule immediately on placing concrete. This immediate working on the concrete on placing without any time interval is likely to press the coarse aggregate down which results in the movement of excess of mortar (or) paste to the surface. Segregation caused entirely account impairs the homogeneity and serviceability of concrete. The excess mortar at the top causes plastic shrinkage cracks.

→ Segregation is difficult to measure quantitatively but it can be easily observed at the time of compacting operation. The pattern of subsidence of concrete in slump test (or) the pattern of spread in the flow test gives a fair idea of the quality of concrete with respect to segregation.

BLEEDING:

→ Bleeding is sometimes referred as water gain. This a particular form of segregation, in which some of the water from the concrete comes out to be the surface of the concrete, being of the lowest specific gravity among all the ingredients of concrete.

→ Bleeding is predominantly observed in a highly wet mix, badly proportioned and insufficiently mixed concrete. In thin members like roof slabs (or) road slabs and when concrete is placed in sunny weather shows excessive bleeding.

→ due to bleeding water rises up and accumulates at the surface. sometimes along with this water, certain quantity of cement also comes to the surface.

→ when the surface is worked up with the trowel and floats the aggregates goes down and the cement and water comes up to top surface. This formation of cement paste at the surface is known as "Laitance".

→ In such a cases the top of slabs and pavements will not have good wearing quality. This laitance formed on roads produces dust in summer and mud in rainy season.

→ water while traversing from bottom to top, makes continous channels, if the water cement ratio is used more than 0.7 the bleeding channels will remain continous and unsegmented by the development of gel. This continous bleeding channels are often responsible for causing permeability of the concrete structures.

→ The bleeding water is likely to accumulate below the aggregates. This accumulation of water creates water voids and reduces the bond b/w the aggregates and the paste.

→ Bleeding rate increases with time up to about one hour or so and there after rate decreases but continues however less till the final setting time of cement.

→ Bleeding presents several serious problem when slip form paver is used for construction of concrete pavements. If too much of bleeding water accumulates on the surface of pavement slab the bleeding water flows out over the unsupported sides which causes collapsing of sides.

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Method of test for bleeding of concrete

→ This method covers determination of relative quantity of mixing water that will bleed from a sample of freshly mixed concrete.

→ A cylindrical container of approximately 0.01 m³ capacity, having an inside diameter of 250mm and inside height of 280mm is used. A tamping bar similar to the one used for slump test is used. A pipette for drawing off free water from the surface a graduated jar of 100cm³ capacity is required for test.

→ A sample of freshly mixed concrete is obtained. The concrete is filled in 50mm layer for a depth of 250 ± 3 mm (5 layers) and each layer is tamped by giving strokes, and top surface is made smooth by trowelling.

→ The test specimen is weighed and the weight of the concrete is noted. Knowing the total water content in 1 m³ of concrete quantity of water in the cylindrical container is also calculated.

→ The cylindrical container is kept in a level surface free from vibration at a temperature of 27°C ± 2°C. It is covered with a lid. Water accumulated at the top is drawn by means of pipette at 10 minutes interval for the first 40 min and at 30 min. interval subsequently till bleeding cease. To facilitate collection of bleeding water the container may be slightly tilted. All the bleeding water collected in a jar.

$$\text{Bleeding \%} = \frac{\text{Total quantity of bleeding water}}{\text{Total quantity of water in sample of concrete}} \times 100$$

STEPS IN MANUFACTURE OF CONCRETE.

→ The various steps of manufacture of concrete are.

1) Batching
2) Mixing
3) Transporting
4) Placing
5) Compacting
6) Curing
7) Finishing.

1) Batching:

→ The measurement of materials for making concrete is known as 'batching'.

→ There are two methods of batching.

i) Volume Batching (ii) Weight Batching.

i) Volume Batching:

→ Volume batching is not a good method for proportioning the material because of the difficulty it offers to measure granular material in terms of volume.

→ Cement is always measured by weight, it is never measured in volume. Generally for each batch mix one bag of cement is used. The volume of 1 bag of cement is taken by 35 litres.

→ Gauge boxes are used for measuring the fine and coarse aggregates. The volume of the box is made equal to the volume of 1 bag of cement i.e 35 litres

→ Gauge boxes are generally called forms. They can be made of timber (or) steel plates.

→ water is proportion either in litres or kg BECAUSE IN THIS case the two units are same as the density of water is one kg/litre. The quantity of water required is a product of water/cement ratio and the weight of cement.

→ For example if the water/cement ratio of 0.5 is specified the quantity of mixing water is required per bag of cement is 0.5×50 = 25 kg (or) litres

Batch volume of materials for mixes

Grade	cement (kg)	sand (lits)	aggregate (litres)
1:1:2 (M200)	50	35	70
1:1½:3 (M200)	50	52.5	105
1:2:3	50	70	105
1:2:4 (M150)	50	70	140
1:2½:5	50	87.5	175
1:3:6	50	105	210

ii) Weigh Batching:

→ Weigh batching is the correct method of measuring the materials. For important concrete weigh batching is adopted.

→ Use of weigh system in batching facilities accuracy, flexibility and simplicity. Different types of weigh batches are available.

→ The particular type to be used, depends upon the nature of the job. Large weigh batching plants have automatic weighing is one of sophistication and requires qualified and experienced engineers. In this further complication will come to adjust water content to water for the moisture content in the aggregates.

→ In small jobs cement is often measured in bags assuming the weight of the bag as 50 kg. In reality the cement bag is made of 50 kg at the factory due to transportation when the bags are used. In fact the weight of a cement bag at the site is considerably less. Some times the loss of weight becomes more than 5 kg. This is one of the sources of error in volume.

→ Batching and weigh batching when the cement is not actually weighed. But in important major concreting jobs, cement is also actually weighed and exact proportion as designed is maintained.

2) MIXING :

→ Through mixing of the material is essential for the production of uniform concrete. The mixing should ensure that the mass becomes homogeneous, uniform in colour and consistency.

→ There are two methods adopted for mixing concrete.

1) Hand mixing.
2) Machine mixing.

1) Hand mixing:

→ Hand mixing is practised for small scale unimportant concrete works.

→ As the mixing cannot be thorough and efficient it is desirable to add 10% more cement to water for the intended concrete produces by this method.

2) Machine mixing:

→ Mixing of concrete is almost invariably carried out by machine for reinforced concrete work and for medium (or) large scale mass concrete work.

→ Machine mixing is not only efficient but also economical when the quantity of concrete to produced is large.

3) Transporting:

→ The methods adopted for transportation of concrete.

i) Mortar pan (ii) Wheel barrow, Hand cart

iii) Crane, Bucket and rope way iv) Truck mixer & dumper

v) Belt conveyors vi) Chute.

vii) Skip and Hoist viii) Transit mixer

ix) Pump and pipeline x) Helicopter.

4) Placing of concrete:

→ It is not enough that a concrete mix correctly designed, batched mixed and transported, it is of of most importance that the concrete must be placed in symmetric manner to yield optimum results.

→ Concrete is invariably laid on foundation bed below the walls (or) columns. Before placing the concrete in the foundation, all the loose earth must be removed from the bed.

→ For the construction of road slabs, airfield slabs and ground floor slabs in buildings, concrete is placed in bays. The ground surface on which the concrete is placed must be free from loose earth, pool of water and other organic matters like grass, roots, leaves etc.

→ When concrete is laid in great thickness as in the case of concrete raft for a high rise building (or) in the construction of concrete pier for abutment (or) in the construction of mass concrete dam, concrete is placed in layers.

→ Before placing the concrete the surface of the previous lift is cleaned thoroughly with water jet and scrubbing by wire brush.

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5) Compaction :

→ Compaction of concrete is the process adopted for expelling the entrapped air from the concrete. In process of mixing, transporting and placing of concrete air is likely to get entrapped in the concrete.

Methods of compaction:

i) Hand compaction

a) Rodding b) Ramming c) Tempping

ii) Compaction by vibration

a) Internal vibrator

b) Formwork vibrator

c) Table vibrator

d) Platform vibrator

e) Surface vibrator

f) Vibratory roller

iii) Compaction by pressure and jarring

iv) Compaction by spinning.

6) Curing :

→ Curing can also be described as keeping the concrete moist and warm enough so that the hydration of cement can continue. More elaborately it can be described as the process of maintaining a satisfactory moisture content and a favourable temp. in concrete during the period immediately following placement, so that hydration of cement may continue until the desired properties are developed to a sufficient degree to meet the requirement of service.

→ A quick surface drying of concrete results in the movement of moisture from the interior to the surface.

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CURING METHODS:

a) Water curing → Immersion, Ponding, Spraying, Wet covering

b) Membrane curing — Steam curing, Electrical, Infra-red radiation

c) Application of heat —

7) FINISHING:

→ Finishing operation is the last operation in making concrete. Finishing in real sense does not apply to all concrete operations

→ For a beam concreting, finishing may not be applicable, Road pavement, airfield pavement, domestic buildings, careful finishing is of great importance.

EFFECT OF TIME & TEMPERATURE ON WORKABILITY:

→ Concrete mixers are generally designed to run at a speed of 15–20 revolutions per minute.

→ For proper mixing it is seen that about 25–30 revolutions are required in a well designed mixer.

→ In the site the normal tendency is to speed up the out-turn of concrete by reducing the mixing time. This results in poor quality of concrete. On the other hand, if the concrete is mixed for a comparatively longer time, it is uneconomical from the point of view of rate of production of concrete and fuel consumption therefore it is of importance to mix the concrete for such a duration which will secure optimum benefit.

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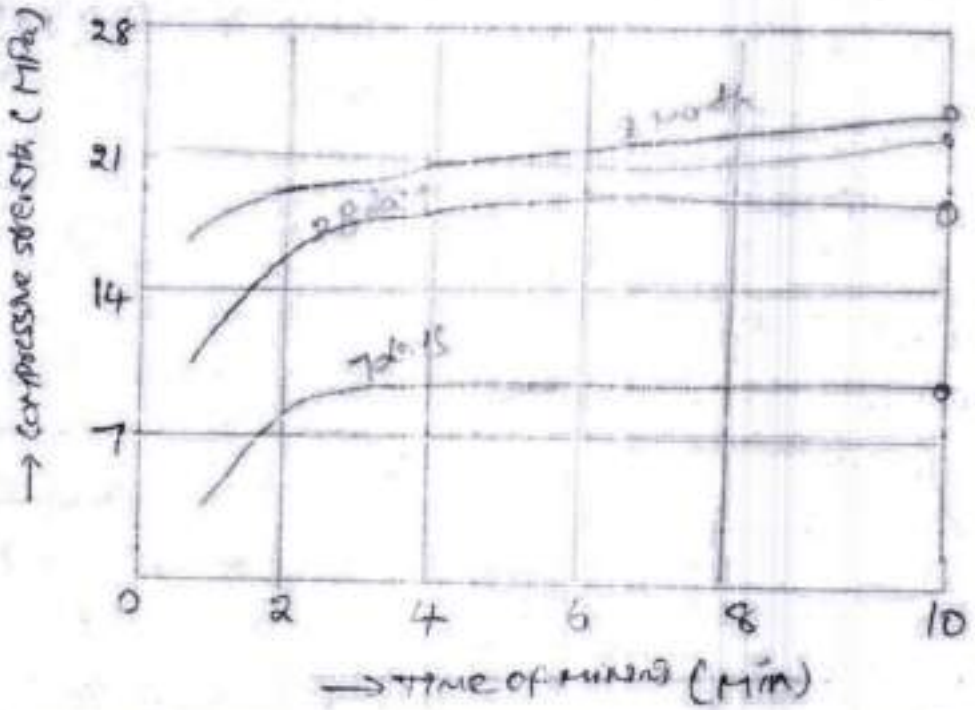

→ It is seen from the experiment that the quality of concrete in terms of compressive strength will increased with the increase in time of mixing but for mixing time beyond two min the improvement in compressive strength is not very significant. The graph shows the effect of mixing time on strength of concrete.

→ Concrete mixer is not a simple apparatus lot of considerations have gone as input in the design of the mixer. Shape of drum, the number of blades, inclination of blades with respect to drum surface. The length of blades, the depth of blades, the space b/w the drum and the blades, the space b/w the metal strips of blades and speed of rotation etc. are important to give uniform mixing quality and optimum time of mixing.

→ Generally mixing time is related to the capacity of mixer. The mixing time varies b/w 1° to 2° minutes. Bigger the capacity of drum more is the mixing time. However modern high speed pan mixer used in RMC, mixes the concrete in about 15-30 secs. one cubic meter (1m³) capacity high speed pan mixer takes only about 2 min. for batching and mixing. The batching plant takes about 12 min. to load a transit mixer of 6m³ capacity.

→ Some times, at some work concrete may run → discharged from the drum and concrete may be kept rotating in the drum for long time, as for instance when some trouble/(or) dispute takes place with the workers (or) when an unanticipated repair (or) modification is required to be done on form work and reinforcement.

→ Long time mixing of concrete will generally result in increase of compressive strength of concrete within limits. Due to mixing over periods the effective water/cement ratio gets reduced.

→ The evaporation of water and formation of excess fines may reduce the workability and hence bring about reduction in strength. The excess of fines may also cause greater shrinkage.

RETEMPERING OF CONCRETE:

→ The process of restoring of concrete if necessary with addition of just the required quantity of water is known as "Retempering of concrete". Sometimes a small quantity of extra cement also added while retempering. Many specifications do not permit mortar regaining renewed mixing with (or) without addition of cement + aggregate (or) water.

→ The production of concrete of excessive slump (or) adding water in excess of designed water cement ratio to compensate for slump loss resulting from delays in delivery should be prohibited.

→ Retempering of concrete is too wet and at a delay of about one hour as an increase in compressive strength of 2 to 15%.

Quality of Mixing Water

→ Concrete is a chemically combined mass which is manufactured from binding materials such their material with water.

Functions of water in concrete:-

→ To wet the surface of aggregate to develop adhesion because the cement paste adheres quick and satisfactory to the surface of the aggregates than to any surface.

→ To make a plastic mixture of the various ingredients and to impart workability to concrete to facilitate placing in the desired position

→ Water is also needed for the hydration of the cementing material to set and harden during the period of curing

→ Quantity of water in the mix plays a vital role on the strength of the concrete, some waters which have adverse effect on hardened concrete, sometimes may not be harmless (or) even beneficial during mixing.

→ The effect on concreting for different types of contamination impurities are described below-

1) Suspended solids:

→ Mixing water with high content of suspended solids should be allowed to stand in a settling tank before use as it undesirable to introduce large quantities of clay and silt into the concrete.

2) Acidity & Alkalinity:

→ Natural water that is slightly acidic are harmless, but presence of humic (or) other organic acids may result

adverse effect over the hardening of concrete. Waters which are highly alkaline should also be tested.

3) Algae:-

→ The presence of algae in mixing water causes air entrainment with a consequent loss of strength. The green (or) brown slime forming algae should be regarded with suspicion and such water should be tested carefully.

4) Sea water:-

→ Sea water contains a total salinity of about 3.5% (78% of the dissolved solids being NaCl and 15% MgCl2 and MgSO4) which produces a slightly higher early strength but a lower long term strength.

→ The loss of strength is usually limited 15% and consequently be tolerated. Sea water reduces the initial setting time of cement but do not effect final setting time.

5) Chloride:-

→ Water containing large amount tends to cause persistant dampness and surface efflorence.

→ The presence of chlorides in concrete containing embedded steel can lead to its corrosion.

6) Moisture content of Aggregate:-

→ Aggregates usually contains some surface moisture. Coarse aggregate rearly contains more than 1% of surface moisture but fine aggregate can contain in excess of 10%.

→ This water can represent a substantial proportion of the total mixing water indicating a significant importance in the quality of water that contributes surface moisture in aggregate.

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UNIT IX

HARDENED CONCRETE

→ The compressive strength of concrete is one of the most important and useful properties of concrete.

→ compressive strength is also used a qualitative measure for other properties of hardened concrete.

→ no exact quantitative relationship b/w compressive strength and flexural strength, tensile strength, modulus of elasticity, wear resistance fire resistance or permeability.

→ The compressive strength of concrete is generally determined by testing cubes when concrete fails under a compressive load the failure is essentially a mixture of crushing and shear failure.

→ The modern version of original water/cement ratio rule can be given as follows.

1) Ratio of cement to mixing water
2) Ratio of cement to aggregates.
3) Grading, surface texture, shape, strength and stiffness of aggregates.
4) Maximum size of aggregate.

Water/cement ratio:

→ strength of concrete primarily depends upon the strength of cement paste. It has been depends upon the dilution of paste

→ The strength of paste increases with cement content and decreases with air and water content

$$S = \frac{A}{B^x}.$$

x = water cement ratio by volume and for 28 days results the constant A & B are 1000 kg/cm and 7 respectively.

→ Abrams w/c ratio law states that the strength of concrete is only dependent upon w/c ratio provided the mixes consist

→ According to the strength of concrete depends and concrete in terms of volume fraction of the constituents by the equation

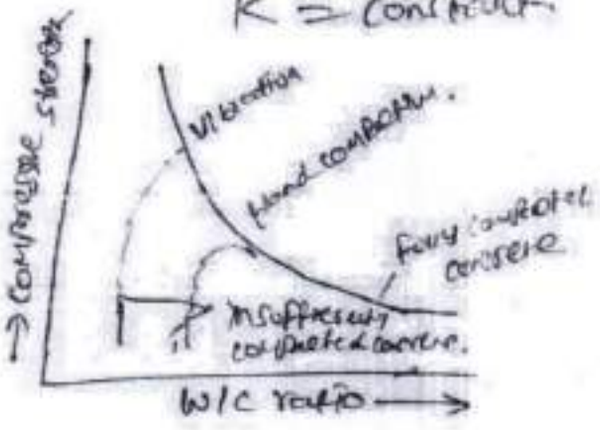
$$S = K\left(\frac{c}{c+e+a}\right)^2$$

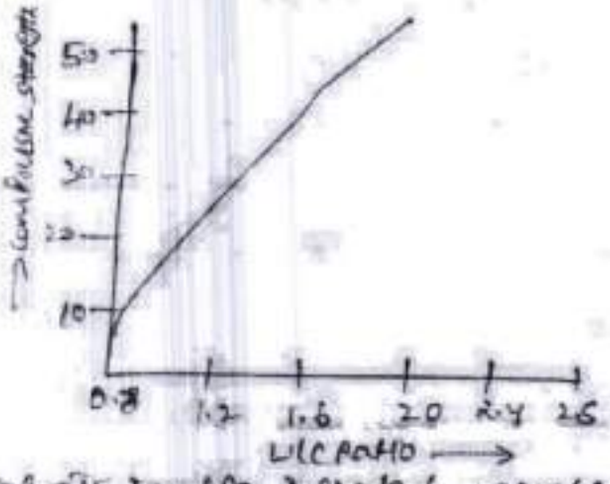
where,

S = strength of concrete

c, e and a = volume of cement, water and air

K = constant





→ In this expression the volume of air is also included because it is not only the water/cement ratio but also the degree of compaction. which indirectly means the volume of air filled voids in the concrete is taken into account in estimating the strength of concrete.

→ It can be seen that lower water/cement ratio could be used when the concrete is vibrated to achieve higher strength, whereas comparatively higher water/cement ratio is required when concrete is hand compacted. In both cases when the water/cement ratio is below the practical limit the strength of concrete falls rapidly due to introduction of air voids.

→ The graph showing the relationship b/w the strength and water/cement ratio is approximately hyperbolic in shape. Sometimes it's difficult to interpolate the intermediate value.

Gel/space ratio:

→ Instead of relating the strength to w/c ratio, the strength can be more related to the solid products of hydration of cement to the space available for formation of this product.

→ Gel/space ratio is defined as the ratio of the volume of the hydrated cement space to the sum of the volumes of the hydrated cement and of the capillary pores.

→ Power experiment showed that the strength of concrete has a specific relationship with the gel/space ratio. He found the relationship to be $240x^3$, where x is the gel/space ratio and 240 represents the intrinsic strength of gel in MPa for the type of cement and specimen used.

→ The relationship b/w the strength and water/cement ratio will hold good primarily for 28 days strength for fully compacted concrete, whereas the relationship b/w the strength and gel/space ratio is independent of age.

→ Gel space ratio can be calculated at any age and for any fraction of cement.

→ The following example show how to calculate gel/space ratio

Calculation of gel/space ratio for complete hydration:

C = weight of cement in gm

V_c = specific volume of cement = 0.319 ml/gm

W_0 = volume of mixing water in (ml)

Assuming that 1ml of cement on hydration will produce 2.06ml of gel

Volume of gel = $C \times 0.319 \times 2.06$

space available = $C \times 0.319 + W_0$

$\therefore$ Gel/space ratio $= \dfrac{\text{vol of gel}}{\text{space available}}$

$$X = \frac{0.657C}{0.319C + W_0}$$

Calculation of gel/space ratio for Partial Hydration:

α = Fraction of cement that has hydrated

Volume of gel $= C \times \alpha \times 0.319 \times 2.06$

Total space available $= C V_c \alpha + W_0$

$\therefore$ Gel/space Ratio $= X = \dfrac{2.06 \times 0.319 \times C\alpha}{0.319 C\alpha + W_0} = \dfrac{0.657\alpha}{0.319\alpha + W_0}$

Ex:

Calculate the Gel/space ratio and the theoretical strength of a sample of concrete made with 500 gm. of cement with 0.5 W/C ratio, on fully hydration & at 60% hydration

Ans

Gel/space ratio $= \dfrac{0.657C}{0.319C + W_0}$ $\left[\begin{array}{l} W_0 = 0.5 \times 500 \\ W_0 = 250 \end{array}\right]$

$$X = \frac{0.657 \times 500}{0.319 \times 500 + 250}$$

$X = 0.8$

$\therefore$ Theoretical strength of concrete $= 240 \times (0.8)^3$

$= 123$ MPa.

Gel/space ratio for 60% hydration $\alpha = 0.6$

$$X = \frac{0.657C\alpha}{0.319C\alpha + W_0}$$

$$X = \frac{0.657 \times 500 \times 0.6}{0.319 \times 500 \times 0.6 + 250}$$

$X = 0.57$

$\therefore$ Theoretical strength of concrete $= 240 \times (0.57)^3$

$= 44.4$ MPa.

Maturity concept of concrete:

→ strength development of concrete depends on both time and temperature. It can be said that strength is a function of summation of product of time and temperature. This summation is called maturity of concrete.

$$\therefore \text{Maturity} = \Sigma (\text{time} \times \text{temp.})$$

→ The datum line for computing maturity is $-11°C$.

→ Maturity is measured in °C-H (or) °C (Degree centigrade)

→ A sample of concrete cured at 18°C for 28 days taken as fully matured concrete.

$$\text{Maturity} = 28 \times 24 \times (18-(-11)).$$
$$= 19488 °C.h.$$

→ In standard calculations the maturity of fully cured concrete is taken as 19,800°C.h.

→ Maturity concept is useful for estimating the strength of concrete at any other maturity as a percentage of strength of concrete of known maturity.

Strength at any maturity as a % of strength of maturity 19,800 C.h $= A + B \log_{10} \frac{(\text{maturity})}{10^3}$

Plowman's coefficient for maturity eqn.

Strength after 28 days at 18°C (MPa)	coefficient	
	A	B
< 17.5	10	68
17.5 – 35.0	21	61
35.0 – 52.5	32	54
52.5 – 70.0	42	46.5

Ex 1)

The strength of a sample of fully matured concrete is found to be 40 MPa find the strength of identical concrete at the age of 7 day when cured at an avg. temp. during day time at 20°C and night time 10°C.

Sol

maturity of concrete

at 7 days $= \Sigma(\text{time} \times \text{temp})$

$= 7 \times 12 \times (20-(-11)) + 7 \times 12 \times (10-(-11))$

$= 4368\,°C\,h.$

∴ strength range of this concrete falls in zone II

∴ $A = 32$, $B = 54$.

% strength of concrete

$$\text{maturity of } 4368\,°C\,h = A + B \log_{10} \frac{(\text{maturity})}{10^3}$$

$$= 32 + 54 \log_{10} \frac{(4368)}{10^3}$$

$$= 66.5\,\%$$

$$\therefore \text{strength at 7 days} = 40 \times \frac{66.5}{100}$$

$$= 26.5 \text{ MPa.}$$

Ex 2 Laboratory experiments conducted at Pune on a particular mix showed a strength of 32.5 MPa for fully matured concrete. Find whether formwork can be removed for an identical concrete placed at Srinagar at the age 15 days when the avg temp. is 15°C. The concrete is likely to sustain a stripping stress of 25 MPa.

Sol maturity of concrete at 15 days $= 15 \times 24 \times (5-(-11))$

$= 5760\,°C\,h.$

Concrete falls in $A = 21$, $B = 61$. zone II.

% strength of concrete $= 21 + 61 \log_{10} \frac{(5760)}{10^3}$

$= 67.38\,\%$

$$\therefore \text{strength at 15 days} = 32.5 \times \frac{67.38}{100}$$

$$= 21.9 \text{ MPa.}$$

Nature of strength factor:

→ The paramount influence of voids in concrete on its strength has been repeatedly mentioned and it should be possible to relate this factor to the actual mechanism of failure.

→ For this purpose concrete is considered to be a brittle material even though it exhibits a small amount of plastic action as fracture under static loading takes place at moderately low total strain

→ a strain of 0.001 to 0.005 at failure has been suggested as the limit of brittle behavior.

→ High strength concrete is more brittle than normal strength concrete but there is no quantitative method of expressing the brittleness of concrete whose behavior in practice falls b/w the brittle and the ductile types.

Fracture & failure:

→ Concrete specimens subjected to any state of stress can support loads of upto 40-50% of ultimate without any apparent signs of distress.

→ Below this level any sustained load results in creep strain which is proportional to the applied stress and can be defined in terms of specific creep. Also concrete is below the fatigue limit.

→ Also the load increased above this level soft but distinct noises of internal disruption can be heard until about 70-90% of ultimate small fissures (or) cracks appear on the surface. At this stage sustained loads result in eventual failure.

Strength in tension & compression:

1) Compressive strength:

→ It is tested in a standard manner which includes full compaction and wet curing for a specified period give results representing the potential quality of the concrete.

→ There are three types of loading in compression test.

i) Uniaxial loading
ii) Biaxial loading
iii) Triaxial loading

→ The uniaxial loading case represents the most conservative system and yields the lowest values in compression.

→ There are three types of failure in compression test.

i) Tension failure (splitting)
ii) Shear failure (sliding)
iii) Combined failure (tension & shear)

2) Tension strength:

→ Although concrete is not normally designed to resist direct tension, the knowledge of tensile strength is of value in estimate the load under which cracking will develop.

→ The absence of cracking is considerable importance in maintaining the continuity of a concrete structure and in many cases in the prevention of corrosion of reinforcement.

→ There are two types of test for strength in tension test.

i) Direct tension test ii) Splitting tensile strength test

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Relation B/W compressive and tensile strength:

→ In reinforced concrete construction the strength of the concrete in compression is only taken into consideration.

→ The tensile strength of concrete is generally not taken into consideration but the design of concrete pavement slab is often based on the flexural strength of concrete.

→ As measurements and control of compressive strength in field are easier and more convinient, it has been customary to find out the compressive strength for different conditions and to correlate this compressive strength to flexural strength.

→ It is seen that strength of concrete in compression and tension are closely related, but the relationship is not the type of direct proportionality.

→ The two ratios of the strength depends on general level of strength of concrete. For higher compressive strength concrete shows higher tensile strength, but the ratio of increase of tensile strength is of decreasing order.

→ The type of coarse aggregate influences this relationship. Crushed aggregate gives relatively higher flexural strength than compressive strength.

→ The tensile strength of concrete as compared to its compressive strength is more sensitive to improper curing.

→ The use of pozzolanic material increased the tensile strength of concrete.

→ Following statical relation b/w tensile and compressive strength

i) $Y = 15.3X - 9.00$ for 20mm max. size aggregate.

ii) $Y = 14.1X - 10.4$ for 20mm max. size natural gravel

iii) $Y = 9.9X - 0.55$ for 40mm max. size crushed aggregate

iv) $Y = 9.8X - 2.52$ for 40mm max. size natural gravel

where, Y = compressive strength of concrete (MPa)

X = flexural strength of concrete (MPa)

→ There are number of empirical relationships b/w tensile strength and compressive strength of concrete.

$$\text{Tensile strength} = K(\text{compressive strength})^n$$

$K = 6.2$ for gravels

$K = 10.4$ crushed rock

$n = 1/2$ to $3/4$

→ Indian standard IS 456-2000 gives the following relationship b/w the compressive strength and flexural strength

$$\text{Flexural strength} = 0.7\sqrt{f_{ck}}$$

f_{ck} = characteristic compressive strength of concrete in N/mm^2.

CURING:

→ The test specimens are stored in place from vibration, in moist air of at least 90% relative humidity and at a temp. of $27° \pm 2°C$ for 24 hours $\pm$ 1/2 hour from the time of addition of water to the dry ingredients.

→ After this period the specimen are removed and removed from the moulds and unless required for test within 24 hours, immediately submerged in clean fresh water or saturated lime solution and kept there until taken out just prior to test.

→ The water or solution in which the specimen are submerged, are renewed every seven days and are maintained at a temp. of $27°C \pm 2°C$. The specimens are not to be allowed to become dry at any time until they have been tested.

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FLEXURAL STRENGTH OF CONCRETE:

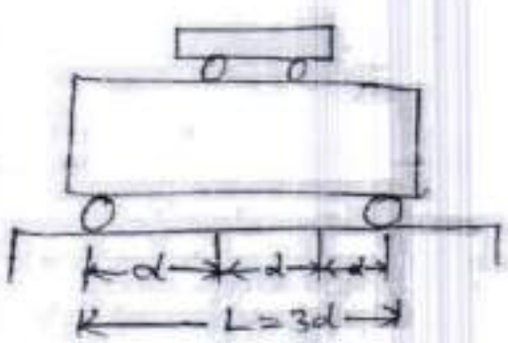
→ Concrete as we know is relatively strong in compression and weak in tension. In reinforced concrete members, little independence is placed on the tensile strength of concrete.

Determination of tensile strength:

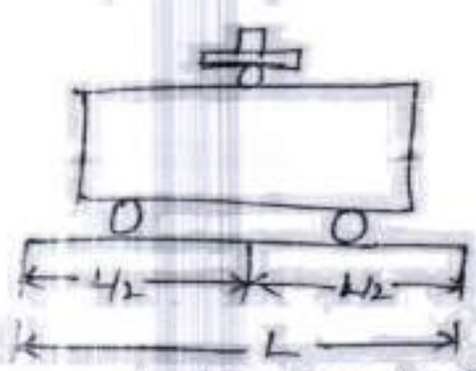
→ Direct measurement of tensile strength of concrete is difficult. Neither specimens nor testing apparatus have been designed which assure uniform distribution of the pull applied to the concrete.

→ The value of the modulus of rupture depends on the dimension of the beam and manner of loading. The system of loading used in finding out the flexural tension are central point loading and third point loading.

→ In central point loading maximum fibre stress will come below the point of loading where the bending moment is maximum. In case of symmetrical two point loading the critical crack may appear at any section, not strong enough to resist the stress within the middle third, where the bending moment is maximum.



Third-point loading



Centre-point loading.

→ The standard size of specimen are 15×15×70 cm. Alternatively if the largest nominal size of the aggregate does not exceed 80 mm, specimen 10×10×50 cm may be used.

SPLIT TENSILE TEST :

→ This is also called as cylinder splitting tension test (or) "Brazilian test"

→ This test is carried out by placing cylindrical specimen horizontally between the loading surface of a compression testing machine and the load is applied until failure of the cylinder, along the vertical diameter.

→ When the load is applied along the generatrix an element on the vertical diameter of the cylinder is subjected to a vertical compressive stress of.

$$\frac{2P}{\pi LD}\left[\frac{D^2}{r(D-r)}-1\right]$$

and a horizontal stress of $\frac{2P}{\pi LD}$

P = compressive load
L = length of cylinder
D = diameter.

→ The loading condition produces a high compressive stress immediately below the two generators to which the load is applied. But the larger portion corresponding to depth is subjected to a uniform tensile stress acting horizontally. It is estimated that the compressive stress is acting for about 1/6 depth and remaining 5/6 depth is subjected to tension.

→ In order to reduce the magnitude of the high compression stresses near the points of application of the load, narrow packing strips of suitable material such as plywood are placed b/w the specimen and loading platens of the testing machine. The packing strips should be soft enough to allow distribution of load over a reasonable area, yet narrow and thin enough to prevent large contact area. Normally a plywood strip of 25mm wide, 3mm thick, 30cm long used.

→ The main advantage of this method is that same type of specimen and the same testing machine as are used for the compression test

→ The splitting test is simple to perform and gives more uniform results than other tension tests.

NON-DESTRUCTIVE TESTING METHODS:

→ In this method is now a powerful method for evaluating existing concrete structures with regard their strength and durability apart from assessment and control of quality of hardened concrete.

