LECTURES NOTES
ON
CONCRETE TECHNOLIGY

Prepared By:

ITI EPSITARANI SETHI

PTGF(Civil)

Department of Civil Engineering

Government Polytechnic, Sonepur

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1. Concrete as a construction material

:- **Concrete** :- The concrete is the mixture suitable binder fine aggregates coarse aggregates proportion & mixed in water for ~~mainteing~~ maintaining work ability in weight & also to hold chemically set, harden & gain strength in dry form.

:- **Grades of concrete** :-

* It is the mixture of ~~concre~~ cement, sand & coarse aggregate with water.
* Grade of concrete is the designation of concrete according to it's compressive strength.
* Concrete grades are denoted by M10, M20, M30 according to their compressive strength.
* The "M" denotes mix design of concrete followed by the compressive strength number in N/mm²
* ~~...~~ mix is the respective ingredient proportions which are cement : sand : Aggregate or cement : fine Aggregate : coarse Aggregate,

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* If we mention M_{10} concrete, it means that the concrete has 10 N/mm² characteristic compressive strength at 28 days.

M10
mix ↙ ↘ compressive strength of concrete in N/mm².

grade		proportion
m_5	→	1 : 5 : 10
$m_{7.5}$	→	1 : 4 : 8
m_{10}	→	1 : 3 : 6
m_{20}	→	1 : 1½ : 3
m_{25}	→	1 : 1 : 2
m_{50}	→	1 : 2 : 4
m_{30}	→	1 : 1 : 2

m_{25} → 1:1:2 → it is the proportion of binding aggregate : fine aggregate : coarse aggregate.

m_{15} → 1:2:4 → PCC structure

m_{20} → 1:1½:3 → RCC structure

Advantages of concrete

→ Availability of concrete ingredients easily.
→ easy handling & moulding of concrete into any shape.
→ easy transportation from the place of mixing to place of casting before initial set takes place.
⇒ Ability of pump/spray to fill into cracks & lining of tunnels.
→ when reinforced, all types of structure are made possible form an ordinary lintel to massive fly over.
→ The property of concrete to posses high compressive strength, makes a concrete structure more economical than that of steel structure

Disadvantages of concrete

→ Due to low tensile strength, concrete is required to be reinforced to avoid cracks.
→ In long structure expansion joints are required to be provided if there is large temperature variance in the area

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→ construction joints are provided to avoid cracks due to drying shrinkage & moisture expansion.

→ soluble salt in concrete cause efflorescence if moisture reacts with them.

→ concrete made with ordinary portland cement, gets integrated in presence of alkalies, sulphates etc.

→ sustained loads develop creep in structures.

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2. Cement

* The word cement usually means portland cement use in civil engg. work. which set under water & harden quickly & strength.
* The setting power of cement is more than lime but cement is similarly in many respect to a good quality of hydraulic lime.
* A small quantity of Gypsum added to Clinker. Then it is converted into lime powder. Then it known as cement.

Composition of cement :-

Ingredient	Percent	Range
lime → (CaO)	62%	(62 to 67)%
silica → (SiO_2)	22%	(17 to 25)%
Alumina → (Al_2O_3)	5%	(3 to 8)%
Calcium sulphate ($CaSO_4$)	4%	(3 to 4)%
Iron oxide (Fe_2O_3)	3%	(3 to 4)%
magnesia (MgO)	2%	(1 to 3)%
Sulphur (S)	1%	(1 to 3)%
Alkalies	1%	(0.2 to 1)%

The lime, silica & Iron oxide give strength to the cement while Allumina gives quick setting. The Alkalies & magnesium oxide

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trioxide are not desirable are excess amount.

Water-cement ratio

The water in concrete has to perform the following two function.

(i) The water enters into chemical action with cement & this action cause the setting & hardening the concrete.

(ii) The water lubricates the aggregate & it facilitates the passage of cement through voids of aggregates. This means that water makes the concrete workable.

It is found theoretically that water required for these two function is about 0.50 to 0.60 times the weight of cement. This ratio of the amount of water to the amount of cement by weight is known as the water-cement ratio & the strength & quality of concrete primarily depend upon this ratio.

usually

The important points to be observed in connection with the water-cement ratio are as follows.

→ The minimum quantity of water should be used to have reasonable degree of workability. The excess water occupies space in concrete & on evaporation, the voids are created in concrete. Thus the excess water affects considerably the strength & durability of concrete. In general it may be stated that addition of one(1) extra litre of water to the concrete of one(1) bag of cement will reduce its strength by about 1.47 N/mm² in other words, the strength of concrete is inversely proportional to the water-cement ratio.

→ Some rules of thumb are developed for deciding the quantity of water to make

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The two such rules are mentioned below. The rules are for ordinary concrete & they assume that the material are non-absorbent & dry.

(a) weight of water = of the weight of the cement + 4% of the weight of total aggregate.

(b) weight of water = of the weight of the cement + 5% of the weight of the total aggregates.

