30 Years

Previous Solved Papers

Civil Services Main Examination

(1995-2024)

Civil Engineering

Paper-II

Topicwise Presentation

Also useful for
Engineering Services Main Exam
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Preface

Civil Service is considered as the most prestigious job in India and it has become a preferred destination by all engineers. In order to reach this estimable position every aspirant has to take arduous journey of Civil Services Examination (CSE). Focused approach and strong determination are the pre-requisites for this journey. Besides this, a good book also comes in the list of essential commodity of this odyssey.

B. Singh (Ex. IES)

I feel extremely glad to launch the revised edition of such a book which will not only make CSE plain sailing, but also with 100% clarity in concepts.

MADE EASY team has prepared this book with utmost care and thorough study of all previous years papers of CSE. The book aims to provide complete solution to all previous years questions with accuracy.

On doing a detailed analysis of previous years CSE question papers, it came to light that a good percentage of questions have been asked in Engineering Services, Indian Forest Service and State Services exams. Hence, this book is a one stop shop for all CSE, ESE, IFS and other competitive exam aspirants.

I would like to acknowledge efforts of entire MADE EASY team who worked day and night to solve previous years papers in a limited time frame and I hope this book will prove to be an essential tool to succeed in competitive exams and my desire to serve student fraternity by providing best study material and quality guidance will get accomplished.

With Best Wishes

B. Singh (Ex. IES)

CMD, MADE EASY Group

Previous Years Solved Papers of

Civil Services Main Examination

Civil Engineering : Paper-II

CONTENTS

1 Building Materials and Construction Technology

1. Concrete

1.1 (i) Explain how fly-ash can be used in the production of bricks.
(ii) Discuss briefly the applications of fibre reinforced concrete in buildings.

[1996 : 20 Marks]

Solution:

(i) Fly-ash building bricks :

- The chemical composition of clays and fly-ash do not differ very much and the residual carbon content in the fly-ash brings economy in the fuel consumption during firing of bricks.
- The process involves the use of fly-ash, lime, sand and a small quantity of magnesium chloride as chemical accelerator. The fly-ash, sand and lime are mixed approximately in the ratio of 80 : 13 : 7. The hydraulic press is used for making these bricks and ultimately, the semi-dried bricks are cured in a steam chamber at appropriate pressure and temperature.
- The fly-ash buildings are superior to the conventional burnt bricks in shape, technical specifications, compressive strength and impermeability. They are also 20% light in weight and about 10 to 15% cheap as compared to the conventional bricks.

(ii) Applications of fibre reinforced concrete :

- The plain concrete fails suddenly when the deflection corresponding to the ultimate flexural strength is exceeded, on the other hand fibre-reinforced concrete (FRC) continue to sustain considerable loads even at deflections considerably in excess of the fracture deflection of the plain concrete.
- Steel FRC (SFRC) is very ductile and particularly well suited for structures which are required to exhibit:
  (a) high fatigue strength, resistance to impact and shock loads.
  (b) shrinkage control of concrete
  (c) very high flexural strength, tensile strength and shear strength
  (d) Erosion and abrasion resistance to splitting
  (e) High thermal resistance
  (f) Earthquake resistance
- The largest application of SFRC is in floor slab construction.
- Glass FRC(GFRC) is used in facing panels, piping for sanitation network systems, and decorative non-recoverable framework.
- Asbestos fibres have thermal, mechanical and chemical resistance making them suitable for sheet product, piles, tiles and corrugated roofing elements.

1.2 Calculate quantities of various ingredient (by weight) of 1 : 2 : 4 cement concrete required to prepare 4 cylinders of 10 cm diameter and 30 cm height.

[1996 : 15 Marks]

Solution:

$$\text{Volume of concrete required} = 4\times\left(\pi\times\frac{d^2}{4}\times h\right) = 4\times\pi\times\frac{(0.1)^2}{4}\times 0.3$$
$$= 9.4248\times 10^{-3}\ \text{m}^3$$

Assume the following :

Cement : specific gravity 3.15 (G_c)

Sand : Specific gravity 2.65 (G_s)

Coarse aggregate : Specific gravity 2.80 (G_G)

Water-cement ratio = 0.5

Volume of concrete = volume of voids + volume of solids

Assume volume of air = 0

$\Rightarrow$ volume of voids = volume of water

$$V_c = V_w + V_c + V_s + V_G$$

or, $$V_c = \frac{M_w}{\rho_w}+\frac{M_c}{G_c.\rho_w}+\frac{M_s}{G_s.\rho_w}+\frac{M_G}{G_a.\rho_w}$$

or, $$V_c = \frac{1}{\rho_w}\left[0.5M_c+\frac{M_c}{3.15}+\frac{2.M_c}{2.65}+\frac{4.M_c}{2.8}\right]$$

or, $$9.4248\times 10^{-3} = \frac{1}{1000}\times[3.007M_c]$$

$\Rightarrow$ $M_c = 3.1408$ kg

$\therefore$ $M_w = 1.5704$ kg;

$M_s = 6.2816$ kg;

$M_G = 12.5632$ kg

1.3 Find the quantity of cement, sand and coarse aggregates required for 15 m^3 of 1 : 5 : 10 plain cement concrete and 50 m^2 of 1 : 5 cement plaster 1.25 cm thick

[1999 : 20 Marks]

Solution:

Volume of concrete = 15 m^3

$W_c : W_s : W_a = 1 : 5 : 10$

Let water-cement ratio be 0.50 and percentage air voids be 3%

$$\text{Net volume of concrete} = 15-\frac{3}{100}\times 15 = 14.55\ \text{m}^3$$

Let specific gravity of cement be 3.15

Let specific gravity of sand be 2.60

Let specific gravity of coarse aggregates be 2.8

$\Rightarrow$ 14.55 = volume of water + volume of solids

or, $$14.55 = \frac{0.5W_c}{1000}+\frac{W_c}{G_c\times 1000}+\frac{W_s}{G_s\times 1000}+\frac{W_a}{G_a\times 1000}$$

or, $$14.55\times 1000 = 0.5W_c+\frac{W_c}{3.15}+\frac{5.W_c}{2.60}+\frac{10W_c}{2.8}$$

$\Rightarrow$ $W_c = 2305.14$ kg

$\therefore$ $W_s = 11525.73$ kg

$$W_a = 23051.4 \text{ kg}$$

$$\text{Volume of plaster} = 50 \times \frac{1.25}{100} = 0.625 \text{ m}^3$$

Considering 25% more due to losses,

$$\therefore \quad \text{Volume of mortar} = 0.625 + 0.25 \times 0.625 = 0.78125 \text{ m}^3$$

[Assuming 1 : 5 as ratio by volume]

$$\text{Quantity of cement required} = \frac{0.78125}{6} = 0.13021 \text{ m}^3$$

$$1 \text{ bag of cement} = 0.0347 \text{ m}^3$$

$$\therefore \quad \text{Number of bags} = \frac{0.13021}{0.0347} = 3.75 \simeq 4 \text{ bags}$$

and $$\text{Quantity of sand} = 0.13021 \times 5 = 0.65105 \text{ m}^3$$

1.4 Materials required per cu.m. of freshly mixed cement concrete are : 312 kg of dry cement, 855 kg of sand, 1010 kg of gravel and 145 kg of fresh water. Bulking, when mixing in the mixer, is 5%. What would be the density of the freshly mixed and poured cement concrete? What would be the total volume of fresh concrete that can be produced in a nominal 6 cu.m. mixer, in which loading during mixing can be only 65% of nominal capacity, per hour if its working cycle is : charging –35 seconds, mixing 170 seconds, discharging 30 seconds and lost time 18 seconds.