→ Though non-destructive testing methods are relatively simple to perform, the analysis and interpretation of test results are not so easy. The special knowledge is required to analyse the hardened properties of concrete.

NDT METHODS

1) Schmidt's Rebound hammer
2) Penetration techniques
3) Pullout test
4) Dynamic (or) vibration methods
5) Pulse velocity method.
6) Radioactive & nuclear methods
7) Magnetic & electrical methods

1) Schmidt's Rebound hammer:

→ It is one of the most commonly adopted equipments for measuring the surface hardness.

→ It consist of a spring control hammer that slides on a plunger within a tubular housing. When the plunger is pressed against the surface of concrete, the mass rebound from the plunger. It retracts against the force of the spring.

→ The hammer impacts against the concrete and the spring control mass rebounds, taking the slider with it along the guide scale.

→ The distance travelled by the mass is called the rebound number. It is indicated by the slider moving along a graduated

→ The test has conducted by horizontally, vertically – upwards (or) downwards (or) at any intermediate angle.

→ At each angle the rebound number will be different for the same concrete and will require seperate calibration (or) correction chart.

Limitations:

* smoothness of surface under test
* size, shape & rigidity of specimen.
* Age of specimen.
* Surface and internal moisture condition of concrete.
* type of coarse aggregate.
* type of cement
* type of mould
* carbonation of concrete surface.

2) Penetration techniques

→ The measurement of hardness by probing techniques was first reported during 1954. Two techniques were used.

→ In one case a hammer known as "Simi" was used to perforate concrete and the depth of borehole was correlated to compressive strength of concrete cubes.

→ In other technique the probing of concrete was achieved by blasting with spit pins and the depth of penetration of the pins was correlated with compressive strength of concrete.

→ The accuracy of this test was found to be ± 25%. However it is further seen that 'simi' and 'spit pins' were more effected by the arrangement of coarse aggregate, than the tests using rebound hammers.

3) Pullout test:

→ A pullout test measures the force required to pull out from the concrete a specially shaped rod whose enlarged end has been cast into that concrete.

→ The stronger the concrete the more is the force required to pullout the. Ideal way to use pullout test in the field would be to incorporate assemblies into the structure.

→ This standard specimen could then be pulled out at any point of time.

→ The force required denotes the strength of concrete. Another way to use pullout test in the field would be to cast one (or) two base blocks of concrete incorporating pullout assemblies.

→ Pullout test could then be performed to assess the strength of concrete.

4) Dynamic (or) Vibration Method:

→ This is the important non destructive method in testing concrete strength and other properties.

→ The fundamental principle on which the dynamic (or) vibration methods are based is velocity of sound through a material.

→ A mathematical relationship could be established b/w the velocity of sound through specimen and its resonant frequency and the relationship of these two to the modulus of elasticity of the material.

→ The relationship which are derived for solid mediums considered to be homogeneous, isotropic and perfectly elastic but they may be applied to heterogeneous materials like concrete.

→ The velocity of sound in a solid can be measured by determining the resonant frequency of specimen (or) by recording the time of travel of short pulses of vibration passing through the samples.

→ In NDT of concrete either resonance method (or) pulse velocity techniques could be adopted.

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5) Pulse velocity method:

→ This can be of two methods

i) Mechanical sonic pulse velocity

ii) Ultrasonic pulse velocity.

i) Mechanical sonic pulse velocity:

→ Out of these two ultrasonic pulse velocity method has gained considerable popularity all over the world.

→ When mechanical impulses are applied to a solid mass, three different kinds of waves are generated.

→ These are generally known as longitudinal waves, shear waves and surface waves. These three waves travel at different speeds.

→ The longitudinal (or) compressional waves travel about twice as fast as the other two types. Shear (or) transverse waves are not so fast, the surface waves are the slowest.

→ The pulses can be generated either by hammer blows (or) by the use of an electro acoustic transducer. Electro acoustic transducers are preferred as they provide better control on the type and frequency of pulses generated. The instrument used is called "Sonic scope".

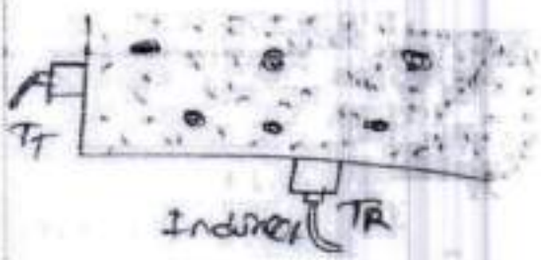
ii) Ultrasonic pulse velocity:

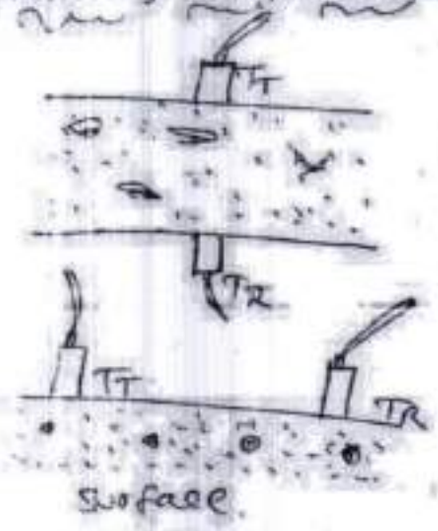
→ This method consists of measuring the time of travel of an ultrasonic pulse, passing through the concrete to be tested. The pulse generator circuit consists of electronic circuit for generating pulses and a transducers for transforming these electronic pulses into mechanical energy having vibration frequencies in the range of 15 to 50 kHz.

→ The time of travel b/w initial onset and the reception of the pulses is measured electronically. The path length b/w transducer divided by the time of travel gives the avg velocity of wave propagation.

Techniques of measuring pulse velocity through concrete:

a) Direct transmission
b) Indirect transmission
c) Surface transmission





T_T = T_R = Transducer transmitters.

Factors affecting the measurement of pulse velocity:

→ The measurement of pulse velocity is affected by another of factors regardless of the properties of concrete.

i) Smoothness of contact surface under test.
ii) Influence of path length on pulse velocity.
iii) Temperature of concrete.
iv) Moisture condition of concrete.
v) Presence of reinforcing steel.

6) Radioactive & Nuclear Methods:

i)
→ The use of X-ray and gamma rays as non destructive method for testing properties of concrete is relatively new. X-ray and γ-ray both components of high energy region on the electromagnetic spectrum penetrate concrete but undergo attenuation in the process.

→ The degree of attenuation depends on the kind of matter traversed its thickness and the wavelength of the radiation.

→ The intensity of incident γ-rays and the emerging γ-rays after passing through the specimens are measured. These two values use for calculating density of structural concrete the most.

γ-rays transmission method has been used to measure the thickness of concrete slabs of known density. γ-radiation sources of known intensity is made to pass and penetrate through the concrete. The intensity at the other face is measured to measure thickness of the concrete is calculated.

ii) → Use of nuclear methods for non destructive measurement of some properties of concrete is of recent region.

→ Two techniques have been reported, namely neutron scattering methods for determining the moisture content of concrete and neutron activation analysis for the determination of cement content. These methods are not suitable for finding out the strength of concrete.

7) Magnetic & Electrical Method:

i) → Battery operated magnetic devices that can measure the depth of reinforcement covers in concrete and detect the position of reinforcement bars are now available. The apparatus is known as cover meter.

ii) → Electrical resistivity methods have seen used to find out the thickness of concrete pavements.

→ The method is based on the principle that the material offers resistance to the passage of an electric current.

→ A concrete pavement has resistivity characteristic that is different from that of the underlying subgrade layers.

→ A change in the slope of the resistivity (vs) depth curve is used to estimate the depth of concrete pavement.

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MODULUS OF ELASTICITY :

→ The stress in steel is 'm' times the stress in concrete. where 'm' is the ratio b/w the modulus of elasticity of steel and concrete. known as modular ratio.

→ The modulus of elasticity can also be determined by subjecting a concrete cube (or) cylinder specimen to uniaxial compression and measuring the deformation by means of dial gauges fixed b/w the certain gauge length.

→ Total gauge reading divided by gauge length will give the strain and load applied divided by area of cross section will give the stress.

→ The modulus of elasticity can also be determined by subjecting a concrete beam to bending and then using the formulae for deflection and substituting other parameters. The modulus of elasticity so found out from actual loading is called static modulus of elasticity.

→ Modulus of elasticity may be measured in tension, compression (or) shear.

→ The modulus in tension is equal to modulus in compression.

→ Modulus of elasticity of concrete increases approximately with the square root of the strength.

Modulus of elasticity as $E_c = 5000\sqrt{f_{ck}}$.

→ The modulus of elasticity of light weight concrete is usually between 40 to 80% of the modulus of elasticity of ordinary concrete of the same strength.

→ The relation b/w the modulus of elasticity and strength is not much effected by temperature upto about 230°C since both the properties vary with temperature in approximately the same manner. Steam cured concrete shows a slightly lower modulus than water-cured concrete of the same strength.

DYNAMIC MODULUS OF ELASTICITY.

→ The value of E is found out by actual loading of concrete. i.e. the static modulus of elasticity does not truly represent the elastic behaviour of concrete due to the phenomenon of creep. The elastic modulus of elasticity will get affected more seriously at higher stresses when the effect of creep is more pronounced.

→ The modulus of elasticity can be determined by subjecting the concrete member to longitudinal vibration at their natural frequency.

→ Modulus of elasticity can be calculated from the following relationship

$$E_d = Kn^2L^2\rho$$

E_d = Dynamic modulus of elasticity.
K = constant
n = resonant frequency.
L = length of specimen.
ρ = density of concrete.

$$E_d = 4\times10^{-5}\, n^2L^2\rho \text{ GPa.}$$

→ The value of E found out in this method by the velocity of sound (or) frequency of sound is referred as dynamic modulus of elasticity, in contrast to the value of E found out by actual loading of the specimen and from stress-strain relationship which is known as static modulus of elasticity.

→ The value of dynamic modulus of elasticity computed from ultrasonic pulse velocity method is somewhat higher than those determined by static method.

→ This is because the modulus of elasticity as determined by dynamic modulus is unaffected by creep. The creep also doesnot significantly effect the initial tangent modulus in the static method.

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→ The value of dynamic modulus and the value of initial tangent modulus ~~of~~ to be more or less agree with each other. Approximate relationship b/w the two modulai expressed in CNI/mm is given by

$$E_c = 1.25\, E_d - 19$$

E_c & E_d are static and dynamic modulus of elasticity

→ For 1:2:4 mixture concrete the relationship is

$$E_c = 1.04\, E_d - 14$$

Poisson's Ratio:

→ Poissons ratio is the ratio b/w lateral strain to the longitudinal strain. It is denoted by 'μ'

→ For normal concrete $\mu = 0.15$ to 0.20

→ Poissons ratio can be determined from ultrasonic pulse velocity method and by finding out the fundamental resonant frequency of longitudinal vibration of concrete beam.

$$\left(\frac{V^2}{2nL}\right)^2 = \frac{1-\mu}{(1+\mu)(1-2\mu)}$$

V = pulse velocity
n = resonant frequency
L = length of beam
μ = 0.2 to 0.25

→ Dynamic modulus of elasticity can also be found out from following eqn.

$$E_d = \rho V^2 \frac{(1+\mu)(1-2\mu)}{(1-\mu)}$$

V = pulse velocity
ρ = density
μ = poissons ratio.

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CREEP:

→ Creep can be defined as the "time-dependent" part of the strain resulting from stress.

→ The gradual increase in strain, without increase in stress, with the time is due to creep. From this explanation creep can also be defined as the increase in strain under sustained stress.

→ Creep of concrete is approximately linear function of stress upto 30 to 40% of its strength.

Measurement of Creep:

→ Creep is usually determined by measuring the change with time in the strain of specimen subjected to constant stress and stored under appropriate condition.

→ It is generally assumed that the creep continues to assume a limiting value after an infinite time under load. It is estimated that 80% of the 20 years creep occurs in 2 years. 55% of 20 years creep occurs in 3 months and 76% of 20 years creep occurs in one year.

→ If creep after one year is taken as unity, then the avg value of creep at later ages are.

1.14 after 2 years
1.20 after 5 years
1.26 after 10 years
1.33 after 20 years
1.36 after 30 years.

→ The relation b/w creep (C) and time (t) is

$$C = \frac{t}{a+bt}$$

$$a = 1/C$$

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FACTORS AFFECTING CREEP:

i) Influence of aggregate:

→ Aggregate undergoes very little creep. It is really the paste which is responsible for the creep. However the aggregates influences the creep of concrete through a restraining effect on the magnitude of creep.

→ The grading, the shape, the maximum size of aggregate have been suggested as factors affecting creep.

→ The Modulus of elasticity of aggregate is one of the important factors influencing creep. It can be easily imagined that the higher the modulus of elasticity the less is the creep.

ii) Influence of mix proportion:

→ The amount of paste content and its quality is one of the most important factors influencing creep.

→ A poorer paste content structure undergoes higher creep. Therefore it can be said that creep increases in water/cement ratio.

→ In other words creep is inversely proportional to strength of concrete.

iii) Influence of Age:

→ Age at which concrete members is loaded will have a predominant effect on the magnitude of creep. This can be easily understood from the fact that the quality of gel improves with time. Such gel creeps less, whereas a young gel under load being not so stronger creeps more.

iv) Effects of Creep:

→ Magnitude of creep is dependent on many factors the main factors being time and level of stress. In reinforced concrete beams, creep increases the deflection with time and may be a critical consideration in design.

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SHRINKAGE:

→ The volume change on account of inherent properties of concrete is known as "shrinkage".

→ One of the most objectionable defects in concrete is the presence of cracks, particularly in floors and pavements due to the shrinkage.

→ It is difficult to make concrete which does not shrink and crack. It is only a question of magnitude.

TYPES OF SHRINKAGE:

1) Plastic shrinkage
2) Drying shrinkage
3) Autogeneous shrinkage
4) Carbonation shrinkage.

1) Plastic shrinkage:

→ Loss of water by evaporation from the surface of concrete (or) by the absorption by aggregate (or) substrate is believed to be the reason of plastic shrinkage.

→ The loss of water results in the reduction volume. The aggregate particles (or) the reinforcement acts in the way of subsidence due to which cracks may appear at the surface (or) internally around the aggregate (or) reinforcement.

→ In case of floors and pavements where the surface area exposed to drying is large as compared to vertic, when that large surface is exposed to hot sun and drying wind the surface of concrete dries very fast which results in plastic shrinkage.

→ Plastic shrinkage can be reduced mainly by preventing the rapid loss of water from surface. This can be done by covering the surface with polyethylene sheets immediately on finishing operation

→ Monomolecular coatings by fog spray that keeps the surface moist.

→ Working at night is an effective method of reducing shrinkage.

2) **DRYING SHRINKAGE:**

→ The drying shrinkage is a long over lasting process when concrete is subjected to drying conditions.

→ The drying shrinkage of concrete is analogous to the mechanism of drying of hardened specimen. The loss of water contained in hardened concrete does not result in any appreciable dimension change.

→ Cement paste shrinks more than mortar and mortar shrinks more than concrete.

→ The rate of shrinkage decreases rapidly with time. It is observed that 14-34% of the 20 years shrinkage occurs in 2 weeks, 40-80% of the 20 year shrinkage occurs in 3 months, 60-85% of the 20 year shrinkage occurs in one year.

→ The volume fraction of aggregate will have some influence on the total shrinkage. The ratio of shrinkage of concrete (S_c) to shrinkage of neat paste (S_p) depends on the aggregate content in the concrete.

$$S_c = S_p (1-a)^n$$

$$n = 1.2 \text{ to } 1.7$$

→ The property of swelling when placed in wet condition and shrinking when placed in drying condition is referred as moisture movement in concrete.

3) **Autogeneous shrinkage:**

→ In a conservative system i.e. where no moisture movement to (or) from the paste is permitted when temperature is constant some shrinkage may occur. The shrinkage of such a conservative system is known as autogeneous shrinkage.

→ Autogeneous shrinkage is of minor importance and is not applicable in practice to many situations except that of mass of concrete in the interior of concrete dam.

→ The magnitude of autogeneous shrinkage is 100×10^{-6}.

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4) Carbonation shrinkage

→ Carbonation shrinkage is a phenomenon very recently recognised. Carbon dioxide present in the atmosphere reacts in the presence of water with hydrated cement.

→ Calcium hydroxide ($Ca(OH)_2$) gets converted to calcium carbonate ($CaCO_3$) and also some other cement compounds are decomposed. Such a complete decomposition of calcium compound in hydrated cement is chemically possible even at the low pressure of carbon dioxide in normal atmosphere. Carbonation penetrates beyond the exposed surface of concrete only very slowly.

→ The rate of penetration of carbon dioxide depends upon the moisture content of the concrete and the relative humidity of the ambient medium.

→ Carbonation of concrete also results in increased strength and reduced permeability.

UNIT-III

MIX DESIGN

FACTORS AFFECTING THE CHOICE OF MIX PROPORTIONS:

1) Compressive strength
2) Workability
3) Durability
4) Max. nominal size of aggregate
5) Fineness modulus & zone of aggregate
6) Quality control

① **Compressive strength:**

→ The compressive strength of any material is defined as the resistance to failure under the action of compressive forces. Especially for concrete, compressive strength is an important parameter to determine the performance of the material during service conditions

→ Concrete mix can be designated (or) proportioned to obtain the required engineering and durability properties as required by the design engineer.

→ Some of the other engineering properties of hardened concrete include elastic modulus, tensile strength, creep co-efficient, density, co-efficient of thermal expansion etc.

Compressive strength of concrete:

→ Concrete specimens are a cast and tested under the action of compressive loads to determine the strength of concrete

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→ Compressive strength is calculated by dividing the failure load by the area of application load, usually after 28 days of curing.

→ The strength of concrete is controlled by the proportioning of cement coarse and fine aggregates, water and various admixtures.

→ The ratio of the water to cement is the chief factor for determining concrete strength. The lower the water-cement ratio the higher is the compressive strength.

→ In normal field the concrete strength can vary from 10MPa to 60MPa.

→ For structures the concrete mixes can be designed to obtain very high compressive strength capacity in the range of 500MPa.

→ The compressive strength of concrete is given in terms of the characteristic compressive strength of 150mm size cubes tested at 28 days.

→ The characteristic strength is defined as the strength of the concrete below which not more than 5% of the test results are expected to fall.

PROCEDURE:

→ Specimen stored in water shall be tested immediately on removal from the water and while they are still in the wet condition.

→ Take the dimension of the specimen to the nearest 0.2mm.

→ Clean the bearing surface of the testing machine.

→ Place the specimen in the machine in such a manner that the load shall be applied to the opposite sides of the specimen.

→ Apply the load gradually without shock & continuously at the rate of 40 kg/cm²/min. till the specimen fails.

→ Record the max. load and note any unusual features in the type of failure.

2) Workability of concrete:

→ "Workability represents consistency and cohesiveness of concrete.

General consideration for workability

i) Water content:

→ The higher the water content, the higher will be the fluidity of concrete, which is one of the important factors affecting workability.

ii) aggregate/cement ratio:

→ The higher the a/c ratio, the leaner is the concrete.

→ In lean concrete, less quantity of paste is available for lubrication per unit surface area of aggregate and hence the mobility reduce.

→ In case of rich concrete with lower aggregate/cement ratio, more paste is available to make the mix cohesive and fatty to give better workability.

iii) size of aggregate:

→ The bigger the size of aggregate, the less the surface area hence, less water is required for wetting the surface and paste is required for lubricating the surface to reduce internal friction.

→ For a given quantity of water and paste bigger size of aggregate will give higher workability.

iv) shape of aggregate:

→ Angular, elongated (or) flaky aggregate makes the concrete very harsh when compared to rounded aggregate (or) cubical shaped aggregates.

→ Round round in shape the frictional resistance is also greatly reduced.

v) surface texture:

→ Total surface area of rough textured aggregate is more than the surface area of smooth rounded aggregate of same volume.

→ Rough textured aggregate will show poor workability and smooth (or) glassy textured aggregate will give better workability.

vi) Grading of aggregates:

→ Better the grading, the less is the void content and higher the workability.

→ When the total voids are less, excess paste is available to give better lubricating effect

vii) Use of Admixtures:

→ Use of air entraining agent being surface-active reduces the internal friction between the particles.

→ Plasticizers and super-plasticizers greatly improve the workability many folds.

3) Durability of concrete:

→ Durability of concrete may be defined as the ability of concrete to resist weathering action, chemical attack, and abrasion while maintaining its desired engineering properties.

→ It is normally refers to the duration of life span of trouble free performance.

Concrete will remain durable if:

→ The cement paste structure is dense and of low permeability

→ Under extreme condition, it has entrained air to resist freeze-thaw cycle.

→ It is made with graded aggregate that are strong and tough

→ The ingredients in the mix contain minimum impurities such as alkalis, chlorides, sulphates and silt.

Factors affecting Durability:

i) Cement content:

→ Mix must be designed to ensure cohesion and prevent segregation and bleeding. If cement is reduced than at fixed w/c ratio the workability will be reduced leading to inadequate compaction

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→ Also even if water is added to improve workability, water cement ratio increases and resulting in highly permeable material.

ii) Compaction:

→ The concrete as a whole contain voids can be caused by inadequate compaction. Usually this being governed by compaction equipments used type of formwork, and density of the steel work.

iii) Curing:

→ It is very important to permit proper strength development and moisture retention and to ensure hydration process occur completely.

iv) Cover:

→ Thickness of concrete cover must follow the limits set in codes.

v) Permeability:

→ The higher permeability usually caused by higher porosity.

→ A proper curing, sufficient cement, proper compaction and suitable concrete cover would provide a low permeability concrete.

Types of Durability of Concrete:

1. Physical durability
2. Chemical durability

1. Physical durability:

→ Freezing and thawing action
→ Percolation / Permeability of water
→ Temperatures stresses.

2. Chemical durability:

→ Alkali aggregate reaction.
→ Sulphate attack
→ Chloride ingress
→ Corrosion of reinforcement.

Causes of durability

1. External causes
2. Internal causes

1. External causes

→ Extreme weathering conditions
→ Extreme temperature.
→ Extreme humidity
→ Abrasion
→ Electrolytic action.

2. Internal causes

→ Physical → Frost action
→ Chemical → Alkali aggregate reaction and
→ Corrosion of steel.

4) Max. nominal size of coarse aggregate:

→ The max. nominal size of the coarse aggregate is determined by sieve analysis and is determined by the sieve size higher than the largest size on which 15% or more of the aggregate is retained.
→ The max. nominal size of the aggregate to be used in concrete is governed by the size of the section and spacing of the reinforcement.
→ According to IS: 456-2000 and IS: 1343-1980, the maximum nominal size of the aggregate should not be more than 1/4th of the max. thickness of the member, and it should be restricted to 5mm less than min. clear distance b/w main bars of 5mm not less than min. clear cover to the reinforcement.
→ The nominal max. size of aggregate, smaller ~~[illegible]~~ ~~[illegible]~~ ~~[illegible]~~ be as large as possible, because for the max. size of the aggregate, smaller is the cement requirement for a particular water/cement ratio.
→ The workability also increases increase in max. size aggregate

→ For the concrete with higher w/c ratio the larger max size of aggregate may be beneficial whereas for high strength concrete 10-20 mm size of aggregate is preferable.

5) Quality control:

→ The strength of concrete varies from batch to batch over a period of time.

→ The source of variability in the strength of concrete may be considered due to variation in the quality of the constituent materials, variations in mix proportions due to batching process, variations in the quality of batching and mixing equipment available, the quality of supervision and workmanship.

→ Controlling the variation is important in lowering the difference b/w minimum strength and characteristic mean strength of the mix and hence reducing the cement content. The factor controlling the difference is quality control.

→ The degree of control is ultimately evaluated by the variation in test results usually expressed in terms of "co-efficient of variation"

→ Most of the mix design procedures are primarily based on the water-cement ratio law and absolute volume system of calculating the amount of materials.

→ According to Abram's law, the strength of fully compacted hardened concrete is approximately inversely proportional to the water content per cubic meter of cement.

$$\text{Absolute volume} = \frac{\text{Mass of loose dry material}}{\text{Sp. Gravity} \times \text{Mass of unit of volume of water.}}$$

Statical Quality control of concrete :-

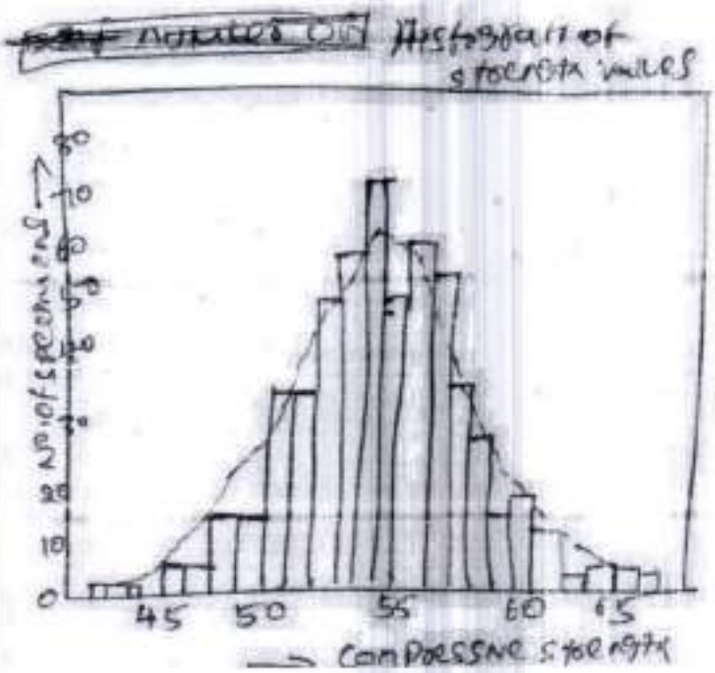
-> The aim of quality control is to limit the variability of much as practicable. Statical quality control method provides a scientific approach to the concrete designer to understand the realistic variability of the materials so as to lay down design specifications with proper tolerance to cater for unavoidable variations.

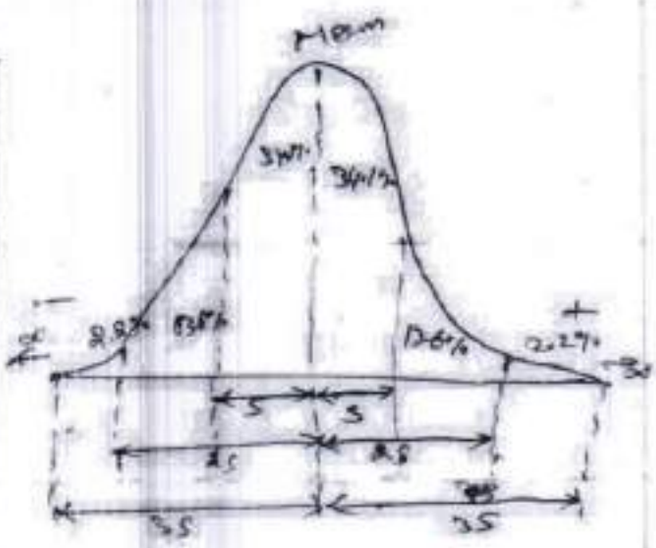
-> The acceptance criteria are based on statical evaluation on the test result of samples taken at random during execution.

-> The method provides a scientific basis of acceptance which is not only realistic but also relatives as required by the design requirements for the concrete construction.

-> The quality of concrete will be of immense value for large contracts where the specifications insist on certain minimum requirements. The effort put in will be more than repaid by resulting savings in the overall concreting operations.

-> The compressive strength test comes from random sampling of a mix, exhibit variations, which are inherent in the various operations involved in the making and testing of concrete.





→ If a number of cube test result are plotted on histogram, the results are found to follow a bell shaped curve known as "normal distribution curve".

→ The results are said to follow a normal distribution curve if they are equally spaced about the mean value and if the largest number of the cubes have a strength closer to the mean value, the few number of results with much greater (or) less value than the mean value.

→ The arithmatic mean (or) the average value of the number of test result gives no indication of the extent of variation of strength. This can be ascertained by relating the individual strength to mean strength and determining the variation from the mean with the help of the properties of normal distribution curve.

Common terminologies:

i) Mean strength:

→ The avg strength obtained by dividing the sum of strength of all the cubes by the number of cubes

$$\bar{x} = \frac{\Sigma x}{n}$$

ii) Variance:

→ This is the measure of variability (or) difference b/w any single observed data from the mean strength.

iii) Standard deviation:

→ This is the root mean square deviation of all the results. (σ)

$$\sigma = \sqrt{\frac{\Sigma (x-\bar{x})^2}{n-1}}$$

iv) Co-efficient of variation:

→ It is an alternative method of expressing the variation of results. This non dimensional measure of variation obtained by dividing the standard deviation by the arithmatic mean.

$$V = \frac{\Sigma}{\bar{x}} \times 100.$$

Various Methods of proportioning mix design.

1) Arbitrary proportion
2) Fineness Modulus Method.
3) Maximum Density method
4) Surface area Method.
5) Indian Road congress, IRC 44 Method.
6) High strength concrete mix design.
7) Mix design based on flexural strength.
8) Road note No 4.
9) ACI comitee 211 method.
10) DOE Method.
11) Mix design for pumpable concrete.
12) Indian standard recommended Method IS 10262-82

→ out of the above methods, some of them are not very widely used these days because of some difficulties (or) drawbacks in the procedures for arriving at the satisfactory proportions.

→ The ACI comitee 211 method, the DOE Method and Indian standard recommended methods are commly used.

→ Since concrete is very commonly placed by pumping these days method of mix design of pumpable concrete has become important.

→ Before we deal with some of the important methods of concrete mix design, it is necessary to get acquainted with statical quality control methods, which are common to all the methods of mix design.

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PROCEDURE FOR CONCRETE MIX DESIGN

1. Determine the mean target strength (f_t) from the specified characteristic compressive strength at 28 days f_{ck} and the level of quality control.

$$f_t = f_{ck} + 1.65\,S$$

S = standard deviation.

2. Obtain the water cement ratio for the desired mean ~~strength~~ target using the empirical relationship b/w compressive strength and water cement ratio so choosen is checked against the limiting w/c ratio.

3. Estimate the amount of entrapped air for maximum nominal size of the aggregate from the table.

4. Select the water content for the required workability and maximum size of aggregates from table.

5. Determine the % of fine aggregates in total aggregate by absolute volume from table for the concrete using crushed coarse aggregate.

6. Adjust the value of water content and % of sand as provided in the table for any difference in workability water cement ratio, grading of fine aggregate and for rounded aggregate the values are given in table.

7. Calculate the cement content from the water-cement ratio and the final water content as arrived after adjustment. Check the cement against the minimum cement content from the requirements of the durability and greater of the two values is adopted.

8. From the quantities of [illegible] of concrete and the % of sand already determined in step 6 and step 7 above, calculate the content of coarse and fine aggregates per unit volume of concrete from the following relation.

$$V = \left[W + \frac{C}{Sc} + \frac{1}{P} \frac{Fa}{Sfa} \right] \times \frac{1}{1000}$$

$$V = \left[W + \frac{C}{Sc} + \frac{1}{1-P} \cdot \frac{Ca}{Sca} \right] \times \frac{1}{1000}$$

V = absolute volume of concrete = gross volume (m³) − volume of entrapped air

Sc = sp. gravity of cement

W = mass of water per cubic metre of concrete, kg.

C = mass of cement per cubic metre of concrete, kg

P = ratio of fine aggregates to total aggregates by absolute volume.

Ca = total masses of fine and coarse aggregates, kg

Sfa, Sca = sp. gravities of saturated surface dry fine and coarse aggregates.

9. Determine the concrete mix proportions for the first trial mix.

10. Prepare the concrete using the calculated proportions and cast three cubes of 150mm size and test them at 28 days after moist curing and check for the strength.

11. Prepare trial mixes with suitable adjustments till the final mix proportions are arrived at.

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PROBLEM

Q). CONCRETE MIX DESIGN - M50 GRADE CONCRETE

Grade Designation = M50

Type of cement = OPC-43 Grade

Brand of cement = ULTRATECH

Admixture = silica

fine aggregate = zone - II

Sp. Gravity

cement = 2.15

fine aggregate = 2.61

C.A (20mm) = 2.65

C.A (10mm) = 2.66

Min. cement = 400 kg/m3

water/cement Ratio = 0.45.

MIX CALCULATION:

1) Target Mean Strength:-

$f_t = f_{ck} + 1.65S$

$f_t = 50 + (1.65 \times 5)$

$f_t = 58.25$ MPa.

2) W/C ratio:-

(IS 10262-2009)

Assume W/C = 0.35

3) calculation of water:-

Approximate water content for 20mm max. size of aggregate = 180 kg/m3 (table No 5, IS 10262)

As plasticizers is proposed we can reduce water content by 20%

100 - 20 = 80% = 0.8

water content = 180 × 0.8 = 144 kg/m3

Calculation of cement content :-

W/C ratio = 0.35

water content / m3 of concrete = 144 kg

cement content = $\frac{144}{0.35}$ = 411.4 kg/m3

cement content = 412 kg/m3 (As per control Min. cement content 400 kg/m3)

Hence OK.

