PIE Tech
POLLACHI INSTITUTE OF ENGINEERING AND TECHNOLOGY
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sky is the limit

Department of Civil Engineering

Regulation 2021

IV Year – VIII Semester

CE3403 – Concrete Technology

UNIT - 1

CONSTITUENT MATERIALS

Cement - Different types - chemical Composition & properties - Hydration of Cement - Tests on Cement - IS Specifications - Aggregates - Classification - Mechanical properties and tests as per BIS - Grading requirements - Water - Quality of water for use in concrete.

Cement:

Cement is the most important constituent, because its used to bind bond and aggregate and it resists atmospheric action. The main raw material for the production of cement is clinker. Clinker is an artificial rock made by heating limestone and other raw materials at specific quantities at high temperature.

Raw materials used for making cement:

1). Limestone ($CaCO_3$)
2). Sand (SiO_2)
3). Slate clay (SiO_2, Al_2O_3, Fe_2O_3)
4). Irone ore (Fe_2O_3)

* The raw materials required for manufacture of cement are calcareous materials, such as limestone (or) chalk, and argillaceous material such as shale (or) clay.

* The process of manufacture of cement consists of grinding the raw materials, mixing them intimately in certain proportions depending upon their purity & composition and burning them in a kiln at a temperature of about 1300 to 1500°C.

* There are two process known as wet and dry processes depending upon whether the mixing and grinding of raw materials is done in wet & dry conditions.

Wet process

* In wet process, the limestone brought from the quarries is first crushed to small fragments. Then it is taken to a ball (or) tube mill where it is mixed with clay (or) shale as the case may be and 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 to 50 per cent, wherein particles crushed to the fineness of Indian standard sieve number 9, are held in suspension.

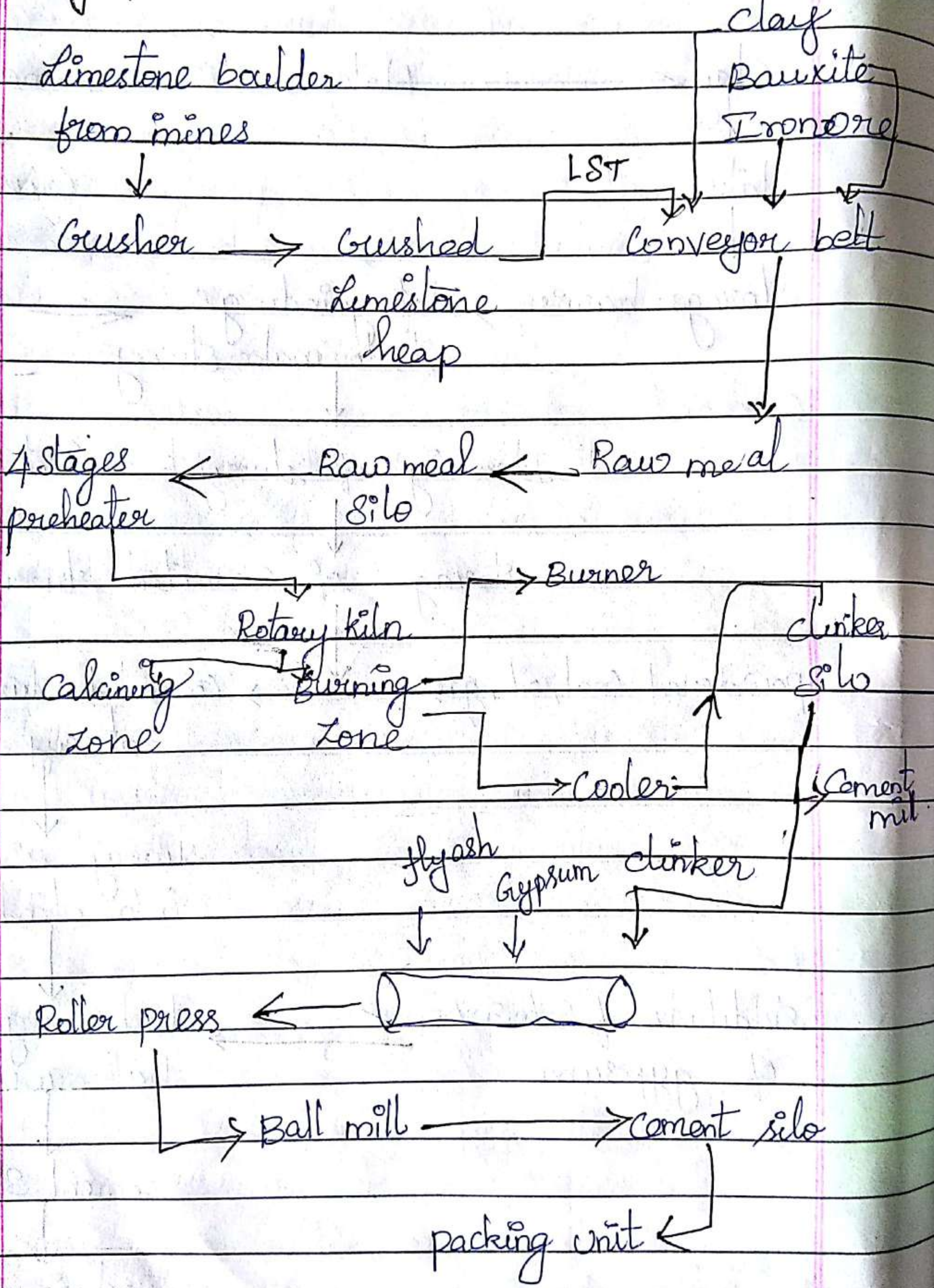
Clay ← Water → Limestone

Clay → Water mill → Storage basins → Wet grinding mills to make slurry

Limestone → Crusher → Storage basins → Wet grinding mills to make slurry

Wet grinding mills to make slurry
↓
Blending of slurry to correct composition
↓
Storage of corrected slurry
↓
Corrected slurry fed to Rotary kiln ← powdered coal, oil, gas
↓
Slurry is converted into clinker
↓
Clinker is ground in ball mill ← Addition of 2 to 3 % of gypsum
↓
Cement Silos
↓
Packing plant

Dry process:



clay
Limestone boulder from mines
Bauxite
Ironore
LST
Crusher
Crushed Limestone heap
Conveyor belt
4 stages preheater
Raw meal silo
Raw meal
Burner
Rotary kiln
clinker silo
Calcining zone
Burning zone
Cooler
Cement mill
Flyash
Gypsum
clinker
Roller press
Ball mill
Cement silo
packing unit

In dry and semi dry process, the raw materials are crushed dry and feed in correct proportions into a grinding mill where they are dried and reduced to a very fine powder. The dry powder then blended and corrected to its right composition and mixed by means of compressed air. After one hour of aeration a uniform mixture is obtained.

TYES OF CEMENT :

1). Ordinary portland cement
. 33 Grade, 43 Grade, 53 Grade.
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
12). Hydrophobic cement
13). Masonry cement
14). Expansive cement
15). Oil well cement

16). Rediset Cement.
17). High Alumina Cement
18). Very high strength cement.

ASTM classification :-

* Portland cement are classified under ther ASTM (American society for testing materials) standards.

* As per ASTM, Cement is designated as type I, type II, type III, type IV, type V and minor types like type IS, Type IP, type IA IIA and IIIA etc.

Type I - General concrete construction.

Type II - General concrete construction exposed to moderate sulphate action, (or where moderate heat of hydration is required.

Type III - For use when high early strength is required.

type IV - For use when low heat of hydration is required.

type V - Use when high sulphate resistance is required.

Type IP - An intimate and uniform blend of portland cement.

Type IA, IIA & IIIA — air-entraining agent is interground where air-enterainment in concrete is desired.

CHEMICAL COMPOSITION AND ITS PROPERTIES:

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

Oxide	per cent content
CaO	60-67
SiO_2	17-25
Al_2O_3	3-8
Fe_2O_3	0.5-6
MgO	0.1-4
Alkalies (K_2O, Na_2O)	0.4-1.3
SO_3	1.3-3.0

* The identification of the major compounds is largely based on "R.H. Bogue's Work" and hence it called "Bogue's compounds".

Tricalcium silicate (C_3S)
Dicalcium silicate (C_2S)
Tricalcium aluminate (C_3A)
Tetracalcium alumino ferrite (C_4AF)

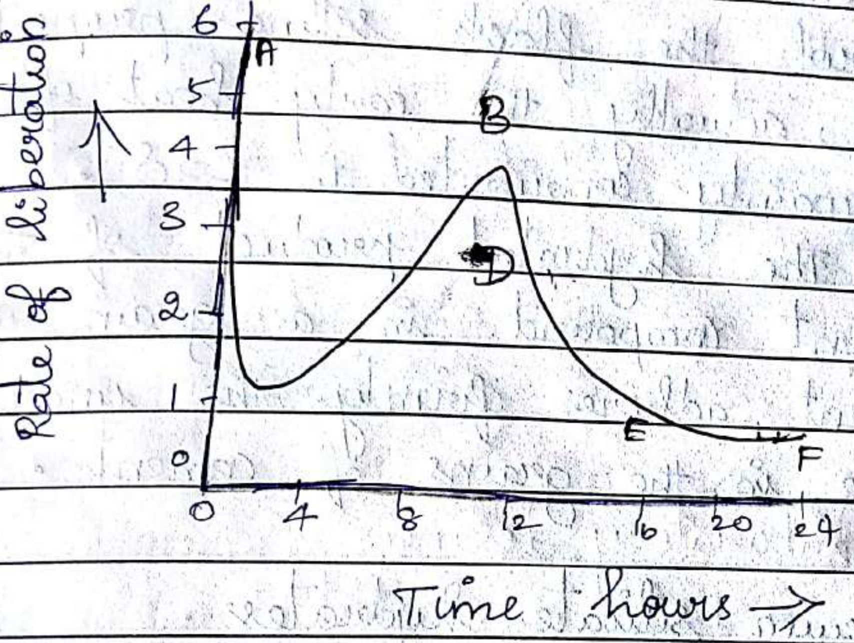
* Tricalcium silicate and dicalcium silicate are the most important compounds responsible for

strength. Together they constitute 70 to 80% of Cement.
* The average C_3S content is about 45 per cent and C_2S is about 25 per cent.
* Cement with a high total alumina and high ferric oxide content is favourable to the production of high early strengths in cement.

HYDRATION OF CEMENT :-

Raw material for cement – Limestone, clay, shale
↓
Component elements in raw materials O_2, Si, Ca, Al, Fe
↓
Oxide Composition in raw materials CaO, SiO_2, Al_2O_3
↓ on burning — clinker formed
Compound Composition C_2S, C_3S, C_3A, C_4AF
↓ on grinding — clinker
Portland cements — various types
↓ on hydration
products of hydration C-S-H gel + $Ca(OH)_2$

* Anhydrous cement does not bind fine and coarse aggregate. It acquires adhesive property only when mixed with water. The chemical reactions that take place between cement and water is referred as hydration of cement.



* Anhydrous cement compounds when mixed with water, react with each other to form hydrated compounds of very low solubility. It is probable that both through solution and solid state types of mechanism may occur during the course of reactions between cement and water.