[2004 : 12 Marks]

Solution:

Let specific gravity of cement be 3.15, of sand be 2.60 and of aggregate be 2.50.

$$\text{Volume of freshly mixed concrete} = \frac{W_w}{1000} + \frac{W_c}{G_c \times 1000} + \frac{W_s}{G_s \times 1000} + \frac{W_a}{G_a \times 1000}$$

$$= \frac{145}{1000} + \frac{312}{3.15 \times 1000} + \frac{855}{2.60 \times 1000} + \frac{1010}{2.5 \times 1000}$$

$$= 0.977 \text{ m}^3$$

$$\text{Density of freshily mixed concrete} = \frac{312 + 855 + 10110 + 145}{0.977} = 2376.66 \text{ kg/m}^3$$

Bulking is 5%,

$$\therefore \quad \text{Volume of poured cement concrete} = 1.05 \times 0.977 = 1.02585 \text{ m}^3$$

$$\text{Density of fresh concrete} = \frac{312 + 855 + 1010 + 145}{1.02585} = 2263.489 \text{ .489 kg/m}^3$$

$$\text{Operating cycle} = 35 + 170 + 30 + 18 = 253 \text{ sec.}$$

$$\text{Number of cycles in 1 hour} = \frac{3600}{253} = 14.229 \simeq 14$$

$$\text{Quantity produced in one cycle} = 0.65 \times 6 = 3.9 \text{ m}^3$$

$$\therefore \quad \text{Quantity produced in one hour} = 3.9 \times 14 = 54.6 \text{ m}^3$$

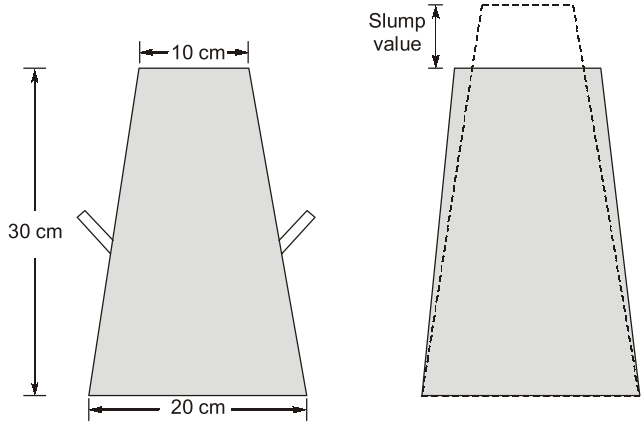
1.5 What is slump? How is it measured? What are the generally recommended maximum and minimum magnitudes of slump for (i) RCC foundation for walls and footings, (ii) Plain footings, (iii) RCC beams and reinforced walls, and (iv) columns in buildings?

[2005 : 12 Marks]

Solution:

Slump is a relative measurement in concrete consistency. It is not an indicator of quality of the material. Slump test is the most common method used to find the workability of the concrete in the field and in laboratory. This test is suitable for concrete having medium to high workability.

- The apparatus of this test consists of metallic mould in the shape of frustum of cone having bottom diameter of 20 cm, top diameter of 10 cm, and height of 30 cm, and a damping rod of height 60 cm and diameter 16 mm.
- In order to perform this test, mould is placed over the level ground and concrete is filled in it in four layers, where each layer is properly compacted with the help of the tamping rod by subjecting it to 25 number of blows.
- When the mould is completely filled, it is lifted in vertically upward direction that causes the concrete to subsidise, where this subsidence is referred as slump value, and it is further used to indicate the workability of the concrete.
- In order to measure the slump value, difference in the level of height of the mould and when the top surface of concrete is subsidised, is noted.



Type of concrete	Slump value (mm)	
	Maximum	Minimum
RCC foundation for walls and footings	75	25
Plain footings	75	25
RCC beams and reinforced walls	100	50
Columns in buildings	100	75

1.6 Calculate the quantities of water, cement, sand and coarse aggregate, by weight, required for a concrete batching plant of 5.0 cubic metre capacity from the following data :

S.No.	Item	Bulk density	Specific Gravity
1.	Cement	1500 kg/m^3	3.15
2.	Sand	1700 kg/m^3	2.60
3.	Coarse aggregate	1600 kg/m^3	2.50

Concrete mix proportion is to be 1 : 1.5 : 3 by weight and water-cement ratio is 0.5 by mass. Percentage of air entrained is 2 by volume.

[2007 : 15 Marks]

Solution:

$$W_c : W_s : W_a = 1 : 1.5 : 3$$
$$W/C = 0.5$$

Air content = 2 %

Total volume of concrete = 5 m^3

G_c = 3.15 ; G_s = 2.60; G_a = 2.50

Let weight of cement be W_c,

Let weight of sand be W_s,

Let weight of aggregate be W_a,

Net volume of concrete = total volume – volume of air in concrete

$$= 5-\left(\frac{2}{100}\times 5\right) = 4.9\ m^3$$

$$4.9 = \text{volume of water + volume of solids}$$

$$4.9 = \frac{0.5\times W_c}{1000}+\left[\frac{W_c}{G_c\times 1000}+\frac{W_s}{G_s\times 1000}+\frac{W_a}{G_a\times 1000}\right]$$

$$4.9 = \frac{0.5W_c}{1000}+\frac{W_c}{3.15\times 1000}+\frac{1.5\times W_c}{2.60\times 1000}+\frac{3\times W_c}{2.50\times 1000}$$

$$4900 = 2.5944\ W_c$$

$\Rightarrow$ W_c = 1888.6954 kg

$\therefore$ W_s = 2833.0431 kg

W_a = 5666.0862 kg

$$\text{Volume of cement} = \frac{1888.6954}{1500} = 1.2591\ m^3$$

$$\text{Volume of sand} = \frac{2833.0431}{1700} = 1.6665\ m^3$$

$$\text{Volume of coarse aggregate} = \frac{5666.0862}{1600} = 3.5413\ m^3$$

1.7 Which two main parameters are defined for fibres in fibre reinforced concrete?

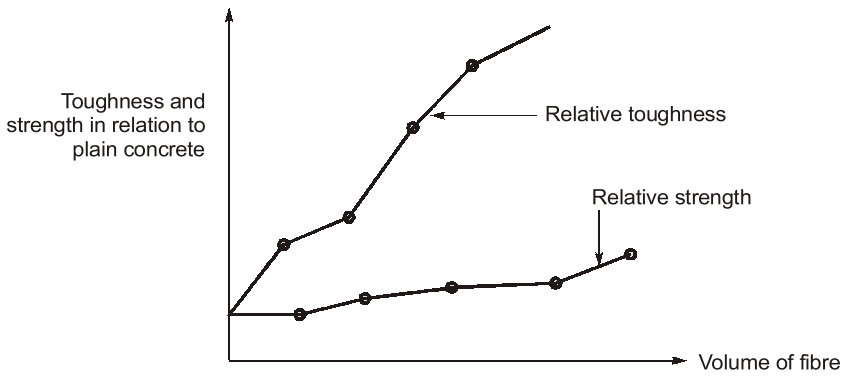
[2007 : 6 Marks]

Solution:

Two main parameters defined for fibres are :

(i) **Aspect ratio of the fibre :** It is the ratio of its length to its diameter. Typical aspect ratio ranges from 30 to 150.

(ii) **Volume of fibres :** The strength of the composite largely depends on the quantity of fibres used in it. It can be seen from the figure that the increase in the volume of fibres, increase approximately linearly, the tensile strength and toughness of the composite. Use of higher percentage of fibre is likely to cause segregation and harshness of concrete and mortar.



Other parameters are :

- Type of fibre, i.e., the material, and the texture
- orientation of the fibre in the matrix

1.8 Prepare a rate analysis for a 1 : 5 : 10 mix of cement concrete made with graded brick ballast, 40 mm down, for foundation work. Brick ballast required is 0.985 cu.m per cu.m of laid and finished work in this case.