Net water-cement ratio by weight	Probable cube crushing strength in N/mm²	
	7 days	28 days
0.35	40	52.5
0.40	35	47
0.45	30	42
0.50	25	37
0.55	22	33
0.60	18	28
0.65	15.5	24.5
0.75	13.5	22
0.75	11.2	20
0.80	10.5	17.5

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Compressive strength of cement.

→ Compressive strength is the capacity of material or structure to resist or withstand under compression. The compressive strength of material to resist failure in form of cracks & fissure.

→ In this test the impact force applied on both face of mortar specimen made with cement & the maximum compressive on that cement specimen bears without failure recorded.

In Technical terms compressive strength of cement means.

The ability of cement specimen to resist the compressive stress when tested under compressive ~~testing~~ Testing machine (CTM)

This test is carried out to determine the compressive strength of cement. Following procedure is adopted.

(i) The mortar of cement & sand is prepared. The proportion is 1:3. ~~which mean the~~ which means x gm of cement is mixed with 3x gm of sand.

(ii) The water is added to the mortar. The water cement ratio is kept as 0.4 which means that x gm of water is added to dry mortar.

(iii) The mortar is placed in moulds in the form of cube with side as 76mm or 70.06mm, 76mm & 70.06mm cube the cement required is 185 gm & 235 gm respectively.

(iv) The mortar after being placed in the moulder is completed in vibrating machine for 2 minutes.

(v) The moulds are placed in a damp cabin for 24 hours.

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(vi) The cubes are then tested on compression testing machine at the end of 3 days & 7 day. The testing of cube is carried out on their 3 sides without packing. Thus 3 cube are tested each time to find out the compressive strength at the end of 3 days & 7 days. The average value is then worked out. During the test the load is to be applied uniformly at the ratio of 350 kg/cm² or 35 N/mm²

(vi) The compressive strength at the end of 3 day should not be less than 115 kg/cm² or 11.50 N/mm² & that at the end of 7 days should not be less than 175 kg/cm² or 17.50 N/mm²

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Fineness:- This test is carried out to check proper grinding of cement. The fineness of cement particles may be determined either by sieve test sieve test or by permeability apparatus test.

In sieve test, the cement weighing 100gm is taken & it is continuously passed for 15 minutes through standard BIS sieve no. 9. The residue is then weighed & this weight should not be more than 10% of original weight.

In permeability apparatus test, specific surface area of cement particles is calculated. This test is better than sieve test it gives an idea of uniformity of fineness. The specific surface acts as a measure of the frequency of particles of average size. The specific surface of cement should not be less than 2250 cm^2/gm.

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Setting time of cement

This test is used to detect the deterioration of cement due to storage. It may however be noted that this purely a conventional types of test & it has got no relation with the setting or harding of actual concrete. The test is carried out to find out initial setting time & final setting time.

initial setting time of cement! —

initial setting time of cement is regarded as the time which elapsed between the moment when water is added to the cement to the time when the cement paste starts losing it's plasticity. experimentally we can say that initial setting time ~~when the~~ elapsed between the moment when water is added to the cement to the time when the vicat plunger penetrates upto 5mm from the bottom.

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Final setting time of cement :-

Final setting time of cement is regraded as the time ~~is added to the cement~~ elapsed between the moment when water is added to the cement to the time when cement lost its plasticity completely i.e the cement sufficient strength to resist any pressure.

Experimentally we can say that the final setting time of cement is the time elapsed between the moment when water is added to the cement to time when circular attachement fails to make any impressions.

hydration of cement :-

* when cement, water, aggregate & additives are mixed together to the exothermic process in the reaction between cement & water. that is called hydration
* measuring the concrete temperature overtime enable you to known how far the concrete is in the hydration process (concrete maturity) & there by also estimated concrete strength. The hydration process is dived into five phases.

5 Phases of hydration process

1. Phase - initial mixing reation
2. Phase - Dormancy
3. phase - Strength accelerations
4. Phase - speed reduction
5. - Phase - steady developement

① initial mixing reation :-

initial after mixing the cement & water comes into contact with each other, a peak in temperature happens.

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The aluminate (C_3A) reacts with calcium & sulfate ions to form ettringite aluminate hydrate. The release of energy from these reactions causes the initial peak.

(2) Dormancy :-

→ A result of the reaction described in phase 1 is a surface coating of the cement particles. The coating keep increase, but also (slow down the reaction (hydration) as the access to calcium & sulfate ions) it's as good as when the concrete was mixed. The amount of hydrated concrete keeps increasing on a steady level while surface of the concrete keep fluid.

→ This is why this phase is used for transporting & pouring the concrete as the concrete stays on a fluid level. The length of this period

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depending on each individual concrete mix & can therefore be optimized depending on the application like winter concrete, length of transport etc.

→ This phase ends with an initial set of the concrete.

③ Strength Acceleration :-

→ A heat increase happen due to the reaction between calcium silicate which create the silicate hydrate. Heat increase also caused by other minor reaction. The creation of silicate hydrate also has a major impact on the concrete strength during this phase

④ Speed reduction :-

A maximum temperature has now been reached & the availab-ility of free particles is now reduced & therefore slow down the temperature increase.