1) Heat of Hydration :

* The reaction of cement with water is exothermic. The reaction liberates a considerable quantity of heat. This liberation

is called heat of hydration.
* On mixing with water, a rapid heat evolution, lasting a few minutes occurs. This is due to the reaction solution of aluminates & sulphates.
* Since retarders are added to control the flash setting properties of C_3A, actually the early heat of hydration is mainly contributed to C_3S.
* The hydrated product of the cement compound in a grain of cement adheres firmly the undrated core in the grains of cement.

2). Calcium silicate hydrates.
During the reaction of C_3S & C_2S with water, calcium silicate hydrated, $Ca(OH)_2$ are formed. It is the essence that determines the good properties of concrete. It make up 50-60 per cent of the volume of solids in a completely hydrated cement paste.

3). calcium hydroxide - constitues 20 to 25% cement paste
4). Calcium aluminium hydrates - C_4AF form $CaO - Fe_2O_3 - H_2O$ on hydration. A hydrated calcium ferrite of the form C_3HbF is comparatively more stable.

The hydrates of C_4AF show a comparatively higher resistance to the attack of sulphates than the hydrates of calcium aluminate.

6. TESTS ON CEMENT:

Testing of cement are in two categories
1). Field testing
2). Laboratory testing

1). Field testing:

The following are the field tests,

*. open the bag and take a good look at the cement. There should not be any visible lumps. the colour of the cement should normally a greenish grey.

*. Thrust your hand into the cement bag. It must give you a cool feeling. There should not be any lump inside.

*. Take a pinch of cement and feel between the fingers. It should give a smooth and not a gritty feeling.

*. Take a handful of cement and throw it on a bucket full of water, the particles should float for some time before they sink.

*. Take about 100 grams of cement and a small quantity of water and make a stiff paste. From the stiff paste, put a cake with sharp edges. put in on a glass plate and slowly take it under water in a bucket. See that the shape of the cake is not disturbed while taking it down to the bottom of the bucket. After 24 hours the cake should retain its original shape and the same time it should also set and attain some strength.

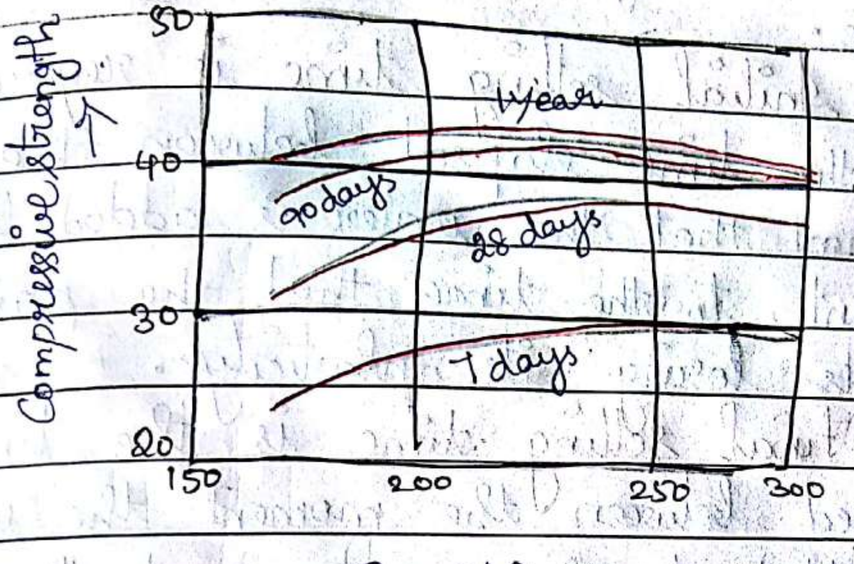
2). Laboratory Testing:

1). Fineness test
2). Setting time test
3). strength test
4). Soundness test
5). Heat of hydration test
6). Chemical Composition test.

*). Fineness test

- The fineness test 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.

• Finer cement offers a greater surface area for hydration and hence faster the development of strength.



Fineness of cement is tested in two ways.

a). By seiving

b). By determination of specific surface by air-premeability apparitus.

a). By seiving :-

Weigh correctly 100 gms of cement and take it on a standard I.S seive. Break down the air-set lumps in the sample fingers. Continuously seive the sample giving circular and vertical motion for a period of 15 minutes. Mechanical seiving is also used. Weigh the residue left on the seive.

This weight shall not exceed 10% for Ordinary cement.

2). Setting Time test :-

* Setting time test of cement as initial setting time and final setting time.

* Initial setting time is regarded as the time elapsed between the moment that the water is added to the cement, to the time that the paste starts losing its plasticity.

*. Final setting time is the time elapsed between the moment the water is added to the cement, and the time when the paste has completely lost its plasticity and has attained sufficient firmness to resist certain definite pressure.

*. The Vicat apparatus is used for setting time test.

*. Take 500 gm of cement sample and guage it with 0.85 times the water required to produce cement paste.

*. The paste shall be filled into the vicat mould in specified manner within 3-5 minutes.

*. The Temperature of water, at the time of gauging shall be within 27°C ± 2°C.

*. Lower the needle gently and bring in contact with surface of test block and quickly release.

*. When the paste starts losing its plasticity, the needle may penetrate only to a depth of 33-35 mm from the top.

*. The period elapsing between 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 33-35mm from top is taken as initial setting time.

*. The cement shall be considered as finally set, when the paste has attained such hardness that the centre needle does not pierce through the paste more than 0.5mm.

3). Strength test :

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

Strength of cement is found on cement sand mortar in specific proportions.

Mix the ingredients thoroughly untile the mixture is of uniform.

Immediately after mixing, the mortar is filled into a cube mould, compact the mortar either by hand or vibrating compaction equipments.

The cube may be kept under wet gunny bag to stimulate 90% relative humidity.

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After 24 hrs, the cubes are removed from the mould & immersed in clean water.

The cubes are tested for the compressive strength.

4). Soundness Test :-

The testing of soundness of cement, to ensure that the cement does not show any appreciable subsequent expansion is of prime importance.

The unsoundness in cement is due to the presence of excess of lime, excess of magnesia, proportions of sulphates.

The Le-chatelier tests detects the unsoundness due to free lime only.

5). Heat of hydration.

The reaction of cement with water is exothermic.

Test for heat of hydration is essentially required to be carried out for low heat cement only.

The test is carried out over a few days by vacuum flask methods, or over a longer period in a calorimeter.

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When tested in standard manner, the heat of hydration shall not be more than 65 cal/gm at 7 days, 75 cal/gm at 28 days.

b). chemical composition Test:

Ratio of percentage of lime to percentage of silica, alumina & iron oxide, when calculated by formula,

$$\frac{CaO - 0.7\,SO_3}{2.8\,SiO_2 + 1.2\,Al_2O_3 + 0.65\,Fe_2O_3}$$ Not greater

than 1.02 and not less than 0.66 called lime saturation factor per cent.

AGGREGATES:

Aggregates are the important constituents in concrete, to reduce the shrinkage and effect economy.

The mere fact that the aggregates occupy 70-80 per cent of the volume of concrete.

Aggregates are classified as

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

Mechanical properties & tests :-

The aggregates mechanical properties to be,

1). Size and shape
2). Texture & source
3). strength
4). Specific gravity & bulk density
5). Moisture content
6). Bulking factor
7). cleanliness
8). Soundness
9). Thermal properties
10). Durability
11). Sieve analysis.

Size & Shape:

Maximum size of aggregate for concrete to be 80 mm.

Maximum size will result in

i). reduction of the cement mortar
ii). Reduction in water requirement
iii). Reduction in drying shrinkage.

Size of aggregate is divided in two categories, i). Fine aggregate whose size 4.75mm & Less,
ii). Coarse aggregate whose size is more than 4.75 mm.

The shape of aggregates is an important characteristics since it affects the workability of concrete.

The shape of aggregates are rounded, Irregular or partly rounded, angular and flaky.

Murdock suggested a different method for expressing the shape of aggregate by a parameter called angularity index.

$$fA = \frac{3fH}{20} + 1.0$$

fH → Angularity number.

Texture :

Surface texture is the property, the measure of which depends upons the relative degree to which particle surfaces are polished (or) dull, smooth & rough.

Surface texture depends on hardness, grain size, pore structure and the degree to which forces acting on the particle surface have smoothened or roughened it.

Strength :-

The test for strength of aggregate is required in following situations.

1). For production of high strength and ultra high strength concrete.

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

iii). Aggregate manufactured by industrial process.

Aggregate by Crushing Value :-

Aggregate crushing value gives a relative measure of the resistance of an aggregate sample to the crushing under gradually applied compressive load.

The test is made on single sized aggregate passing 12.5 mm & retained on 10 mm seive.

The aggregate is placed in cylindrical mould and a load of 40 tons is applied to finer through a plunger.

The material crushed to finer than 2.36 mm is separated and expressed as a percentage of original weight.

Aggregate Impact Value :

The aggregate kept in a mould is subjected to fifteen blows of a metal hammer of weight 14 kgs, falling from a height of 38 cms.

The finer material passing through 2.36 mm.

Aggregate abrasion value:-

Aggregate testing with respect to its resistance to wear is an important test for aggregate to used for road construction:

- Deval attrition test - particle are subjected to wear in an iron cylinder rotated 10000 times at certain speed.
- Dorry abrasion test - tests involve in subjecting a cylindrical specimen of 25 cm height, 25 cm diameter to the abrasion against rotating metal disk sprinkled with quartz sand.
- Los Angeless Test.

Specific Gravity - Average specific gravity varies from 2.6 to 2.8.

GRADING OF AGGREGATES:-

Aggregate comprises about 55 per cent of the volume of mortar and about 85 per cent of volume of mass concrete.

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

Good grading implies that a sample of aggregates contains all standard fraction of aggregates in required proportions that the sample contains minimum voids.

The convient system of expressing the gradation of aggregate is one which the consecutive sieve openings are constantly doubled such as 10 mm, 20 mm & 40 mm etc.

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

The aggregate fraction from 80 mm to 4.75 mm coarse aggregate and 4.75 mm to 150 micron fine aggregate.

Grading pattern of a sample is assessed by sieving a sample successively through all the sieves mounted one over the other in order of size.

Sieving is done either by manually (or) mechanically, shaken in all direction. From sieve analysis, the fineness modulus to be determined.

Fineness modulus is an empirical factor obtained by adding the cumulative percentage of aggregate retained on each of the standard sieves ranging from 80mm to 150 micron & dividing by 100.

Some aggregates may not be specified by desirable grading, in such a cases Combining two or more aggregates from different sources to get desirable gradings.

WATER

Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement.

It helps to form the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully.

QUALITY OF WATER

Some water containing a small amount of sugar would be suitable for drinking but not for mixing concrete.

Some specification accept the water for making concrete if pH value of water lies between 6 and 8, the water is free from organic matter.

Carbonates and bi-carbonates of sodium and potassium effect the setting time of cement.

Sodium carbonate may cause quick setting, potassium bi-carbonates may either accelerates (or) retard the setting.

Higher concentration of salts will reduce the concrete strength.

Brackish water contains chlorides (exceed 10,000) & sulphates (exceed 3,000 ppm), the water is harmless, but water with even high salt content has been used satisfactorily.

Salts of Mn, Pb, Zn, Cu cause a reduction in strength of concrete.

Silt and suspended imp particles are undesirable with setting, hardening and bond characteristics.