Cost of brick ballast : ₹1800 /- per cu.m;

Medium sand : ₹970/- per cu.m

Cost per bag of cement : ₹170/-

Labour required per 10 Cu.m of finished work :

Senior mason : 1/2 number @ ₹320/- per day;

Mason : 6 number @ ₹275/- per day;

Men labour : 16 numbers @ ₹150/- per day.

[2008 : 12 Marks]

Solution:

Assume the following:

Cement : Specific gravity 3.15 and weight in each bag 50 kg.

Sand : Specific gravity 2.65 and unit weight 16 kN/m^3 when dry.

Coarse aggregate : Specific gravity 2.80 and unit weight 15 kN/m^3 when dry.

Water-cement ratio be 0.5

let total laid and finished work = 1 m^3

$$\therefore \quad 1\ m^3 = \frac{0.5W_c}{1000} + \frac{W_c}{3.15\times1000} + \frac{5W_c}{2.65\times1000} + \frac{10W_c}{2.8\times1000}$$

(We have assumed 0% air content)

$$\Rightarrow \quad W_c = 159.34\ kg$$
$$W_s = 796.7\ kg$$
$$W_a = 1593.4\ kg$$

$$\text{Number of cement bags} = \frac{159.34}{50} = 3.18, \text{ say } 4$$

$$\text{volume of sand} = \frac{796.7\times9.81}{16\times10^3} = 0.49\ m^3$$

$$\text{Volume of coarse aggregate} = \frac{1593.4\times9.81}{15\times10^3} = 1.042\ m^3$$

{We have assumed coarse aggregate used is same as brick ballast}

$\therefore$ Total volume of brick ballast = 1.042 + 0.985 = 2.027 m^3

Item	Quantity	Rate	Cost
Cement	4 bags	170/-	₹680
Sand	0.49 m^3	970/-	₹475.3
Ballast	2.027 m^3	1800/-	₹3648.6
			₹4803.9/m^3 of work

Labour	Number (per m^3)	Rate (₹/day)	Cost (₹)
S.mason	0.05	320/-	16
Mason	0.6	275/-	165
Men	1.6	150/-	240
			₹421

Total cost for cu.m of finished work = ₹(4803.9 + 421) = ₹5224.9

1.9 Explain in detail the need and procedure for conducting water absorption test for coarse aggregate to be used in cement concrete.

[2009 : 6 Marks]

Solution:

The water absorption of an aggregate is the percentage by weight of water absorbed in terms of oven dry weight of specimen and it is an accepted measure of porosity. For aggregates normally used in construction, the water absorption value varies from 0.1 to 2%.

Procedure :

(i) The sample of not less than 2000 g should be thoroughly washed to remove finer particles and dust, drained and then placed in the wire basket and immersed in distilled water at a temperature between 22 and 32°C.

(ii) After immersion, the entrapped air should be removed by lifting the basket and allowing it to drop 25 times in 25 seconds. The basket and sample should remain immersed for a period of 24 + 1/2 hrs afterwards.

(iii) The basket and aggregates should then be removed from the water, after which the aggregates should be gently emptied from the basket. The aggregates should be surface dried and weighed (A).

(iv) The aggregates should then be placed in an oven at a temperature of 100 to 110°C for 24 hours. It should then be removed from oven, cooled and weighted (B).

$$\text{Water absorption} = \left(\frac{A-B}{B}\right)\times 100$$

1.10 How does water cement ratio affect the strength of concrete?

[2010 : 5 Marks]

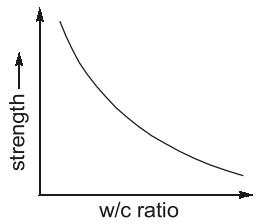
Solution:

The water in concrete has to perform the following two functions :

(i) The water enters chemical action with cement and this action causes the setting and hardening of concrete

(ii) Water makes the concrete workable.

The minimum quantity of water should be used to have reasonable degree of workability. The excess water occupies space in concrete and on evaporation, the voids are created in concrete. Thus the excess water affects considerably the strength and durability of concrete. In general, it may be stated that addition of one extra litre of water to the concrete of one bag of cement will reduce its strength by about 1.47 N/mm^2. In other words, the strength of concrete is inversely proportional to the water-cement ratio.



1.11 Describe in brief the advantage of hollow concrete masonry.

[2011 : 15 Marks]

Solution:

(i) **Rapid execution of work :** Hollow concrete block are of uniform and regular size and it has less weight. This facilitates rapid execution of work.

(ii) **Increase in Floor Area :** It is possible to construct thin walls using hollow blocks. Therefore it helps to save space and increase floor area.

(iii) **Reduce Construction Cost :** It helps in saving construction materials.

(iv) **Better Insulation Properties :** Hollow concrete block have good insulating properties against sound, heat and dampness.

(v) **More durable :** It requires no protective covering.

(vi) **Employment of unskilled labour :** As construction is easy, therefore unskilled labour can be employed.

(vii) Good bonding of mortar and plaster due to presence of rough surface on concrete blocks.

1.12 (i) Which cement would your recommend for
- **mass concrete**
- **low permeability concrete**
- **high strength concrete?**

(ii) Which type of cement concrete you will recommend for 'blast resistance purpose' and why?

[2012 : 5 Marks]

Solution:

(i) Mass concrete → Low heat cement

Low permeability concrete → Portland slag cement

High strength concrete → Rapid hardening cement or 53 grade OPC

(ii) Blast load is applied to concrete structures as an impulsive load of extremely short duration with very high pressure and heat. Therefore, a new material with high-energy absorption capacity and high resistance against impact is a better material for blast resistant design. Ultra-high performance concrete (UHPC) is a new type of concrete that is being developed by agencies. UHPC is characterized by being a steel fibre-reinforced cement composite material with compressive strengths in excess of 150 MPa. It is also characterized by its constituent material make-up, typically fine grained sand, silica fume, small steel fibres and special blends of high strength portland cement.

1.13 Name and discuss at least three advantages of adding appropriate polymer as admixture in cement concrete.

[2013 : 10 Marks]

Solution:

Plasticizers are usually based on lignosulphates, which is a natural polymer, derived from wood processing in the paper industry. These admixtures are used for following purposes :

(i) To achieve a higher strength by decreasing the water cement ratio at the same workability as in admixture free mix.

(ii) To achieve the same workability by decreasing the cement content so as to reduce the heat of hydration in mass concrete.

(iii) To increase the workability so as to ease placing in accessible locations

(iv) Water reduction more than 5% but less then 12%

Action involved :

(i) Dispersion : Surface active agents alter the physical chemical forces at the interface. They are adsorbed on the cement particles, giving them a negative charge which leads to repulsion between the particles. Electrostatic forces are developed causing disintegration and free water become available for workability.

(ii) Lubrication : As these agents are organic by nature, thus they lubricate the mix reducing the friction and increasing the workability.

(iii) Retardation : A thin layer is formed over the cement particles protecting them from hydration and increasing the setting time. Most normal plasticizers give some retardation, 30 – 90 minutes.

1.14 What kind of special attention is necessary for maturing concrete made with fly ash cement as per BSI codal provision?

[2013 : 5 Marks]

Solution:

- Fly ash shall have its chemical characteristics and physical requirements, etc. conforming to **IS : 3812 (Part-I)** and shall be duly certified.
- As per **IS : 1489 (Part-I)** maximum 35% of OPC by mass is permitted to be substituted with flyash conforming to **IS : 3812 (Part-I).**
- When tested by air permeability method, the specific surface of portland-pozzolana cement shall not be less than 300 m^2/kg.
- When tested by **Le Chatelier's** method and **Autoclave test,** unaerated portland-pozzolana cement shall not have an expansion of more than 10 mm and 0.8% respectively.
- Typically, concrete made with fly ash will be slightly lower in strength than plain cement concrete upto 28 days, equal strength at 28 days, and substantially higher strength within a year's time. Developing sustainable concrete to last more than 100 years requires extending the 28 day specifications. Extended age parameters can assure more durable concrete.