5) Calculation for C.A & F.A :-

Volume of concrete = 1 m3

volume of cement = $\frac{412}{(3.15 \times 1000)}$ = 0.1308 m3

Volume of water = $\frac{144}{1 \times 1000}$ = 0.1440 m3

Volume of admixture = $\frac{4.944}{(1.145 \times 1000)}$ = 0.0043 m3

Total vol of materials except C.A = 0.1308 + 0.1440 + 0.0043 = 0.2791

Volume of CA & F.A = 1 − 0.2791 = 0.7209 m3.

Volume of F.A = 0.7209 × 0.33 = 0.2379 m3 (Assume 33% by volume of total aggregate)

Volume of C.A = 0.7209 − 0.2379 = 0.4830 m3.

weight of F.A = 0.2379 × 2.61 × 1000 = 1282.365 kg/m3 = 620.9178 kg/m3

say weight of C.A = 1284 kg/m3.

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considering 20mm : 10mm = 0.55 : 0.45

... 20mm = 706 kg
10mm = 578 kg.

Hence mix details / m3

increasing cement, water, admixture by 2.5% for mix specimens.

cement = 422 x 1.025 = 432 kg.

water = 144 x 1.025 = 147.8 kg

F.A = 621 kg

C.A 20mm = 706 kg.

C.A 10mm = 578 kg

Admixture = 1.2% by weight of cement = 5.064 kg.

water : cement = F.A : CA = 0.35 : 1 : 1.472 : 5.043.

Observations from concrete mix designs—

A. Mix was cohesive & homogeneous

B. Slump = 120mm

C. No. of cube cast = 9 nos.

7 days avg compressive strength = 52.07 MPa

28 days avg compressive strength = 62.52 MPa.

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UNIT - V

SPECIAL CONCRETE

LIGHT WEIGHT CONCRETE:

-> one of the disadvantages of conventional concrete is the high self weight of concrete.

-> density of normal concrete is in the order of 2200 to 2400 kg/m3. This heavy self weight will make it to some extent an uneconomical structural material.

-> Attempts have been made in the past to reduce the self weight of concrete to increase the efficiency of concrete as structural material.

-> The light weight concrete as we call is a concrete whose density varies from 300 to 1850 kg/m3.

-> There are many advantages of having low density. It helps in reduction of dead load, increases the progress of building, and lowers haulage and handling costs.

-> The weight of a building on the foundation is an important factor in design, particularly in the case of weak soil and tall structures.

-> In framed structures, the beams and columns have to carry load of floors and walls. This are made up of light-weight concrete it will result in considerable economy.

-> Another most important characteristic of light weight concrete is the relatively low thermal conductivity, a property which improves with decreasing density.

-> In extreme climatic conditions and also in case of buildings where air conditioning is to be installed, the use of light weight concrete with low thermal conductivity will be of considerable advantage from the point of view of thermal comforts and lower power consumption.

-> The adoption of light weight concrete gives an outlet for industrial wastes such as clinker, flyash, slag etc.

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→ Basically there is only two methods of making concrete light.
i.e by the inclusion of air in concrete.
i) By replacing the usual mineral aggregates by cellular porous (or) light weight aggregates.
ii) By introducing gas (or) air bubbles in mortar. This is known as aerated concrete.
iii) By omitting sand fraction from the aggregate. This is called no-fines concrete.

→ A particular type of light-weight concrete called structural light weight concrete is one which is comparatively lighter than conventional concrete but at the same time strong enough to be used for structural purposes.

LIGHT WEIGHT AGGREGATE CONCRETE:

→ very often light-weight concrete is made by the use of light weight aggregates. we have seen that different light-weight aggregates have different densities.

→ naturally when this aggregate used, concrete of different densities are obtained. By using expanded perlite (or) vermiculite, a concrete of density as low as 300 kg/m³ can be produced, and by the use of expanded slag, sintered fly ash, bloated clay etc. a concrete of density 1900 kg/m³ can be obtained.

→ The strength of the light weight concrete may also vary from about 0.3 N/mm² to 40 N/mm². A cement content of 200 kg/m³ to about 500 kg/m³ may be used.

→ Strength of light weight concrete depends on the density of concrete. Less porous aggregates which are heavier in weight produces stronger concrete particularly with higher cement content.

→ The grading of aggregate, the water/cement ratio, the degree of compaction also effect the strength of concrete.

→ Most of the light-weight aggregate with the exception of bloated clay and sintered fly ash are angular in shape and rough in texture they produce harsh mix.

→ The strength of aggregate will also be influenced by the type of fine aggregates. For increasing the strength, for improving the workability and for reducing the water requirements, some times natural sand is used instead of crushed sand made out of light-weight aggregate.

→ Most of the light weight aggregates have a high and rapid absorption quality. This is one of the important difficulties in applying the normal mix design procedure to the light weight concrete.

→ Light weight concrete being comparatively porous when used for reinforced concrete, reinforcement may become prone to corrosion. Either the reinforcement must be coated with anticorrosive compound (or) the concrete must be plastered at the surface by normal mortar to inhibit the penetration of air and moisture inside.

Design :

→ Mix design methods applying to normal weight concrete are generally difficult to use with light weight aggregate concrete. The lack of accurate value of absorption, specific gravity, and free moisture content in the aggregate make it difficult to apply the water/cement ratio accurately for mix proportioning.

→ Light weight concrete mix design is usually established by trial mixes. The proportion of fine to coarse aggregate and the cement and water requirement are estimated based on the previous experience with particular aggregate.

→ Sometimes the aggregate is saturated before mixing so that it doesn't take up the water used for mixing.

→ The quality of concrete does not get altered on account of absorption by aggregate. It has been seen that the strength

of the resulting concrete is about 5 to 10 % lower than when only aggregate is used for the same content and workability.

Mixing Procedure:

→ Mixing procedure for light weight concretes may vary with different types of aggregates. The general practice for structural light weight concrete is to mix the aggregates and about 2/3 of the mixing water for a period upto one minute prior to the addition of cement and the balance mixing water.

→ Mixing is done continously as required for homogeneity. Usually 2 or 3 more minutes are required to get uniform mixing. In case of some insulating concrete the aggregate is added at the end of mixing to minimize degradation.

Aerated concrete / cellular concrete:

→ Aerated concrete is made by introducing air (or) gas into slurry composed of portland cement (or) lime and finely crushed siliceous fiver so that when the mix sets and hardens, a cellular structure is formed. Though it is called aerated concrete it is not a concrete in the correct sense of the word. It is mixture of water, cement and finely crushed sand.

→ Aerated concrete is also referred as gas concrete, foam concrete, cellular concrete.

→ There are several ways in which aerated concrete can be manufactured.

(a) By the formation of gas by chemical reaction within the mass during liquid (or) plastic state.

(b) By mixing performed stable foam with the slurry.

(c) By using finely powdered metal.

-> Powdered zinc may also be added in place of aluminium powder. Hydrogen peroxide and bleaching powder have also been used instead of metal powder. But this practice is not widely followed at present.

(b)
-> In the stable foam is mixed with cement and crushed sand slurry thus casting the cellular structure when this gets set and hardened.

-> However this method cannot be employed for decreasing the density of the concrete beyond a certain point and as such the use of air entrainment is not often practised for making aerated concrete.

(a)
-> Gasification method is most widely adopted method using aluminium powder for such other similar material. This method is adopted in the large scale manufacture of aerated concrete in the factory where in the whole process is mechanised and the product is subjected to high pressure steam curing i.e. the products are autoclaved.

NO FINES CONCRETE :

-> No fines concrete as the term implies is a kind of concrete from which the fine aggregate fraction had been omitted. This concrete made up of only coarse aggregate, cement and water.

-> Very often only single sized coarse aggregate of size passing through 20mm retained on 10mm is used.

-> No fines concrete is becoming popular because of some of the advantages it posses over the conventional concrete.

-> This single sized aggregates take a good no fines concrete, which in addition to having more voids and hence light in weight also offers an architectural attractive look.

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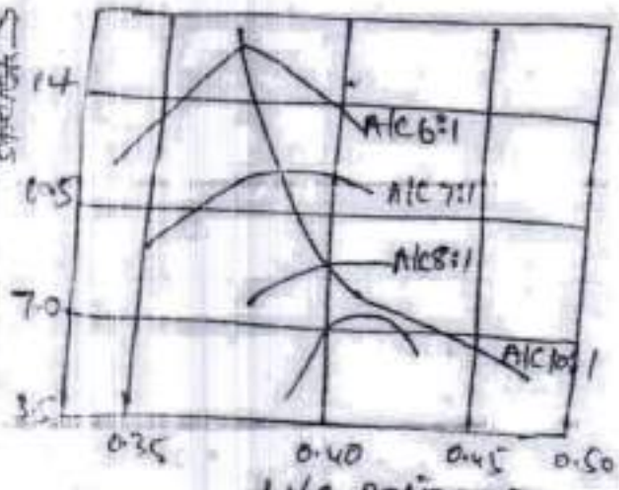
Mix Proportion:

→ No fines concrete is generally made with the aggregate/cement ratio from 6:1 to 10:1.

→ Aggregates are used normally of size passing through 20mm and retained on 10mm unlike the conventional concrete, in which strength is primarily controlled by the water/cement ratio the strength of fines concrete is dependent on the water/cement ratio, aggregate cement ratio and unit weight of concrete.

→ The w/c ratio for satisfactory consistency will vary b/w a narrow range of 0.35 and 0.52

→ If too low w/c ratio is adopted the paste will be so dry that aggregates does not get properly coated with paste which result in insufficient.



→ On the other hand if the w/c ratio is too high, the paste flows to the bottom of the concrete, particularly when vibrated and fills up the voids b/w the aggregates at the bottom and make that portion dense.

→ No standard method is available, like slump test (or) compacting factor test for measuring the consistency of no-fines concrete.

→ No fines concrete when conventional aggregates are used, may show a density of about 1600 to 1900 kg/m³, but when no-fines concrete is made by using light weight aggregate, the density may come to about 300 kg/m³.

→ The bond strength of no fines concrete is very low and therefore reinforcement is not used in conjunction with no fines concrete. However if reinforcement is required to be used in no fines concrete, it is advisable to smear the RC with cement paste to improve the bond and also to protect it from rusting.

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HIGH DENSITY CONCRETE:

→ Density of normal concrete is in the order of about 2400 kg/m³

→ The density of light weight concrete will be less than about density 1900 kg/m³.

→ To call the concrete, as high density concrete it must have unit weight varying from about 3360 kg/m³ — 3640 kg/m³, which is about 50% higher than the unit weight of conventional concrete.

→ The advent of the nuclear energy industry presents a considerable demand on the concrete technologists.

→ Large scale production of penetrating radiation and radioactive materials are as a result of the use of nuclear reactors, particle accelerator, industrial radiography, and X-ray, γ-ray therapy, require the need of shielding material for the protection of operating personnel against the biological hazards such radiation.

→ Concrete both high density and normal density are effective and economic construction material for permanent shielding purposes.

Types of Radiation and Hazards:

→ There are two general classes of radiation.

1) Electromagnetic waves
2) Nuclear particles

→ Electromagnetic waves the high energy, high frequency waves known as X- and γ-rays are only types which require shielding for the protection of personnel. They are similar to light rays but of higher energy greater penetrating power.

→ Nuclear particles consist of nuclei of atoms or fragments thereof. They include neutrons, protons, alpha and beta particles of these all neutrons possess an electric charge.

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FIBRE REINFORCED CONCRETE :

→ Fibre reinforced concrete can be defined as a composite material consisting of mixtures of cement, mortar or concrete and discontinuous, discrete, uniformly dispersed suitable fibres. continuous meshes, woven fabrics and long wires or rods are not considered to be discrete.

→ Fibre is a small piece of reinforcing material possessing certain characteristics properties. It may be circular or flat.

→ The fibre is often described by a convenient parameter called 'aspect ratio' i.e ratio of its length to its diameter. The ratio ranges from 30 to 150.

TYPES OF F.R.C

→ Although every type of the fibre has been tried out in cement and concrete, not all of them can be effectively and economically used. Each types of fibre has its characteristic properties and limitations.

→ Some of the fibres could be used are

1) Steel fibres
2) Polypropylene fibres
3) nylons fibres
4) asbestos fibre
5) coir fibre
6) Glass fibre
7) Carbon fibre

1) Steel fibre :

→ It is one of the most commonly used fibre. Generally round fibres are used.

→ They diameter may vary from 0.25 to 0.75 mm. The steel fibre is likely to get rusted and lose some of its strengths. But investigations have shown that the rusting of fibres takes place only at the surface.

2) Polypropylene & nylon fibres :-

→ This fibres are found to be suitable to increase the impact strength. They posses very high tensile strength, but their low modulus of elasticity and higher elongation do not contribute to the flexural strength.

b) Asbestos fibre :-

→ Asbestos is a mineral fibre and has proved to be most successful of all fibres as it can be mixed with portland cement.

→ Tensile strength of asbestos varies b/w 560 to 980 N/mm². The composite product called asbestos cement has considerably higher flexural strength than the portland cement paste.

→ For unimportant fibre concrete, organic fibres like coir, jute, canesplits are also used.

5) Glass fibre :

→ It is a recent introduction in making fibre concrete. It has very high tensile strength 1020 – 4080 N/mm².

→ Glass fibres which is originally used in construction with cement and found to be affected by alkaline condition of cement.

→ Therefore alkali-resistant glass fibre by trade name "CEM-FIL" have been developed and used. The alkali resistant fibre reinforced concrete shows considerable improvements in durability to the conventional E-Glass fibre.

6) Carbon fibre :

→ Carbon fibre posses very high tensile strength 2110 to 2815 N/mm² and Young's modulus. It has been reported that cement composite made with carbon fibre as reinforcement will have very high modulus of elasticity and flexural strength.

→ The use of carbon fibres for structures like cladings, panels, and shells will have promising future.

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FACTORS AFFECTING PROPERTIES OF FRC.

→ F.R.C reinforced concrete is the composite material containing fibres in the cement matrix in an orderly manner (or) randomly distributed manner.

→ Its properties would obviously depend upon the efficient transfer of stresses between matrix and the fibres, which is largely dependent on the type of fibre, fibre geometry, fibre content, orientation and distribution of the fibres, mixing and compaction techniques of concrete, and size and shape of the aggregate.

1) Relative fibre matrix stiffness:-

→ The modulus of elasticity of matrix must be much lower than that of fibre for efficient stress transfer. Low modulus of fibres such as nylons and polypropylene are therefore unlikely to give strength improvement, but they help in the absorption of large energy and therefore impart greater degree of toughness and resistance to impact.

→ High modulus fibres such as steel, glass and carbon impart strength and stiffness to the composite.

→ A good bond is essential for improving tensile strength of the composite.

→ The interfacial bond could be improved by larger area of contact improving the frictional properties and degree of gripping and by treating the steel fibres with sodium hydroxide (or) acetone.

2) Volume of fibres:-

→ The strength of the composite largely depends on the quantity of fibres used. If use of higher percentage of fibres is likely to cause segregation and harshness of concrete and mortar.

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3) Aspect ratio of Fibre :-

→ Another important factor which influences the properties and behaviour of the composite is the aspect ratio of the fibre. It has been reported that upto aspect ratio of 75, increase in the aspect ratio increases the ultimate strength of the concrete linearly. Beyond 75 relative strength and toughness is reduced.

4) Orientation of Fibres :

→ One of the differences b/w conventional reinforcement and fibre reinforcement is that in conventional reinforcement, bars are oriented in the direction desired while fibres are randomly oriented.

→ To see the effect of randomness, model specimens reinforced with 0.5 % volume of fibres were tested.

5) Workability and compaction of concrete :-

→ Incorporation of steel fibre decreases the workability considerably. This situation adversely affects the condition of fresh mix. Even prolonged external vibration fails to compact the concrete.

→ The fibre volume which this situation is reached depends on the length and diameter of the fibre.

→ Another consequence of poor workability is non-uniform distribution of the fibres. Generally the workability and compaction standard of the mix is improved through increase w/c ratio.

6) Size of coarse aggregate :-

→ Several investigations recommended that the max. size of the coarse aggregate should be restricted to 10mm, to avoid appreciable reduction in strength of the composite.

7) Mixing :-

→ Mixing of fibre reinforced concrete needs careful conditions to avoid balling of fibres, segregation and in general the difficulty of mixing the materials uniformly.

→ Increase in the aspect ratio, volume % and size and quantity of coarse aggregate intensify the difficulties and balling tendencies.

→ A steel fibre content in excess of 2% by volume and an aspect ratio of more than 100 are difficult to mix.

→ The typical proportions for fibre reinforced concrete is

Cement content : 325 – 550 kg/m³

W/C ratio : 0.4 to 0.6

% of sand to total aggregate : 50 to 100%

Max. Aggregate size : 10 mm.

Air content : 6 – 9 %

Fibre content : 0.5 – 2.5%

: Steel – 1 % – 78 kg/m³

Glass – 1% – 25 kg/m³

Nylon – 1 % – 11 kg/m³

Applications :

→ Fibre reinforced concrete is increasingly used on account of the advantages of increased static and dynamic tensile strength, energy absorbing characteristics and better fatigue strength.

→ The uniform dispersion of fibres throughout the concrete provides isotropic properties not common to conventionally reinforced concrete.

→ F.R.C has been used on overlays of air field, road pavements, industrial floorings, bridge decks, canal lining, explosive resistant structures, refractory linings etc.

→ F.R.C concrete can also be used for the fabrication of precast pipes, boats, beams, stair case steps, wall panels, roof panels, manhole covers etc.

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POLYMER CONCRETE :-

→ continous research by concrete technologists to understand improve and develop the properties of concrete has resulted in a new type of concrete known as "Polymer Concrete".

→ The porosity is due to air voids, water voids (or) due to the inherent porosity of gel structure itself. on account of the porosity, the strength of concrete is naturally reduced. It is conceived by many research workers that reduction of porosity results in increase of strength of concrete.

→ Therefore process like vibration, pressure application spinning etc. have been practiced mainly to reduce porosity. All these methods have been found to be helpful to a great extent, but none of these methods could really help to reduce the water voids and the inherent porosity of gel which is estimated to be about 28%.

→ The development of concrete-polymer composite material is directed at producing a new material by combining the current technology of cement concrete with the modern technology of polymer chemistry.

TYPES OF POLYMER CONCRETE :

① Polymer impregnated concrete: is one of the widely used polymer composite. It is nothing but a pre cast conventional concrete, cured and dried in oven, (or) by dielectric heating from which the air and dried in the open cell is removed by vaccum. Then a low viscosity monomer is diffused through the open cell and polymerised by using radiation, application of heat (or) by chemical initiation.

→ Mainly the following types of monomer are used.

a) Methylmethacrylate
b) Styrene
c) Acrylonitrile
d) t-butyl styrene.
e) other thermoplastic monomers.

→ The amount of monomer that can be loaded into a concrete specimen is limited by the amount of water and air that

has occurred the [illegible] state.

→ It is necessary to know the concentration of water and air void in the system to determine the rate of monomer penetration. However the main research effort has been towards obtaining a maximum monomer loading in concrete by the removal of water and air from the concrete by vacuum (or) thermal drying, the latter being more practicable for water removal because of its rapidity.

2) Polymer cement concrete (PCC)

→ Polymer cement concrete is made by mixing cement, aggregates, water and monomer. Such plastic mixture is cast in moulds, cured, dried and polymerised. The monomers that are used in PCC are.

a) Polyster-styrene
b) Epoxy-styrene
c) furans
d) vinylidene chloride.

→ However the results in obtained by the production of PCC in this way have been disappointing and have shown relatively modest improvement of strength and durability. In many cases, materials poorer than ordinary concrete are obtained.

→ This behaviour is explained by the fact that organic materials are incompatible with aqueous system and sometimes interfere with the alkaline cement hydration process.

3) Polymer concrete :-

→ Polymer concrete is an aggregate bound with a polymer binder instead of portland cement as in conventional concrete.

→ The main technique in producing PC is to minimise void volume in the aggregate mass so as to reduce the quantity of polymer needed for binding the aggregates.

→ This is achieved by properly grading and mixing the aggregates to attain the maximum density and minimum void volume.

→ The graded aggregates are prepacked and vibrated in a mould. Monomer is then diffused up through the aggregates and polymerisation is initiated by radiation (or) chemical means.

→ An important reason for the development of this material is the advantage it offers over conventional concrete where the alkaline portland cement on curing, forms internal voids water can be entrapped in these voids which on freezing can readily crack the concrete.

→ Polymer concretes tend to be brittle and it is reported that dispersion of fibre reinforcement would improve the toughness and tensile strength of the material.

→ The use of fibrous polyester concrete (FPC) in the compressive strength of reinforced concrete beams provides a rich strength, ductile concrete at reasonable cost.

4) Partially impregnated and surface coated concrete:

→ Partial impregnation may be sufficient in situations where the major equipment is surface resistance against chemical and mechanical attack in addition to strength increase.

→ Even with only partial impregnation, significant increases in the strength of original concrete has been obtained.

→ The depth of monomer penetration is dependent upon following.

1) Pore structure of hardened and dried concrete.

2) The duration of soaking.

3) viscosity of the monomer.

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Application of polymer impregnated concrete:

1) Prefabricated structural elements.
2) prestressed concrete
3) Marine works
4) Desalination plants
5) Nuclear power plants
6) sewage works - pipe & storage work.
7) ferrocement products
(0) water proofing structures
11) Industrial applications.

SELF COMPACTING CONCRETE:

→ Modern application of self compacting concrete (SCC) is focussed on high performance, better and more reliable and uniform quality.
→ self compacting concrete has been described as "the most revolutionary development in concrete construction for several decades"
→ Originally developed in Japan to offset a growing shortage of skilled labour, it has proved to be beneficial from the following points.

1) faster construction
2) Reduction to site manpower
3) Better surface finish
4) faster placing
5) Improved durability
6) Greater freedom in design
7) Thinner concrete sections
8) Reduced noise level
9) safer working environment

Material for SCC

Cement: ordinary portland cement, 43 to 53 grades can be used.

Aggregates:

→ The maximum size of aggregate is generally limited to 20mm. Aggregate of size 10to12mm is desirable for structures having congested reinforcement. Possible size of aggregate higher than 20mm could also be used.

Mixing water:

→ water quality must be stabilised on the same line as that for using reinforced concrete or prestressed concrete.

Chemical admixtures:

→ super plasticizers are an essential component of SCC to provide necessary workability. The new generation super plasticizers formed poly-carboxylated ethers (PCE) is particularly useful for SCC.

Mineral admixtures:

a) Fly ash
b) GGBFS
c) Silica fume
d) Stone powder
e) Fibres.

TYPES OF SSC

→ There are three types of SSC

i) Powder type:

→ This is proportioned to give the required self compactability by reducing the water-powder ratio and provide adequate segregation resistance.

→ powdered type SSC made by increasing powder content

ii) Viscosity modifying admixtures:

→ by the use of viscosity SSC by the use of viscosity modifying admixtures to avoid segregation

~~→ increasing powder content and using VMA.~~

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iii) Combined type :-

-> reduce the water powder ratio.
-> It is made by increasing powder content and using VMA.

MIX DESIGN:

1) Determine the desired air content.
2) Determine the coarse aggregate volume.
3) Determine the sand content
4) Design the paste composition.
5) Determine the optimum water/powder ratio & superplasticizer dosage in mortar.

TESTS ON CONCRETE:

-> The concrete composition is now determined and the super-plasticizer dosage is finally selected on the basis of tests on concrete

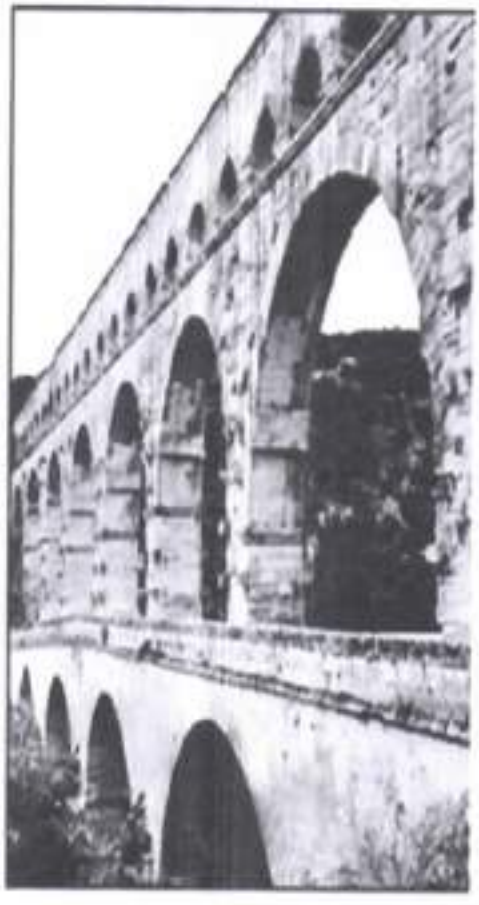
Guidelines for mix composition:

Coarse aggregate <50%
Water/powder ratio = 0.8 to 1.0
Total powder content = 400-600 kg/m3.
Sand content = < 40% of the mortar.
Sand < 50% of paste volume.
Sand > 50% weight of total aggregate.
Free water < 200 litres
Paste > 40% of the volume of the mix.

8. OHD/LCD SHEETS /CDS/DVDS/PPT (SOFT/HARD COPIES)

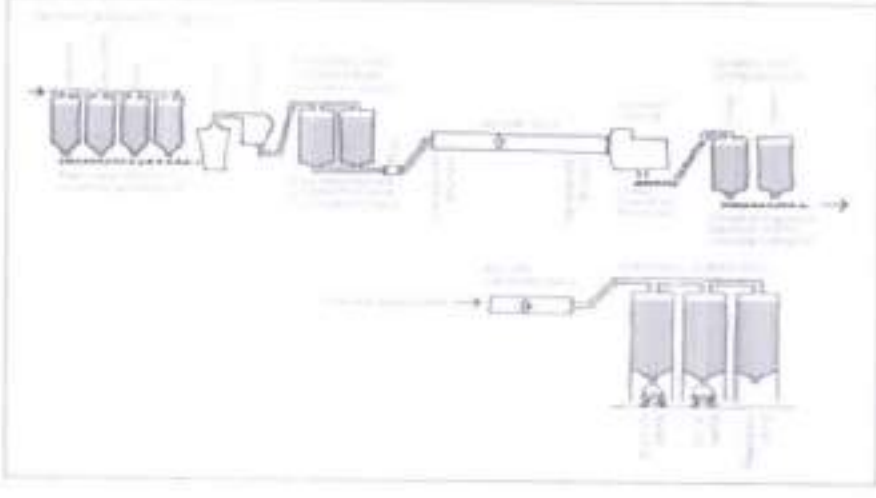
Concrete has deep roots in history:
Wall at Palestrina, Italy, 1st Century BC

Roman Aqueduct & Pantheon



CONCRETE

Portland Cement Manufacturing Process



PHYSICAL PROPERTIES OF CEMENT

FIELD TEST

LABORATORY TEST

SETTING TIME TEST

FINENESS TEST

STRENGTH TEST

TYPES OF CEMENT

ORDINARY PORTLAND CEMENT

RAPID HARDENING CEMENT

QUICK SETTING CEMENT

LOW HEAT CEMENT

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AGGREGATE CLASSIFICATION:SIZE

FINE AGGREGATE

COARSE AGGREGATE

NORMAL AGGREGATE

LIGHT WEIGHT AGGREGATE

AGGREGATE CLASSIFICATION:SHAPE

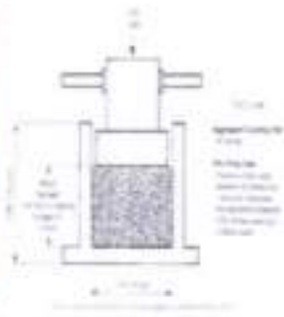
PROPERTIES OF AGGREGATE

Specific gravity test

Bulk density test

PROPERTIES OF AGGREGATE

IMPACT TEST



CRUSHING TEST

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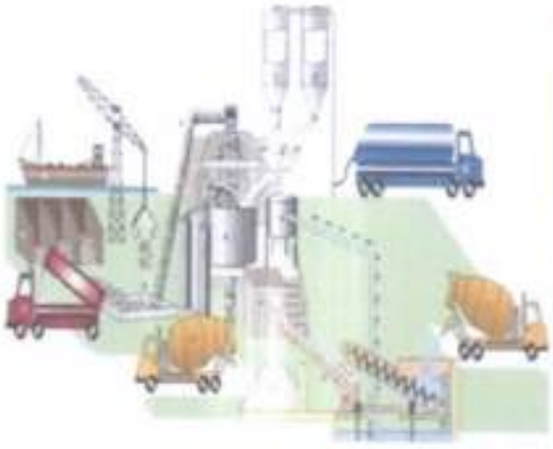
ADMIXTURES

CHEMICAL ADMIXTURES

MINERAL ADMIXTURES

FRESH CONCRETE

MANUFACTURING PROCESS OF CONCRETE



BATCHING OF CONCRETE

WEIGH BATCHING

VOLUME BATCHING

MIXING OF CONCRETE

HAND MIXING

MACHINE MIXING

TRANSPORTING

TRUCK

WHEEL BARROW

CHUTE

PLACING OF CONCRETE

CONVEYOR BELT

PUMPING OF CONCRETE

CURING

WATER

MEMBRANE

ELECTRICAL

WORKABILITY

FACTORS AFFECTING WORKABILITY

- water content
- mix proportion
- size of aggregate
- shape of aggregate
- texture of aggregate
- grading of aggregate
- use of admixtures

MEASUREMENT OF WORKABILITY

SLUMP TEST

COMPACTION FACTOR TEST

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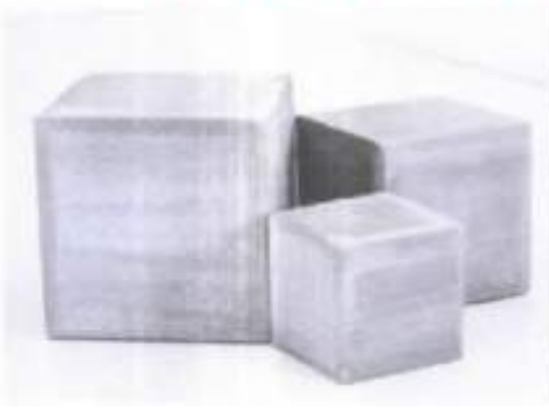
FLOW TEST

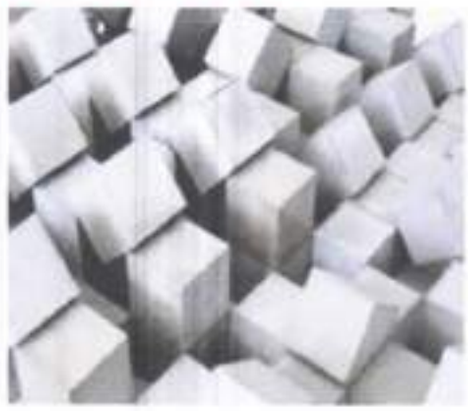
VEE-BEE CONSISTOMETER

BLEEDING OF CONCRETE

SEGGREGATION OF CONCRETE

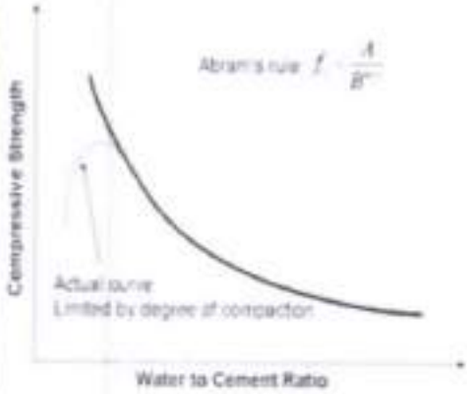
HARDENED CONCRETE



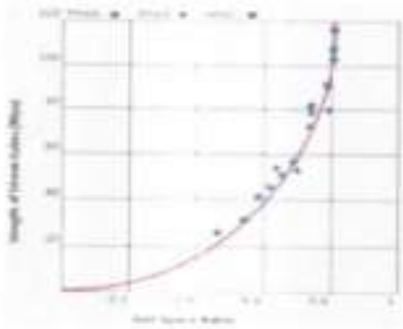


ABRAM'S LAW

WATER/CEMENT RATIO



GEL/SPACE RATIO



CALCULATION OF GEL/SPACE RATIO:

FULL HYDRATION:

$$\text{GEL SPACE RATIO} = \frac{0.657C}{0.319Ca + wo}$$

PARTIAL HYDRATION:

$$\text{GEL SPACE RATIO} = \frac{0.657Ca}{0.319Ca + wo}$$

MATURITY CONCEPT

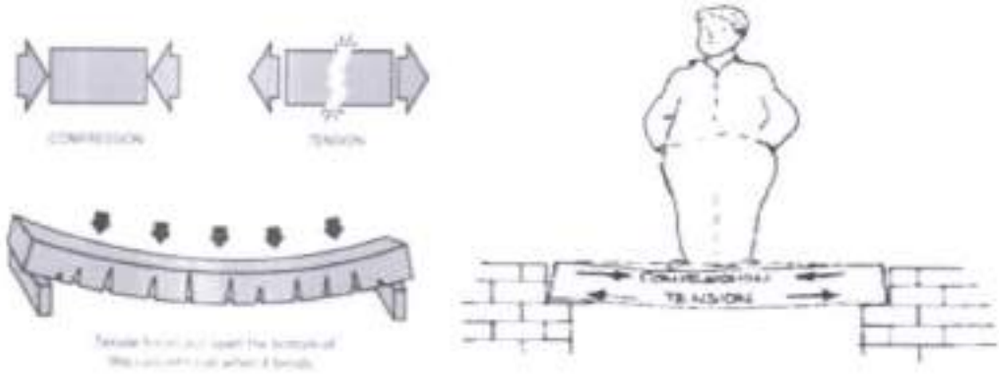
sensor for monitoring the temperature of concrete from fresh to hardened stage.