Consideration regarding quality of water

1). Neutralize 100 ml sample of water using phenophthaline as indicator, not require more than 5 ml of 0.02 NaOH.

2). To neutralize 100ml of sample of water, using mixed indicator, it should not require more than 25 ml of 0.02 normal H_2SO_4.

CHEMICAL AND MINERAL ADMIXTURES

Accelerators – Retarders – plasticizers – super plasticizers – Water proofers – Mineral admixture like fly ash, silica fume, ground Granulated blast furnace slag & metakaoline – Effects on concrete properties.

Admixtures:

* Admixture is defined as a material, other than cement, water and aggregates, that is used as an 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 cement factory.

Kinds of Admixtures:

- plasticizers
- Super – plasticizers
- Retarders & Retarding plasticizers
- Accelerators & Accelerating plasticizers
- Air-Entraining admixtures
- Mineral admixtures
- Gas forming admixtures
- Air-detraining admixtures
- Alkali-aggregate Expansion Inhibiting admixtures
- Workability admixtures
- Grouting admixtures

- Corrosion inhibiting admixtures
- Bonding admixtures
- Colouring admixtures
- Germicidal & Insecticidal admixtures.

Accelerators :

* Accelorating admixtures are added to concrete to increase the rate of early strength development in concrete to
  1). permit earlier removal of formwork
  2). Reduce the required period of curing
  3). Advance the time that a structure can be placed in service
  4). Partially compensate for the retarding effect of low temperature during cold weather concreting.
  5). in the emergency repair work.
* Commonly used materials as an accelerator was Calcium chloride.
* some of the soluble carbondtes, silicates, fluosilicates and some of the Organic Compounds such as triethenolamine are used, since it is very expensive.
* Calcium chloride is harmful for reinforced Concrete and prestressed concrete. It may be used for plain cement Concrete in comparatively high dose.

*. The availability of powerful accelerator, the under water concreting has become easy.
*. The use of such powerful accelerators have facilitated, the basement waterproofing operations.
*. In the field of prefabrications also it has become an invaluable material.

Accelerating plasticizers:
*. Certain ingredients are added to accelerate the strength development of concrete to plasticizers & superplasticizers.
*. Such accelerating plasticizers, when added to concrete result in faster development for strength.
*. The accelerating materials are triethenolamine chlorides, calcium nitrite, nitrates and fluosilicates etc.

Retarders :-
*. A retarder is an admixture that slows down the chemical process of hydration so that concrete remains plastic and workable for a longer time that than concrete without the retarder.
*. Retarders are used to overcome the accelerating effect of high temperature on setting properties of

concrete in hot weather concreting.

*. They are also used in casting in grouting oil wells.

*. Retarding admixtures are used to obtain exposed aggregate look in concrete.

*. Retarder is calcium sulphate. It is the underground to retard the setting of cement.

*. The retarder sprayed to the surface of the formwork, prevents the hardening of matrix at the interface of concrete and formwork, whereas the rest of the concrete gets hardened.

Retarding plasticizers.

*. Retarding plasticizers are important category of admixtures often used in the ready mixed concrete industry for the purposes of retaining the slump loss, during high temperature, long transportation, to avoid construction (or) cold joints, slip form construction and regulation of heat of hydration.

plasticizers :

*. Requirement of right workability is the essence of good concrete. Concrete in different situation require different degree of workability.

*. plasticizers can help the difficult conditions for obtaining higher workability without using excess of water.

*. The excess of water will not improve the inherent good qualities such as homogenity and cohesiveness of the mix which reduces the tendency for segregation and bleeding.

*. The use of plasticizer for mass concrete to reduce the water requirement for making concrete of higher workability (or) flowing concrete.

*. plasticizers has become almost an universal practice to reduce water/cement ratio & increases the strength.

*. Reduction in w/c ratio improves the durability of concrete.

*. The use of plasticizers is employed to reduce the cement content and heat of hydration in mass concrete.

*. The reduction in w/c ratio improves the durability of concrete.

*. plasticizers is employed to reduce

the cement content and heat of hydration in mass concrete.

*. The basic products constituting plasticizers are:

1). Anionic surfactants, such as lignosulphonates and salts of sulphonates hydrocarbons.

2). Nonionic surfactants, such as polyglycol esters, acid for hydroxylated carboxylic acids, carbohydrates, etc.

*. Calcium, sodium and ammonium lignosulphonates are most commonly used. plasticizers are used in the amount of 0.1% to 0.4% by weight of cement.

*. These doses, at constant workability the reduction in mixing water is expected to be of the order of 5% to 15%, naturally increases the strength.

*. Some plasticizers, while improving the workability, entrains air. The entertainment of air reduces the mechanical strength.

*. A good plasticizer is one which does not cause air-entertainment in concrete more than 1 or 2%.

Action of plasticizers:-

*. The action of plasticizers is mainly to fluidify the mix and

improve the workability of concrete, mortar, grout.

The mechanism that are involved are

1). Dispersion - Have tendency to flocculate in wet concrete. These flocculation entraps certain amount of water used in the mix and thereby all the water is not freely available to fluidify the mix.

2). Retarding Effect :- The quantity of available plasticizers will progressively decrease as the polymers become entrapped in hydration products.

*. Reduction in the surface tension of water.

*. Induced electrostatic repulsion between particles of cement.

*. Dispersion of cement grains, releasing water trapped within cement flocs.

*. Lubricating film between cement particles.

Superplasticizers :-

Superplasticizers constitute a relatively new category and improved version of plasticizer the use of which was developed in Japan & Germany during 1960 & 1970 respectively.

*. Use of superplasticizers permit the reduction of water to the extent upto 30 per cent without reducing workability in contrast to the possible reduction upto 15 per cent in case of plasticizers.

*. The use of superplasticizer is practiced for production of flowing, self levelling, self compacting and for the production of high strength and high performance concrete.

*. superplasticizers are more powerful as dispersing agents and they are high range water reducers.

*. It also called as High Range water reducers.

*. Superplasticizer which has made it possible to use fly ash, slag and silica fume to make high performance concrete.

*. Super plasticizer can produce,

* at the same w/c ratio much more workable concrete than the plain ones.

* For the same workability, it permits the use of low w/c ratio.

The superplasticizers produce a homogenous, cohesive concrete generally without any tendency for segregation and bleeding.

Classification of superplasticizer:

- Sulphonated malamine - formaldehyde Condensates (SMF).
- Sulphonated naphthalene - formaldehyde Condensates (SNF).
- Modified lignosulphonates (MLS).
- Acrylic polymer (AP)
- Copolymer of Carboxylic acrylic ester (CAE)
- Cross linked acrylic polymer (CLAP)
- polycarboxylate ester (PC)
- Multicarboxylatethers (MCE)

*. plasticizers & superplasticizes are water based.

*. Cost should be based on efficiencies and solid content.

Effecting the workability:

- Types of Superplasticizer.
- Dosage
- Mix composition
- Mixing procedure
- Variability in cement composition
- Equipments.

Fly Ash:

*. Fly ash is finely divided residue resulting from the combustion of powdered coal and transporated by the flue gases and collected by electrostatic precipitator.

*. Fly ash is the most widely used pozzalanic material all over the world.

*. Fly ash is as essential an ingredient of the mixture as are portland cement, aggregate, water and chemical admixtures.

*. The importance and use of fly ash in concrete has grown so much that it has almost become a common ingredient in concrete, particularly for making high strength and high performance concrete.

*. There are two way that the fly ash can be used,

i). To intergrind certain percentage of fly ash with cement clinker at the factory to produce portland pozzolana cement

ii). To use the fly ash as an admixture at the time of making concrete at the site of work.

*. The quality of fly ash is governed by IS 3812 - part I - 2003.

*. High fineness, low carbon content, good reactivity are the essence of good fly ash.

*. Fly ash is produced by rapid cooling and solidification of molten ash, a large portion of components comprising fly ash particles are in amorphous state.

*. ASTM broadly classify fly ash in two classes,

Class F : CaO content less than 5%.
burning of anthracite, bituminous coal.

Class C : CaO excess 10%. (burning lignite)

Effects of fly ash on fresh concrete :-

* Good fly ash with high fineness, low carbon content, highly reactive forms only a small fraction of total fly ash collected.

Fly ash particle size:

* particles are mostly glassy, solid and spherical.

*. The particles of fly ash range in size mostly from 1 to 100 microns.

*. Use of right quality of fly ash, results in reduction of water demand for desired slump.

*. With the reduction of unit water content, bleeding and drying shrinkage will also be reduced.

Durability of concrete:

*. sufficiently cured concrete containing good quality fly ash shows dense structure which offers high resistivity to the infiltration (or) deleterious substances.

Bleeding and setting time

*. setting time is little longer than that of conventional concrete, because of low w/c ratio, low rate of reaction and high content of superplasticizers.

*. W/c content is low in high volume fly ash, the bleeding is very low.

Silica fume:

*. Silica fume also referred to as microsilica or condensed silica fume, is used as an artificial pozzalanic admixtures.

*. silica fume is very fine pozzolanic material composed of ultrafine, amorphous glassy sphere of SiO_2 produced during the manufacture of silicon or ferro-silicon by electric arc furnace at temperature of over 2000°C.

*. The fumes are collected and bagged called silica fume, further processed to remove impurities and to control particle size.

*. It is extremely fine with particle size less than 1 micron.
*. Silica fume has specific surface area of about 20,000 m^2/Kg.
*. The high strengths of high performance concrete containing silica fume are attributable to large degree, to the reduction in water content which becomes possible in the presence of high dose of superplasticizer and dense packing of cement paste.

Metakaolin:

*. Considerable research has been done on natural pozzolans, namely on thermally activated ordinary clay and kaolinitic clays.
*. These unpurified materials have often been called metakaolin.
*. Highly reactive metakaolin is made by water processing to remove unreactive impurities to make 100% reactive pozzolan.
*. such a product, white (or) cream in colour, purified thermally activated is called <u>high reactive Metakaolin</u>.
*. High reactive metakaolin shows high pozzolanic reactivity and reduction in $Ca(OH)_2$.
*. The cement paste undergoes distinct densification.

*. The improvement offered by this densification includes an increase in strength and decrease in permeability.
*. The high reactive metakaolin is having the potential to compete with silica fume.

Ground Granulated Blast Furnace slag

*. Ground granulated blast-furnace slag is another important mineral admixture like fly ash a non-metallic product consisting essentially of silicates and aluminates of calcium.
*. The molten slag is rapidly chilled by quenching in water to form a glassy sand like granulated material, 45 micron specific surface of about 400 to 600 m^2/kg.
*. The chemical composition of Blast furnace slag is similar to that of Cement clinker.
*. The blast furnace slag is mainly used in India for manufacturing slag cement.
*. There are two methods of making blast furnace slag cement.

i). Blast furnace slag is interground with cement clinker along with gypsum.

ii). Blast furnace slag is separately ground and then mixed with the cement.

*. Fly ash is used as an admixture in making concrete Ground Granular Blast Furnace Slag popularly called GGBS.

*. The replacement of cement with GGBS will reduce the unit content of water necessary to obtain the slump.

*. The surface configuration and particle shape of slag being different than cement particle.