1.15 What are the standards given in IS : 456 – 2000 to produce good quality concrete ? Distinguish between repair, restoration and rehabilitation.

[2014 : 10 Marks]

Solution:

Section 10.1 (page 23) of **IS 456 : 2000** provides quality assurance measures to produce good quality concrete.

- Quality assurance measures are both technical and organizational.
- The job of quality control and assurance would involve quality audit of both the inputs as well as outputs.
- Inputs are in the form of materials for concrete; workmanship in all stages of batching, mixing, transportation, placing, compaction and curing; and related plant machinery and equipment; resulting in the output in the form of concrete in place.
- To ensure proper performance, it is necessary that each step in concreting which will be covered by next step is inspected as the work proceeds.
- Each party involved in the realization of a project should establish and implement a quality assurance plan.
- Such documentation should generally include :
  (a) test reports and manufactures certificate for materials, concrete mix design details;
  (b) pour cards for site organization and clearance for concrete placements.
  (c) record of site inspection of workmanship, field tests;
  (d) non-conformance reports, change orders;
  (e) quality control charts
  (f) statistical analysis.
- Volume batching may be allowed only where weight batching is not possible.
- The accuracy of the measuring equipment shall be within ± 2% of the quantity of cement being measured and within ± 3% of quantity of aggregate, admixtures and water being measured.
- Concrete shall be mixed in a mechanical mixer. The mixing time shall be atleast 2 min.

Repair : The main purpose of repairs is to bring back the architectural shape of the building so that all services start working and the functioning of building is resumed quickly. Repair does not pretend to improve structural strength of building. e.g. : Patching up of defects such as cracks.

Restoration : It is the restitution of strength the building had before the damage occurred. The main purpose is to carry out structural repairs to load bearing elements. It may involve cutting portions of elements and rebuilding them, inserting temporary supports, etc. e.g. : injecting epoxy like material, which is strong in tension, into the cracks, in walls, etc.

Rehabilitation : Rehabilitation methods, in addition to restoring structural integrity and shape, mitigate or stop the process responsible for the damage. Because rehabilitation includes addressing the cause of the problem itself, the repairs last significantly longer.

1.16 State the significance of 'Rate Analysis' in Estimating and costing of building. Calculate the quantities of cement, sand and coarse aggregate for preparing 1 cu.m of concrete of 1 : 2 : 4 proportion. Also calculate the number of bricks required of size 20 × 10 × 10 for constructing 1 m^2 of brick masonry wall. Explain any one method of building valuation.

[2014 : 20 Marks]

Solution:

At various stages in the project management, we need to know,

- How much is cost of executing unit amount of work.
- How many equipment or labour are required to execute unit amount of an item of work.

These things are required for the purpose of eliminating cost of construction, material planning, labour and equipment allocation in the scheduling etc. Obtaining the cost of unit amount of an item is called rate analysis. To obtain the rate of an item, generally following cost are considered.

- Cost of material
- Cost of labour
- Cost of equipment, plant tools etc.
- Overhead cost
- Profit

$$\text{Volume of concrete} = 1\ m^3$$

$$W_c : W_s : W_a = 1 : 2 : 4$$

Let water cement ratio be 0.5 and % air content be 3%.

Let us assume specific gravity of cement, sand and coarse aggregate equal to 3.15, 2.60 and 2.50 respectively.

$$\text{Net volume of concrete} = 1 - \frac{3}{100} \times 1 = 0.97\ m^3$$

$$\frac{0.5W_c}{1000} + \frac{W_c}{G_c \times 1000} + \frac{W_s}{G_s \times 1000} + \frac{W_a}{G_a \times 1000} = 0.97$$

or, $$0.5W_c + \frac{W_c}{3.15} + \frac{2.W_c}{2.60} + \frac{4.W_c}{2.50} = 0.97 \times 1000$$

$\Rightarrow$ $$W_c = 304.391 \text{ kg (weight of cement)}$$

$\therefore$ $$\text{Weight of sand} = 2W_c = 608.782 \text{ kg}$$

$$\text{Weight of coarse aggregate} = 4W_c = 1217.564 \text{ kg}$$

Let us assume one brick thick wall, i.e. $t = 20$ cm

$\Rightarrow$ $$\text{Number of bricks} = \frac{\text{Brickwork volume}}{\text{volume of 1 brick}} = \frac{20 \times 1 \times (100)^2}{20 \times 10 \times 10} = 100 \text{ bricks}$$

Methods of building valuation :

(i) Rental method
(ii) Profit based method
(iii) Depreciation method

Rental method of valuation :

- In this method, net income by way of rent is found out by deducting all out goings from the gross rent.
- A suitable rate of interest as prevailing in the market is assumed and year's purchase is calculated.

- This net income multiplied by Y.P. gives the capitalized value or valuation of the property.
- This method is applicable when the rent is known or probable rent is determined by enquiries.

1.17 Write short notes on the following:

(i) Acid attack (ii) Sulphate attack (iii) Alkali attack

On cement concrete

[2014 : 15 Marks]

Solution:

(i) **Acid Attack :** Portland cement is not acid resistant and acid attack may remove part of the set cement. Acids are formed by the dissolution in water of carbon dioxide or sulphur dioxide from the atmosphere. Acids can also come from industrial wastes. Good dense concrete with adequate cover is required and sulphate-resistant cements should be used if necessary.

(ii) **Sulphate Attack :** Sulphate are present in most cement and some aggregates. Sulphates may also be present in soils, groundwater and sea water, industrial wastes and acid rain. The products of sulphate attack on concrete occupy a larger space than the original material and this causes the concrete to disintegrate and permits corrosion of steel to begin. Sulphate-resisting portland cement should be used where sulphates are present in the soil, water or atmosphere and come into contact with concrete. Super-sulphated cement, made from blast furnace slag, can also be used.

(iii) **Alkali Attack :** A chemical reaction can take place between alkali in cement and certain forms of silica in aggregate. The reaction produces a gel which absorbs water and expands in volume, resulting in cracking and disintegration of the concrete. The reaction only occurs when the following thing are present together:

(a) a high moisture level in the concrete.

(b) cement with a high alkali content or some other source of alkali content.

(c) aggregate containing an alkali-reactive constituent.

1.18 What is meant by proportioning of concrete? Discuss its properties. Describe different methods of proportioning concrete.

[2015 : 15 Marks]

Solution:

The process of selection 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.

In general, the proportions of coarse aggregate, fine aggregate, cement and water should be such that the resulting concrete has the following properties :

(i) when concrete is fresh, it should have enough workability so that it can be placed in the framework economically.

(ii) The concrete must possess maximum density or in other words, it should be the strongest and most watertight.

(iii) The cost of materials and labour required to form the concrete should be minimum.

Different methods of proportioning concrete:

1. **Arbitrary method :**
   - The proportions of cement, sand and coarse aggregate are fixed arbitrarily such as 1 : 2 : 4 or 1 : 3 : 6 etc.
   - Usually, the fine to coarse ratio is 1 : 2
   - In this method, there is no rigid control over the strength of the concrete mix.
2. **Fineness modulus method :**
   - The fineness modulus of sand aggregates is determined by the standard tests carried out with a set of ten BIS sieves and dividing the sum by 100.
   - It is found from various experiments that certain values of fineness modulus for fine and coarse aggregates and mixed aggregates give better workability with less quantity of cement.

- The aggregates are mixed in such a proportion that the recommended fineness modulus of the combined aggregates is obtained.