NATURE OF CONCRETE

FRACTURE OF CONCRETE CUBE

FAILURE OF CONCRETE CUBE

STRENGTH IN TENSION AND COMPRESSION



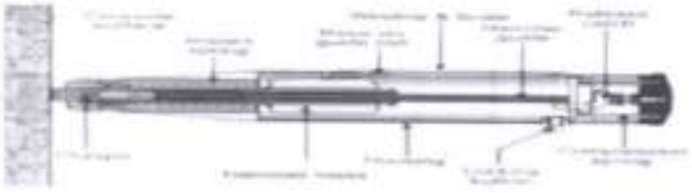
TESTING OF HARDENED CONCRETE

COMPRESSIVE STRENGTH OF CONCRETE

TENSILE STRENGTH OF CONCRETE

FLEXURAL TEST ***SPLIT TENSILE TEST***

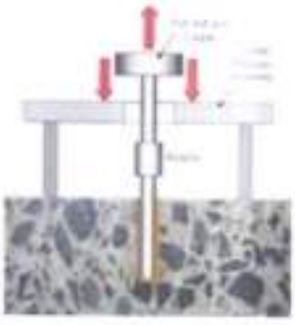
NDT METHODS



REBOUND HAMMER TEST

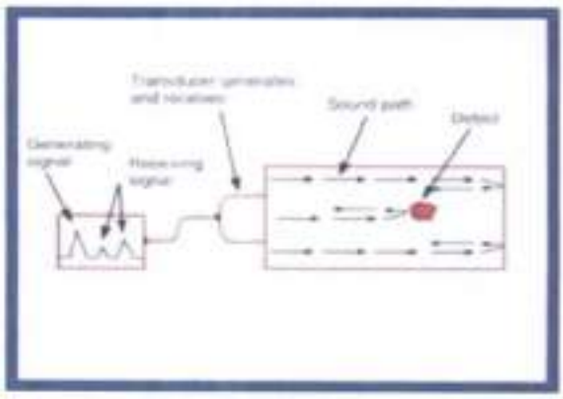


ULTRA SONIC PULSE VELOCITY



PULLOUT TEST

CTS Electrical Resistivity Testing Using Proceq Resi



ELECTRICAL RESISSTIVITY METHOD

SHRINKAGE

DRYING SHRINKAGE

PLASTIC SHRINKAGE

MIX DESIGN

FACTORS IN THE CHOICE OF MIX DESIGN

Compressive strength of concrete

Workability of concrete

Durability of concrete

Nominal size of aggregate

Fineness modulus

Quality control

MIX DESIGN PROCEDURE

TARGET MEAN STRENGTH:

$$f_{ck}' = f_{ck} - 1.65s$$

WATER/CEMENT RATIO:

Exposure	P.C.C			R.C.C		
	Minimum Cement Content Kg/m³	Max Free Water - Cement Ratio	Minimum Grade of Concrete	Minimum Cement Content Kg/m³	Max Free Water - Cement Ratio	Minimum Grade of Concrete
Mild	220	0.6	-	300	0.55	M20
Moderate	240	0.6	M15	300	0.5	M25
Severe	250	0.5	M20	320	0.45	M30
Very severe	260	0.45	M20	340	0.45	M35
Extreme	280	0.4	M25	360	0.4	M40

CALCULATION OF WATER

Table 2 Maximum Water Content per Cubic Metre of Concrete for Nominal Maximum Size of Aggregate
(*Clauses* 4.2, A-5 *and* B-5)

Sl No.	Nominal Maximum Size of Aggregate	Maximum Water Content [1]
	mm	kg
(1)	(2)	(3)
i)	10	208
ii)	20	186
iii)	40	165

CEMENT CONTENT:

take from above step

COARSE AND FINE AGGREGATES:

Maximum Size of Aggregate (mm)	Volume of Coarse Aggregate per Unit Volume of Total Aggregate			
	Zone IV	Zone III	Zone II	Zone I
10	0.50	0.48	0.46	0.44
20	0.66	0.64	0.62	0.60
40	0.75	0.73	0.71	0.69

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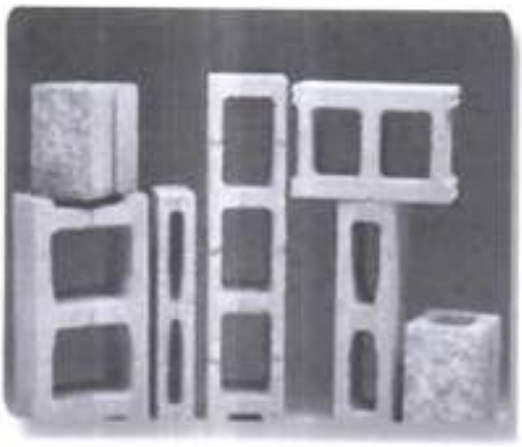
SPECIAL CONCRETE

LIGHT WEIGHT AGGREGATE CONCRETE



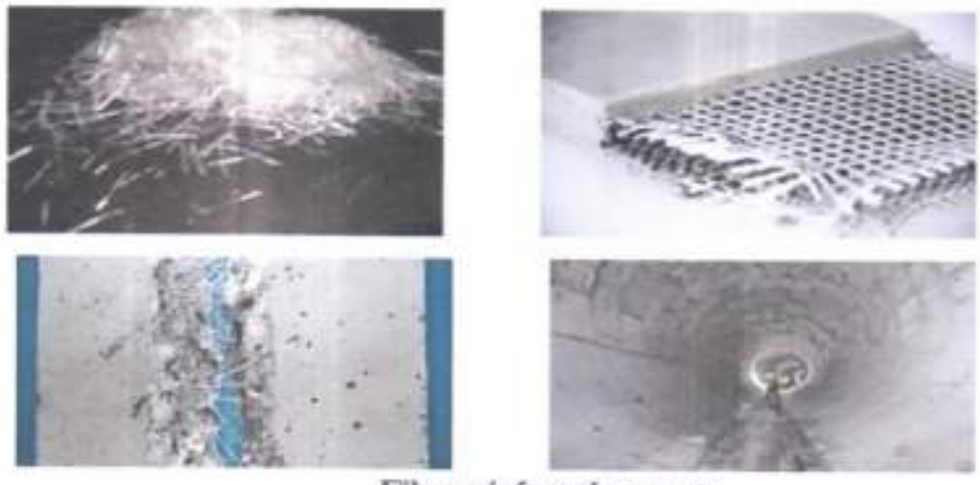
LIGHT WEIGHT CONCRETE

Cellular concrete

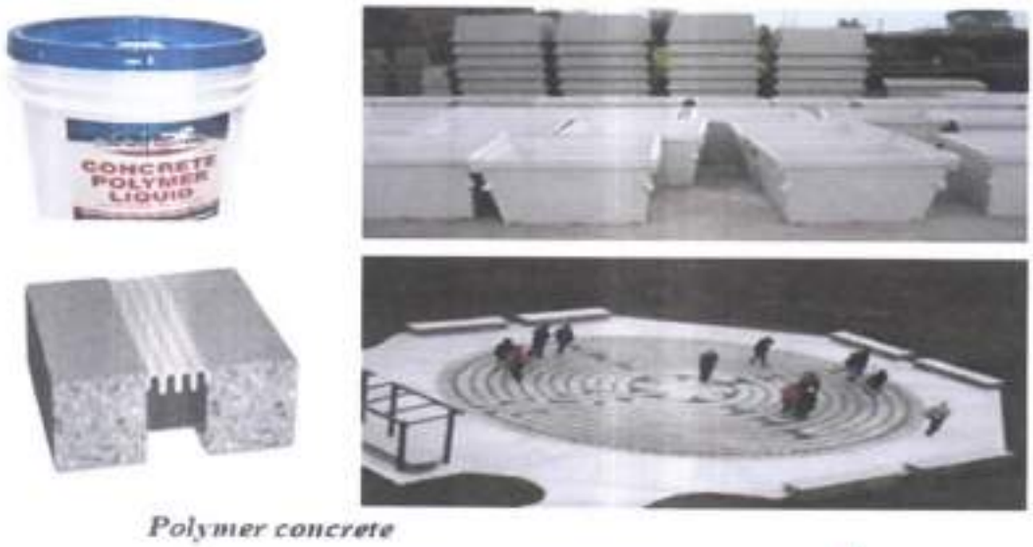
NO FINES CONCRETE (OR) PERVIOUS CONCRETE

Self compacting concrete

High density concrete



Fibre reinforced concrete



Polymer concrete

9. University Previous Question papers

R13

Code No: 115EF

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD

B. Tech III Year I Semester Examinations, November - 2015

CONCRETE TECHNOLOGY

(Common to CE, CEO)

Time: 3 hours **Max. Marks: 75**

Note: This question paper contains two parts A and B.
Part A is compulsory which carries 25 marks. Answer all questions in Part A. Part B consists of 5 Units. Answer any one full question from each unit. Each question carries 10 marks and may have a, b, c as sub questions.

PART - A (25 Marks)

1.a)	List out different grades of cement	[2]
b)	Explain about hardening of concrete.	[3]
c)	Define workability.	[2]
d)	Explain about bleeding.	[3]
e)	Explain rheology of creep.	[2]
f)	Brief out different types of durability.	[3]
g)	What is the difference between pumpable and normal concrete?	[2]
h)	Explain statistical quality control of concrete.	[3]
i)	What is aspect ratio of fibers?	[2]
j)	Explain about light weight aggregates.	[3]

PART-B (50 Marks)

2.a)	Explain in detail about manufacture of by-product of cement.	
b)	Explain in detail about influence of compound composition on properties of cement.	[5+5]

OR

3.a)	Explain deleterious substance in aggregate and soundness of aggregate.	
b)	Explain about gap graded aggregate and IRS grading.	[5+5]
4.a)	Explain setting times of concrete.	
b)	Explain effect of time and temperature on workability of concrete.	[5+5]

OR

5.	Explain in detail about measurement of workability by different tests.	[10]
6.a)	Explain factors affecting strength of concrete.	
b)	Explain nature of creep and effects of creep on structural concrete.	[5+5]

OR

7.	Explain in detail about maturity concept of concrete with illustrative examples.	[10]
8.a)	Explain in detail about durability of concrete.	
b)	What are different variables in proportioning that influence mix design of pumpable concrete?	[5+5]

OR

9.	Design M 20 normal concrete mixture available data according to IS 10262-2009.	[10]
10.	Explain in detail about Self compacting concrete.	[10]

OR

11.	Explain in detail about Fiber reinforced concrete.	[10]

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R13

Code No: 115EP

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD

B.Tech III Year I Semester Examinations, February/March - 2016

CONCRETE TECHNOLOGY

(Common to CE, CEE)

Time: 3 hours **Max. Marks: 75**

Note: This question paper contains two parts A and B.
Part A is compulsory which carries 25 marks. Answer all questions in Part A.
Part B consists of 5 Units. Answer any one full question from each unit.
Each question carries 10 marks and may have a, b, c as sub questions.

Part- A

(25 Marks)

1.a) What is the role of calcium silicates in the hydration process of cement? [2]
b) Explain about surface acting admixture. [3]
c) Write about the various types of cement. [2]
d) Explain about LATTANCE. [3]
e) What are different types of sulphate solutions in the soil? [2]
f) What is the relation between creep and time? [3]
g) How bulking of sand is corrected in field mixes? [2]
h) What is entrapped air? How it is accounted in concrete mix design? [3]
i) What is no fines concrete? [2]
j) Explain about cellular concrete? [3]

Part-B

(50 Marks)

2.a) Explain about set controlling admixtures? [5]
b) What is alkali aggregate reaction? What factors promote alkali aggregate reactions and how it can be controlled? [5+5]

OR

3.a) Explain the method of determining the fineness of cement by sieve analysis method? [5+5]
b) Explain the shape tests on aggregate?

4.a) Explain in detail about bleeding and segregation of concrete? How it can be controlled?
b) Explain slump test on fresh concrete and the recommended slump values for different work abilities? [5+5]

OR

5.a) Discuss about the quality of mixing water requirements as per IS code provisions? [5+5]
b) Explain the steps in manufacture of concrete in an actual batch?

6.a) Calculate the Cbl/Space area and hence estimate the 28 day strength for one bag of cement with 0.55 W/C ratio at 75% hydration?
b) Explain the creep behavior of concrete with the help of creep curve? [5+5]

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8. a) Explain Maturity of concrete.
b) Write short Notes on Gel/ space ratio. [5+5]

OR

9. a) Write step wise procedure for mix design of concrete as per Indian Standards.
b) Define durability and its significance. [5+5]

10. a) Explain light weight aggregate concrete.
b) Write shortnotes on self compacting concrete. [5+5]

OR

11. a) Explain various types of polymer concrete.
b) Write short notes on no-fines concrete. [5+5]

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R13

Code No: 115EP

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD

B. Tech III Year I Semester Examinations, November/December - 2016

CONCRETE TECHNOLOGY

(Common to CE, CSE)

Time: 3 hours **Max. Marks: 75**

Note: This question paper contains two parts A and B.
Part A is compulsory which carries 25 marks. Answer all questions in Part A. Part B consists of 5 Units. Answer any one full question from each unit. Each question carries 10 marks and may have a, b as sub questions.

PART - A

(25 Marks)

1.a) Give the chemical composition of cement. [2]
b) What is fineness modulus of aggregate? What does it indicates? [2]
c) Define initial setting time and final setting time of cement. [2]
d) What is the purpose of adding water in concrete? [3]
e) Define water cement ratio. [2]
f) State necessity of curing for cement concrete. [3]
g) Give any two requirements of concrete mix design. [2]
h) Differentiate preliminary mix and trial mixes. [3]
i) Give two applications of light weight concrete. [2]
j) Give the advantages of fiber reinforced concrete. [3]

PART - B

(50 Marks)

2. Explain different methods of proportionment of mix ture concrete aggregates. [10]

OR

3.a) What is heat of hydration? How does this affect the quality of concrete? [5+5]
b) Explain different laboratory tests to be conducted on cement to decide its quality.

4.a) What are the various tests to measure workability? Explain any one with neat sketch. [5+5]
b) Explain segregation and bleeding in concrete.

OR

5.a) List out the factors affecting workability and explain them. [5+5]
b) Write short notes on Quality of mixing water.

6. List out the non-destructive tests and explain any two non - destructive testing methods on hardened concrete. [10]

OR

7.a) Define creep and explain the relation between creep and time. [5+5]
b) Explain shrinkage and types of shrinkage.

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R13

Code No: 115EP

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD

B. Tech III Year I Semester Examinations, March - 2017

CONCRETE TECHNOLOGY

(Common to CE, CSM)

Time: 3 hours **Max. Marks: 75**

Note: This question paper contains two parts A and B.
Part A is compulsory which carries 25 marks. Answer all questions in Part A. Part B consists of 5 Units. Answer any one full question from each unit. Each question carries 10 marks and may have a, b, c as sub questions.

PART - A

(25 Marks)

1.a) What is flash set of cement and how to avoid this? [2]
b) Explain the mechanism of deflocculating of cement by superplasticizer. [3]
c) Define workability in terms of energy. [2]
d) Define fineness and factors responsible for it. [3]
e) State Abrams's water cement ratio law. [2]
f) How does drying shrinkage affect concrete? [3]
g) State the merits and demerits of IS mix design method. [2]
h) What do you understand by large mean strength? [3]
i) Give the application of cellular concrete. [2]
j) What is 'no-fines' concrete? [3]

PART - B

(50 Marks)

2.a) Explain how the Bogue's compounds participate in the development of strength of cement.
b) Explain the effect of h/D ratio and size of aggregate on the strength properties of concrete. [5+5]

OR

3.a) What is Alkali aggregate reaction and how it can be controlled.
b) What are the desired requisites? Explain different types of admixtures. [5+5]

4.a) List the factors affecting the workability of concrete.
b) Explain the procedure for designing the mixing times of concrete. [5+5]

OR

5.a) Discuss the applicability of the various workability tests to concretes of different levels of workability.
b) Define bleeding and segregation of concrete and Explain the methods to control them. [5+5]

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Code No: 125EP

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD

B. Tech III Year I Semester Examinations, November/December - 2017

CONCRETE TECHNOLOGY

(Common to CE, CT)

Time: 3 hours **Max. Marks: 75**

Note: This question paper contains two parts A and B.
Part A is compulsory which carries 25 marks. Answer all questions in Part A. Part B consists of 5 Units. Answer any one full question from each unit. Each question carries 10 marks and may have a, b, c as sub questions.

PART – A

(25 Marks)

1.a) What does the grade of cement indicate? [2]
b) What are the various classes of admixtures? [3]
c) For which type of cracks do you use Vee Bee test? What are the units of measurement? [2]
d) What is the simple test for suitability of water as per IS 456 code? [3]
e) State the Abrams's law. [2]
f) What are the different types of shrinkage of concrete? [3]
g) Define the term "Durability" of concrete? [3]
h) Differentiate between plastic concrete mix and wet concrete mix in concrete mix design. [2]
i) What is Cellular concrete? [2]
j) Differentiate between RCC and prestressed concrete. [3]

PART – B

(50 Marks)

2.a) Explain the chemical components of ordinary Portland cement.
b) What is bulking of fine aggregate? Explain how to bring down it is percentage? [4+6]

OR

3.a) Explain in detail the tests conducted on fine aggregates.
b) Determine the fineness modulus of following sand samples weighing 2 kg. [5+5]

S.No.	Sieve size	Weight retained in grams
1	40 mm	0
2	20 mm	200
3	10 mm	600
4	4.75 mm	500
5	2.36 mm	0

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10. MID exam Descriptive Question Papers with Key

VAAGESWARI COLLEGE OF ENGINEERING

(Approved by AICTE, Affiliated to JNTUH)

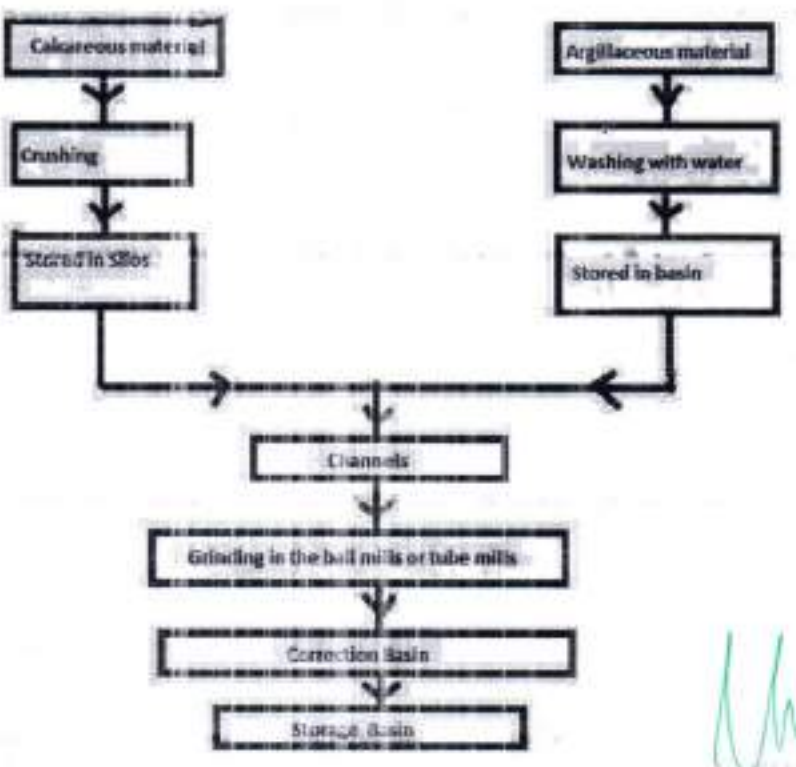
MID-I

Q.NO	Question	BLOOMS LEVEL	COURSE OUTCOME
1	Give step by step method of manufacturing process of cement.	Understand	CO1
2	What is Admixtures and explain the classification of admixtures?	understand	CO1
3	a) Explain the mechanical properties of aggregates? b) Explain the classification of aggregates?	understand	CO1
4	Briefly explain manufacturing procedure of concrete.	understand	CO2

KEY

1. **Explain the manufacturing process of cement with flow chart**

The basic ingredients of both the dry and wet processes are the same. By mass, lime and silica make up approximately 85% of Portland cement. The materials that are commonly used are limestone, shells, chalk, shale, clay, slate, silica sand, and iron ore.



2. **What is Admixtures and explain the classification of admixtures?**

A material other than water, aggregates, or cement that is used as an ingredient of concrete or mortar to control setting and early hardening, workability, or to provide additional cementing properties.

1. **Chemical admixtures**

Accelerators, Retarders, Water-reducing agents, Super plasticizers, Air entraining agents etc.

Water-reducing admixture / Plasticizers

- To achieve a higher strength by decreasing the water cement ratio at the same workability as an admixture free mix.
- To achieve the same workability by decreasing the cement content so as to reduce the heat of hydration in mass concrete.
- To increase the workability so as to ease placing in accessible locations
- Water reduction more than 5% but less than 12%.

Super Plasticizers:

These are more recent and more effective type of water reducing admixtures also known as *high range water reducer.*

Accelerator

An admixture which, when added to concrete, mortar, or grout, increases the rate of hydration of hydraulic cement, shortens the time of set in concrete, or increases the rate of hardening or strength development.

Air Entrained Admixtures:

An addition for hydraulic cement or an admixture for concrete or mortar which causes air, usually in small quantity, to be incorporated in the form of minute bubbles in the concrete or mortar during mixing, usually to increase its workability and frost resistance. Air-entraining admixtures are surfactants that change the surface tension of the water. Traditionally, they were based on fatty acid salts or vinsol resin but these have largely been replaced by synthetic surfactants or blends of surfactants to give improved stability and void characteristics to the entrained air. Air entrainment is used to produce a number of effects in both the plastic and the hardened concrete

2. **Mineral admixtures**

Fly-ash Blast-furnace slag, Silica fume and Rice husk Ash etc

Fly Ash:

The finely divided residue resulting from the combustion of ground or powdered coal. Fly ash is generally captured from the chimneys of coal-fired power plants; it has POZZOLANIC properties, and is sometimes blended with cement for this reason.

Fly ash includes substantial amounts of silicon dioxide (SiO_2) (both amorphous and crystalline) and calcium oxide (CaO). Toxic constituents include arsenic, beryllium, boron, cadmium, chromium, cobalt, lead, manganese, mercury, molybdenum, selenium, strontium, thallium, and vanadium.

Silica Fume:

The terms condensed silica fume, microsilica, silica fume and volatilized silica are often used to describe the by-products extracted from the exhaust gases of silicon, ferrosilicon and other metal alloy furnaces. However, the terms microsilica and silica fume are used to describe those condensed silica fumes that are of high quality, for use in the cement and concrete industry.

Rice Husk Ash:

This is a bio waste from the husk left from the grains of rice. It is used as a pozzolanic material in cement to increase durability and strength. The silica is absorbed from the ground and gathered in the husk where it makes a structure and is filled with cellulose. When cellulose is burned, only silica is left which is grinded to fine powder which is used as pozzolana.

3.a). Explain the mechanical properties of aggregates?

Specific gravity

The ratio of weight of oven dried aggregates maintained for 24 hours at a temperature of 100 to 110^0C, to the weight of equal volume of water displaced by saturated dry surface aggregate is known as specific gravity of aggregates.

Specific gravities are primarily of two types.

- Apparent specific gravity
- Bulk specific gravity

Bulk density

It is defined as the weight of the aggregate required to fill a container of unit volume. It is generally expressed in kg/litre.

Bulk density of aggregates depends upon the following 3 factors.

- Degree of compaction
- Grading of aggregates
- Shape of aggregate particles

Porosity

The minute holes formed in rocks during solidification of the molten magma, due to air bubbles, are known as pores. Rocks containing pores are called porous rocks.

Adsorption and Moisture content

Water absorption may be defined as the difference between the weight of very dry aggregates and the weight of the saturated aggregates with surface dry conditions.

Depending upon the amount of moisture content in aggregates, it can exist in any of the 4 conditions.

- Very dry aggregate (having no moisture)
- Dry aggregate (contain some moisture in its pores)
- Saturated surface dry aggregate (pores completely filled with moisture but no moisture on surface)
- Moist or wet aggregates (pores are filled with moisture and also having moisture on surface)

3. b). Explain the classification of aggregates?

Aggregates are classified according to shape

- Rounded aggregates
- Irregular or partly rounded aggregates
- Angular aggregates
- Flaky aggregates

- Elongated aggregates
- Flaky and elongated aggregates

Aggregates are classified according to size

- Fine aggregate
- Coarse aggregate

Aggregates are classified according to source

- Igneous rocks
- Sedimentary rocks
- Metamorphic rocks

Aggregates are classified according to weight

- Normal weight aggregates
- Light weight aggregates
- Heavy weight aggregates

3. **Briefly explain manufacturing procedureofconcrete.**

Batching:
The measurement of materials making concrete is known as batching, these batching are two methods weigh batching and volume batching

Mixing:
Mixing of material is essential for the production of uniform concrete. The mixing should ensure that the mass becomes uniform in color and consistency .there are two methods adopted for mixing concrete hand mixing and machine mixing

Transporting:
The method adopted for transportation of concrete
Mortar pan, wheel barrow hand cart, crane bucket and rope way, truck mixer, belt conveyor, transit mixer, pump and pipeline, helicopter.

Placing of concrete:
Concrete is invariably laid as a foundation bed below the walls or columns before placing the concrete in the foundation all the loose earth must be removed from the bed.

Compaction:
Compaction of concrete is the process adopted for expelling the entrapped air from the concrete. The method of compaction is hand compaction, vibration compaction, compaction by pressure and jolting, compaction by spinning.

Curing:
curing can also be described as keeping the concrete moist and warm enough so that the hydration of cement can continue more elaborately it can be described as the process of maintaining a satisfactory moisture content and a favorable temperature in concrete during the period immediately following placement so that hydration of cement may continue until the desired properties are developed to a sufficient degree to meet the requirement of service. Curing methods are water curing, membrane curing, and application of heat.

Finishing:
It's the last operation making concrete. Its increases does not apply to all concrete operations

11. Assignment topics with materials

UNIT-I

CEMENT

1. **Define mortar and its types**
2. **Explain about hydration of cement**
3. **What are the basic testing of cement**
4. **Determine the compressive strength of cement.**

TOPIC 1: Mortar and its types

The mortar is a paste like substance prepared by adding required amount of water to a dry mixture of sand or fine aggregate with some binding material like clay, lime or cement.

Limemortar:

If lime is used as a binding material, the resulting mortar is known as lime mortar.

Mudmortar:

When clay is used as a binding material, the resulting mortar is known as mud mortar

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TOPIC 2:Hydration

The setting and hardening of concrete are the result of chemical and physical processes that take place between Portland cement and water, i.e. hydration. To understand the properties and behaviour of cement and concrete some knowledge of the chemistry of hydration is necessary.

A) Hydration reactions of pure cementcompounds

The chemical reactions describing the hydration of the cement are complex. One approach is to study the hydration of the individual compounds separately. This assumes that the hydration of each compound takes place independently of theothers.

I. Calciumsilicates

Hydration of the two calcium silicates gives similar chemical products, differing only in the amount of calcium hydroxide formed, the heat released, and reaction rate.

$2\ C_3S + 7\ H \rightarrow C_3S_2H_4 + 3\ CH$ $2\ C_2S + 5\ H \rightarrow C_3S_2H_4 + CH$

The principal hydration product is $C_3S_2H_4$, calcium silicate hydrate, or C-S-H (non- stoichiometric). This product is not a well-defined compound. The formula $C_3S_2H_4$is only an approximate description. It has amorphous structure making up of poorly organized layers and is called glue gel binder. C-S-H is believed to be the material governing concrete strength. Another product is CH - $Ca(OH)_2$, calcium hydroxide. This product is a hexagonal crystal often forming stacks of plates. CH can bring the pH value to over 12 and it is good for corrosion protection ofsteel.

II. Tri-calciumaluminate

Without gypsum, C_3A reacts very rapidly with water:

$C_3A + 6\ H \rightarrow C_3AH_6$

The reaction is so fast that it results in flash set, which is the immediate stiffening after mixing, making proper placing, compacting and finishing impossible.

With gypsum, the primary initial reaction of C_3A with water is

$C_3A + 3\ (C\ S\ H_2) + 26\ H \rightarrow C_6A\ S_3H_{32}$

The 6-calcium aluminate trisulfate-32-hydrate is usually called ettringite. The formation of ettringite slows down the hydration of C_3A by creating a diffusion barrier around C_3A. Flash set is thus avoided. Even with gypsum, the formation of ettringite occurs faster than the hydration of the calcium silicates.

It therefore contributes to the initial stiffening, setting and early strength development. In normal cement mixes,theettringite is not stable and will further react to form monosulphate ($C_4A\,S\,H_{18}$)

B) Kinetics andReactivity's

The rate of hydration during the first few days is in the order of $C_3A > C_3S > C_4AF > C_2S$.

C) Calorimetric curve of Portlandcement

A typical calorimetric curve of Portland cement is shown in the following figure. The second heat peaks of both C_3S and C_3A can generally be distinguished, although their order of occurrence can be reversed.

D) Setting andHydration

Initial set of cement corresponds closely to the end of the induction period, 2-4 hours after mixing. Initial set indicates the beginning of forming of gel or beginning of solidification. It represents approximately the time at which fresh concrete can no longer be properly mixed, placed or compacted. The final set occurs 5-10 hours after mixing, within the acceleration period. It represents approximately the time after which strength develops at a significant rate.

In practice, initial and final set are determined in a rather arbitrary manner with the penetration test.

TOPIC 3: Basic test of cement

Fineness (= surface area / weight):

This test determines the average size ofcement grains. The typical value of fineness is 350 m^2 / kg.Fineness controls the rate and completeness of hydration. The finer a cement,the more rapidly it reacts, the higher the rate of heat evolution and the higher the early strength.

Normal consistency test:

This test is to determine the water required to achievea desired plasticity state (called normal consistency) of cement paste. It is obtained with the Vicat apparatus by measuring the penetration of a loaded needle.

Time of setting:

This test is to determine the time required for cement paste to harden. Initial set cannot be too early due to the requirement of mixing, conveying, placing and casting. Final set cannot be too late owing to the requirement of strength development. Time of setting is measured by Vicat apparatus. Initial setting time is defined as the time at which the needle penetrates 25 mm into cement paste. Final setting time is the time at which the needle does not sink visibly into the cement paste.

Soundness:

Unsoundness in cement paste refers to excessive volume change after setting. Unsoundness in cement is caused by the slow hydration of MgO or freelime.

Their reactions are $MgO + H_2O = Mg(OH)_2$ and $CaO + H_2O = Ca(OH)_2$. Another factor that can cause

unsoundness is the delayed formation of ettringite after cement and concrete have hardened. The pressure from crystal growth will lead to cracking and damage. The soundness of the cement must be tested by accelerated methods. An example is the Le Chatelier test (BS 4550). This test is to measure the potential for volumetric change of cement paste. Another method is called Autoclave Expansion test (ASTM C151) which use an autoclave to increase the temperature to accelerate the process.

Strength:

The strength of cement is measured on mortar specimens made of cement and standard sand (silica). Compression test is carried out on a 2" cube with S/C ratio of 2.75:1 and w/cratio of 0.485 for Portland cements. The specimens are tested wet, using a loading rate at which the specimen will fail in 20 to 80 s. The direct tensile test is carried out on a specimen shaped like a dumbbell. The load is applied through specifically designed grips. Flexural strength is measured on a 40 x 40 x 160 mm prism beam test under a centre-point bending.

TOPIC 4: Compressive Strength of Cement

This test is carried out to determine the **compressive strength of cement**.

Test Procedure for compressive strength of cement:

(i) The mortar of cement and sand is prepared. The proportion is 1:3 which means that (X) gm of cement is mixed with 3(X) gm of sand.

(ii) The water is added to the mortar. The water cement ratio is kept as 0.4 which means that (X) gm of water is added to dry mortar.