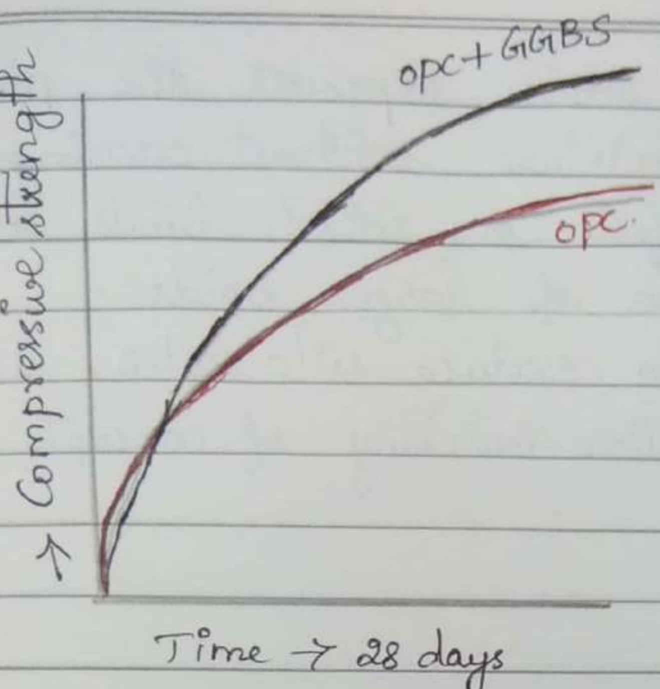
*. Cement with GGBS develops strength more slowly than portland cement, early strength is lower, 28-day strength is similar and ultimate strength significantly higher.

*. The hydration of GGBS concrete is less exothermic.

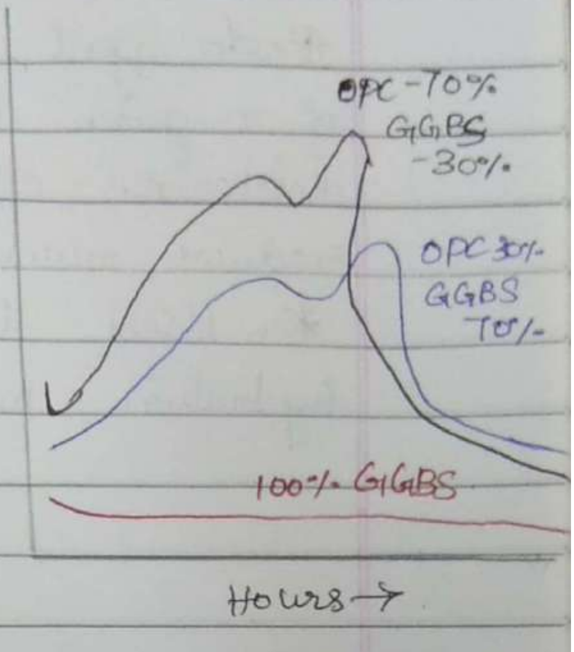
*. Use of GGBS will sharply reduce thermal stressing of mass concrete, micro-cracking.

*. Chloride ions penetrate the concrete, cause severe damage through corrosion, where GGBS offers resistance to chloride penetration.

*. Use of GGBS, 50% significantly reduces available C3A content, this helps in preventing the sulphate to form delayed ettringite in concrete.



STRENGTH



HEAT OF HYDRATION

Water Proofing Admixtures:

* Water proofing admixtures may be obtained in powder, paste or liquid form and may consist of pore filling (or) water repellent materials.
* The chief materials in the pore filling class of silicate of soda, aluminimum and zinc sulphates, calcium chloride.
* The action is to improve the workability and to facilitate the reduction of water for given workability and to make dense concrete which is basically impervious.
* Water proofing admixtures may contain butyl stearate, the action of which is similar to soaps, but it does not give frothing action.

* An agent which improves the plasticity of a given mixture without causing deleterious effects (or) which limits bleeding, reduces number of larger voids.
* Used to reduce w/c ratio, heat of hydration, micro-cracking of concrete.

UNIT - III

PROPORTIONING OF CONCRETE MIX

principles of mix proportioning - Properties of concrete related to Mix Design - physical properties required for mix design - Design Mix and Nominal Mix - BIS Method of Mix design - Mix design examples.

Definition:

Concrete mix design is defined as the appropriate selection and proportioning of constituents to produce a concrete with pre-defined characteristics in the fresh and hardened states.

Concrete mix are designed in order to achieve a defined workability, strength and durability.

Principles of mix proportioning:

The data required for the principle of design of concrete mix involves,

1). Determination of the proportions of the given constituents, namely, cement, water, fine aggregate, coarse aggregates and admixtures which would produce concrete possessing specified properties both in fresh & hardened state with the maximum overall economy.

2). The environment exposure condition for the structure.

3). The grades of concrete, M20 & M25 which denotes the characteristic strength f_{ck} of 20 & 25 N/mm^2.

4). The type of Cement
e.g Ordinary portland cement
Portland pozzalana Cement
portlant slag. (IS 456:2000).

5). The type and size of aggregate.

6). The nominal maximum size of aggregates are 40mm, 20mm, 10mm according to IS-383:1970 & IS456:2000.

7). Maximum & minimum cement content according to IS 456:2000 table 7.6(a).

8). The degree of ~~[illegible]~~ workability of concrete based on placing condition.

9). Air content.

10). Type of admixtures.

Factors in the choice of mix proportioning:

- Grade designation.
- Type of cement
- Maximum nominal size of aggregates
- Minimum water-cement ratio
- Workability
- Minimum cement content.

Properties of Concrete Related to Mix Design

The most important properties of concrete

1). Workability

2). Durability
3). Strength
4). Volume change
5). air entrainment
6). Density.

1). Workability

The degree of workability necessary in a concrete mix design entirely upon the purpose for which it is used and the methods and equipment used in handling and placing it in the work.

The factors that affect the workability of concrete are,

*. size distribution of aggregate
*. shape of the aggregate particles
*. Gradation and relative proportions of the fine and coarse aggregates.
*. Plasticity
*. Cohesiveness
*. Consistency of the mix.

Well rounded gravel will have better workability with finer sand, which is needed to fill the smaller void areas.

2). Durability:

To ensure high degree of durability, it is essential that clean, sound materials, and lowest possible water content are used in the concrete, together with thorough mixing.

Cure concrete properly for specified days in order to develop good durability.

A good air void system is also essential to have a durable concrete when the concrete is exposed to freeze-thaw conditions.

3). strength

The use of minimum quantity of water required for proper placement ensure the greatest strength from the concrete.

It is essential that freshly mixed concrete be thoroughly consolidated to eliminate the air pockets and secure maximum density in the structure.

4). Volume change:

Constant volume changes results in ultimate failure (or) deterioation of concrete.

plastic shrinkage is caused volume loss due to hydration and by exploration.

At the hardened stage, the concrete is subjected to volumetric changes due to temperature difference in concrete, this will results in volume change and ultimate deformation.

5). Air Entertainment:

Air Entrainment concrete has air in finely divided form induced in Concrete. It is formed by addition of air-Ettaraining Admixture.

Entrained air in the concrete, in the form of layer number of small air bubble results in foaming action.

Entraining air results in prevention of Freeze - Thaw effects.

Increase cohesiveness and workability of the mix.

6) Density

Minimum water content consistent with good workability.

Minimum air content consistent with adequate workability.

Thorough consolidation during placement.

Using well-graded aggregate of the layers possible maximum size.

Physical properties of materials required for Mix Design.

1). Cement:

The important properties of cement required for mix design are strength / grade of cement and initial and final setting time of cement.

1). strength / grade of cement

Grade of cement indicates minimum strength of cement in N/mm^2 tested as per standard conditions laid down by IS codes.

Higher the strength of cement, higher is the strength of concrete for the same water / cement ratio.

The IS 10262 for mix design gives the different curves of cement based on the actual strength of cement on 28^{th} day.

Blended cements achieve strengths later than Ordinary portland cements and require extended curing period.

Use of these cements result in more durable concrete by offering greater resistance to sulphate and chloride attacks.

2). Initial and Final setting time of cement

The initial setting time of cement indicates the time after which the cement paste loses its plasticity.

The minimum initial setting time specified is 30 minute.

Beginning of hardening of cement paste indicates the final setting of cement.

The maximum limit for final setting permitted is 600 minute.

2). Fine Aggregates

The important properties of fine aggregate required for mix design are gradation of fine aggregate, specific gravity of fine aggregate, silt content by weight.

1. Gradation of fine aggregates

The sieve analysis is done by passing sand through a set of standard sieves and finding out cumulative passing percentage through sieve analysis.

The IS 383-1970 classifies fine aggregates in 4 zones, to zone I representing coarse sand, to zone IV representing the fine sand.

The fineness of sand found by sieve analysis governs the proportion of sand in concrete.

Fineness modulus is given by division of the summation of cumulative retained fractions for standard sieves upto 150-micron sieve size by 100.

Type of Sand	FM
Fine	2.0 to 2.8
Medium	2.8 to 3.2
Coarse	3.2 and above.

2). Specific gravity

The ratio of solid density of sand

particles to the density of water.

The specific gravity of sand is found with the help of pycnometer bottles.

The specific gravity of fine aggregate may vary in general, from 2.6 to 2.8.

3). silt content by weight

This is found by wet-sieving of sand and material passing 75 micron sieve is classified by silt.

This silt affects the workability of concrete, results in higher water / cement ratio and lower strength.

The upper limit for 75 micron sieve incase of sand is 3% by weight.

2). Coarse Aggregate

The important properties of coarse aggregate required for mix design are maximum size of coarse aggregate, grading of coarse aggregate, shape of coarse aggregate, strength of coarse aggregate and aggregate absorption.

1). Maximum size of coarse aggregate:

Maximum size of aggregate is the standard sieve size (40 mm, 25 mm, 20 mm, 12.5 mm, 10mm) through which at least 90% of coarse aggregate will pass.

Maximum size of aggregate affects the workability and strength of concrete.
Maximum size of coarse aggregate reduces, surface area of coarse aggregate increases.

2). Grading of coarse aggregate:

The coarse aggregate grading limits are given in IS 383: 1970 - Table 2.
The grading of coarse aggregate is important to get cohesive and dense concrete.
By proper grading of coarse aggregate, the possibility of segregation is minimized, especially for higher workability.
Proper grading of coarse aggregates also improves the compact ability of concrete.

3). Shape

Coarse aggregates can have round, angular, irregular shape.
Rounded aggregates because of lower surface area will have lowest water demand and also have lowest mortar paste requirement.
Flakiness and elongation also reduces the flexural strength of concrete.

4). Strength of Coarse aggregate:

Material strength of coarse aggregate is indicated by crushing strength of rock, aggregate crushing value, aggregate impact value, aggregate abrasion value.

5). Aggregate absorption:

Aggregate can absorb water up to 2% by weight when in bone dry state; in some cases the aggregate absorption can be as high as 5%..

Aggregate absorption is used for applying a correction factor for aggregates in dry condition and determining water demand of concrete in saturated surface dry conditions.

Nominal Mix And Design Mix:

Mix design is a process of selecting suitable ingredients and determining their relative proportions with the objectives producing concrete having certain minimum workability, strength and durability.

1). Nominal Mix:

It is used for relatively unimportant and simpler concrete works.