3. Minimum Voids Method :
   - The voids of coarse aggregate and fine aggregate are determined separately and to get the dense concrete, it is so arranged that the quantity of fine aggregate completely fills the voids of the coarse aggregate;
   - the quantity of cement completely fills the voids of fine aggregate
   - sufficient water is added to make the mix workable.
4. Maximum density method :
   - It is based on the principle that the densest concrete is achieved by proportioning its aggregates in such a manner that the heaviest weight of concrete for same volume is obtained.
   - A box is filled with varying proportions of fine and coarse aggregates. The proportion which gives heaviest weight is then adopted.
5. Water-cement ratio method :
   - The lower water content produces stiff paste having greater binding property and hence the lowering of water-cement ratio within certain limits results in the increased strength.
   - The higher water content increases the workability. But it is not useful for the chemical action. The excess water evaporates leaving pores in the concrete. Thus the increased water-cement ratio lowers the strength of concrete.
   - Thus optimum water-cement ratio for the concrete of required compressive strength is decided from graphs and expressions developed from various experiments.

1.19 From workability and strength considerations, it is found that a concrete should have a unit water content and water-cement ratio of 180 kg/m^3 and 0.50, respectively. Also, from a durability point of view, the maximum water-cement ratio allowed is 0.45.
Now, assuming that the mortar content of the mix should be 60% (by volume), determine the content of cement, sand and coarse aggregate in kg/m^3 of concrete. Take specific gravity of cement, sand and coarse aggregate to be 3.14, 2.65 and 2.71, respectively, and ignore air content.
[2016 : 10 Marks]

Solution:

Given, water content = 180 kg/m^3

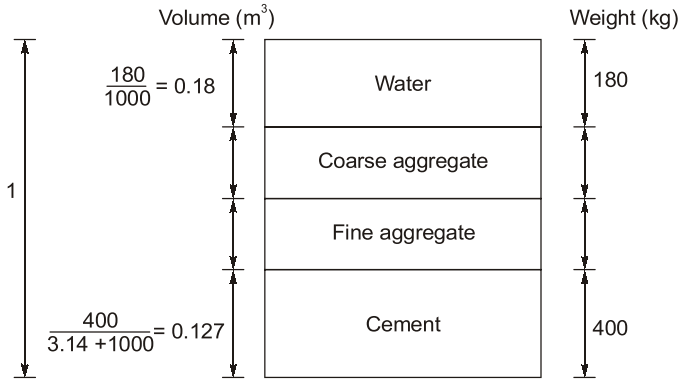
From durability point of view,

Maximum water cement ratio = 0.45

$\therefore$ In 1 m^3 of concrete (180 kg) water is present

$\therefore$ Cement content in 1 m^3 of concrete $= \frac{180}{0.45} = 400$ kg

Neglect air void as per question



$\therefore$ $V_{CA} + V_{FA} = 1 - 0.18 - 0.127 = 0.693\ m^3$ ...(i)

Now, it is given that mortar content is 60% by volume

i.e., $V_w + V_{cement} + V_{FA} = 0.6$

$0.18 + 0.127 + V_{FA} = 0.6$

$V_{FA} = 0.293\ m^3$

From eq. (i)

$V_{CA} = 0.693 - 0.293 = 0.40\ m^3$

$\therefore$ Mass of sand/FA $= 2.65 \times 1000 \times 0.293 = 776.45$ kg

Mass of coarse aggregate $= 2.71 \times 1000 \times 0.40 = 1084$ kg

$\therefore$ In 1 m^3 of concrete

Cement content = 400 kg

Fine aggregate = 776.45 kg

Coarse aggregate = 1084 kg

1.20 Define fibre reinforced concrete. Briefly explain how the presence of fibres in the matrix affects the properties of concrete.

[2016 : 15 Marks]

Solution:

Fiber reinforced concrete: In case of plain concrete, the presence of micro-cracks at the interface of mortar and aggregate is mainly responsible for its weakness. This weakness is overcome by adding fibres in the mix. These fibres help to transfer the load at the internal micro-cracks. This type of concrete is called as fiber-reinforced concrete.

- These added fibres interlock and entangle around the aggregate particles and thus reduce the workability but the mix becomes more cohesive and less prone to segregation.
- The required fibres are obtained from steel, glass, organic polymers etc.

Effect of fibres in the matrix on the properties of concrete: In fibre reinforced concrete, the fibres are randomly oriented in the matrix. The tensile cracking strain of cement matrix is much lower than the yield or ultimate strain of steel fibres.

- Therefore when a fibre reinforced concrete is loaded, the matrix will crack long before the fibres can be fractured.
- Once the matrix is cracked, the fibre reinforced concrete continues to carry the increased tensile stress. The peak stress and the peak strain of the fibre reinforced concrete are greater than those of the matrix alone.
- In fibre reinforced concrete, the fracture is a continuous process in which the cracking occurs over a wide range of loading and the de-bonding of fibres occurs over many stages.
- The pull-out resistance (i.e. bond) of fibres depends on the average bond strength between the fibres and the matrix, the number of fibres crossing the crack, the length and diameter of the fibres etc.
- Improvement in the structural performance of fibre reinforced concrete depends on the strength of fibres itself, volume of fibre reinforcement, dispersion and orientation of fibres, their shape and aspect ratio (i.e. l/d).
- Higher strength, larger volume, larger length and smaller diameter of fibres have been found independently to improve the strength of fibre reinforced concrete.
- Unidirectional fibres uniformly distributed throughout the volume are most efficient in uniaxial tension.
- Flexural strength depends on unidirectional alignment of fibres dispersed away from the neutral plane.
- Flexural shear strength demands random orientation of fibres.
- Proper shape and a higher aspect ratio are also required to develop adequate bond between the concrete and the fibres so that fracture strength of fibres may be fully utilized.

1.21 Discuss briefly the provisions in IS 456-2000 to ensure durability of reinforced concrete structures.
[2016 : 10 Marks]

Solution:

Provisions of IS 456: 2000 to ensure durability of reinforced concrete structures: Cl 8.1 defines *durable concrete* as "the one that performs satisfactorily in the working environment during its anticipated exposure conditions during service."

Requirements for durability:

- **Shape and size of member (Cl. 8.2.1):** The shape or the design details of the exposed structures should be such as to promote good drainage of water and to avoid standing pools and rundown of water. Care must be taken to minimize any cracks that may collect or transmit water. Adequate curing is essential to make for early loss of water.
- **Exposure conditions (Cl. 8.2.2):** The general environment to which concrete is exposed during its working life is classified into five levels as mild, moderate, severe, very severe and extreme.
  (i) Where freezing and thawing actions under wet conditions exist, enhanced durability can be achieved by use of suitable air entraining admixtures. But since air entrainment reduces the strength of concrete and thus suitable adjustments must be made in the design mix. **(Cl. 8.2.2.3)**
  (ii) **Table 4 of IS 456: 2000** specifies requirements for the type of cement, maximum free water/cement ratio and minimum cement content for concrete exposed to sulphate environment.
- **Cover requirements (Cl. 8.2.3): Table 16 of IS 456: 2000** specifies nominal cover to meet durability requirements as described below.

Exposure condition	Minimum nominal cover (mm)
Mild	20
Moderate	30
Severe	45
Very severe	50
Extreme	75

- **Maximum cement content (Cl. 8.2.4.2):** Cement content not including fly ash and ground granulated blast furnace slag in excess of 450 kg/m^3 must not be used.
- **Compaction, finishing and curing (Cl. 8.2.7):** Adequate compaction without segregation must be ensured by providing suitable workability and by proper placing and compaction. Good finishing is essential for durable concrete.
- **Concrete in sea water (Cl. 8.2.8):** Concrete in sea water or exposed directly along the sea coast shall be at least M20 grade for plain concrete and M30 grade for reinforced concrete. Use of slag or pozzolana is beneficial under such conditions.