(iii) The mortar is placed in moulds. The test specimens are in the form of cubes with side as 70.6 mm or 76 mm. The moulds are of metal and they are constructed in such a way that the specimens can be easily taken out without being damaged. For 70.6 mm and 76 mm cubes, the cement required is 185 gm and 235 gm respectively.

The mortar, after being placed in the moulds, is compacted in vibrating machine for 2 minutes.

(iv) Themoulds are placed in a damp cabin for 24 hours.

(vi) The specimens are removed from the moulds and they are submerged in clean water for curing.

(vii) The cubes are then tested in **compression testing machine** at the end of 3 days and 7 days. The testing of cubes is carried out on their three sides without packing. Thus three cubes are tested each time to find out the compressive strength at the end of 3 days and 7 days. The average value is then worked out. During the test, the load is to be applied uniformly at the rate of 350 kg/cm2 or 35 N/mm2.

(viii) The **compressive strength of cement** at the end of 3 days should not be less than 115 kg/cm2 or N/mm2 and that at the end of 7 days should not be less than 175 kg/cm2 or 17.50 N/mm2.

UNIT-II

AGGREGATES & ADMIXTURES

1. **Define aggregate and its classification**
2. **Explain the admixtures classification and functions**

TOPIC 1:Define aggregate and its classification

Aggregates are defined as inert, granular, and inorganic materials that normally consist of stone or stone- like solids. Aggregates can be used alone (in road bases and various types of fill) or can be used with cementing materials (such as Portland cement or asphalt cement) to form composite materials or concrete. The most popular use of aggregates is to form Portland cement concrete. Approximately three-fourths of the volume of Portland cement concrete is occupied by aggregate. It is inevitable that a constituent occupying such a large percentage of the mass should have an important effect on the properties of both the fresh and hardened products. As another important application, aggregates are used in asphalt cement concrete in which they occupy 90% or more of the total volume. Once again, aggregates can largely influence the composite properties due to its large volume fraction.

Classification ofAggregate

Aggregates can be divided into several categories according to different criteria.

In accordance withsize:

Coarse aggregate: Aggregates predominately retained on the No. 4 (4.75 mm) sieve. For mass concrete, the maximum size can be as large as 150 mm.

Fine aggregate (sand): Aggregates passing No.4 (4.75 mm) sieve and predominately retained on the No. 200(75 μm) sieve.

In accordance withsources:

Natural aggregates: This kind of aggregate is taken from natural deposits without changing their nature during the process of production such as crushing and grinding. Some examples in this category are sand, crushed limestone, and gravel.

Manufactured (synthetic) aggregates: This is a kind of man-made materials produced as a main product or an industrial by-product. Some examples are blast furnace slag, lightweight aggregate (e.g. expanded perlite), and heavy weight aggregates (e.g. iron ore or crushed steel).

In accordance with unitweight:

Light weight aggregate: The unit weight of aggregate is less than 1120kg/m^3. The corresponding

concrete has a bulk density less than 1800kg/m^3. (cinder, blast-furnace slag, volcanic pumice).

Normal weight aggregate: The aggregate has unit weight of 1520-1680kg/m^3. The concrete made with this type of aggregate has a bulk density of 2300-2400 kg/m^3.

Heavy weight aggregate: The unit weight is greater than 2100 kg/m^3. The bulk density of the corresponding concrete is greater than 3200 kg/m^3. A typical example is magnesite limonite, a heavy iron ore. Heavy weight concrete is used in special structures such as radiation shields.

In accordance withorigin:

Igneous rock Aggregate:

- Hard, tough anddense.
- Massive structures: crystalline, glassy or both depending on the rate at which they are cooledduring formation.
- Acidic or basic: percentage of silicacontent.
- Light or darkcoloured.
- Chemically active: react withalkalis.

Sedimentary rock Aggregate:

- Igneous or metamorphic rocks subjected to weatheringagencies.
- Decompose, fragmentize, transport and deposit deep beneath ocean bed are cementedtogether.
- Range from soft-hard, porous-dense,light-heavy and can beflaky.
- Suitabilitydecidedby:degreeofconsolidation, typeofcementation,thicknessoflayerand contamination.

Metamorphic rock Aggregate:

- Rocks subjected to high temperature andpressure.
- Economic factor intoconsideration.
- Least overallexpense.

TOPIC 2: **Admixtures can be classified by function asfollows:**

1. Air-entraining admixtures
2. Water-reducing admixtures
3. Plasticizers
4. Accelerating admixtures
5. Retarding admixtures
6. Hydration-control admixtures
7. Corrosion inhibitors
8. Shrinkage reducers
9. Alkali-silica reactivity inhibitors
10. Colouring admixtures
11. Miscellaneous admixtures such as workability, bonding, damp proofing, permeability reducing, grouting, gas forming, anti-washout, foaming, and pumping admixtures.

Concrete should be workable, finish able, strong, durable, watertight, and wear resistant. These qualities can often be obtained easily and economically by the selection of suitable materials rather than by resorting to admixtures (except air-entraining admixtures when needed).

The major reasons for using admixtures

1. To reduce the cost of concrete construction
2. To achieve certain properties in concrete more effectively than by other means
3. To maintain the quality of concrete during the stages of mixing, transporting, placing, and curing in adverse weather conditions
4. To overcome certain emergencies during concreting operations

UNIT-III

FRESH CONCRETE

1. Define workability and factors affecting workability
2. Explain about segregation and bleeding of concrete
3. Explain various methods of measuring workability

TOPIC 1: Workability

All the characteristics above describe many different aspects of concrete behavior. The term workability is used to represent all the qualities mentioned. Workability is often defined in terms of

the amount of mechanical energy, or work, required to fully compact concrete without segregation. This is important since the final strength is a function of compaction.

The concept of viscosity is a measure of how a material behaves under stress. For a Newtonian fluid, the relationship may be written as:

$$\tau = \eta D$$

Where *t*is the shear stress, ***n*** is the viscosity, and ***D*** is the rate of shear or velocity gradient.For a very dilute suspension of solids in liquids, this relationship holds true. However, for large volumes of suspended solids, like concrete, the Newtonian model does not work. Concrete has an initial shear strength that must be exceeded before it will flow. This type of behaviour is described by the Bingham model:

$$\tau - \tau_0 = \eta D$$

Where ***t0*** is the yield shear stress, ***n*** is the plastic viscosity.

Factors AffectingWorkability

Water Content of the Mix:

This is the single most important fact or governing workability of concrete. A group of particles requires a certain amount of water. Water is absorbed on the particle surface, in the volumes between particles, and provides "lubrication" to help the particles move past one another more easily. Therefore, finer particles, necessary for plastic behaviour, require more water. Some side- effects of increased water are loss of strength and possible segregation.

Influence of Aggregate Mix Proportions:

Increasing the proportion of aggregates relative to the cement will decrease the workability of the concrete. Also, any additional fines will require more cement in the mix. An "over sanded" mix will be permeable and less economical. A concrete deficient of fines will be difficult to finish and prone to segregation.

Aggregate Properties:

The ratio of coarse/fine aggregate is not the only factor affecting workability. The gradation and particle size of sands are important. Shape and texture of aggregate will also affect workability. Spherical shaped particles will not have the interaction problems associated with more angular particles. Also, spherical shapes have a low surface/volume ratio, therefore, less cement will be required to coat each particle and more will be available to contribute to the workability of the

concrete. Aggregate which is porous will absorb more water leaving less to provide workability. It is important to distinguish between total water content, which includes absorbed water, and free water which is available for improving workability.

Time and Temperature:

In general, increasing temperature will cause an increase in the rate of hydration and evaporation. Both of these effects lead to a loss of workability.

Loss of Workability:

Workability will decrease with time due to several factors; continued slow hydration of C3S and C3A during dormant period, loss of water through evaporation and absorption, increased particle interaction due to the formation of hydration products on the particle surface. Loss of workability is measured as "slump loss" with-time.

Cement Characteristics:

Cement characteristics are less important than aggregate properties in determining workability. However, the increased fineness of rapid-hardening cements will result in rapid hydration and increased water requirements, both of which reduce workability.

Admixtures:

In general, air-entraining, water-reducing, and set-retarding admixtures will all improve workability. However, some chemical admixtures will react differently with cements and aggregates and may result in reduced workability.

TOPIC 2: Segregation and Bleeding

Segregation:

Segregation refers to a separation of the components of fresh concrete, resulting in a non-uniform mix. This can be seen as a separation of coarse aggregate from the mortar, caused from either the settling of heavy aggregate to the bottom or the separation of the aggregate from the mix due to improper placement.

Some factors that increase segregation are:

1. Larger maximum particle size (25mm) and proportion of the larger particles.
2. High specific gravity of coarse aggregate.
3. Decrease in the amount of fine particles.
4. Particle shape and texture.
5. Water/cement ratio.

Bleeding:

Bleeding is defined as the appearance of water on the surface of concrete after it has consolidated but before it is set. Since mixing water is the lightest component of the concrete, this is a special form of segregation. Bleeding is generally the result of aggregates settling into the mix and releasing their mixing water. Some bleeding is normal for good concrete.

However, if bleeding becomes too localized, channels will form resulting in "craters". The upper layers will become too rich in cement with a high w/c ratio causing a weak, porous structure. Salt may crystallize on the surface which will affect bonding with additional lifts of concrete. This formation should always be removed by brushing and washing the surface. Also, water pockets may form under large aggregates and reinforcing bars reducing the bond.

Bleeding may be reduced by:

- Increasing cement fineness.
- Increasing the rate of hydration.
- Using air-entraining admixtures.
- Reducing the water content.

TOPIC 3: Measurement of Workability

Workability, a term applied to many concrete properties, can be adequately measured by three characteristics:

1. Compatibility, the ease with which the concrete can be compacted and air void removed.
2. Mobility, ease with which concrete can flow into forms and around reinforcement.
3. Stability, ability for concrete to remain stable and homogeneous during handling and vibration without excessive segregation.

Different empirical measurements of workability have been developed over the years. None of these tests measure workability in terms of the fundamental properties of concrete. However, the following tests have been developed:

Slump Test:

The oldest, most widely used test for determining workability. The device is a hollow cone-shaped mould. The mould is filled in three layers of each volume. Each layer is rodded with a 16mm steel rod 25 times. The mould is then lifted away and the change in the height of the concrete is measured against the mould. The slump test is a measure of the resistance of concrete to flow under its own weight.

There are three classifications of slump; "true" slump, shear slump, and collapse slump. True slump is a general reduction in height of the mass without any breaking up. Shear slump indicates a lack of cohesion, tends to occur in harsh mixes. This type of result implies the concrete is not suitable for placement. Collapse slump generally indicates a very wet mix. With different aggregates or mix properties, the same slump can be measured for very different concretes.

Compaction Test:

Concrete strength is proportional to its relative density. A test to determine the compaction factor was developed in 1947. It involves dropping a volume of concrete from one hopper to another and measuring the volume of concrete in the final hopper to that of a fully compacted volume. This test is difficult to run in the field and is not practical for large aggregates (over 1in.).

Flow Test:

Measures a concretes ability to flow under vibration and provides information on its tendency to segregate. There are a number of tests available but none are recognized by ASTM. However, the flow table test described for mortar flows is occasionally used.

Re-moulding Test:

Developed to measure the work required to cause concrete not only to flow but also to conform to a new shape.

Vebee Test:

A standard slump cone is cast, the mould removed, and a transparent disk placed on top of the cone. The sample is then vibrated till the disk is completely covered with mortar. The time required for this is called the Vebee time.

Thaulow Drop Table - Similar to the Vebee test except a cylinder of concrete is remoulded on a drop table. The number of drops to achieve this remoulding is counted.

Penetration Test:

A measure of the penetration of some indenter into concrete. Only the Kelly ball penetration test is included in the ASTM Standards. The Kelly ball penetration test measures the penetration of a 30 lb. hemisphere into fresh concrete. This test can be performed on concrete in a buggy, open truck, or in form if they are not too narrow. It can be compared to the slump test for a measure of concrete consistency.

TOPIC 4: Setting of Concrete

Setting is defined as the onset of rigidity in fresh concrete. Hardening is the development of useable

and measurable strength; setting precedes hardening. Both are gradual changes controlled by hydration. Fresh concrete will lose measurable slump before initial set and measurable strength will be achieved after final set.

Setting is controlled by the hydration of C_3S. The period of good workability is during the dormant period, (stage 2). Initial set corresponds to the beginning of stage 3, a period of rapid hydration. Final set is the midpoint of this acceleration phase. A rapid increase in temperature is associated with stage 3 hydration, with a maximum rate at final set.

If large amounts of ettringite rapidly form from C_3A hydration, the setting times will be reduced. Cements with high percentages of C_3A, such as expansive or set-regulated cements, are entirely controlled by ettringite formation.

Abnormal Setting Behavior

False Set: Early stiffening of concrete, fluidity may be restored by remixing. Basically, it is a result of hydration of dehydrated gypsum, which forms rigid crystals. Because there are few of these crystals and they are weak, the matrix can be destroyed by remixing. Accelerated hydration of C3A will cause rapid development of ettringite and false-set.

Flash Set: Stiffening of concrete due to the rapid development of large quantities of C3A hydration products which cannot be returned to a fluid state with mixing. This is generally no longer a problem since the introduction of gypsum to control C3A hydration. However, some admixtures will increase C3A hydration and flash set may be a problem.

UNIT-IV

HARDENED CONCRETE

1. **Explain about the strength of hardened concrete**
2. **Explain Dimensional stability—Shrinkage and creep**
3. **What are the factors affecting in creep explain briefly.**

TOPIC 1: Strength of hardened concrete

Strength is defined as the ability of a material to resist stress without failure. The failure of concrete is due to cracking. Under direct tension, concrete failure is due to the propagation of a single major crack. In compression, failure involves the propagation of a large number of cracks, leading to a mode of disintegration commonly referred to as 'crushing'.

The strength is the property generally specified in construction design and quality control, for the following reasons:

(1) It is relatively easy to measure, and

(2) Other properties are related to the strength and can be deduced from strength data.
The 28-day compressive strength of concrete determined by a standard uni-axial compression testis accepted universally as a general index of concrete strength.

TOPIC 2:Dimensional stability--Shrinkage and creep

Dimensional stability of a construction material refers to its dimensional change over a long period of time. If the change is so small that it will not cause any structural problems, the material is dimensionally stable. For concrete, drying shrinkage and creep are two phenomena that compromise its dimensional stability.

Shrinkage and creep are often discussed together because they are both governed by the deformation of hydrated cement paste within concrete. The aggregate in concrete does not shrink or creep, and they serve to restrain the deformation.

Drying shrinkage

After concrete has been cured and begins to dry, the excessive water that has not reacted with the cement will begin to migrate from the interior of the concrete mass to the surface. As the moisture evaporates, the concrete volume shrinks. The loss of moisture from the concrete varies with distance from the surface. The shortening per unit length associated with the reduction in volume due to moisture loss is termed the shrinkage. Shrinkage is sensitive to the relative humidity. For higher relative humidity, there is less evaporation and hence reduced shrinkage. When concrete is exposed to 100% relative humidity or submerged in water, it will actually swell slightly.

Shrinkage can create stress inside concrete. Because concrete adjacent to the surface of a member dries more rapidly than the interior, shrinkage strains are initially larger near the surface than in the interior. As a result of the differential shrinkage, a set of internal self-balancing forces, i.e. compression in the interior and tension on the outside, is set up.

In additional to the self-balancing stresses set up by differential shrinkage, the overall shrinkage creates stresses if members are restrained in the direction along which shrinkage occurs. If the tensile stress induced by restrained shrinkage exceeds the tensile strength of concrete, cracking will take place in the restrained structural element. If shrinkage cracks are not properly controlled, they permit the passage of water, expose steel reinforcements to the atmosphere, reduce shear strength of the member and are bad for appearance of the structure. Shrinkage cracking is often controlled with the incorporation of sufficient reinforcing steel, or the provision of joints to allow movement. After drying shrinkage occurs, if the concrete member is allowed to absorb water, only part of the shrinkage is reversible. This is because water is lost from the capillary pores, the gel pores (i.e., the pore within

the C-S-H), as well as the space between the C-S-H layers. The water lost from the capillary and gel pores can be easily replenished. However, once water is lost from the interlayer space, the bond between the layers becomes stronger as they get closer to one another. On wetting, it is more difficult for water to re-enter. As a result, part of the shrinkage is irreversible.

The magnitude of the ultimate shrinkage is primarily a function of initial water content of the concrete and the relative humidity of the surrounding environment. For the same w/c ratio, with increasing aggregate content, shrinkage is reduced. For concrete with fixed aggregate/cement ratio, as the w/c ratio increases, the cement becomes more porous and can hold more water. Its ultimate shrinkage is hence also higher. If a stiffer aggregate is used, shrinkage is reduced.

The shrinkage strain, ε , is time dependent. Approximately 90% of the ultimate shrinkage occurs during the first year.

Both the rate at which shrinkage occurs and the magnitude of the total shrinkage increase as the ratio of surface to volume increases. This is because the larger the surface area, the more rapidly moisture can evaporate.

Based on a number of local investigations in Hong Kong, the value of shrinkage strain (after one year) for plain concrete members appears to lie between 0.0004 and 0.0007 (although value as high as 0.0009 has been reported). For reinforced concrete members, the shrinkage strain values are reduced, as reinforcement is helpful in reducing shrinkage.

Creep

Creep is defined as the time-dependent deformation under a constant load. Water movement under stress is a major mechanism leading to creeping of concrete. As a result, factors affecting shrinkage also affect creep in a similar way. Besides moisture movement, there is evidence that creep may also be due to time-dependent formation and propagation of microcracks, as well as microstructural adjustment under high stresses (where stress concentration exists). These mechanisms, together with water loss from the gel interlayer, lead to irreversible creep. Creeping develops rapidly at the beginning and gradually decreases with time. Approximately 75% of ultimate creep occurs during the first year. The ultimate creep strain (after 20 years) can be 3-6 times the elastic strain.

Creep can influence reinforced concrete in the following aspects.

i). Due to the delayed effects of creep, the long-term deflection of a beam can be 2-3 times larger than the initial deflection.

ii). Creeping results in the reduction of stress in pre-stressed concrete which can lead to

increased cracking and deflection under service load.

iii). In a R.C column supporting a constant load, creep can cause the initial stress in the steel to double or triple with time because steel is non-creeping and thus take over the force reduced in concrete due to creep.

Creep is significantly influenced by the stress level. For concrete stress less than 50% of its strength, creep is linear with stress. In this case, the burger's body, which is a combination of Maxwell and Kelvin models, is a reasonable representation of creep behaviour. For stress more than 50% of the strength, the creep is a nonlinear function of stress, and linear viscoelastic models are no longer applicable. For stress level higher than 75-80% of strength, creep rupture can occur. It is therefore very important to keep in mind that in the design of concrete column, 0.8 f is taken to be the strength limit.

TOPIC 3: Factors Affecting Creep Of Concrete

a) w/c ratio: The higher the w/c ratio, the higher is the creep.

b) Aggregate stiffness (elastic modulus): The stiffer the aggregate, the smaller the creep.

c) Aggregate fraction: higher aggregate fraction leads to reduced creep.

d) Theoretical thickness: The theoretical thickness is defined as the ratio of section area to the semi- perimeter in contact with the atmosphere. Higher the theoretical thickness, smaller the creep and shrinkage.

e) Temperature: with increasing temperature, both the rate of creep and the ultimate creep increase. This is due to the increase in diffusion rate with temperature, as well as the removal of more water at a higher temperature.

f) Humidity: with higher humidity in the air, there is less exchange of moisture between the concrete and the surrounding environment. The amount of creep is hence reduced.

g) Age of concrete at loading: The creep strain at a given time after the application of loading is lower if loading is applied to concrete at a higher age. For example, if the same loading is applied to 14 day and 56 day concrete (of the same mix), and creep strain is measured at 28 and 70 days respectively (i.e., 14 days after load application), the 56 day concrete is found to creep less. This is because the hydration reaction has progressed to a greater extent in the 56 day concrete. With less capillary pores to hold water, creep is reduced.

UNIT-V

MIX DESIGN & SPECIAL CONCRETE

1. **Explain the test procedure for concrete mix design**
2. **Define special concrete and its types**
3. **Explain about polymer concrete**
4. **Define self-compacting concrete and its types**

TOPIC 1: Procedure for Concrete Mix Design –IS456:2000

1. Determine the mean target strength ft from the specified characteristic compressive strength at 28-day $f_{ck}$and the level of quality control. $f_t = f_{ck} + 1.65S$

Where, S is the standard deviation obtained from the Table of approximate contents given after the design mix.

2. Obtain the water cement ratio for the desired mean target using the empirical relationship between compressive strength and water cement ratio so chosen is checked against the limiting water cement ratio. The water cement ratio so chosen is checked against the limiting water cement ratio for the requirements of durability given in table and adopts the lower of the two values.

3. Estimate the amount of entrapped air for maximum nominal size of the aggregate fromthe table.

4. Select the water content, for the required workability and maximum size of aggregates(for aggregates in saturated surface dry condition) from table.

5. Determine the percentage of fine aggregate in total aggregate by absolute volume from table for the concrete using crushed coarse aggregate.

6. Adjust the values of water content and percentage of sand as provided in the table for any difference in workability, water cement ratio, grading of fine aggregate and for rounded aggregate the values are given in table.

7. Calculate the cement content form the water-cement ratio and the final water content as arrived after adjustment. Check the cement against the minimum cement content from the requirements of the durability, and greater of the two values is adopted.

8. From the quantities of water and cement per unit volume of concrete and the percentage of sand already determined in steps 6 and 7 above, calculate the content of coarse and fine aggregates per unit volume of concrete from the following relations:

$$V = \left[W + \frac{C}{S_c} + \frac{1}{p}\frac{f_a}{S_{fa}}\right] \times \frac{1}{1000}$$

$$V = \left[W + \frac{C}{S_c} + \frac{1}{1-p}\frac{C_a}{S_{ca}}\right] \times \frac{1}{1000}$$

Where, V = absolute volume of concrete = gross volume ($1m^3$) minus the volume of entrapped air

S_c = specific gravity of cement

W = Mass of water per cubic metre of concrete, kg C = mass of cement per cubic metre of concrete, kg
p = ratio of fine aggregate to total aggregate by absolute volume

fa, Ca = total masses of fine and coarse aggregates, per cubic metre of concrete, respectively, kg, and

S_{fa}, S_{ca} = specific gravities of saturated surface dry fine and coarse aggregates, respectively

9. Determine the concrete mix proportions for the first trial mix.
10. Prepare the concrete using the calculated proportions and cast three cubes of 150 mm size and test them wet after 28-days moist curing and check for thestrength.
11. Prepare trial mixes with suitable adjustments till the final mix proportions arrived.

TOPIC 2: SPECIAL CONCRETE

Special types of concrete are those with out-of-the-ordinary properties or those produced by unusual techniques. Concrete is by definition a composite material consisting essentially of a binding medium and aggregate particles, and it can take many forms.

These concretes do have advantages as well as disadvantages.

Types of special concrete

1. High Volume Fly Ash Concrete.
2. Silica fumes concrete.
3. GGBS, Slag based concrete.
4. Ternary blend concrete.
5. Light weight concrete.
6. Polymer concrete.

7. Self-Compacting Concrete.
8. Coloured Concrete.
9. Fibre-reinforced Concrete.
10. Pervious Concrete.
11. Water-proof Concrete.
12. Temperature Controlled Concrete

TOPIC 3: Polymer concrete

Polymer concrete is part of group of concretes that use polymers to supplement or replace cement as a binder. The types include polymer-impregnated concrete, polymer concrete, and polymer-Portland-cement concrete.

- In polymer concrete, thermosetting resins are used as the principal polymer component due to their high thermal stability and resistance to a wide variety of chemicals.
- Polymer concrete is also composed of aggregates that include silica, quartz, granite, limestone, and other high quality material.
- Polymer concrete may be used for new construction or repairing of old concrete.
- The low permeability and corrosive resistance of polymer concrete allows it to be used in swimming pools, sewer structure applications, drainage channels, electrolytic cells for base metal recovery, and other structures that contain liquids or corrosive chemicals.
- It is especially suited to the construction and rehabilitation of manholes due to their ability to withstand toxic and corrosive sewer gases and bacteria commonly found in sewer systems.
- It can also be used as a replacement for asphalt pavement, for higher durability and higher strength.
- Polymer concrete has historically not been widely adopted due to the high costs and difficulty associated with traditional manufacturing techniques.

TOPIC 4: Self compacting concrete

Self-compacting concrete (SCC) is an innovative concrete that does not require vibration for placing and compaction. It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement.

The hardened concrete is dense, homogeneous and has the same engineering properties and durability as traditional vibrated concrete.

Very close to the Kolhapur there is project of steel industry, sand used for the formation of mould when the moulds are opened the waste sand is dumped for the filling the low lying areas while doing this the agriculture areas is converted into barren area. Because there is no space for the waste other than the land filling. similar case is in case of aluminium industry where red mud is concluded to be waste, which contains lot amount of bauxite and that is why red mud is also dump in the nearby areas here it is causing big threat for the society and it is disturbing the eco system of the environment. So it is the need to use this particular otherwise waste material for the constructive in such fashion in the case of concrete so that concrete which became cost effective as well as eco-friendly.

Types

Powder type of self-compacting concrete: This is proportioned to give the required self-compactability by reducing the water-powder ratio and provide adequate segregation resistance.

Viscosity agent type self-compacting concrete: This type is proportioned to provide self-compaction by the use of viscosity modifying admixture to provide segregation resistance.

Combination type self-compacting concrete: This type is proportioned so as to obtain self-compactability mainly by reducing the water powder ratio.

13. Unit wise-Question bank

UNIT-I
CEMENT

Two marks question with answers

1. **What is the chemical composition of cement?**

Composition of Portland cement consists essentially of compounds of lime (calcium oxide, CaO) mixed with silica (silicon dioxide, SiO_2) and alumina (aluminum oxide, Al_2O_3). The lime is obtained from a calcareous (lime-containing) raw material, and the other oxides are derived from an argillaceous (clayey) material.

2. **What is grade of cement? List any three grades of cement with their strengths.**

- 721 hr not less than 23 MPa for 43 grade, 27 MPa for 53 grade
- 1682 hrs not less than 33MPa for 43 grade, 37MPa for 53 grade
- 6724 hrs not less than 43MPa for 43 grade, 53 MPa for 53 grade

3. **Explain bogue's compounds of cement?**

Thorn bohm's description of the minerals in cement was found to be similar to Bogue's compound. Hence, Bough's Compounds C3S, C2S, C3A, C4AF are sometimes called in literature as Alite, Belite, Celite, and Felite.

4. **Define hydration of cement?**

The water causes the hardening of concrete through a process called hydration. Hydration is a chemical reaction in which the major compounds in cement form chemical bonds with water molecules and become hydrates or hydration products.

5. **Write brief about Portland cement?**

Concrete is made by Portland cement, water and aggregates. Portland cement is hydraulic cement that hardens in water to form a water-resistant compound. The hydration products act as binder to hold the aggregates together to form concrete. The name Portland cement comes from the fact that the colour and quality of the resulting concrete are similar to Portland stone, a kind of limestone found in England.

Three marks question with answers

1. **List various types of cement.**

- Rapid Hardening Cement
- Quick setting cement
- Low Heat Cement
- Sulphates resisting cement
- Blast Furnace Slag Cement
- High Alumina Cement
- White Cement
- Coloured cement
- Pozzolanic Cement
- Air Entraining Cement
- Hydrographic cement

2. **What is the purpose of plasticizer in concrete?**

Plasticizers or water reducers, and superplasticizer or high range water reducers, are chemical admixtures that can be added to concrete mixtures to improve workability. Unless the mix is "starved" of water, the strength of concrete is inversely proportional to the amount of water added or water-cement (w/c) ratio.

3. **Explain about Normal consistency test?**

This test is to determine the water required to achieve a desired plasticity state (called normal consistency) of cement paste. It is obtained with the Vicat apparatus by measuring the penetration of a loaded needle.

4. **Explain about Soundness of cement?**

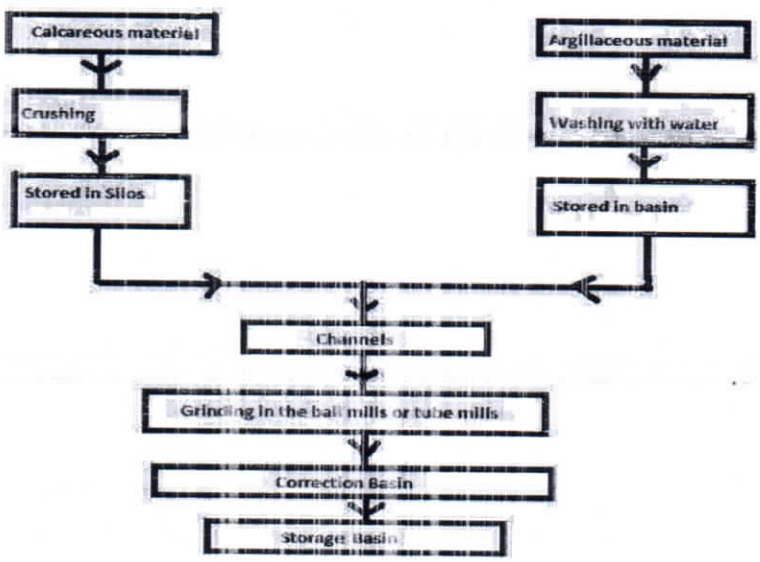
Unsoundness in cement paste refers to excessive volume change after setting and cement is caused by the slow hydration of MgO or free lime. Their reactions are $MgO + H_2O = Mg(OH)_2$ and $CaO + H_2O = Ca(OH)_2$. Another factor that can cause unsoundness is the delayed formation of cement and concrete have hardened. The pressure from crystal growth will lead to cracking and damage. The soundness of the cement must be tested by accelerated methods. Le Chatelier test this test is to measure the potential for volumetric change of cement paste. Another method is Autoclave Expansion test which use an autoclave to increase the temperature to accelerate the process.

Five marks question with answers

1. **Explain the manufacturing process of cement?**

Manufacturing Portland cement:

The basic ingredients of both the dry and wet processes are the same. By mass, lime and silica make up approximately 85% of Portland cement. The materials that are commonly used are limestone, shells, chalk, shale, clay, slate, silica sand, and iron ore.



2. **What is hydrated cement? Explain the heat of hydration**

A compound produced by combining a substance chemically with water. Many minerals and crystalline substances are hydrates. To combine a compound with water, especially to form a hydrate.to supply water to a person in order to restore or maintain a balance of fluids.

Heat of Hydration

The heat of hydration is the heat generated when water and portland cement react. Heat of hydration is most influenced by the proportion of C_3S and C_3A in the cement, but is also influenced by water-cement ratio, fineness and curing temperature. As each one of these factors is increased, heat of hydration increases. In large mass concrete structures such as gravity dams, hydration heat is produced significantly faster than it can be dissipated (especially in the center of large concrete masses), which can create high temperatures in the center of these large concrete masses that, in turn, may cause undesirable stresses as the concrete cools to ambient temperature. Conversely, the heat of hydration can help maintain

3. **Explain the testing method of Compressive Strength of Cement**

This test is carried out to determine the **compressive strength of cement.**

Test Procedure for compressive strength of cement:

(i) The mortar of cement and sand is prepared. The proportion is 1:3 which means that (X) gm of cement is mixed with 3(X) gm of sand.

(ii) The water is added to the mortar. The water cement ratio is kept as 0.4 which means that (X) gm of water is added to dry mortar.

(iii) The mortar is placed in moulds. The test specimens are in the form of cubes with side as 70.6 mm or 76 mm. The moulds are of metal and they are constructed in such a way that the specimens can be easily taken out without being damaged. For 70.6 mm and 76 mm cubes, the cement required is 185 gm and 235 gm respectively.

The mortar, after being placed in the moulds, is compacted in vibrating machine for 2 minutes.

(iv) Themoulds are placed in a damp cabin for 24 hours.

(vi) The specimens are removed from the moulds and they are submerged in clean water for curing.

(vii) The cubes are then tested in **compression testing machine** at the end of 3 days and 7 days. The testing of cubes is carried out on their three sides without packing. Thus three cubes are tested each time to find out the compressive strength at the end of 3 days and 7 days. The average value is then worked out. During the test, the load is to be applied uniformly at the rate of 350 kg/cm2 or 35 N/mm2.

(viii) The **compressive strength of cement** at the end of 3 days should not be less than 115 kg/cm2 or 11.50 N/mm2 and that at the end of 7 days should no be less than 175 kg/cm2 or N/mm2.