In this type of mix, all ingredients are prescribed and their proportions are specified. Nominal mix concrete may be used for concrete of M20 or lower.

Grade	Maximum Quantity of aggregate	Ratio of mass	Maximum quantity of water
M5	800	1:2	60
M7.5	625	varies from	45
M10	480	1.1.50 to	34
M15	330	1.2.50	32
M20	250		30.

2) Design Mix.

It is a performance based mix where choice of ingredients and proportioning are left to the designer to be decided. The user has to specify only the requirements of concrete in fresh as well as hardened state.

The requirements in fresh concrete are workability and finishing characteristics, whereas in hardened concrete these are mainly the compressive strength & durability.

BIS method of Mix Design:

Indian standard IS 10262 : 2002 provides the guidelines for proportioning concrete mixes as per the requirements using the concrete making materials including other supplementary materials identified for this purpose.

The proportioning is carried out to achieve specified characteristics specified age, workability of fresh concrete and durability requirements.

This standard is applicable for ordinary and standard concrete grades only.

Step by step procedure:

1). Target mean strength for mix design

The concrete mix has to be proportioned

for higher target mean compressive strength ($\overline{f_{ck}}$):

$$\overline{f_{ck}} = f_{ck} + t \times S.$$

The value of 't' Can ben as 1.65 as per IS 10262, table 2.

$$\overline{f_{ck}} = f_{ck} + 1.65\,S.$$

The standard deviation is taken as per IS 456 : 2000.

Grade of Concrete	Assumed standard deviation
M10	3.50
M15	
M20	4.00
M25	
M30	5.00
M35	
M40	
M45	
M50	

2). Selection of water/cement ratio:

The water-cement ratio given in table 5 of IS-456 - for respective environment exposure conditions may be used as starting point.

The Preliminary w/c ratio corresponding to the target strength at 28 days may be selected from the relationships.

3) Estimation of entrapped air

Approximate amount of entrapped air is to be expected in normal concrete is given in table

Nominal maximum Size of aggregate	Entrapped air, % of volume of concrete
10	3.0
20	2.0
40	1.0

4). selection of water content:

An increase in aggregate size, a reduction in water-cement ratio and slump, and use of rounded aggregate and water reducing admixtures, will reduce the water demand.

5). Selection of water content and fine to total aggregate:

For the desired workability, the quantity of mixing water per unit volume of concrete and the ratio of fine aggregate to total aggregate by absolute volume are to be estimated depending upon the nominal maximum size and type of aggregates.

6) Calculation of cement content:

The cement content per unit volume of concrete may be calculated from the free water-cement ratio and the quantity of water per unit volume of concrete. The cement content so calculated shall be checked against the minimum cement content for the requirements of durability.

7). Calculation of aggregate content:

With the quantities of water and cement per unit volume of concrete and the ratio of fine to total aggregate determined, the total aggregate content per unit volume of concrete calculated.

$$V = \left[W + \frac{C}{S_c} + \frac{1}{P} \cdot \frac{f_a}{S_{fa}}\right] \times \frac{1}{1000}$$

$$V = \left[W + \frac{C}{S_c} + \frac{1}{1-P} \cdot \frac{C_a}{S_{ca}}\right] \times \frac{1}{1000}$$

W = mass of water / m^3 of concrete

S_c = Specific gravity of cement.

P = Ratio of fine aggregate to total aggregate.

f_a = Total mass of fine aggregate.

C_a = Total mass of coarse aggregate.

8). Combination of different coarse aggregate fractions.

The coarse aggregate used should conform to IS 383:1970.

Coarse aggregate of different sizes should be combined in suitable proportions so as to result in an overall grading.

conforming to table 2 of IS 383 : 1970 for the particular nominal maximum size of aggregates.

9) Calculation of batch masses

The masses of the various ingredients for concrete of a particular batch size may be calculated.

The calculated mix proportions shall be checked by means of trial batches.

Problems (or) Examples of Mix Design.

Design a concrete mix for RC work. For the following requirements using IS 10262 : 2009 code.

Characteristic strength @ 28 days = 35 Mpa.
Exposure conditions = severe
Degree of workability = Slump - 50 mm
Quality control = very good.
Cement : OPC (sp. gravity = 3.15)
Fine aggregate : Zone II sand (sp. gravity = 2.64)
Coarse aggregate : Max. size 20 mm.
Water absorption of CA = 1%.
Free surface moisture in sand = 2%.
Assume any required data

Soln.

Step 1 : Target strength for mix proportioning

$$\bar{f}_{ck} = f_{ck} + 1.65 S$$

From table 1, IS 10262 - 2009, S = 5 N/mm².

Target strength, $\bar{f}_{ck} = 35 + 1.65(5)$
$= 43.25 \text{ N/mm}^2$.

Step 2 :- Water - Cement ratio
From table 5, IS 456 : 2000,

Max. w/c Ratio = 0.45 (severe Exposure)
Adopt w/c Ratio as 0.40 as the cement is 43 grade

$0.4 < 0.45$
Hence O.K.

Step 3 :- Selection of water content.
From table 2 of IS 10262 : 2009.
Maximum water content = 186 litres.
(For 25-50 mm slump large and for 20 mm aggregates).
Estimated water content for 25-50 mm slump } = 186 litres.

Step 4 :- Calculation of cement content
W/c ratio = 0.4
Cement content $= \frac{186}{0.4} = 465 \text{ kg/m}^3$.

From table 5, IS 456:200, Minimum cement content for exposure (severe) conditions
$= 320 \text{ kg/m}^3$.
$465 > 320 \text{ kg/m}^3$.
Hence O.K.

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Step 5 :- proportions of volume of C.A and F.A content

From table 3 of IS 10262 : 2009, volume of C.A corresponding of 20mm size aggregate & fine aggregate (Zone II).

For w/c ratio of 0.5 = 0.62.

volume of C.A for w/c of 0.4 = 0.64.

volume of F.A for w/c of 0.4 = 0.36.

Step 6 :- Mix Calculations :

a). volume of concrete (a) = 1 m³.

b). Volume of cement $= \frac{\text{Mass of Cement}}{\text{Sp. gravity of cement}} \times \frac{1}{1000}$

$= \frac{465}{3.15} \times \frac{1}{1000}$

(b) = 0.148 m³.

c). volume of water $= \frac{186}{1} \times \frac{1}{1000}$

(c) = 0.186 m³.

d). volume of all in aggreates (Z) = a − (b+c)

= 1 − (0.148 + 0.186).

= 0.666 m³.

e). Mass of Coarse aggregate = Z × volume of CA × Sp. gravity of CA × 1000

= 0.666 × 0.64 × 2.7 × 1000

= 1150.85 kg.

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f). Mass of fine aggregate = Z × Volume of FA × Sp. gravity of FA × 1000

$= 0.666 \times 0.36 \times 2.64 \times 1000$

$= 632.97$ kg.

Mix proportions:

Cement : 465 kg/m³

Water : 186 litres.

Fine aggregate : 632.97 kg/m³

Coarse aggregate : 1150.85 kg/m³

w/c ratio : 0.4.

Design a concrete mix for M30 grade of Concrete using F-type fly ash. Adopt BIS method with the following data.

1). Type of cement = OPC 43 grade.
2). Max. Size of aggregate = 20 mm.
3). Exposure conditions = Severe.
4). Workability = 100 mm slump.
5). Minimum Cement Content = 320 kg/m³.
6). Max. w/c ratio = 0.46.
7). Method of placing concrete = pumping
8). Degree of supervision = good.
9). Type of aggregate : Crushed angular aggregate.
10). Super plasticizer will be used.
11). Specific gravity of CA : 2.80
12). Specific gravity of FA = 2.70

13). specific gravity of fly ash = 2.20
14). Water absorption of C.A = 0.5 %.
F.A nill. Grading of C.A is conforming to table 2 of IS 383 & grading of F.A is falling in Zone I.

Step 1 :- Target strength

$\bar{f}_{ck} = f_{ck} + 1.65 S$.

From Table 1, $S = 5$.

$\bar{f}_{ck} = 30 + 1.65(5) = 38.25\ N/mm^2$.

Step 2 :- Selection of w/c ratio

From table 5, IS 456 : 2000, w/c is 0.46.

Step 3 :- Selection of water content

From table 2, IS 10262 : 2009

Maximum water content = 186 litres.

Estimated water content for 100mm slump

$= 186 + \left(\frac{6}{100} \times 186\right)$

$= 197$ litres.

Step 4 :- Calculation of Cement content

Water - Cement ratio = 0.46.

Cement content $= \frac{197}{0.46} = 428\ kg/m^3$.

Step 5 :- Proportion of volume of CA to FA content

From table 3 of IS 10262 : 2009,

volume of C.A corresponding to 20mm size aggregate and F.A (zone 2) for w/c ratio of 0.5

= 0.60

Step 6:- Mix calculation :-

a). Volume of Concrete $= 1 m^3$.

b). Volume of Cement $= \frac{\text{Mass of Cement}}{\text{Sp. gravity of cement}} \times \frac{1}{1000}$

$= \frac{413}{3.15} \times \frac{1}{1000}$

$= 0.131 m^3$.

c). Volume of Water $= \frac{197}{1} \times \frac{1}{1000}$

$= 0.197 m^3$.

d). Volume of all in aggregates $= Z = a-(b+c)$.

$Z = 1-(0.131+0.186)$

$Z = 0.683 m^3$.

e). Mass of fine aggregate $= Z \times$ volume of FA $\times$ Sp gravity of FA $\times 1000$

$= 0.683 \times 0.39 \times 2.75 \times 1000$

$= 719$ kg.

f). Mass of Coarse aggregate $= Z \times$ volume of CA $\times$ Sp. gravity of CA $\times 1000$

$= 0.683 \times 0.58 \times 2.80 \times 1000$

$= 1109$ kg.

Mix proportions:

Cement : 428 kg/m^3

Water : 197 litres

F.A : 719 kg

C.A : 1109 kg.

w/c Ratio : 0.46

Unit - IV

Fresh and hardened properties of concrete

workability

Workability is the amount of energy to overcome Friction while compacting. Also defined as the relative ease with which concrete can be mixed, transported, moulded and compacted.

Tests for workability of concrete

i) Slump Test
ii) compaction factor test
iii) Segregation and Bleeding

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.
* It is not suitable to very wet and very dry concrete

Slump cone Appartus

Bottom diameter : 20 cm
Top diameter : 10 cm
Height : 30 cm
Thickness of sheet (metallic) : 1.6 mm
Steel tamping rod : 16 mm dia
length : 0.6 m

* The Internal surface of the mould is thorougly cleaned and free from moisture and adherence of any old set concrete

* The mould is placed on a smooth, horizontal, rigid non-absorbant surface

* The mould filled in four layers, each approximately 1/4 of the height of the mould.

* Each layer is tamped 25 times by the tamping rod.

* The top layer is leveled by using trowel & rod.

* The mould is Removed from the concrete by raising It slowly and carefully in a vertical direction.