1.22 What tests are carried out to determine the mechanical properties of coarse aggregates used in concrete? (Not exceeding 50 words)
[2016 : 5 Marks]

Solution:

Following tests are carried out in laboratory on the samples of aggregates to ascertain their some of the properties:

1. **Abrasion test:** In order to determine the hardness or resistance to wear, the abrasion test is carried out by anyone of the following three methods:
   (i) Deval abrasion test (ii) Dorry abrasion test (iii) Los Angeles abrasion test
2. **Crushing test:** This test is carried out to assess the strength of coarse aggregate when compressive load is gradually applied.
3. **Impact test:** The toughness of rock means resistance to fracture from impact or absence of brittleness. The impact test is designed to evaluate the toughness of stones.

4. **Shape test:** The shape test is carried out to get a rough idea of the relative shapes of the aggregates. The evaluation of the shape of the particles is made in the form of the following three terms.
   (i) Angularity number (ii) Elongation index (iii) Flakiness index
5. **Soundness test:** This test originated in Europe in the early nineteenth century and it is intended to assess the resistance of the aggregate to weathering.
6. **Specific gravity and water absorption test:** The inherent properties of specific gravity and water absorption are often important to get an idea of strength or quality of the material.
6. **Stripping value test:** This test is also known as bitumen affinity test and it is carried out to known the behaviour of aggregates towards bitumen.

1.23 Describe in brief the various methods of proportioning concrete. **[2017 : 5 Marks]**

Solution:

The various methods of proportioning the concrete are as follows:

1. Indian Standard Recommended Method IS 10262 : 82
2. American concrete Institute method of mix design
3. DOE Method
4. Mix design for pumpable concrete
5. IRC 44 method
6. Mix design based on flexural strength
7. Arbitrary proportion
8. Fineness modulus method
9. Maximum density method
10. Surface area method

1.24 The design mix proportion of Cement : Fine agg. : Coarse agg. : Water for a concrete mix of grade M25 at Saturated Surface Dry (SSD) condition is 1 : 1.2 : 2.4 : 0.4 (by weight). Find out the revised mix proportion due to change of material characteristics (Fine and Coarse agg.) for raining day before casting at site.

Given : (i) Sp. gravity of Fine and Coarse agg. = 2.6 and 2.65 respectively.
(ii) Surface moisture (%) on Fine and Coarse agg. = 2.5 and 1.5 respectively.

How the durability factor is taken up during concrete mix design as per I.S. code?

[2017 : 10 Marks]

Solution:

Given: Design Mix proportion of grade M-25:

Water	Cement	Fine Aggregate	Coarse Aggregate
0.40	1.0	1.2	2.40 (By weight)

For 50 kg of cement, the quantity materials are worked out as below,

(a) Cement = 50 kg

(b) Sand (Fine Aggregate) = 60 kg

(c) Coarse Aggregate = 120 kg

Given: Specific gravity of *FA* = 2.60 and *CA* = 2.65,
Surface moisture (%) on *FA* = 2.5%
Surface moisture (%) on *CA* = 1.5%

(d) Water

1. For water cement ratio of 0.40 quantity = 20.0 litres
2. Quantity of water to be deducted for free surface moisture present in sand

$$= -\frac{2.5}{100} \times 60 = -1.5 \text{ kg}$$

3. Quantity of water to be deducted for free surface moisture present in coarse aggregate

$$= -\frac{1.50}{100} \times 120 = -1.8 \text{ kg}$$

4. Actual quantity of water to be added = 20 – 1.50 – 1.80 = 16.7 kg

(e) Actual quantity of sand required after allowing mass of free moisture
= 60 + 1.5 = 61.5 kg

(f) Actual quantity of coarse aggregate required = 120 + 1.80 = 121.80 kg

Therefore actual quantities of different constituents required for the mix are:

	Water	Cement	Sand (FA)	Coarse Aggregate(CA)
	16.7	50	61.50	121.80
Revised mix proportion	0.334	1	1.23	2.436

How durability factor is taken up in concrete mix design:

The physical properties of concrete, compressive strength is often taken as index of its quality in terms of durability, impermeability of water tightness and is easily measurable. Therefore, the mix design is generally carried out for a particular compressive strength of concrete, coupled with adequate workability, so that fresh concrete can be property placed and compacted. In addition, the mix proportions are also checked against the requirement of adequate durability for the type of exposure condition anticipated in service.

The free water/cement ratio selected on target mean strength criteria and workability criteria as per IS : 10262 should be checked against the limiting water/cement ratio for requirements of durability and the lower of two values are adopted.

1.25 Explain the following:

(i) Bulking of sand (ii) Fineness modulus (iii) Water cement ratio (iv) Slump test

[2018 : 15 Marks]

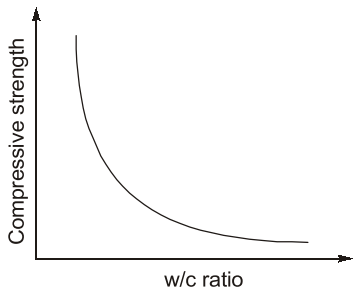
Solution:

(i) **Bulking of sand :** The increase in volume of dry sand due to absorption of moisture is called bulking of sand. When dry sand comes in contact with moisture, a thin film is formed around the particles, which causes them to get apart from each other. This result in increase in volume of the sand. It has been found that at 4-5% of moisture content of dry sand, the bulking of sand is about 30%. Further addition of moisture leads to breaking of the film and subsequent decrease in volume of the sand. When the quantity of water in sand becomes more than 20% or the sand is fully immersed in water its volume becomes the same as that of dry sand.

(ii) **Fineness modulus:** The fineness modulus is an empirical figure obtained by adding the total percentage of aggregate retained on each of specified series of sieves, and dividing the sum by 100.

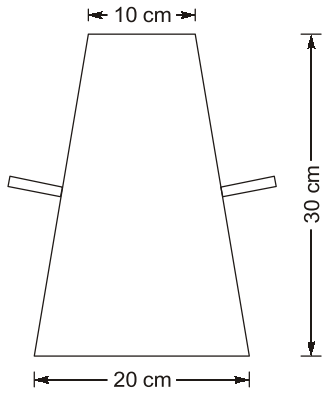
Fineness modulus of finer aggregate is lower than fineness modulus of coarse aggregate.

(iii) **Water cement ratio:** Water cement ratio is defined as the ratio of mass of free water i.e., excluding that absorbed by the aggregates) to that of cement in a concrete mixture. It is the major factor that controls the strength and many other properties of the concrete.



The strength of concrete increases with the cement content and decreases with the air and water content. As per Abrahm's w/c ratio law, the strength of the concrete is mainly depend upon the w/c ratio provide concrete is workable. Lower w/c ratio can be used when concrete is vibrated to achieve higher strength whereas comparatively higher strength is required when concrete is to be compacted.

(iv) **Slump test:** The concrete slump test measures the consistency of the fresh concrete before it sets. It is performed to test the workability of freshly made concrete, and therefore the ease with which concrete flows. This test is suitable for concrete having medium to high workability.



The apparatus of this test consists of metallic mould in the shape of frustrum having bottom diameter of 20 cm, top diameter of 10 cm and height of 30 cm and tampering rod of height 60 cm and diameter 16 mm.

In order to perform this test, mould is placed over level ground and concrete is filled in 4 layers, where each layer is compacted properly with the help of tempering rod by subjecting it to 25 number of blows.

When the mould is completely filled, it is lifted verticality upward that causes the concrete to subsidies, where this subsidence is referred to as slump value and it is further used to indicate the workability of the concrete. In order to measure the slump value, difference in the level of height of the mould and when the top surface of concrete is subsidized is noted.

1.26 (i) Why is cube strength different from cylinder strength for the same grade of concrete?
(ii) What is Bauschinger effect? Where is it relevant?