Objective question with answers

1. For quality control of Portland cement, the test essentially done is [ ]
   A. Setting time B. Soundness C. tensile strength D. All the above
2. Lower the normal consistency value, [ ]
   A. Lower will be the strength of concrete B. Medium will be the strength of concrete
   C. Higher will be the strength of concrete D. None of the above
3. The mixture of different ingredients of cement, is burnt at [ ]
   A.1000°C B.1200°C C.1400°C D.1900°C
4. The size of vic at needle, used to conduct setting of cement is [ ]
   A. 10mmDia B.1mm^2 C.3mm2 D. 10 mm Dia

5. To obtain cement dry powder, lime stones and shales or their slurry, is burnt in a rotary kiln at a temperature between [ ]
   A. 1100° and 1200°C B. 1200° and 1300°C
   C. 1300° and 1400°C D. 1400° and 1500°C
6. Vicat's apparatus is used for [ ]
   A. Fineness test B.consistency test C. setting time test D. B and C

7. Fine aggregates are the aggregates having the size less than: [ ]
   A. 5mm B.4.75mm C. 3.50mm D. 2mm

8. For the improvement of workability of concrete, the shape of aggregate recommended is
   A. Angular B.Round C.Flaky D.Irregular

9. In an ordinary Portland cement, the composition oflimeis [ ]
   A. 50% B.63% C.21% D.33%

10. Inconcretecubetest,thestandardsizeofcubeis [ ]
   A. 15 cm x 15 cm x15cm B. 10 cm x 10 cm x 10cm
   C. 20 cm x20cmx 20cm D. None

KEY

Q.NO	1	2	3	4	5	6	7	8	9	10
ANS	D	A	C	B	D	D	B	B	B	A

Fill in the blanks question with answers

1. Approximate percentage range of CaO in OPC is=
2. Approximate percentage range of Al_2O_3 in OPCis =
3. Approximate percentage of SIO_2in OPC is=
4. _ number of grades available in OPC
5. Which compound is liberates higher Vheat=
6. Which compound is liberate slower heat=
7. In M20 concrete M refers to=
8. At an early age greater strength contribute compound is=
9. The role of gypsum in cement is=
10. Least strength contributes compounds is=

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KEY

Q.NO	ANSWERS
1	60-67%
2	3-8_%
3	17-25%
4	3
5	C_3A
6	C4AF
7	mix proportion
8	C_2S
9	control the "setting of cement"
10	C4AF

UNIT-II

AGGREGATE AND ADMIXTURES

Two marks question with answers

1. **How does alkali aggregate reaction affect concrete?**

➢ The alkali–silica reaction (ASR), more commonly known as "concrete cancer", is a swelling reaction that occurs over time in concrete between the highly alkaline cement paste and the reactive non-crystalline (amorphous) silica found in many common aggregates, given sufficient moisture.

2. **What is the common classification of aggregates?**

Aggregates are classified into 2 types according to size

- Fine aggregate
- Coarse aggregate

Aggregates are classified according to shape

- Rounded aggregates
- Irregular or partly rounded aggregates
- Angular aggregates
- Flaky aggregates
- Elongated aggregates
- Flaky and elongated aggregates

3. List out the types of admixtures?

a) Accelerating admixtures

b) Retarding admixtures

c) Water-reducing admixtures

d) Air-entraining admixtures

e) Super plasticizing admixtures

f) Air-entraining admixtures

g) Accelerating admixtures

h) Water reducing and set controlling admixtures

i) Admixtures for flowing concrete

j) Miscellaneous admixtures

4. Define admixtures?

A material other than water, aggregates, or cement that is used as an ingredient of concrete or mortar to control setting and early hardening, workability, or to provide additional cementing properties

5. Explain Alkali Aggregate Reaction

Alkali–aggregate reaction is a term mainly referring to a reaction which occurs over time in concrete between the highly alkaline cement paste and non-crystalline silicon dioxide, which is found in many common aggregates. This reaction can cause expansion of the altered aggregate, leading to spalling and loss of strength of the concrete. The alkali–aggregate reaction is a general, but relatively vague, expression which can lead to confusion. More precise definitions include the following:

1. Alkali–silica reaction (ASR, the most common reaction of this type);
2. Alkali–silicate reaction, and;
3. Alkali–carbonate reaction

Five marks question with answers

1. Explain the soundness of aggregate?

Soundness of Aggregate

The soundness test determines an aggregate's resistance to disintegration by weathering and, in particular, freeze-thaw cycles. Aggregates that are durable (resistant to weathering) are less likely to degrade in the field and cause premature HMA pavement distress and potentially, failure.

The soundness test repeatedly submerges an aggregate sample in a sodium sulphate or magnesium sulphate solution. This process causes salt crystals to form in the aggregate's water permeable pores. The formation of these crystals creates internal forces that apply pressure on aggregate pores and tend to break the aggregate. After a specified number of submerging and drying repetitions, the aggregate is sieved to determine the percent loss of material.

2. What is Admixtures and explain the classification of admixtures?

A material other than water, aggregates, or cement that is used as an ingredient of concrete or mortar to control setting and early hardening, workability, or to provide additional cementing properties.

Chemical admixtures: Accelerators, Retarders, Water-reducing agents, Super plasticizers, Air entraining agents etc.

Water-reducing admixture / Plasticizers

- To achieve a higher strength by decreasing the water cement ratio at the same workability as an admixture free mix.
- To achieve the same workability by decreasing the cement content so as to reduce the heat of hydration in mass concrete.
- To increase the workability so as to ease placing in accessible locations
- Water reduction more than 5% but less than 12%.

Super Plasticizers:

These are more recent and more effective type of water reducing admixtures also known as *high range water reducer.*

Accelerator

An admixture which, when added to concrete, mortar, or grout, increases the rate of hydration of hydraulic cement, shortens the time of set in concrete, or increases the rate of hardening or strength development.

Air Entrained Admixtures:

An addition for hydraulic cement or an admixture for concrete or mortar which causes air, usually in small quantity, to be incorporated in the form of minute bubbles in the concrete or mortar during mixing, usually to increase its workability **and** frost resistance. Air-entraining admixtures are **surfactants** that change the surface tension of the water. Traditionally, they were based on fatty acid salts or vinsol resin but these have largely been replaced by synthetic

surfactants or blends of surfactants to give improved stability and void characteristics to the entrained air. Air entrainment is used to produce a number of effects in both the plastic and the hardened concrete

Mineral admixtures

Fly-ash Blast-furnace slag, Silica fume and Rice husk Ash etc

Fly Ash:

The finely divided residue resulting from the combustion of ground or powdered coal. Fly ash is generally captured from the chimneys of coal-fired power plants; it has POZZOLANIC properties, and is sometimes blended with cement for this reason.

Fly ash includes substantial amounts of silicon dioxide (SiO_2) (both amorphous and crystalline) and calcium oxide (CaO). Toxic constituents include arsenic, beryllium, boron, cadmium, chromium, cobalt, lead, manganese, mercury, molybdenum, selenium, strontium, thallium, and vanadium.

Silica Fume:

The terms condensed silica fume, microsilica, silica fume and volatilized silica are often used to describe the by-products extracted from the exhaust gases of silicon, ferrosilicon and other metal alloy furnaces. However, the terms micro silica and silica fume are used to describe those condensed silica fumes that are of high quality, for use in the cement and concrete industry.

Rice Husk Ash:

This is a bio waste from the husk left from the grains of rice. It is used as a pozzolanic material in cement to increase durability and strength. The silica is absorbed from the ground and gathered in the husk where it makes a structure and is filled with cellulose. When cellulose is burned, only silica is left which is grinded to fine powder which is used as pozzolana.

3. **How does alkali aggregate reaction affect concrete? Also explain thermal properties of aggregates?**

Alkali–aggregate reaction is a term mainly referring to a reaction which occurs over time in concrete between the highly alkaline cement paste and non-crystalline silicon dioxide, which is found in many common aggregates. This reaction can cause expansion of the altered aggregate, leading to spalling and loss of strength of the concrete.

The alkali–aggregate reaction is a general, but relatively vague, expression which can lead to confusion. More precise definitions include the following:

1. Alkali–silica reaction (ASR, the most common reaction of this type);
2. Alkali–silicate reaction, and;
3. Alkali–carbonate reaction.

Thermal properties:

Rock and aggregates posses' three thermal properties which are coefficient of expansion, specific heat and thermal conductivity

The thermal conductivity varies with the density of concrete, with heavier aggregates resulting in higher thermal conductivity. The conductivity of concretes known generally to decrease with increased temperature, through the loss of pore water and the dehydration of cement paste.

4. **What is Bulk Density of Aggregates**

Bulk density of aggregates is the mass of aggregates required to fill the container of a unit volume after aggregates are batched based on volume It depends on the packing of aggregate i.e. either loosely packed aggregates or well dense compacted aggregates. In case, if the specific gravity of material is known, then it depends on the shape and size of particles. It is because, if all the particles are of same size than packing can be done up to a very limited extent. If the addition of smaller particles is possible within the voids of larger particles than these smaller particles enhance the bulk density of the packed material. Shape of the particles also influence very widely, because closeness particles depends on the shape of aggregates.

Loose Bulk Density

Loose bulk density can be determined by filling the container with dried aggregates until it overflows from the container. Now level the top surface of container by rolling a rod on it. After that, weight the aggregate mass that is inside the container and divide it by the volume of container. This will give you the bulk density of the loose aggregates.

Compacted Bulk Density

Compacted bulk density can be determined by filling the container in three layers and tamped each layer with a 16mm diameter rounded nosed rod. After filling in three layersnow leveled the top surface and evaluate compacted bulk density by using the same expression as for loose bulk density.

5. **Explain the classification of aggregates?**

Aggregates are classified according to shape

1.Rounded aggregates

2.Irregular or partly rounded aggregates

3.Angular aggregates

4.Flaky aggregates

5.Elongated aggregates

6.Flaky and elongated aggregates

Aggregates are classified according to size

1.Fine aggregate

2.Coarse aggregate

Aggregates are classified according to source

1. Igneous rocks
2. Sedimentary rocks
3. Metamorphic rocks

Aggregates are classified according to weight

1. Normal weight aggregates
2. Light weight aggregates
3. Heavy weight aggregates

Objectives question with answers

1. The rock which is notcalcareous,is: [ ]

   A.limestone B.Macl C.Chalk D.Laterite

2. The resistance of an aggregate to compressive forces isknownas [ ]

   A.Crushingstrength B. Impact value C. Shear resistance D.None of the above

3. For the improvement of workability of concrete, the shape of aggregate recommendedis

   A.Angular B.Round C.Flaky D.Irregular

4. Determination of Moisture Content of aggregateby [ ]

   A.Dryingmethod B. Displacementmethod

   C. CalciumCarbidemethod D. All of theabove.

5. Factors which promote alkali aggregate reactionare [ ]

   A. Reactive typeofaggregate B. High alkalicontent

   C. AvailabilityofMoisture D. All theabove

6. In concrete the fine aggregates is usedto [ ]

   A. Fill up the voidsincement B. Fill up the voids in coarseaggregate

   C. Fill up the voidsinsand D. All theabove

7. In Shape Test, the dimension of thickness gauge is calculatedas [ ]

   A. 2.4timestheaverageofthesizeofretainedandpassingSieve

   B. 1.2timestheaverageofthesizeofretainedandpassingSieve

   C. 0.6timestheaverageofthesizeofretainedandpassingSieve

   D. 1.8timestheaverageofthesizeofretainedandpassingSieve

8. In concrete the material used as a fineaggregateis [ ]

   A. Cement B.Sand C.jelly D.Gypsum

9. The commonly used material in the manufacture of cementis[]

A.sandstone B.Slate C.limestone D.graphite.

KEY

Q.NO	1	2	3	4	5	6	7	8	9	10
ANS	B	C	B	D	D	D		B	C	

Fill in the blanks question with answers

1. Thesizeofthecoarseaggregateismorethan=
2. Thesizeofthefineaggregateislessthan=
3. The minimum 28 days' compressive strength of 43 grade cementis=
4. The easiness of handling concrete is knownas=
5. Device which is used to find out normal consistency of cementis=

KEY

Q.NO	ANSWERS
1	4.75mm
2	4.75mm
3	43Mpa
4	workability
5	vicats apparatus
6	
7	

UNIT-III
FRESH CONCRETE

Two marks question with answers

1. Definebleeding.

Bleeding is one form of segregation, where water comes out to the surface of the concrete, being lowest specific gravity among all the ingredients of concrete. Bleeding can be easily identified in the field by the appearance of a thin layer of water in the top surface of freshly mixed concrete.

2. DefineSegregation.

Segregation in concrete is commonly thought as separation of some size groups of aggregates from cement mortar in isolated locations with corresponding deficiencies of these materials in other locations. Segregation results in proportions of the laid concrete being in variation to those as designed Segregation could result from internal factors such as concrete that is not proportioned properly and not mixed adequately, or too workable a mix. It also could result from external factors such as too much vibration, improper transportation, placement, or adverse weather conditions. The corresponding increase in proportion of cement paste in upper areas would tend to make them susceptible to increased shrinkage and formation of cracks. These cracks could be 10 μm to 500 μm wide, formed perpendicular to the surface, and be in the form of map patterns."

1. **Define workability.**

According to Granville "it is that property of the concrete which determines the amount of useful internal work necessary to produce full compaction."

Powers defined it as "that property of plastic concrete mixture which determines the ease with which it can be placed and the degree to which it resists segregation"

ACI (American Concrete Institute) defines it as 'that property of freshly mixed concrete or mortar which determines the ease and homogeneity with which it can be mixed, placed, consolidated and finished'.

ASTM (American Society for Testing and Materials) defines it as "that property determining the effort required to manipulate a freshly mixed quantity of concrete with minimum loss of homogeneity".

4. List the different factors affecting workability.

- Cement content of concrete.
- Water content of concrete.
- Mix proportions of concrete.
- Size of aggregates.
- Shape of aggregates.
- Grading of aggregates.
- Surface texture of aggregates.
- Use of admixtures in concrete.

5. Define Compacting Factor of workable concrete?

The ratio of the weight of partially compacted concrete to the weight of the concrete when fully compacted in the same mould. The Compacting Factor Apparatus is used to determine the compaction factor of concrete with low, medium and high workability.

Three marks question with answers

1. **What is the slump test for?**

The slump test is a means of assessing the consistency of fresh concrete. It is used, indirectly, as a means of checking that the correct amount of water has been added to the mix.

2. **What is mixing of concrete and its methods?**

Through mixing of concrete is essential for the production of uniform concrete. The mixing should ensure that the mass becomes homogeneous, uniform in colour and consistency. There are two methods adopted for mixing concrete hand mixing and machine mixing

3. **Define compaction and its methods?**

Compaction of concrete is the process adopted for expelling the entrapped air from the concrete. In process of mixing, transporting, and placing of concrete air is likely to get entrapped in the concrete.

Methods of compaction:

- Hand compaction
- Compaction by vibrators
- Compaction by pressure and jolting
- Compaction by spinning

4. Flow Table Test

The flow table test or flow test, also known as the slump-flow test, is a method to determine consistency of fresh concrete. Flow table test is also used to identify transportable moisture limit of solid bulk cargoes. It is used primarily for assessing concrete that is too fluid (workable) to be measured using the slump test, because the concrete will not retain its shape when the cone is removed.

Application when fresh concrete is delivered to a site by a truck mixer, its consistency needs to be checked before it is poured into formwork.

If consistency is not at the desired level, concrete will not have the required strength and other qualities once it has set. If concrete is too pasty, cavities may form within it. Rebar may become corroded, and concrete will crack. Cavities also reduce the concrete strength.

5. What is meant by proportioning of concrete?

The process of relative proportions of cement, sand, coarse aggregate and water, so as to obtain a concrete of desired quality is known as the proportioning of concrete.

The proportions of coarse aggregate, cement and water should be such that the resulting concrete has the following properties:

- When concrete is fresh, it should have enough workability so that it can be placed in the formwork economically.
- The concrete must possess maximum density or in the other words, it should be strongest and most water-tight.
- The cost of materials and labour required to form concrete should be minimum.

<u>Five marks question with answers</u>

1. Explain in detail the slump test procedure and working principles

Concrete slump test is to determine the workability or consistency of concrete mix prepared at the laboratory or the construction site during the progress of the work. Concrete slump test is

carried out from batch to batch to check the uniform quality of concrete during construction. The slump test is the most simple workability test for concrete, involves low cost and provides immediate results

Factors which influence the concrete slump test:

1. Material properties like chemistry, fineness, particle size distribution, moisture content and temperature of cementitious materials. Size, texture, combined grading, cleanliness and moisture content of the aggregates,
2. Chemical admixtures dosage, type, combination, interaction, sequence of addition and its effectiveness,
3. Air content of concrete,
4. Concrete batching, mixing and transporting methods and equipment,
5. Temperature of the concrete,
6. Sampling of concrete, slump-testing technique and the condition of test equipment,
7. The amount of free water in the concrete, and
8. Time since mixing of concrete at the time of testing.

PROCEDURE FOR CONCRETE SLUMP TEST:

1. Clean the internal surface of the mould and apply oil.
2. Place the mould on a smooth horizontal non- porous base plate.
3. Fill the mould with the prepared concrete mix in 4 approximately equal layers.
4. Tamp each layer with 25 strokes of the rounded end of the tamping rod in a uniform manner over the cross section of the mould. For the subsequent layers, the tamping should penetrate into the underlying layer.
5. Remove the excess concrete and level the surface with a trowel.
6. Clean away the mortar or water leaked out between the mould and the base plate.
7. Raise the mould from the concrete immediately and slowly in vertical direction.
8. Measure the slump as the difference between the height of the mould and that of height point of the specimen being tested.

2. Explain brieflyFactors affecting workability

Workable concrete shows very less internal friction between particles and overcomes the frictional resistance with just the amount of compacting efforts provided. Workability of the concrete depends on a number of interrelating factors. Water content, aggregate properties, use of admixtures, fineness of cement are the factors affecting workability.

1. **Water content:**

The increase in water content increases the fluidity of the concrete thus providing greater lubrication. This helps to increase the workability of the concrete. Increasing the water content should be the last resort to improve the workability in the concrete as this will seriously affect the strength of the concrete. Even if more amount of water is to be added, more cement also should be added so that the water/ cement ratio remains the same and hence the strength of the concrete remains unaffected.

2. **Size of aggregates:**

The surface area of bigger aggregates is less and hence less amount of water is required for lubricating the surface to reduce the friction. Thus the concrete having large sized aggregate is more workable (of course, within certain limits).

3. **Mix proportions:**

Aggregate/ cement ratio is the measure of how lean or rich the concrete is. If aggregate/ cement ratio is higher, the concrete becomes leaner. In lean concrete less paste is available for the lubrication of the aggregate, while in rich concrete with low a/c ratio, more paste is available which makes the mix more cohesive and hence provides better workability.

4. **Shape of aggregates:**

Rounded aggregates have considerably less surface area and less voids in comparison to angular or flaky aggregates which provide better possibility of overcoming the frictional resistance. Further, angular and flaky aggregates make concrete very harsh.

5. **Surface texture of aggregates:**

The aggregates having smooth or glossy texture have less surface area compared to rough textured aggregates. This provides better workability as less amount of water is required for lubricating effect. But, taking into account the poor interlocking action provided by the glossy textured aggregate, its use is generally discouraged in high strength concrete.

6. **Grading of aggregates:**

Well graded aggregate is the one with least amount of voids in a given volume. If the grading of aggregate is good, the voids will be less and hence higher the workability.

7. **Use of admixtures:**

Use of admixtures in concrete is the major factor that affects the workability. The use of plasticizers and super-plasticizers amply increase the workability of the concrete. Air entraining agents produce air bubbles which act as rollers between particles and provide better mobility thus improving the workability.

8. **Time and temperature:**

Fresh concrete gets stiffened as the time flows. This is because some of the water used to mix the concrete gets evaporated and some gets absorbed by the aggregates. Thus the workability of concrete reduces with time. This loss of workability with time is known *as slump loss.* The effect of temperature on workability of concrete is noteworthy. As the temperature increases, the workability of the mix reduces.

3. Explain the Measurements of workability/Workability Tests

Slump test

- It is the most common method for measuring the workability of freshly mixed concrete. It can be performed both in lab and at site. Uniformity of the concrete regarding workability and quality aspects can be assessed from batch to batch by observing the nature in which the concrete slumps. It is not very suitable for very wet or very dry concrete.
- A steel mould in the form of frustum of cone is used in slump test which has the top diameter of 100 mm, bottom diameter of 200 mm and the height is 300 mm. According to Indian standard specification, the maximum size of the aggregate in concrete that can be used to perform slump test is restricted to 38 mm.
- The mould is cleaned and freed from any surface moistures and then the concrete is placed in three layers. Each layer is tamped 25 times with a standard tamping rod (16 mm dia, 0.6 meter length). Immediately after filling, the cone is slowly lifted and the concrete is allowed to subside. The decrease in the height of the center of the slumped concrete is called slump and is measured to the nearest 5mm.
- If the concrete subsides evenly all round, the slump measured is true slump. If one half of the cone slides down an inclined plane, a shear slump is said to have taken place and the test has to be repeated. Too wet mix shows collapsible nature of slump.

Compacting factor test

- This test is generally carried out in laboratory but can be used in site also. It is particularly useful for concrete mixes of very low workability (or very dry concrete) as they are insensitive to slump test.
- This test works on the principle of determining the degree of compaction achieved by a standard amount of work done by allowing the concrete to fall through a standard height.

Container	Top diameter (mm)	Bottom diameter (mm)	Height (mm)
Upper hopper	254	127	279

Lower hopper	229	127	229
Cylinder	152	152	305
Distance between bottom of upper hopper and top of lower hopper = 203 mm			
Distance between bottom of lower hopper and top of cylinder = 203 mm			

- The concrete is placed in the upper hopper gently so that no effort is applied to produce compaction. The bottom door is opened so that the concrete falls on the lower hopper. Again the bottom door of the lower hopper is opened and the concrete falls on the cylinder. After removing the excess concrete by the help of blades, the weight of the cylinder (known volume) is taken to nearest 10 grams. This weight is known as "weight of partially compacted concrete". The cylinder is emptied and then filled with the same sample rammed heavily so as to obtain full compaction. The cylinder is weighed to nearest 10 grams. This weight is known as "weight of fully compacted concrete".
- Compacting factor = (weight of partially compacted concrete) / (weight of fully compacted concrete)

Vee-Bee test

- Vee-Bee test is a good laboratory test suitable for stiff concrete mixes having low and very low workability. It consists of a vibrating table, a metal pot, a sheet of metal cone and a standard iron rod.
- In this test, Slump test as mentioned above is performed by placing the slump cone inside the sheet metal cylindrical pot. Then the vibration is started and the time on a stop watch is noted. The time taken by the concrete to take cylindrical shape after the conical shape disappears is noted. This time recorded is known as Vee-Bee Degree or Vee-Bee seconds.

Flow Test

- This is a laboratory test. It gives an indication of the quality of the concrete with respect to consistency, cohesiveness and the proneness to segregation. The spread of the flow of the concrete is measured and this is related to workability. This test is best suitable for flowing concrete made by the use of superplasticizing admixtures.

Kelly Ball Test

- This is a simple field test consisting of the determination of the indentation made by 15 cm diameter metal hemisphere weighing 13.6 kg when freely placed on fresh concrete. It is quite faster and provides precise measurement of workability than slump test. But it requires large amount of concrete to be

4. Briefly explain manufacturing procedureofconcrete.

Batching:

The measurement of materials making concrete is known as batching, these batching are two methods weigh batching and volume batching

Mixing:

Mixing of material is essential for the production of uniform concrete. The mixing should ensure that the mass becomes uniform in color and consistency .there are two methods adopted for mixing concrete hand mixing and machine mixing

Transporting:

The method adopted for transportation of concrete

Mortar pan, wheel barrow hand cart, crane bucket and rope way, truck mixer, belt conveyor, transit mixer, pump and pipeline, helicopter.

Placing of concrete:

Concrete is invariably laid as a foundation bed below the walls or columns before placing the concrete in the foundation all the loose earth must be removed from the bed.

Compaction:

Compaction of concrete is the process adopted for expelling the entrapped air from the concrete. the method of compaction is hand compaction, vibration compaction, compaction by pressure and jolting, compaction by spinning.

Curing:

curing can also be described as keeping the concrete moist and warm enough so that the hydration of cement can continue more elaborately it can be described as the process of maintaining a satisfactory moisture content and a favorable temperature in concrete during the period immediately following placement so that hydration of cement may continue until the desired properties are developed to a sufficient degree to meet the requirement of service. Curing methods are water curing, membrane curing, and application of heat.

Finishing:

It's the last operation making concrete. Its increases does not apply to all concrete operations

5. Explain briefly quality of mixing water inconcrete

Concrete is a chemically combined mass which is manufactured from binding materials and inert materials with water.

Function of Water in Concrete:

To wet the surface of aggregates to develop adhesion because the cement pastes adheres

quickly and satisfactory to the wet surface of the aggregates than to a dry surface. To prepare a plastic mixture of the various ingredients and to impart workability to concrete to facilitate placing in the desired position and

Water is also needed for the hydration of the cementing materials to set and harden during the period of curing.

The quantity of water in the mix plays a vital role on the strength of the concrete. Some water which have adverse effect on hardened concrete. Sometimes may not be harmless or even beneficial during mixing. So clear distinction should be made between the effect on hardened concrete and the quality of mixing water.

The effect on concreting for different types of contamination or impurities are described below:

Suspended Solids:

Mixing water which high content of suspended solids should be allowed to stand in a setting basing before use as it is undesirable to introduce large quantities of clay and slit into the concrete.

Acidity and Alkalinity:

Natural water that is slightly acidic are harmless, but presence of humic or other organic acids may result adverse affect over the hardening of concrete. Water which are highly alkaline should also be tested.

Algae:

The presence of algae in mixing water causes air entrainments with a consequent loss of strength. The green or brown slime forming algae should be regarded with suspicion and such water should be tested carefully.

Sea Water:

Sea water contains a total salinity of about 3.5%(78% of the dissolved solids being NaCl and 15% $MgCl_2$ and $MgSO_4$), which produces a slightly higher early strength but a lower long-term strength. The loss of strength is usually limited to 15% and can therefore be tolerated. Sea water reduces the initial setting time of cement but do not effect final setting time.

Chloride:

Water containing large amount of chlorides tends to cause persistent dampness and surface efflorescence. The presence of chlorides in concrete containing embedded steel can lead to its corrosion.

Moisture Content of Aggregate:

Aggregate usually contains some surface moisture. Coarse aggregate rarely contains more than 1% of surface moisture but fine aggregate can contain in excess of 10%. This water can

represent a substantial proportion of the total mixing water indicating a significant importance in the quality of the water that contributes surface moisture in aggregate

6. Explain the Effect of time and temperature on workability

When fresh concrete is laid at the site then proper curing of concrete is required, because structures are exposed to the environment and in these conditions if there is no such an arrangement against the environment, then there are many factors that affect the workability of concrete and temperature is One of them. Temperature, almost in every aspect has negative effects on the properties of concrete and same is the case with the workability of fresh concrete.

When temperature increases, then in the same proportion workability of fresh concrete decreases. The reason that stands behind is " when temperature increases then evaporation rate also increases due to that hydration rate decreases and hence, concrete will gain strength earlier ". Due to fast hydration of concrete, a hardening comes in concrete and that decreases the workability of fresh concrete. Therefore, In return manipulation of concrete becomes very difficult.

It indicates that the temperature has a negative effect on the workability of concrete as well as strength up to some extent. Temperature decreases the setting time by increasing hydration rate and that increase the early age strength of the concrete.

This is an advantage that less time will be required before removing of form works on site, but this decrease the use of proper placement of concrete in the initial stages. And if concrete is not properly laid, then strength distribution will not remain the same throughout the cross-section

7. Explain briefly the setting time of concrete?

Generally Initial setting is the time elapsed between the moment water is added to the cement to the time at which paste starts losing its plasticity. Final setting time of cement is the time elapsed between the moment the water is added to the cement to the time at which paste has completely lost its plasticity and attained sufficient firmness to resist certain definite pressure.

Cement + water = paste

Paste + fine aggregate = mortar,

Mortar + coarse aggregate = concrete

Time is required for mixing, transporting, placing, compacting and finishing. During this time

the above mentioned cement paste/mortar/concrete must be in plastic condition which is termed as Initial setting time of cement. Here 30 min are given while handling these mixing operations, here fineness of cement and suitable constituents are maintained in such a way that concrete is remained in plastic condition for handling procedures.

Initial setting time:

1. Cement is mixed with 0.85 times the water required for standard consistency.
2. As per vicat's test "the time elapsed since the addition of water to the cement up to the time at which the needle cannot penetrate 5 to 7 mm from the bottom of the vicat'smould.

Final setting time:

1. Determined by Vicat's apparatus using vicat's needle with annular collar of 5cm diameter.
2. As per vicat's test "the time elapsed since the addition of water to the cement up to the time at which the needle with annular collar can only make a mark on the hard cement surface.

8. What is segregation and how can it be prevented?

Segregation of concrete is separation of ingredients of concrete from each other. In good concrete all concrete aggregates are evenly coated with sand and cement paste and forms a homogeneous mass.

During handling, transporting and placing, due to jerks and vibrations the paste of cement and sands gets separated from coarse aggregate. If concrete segregates during transit it should be remixed properly before depositing. However a concrete where initial setting time is over, should not be used.

Prevention of Segregation of Concrete:

Wherever depth of concreting is more than 1.5 meters it should be placed through temporary inclined chutes. The angle of inclination may be kept between 1:3 and 1:2 so that concrete from top of chutes travels smoothly to bottom, use of small quantity of free water from top at intervals helps in lubricating the path of flow of concrete to bottom smoothly. The delivery end of chute should be as close as possible to the point of deposit.

Segregation in deep foundations and rafts of thickness more than 1 meter, there is every possibility of presence of segregated concrete near bottom or in center if proper supervision is not there. Such segregation can be detected by advanced method of testing like ultrasonic testing. In case of doubt random ultrasonic testing should be conducted and if it is present, designer's opinion should be taken. This type of segregation can be rectified by pressure grounding with special chemical compounds.

After any defect rectified by pressure grouting core test has to be performed to ensure that the strength of concrete has reached to the desired level

9. What is meant by curing of concrete?

Curing of concrete is defined as the process of maintaining the moisture and temperature conditions of concrete for hydration reaction to normally so that concrete develops hardened properties over time. The main components which need to be taken care are moisture, heat and time during curing process.

Why curing of concrete is required?
Curing of concrete is required for the following reasons:

- To prevent the concrete to dry out prematurely due to solar radiation and wind. This prevents plastic shrinkage of concrete.
- It helps to maintain the concrete temperature by allowing the hydration process. Hydration process requires water to carry on and releases heat.
- Curing helps the concrete to harden and bond with internal materials and reinforcement. This helps to prevent damage to bond between concrete and reinforcement due to vibration and impact.
- This helps development of impermeable, crack free and durable concrete.

Objective question with answers

1. In rich mixes; use of _size aggregate givesbetterresults. [ ]
   A. Larger B.Medium C.Smaller D.None

2. For given water content, workability decreases if the concrete aggregates contain an excess of
   A. Thin particles B. elongated particles Flakyparticles D. all theabove
   B.

3. For ensuring quality of concrete use [ ]
   A. Single sized aggregates B. two sized aggregate
   C. graded aggregates D. coarseaggregates

4. The standard sand now a days used in India, is obtained from [ ]
   A. Jaipur B.Jullundur C.Hyderabad D.Ennore

5. The maximum amount of dust which may be permitted in aggregates is [ ]
   A. 5%of the total aggregates for low workability with a coarse grading
   B. 10% of the total aggregates for low workability with a fine grading
   C. 20% of the total aggregates for a mix having high workability with finegrading
   D. all the above.

6. The bulk density of aggregates does not depend upon: [ ]
   A. size and shape of aggregates B. specific gravity ofaggregates

C. gradingofaggregates D. size and shape of the container

7. An aggregate is said to be flaky if its least dimension is less than [ ]
A. 1/5th ofmeandimension B. 2/5th of meandimension
C. 3/5th ofmeandimension D. 4/5th of meandimension

8. To ensure constant moisture content inaggregates [ ]
A. height of each aggregate pile should not exceed 1.50m
B. aggregatepileshouldbeleftfor24hoursbeforeaggregatesareused
C. conical heaps of aggregates should be avoided to prevent moisturevariation
D. all theabove

9. For the construction of cement concrete floor, the maximum permissible size of fine aggregate is [ ]
A.4.75mm B.6.23mm C.8.12mm D. 10.50mm

10. The process of proper and accurate measurement of concrete ingredients for uniformity of proportion, is known [ ]
A. grading B.Curing C.Mixing D.Batching

KEY

Q.NO	1	2	3	4	5	6	7	8	9	10
ANS	C	D	C	D	D	D	C	D	D	D

Fill in the blanks question with answers

1. In rich mixes; use of size aggregate gives better results.

2. Slump test is done for=

3. Concrete mainly consists of=

4. Workability of concrete is measured by =

5. The property of separation of cement paste from concrete material is known as=

6. Commonly employed test for measurement of cement workability is=

7. The process of proper and accurate measurement of concrete ingredients foruniformity of proportion is known=

8. In order to make concrete durable, the water cement ratio should be=

9.While compacting the concrete by a mechanical vibrator, the slump should not exceed=

10. Compacting factor formula =

Q.NO	ANSWERS
1	small
2	concrete
3	cement, aggregates and admixtures
4	slump test
5	segregation
6	vee-bee test
7	batching
8	Moderate
9	5CM
10	partially compacted concrete/fully compacted concrete

Two marks question with answers

UNIT-IV HARDENED CONCRETE

1. Define Water/cement ratio?

The water–cement ratio is the ratio of the weight of water to the weight of cement used in a concrete mix. A lower ratio leads to higher strength and durability, but may make the mix difficult to work with and form. Workability can be resolved with the use of plasticizers or super-plasticizers.