* This allowed the concrete to subside. this subsides is Reffred as slump of the concrete

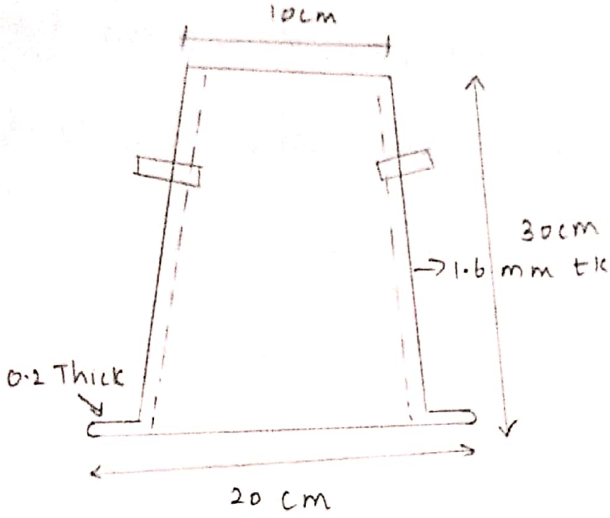
* The difference in level between the height of the mould and that of the highest point of subsided concrete is measured.

* The difference in height in mm, is taken as slump of concrete.

True slump

The concrete slumps evenly

True slump



mould For slump Test

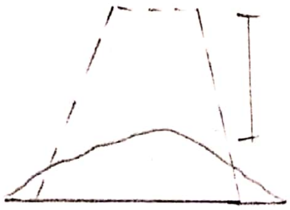
Shear slump

* One half of the cone slides down.

* Shear slump always Indicates the concrete is non - cohesive & characteristic of segregation.


Shear

Collapse


Collapse

Recommended slumps for various concrete works (in mm)

i) pavement - 25-50
ii) Piles - 100-150
iii) mass concrete structure - 25-50
iv) Reinforced slab,
v) beam, footing - 50-100

*Advantage ⇒ Suitable For Field Application, suitable for concrete of high and medium workability.

ii) Compaction Factor Test

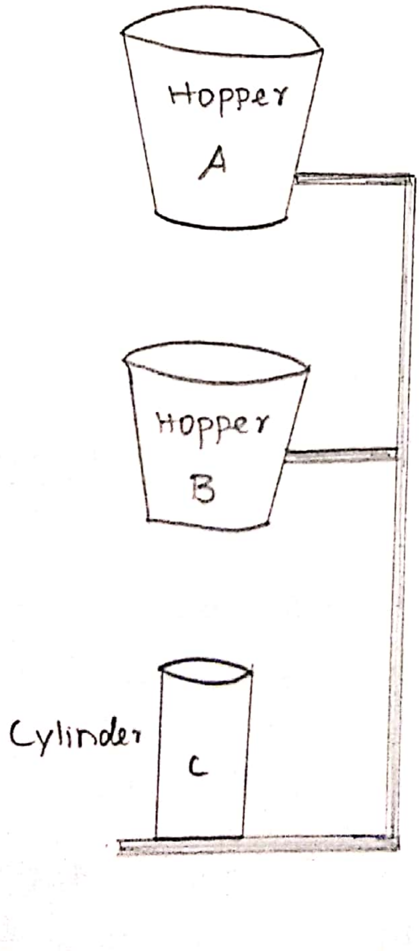
* The compaction factor test is the workability test for concrete conducted in laboratory.

* The compaction factor is the ratio of the weights of partially compacted to fully compacted concrete.

* It was developed by Road Research lab in UK used to determine workability of concrete.

* The compaction factor test is used for concrete which have low workability for which slump test is not suitable.

Apparatus



Upper hopper - A

Top Internal dia - 25.4 cm

Bottom Internal dia - 12.7 cm

Internal height - 27.9 cm

Lower hopper - B

Top Internal dia - 22.9 cm

Bottom Internal dia - 12.7 cm

Internal height - 22.9 cm

cylinder - c

Internal dia - 15.2 cm

Internal height - 30.5 cm

Distance between each hopper & cylinder - 20.3 cm

* concrete mix is prepared, place the concrete sample gently in the upper hopper to its brim using the hand scoop and level it. (apply oil to the internal hopper to avoid sticking)

* open the trapdoor at the bottom of the upper hopper so that concrete fall into the lower hopper, push the stickling on its sides gently with rod.

* open the trapdoor of the lower hopper and allow the concrete to fall into the cylinder below.

* cut the excess of concrete above the top level of cylinder using trowels and level it. clean the outside of the cylinder.

* weight the cylinder with concrete by using weighing machine., the weight of partially compacted concrete (w_1)

* Empty the cylinder and then refill it with the same concrete mix in layers, each layer being heavily Rammed to obtain full compaction.

* weigh the cylinder with fully compacted this weight is known as (W_2)

* Find the empty weight of the cylinde (w_1)

* The compaction factor values ranges from <u>0.7 to 0.95.</u>

iii) Segregation and Bleeding

Segregation

* Segregation can be defined as the separation of the constituent materials of concrete.

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

Three types of segregation

→ The coarse aggregate Separating out or Settling down from the concrete mixture.

→ The cement paste separate away from the coarse aggregate.

→ The water separate from the mixture.

* A well grade concrete consider some parameter Such as grading, size, shape & surface texture

Reason for segregation

* Improper Binding of materials

* Insufficient mixed concrete with excess water

* Conveyance of concrete by conveyor belts, wheel barrow, long distance haul by dumper, long lift by skip and hoist are promoting segregation of concrete

Dry

→ vibration of concrete is one of the Important method, Dry mix should be vibrated, if too wet mix is excessively vibrated the concrete gets segregated.

→ * In Recent time concrete with very high slump Particulary in RMC. we used.

* The slump Value for Batching point 150mm d, Pumping point 100mm are required. at both these Points cubes are cast.

* One has to take care to compact the cube mould It may get segregated and show low strength.

→ while finishing concrete floors or pavement, the Immediate working on the concrete on placing without any time Interval the segregation will occurs. (Topress the concrete coarse aggregate down, paste on surface)

→ Improper propotioning mix, Improper handling, transporting, placing, compacting, Finishing are Reason segregation

How to Reduce the segregation

* pozzolanic materials, air-entraining agents

* segregation is difficult to measure quantitatively. but it can be easily observed at the time of concreting operation

Bleeding

* Bleeding is sometimes Referred as water gain

It is a particular form of segregation, in which some of the water from the concrete comes out to the surface of the concrete.

* Due to bleeding water comes up and accumulates at the surface. Sometimes along with this water, certain quantity of cement also comes to the surface.

* The formation of cement paste at the surface is known as "Laitance".

* The laitance formed on roads produces dust in summer & mud in rainy season

* The laitance can develops higher shrinkage cracks.

* If the water cement ratio more than 7, and the Bleeding will continous It causing permeability of concrete structures.

* The Bleeding Rate Increases upto 1 hr

It Decreases the Final setting time of cement.

→ * Bleeding presents very serious problem when slip form paver is used for construction of concrete pavements.

* If high content of Bleeding water accumulates on the surface, the water flows out the unsupported side

* which causes collapsing of sides, and delays the texturing and application of curing compounds

* Bleeding is predominantly observed in a highly wet mix, Badly proportioned & Insufficient mixed concrete.

* Bleeding is Reduced by using
  i) pozzolanic material
  ii) Air entraining agent
  iii) Finer cement
  iv) Cement with low alkali content

Determination of compressive and Flexural strength

Compressive Strength test

* Compression test is the most common test conducted on hardend concrete

* Reason → It is easy test to perform
  → most of the desirable characteristic properties of concrete are qualitively Related to its compressive strength

* The test is carried out on specimens cubical (or) cylindrical in shape. prism is also used sometimes

* part of the beam could be used to find out the compressive strength.

Specimen

Cube specimen size - 15 x 15 x 15 cm (or) 10 x 10 x 10 cm
Aggregate size - 20mm

Cylindrical specimen size - 15 cm dia, 30 cm long
Tamping steel Rod size - 16 mm dia, 0.6 m long

moulds

* metal, steel (or) cast iron used.

Cylindrical mould

mould Internal Dia - 14.95 cm to 15.05 cm

height maintained - 30 cm ± 0.1 mm

Base plate - 6.5 mm thick

* The base plate is attached to the mould by springs (or) screws.
* The mould are thinly coated with mould oil to prevent adhesion of concrete.

Compaction

i) compacting by hand
ii) compacting by vibration

compacting by hand

* Standard tamping bar is used for compaction

cube → 35 strokes per layer for 15 cm mould
25 strokes per layer for 10 cm mould.

cylinder → 30 strokes per layer
* The voids are left by the Trapping rod.

compacting by vibration

The compacting by vibration each layer is vibrated by means of an electric (or) pneumatic hammer, vibrating table also used.

procedure

* The 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 these specimen should be made even and smooth, this is done by putting cement paste.
* These specimens are tested by compression testing machine after 7 days curing & 28 days curing
* load applied gradually at the rate of 140 kg/cm^2 per minute till the specimens fails.
* load at the failure divided by area of specimen gives the compressive strength of concrete

$$\text{compressive strength} = \frac{\text{load}}{\text{cross-sectional Area}}$$

Pro

Flexural Strength of concrete (Tensile strength)

* Concrete as we know strong in compression and weak in tension

* Steel bars are provided to resist all tensile Force (steel strong in tension)

* Determination of flexural strength of concrete, when a road slab with Inadequate Sub-grade Support is subjected to wheel loads and volume changes due to temperature / shrinking.
(Refer M.S Shetty page no: 428)

Equipment & Apparatus.

Beam mould

Size - 15 x 15 x 70 cm
(Aggregate size less than 38mm)

Size - 10 x 10 x 50 cm
(Aggregate size less than 19mm)

Tamping bar

length - 40 cm

weight - 2 kg

Testing machine

The bed of the testing machine with two steel roller 38mm in dia
i) Central point loading
ii) Two point loading

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Procedure

* The concrete is prepared and placed on the mould. each layer tamped at 25 times

* After a day a mould is Removed and the Speciment is placed in curing tank at temperatute of 27 ± 2°c

* The test specimen Removed from the tank at dried 7 days & 28 days for testing

* The specimen is placed on the rollers and centre with the longitudinal axis of the specimen

* The load apply 400kg/min for 150mm specimen & 180kg/min for 100mm sepecimen

* note the load at which cylinder face by developing cracks. measures the distance between the line of the cracks to the nearest supports.