[2019 : 10 Marks]

Solution:

(i)
- Of the various strength of concrete, the determination of compressive strength has received a large amount of attention because the concrete is primarily meant to withstand compressive stress.
- Cubes, cylinders and prisms are the three types of compression test specimens used to determine the compressive strength on testing machine.
- The compressive strengths given by different specimens for the same concrete mix are different.
- In case of cylinder end effects have less influence, in these specimens and it is generally agreed that the cylinder strength of concrete is a good estimate of the monoaxial compressive strength.
- A cube of concrete is expected to have strength 15 percent greater than cylinder strength because contact area of a standard cube mould with the upper plate in the testing machine is more which results in more confinement more confinement resist against specimen expansion resulting in more compressive strength.

(ii) The ideal stress-strain curve for mild steel in compression is identical to the one in tension upto the point of maximum stress. However, the actual behaviour is different and indicates an apparently reduced yield stress in compression. This decrease in the yield strength in compression takes place only when the direction of the strain changes. The divergence from the ideal path is called the Bauchinger effect.
- When stiffness is of primary concern e.g. deflection or buckling, the Bauchinger effect must be given due consideration.

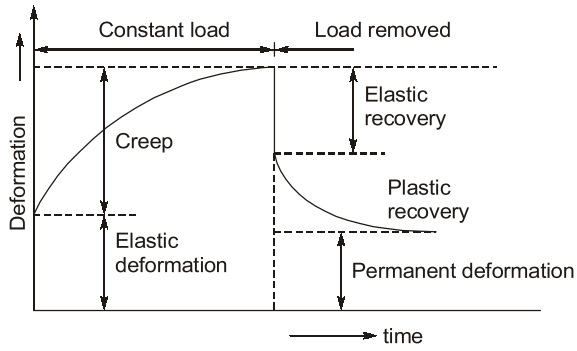
1.27 What does creep of concrete mean? Is creep harmful or beneficial? What factors influence creep?

[2019 : 10 Marks]

Solution:

Creep: It is continued deformation with time under a constant load, it may be defined as increase of strain in concrete with time under sustained stress, this is also known as plastic flow or time yield.

- Creep may be due to closer of internal voids, viscous flow of the cement paste and flow of water out of the cement gel. In reinforced concrete structures it is of advantage since it causes better distribution of stresses. For example in a R.C.C column there is a reduction of stress in concrete and a corresponding increase of stress in steel due to creep. As another example creep Lelieves the high stressed portions of concrete in a continuous beam and increases the stress in the adjacent less stressed portion. Creep causes large deformations and deflections is undesirable. The deformation of hardened concrete is as shown in fig.



- In general creep increases when:
  - Cement content is high
  - Water cement ratio is high
  - Aggregate content is low
  - Air entertainment is high
  - Relative humidity is low
  - Temperature is high
  - Loading occurs at an early age
  - Loading is sustained over a long period

  Hence, all the factors which influence creep includes type of aggregate, cement and admixtures, entrained air, mix proportions, mixing time and consolidation, age of concrete, level of sustained stress, ambient humidity, temperature and the size of the specimen.

1.28 Explain the following:

(i) High performance concrete
(ii) Self-compacting concrete
(iii) Fibre-reinforced concrete
(iv) Polymer concrete
(v) Ferro-cement

[2019 : 15 Marks]

Solution:

(i) High Performance Concrete:

- High performance concrete is defined as concrete which meets special performance and uniformity requirements that cannot always be achieved routinely by using only conventional materials and normal mixing, placing and curing practices. The requirement may involve enhancements of characteristics such as placement and compaction without segregation, long-term mechanical properties, high early age strength, toughness, volume stability, durability service life in severe environments, flow ability and self-levelling capability or low heat of hydration. Often a higher modulus of elasticity, not the compressive strength is the controlling requirements in HPC construction.
- A high-strength concrete is always a high performance concrete, but a high performance concrete is not always a high strength concrete.

(ii) Self Compacting Concrete:

- Self compacting concrete (SCC) is a very special type of concrete which can flow and fill into every corner of formwork even in the presence of congested reinforcement, purely by means of its own weight and without need of vibrating compaction, tamping etc.
- Self-compacting concrete as it sounds is nothing different from normal concrete. It is just usage of extra admixtures (superplasticizers and viscosity modifying admixtures) and different amount of composite materials that makes SCC act different to normal one.
- A well designed SSC mix does not segregate has high deformability and excellent stability characteristics.

- Self compacting concrete is characterised by high powder content. The parameter that is important in SCC is water-powder ratio; water-cement ratio is completely ignored. Other important parameters are fly ash content, sand-aggregate ratio, paste percentage, types of admixtures used etc. The aggregate content in SCC is smaller than that for conventional concrete requiring vibration.

(iii) Fibre Reinforced Concrete:

- Conventional concrete is modified by random dispersal of short discrete fine fibers of asbestos, steel, sisal, glass, carbon, poly-propylene, nylon etc. such a concrete is known as fibre reinforced concrete (FRC). Asbestos cement fibers so far have proved to be commercially successful.
- The improvement in structural performance depends on the strength characteristics volume, spacing, dispersion and orientation shape and their aspect ratio (ratio of length to diameter) of fibers.
- A fibre reinforced concrete requires a considerably greater amount of fine aggregate than that for conventional concrete for convenient handling for FRC to be fully effective, each fibre needs to be fully embedded in the matrix thus the cement paste requirement is more.
- Fibre reinforced concrete is useful in hydraulic structures, airfield pavements, highways, bridge decks, heavy duty floors, and tunnel linings.

(iv) Polymer Concrete:

- The strength of concrete is greatly affected by porosity. Obviously, attempts to reduce it by vibration, pressure application, spinning etc. However, these are of little help in reducing the water voids and the inherent porosity of gel which is about 28 percent.
- The impregnation of monomer and subsequent polymerisation reduces the inherent porosity of the concrete polymers-polyvinyl acetate, homopolymer emulsions, and vinyl acetate copolymer emulsions are added to increase strength, resistance to oil, grease and abrasion. They also improve bond between new and old concrete and are useful for prefabricated structural elements and prestressed concrete. The disadvantages are that they are very brittle and expensive.

(v) Ferrocement:

- Ferrocement is a composite material in which the filler material (called matrix), cement mortar, is reinforced with fibres, usually steel mesh dispersed throughout the composite, which results in better structural performances than individual ones. The fibres imparts tensile strength to the mass.
- Ferrocement which is specially advantageous in spatial structure has relatively better mechanical properties and durability than ordinary reinforced concrete within certain loading limits, it behaves as homogenous.
- Ferrocement is used in thin walled structures where strength and rigidity are developed through form or shape. It has distinct advantage of being moldable and of one piece construction. Other major advantages are its low cost and its non-flammability and high corrosion resistance characteristics.

1.29 (i) What are the materials used for thermal insulation over roof? Describe the three types of membrane used for roof waterproofing.

(ii) What are the most effective ways of providing durability to concrete against chemical attack in a known adverse environment?

[2019 : 20 Marks]

Solution:

(i) Thermal insulating materials may be in the following forms:

(a) Slab or block insulation
(b) Blanket insulation
(c) Loose fill insulation
(d) Bat insulating materials
(e) Insulating board
(f) Reflective sheet materials
(g) Light weight materials

1. **Blanket insulation:** These are flexible fibrous rolls made from minerals wool, processed wood fibers, cotton, animals hair etc. available in thickness of 12 to 80 mm. These are directly spread on the wall or ceiling surface.
2. **Slab or block insulation:** They are known as blocks or boards, 2.5 cm thick and 60 cm × 120 cm (or more) in area. These may be made of cork board, minerals wool, vermiculite, cellular glass, cellular rubber, saw dust, asbestos cement etc. These are fixed to walls or roofs.
3. **Loose fill insulation:** These may consists of fibrous materials like rock wool, slag wool, cellulose or wood fibre wool etc. filled loosely in the studding space.
4. **Bet insulating materials:** These are similar to blanket insulations except that these are small in size but of greater thickness. These are also spread on surface of walls and ceilings.
5. **Insulating boards:** These are used for interior lining of walls, and also for partition walls, structural insulating board is manufactured by first making a pulp of wood, cane or other materials and then passing them in form of boards by adding suitable adhesives. They are available in different sizes and thickness.
6. **Reflecting sheet materials:** Reflecting sheet materials have high reflectivity and low emissibility, thus offering high heat resistance. Solar energy striking reflective surfaces get reflected and amount of heat which may get transmitted is greatly reduced. Reflective insulations may consists of gypsum boards, steel sheet reflective materials, aluminium foils, sheet aluminium reflective materials etc.
7. **Light Weight Aggregate:** Heat resistance of concrete can be greatly increased by using light weight aggregates like blast furnace slag, burnt clay aggregates, vermiculite etc.