2. What is meant by gel-space ratio?

Strengths of cement pastes with different mixture properties and maturities depend in a very similar over linear fashion on the gel–space ratio, which is the ratio of the volume of hydration products over the volume of both hydration products and capillary pores.

3. Why is the modulus of elasticity important?

It is dependent upon temperature and pressure however. The Young's Modulus (or Elastic Modulus) is in essence the stiffness of a material. In other words, it is how easily it is bended or stretched. When a material reached a certain stress, the material will begin to deform.

4. Define Shrinkage cracking?

When concrete is subjected to compressive loading it deforms instantaneously. This immediate deformation is called instantaneous strain. ... This time-dependent strain is termed as creep. Drying shrinkage (often, simply shrinkage) is the reduction in volume of hardened concrete due to loss of moisture by evaporation.

Drying shrinkage is defined as the contracting of a hardened concrete mixture due to the loss of capillary water. This shrinkage causes an increase in tensile stress, which may lead to cracking, internal warping, and external deflection, before the concrete is subjected to any kind of loading.

5. Define Tension cracking?

The stress intensity factors at the tension crack tip are computed with three tensile loading conditions Instead, researchers believe that the angular outline was produced by giant tension cracks in the moon's crust as it cooled around an upwelling plume of hot material from the deep interior.

Three marks question with answers

1. **Define Concrete creep**

Concrete creep is defined as deformation of structure under sustained load. Basically as long term pressure or stress on concrete can make it change shape. This deformation usually occurs in the direction the force is being applied. Like a concrete column getting more compressed, or a beam bending.

2. **What is plastic shrinkage?**

They are usually parallel to each other on the order of 1 to 3 feet apart, relatively shallow, and generally do not intersect the perimeter of the slab. Plastic shrinkage cracking is more likely to occur when high evaporation rates cause the concrete surface to dry out before it has set.

3. **What is Poisson's ratio?**

Poisson's ratio is the ratio of transverse contraction strain to longitudinal extension strain in the direction of stretching force. Tensile deformation is considered positive and compressive deformation is considered negative.

4. **What is the modulus of elasticity?**

Young's modulus(E) describes tensile elasticity, or the tendency of an object to deform along an axis when opposing forces are applied along that axis; it is defined as the ratio of tensile stress to tensile strain. It is often referred to simply as the elastic modulus.

5. **What is tensile modulus?**

Tensile Modulus is defined as the "ratio of stress (force per unit area) along an axis to strain (ratio of deformation over initial length) along that axis" It can be used to predict the elongation or compression of an object as long as the stress is less than the yield strength of the material

Five marks question with answers

1. Explain nondestructive tests. What are the codal provisions for NDT?

Nondestructive testing of concrete can be defined as the test method used to examine the properties of concrete used in the actual structure. These test methods can also be said as in-situ tests or in-place tests. Traditionally these tests are said to be as the non-destructive test although some minor damage to the structure may be involved. An important feature of non-destructive test is that the place where test is done can be used for re-testing. The use of non-destructive tests has increased the safety level of construction and also helps in improving the scheduling of construction. All this increases the speed of construction besides keeping the economy of construction in considerable limits.

These tests can be categorized in two parts:

- Tests used to determine the strength of concrete
- Tests used to determine the other characteristics of concrete like voids, cracks etc

The most common tests which are usually conducted are:

Rebound Hammer Test

It is one of the oldest nondestructive tests. This test is widely used because of its economical procedure

Penetration Resistance Test

In this test resistance to the penetration of steel rod in the concrete is used as the strength value

Ultrasonic Pulse Velocity Test

This test has automatic program apparatus. Apparatus is just placed on specimen. The waves

pass through the specimen. Time taken by waves to reach from one end of specimen to other is considered to be the strength of specimen. Less the time taken, weaker will be the specimen and vice versa

Pull out Test

This test measure the strength of specimen by means of special tension jacks that are usually used to be inserted in test specimen

2.Explain briefly factors affecting concrete strength

Concrete strength is affected by many factors, such as quality of raw materials, water/cement ratio, coarse/fine aggregate ratio, and age of concrete, compaction of concrete, temperature, relative humidity and curing of concrete.

Quality of Raw Materials:

Cement, aggregate and water

Water / Cement Ratio:

The higher the water/cement ratio, the greater the initial spacing between the cement grains and the greater the volume of residual voids not filled by hydration products.

Coarse / fine aggregate ratio:

Following points should be noted for coarse/fine aggregate ratio:

- If the proportion of fines is increased in relation to the coarse aggregate, the overall aggregate surface area will increase.
- If the surface area of the aggregate has increased, the water demand will also increase.
- Assuming the water demand has increased, the water cement ratio will increase.
- Since the water cement ratio has increased, the compressive strength will decrease.

Age of concrete:

The degree of hydration is synonymous with the age of concrete provided the concrete has not been allowed to dry out or the temperature is too low.

Compaction of concrete:

Any entrapped air resulting from inadequate compaction of the plastic concrete will lead to a reduction in strength. If there was 10% trapped air in the concrete, the strength will fall down in the range of 30 to 40%.

Temperature

The rate of hydration reaction is temperature dependent. If the temperature increases the reaction also increases. This means that the concrete kept at higher temperature will gain strength more quickly than a similar concrete kept at a lower temperature.

Relative humidity:

If the concrete is allowed to dry out, the hydration reaction will stop. The hydration reaction cannot proceed without moisture. The three curves shows the strength development of similar concretes exposed to different conditions

Curing:

It should be clear from what has been said above that the detrimental effects of storage of concrete in a dry environment can be reduced if the concrete is adequately cured to prevent excessive moisture loss.

3. Explain neat procedure for Compressive strength of concrete?

Out of many test applied to the concrete, this is the utmost important which gives an idea about all the characteristics of concrete. By this single test one judge that whether Concreting has been done properly or not.

Compressive strength of concrete depends on many factors such as water-cement ratio, cement strength, quality of concrete material, and quality control during production of concrete etc.

Procedure: Compressive Strength Test of Concrete Cubes

For cube test two types of specimens either cubes of 15cm X 15cm X 15cm or 10cm X 10cm x 10cm depending upon the size of aggregate are used. For most of the works cubical moulds of size 15cm x 15cm x 15cm are commonly used.

This concrete is poured in the mould and tempered properly so as not to have any voids. After 24 hours these moulds are removed and test specimens are put in water for curing. The top surface of this specimen should be made even and smooth. This is done by putting cement paste and spreading smoothly on whole area of specimen.

These specimens are tested by compression testing machine after 7 days curing or 28 days curing. Load should be applied gradually at the rate of 140 kg/cm2 per minute till the Specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete.

4. What is tensile strength of concrete? Explain its types in detail?

Flexural strength of concrete:

Flexural strength is one measure of the tensile strength of concrete. It is a measure of an unreinforced concrete beam or slab to resist failure in bending. It is measured by loading 6 x 6 inch (150 x 150-mm) concrete beams with a span length at least three times the depth. The flexural strength is expressed as Modulus of Rupture (MR) in psi (MPa) and is determined by standard test methods ASTM C 78 (third-point loading) or ASTM C 293 (center-point loading).
Flexural Strength of Concrete Flexural MR is about 10 to 20 percent of compressive strength depending on the type, size and volume of coarse aggregate used. However, the best correlation for specific materials is obtained by laboratory tests for given materials and mix design. The MR determined by third-point loading is lower than the MR determined by center-point loading, sometimes by as much as 15%.

Split tensile strength of concrete:

The tensile strength of concrete is one of the basic and important properties. Splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete.

The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. The concrete develops cracks when subjected to tensile forces. Thus, it is necessary to determine the tensile strength of concrete to determine the load at which the concrete members may crack.

5.Explain in detail the creep of concrete and its factors?

Creep is the time-dependent flow of concrete caused by its being subjected to stress. This deformation, which occurs rapidly at first and then decreases with time, can be several times larger than the strains due to elastic shortening.Using more scientific approach; When load is applied to concrete at time to, a deformation occurs immediately which can be expressed as the elastic strain, ε (to). If this applied load is left on concrete producing a constant stress, the instantaneous elastic strain ε (to) begins to increase.
The rate of increase is fast during the first 3 months, after which it begins to slow down.

Factors effecting creep

Creep has been found to depend on

-the mix proportions (w/c ratio,aggregate type)

-humidity,temperature

-curing conditions,

-maturity of the concrete when first loaded

The deformation due to creep causes a shortening of the pre-stressing strands, which leads to a loss in stress in the strand.

Effects of Creep:

Creep of plain concrete does not by itself affect strength, although under very high stresses creep hastens the approach of the limiting strain at which failure takes place.

The influence of creep on the ultimate strength of a simply supported, reinforced concrete beam subjected to a sustained load is insignificant, but deflection increases considerably and may in many cases be a critical consideration in design.

Another instance of the adverse effects of creep is its influence on the stability of the structure through increase in deformation and consequent transfer of load to other components.

Thus, even when creep does not affect the ultimate strength of the component in which it takes place, its effect may be extremely serious as far as the performance of the structure as a whole is concerned.

The loss of prestress due to creep is well known and accounted for the failure of all early attempts at prestressing. Only with the introduction of high tensile steel did prestressing become a successful operation.

The effects of creep may thus be harmful. On the whole, however, creep unlike shrinkage is beneficial in relieving stress concentrations and has contributed to the success of concrete as a structural material.

6. Explain in detail the shrinkage of concrete and its types?

Concrete is subjected to changes in volume either autogenus or induced. Volume change is one of the most detrimental properties of concrete, which affects the long-term strength and durability. To the practical engineer, the aspect of volume change in concrete is important from the point of view that it causes unsightly cracks in concrete.

We have discussed elsewhere the effect of volume change due to thermal properties of aggregate and concrete, due to alkali/aggregate reaction, due to sulphate action etc. Presently we shall discuss the volume change on account of inherent properties of concrete "**shrinkage**".

One of the most objectionable defects in concrete is the presence of cracks, particularly in floors and pavements. One of the important factors that contribute to the cracks in floors and pavements is that due to shrinkage. It is difficult to make concrete which does not shrink and crack. It is only a question of magnitude.

Now the question is how to reduce the shrinkage and shrinkage cracks in concrete structures. The term shrinkage is loosely used to describe the various aspects of volume changes in

concrete due to loss of moisture at different stages due to different reasons.

Types of Shrinkage in Concrete

To understand this aspect more closely, shrinkage can be classified in the following way:

(a) Plastic Shrinkage

(b) Drying Shrinkage

(c) Autogeneous Shrinkage

(d) Carbonation Shrinkage

7. Define modulus of elasticity and dynamic modulus of elasticity?

Modulus Elasticity

Defining modulus of elasticity of concrete is difficult; Because concrete is not a linearly elastic material Since the slope of σ-ε curve of concrete is not constant. We must first describe modulus of elasticity (Ec). In general; Modulus of elasticity defined for concrete is the instantaneous Ec. This is not influenced by the time effect (mean Ec is function of many variables) Instantaneous Ec can be defined in 3 ways.

– Initial Modulus of Elasticity, E

– Secant modulus

– Tangent modulus

Dynamic Modulus of Elasticity

Dynamic modulus is the ratio of stress to strain under vibratory conditions (calculated from data obtained from either free or forced vibration tests, in shear, compression, or elongation). It is a property of visco elastic materials

8. What is curing? What are the different methods of curing?

Curing can be described as keeping the concrete moist and warm enough so that the hydration of cement can continue. More elaborately, it can be described as the process of maintaining satisfactory moisture content and a favorable temperature in concrete during the period immediately following placement, so that hydration of cement may continue until the desired properties are developed to a sufficient degree to meet the requirement of service.

If curing is neglected in the early period of hydration, the quality of concrete will experience a sort of irreparable loss. An efficient curing in the early period of hydration can be compared to a good and wholesome feeding given to a new born baby.

Methods of Curing Concrete

Concrete curing methods may be divided broadly into four categories:

1. Water curing
2. Membrane curing
3. Application of heat
4. Miscellaneous

1. Water curing

This is by far the best method of curing as it satisfies all the requirements of curing, namely, promotion of hydration, elimination of shrinkage and absorption of the heat of hydration. It is pointed out that even if the membrane method is adopted, it is desirable that a certain extent of water curing is done before the concrete is covered with membranes. Water curing can be done in the following ways:

- Immersion
- Ponding
- Spraying or Fogging
- Wet Covering

2. Membrane curing

Sometimes, concrete works are carried out in places where there is acute shortage of water. The lavish application of water for water curing is not possible for reasons of economy. Curing does not mean only application of water; it means also creation of conditions for promotion of uninterrupted and progressive hydration. It is also pointed out that the quantity of water, normally mixed for making concrete is more than sufficient to hydrate the cement, provided this water is not allowed to go out from the body of concrete. For this reason, concrete could be covered with membrane which will effectively seal off the evaporation of water from concrete.

3. Application of heat

The development of strength of concrete is a function of not only time but also that of temperature. When concrete is subjected to higher temperature it accelerates the hydration process resulting in faster development of strength. Concrete cannot be subjected to dry heat to accelerate the hydration process as the presence of moisture is also an essential requisite. Therefore, subjecting the concrete to higher temperature and maintaining the required wetness

can be achieved by subjecting the concrete to steam curing. A faster attainment of strength will contribute to many other advantages mentioned below. The exposure of concrete to higher temperature is done in the following manner:

- Steam curing at ordinary pressure
- Steam curing at high pressure
- Curing by Infra-red radiation
- Electrical curing.

4. Miscellaneous methods

Calcium chloride is used either as a surface coating or as an admixture. It has been used satisfactorily as a curing medium. Both these methods are based on the fact that calcium chloride being a salt shows affinity for moisture. The salt not only absorbs moisture from atmosphere but also retains it at the surface. This moisture held at the surface prevents the mixing water from evaporation and thereby keeps the concrete wet for a long time to promote hydration. Formwork prevents escaping of moisture from the concrete, particularly, in the case of beams and columns.

Keeping the form work intact and sealing the joint with wax or any other sealing compound prevents the evaporation of moisture from the concrete. This procedure of promoting hydration can be considered as one of the miscellaneous methods of curing.

9. Explain the procedure for Ultra Sonic Pulse Velocity(UPV)

UPV Procedure

i) Preparing for use: Before switching on the 'V' meter, the transducers should be connected to the sockets marked "TRAN" and " REC". The 'V' meter may be operated with either:

a) the internal battery,

b) an external battery or

c) the A.C line.

ii) Set reference: A reference bar is provided to check the instrument zero. The pulse time for the bar is engraved on it. Apply a smear of grease to the transducer faces before placing it on the opposite ends of the bar. Adjust the 'SET REF' control until the reference bar transit time is obtained on the instrument read-out.

iii) Range selection: For maximum accuracy, it is recommended that the 0.1 microsecond range be selected for path length upto 400mm.

iv) Pulse velocity: Having determined the most suitable test points on the material to be tested, make careful measurement of the path length 'L'. Apply couplant to the surfaces of the transducers and press it hard onto the surface of the material. Do not move the transducers

while a reading is being taken, as this can generate noise signals and errors in measurements. Continue holding the transducers onto the surface of the material until a consistent reading appears on the display, which is the time in microsecond for the ultrasonic pulse to travel the distance 'L'. The mean value of the display readings should be taken when the units digit hunts between two values

Pulse velocity= (Path length/Travel time)

v) Separation of transducer leads: It is advisable to prevent the two transducer leads from coming into close contact with each other when the transit time measurements are being taken. If this is not done, the receiver lead might pick-up unwanted signals from the transmitter lead and this would result in an incorrect display of the transit time

10. Explain the procedure for rebound hammer test?

Procedure for rebound hammer.

i) Before commencement of a test, the rebound hammer should be tested against the test anvil, to get reliable results, for which the manufacturer of the rebound hammer indicates the range of readings on the anvil suitable for different types of rebound hammer.

ii) Apply light pressure on the plunger – it will release it from the locked position and allow it to extend to the ready position for the test.

iii) Press the plunger against the surface of the concrete, keeping the instrument perpendicular to the test surface. Apply a gradual increase in pressure until the hammer impacts. (Do not touch the button while depressing the plunger. Press the button after impact, in case it is not convenient to note the rebound reading in that position.)

iv)Take the average of about 15 readings.

Interpretation of Results

The rebound reading on the indicator scale has been calibrated by the manufacturer of the rebound hammer for horizontal impact, that is, on a vertical surface, to indicate the compressive strength. When used in any other position, appropriate correction as given by the manufacturer is to be taken into account.

Objective question with answers

1. In ultrasonic test for hardened concrete good quality ofconcreteisindicatedifthepulsevelocityis
   A. below3km/s B. above 3.5km/s
   C. Above4.5km/s D. None of theabove

2. Specified compressive strength of concrete is obtainedfrom cube tests at the end of
   A. 3days B.7days C.14days D. 28days

3. Shrinkage in concrete can be reduced by using
   A. low watercementratio B. less cement in theconcrete
   C. properconcretemix D.None

4. The ratio between stress in steel to that of stress in concrete in expressedas
   A. Poisson'sratio B. Modularratio C. Densityratio D.None

5. Select the Non – destructive test amongthefollowing
   A. Compressiontest B. Flexuretest C. Reboundhammerstest D. All theabove

6. According to IS 456-2000, the modulus of elasticity of concrete Ec, can be taken
   A. Ec = 570√fck B. 5700fck C.5700√fck D.5000√fck

7. Compressive strength of M 150 grade concrete is
   A.100 Kg/cm^2 B.150 Kg/cm^2 C.200Kg/cm^2 D. 300Kg/cm^2

8. The process of mixing, transporting, placing and compacting concrete using OPC should not take more than
   A. 30 min B.40 min C. 50 min D. 90 min

9. Strength of concrete with passage of time
   A. Increases B. Decreases C. Equal D. None

Q.NO	1	2	3	4	5	6	7	8	9	10
ANS	C	D	A	B	C	D	B	A	A	A

Fill in the Blanks question with answers

1. Modulus of rupture of concrete is a measure of=
2. Increase in the moisture content in concrete =
3. The factor of safety for concrete _than steel
4. Select the Non – destructive test=
5. Modulus of rupture of concrete is a measure of=
6. The formula for determining the cement content is given by=
7. Maturity of concrete is the product of=
8. As per IS: 456-2000, the high strength concrete should have thecharacteristic Strengthof=
9. The ratio between stress in steel to that of stress in concrete in expressed as=
10. Concrete gains strength due to=

KEY

Q.NO	ANSWER
1	Tensile strength
2	Reducesthestrength
3	Greater
4	rebound hammer test
5	flexural strength
6	water/cement ratio
7	time x temperature
8	>M 40
9	modular ratio
10	hydration of cement

UNIT-V

MIX DESIGN & SPECIAL CONCRETE

Two marks question with answers

1. **Define concrete mix design?**

Mix design can be defined as the process of selecting suitable ingredients of concrete and determining their relative proportions with the object of producing concrete of certain minimum strength and durability as economically as possible. One of the ultimate aims of studying the various properties of the materials of concrete, plastic concrete and hardened concrete is to enable a concrete technologist to design a concrete mix for a particular strength and durability.

2. **What are the factors influencing the selection of materials?**

A wide range of construction materials is available. The proper selection of materials to be used in a particular construction project depends on the following factors

- Strength
- Availability
- Durability
- Workability
- Ease of Transportation
- Cost
- Aesthetics
- Resistance to Fire
- Ease of Cleaning

3. **What are the Requirements of concrete mix design as per BIS?**

The requirements which form the basis of selection and proportioning of mix ingredients are

a) The minimum compressive strength required from structural consideration

b) The adequate workability necessary for full compaction with the compacting equipment available.

c) Maximum water-cement ratio and/or maximum cement content to give adequate durability for the particular site conditions

d) Maximum cement content to avoid shrinkage cracking due to temperature cycle in mass

concrete.

4. What are the types of concrete mixes? Explain

1. Nominal Mixes: In the past the specifications for concrete prescribed the proportions of cement, fine and coarse aggregates. These mixes of fixed cement-aggregate ratio which ensures adequate strength are termed nominal mixes. These offer simplicity and under normal circumstances, have a margin of strength above that specified. However, due to the variability of mix ingredients the nominal concrete for a given workability varies widely in strength.

2. Standard mixes: The nominal mixes of fixed cement-aggregate ratio (by volume) vary widely in strength and may result in under- or over-rich mixes. For this reason, the minimum compressive strength has been included in many specifications. These mixes are termed standard mixes.

5. What are the Factors affecting the choice of mix proportions?

- Compressive strength of concrete
- Workability of concrete
- Durability of concrete
- Maximum nominal size of aggregate
- Grading and type of aggregate
- Quality Control at site

6. Define Aerated Concrete

Autoclaved aerated concrete (AAC), also known as autoclaved cellular concrete (ACC), autoclaved lightweight concrete (ALC), autoclaved concrete, cellular concrete, porous concrete, Aircrete, Hebel Block, and Ytong is a lightweight, precast, foam concrete building material invented in the mid-1920s that simultaneously provides structure, insulation, and fire- and mold-resistance. AAC products include blocks, wall panels, floor and roof panels, cladding (facade) panels and lintel

7. What is the general use of Shotcrete?

Shotcrete is concrete (or sometimes mortar) conveyed through a hose and pneumatically projected at high velocity onto a surface, as a construction technique. It is reinforced by conventional steel rods, steel mesh, and/or fibers.

8. **What is meant by No fine concrete?**

No-Fines Concrete is a method of producing light concrete by omitting the fines from conventional concrete. No-fines concrete as the term implies, is a kind of concrete from which the fine aggregate fraction has been omitted. This concrete is made up of only coarse aggregate, cement and water.

9. **What do you mean by Fibre Reinforced Concrete?**

Fiber reinforced concrete (FRC) is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibers that are uniformly distributed and randomly oriented. Fibers include steel fibers, glass fibers, synthetic fibers and natural fibers.

Three marks question with answers

1. **What is M20 Mix concrete?**

If the ratio for M20 concrete is 1:1.5:3 then 1 part cement, 1.5 part sand and 3 part aggregate (crushed stone) in volume is batched for mixing. Ordinary concrete up to M20 grade can be designed by nominal mix concrete procedure.

2. **Define Standard mixes.**

The nominal mixes of fixed cement-aggregate ratio (by volume) vary widely in strength and may result in under- or over-rich mixes. For this reason, the minimum compressive strength has been included in many specifications. These mixes are termed standard mixes.

3. **What are designed mixes?**

In these mixes the performance of the concrete is specified by the designer but the mix proportions are determined by the producer of concrete, except that the minimum cement content can be laid down. This is most rational approach to the selection of mix proportions with specific materials in mind possessing more or less unique characteristics. The approach results in the production of concrete with the appropriate properties most economically. However, the designed mix does not serve as a guide since this does not guarantee the correct mix proportions for the prescribed performance.

4. **What is an acceptance criterion of concrete?**

It is often observed that construction engineer neglects acceptance criteria of the concrete from flexural strength point of view under the argument that flexural strength of the concrete is of no/least importance as in the strength design the tensile strength of the concrete is neglected.

5. What is self-compacting concrete?

Self-consolidating concrete, also known as self-compacting concrete (SCC), is a highly flowable, non-segregating concrete that spreads into place, fills formwork, and encapsulates even the most congested reinforcement, all without any mechanical vibration.

6. What is the Aspect ratio of the fiber?

- A fiber's aspect ratio is defined as its length divided by its diameter.
- Long, thin fibers (fiber B) often provide superior properties, but are also often more expensive to produce and may be more difficult to disperse uniformly in the composite.
- Small aspect ratio fibers(fiber A) typically provide better compressive properties but these composites are typically less resistant to damage propogation.

7. What is SIFCON?

Slurry infiltrated fibre concrete (SIFCON) is one of the recently developed construction material. SIFCON could be considered as a special type of fibre concrete with high fibre content. The matrix consists of cement slurry or flowing cement mortar.

8. What are the types of polymer concrete?

- Polymer impregnated concrete (PIC).
- Polymer cement concrete (PCC).
- Polymer concrete (PC).

9. What is meant by high performance of concrete?

High performance concrete is a concrete mixture, which possess high durability and high strength when compared to conventional concrete. This concrete contains one or more of cementious materials such as fly ash, Silica fume or ground granulated blast furnace slag and usually a super plasticizer.

Five marks question with answers

1. **Describe ACI method of mix design in detail.**

ACI method of concrete mix design is based on the estimated weight of the concrete per unit volume. This method takes into consideration the requirements for consistency, workability, strength and durability.

Following are the steps of ACI Method of Concrete Mix Design:

(a) Depending on the degree of workability and placing condition determine the slump value.

(b) Depending on the economical availability and dimensions of the structure determine the maximum size of aggregate.

(c) For the given slump and maximum size of coarse aggregate determine the amount of mixing water

(d) Determine the minimum water-cement ratio either from strength considerations or from durability considerations.

(e) Determine the amount of cement per unit volume of concrete from steps (c) and (d). This cement content should not be less than the cement content required based on durability criteria.

(f) Determine the amount of coarse aggregate required for a unit volume of concrete. This value is multiplied by the dry rodded unit weight of the aggregate to get the required dry weight.

(g) Determine the amount of fine aggregate. If the weight of concrete per unit volume is assumed, the required weight of fine aggregate is obtained by the difference between the weight of fresh concrete and the total weight of all other ingredients.

2. **Describe Indian standard method of mix design in detail**

1. Determine the mean target strength ft from the specified characteristic compressive strength at 28-day fck and the level of quality control.

$f_t = f_{ck} + 1.65\ S$

where S is the standard deviation obtained from the Table of approximate contents given

after the design mix.

2. Obtain the water cement ratio for the desired mean target using the empirical relationship between compressive strength and water cement ratio so chosen is checked against the limiting water cement ratio. The water cement ratio so chosen is checked against the limiting water cement ratio for the requirements of durability given in table and adopts the lower of the two values.

3. Estimate the amount of entrapped air for maximum nominal size of the aggregate from the table.

4. Select the water content, for the required workability and maximum size of aggregates (for aggregates in saturated surface dry condition) from table.

5. Determine the percentage of fine aggregate in total aggregate by absolute volume from table for the concrete using crushed coarse aggregate.

6. Adjust the values of water content and percentage of sand as provided in the table for any difference in workability, water cement ratio, grading of fine aggregate and for rounded aggregate the values are given in table.

7. Calculate the cement content form the water-cement ratio and the final water content as arrived after adjustment. Check the cement against the minimum cement content from the requirements of the durability, and greater of the two values is adopted.

8. From the quantities of water and cement per unit volume of concrete and the percentage of sand already determined in steps 6 and 7 above, calculate the content of coarse and fine aggregates per unit volume of concrete from the following relations:

$$V = \left[W + \frac{C}{S_c} + \frac{1}{p}\frac{f_a}{S_{fa}}\right] \times \frac{1}{1000}$$

$$V = \left[W + \frac{C}{S_c} + \frac{1}{1-p}\frac{C_a}{S_{ca}}\right] \times \frac{1}{1000}$$

9. Determine the concrete mix proportions for the first trial mix.

10. Prepare the concrete using the calculated proportions and cast three cubes of 150

11. Prepare trial mixes with suitable adjustments till the final mix proportions are arrived at.

3. Explain in detail about the statistical quality control and acceptance criteria of concrete.

Concrete cube strength is a random variable and the test results are influenced by many different factors related to variations in the materials, batching, sampling, concrete testing, equipment and personnel.

Being a random variable, the results of a concrete cube test taken from a particular grade of concrete will, for practical purposes, take the form of a normal distribution when plotted graphically. **This type of distribution is sometimes called a "bell" curve because of its shape.** Like many aspects of concrete technology this is not strictly true – low strength and very high strength concrete test results give skewed distribution curves to the left and right respectively, but for practical purposes a symmetrical distribution is assumed.

The normal distribution curve is characterised by two values: the mean or average value, and the standard deviation which quantifies the spread of the curve either side of the mean value. The requirement that the average strength exceeds the specified (characteristic) strength by 1.64 times the standard deviation implies that slightly fewer than 5% of results will fall below the specified strength.
The only factor under the concrete suppliers control is the standard deviation, the specified strength and the "1.64" being fixed.

The value 1.64 x SD is called the margin. The higher the SD, the higher the margin and the higher the average binder content of the concrete. In other words, **the higher the SD, the more expensive the concrete in terms of binder cost.**

For example, improving control from poor (SD = 7 MPa) to good (SD = 5 MPa) reduces the margin by 1.64 *(7-5) MPa = 3.4 MPa. **A reduction in average strength by 3.4 MPa is equivalent to saving 20 kg of binder**per cubic metre of concrete.

At current prices this is a saving of roughly R25 / m^3. Of course one has to balance this against the cost of the additional quality control necessary to reduce the SD and there is an

optimum point where it becomes uneconomical to reduce the SD any further. For sophisticated concrete suppliers this point would be an SD somewhere in the region of 2.5 to 3 MPa.

4.Define Nominal Mixes and Standard mixes. What are designed Mixes?

Nominal Mixes:

In the past the specifications for concrete prescribed the proportions of cement, fine and coarse aggregates. These mixes of fixed cement-aggregate ratio which ensures adequate strength are termed nominal mixes. These offer simplicity and under normal circumstances, have a margin of strength above that specified. However, due to the variability of mix ingredients the nominal concrete for a given workability varies widely in strength.

Standard mixes:

The nominal mixes of fixed cement-aggregate ratio (by volume) vary widely in strength and may result in under- or over-rich mixes. For this reason, the minimum compressive strength has been included in many specifications. These mixes are termed standard mixes.

Design mixes:

In these mixes the performance of the concrete is specified by the designer but the mix proportions are determined by the producer of concrete, except that the minimum cement content can be laid down. This is most rational approach to the selection of mix proportions with specific materials in mind possessing more or less unique characteristics. The approach results in the production of concrete with the appropriate properties most economically. However, the designed mix does not serve as a guide since this does not guarantee the correct mix proportions for the prescribed performance.

5. Explain detail the factors in the choice of mix design

Concrete mix design:

It is defined as the appropriate selection and proportioning of constituents to produce a concrete with pre-defined characteristics in the fresh and hardened states. In general, concrete mixes are designed in order to achieve a defined workability, strength and durability.

The various factors affecting the choice of concrete mix design are:

Compressive strength of concrete:

It is one of the most important properties of concrete and influences many other describable properties of the hardened concrete. The mean compressive strength required at a specific age, usually 28 days, determines the nominal water-cement ratio of the mix. The other factor affecting the strength of concrete at a given age and cured at a prescribed temperature is the degree of compaction. According to Abraham's law the strength of fully compacted concrete is inversely proportional to the water-cement ratio.

Workability of concrete:

The degree of workability required depends on three factors. These are the size of the section to be concreted, the amount of reinforcement, and the method of compaction to be used. For the narrow and complicated section with numerous corners or inaccessible parts, the concrete must have a high workability so that full compaction can be achieved with a reasonable amount of effort. This also applies to the embedded steel sections. The desired workability depends on the compacting equipment available at the site.

Durability of concrete:

The durability of concrete is its resistance to the aggressive environmental conditions. High strength concrete is generally more durable than low strength concrete. In the situations when the high strength is not necessary but the conditions of exposure are such that high durability is vital, the durability requirement will determine the water-cement ratio to be used.

Maximum nominal size of aggregate

In general, larger the maximum size of aggregate, smaller is the cement requirement for a particular water-cement ratio, because the workability of concrete increases with increase in maximum size of the aggregate. However, the compressive strength tends to increase with the decrease in size of aggregate. IS 456:2000 and IS 1343:1980 recommend that the nominal size of the aggregate should be as large as possible.

Grading and type of aggregate

The grading of aggregate influences the mix proportions for a specified workability and water-cement ratio. Coarser the grading leaner will be mix which can be used. Very lean mix is not

desirable since it does not contain enough finer material to make the concrete cohesive. The type of aggregate influences strongly the aggregate-cement ratio for the desired workability and stipulated water cement ratio. An important feature of a satisfactory aggregate is the uniformity of the grading which can be achieved by mixing different size fractions.

Quality Control at site:

The degree of control can be estimated statistically by the variations in test results. The variation in strength results from the variations in the properties of the mix ingredients and lack of control of accuracy in batching, mixing, placing, curing and testing. The lower the difference between the mean and minimum strengths of the mix lower will be the cement-content required. The factor controlling this difference is termed as quality control

5. Write a brief note on self-compacting concrete?

SCC is defined as "a concrete that is able to flow under its own weight and completely fill the formwork, while maintaining homogeneity even in the presence of congested reinforcement, and then consolidate without the need for vibrating compaction"

The noise associated with the compaction of conventional concrete can be significant. SCC affords quiet casting, and the environmental loadings from noise are therefore reduced. It also eliminates the issue of blood circulatory problems caused by the vibration of concrete.