* consider as a If It is greater than

i) >200mm,

Flexural strength (or)

modulus of Rupture $f_b = \frac{P \times L}{bd^2}$

ii) less than 200mm

$f_b = \frac{3Pa}{bd^2}$

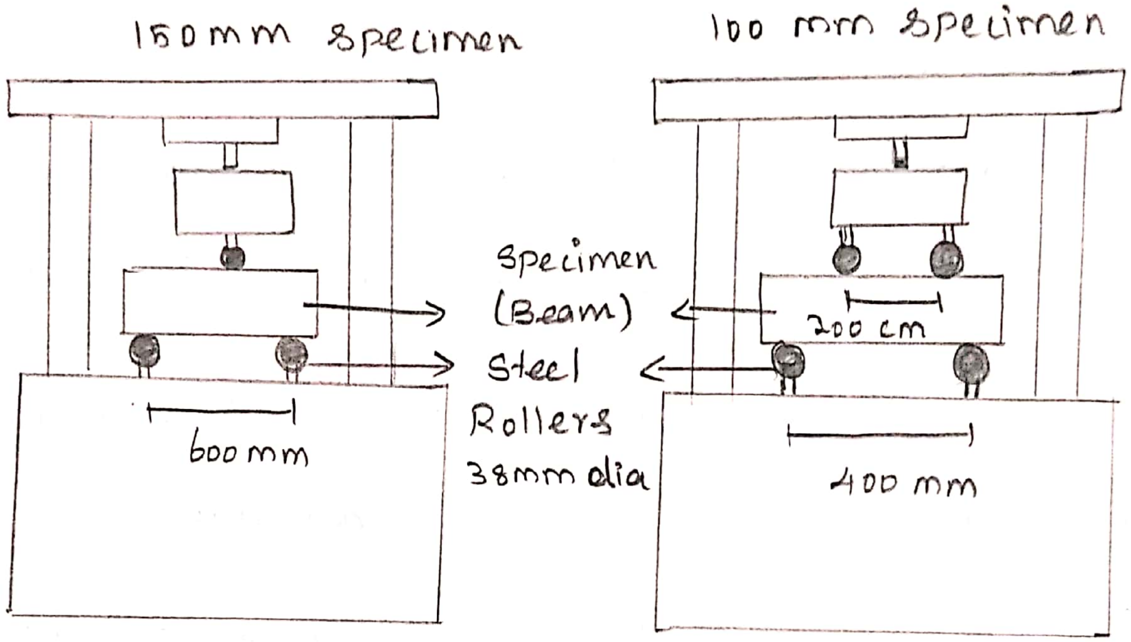
b - width of the beam in mm

d - failure point depth in mm

L - supported length in mm

p - maximum load applied to the beam in kg

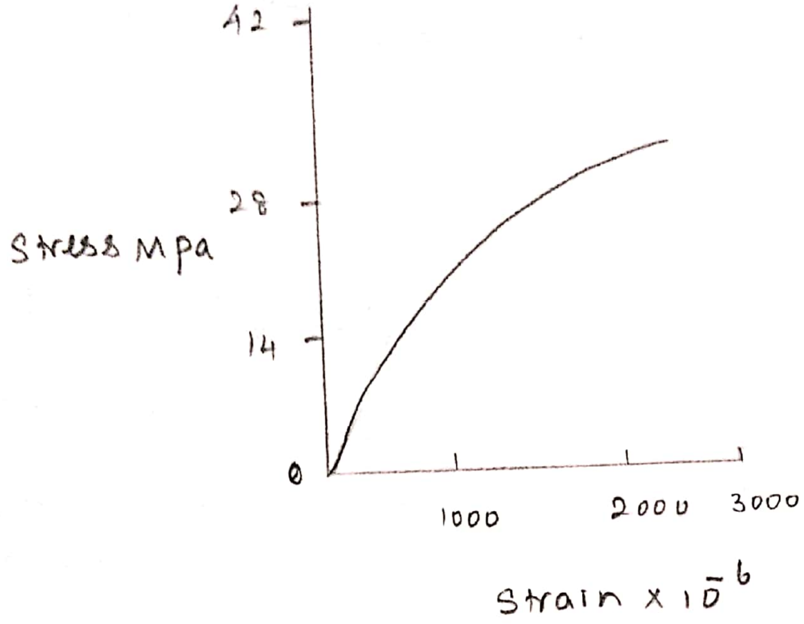
a - Distance between the line of fracture and nearest support



Central point loading

Two point Loading

Stress / strain curves for concrete



* The stress strain curve of concrete is obtained by testing concrete cylinder speciment at age of 28 days using compressive test machine.

* The stress strain curve of concrete allows designers and engineers to anticipate the behavior of concrete is used in Building construction.

* The performance of concrete structure is controlled by the stress strain curve relationship and the type of stress to which the concrete is subjected in the structure.

Note :- The stress strain curve is a graphical Representation of concrete behavior under load. It is produced by plotting concrete compress strain at various interval of concrete compressive loading (stress)

Prope

Determination of young's modulus.

$$E_c = 57000\sqrt{f_c}$$

f_c - concrete strength

* modulus of elasticity of a material is a number which is defined by the ratio of the applied stress to the corresponding strain within the elastic limit

$$E = \frac{f}{s}$$

f → applied stress

s → strain to the correspond applied stress

* The modulus of elasticity of concrete can be defined as the slope of the line drawn from a stress of zero. to a compressive stress of 0.45 f'c

* As concrete is a heterogeneous material. the strength of concrete is dependent on the relative proportion & modulus of elasticity of the aggregate.

Note : The Ratio of normal stress to longitudinal strain within the limit of proportionality

Factor affecting youngs modulus

* stress & strain
* Change in length
* elongation
* Effect in temperature
* Effect in Impurities

properties of hardend concrete

i) strength of concrete
ii) concrete creep
iii) shrinkage
iv) water tightness(Impermeability
v) modulus of Elasticity

i) Strength of concrete

The strength of concrete is basically Referred to compressive strength and it depends upon three factor

i) paste strength
ii) Interfacial strength
iii) Aggregate strength

Paste strength

It is mainly due to the binding properties of cement that the Ingredients are compacted together. If the paste has higher binding strength, higher will be strength of concrete

Interfacial bonding

* It is very necessary regarding the strength
* The aggregate should be washed for a better bonding between paste and aggregate.

Aggregate Strength

* It is mainly the aggregate that provide strength to concrete especially coarse aggregate which act Just like bones in the body

* Rough and angular aggregates provides Better bonding and high strength.

Factors affecting Strength of concrete

* Water - cement Ratio
* Type of cement material
* Type of Aggregate
* Air content
* Admixture

ii) Concrete creep

* Deformation of structure under sustained load.

* long term pressure (or) stress on concrete can make it change shape.

* This deformation usually occurs in the direction the force is applied.

Durabi...

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Durability

Durability might be defined as the ability to maintain satisfactory performance over and extended service life of Building.

iii) Shrinkage

Shrinkage is the volume decrease of concrete caused by drying and chemical changes. (or) the Reduction of volume for the setting and hardening of concrete is defined shrinkage.

iv) water tightness.

* Another property of concrete is water tightness. sometime its called Impermeability of concrete.

* water tightness of concrete is directly Related to the durability of concrete. the lesser Permeability the more the durability of concrete

v) modulus of Elasticity

It is depends on the modulus of Elasticity of the concrete Ingredients and their mix proportions.

Unit - V

Special Concrete

Light weight concretes

* Light weight concrete called structural light-weight concrete is comparatively lighter than conventional Concrete but at the same time strong enough to be used for structural purposes.

* Lightweight weight concrete mixture is made with a lightweight coarse aggregate and sometimes a portion (or) entire fine aggregates may be lightweight Insted of normal aggregates.

→ Lightweight concrete density (1440 to 1840 kg/m³)

→ Normal weight concrete density (2240 to 2400 kg/m³)

Types of lightweight concrete

i) lightweight Aggregate concrete

ii) Aerated concrete

iii) No Fines concrete

iv) low density concrete

i) light weight Aggregate concrete

* This type of concrete particularly need to reduce weight in a structure & Important consideration for design (or) For economy

* Light weight Aggregates - pumice. Foamed slag

ii) Aerated concrete

* It is low density, thermal conductivity and strength.

* Aerated concrete is a lightweight, cellular material consisting of cement and lime, sand. It is made by physical (or) chemical process.

* Air (or) gas is Introduced into a slurry, It generally contains no coarse material.

iii) No Fines concrete

* It is generally means concrete composed of cement and a coarse aggregate only.

* It mainly used for load bearing, cast in situ external & Internal wall, non load bearing wall, under floor filling for solid ground floors.

iv) low Density concrete

* These are employing chiefly for Insulation purpose, high heat Insulation, compressive strength are low.

* Density of this concrete is 800 kg/m3

Advantages of Lightweight concrete

* Reduced dead load of wet concrete allows longer span to be poured. this save labor and time for each floor.
* Improved Durability
* lower handling cost.
* Superior Fire Resistance
* low thermal conductivity
* Easier transportation

Disadvantages of lightweight concrete

slower drying time, which means that contractors of flooring system have to wait longer to proceed with Flooring Installation

uses of lightweight concrete

* construction of partition walls and panel walls in frame structures
* General Insulation of walls.
* It also used for reinforced concrete
* External walls of small house.

High Strength concrete

* The strength of the concrete depends upon the strength of the components, their deformation properties, adhesion between the pas & aggregate surface with most natural aggregate is to make concretes upto 120mpa compressive strength by Improving strength of cement paste which controlled through the water cement ratio

* HSC may defined as concrete specified characteristic cube strength 60 to 100 N/mm^2 and also higher strength have been achived

Ingredient

→ Cement (portland cement)

→ coarse aggregate (10–12 mm)

→ Fine aggregate (rounded particle shape & smooth texture)

→ chemical admixture (Superplasticizer)

→ Mineral admixture (consist of flyash & silica fume)

Advantages of HSC

→ High Durability

→ low cost

Disadvantages of HSC

→ High material cost

→ low water cement ratio require special curing

Application of High Strength concrete

* It is used for Bridge construction
* In high rise structures in US cities used HSC
* used in shear walls, foundation.
* HSC used in the construction of highway Bridges.
* HSC of concrete result Reduction in coloumn size, Increase floor space.
* It effectively used in domes, Folded plates, shells & arches, column, piles

Geopolymer concrete

* It is an Inorganic alumino-silicate polymer, synthesized from predominantly silicon and aluminium material such as fly ash.
* The polymerisation process may be assisted by applied heat followed by drying
* The Geopolymer gel binds loose coarse and Fine aggregate
* Geopolymer gel Replace the C-S-H gel in cement concrete.

* The Re chemical Reaction period is substantially Fast and the Required curing may be within 24 to 48 hr

* Egyptain pyramids were build by casting geopolymer on site

* Geopolymer possesses excellent mechanical property It does not dissolved in acidic solution

* It Does not generate any deleterious alkali aggregate Reaction even in presence of high alkalinity

* low calcium. Fly ash, sodium hydroxide, sodium silicate, to Improve the workability of fresh concrete.

Advantages of Geopolymer

* Greater corrosion resistance.
* High fire resistance
* lower shrinkage
* Greenhouse gas Reduction potential
* low permeability
* Eco-friendly
* Better compressive strength
* The price of fly ash is low

Disadvantages of geopolymer

* Difficult to create geopolymer
* The process of Geopolymerization is Sensitive

Applications

* pre cast concrete products like railway sleepers, electric power poles, parking tiles, sewer pipes, etc.
* Marine structures due to resistance against chemical attacks.

High performance concrete

* It posses high durability and high Strength when compared to conventional concrete
* This concrete contains one (or) more of Cementious material such as fly ash, silica Fume, Super plasticizer
* Hpc not a special concrete

Ingredient for Hpc

→ cement (conteun C_3A & C_3S)
→ Fine aggregate (river sand & crushed stones)
→ Coarse aggregate (least porous & strong)
→ Chemical admixtures (Retardes, platicizers)
→ Mineral admixtures (Fly ash, silica Fume)

Advantages of Hpc

* Reduction in size of columns
* Speed of construction
* most economical material interms of time and money
* Durability against chloride attak
* low shrinkage and high strength
* High tensile strength
* Reduced maintenance cost
* wearing Resistance, abrasion Resistance
* Higher seismic resistance

Disadvantages

* Initial cost High
* Hpc has to be manufactured and placed more carefully than normal concrete
* In concrete plant and at delivery site additional tests are required.