Membrane used for roof waterproofing:

(a) **Liquid waterproofing membrane:** Liquid membrane is a thin coating which consists of usually a primer coat and two coats of top coats which are applied by spray, roller or trowel. It offers more flexibility then the cementitious types of waterproofing.

(b) **Bituminous membrane waterproofing:** Bituminous membrane waterproofing is a popular method used for low sloped roofs due to their proven performance. Bituminous waterproofing membrane have torch on membrane and self-adhesive membrane.

(c) **Polyurethane liquid membrane waterproofing:** It is used for the flat roof area and exposed to weathering. It can offer higher flexibility. It is very sensitive to moisture content present.

(ii) A durable concrete is one that performs satisfactory under anticipated exposure conditions for stipulated life of the structure. Although concrete is a very durable material, concrete structures have shown poor durability and strength loss within few year of their service life due to weathering action, chemical attack and abrasion.

- Concrete has gel pores and capillary cavities. About 1/3 of gel pores are so small that they hardly pass any water through them. The extent of capillary cavities, which depends on the w/c ratio, is the major factor contributing to permeability. The remedies are:
  1. Use of puzzolanic materials.
  2. Air entrainment up to 6 percent.
  3. High pressure steam curing in conjunctions with silica.
- For a durable concrete, use of lowest possible water cement ratio is the fundamental requirement to produce dense and impermeable concrete.
- The recommendations for making durable concrete usually envisage limits for maximum water-cement ratio, thickness of cover, type of cement and the amounts of chlorides and sulphates in the concrete. Against sulphate attack the remedy is to use low C_3A content cements such as blast furnace slag cement, sulphate resisting cement, supersulphated cement and by reducing the permeability.

1.30 Indicate (in bulleted form) the advantages of ferro-cement over the conventional RCC. Can we use the ferro-cement tanks for high capacity like 25000 litres or above? Justify your answer.

[2021 : 10 marks]

Solution:

- Ferrocement is composite material in which the filler material is called matrix, wherein cement mortar is reinforced with fibers, usually with steel mesh dispersed throughout the composite, which results in better structural performance.
- The fibers impart tensile strength to the mass.
- In ferrocement structures, the reinforcement consists of small diameter wire meshes which results in uniform distribution of reinforcement throughout the thickness of element which finally increases resistance against cracking. Moreover, toughness, fatigue resistance, impermeability, performance, strength also increase.
- No form work is required since wire mesh and chicken mesh receive mortar wherein the mortar applied with pressure is held in position by mechanical interlocking.
- The high surface area to volume ratio i.e. specific surface of ferrocement results in better crack arrest mechanism i.e. the propagation of cracks are arrested resulting in high tensile strength of materials.
- It is cheap, non-inflammable, high corrosion resistive.
- It is used in thin-walled structure where strength develops through shape.
- It has advantage of being moldable and of one piece construction.
- It has more bond strength between reinforcement and concrete.
- Smaller dimension of mesh, smaller spacing between wires, increases the first crack stress.
- As it has excellent control over crack and impermeability characteristics, so it is suitable for liquid retaining structures, gas container, canal lining, caissons etc.
- As it is cheaper than RCC, so it can be used for low cost roofing, pre cast units, manhole cover, dome, grid surfaces, corrugated sheets etc.

1.31 Briefly explain the deterioration of concrete caused by (i) leaching action, and (ii) chemical interaction.

[2022 : 10 Marks]

Solution:

(i) **Leaching action :** This type of deterioration may be caused by dissolution of ingredients of hardened cement by aqueous solution i.e. by leaching process. Since calcium hydroxide is a readily soluble ingredient of hardened cement, destruction of concrete by leaching action is also called lime leaching. It is greatly dependent upon permeability of concrete. When free lime of concrete is leached out, hydrolysis of calcium silicates and aluminates takes place to release more lime for further leaching action. Out of silicate hydrates, dicalcium hydrosilicate ($2CaO.SiO_2.aq.$) which is the most unstable compound, in absence of a saturated solution of calcium hydroxide, dissociates at a faster rate to liberate more of lime. Whereas, among the aluminate hydrates, tetra calcium aluminate hydrate ($4CaO.Al_2O_3.H_2O$) is least stable in absence of calcium hydroxide. Therefore, when concentration of lime inside concrete is reduced on account of leaching action, more of it will dislocate to produce additional amount of lime.

Table below depicts variation in solubility of lime with nature of salts and their concentration in a solution.

Chemical	Concentration (percent)	Solubility (gm/liter)
Distilled water	-	1.18
Na_2SO_4	1.0	2.14
Na_2SO_3	2.0	3.00
NaOH	0.5	0.18

Increased solubility of lime accelerates destruction of concrete and after about 10% losses in terms of initial cement, concrete starts rapidly losing its strength. When leached out lime reacts with atmospheric carbon dioxide gas, concrete surface gets covered with white residue of calcium carbonate. It is also called as white death of concrete due to leaching action.

(ii) **Chemical interaction :** Deterioration may be caused by chemical reaction between hardened cement constituents of concrete and chemical of a solution. The reaction products formed may be either water soluble and may get removed from internal structure of concrete by a diffusion process, or the reaction products if insoluble in water may get deposited on surface of concrete as an amorphous mass having no binding properties, with the result that it can be easily washed out from concrete surface.
Acid first react with free lime of concrete forming calcium salts and later on attack hydrosilicates and hydroaluminates forming corresponding calcium salts, where solubility will be to the extent of deterioration caused to concrete.

1.32 What do you understand by workability of concrete? Write the procedure for any one measurement method available to check the workability of concrete.

[2023 : 10 Marks]

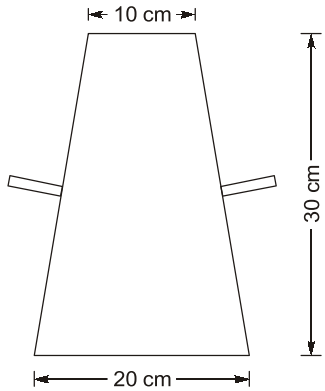
Solution:

As per IS : 6461 (Part VII)-1973 workability can be defined as that property of freshly mixed concrete or mortar which determines the ease and homogeneity with which it can be mixed, placed, compacted and finished.

Slump test is one of the methods available to check the workability of concrete.

Slump test: The concrete slump test measures the consistency of the fresh concrete before it sets. It is performed to test the workability of freshly made concrete, and therefore the ease with which concrete flows. This test is suitable for concrete having medium to high workability.

The apparatus of this test consists of a metallic mould in the shape of frustrum having bottom diameter of 20 cm, top diameter of 10 cm and height of 30 cm and a tampering rod of length 60 cm and diameter 16 mm.



In order to perform this test, mould is placed on a level ground and concrete is filled in four layers, where each layer is compacted properly with the help of tempering rod by subjecting it to 25 number of blows.

When the mould is completely filled, it is lifted verticality upward that causes the concrete to subside, where this subsidence is referred to as slump value and it is further used to indicate the workability of the concrete. In order to measure the slump value, difference in the level of height of the mould and the top surface of concrete when it has subsided noted.