SCC affords the designer greater flexibility in designing complex shapes. It is independent of the quality of mechanical vibration and therefore provides homogeneity leading to improved durability and potential for reuse.

Self compacting concrete (SCC) can be classified as an advanced construction material. The SCC as the name suggests, does not require to be vibrated to achieve full compaction. This offers following benefits and advantages over conventional concrete.

- Improved quality of concrete and reduction of onsite repairs.
- Faster construction times.
- Lower overall costs.
- Facilitation of introduction of automation into concrete construction.
- Improvement of health and safety is also achieved through elimination of handling of vibrators.
- Substantial reduction of environmental noise loading on and around a site.

6. Explain the properties of polymer Impregnated Concrete.

Polymer impregnated concrete consists of polymers or epoxies which are used to impart certain special properties to concrete. Various applications of polymers in concrete and their properties is discussed. The polymers are used in the concrete due to the following reasons:

- Polymers improve the strength and durability of hardened concrete
- The chemical resistance and the impermeability of hardened concrete is increased
- The flow properties of fresh concrete can be modified based on the required specifications
- The bond characteristics between old and new concrete can be improved

Some of the polymers that are used popularly are:

1. Urethanes: Urethanes are produced by the reaction of isocyanates with the polyols
2. Acrylics: These are esters of acrylic and methacrylic acids
3. Vinyl
4. Epoxies: These are type of synthetic fibers
5. SBR or Styrene Butadiene Resins: These are synthetic rubbers in the solution

6. Applications of Different Polymers in Concrete

The different ways in which the polymer is introduced into the concrete (hardened concrete) will vary widely based on the commercial objective. The polymers can be employed in concrete in different ways. They are:

- Polymer Impregnated Concrete (PIC)
- Polymer-Modified Concrete (PMC)
- Polymer Concrete (PC)
- Polymer as Protective Coating
- Polymer as Bonding Agent
- Other Applications

7. Explain briefly about the types of fiber reinforced concrete

Different Types of Fiber Reinforced Concrete

Following are the different type of fibers generally used in the construction industries.

- Steel Fiber Reinforced Concrete
- Polypropylene Fiber Reinforced (PFR) cement mortar & concrete
- GFRC Glass Fiber Reinforced Concrete
- Asbestos Fibers
- Carbon Fibers
- Organic Fibers

Steel Fiber Reinforced Concrete:

A no of steel fiber types are available as reinforcement. Round steel fiber the commonly used type are produced by cutting round wire in to short length. The typical diameter lies in the range of 0.25 to 0.75mm. Steel fibers having a rectangular c/s are produced by silting the sheets about 0.25mm thick. Fiber made from mild steel drawn wire. Conforming to IS:280-1976 with the diameter of wire varying from 0.3 to 0.5mm have been practically used in India. Round steel fibers are produced by cutting or chopping the wire, flat sheet fibers having a typical c/s ranging from 0.15 to 0.41mm in thickness and 0.25 to 0.90mm in width are produced by silting flat sheets. Deformed fiber, which are loosely bounded with water-soluble glue in the form of a bundle are also available. Since individual fibers tend to cluster together, their uniform distribution in the matrix is often difficult. This may be avoided by adding fibers bundles, which separate during the mixing process.

Polypropylene Fiber Reinforced (PFR) concrete:

Polypropylene is one of the cheapest & abundantly available polymers polypropylene fibers are resistant to most chemical & it would be cementitious matrix which would deteriorate first under aggressive chemical attack. Its melting point is high (about 165 degrees centigrade). So that a working temp. As (100 degree centigrade) may be sustained for short periods without detriment to fiber properties.

Polypropylene fibers being hydrophobic can be easily mixed as they do not need lengthy contact during mixing and only need to be evenly distressed in the mix.

Polypropylene short fibers in small volume fractions between 0.5 to 15 commercially used in concrete.

8. Glass Fiber Reinforced Concrete:

Glass fiber is made up from 200-400 individual filaments which are lightly bonded to make up a stand. These stands can be chopped into various lengths, or combined to make cloth mat or tape. Using the conventional mixing techniques for normal concrete it is not possible to mix more than about 2% (by volume) of fibers of a length of 25mm.

The major appliance of glass fiber has been in reinforcing the cement or mortar matrices used in the production of thin-sheet products. The commonly used verities of glass fibers are e-glass used. In the reinforced of plastics & AR glass E-glass has inadequate resistance to alkalis present in Portland cement where AR-glass has improved alkali resistant characteristics. Sometimes polymers are also added in the mixes to improve some physical properties such as moisture movement.

Asbestos Fibers:

The naturally available inexpensive mineral fiber, asbestos, has been successfully combined with Portland cement paste to form a widely used product called asbestos cement. Asbestos fibers here thermal mechanical & chemical resistance making them suitable for sheet product pipes, tiles and corrugated roofing elements. Asbestos cement board is approximately two or four times that of unreinforced matrix. However, due to relatively short length (10mm) the fiber have low impact strength.

Carbon Fibers:

Carbon fibers from the most recent & probability the most spectacular addition to the range of fiber available for commercial use. Carbon fiber comes under the very high modulus of elasticity and flexural strength. These are expansive. Their strength & stiffness characteristics have been found to be superior even to those of steel. But they are more vulnerable to damage than even glass fiber, and hence are generally treated with resign coating.

Organic Fibers:

Organic fiber such as polypropylene or natural fiber may be chemically more inert than either steel or glass fibers. They are also cheaper, especially if natural. A large volume of vegetable fiber may be used to obtain a multiple cracking composite. The problem of mixing and uniform dispersion may be solved by adding a super plasticize.

9. Explain about polymer – modified concrete

Polymer concretes are a type of concrete that use polymers to replace lime-type cements as a binder. In some cases the polymer is used in addition to portland cement to form Polymer Cement Concrete (PCC) or Polymer Modified Concrete (PMC)

Properties

The exact properties depend on the mixture, polymer, aggregate used etc. etc. but generally speaking with mixtures used:

- The binder is more expensive than cement
- Significantly greater tensile strength than unreinforced Portland concrete (since plastic is 'stickier' than cement and has reasonable tensile strength)[1]
- Similar or greater compressive strength to Portland concrete[1]
- Much faster curing
- Good adhesion to most surfaces, including to reinforcements
- Good long-term durability with respect to freeze and thaw cycles[1]
- Low permeability to water and aggressive solutions
- Good chemical resistance
- Good resistance against corrosion
- Lighter weight (slightly less dense than traditional concrete, depending on the resin content of the mix)
- May be vibrated to fill voids in forms
- Allows use of regular form-release agents (in some applications)
- Dielectric

- Product hard to manipulate with conventional tools such as drills and presses due to its density. Recommend getting pre-modified product from the manufacturer
- Small boxes are more costly when compared to its precast counterpart however pre cast concretes induction of stacking or steel covers quickly bridge the gap.

10. How can high-strength concrete be classified? Explain.

High strength concrete is defined purely on the basis of its compressive strength, defined the **high-performance concrete (HPC)** as concrete mixtures possessing high workability, high durability and high ultimate strength.

High strength of concrete is achieved by reducing porosity, in-homogeneity, and micro-cracks in the hydrated cement paste and the transition zone. Consequently, there is a reduction of the thickness of the interfacial transition zone in high-strength concrete. The densification of the interfacial transition zone allows for efficient load transfer between the cement mortar and the coarse aggregate, contributing to the strength of the concrete. For very high-strength concrete where the matrix is extremely dense, a weak aggregate may become the weak link in concrete strength.

Materials for High-Strength Concrete:

Cement

Cement composition and fineness play an important role in achieving high strength of concrete. It is also required that the cement is compatible with chemical admixtures to obtain the high-strength. Experience has shown that low-C3A cements generally produce concrete with improved rheology.

Aggregate

Selection of right aggregates plays an important role for the design of high-strength concrete mix. The low-water to cement ratio used in high-strength concrete makes the concrete denser and the aggregate may become the weak link in the development of the mechanical strength. Extreme care is necessary, therefore, in the selection of aggregate to be used in very high-strength concrete.

The particle size distribution of the fine aggregates plays an important role in the high strength concrete. The particle size distribution of fine aggregate that meets the ASTM specifications is adequate for high-strength concrete mixtures.

Guidelines for the selection of materials:

- For the higher target compressive strength of concrete, the maximum size of concrete selected should be small, so that the concrete can become more dense and compact and less void ratio.
- Up to 70 MPa compressive strength can be produced with a good coarse aggregate of a maximum size ranging from 20 to 28 mm.
- To produce 100 MPa compressive strength aggregate with a maximum size of 10 to 20 mm should be used.
- To date, concretes with compressive strengths of over 125 MPa have been produced, with 10 to 14 mm maximum size coarse aggregate.
- Using supplementary cementitious materials, such as blast-furnace slag, fly ash and natural pozzolans, not only reduces the production cost of concrete, but also addresses the slump loss problem.
- The optimum substitution level is often determined by the loss in 12- or 24-hour strength that is considered acceptable, given climatic conditions or the minimum strength required.
- While silica fume is usually not really necessary for compressive strengths under 70 MPa, most concrete mixtures contain it when higher strengths are specified.

11. Explain the polymer concrete and its advantages and types?

➢ Polymer concrete is an ordinary concrete produced with OPC (Ordinary portland cement) wet cured and inseminated with liquid or vaporous chemical compound (Methyl methacrylate monomer) and polymerized by gamma radiation or with chemical initiated implies, i.e by utilizing thermal catalytic method (Adding 3% Benzoyl peroxide) to the monomer as a catalyst. The impregnation is helped by drying the concrete at an extreme temperature by evacuations and absorbing the monomer under limited pressure.

Application of Polymer Concrete:

Polymer concrete is broadly utilizing in several circumstances as following

1. Nuclear power plants.
2. Kerb-stones.
3. Prefabricated structural element.
4. Precast slabs for bridge decks.
5. Roads.
6. Marine Works.
7. Pre-stressed concrete.
8. Irrigation works.
9. Sewage works.
10. Waterproofing of building.

Advantages of polymer concrete:

1. It has high impact resistance and high compressive strength.
2. Polymer concrete is highly resistant to freezing and thawing.
3. Highly resistant to chemical attack and abrasion.
4. Permeability is lower than other conventional concrete.

Objective question with answers

1. The compaction of concrete, improves [ ]

   A. Density B.Strength C. Durability D. all theabove.

2. Segregation is responsible for [ ]

   A. honey-combed concrete B. porous layers in concrete

   C. surface scaling in concrete D. sand streaks in concrete

3. Addition of pozzolanatocement [ ]

   A. decreasesworkability B. increasesstrength

   C. increases heatofhydration D. Increaseworkability

4. Permissiblecompressivestrengthof M150concretegradeis [ ]

A. 100kg/cm^2 B.150kg/cm^2

C.200kg/cm^2 D. 250kg/cm2

5. Pozzolana cement is used with confidence forconstructionof [ ]

A. Dams B.massivefoundations C. Abutments D. All the above

6. Efflorescence in cement is caused due to an excessof [ ]

A. Alumina B. iron oxide C.MagnesiumOxide D.alkalis

7. ThediameteroftheVicatplungeris10mmanditslengthvariesfrom [ ]

A. 20 mm to30mm B. 30 mm to40mm C. 40 mm to50mm D. 50 mm to 60mm

8. The ratio of various ingredients (cement, sand, aggregates) in concrete of grade M 20, is

A. 1:2:4 B. 1:3: 6 C. A&B D. None of theAbove

9. Tri-calciumaluminate [ ]

A. reacts fastwithwater B. generates less heat ofhydration

C. causes initial setting and early strength ofcement

D. does not contribute to develop ultimatestrength

10. Hightemperature

A. increases the strengthofconcrete B. decreases the strength ofconcrete

C. has no affecton the strengthofconcrete D. none ofthese.

KEY

Q.NO	1	2	3	4	5	6	7	8	9	10
ANS	D	A	A	C	D	C	C	D	C	C

Fill In the Blanks question with answers

1. Increase in the moisture contentinconcrete=

2. Modulus of rupture of concrete is a measureof=

3. The relation between modulus of rupture for and characteristic strength ofconcrete fck is givenby =

4. ModulusofelasticityofsteelasperIS:456—2000shallbetaken as =

5. The factor of safety for concrete _than steel

6. The characteristic strength of M50 concreteis=

7. Maturity of concrete is the productof =

8. The cylindrical strength of concrete istimes the strength ofthecube

9. The ratio of various ingredients in concrete of grade M 25=

10. The ratio of various ingredients in concrete of grade M 10 =

KEY

Q.NO	ANSWERS
1	Decreases strength
2	Flexural strength
3	$0.7\sqrt{fck}$
4	$2 \times 10^{6} N/cm^2$
5	LESS
6	50N/mm2
7	Time x Temp
8	1.25times
9	1:1:4
10	1:3:6

14. COURSE ATTAINMENT

VAAGESWARI COLLEGE OF ENGINERING							
Department:		CIVIL ENGINEERING					
		Course Outcome Attainment - Internal Assessments					
Name of the Faculty:				Academic Year:		2020-21	
Branch & Section:		CIVIL A&B		Exam:		Mid-1	
Course:		CT		Semister:		I	
Sl.No	Roll Number	Question No.				Objective	Assignment
		1	2	3	4		
Maximum Marks		5	5	5	5	10	5
1	17WJ1A0167			2	1	8	5
2	18S41A0101			2		7	5
3	18S41A0103	5			4	6	5
4	18S41A0104	4.5			2.5	8	5
5	18S41A0105	5			3	6	5
6	18S41A0106	4.5			1.5	7	5
7	18S41A0107	4				8	5
8	18S41A0108	3		2		8	5
9	18S41A0109	4			4	8	5
10	18S41A0110	5			4	8	5
11	18S41A0111	5			5	8	5
12	18S41A0113	5			4	6	5
13	18S41A0114			3		7	5
14	18S41A0115	4.5			1.5	7	5
15	18S41A0116	5			5	7	5
16	18S41A0117	3			5	8	5
17	18S41A0118	3				8	5
18	18S41A0120	AB	AB	AB	AB	AB	5
19	18S41A0121	5			1	7	5
20	18S41A0122	4.5			5	6.5	5
21	18S41A0123	5			4	7	5
22	18S41A0124	5	5			8	5
23	18S41A0125			1		8	5
24	18S41A0126				3	7	5
25	18S41A0127		3	2		7	5
26	18S41A0129	5	5			7	5
27	18S41A0132	5	5			7	5
28	18S41A0133	3.5			1.5	7	5
29	18S41A0135	5			3	7	5
30	18S41A0136	4.5		1.5		7	5
31	18S41A0137	4.5	2.5			7	5

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32	18S41A0138		3	4		7	5
33	18S41A0140		2	5		7	5
34	18S41A0141	4		5		7	5
35	19S45A0101		3	4		8	5
36	19S45A0102	4	5			8	5
37	19S45A0103	5	5			8	5
38	19S45A0104	5	3			7	5
39	19S45A0105	4		2		7	5
40	19S45A0106	AB	AB	AB	AB	AB	5
41	19S45A0107	2.5	3.5			7	5
42	19S45A0108	4	3			7	5
43	19S45A0109	5	3			8	5
44	19S45A0110	5	5			8	5
45	19S45A0111	4.5	4.5			7	5
46	19S45A0112	AB	AB	AB	AB	AB	5
47	19S45A0113		2.5	2.5		8	5
48	19S45A0114	5	3			8	5
49	19S45A0115	5	2			7	5
50	19S45A0116		4	2		7	5
51	19S45A0117	5	5			8	5
52	19S45A0118	3	2.5			7.5	5
53	19S45A0119	AB	AB	AB	AB	AB	5
54	19S45A0120	2.5	3.5			7	5
55	19S45A0121		2			6	5
56	19S45A0122		3		3	7	5
57	19S45A0123	AB	AB	AB	AB	AB	5
58	19S45A0124		3.5	2.5		6	5
59	19S45A0125		3		3	7	5
60	16S41A0112	AB	AB	AB	AB	AB	5
61	16S41A0182	AB	AB	AB	AB	AB	5
62	17S41A0116	AB	AB	AB	AB	AB	5
63	17S41A0117		1	2		5	5
64	17S41A0123				1	7	5
65	17S41A0125		2	1		6	5
66	17S41A0136	2				6	5
67	17S41A0163	2	1			6	5
68	17S41A0166	1		1		6	5
69	18S45A0109	2	3			7	5
70	18S45A0116	AB	AB	AB	AB	AB	5
71	18S41A0145	1				4	5
72	18S41A0147	2				6	5
73	18S41A0148	2.5	1.5			6	5
74	18S41A0150	AB	AB	AB	AB	AB	5

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75	18S41A0151	4	3			5	5
76	18S41A0153	1	1			7	5
77	18S41A0154	5		4		7	5
78	18S41A0155	4	4			6	5
79	18S41A0157			1		7	5
80	18S41A0158	5				5	5
81	18S41A0159	4	4			6	5
82	18S41A0160	5	4			8	5
83	18S41A0161	3	3			8	5
84	18S41A0162	5	3			7	5
85	18S41A0166	5		5		7	5
86	18S41A0170		2.5	2.5		7	5
87	18S41A0171	5	3			7	5
88	19S45A0126		1	1		7	5
89	19S45A0127	4	3			7	5
90	19S45A0128		3		2	7	5
91	19S45A0129			2	2	7	5
92	19S45A0130	1		3		7	5
93	19S45A0131		3		1	7	5
94	19S45A0132	4				7	5
95	19S45A0133		3		2	9	5
96	19S45A0134	4			3	8	5
97	19S45A0135	4	3			8	5
98	19S45A0136	4.5	3.5			7	5
99	19S45A0137	5		2.5		6.5	5
100	19S45A0138	5	4			7	5
101	19S45A0139	2.5	3.5			7	5
102	19S45A0140	5		5		9	5
103	19S45A0141		3	4		7	5
104	19S45A0142		3			8	5
105	19S45A0143		3		3	7	5
106	19S45A0144		1	2		6	5
107	19S45A0145		2		2	7	5
108	19S45A0146		3	3		7	5
109	19S45A0147		3		3	7	5
110	19S45A0148	AB	AB	AB	AB	AB	5
111	19S45A0149	5	5			9	5
112	19S45A0150	2	2			7	5
113	19S45A0151	5	4			7	5
114	19S45A0152		3	3		7	5
115	19S45A0153	AB	AB	AB	AB	AB	5
116	19S45A0154	5	5			7	5
117	19S45A0155		3	2		8	5

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118	19S45A0156	5	3			7	5
119	19S45A0157	AB	AB	AB	AB	AB	5
120	19S45A0158	2	3			8	5
121	19S45A0159		3		2	6	5
No. of students attempted		86	79	45	43	121	121
Max Marks Question wise		5	5	5	5	10	5
Threshold 55%		2.75	2.75	2.75	2.75	5.5	2.75
No. of Students above thresold		59	50	12	17	104	121
% of Students>Target Score		68.61	63.3	26.67	39.54	85.96	100
Attainment Level		3	3	1	1	3	3

Attainment Level 1: 40% students score more than threshold
Attainment Level 2: 50% students score more than threshold
Attainment Level 3: 60% students score more than threshold

Course Outcome Mapping with each Question						
CO's	Question No				Objective	Assignment
	1	2	3	4		
Course outcome - 1	y				y	y
Course outcome - 2		y	y		y	y
Course outcome - 3				y	y	y
Course outcome - 4					y	y
Course outcome - 5					y	y

Course Outcome Attainment based on Exam Questions in terms of percentage of total students when mapped to each question						
CO's	Question No				Objective	Assignment
	1	2	3	4		
Course outcome - 1	3				3	3
Course outcome - 2		3	1		3	3
Course outcome - 3				1	3	3
Course outcome - 4					3	3
Course outcome - 5					3	3

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Course Outcome Attainment based on Exam Questions in terms of percentage of total students when mapped to each question				
CO's	Subjective	Objective	Assignment	Attainment Level
Course outcome - 1	3	3	3	3.00
Course outcome - 2	2	3	3	2.67
Course outcome - 3	1	3	3	2.33
Course outcome - 4		3	3	3.00
Course outcome - 5		3	3	3.00

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Department:	CIVIL ENGINEERING					
Course Outcome Attainment - Internal Assessments						
Name of the Faculty:			Academic Year:		2020-21	
Branch & Section:	CIVIL A&B		Exam:		Mid-2	
Course:	CT		Semister:		I	
Sl.No	Roll Number	Question No.				Objective	Assignment
		1	2	3	4		
Maximum Marks		5	5	5	5	10	5
1	18S41A0101				4	6	5
2	18S41A0103	5			3	8	5
3	18S41A0104	5			1	8	5
4	18S41A0105	1			2	8	5
5	18S41A0106	5				7	5
6	18S41A0107	5			3	8	5
7	18S41A0108	4			3	7	5
8	18S41A0109	5			3	8	5
9	18S41A0110	5			4	7	5
10	18S41A0111	5			5	9	5
11	18S41A0113	1	2			8	5
12	18S41A0114	0				8	5
13	18S41A0115	2	1			8	5
14	18S41A0116	5	4			9	5
15	18S41A0117	5			4	9	5
16	18S41A0118	5	1			7	5
17	18S41A0120	AB	AB	AB	AB	AB	5
18	18S41A0121				4	7	5
19	18S41A0122	5			5	9	5
20	18S41A0123	5			3	8	5
21	18S41A0124	5	3			9	5
22	18S41A0125	1				9	5
23	18S41A0126		5			8	5
24	18S41A0127	2			3	7	5

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25	18S41A0129		2		3	9	5
26	18S41A0132				3	8	5
27	18S41A0133	1				8	5
28	18S41A0135	5			3	7	5
29	18S41A0136	4				7	5
30	18S41A0137	5	5			6	5
31	18S41A0138	5				8	5
32	18S41A0140	5				8	5
33	18S41A0141	5			3	5	5
34	19S45A0101	5				7	5
35	19S45A0102	5			4	9	5
36	19S45A0103	5			4	9	5
37	19S45A0104	1			3	9	5
38	19S45A0105	5			4	8	5
39	19S45A0106				3	7	5
40	19S45A0107	5			3	8	5
41	19S45A0108	5			3	8	5
42	19S45A0109	5			4	9	5
43	19S45A0110	5			4	8	5
44	19S45A0111		4		4	7	5
45	19S45A0112	AB	AB	AB	AB	AB	5
46	19S45A0113	3			2	8	5
47	19S45A0114	5				9	5
48	19S45A0115	5			4	9	5
49	19S45A0116		3		2	8	5
50	19S45A0117	5	4			9	5
51	19S45A0118	AB	AB	AB	AB	AB	5
52	19S45A0119	1	1			7	5
53	19S45A0120	5			4	9	5
54	19S45A0121	5			4	9	5
55	19S45A0122	5			4	8	5
56	19S45A0123	5				8	5
57	19S45A0124	5				8	5
58	19S45A0125	5			3	8	5
59	17S41A0116	AB	AB	AB	AB	AB	5
60	17S41A0123	2				8	5
61	17S41A0136	1	1			8	5
62	17S41A0163	2	1			8	5
63	18S41A0145	5				7	5
64	18S41A0147	1			2	7	5
65	18S41A0148	4			2	7	5
66	18S41A0150	5	4			6	5
67	18S41A0151	5	1			7	5

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68	18S41A0153				2	8	5
69	18S41A0154	5		5		8	5
70	18S41A0155	5			4	9	5
71	18S41A0157	4				8	5
72	18S41A0158	5			4	8	5
73	18S41A0159		3		4	9	5
74	18S41A0160	5	2			8	5
75	18S41A0161	5			3	9	5
76	18S41A0162	5			3	7	5
77	18S41A0166	5			3	7	5
78	18S41A0170	5		4		7	5
79	18S41A0171	5			3	9	5
80	19S45A0126	5			3	8	5
81	19S45A0127	2	1			7	5
82	19S45A0128	5				8	5
83	19S45A0129	3				8	5
84	19S45A0130	5		2		9	5
85	19S45A0131	5				8	5
86	19S45A0132	3	1			7	5
87	19S45A0133	1			3	9	5
88	19S45A0134	4				9	5
89	19S45A0135	5		3		8	5
90	19S45A0136	5		3		8	5
91	19S45A0137	5			3	8	5
92	19S45A0138	5			3	8	5
93	19S45A0139	3			3	8	5
94	19S45A0140		2		4	8	5
95	19S45A0141	1			3	8	5
96	19S45A0142	2			3	8	5
97	19S45A0143	5			2	9	5
98	19S45A0144	1			2	7	5
99	19S45A0145	1			2	8	5
100	19S45A0146	5			3	8	5
101	19S45A0147	4			3	8	5
102	19S45A0148	4			1	7	5
103	19S45A0149	5			3	9	5
104	19S45A0150	1			1	8	5
105	19S45A0151	5		2		8	5
106	19S45A0152	5		3		8	5
107	19S45A0153	2			3	7	5
108	19S45A0154	5	4			7	5
109	19S45A0155	4			2	8	5
110	19S45A0156	5			3	9	5

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111	19S45A0157	3	3			9	5
112	19S45A0158	4			1	9	5
113	19S45A0159	1			2	9	5
114	20S48A0101	5	1			8	5
115	16S41AO112	AB	AB	AB	AB	AB	5
116	16S41A0182		1	1		8	5
117	17S41A0117	1				8	5
118	17S41A0125	1			2	8	5
119	17S41A0166	1		1		8	5
120	18S45A0109			3	3	8	5
121	18S45A0116	5			3	7	5
No. of students attempted		108	30	15	74	121	121
Max Marks Question wise		5	5	5	5	10	5
Threshold 55%		2.75	2.75	2.75	2.75	5.5	2.75
No. of Students above thresold		78	11	6	53	115	121
% of Students>Target Score		72.23	36.67	40	71.63	95.05	100
Attainment Level		3	1	1	3	3	3

Attainment Level 1: 40% students score more than threshold
Attainment Level 2: 50% students score more than threshold
Attainment Level 3: 60% students score more than threshold

Course Outcome Mapping with each Question						
CO's	Question No				Objective	Assignment
	1	2	3	4		
Course outcome - 1	y				y	y
Course outcome - 2		y	y		y	y
Course outcome - 3				y	y	y
Course outcome - 4					y	y
Course outcome - 5					y	y

Course Outcome Attainment based on Exam Questions in terms of percentage of total students when mapped to each question						
CO's	Question No				Objective	Assignment
	1	2	3	4		
Course outcome - 1	3				3	3
Course outcome - 2		1	1		3	3

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Course outcome - 3				3	3	3
Course outcome - 4					3	3
Course outcome - 5					3	3

Course Outcome Attainment based on Exam Questions in terms of percentage of total students when mapped to each question				
CO's	Subjective	Objective	Assignment	Attainment Level
Course outcome - 1	3	3	3	3.00
Course outcome - 2	1	3	3	2.33
Course outcome - 3	3	3	3	3.00
Course outcome - 4		3	3	3.00
Course outcome - 5		3	3	3.00

VAAGESWARI COLLEGE OF ENGINERING

Department:	**CIVIL ENGINEERING**	
	Course Outcome Attainment External Examination	
Name of the Faculty:		Academic Year:
Branch & Section:	CIVIL A&B	Exam:
Course:	CT	Semister:

S.NO.	HALLTICKET NO	TOTAL(Max. Score:75)
1	17WJ1A0167	
2	16S41A0112	-1
3	16S41A0182	6
4	17S41A0116	
5	17S41A0117	9
6	17S41A0123	11
7	17S41A0125	3
8	17S41A0136	26
9	17S41A0163	26
10	17S41A0166	0
11	18S41A0101	16
12	18S41A0103	32
13	18S41A0104	26
14	18S41A0105	26
15	18S41A0106	4
16	18S41A0107	11
17	18S41A0108	4
18	18S41A0109	40
19	18S41A0110	28

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20	18S41A0111	26
21	18S41A0113	17
22	18S41A0114	9
23	18S41A0115	30
24	18S41A0116	29
25	18S41A0117	31
26	18S41A0118	28
27	18S41A0120	
28	18S41A0121	11
29	18S41A0122	38
30	18S41A0123	26
31	18S41A0124	28
32	18S41A0125	15
33	18S41A0126	26
34	18S41A0127	28
35	18S41A0129	33
36	18S41A0132	26
37	18S41A0133	14
38	18S41A0135	26
39	18S41A0136	14
40	18S41A0137	27
41	18S41A0138	8
42	18S41A0140	8
43	18S41A0141	34
44	18S41A0145	3
45	18S41A0147	13
46	18S41A0148	13
47	18S41A0150	27
48	18S41A0151	28
49	18S41A0153	6
50	18S41A0154	33
51	18S41A0155	26
52	18S41A0157	11
53	18S41A0158	37
54	18S41A0159	41
55	18S41A0160	37
56	18S41A0161	36
57	18S41A0162	32
58	18S41A0166	44
59	18S41A0170	13
60	18S41A0171	26
61	18S45A0109	15
62	18S45A0116	30

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63	19S45A0101	4
64	19S45A0102	33
65	19S45A0103	48
66	19S45A0104	9
67	19S45A0105	39
68	19S45A0106	6
69	19S45A0107	26
70	19S45A0108	32
71	19S45A0109	32
72	19S45A0110	39
73	19S45A0111	26
74	19S45A0112	
75	19S45A0113	26
76	19S45A0114	40
77	19S45A0115	39
78	19S45A0116	26
79	19S45A0117	38
80	19S45A0118	-1
81	19S45A0119	30
82	19S45A0120	31
83	19S45A0121	26
84	19S45A0122	26
85	19S45A0123	6
86	19S45A0124	29
87	19S45A0125	35
88	19S45A0126	15
89	19S45A0127	28
90	19S45A0128	26
91	19S45A0129	26
92	19S45A0130	26
93	19S45A0131	26
94	19S45A0132	34
95	19S45A0133	26
96	19S45A0134	28
97	19S45A0135	26
98	19S45A0136	37
99	19S45A0137	26
100	19S45A0138	37
101	19S45A0139	29
102	19S45A0140	38
103	19S45A0141	26
104	19S45A0142	26
105	19S45A0143	35

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106	19S45A0144	26
107	19S45A0145	35
108	19S45A0146	28
109	19S45A0147	33
110	19S45A0148	32
111	19S45A0149	31
112	19S45A0150	5
113	19S45A0151	26
114	19S45A0152	34
115	19S45A0153	29
116	19S45A0154	28
117	19S45A0155	26
118	19S45A0156	33
119	19S45A0157	41
120	19S45A0158	26
121	19S45A0159	30
122	20S48A0101	16

No. of students who attempted the subject	116
Max. Marks	75
Thresold 40%	30
No. of students who scored more than the target score	40
Percentage of students who scored more than target score	34.48
Overall External Attainment level	**1**

Attainment Level	**1:**	**40% students score more than threshold**
Attainment Level	**2:**	**50% students score more than threshold**
Attainment Level	**3:**	**60% students score more than threshold**

VAAGESWARI COLLEGE OF ENGINERING

Department:	**CIVIL ENGINEERING**		
Overall Course Outcome Attainment			
Name of the Faculty:		Academic Year:	2020-21
Branch & Section:	CIVIL A&B	Exam:	
Course:	CT	Semister:	I

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Course Outcomes	1st Internal Exam	2nd Internal Exam	Internal Exam(Avg.)	University Exam
Course outcome - 1	2.67	3.00	2.84	3.00
Course outcome - 2	2.83	2.33	2.58	3.00
Course outcome - 3	3.00	3.00	3.00	3.00
Course outcome - 4	3.00	3.00	3.00	3.00
Course outcome - 5	3.00	3.00	3.00	3.00
Average			2.88	3.00

Final CO Attainment for the Subject	2.970833333

COURSE OUTCOMES AND PROGRAM OUTCOMES MAPPING														
	PO1	PO2	PO3	PO 4	PO5	PO 6	PO 7	PO 8	PO 9	PO1 0	PO1 1	PO1 2	PSO 1	PSO 2
Course outcome - 1	2	3	3	-	2	-	-	-	-	1	-	-	-	-
Course outcome - 2	3	2	3	-	1	-	-	-	-	2	-	-	-	-
Course outcome - 3	2	2	3	-	2	-	-	-	-	1	-	-	1	1
Course outcome - 4	2	2	2	-	1	-	-	-	-	2	-	-	-	-
Course outcome - 5	2	2	3	-	2	-	-	-	-	2	-	-	-	-
Average Pos	2.2	2.2	2.8	-	1.6	-	-	-	-	1.6	-	-	1	1
PO ATTAINMENT	**2.18**	**2.18**	**2.77**	-	**1.58**	-	-	-	-	**1.58**	-	-	**0.99**	**0.99**

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15. CO-PO MAPPING

Course Outcomes	Program Outcomes											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3		3						3		
CO2	3			3						1		
CO3	1		3	3						3		
CO4	3	3	3							1		
CO5	3		3	1						1		

1: Slight (Low) **2: Moderate (Medium)** **3: Substantial (High)**

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