Applications

→ Bridges

→ High Rise Buildings

→ Tunnels

→ pavements

→ Nuclear structures

polymer concrete

* Concrete is porous
* The porosity is Due to air & water voids
* the porosity Reduced the Strength of concrete.

Reduction of porosity is Increase the concrete strength

* The Impregnation of monomer and subsequent polymerization is the lastest techniques adopted to reduse inherent porosity of concrete & Increase the strength.

Types of polymer concrete

i) polymer Impregnated concrete

ii) polymer cement concrete

i) polymer Impregnated concrete

* It is a precast conventional concrete cured and dried in oven (or) by dielectric heating from which the air in the open cell is Removed by vacuum.

* Then a low viscosity monomer is diffused through the open cell & polymerized by using Radiation, application of heat (or) by chemical Initiation.

* Acrylonitrile, T-butyl styrene monomers are used.

ii) polymer cement concrete

* polymer cement concrete is made by mixing cement, aggregate, water, monomer

* Such plastic mixture in cast in mould, cured dried & polymerized.

* polyster - styrene, Epoxy styrene. monomer are used.

uses

* polymer concrete may be used for new construction (or) repairing of old concrete.

* The low permeability and corresive Resistance of polymer concrete allows it to be used in swimming pools, sewer structure, Drainage channels, man holes.

* It can also be used as a bonded wearing course for asphalt pavement for higher durability and higher strength upon a concrete substrate.

Fibre Reinforced concrete

* plain concrete posses a very low tensile strength, limited ductility and little resistance to cracking.

* Internal microcracks are inherently present in the concrete and its poor tensile strength is due to the propagation of such microcracks, eventually leading to brittle fracture of concrete.

Types of fibers

* steel fiber, glass fiber, synthetic fibers, natural fiber

* Fibers are usually used in concrete to contr cracking due to plastic shrinkage and to drying shrinkage

* They also Reduce the permeability of concrete and Reduce bleeding of water.

* Fiber Reinforced concrete is used when there is Requirement for elimination small cracks.

Advantages

* High compression strength
* High tensile strength
* High elasticity modulus
* Ductile Behavior
* High Durability

Disadvantages

* Increase in specific gravity of the concrete
* High maintenance cost
* Corrosion of steel fibers.

Applications

* Thin sheets
* Roof tiles
* pipes, shotcrete
* panels
* Curtain walls

Ferro cement

* It is a type of thin wall reinforced concrete Commonly constructed of hydraulic cement mortar, Reinforced with closely spaced layers of continous & Relatively small size wire mesh.

* The mesh mey be made of metallic (or) other Suitable materials.

* Mortar provides the mass and wire mesh Imparts tensile strength & ductility.

Note: Ferro cement is a composite material which used in building with cement, sand, water, wire mesh material often called a thin shell.

Properties of Ferro cement

* It is very durable, cheap and versatile material
* low w/c ratio produces Impermeable structures
* less shrinkage, low weight
* High tensile strength & stiffness
* Better Impact and punching sheae resistance
* undergo large deformation before cracking (or) high deflection.

Advantages of Ferro cement

* It is highly versatile and can be formed in almost any shape for wide range of uses
* 20% savings on material and cost
* Suitability for pre casting
* Flexibility in cutting, drilling, Jointing
* Good Fire Resistance
* low maintenance cost
* Easy Repairability, noncorrosive nature and easier mouldability to any required shape.
* less crack widths compared to conventional concrete.
* Simplicity of its construction

Casting techniques

→ Hand plastering
→ Centrifuging
→ Guniting
→ Semi - mechanised process

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Disadvantages of ferro cement

* Low shear strength
* low ductility
* large no of labours required
* Susceptibility to stress rupture failure
* It is difficult to fasten to ferrocement with bolt, screw, welding

Application of ferro cement

* Ferro cement has been sucessfully used for casting water tanks
* It is been used for Building Boat.
* It is also been used for creating man hole cover
* Ferro cement is also been used for making Roofs.
* It is also been used for casting Benches, chairs, etc
* Grain storage bin, silos, canal lining, pipes, shells for fish and poultry farms are make by using ferrocement.

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Ready mix concrete

* Ready mix concrete (RMC) is a ready to use material with predetermined mixture of cement, sand, aggregates and water.

* The Increasing availability of special transport vehicles, supplied by the new and fast growing automobile Industry, played a positive role in the development of RMC Industry.

Materials Required for RMC

i) Aggregates (Reduces shrinkage)

ii) Cement

iii) Admixture (Air entraining agent)

iv) Fly ash (partial Replace for cement, sand)

v) water

Equipment Required

→ Storage of materials - silos, containers

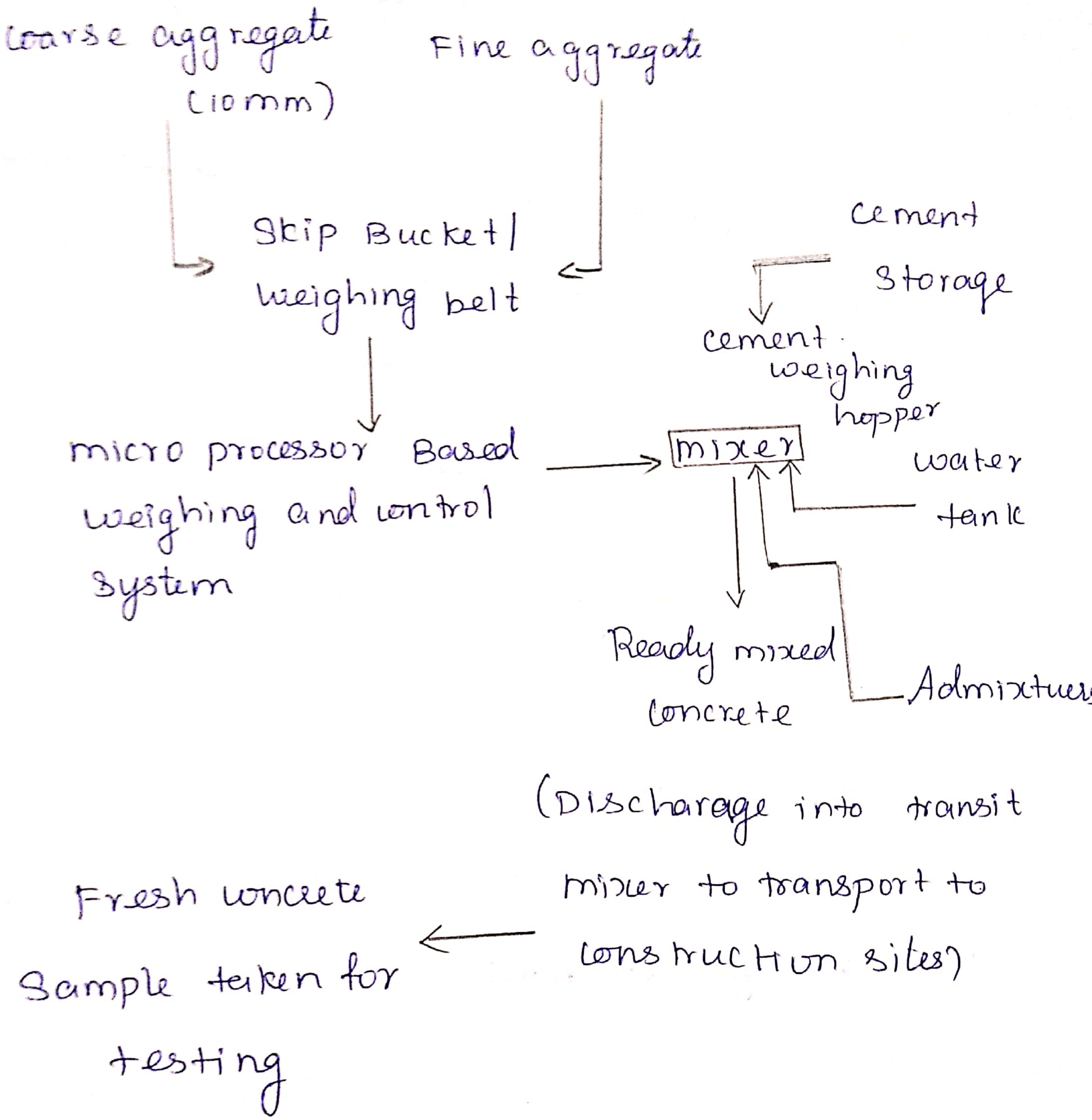
→ Batching arrangement

→ mixing equipment

→ Electrical, hydraulic drives

→ Conveying system (Belt / Screw conveyors)

manufacturing process Flowchart



Advantages of RMC

* A centralized concrete Batching plant can serve a wide area
* The plants are located in areas zoned for Industrial use and delivery trucks can service Residential districts (or) inner cities.
* Better Quality concrete is produced
* Time Required is greatly Reduced
* labour associated with production of Concrete is eliminated
* wastage of Basic materials is avoided

Disadvantages of RMC

* The materials are Batched at a central plant, the mixing begins at that plant, so the travelling time from the plant to the site is critical over longer distance.
* Concrete limited time span between mixing and going-off means that ready mix should be placed with in 10 minutes of Batching at the plant

shotcrete

Mortar (or) high performance concrete conveyed through a hose at high velocity onto a backing Surface

Classification of shotcrete

→ Dry mix shotcrete

→ wet mix shotcrete

Dry process

* Dry shotcrete components, which may be slightly predamped to Reduse dust, are fed into a hopper with continuous agitation

* compressed air is Introduced through Rotating Barrel to convey the materials in a continuous stream through delivery hose. water is added to the mix at the nozzle

* Then the material is consolidated on Receiving surface by high Impact velocity

Advantage of Dry process

* Easy start up, shutdown d clean up
* control of materials is on site
* widely used in mining

wet process

* Shotcrete components and water are mixed Before delivery into a positive displacement pumping unit.
* which then delivers the mix hydraulically to the nozzle where air is added to the material onto the rock surface.
* mostly wet process shotcreting is done with premixed mortar (or) small aggregate Concrete.

Advantages of wet process.

* No Formwork is Required
* cost effective method for placing concrete
* Ideal for Irregular surface applications

SIFCON Concrete

* SIFCON is the slurry Infiltrated Fiber concrete.

* The strength of the concrete is high with the flexural strength and is suitable for earthquake prone areas

* The cement slurry is Introduced over the steel fibers.

* The coarse aggregate is omitted

* The strength of sifcon is higher than FRC.

* The sifcon posses high flow ability and passing ability

Test For SIFCON

→ Compressive strength

→ Flexural strength

→ Impact test

material used :

- opc 53 grade
- ordinary sand
- coiled steel Fiber (0.2-0.5mm tk)
- Super plasticizer

Merits

* low material cost
* Improved structure behaviour

Demerits

* It cannot be appointed in hydraulic structures
* Needs care and techniques for fabrication
* Corrosion Inhibitors may be necessary
* It needs good compaction & supervision

Applications

* highway pavements
* mine & tunnel linings
* Bridge deck overlays
* hydraulic structures
* earthquake resistance structures

Dr. Ch. [signature] 3/12/24