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→ This phase often end with the desired strength & the formwork around the concrete can now be removed, monitoring of concrete maturity & temperature & therefore enable the user with the exact time where this is possible.

(5) Steady Development / post form work :-

→ The hydration process is now slow down & will continue slowly to finish the remaining available cement & water particle. The formwork is now ~~avoid~~ often removed & the concrete will now over time finish the hydration.

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Aggregates

Aggregates are the important constituents in concrete. They give body to the concrete. reduce shrinkage & effect economy.

→ Earlier, aggregates were considered as chemically inert materials but now it has been recognised that some of the aggregates are chemically active & also that certain aggregates & paste.

→ The mere fact that the aggregate occupy 70-80% of volume of concrete. their impact on

→ ~~To know more about the concrete~~ various characteristic & properties of concrete is ~~undoub~~ undoubtedly considerable.

→ To know more about the concrete it is very essential that one should know more about the aggregates which constitute major volume in concrete.

→ without the study of the aggregate in depth & range the study of concrete is incomplete.

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Classification of Aggregates.

The classification of the aggregates is generally on their
→ geological origin
→ size, shape, unit weight etc.

① Classification According to Geological origin: — The aggregates are usually derived from natural sources & many have been naturally reduced to size or may have to be reduced by crushing. The suitability of the locally available aggregate depends upon the geological history of the region. It is divided into 2 categories. that are ① natural ② Artificial Aggregates

Natural Aggregates: — These aggregates are generally obtained from natural deposits of sand & gravel or from quarries by cutting rocks. The cheapest among them are the natural sand & gravel which have been

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reduced to their present size by natural agents. such as water wind ^ snow. etc.

→ The river deposits are the most common & are of good quality. The second most commonly used source of aggregate is the quarried rock which is reduced to size by crushing

→ Natural rocks can be classified according to their geological mode of formation. i.e igneous sedimentary or metamorphic origin

→ ~~rock group~~

Igneous rocks :— Aggregates from igneous rocks are highly satisfactory because they are normally hard, tough & dense. They have massive structure with crystalline glassy texture. The bulk of concrete aggregates are of igneous rock. The aggregates may be acidic or alkaline depending upon silica content & of light or dark color.

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* The quality of aggregates derived from sedimentary rocks vary depending upon the formation history of the rock. Limestones & some siliceous sand stones have proved to be source of good concrete aggregate. Sedimentary rocks may very from soft to hard porouse to dense & light to heavy. They may also yield flaky aggregates.
* The metamorphic rocks show foliated structure. In some case individual aggregate may exhibit foliation which is not a desirable characteristic in aggregate. However, many metamorphic rock particularly quartzite & gneiss have provided good concrete aggregate.

Artificial Aggregate: The most widely used artificial aggregate are clean broken bricks & air-cooled fresh blast-furnace slag. The broken bricks of good quality provided

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a satisfactory aggregate for the mass concrete & are not suitable for reinforced concrete work if the crushing strength of brick is less than 30 to 35 mpa. The brick aggregate is not suitable for waterproof construction, it has poor resistance to wear & hence is not used in concrete for the road work.

→ The blast-furnace-slag is the by product obtained simultaneously with pig iron in the blast furnace which is cooled slowly in air. carefully selected slag produces concrete having properties comparable to that produced by using gravel aggregates. However, the corrosion of steel is more due to sulfur content of slag, but the concrete made with blast furnace slag aggregate has good fire resisting qualities.

② Classification According to size
The size of aggregate used in concrete range from few centimetres or more, down to few microns.

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The maximum size of the aggregate may vary. but in each case it is to be so graded that the particles of different size fraction are incorporated in the mix. in appropriate proportion.

→ The particle size distribution is called the grading of the aggregate

→ According to the size the aggregate is classified.

fine, coarse, & all in aggregate.

Fine aggregate:- It is the aggregates most of which passes through a 4.75 mm IS sieve & contains only that much coarser material as permitted by the specification.

→ Sand is generally considered to have a lower size limit about 0.07 mm.

→ Material having between 0.06mm & 0.002 mm is called as silt & silt smaller particles are called clay.

→ The soft deposit consisting of sand, silt & clay in about equal proportions is called loam.

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The fine aggregate may be one of the following types.

(1) Natural sand:- The fine aggregate resulting from natural disintegration of rock that which has been deposited by stream & glacial agencies.

(2) Crushed stone sand - that is the fine aggregate produced by crushing hard stone.

(3) Crushed gravel sand - that is the fine aggregate produced by crushing natural gravel.

Coarse Aggregate:- The aggregates most of which are retained on the 4.75mm IS sieve & contain only that much of fine material as is permitted by the specifications are termed coarse aggregates.

→ The coarse aggregates may be one of the following types.

1. Crushed gravel or stone obtained by the crushing of gravel or hard stone.
2. Uncrushed gravel or stone resulting from the natural disintegration of rock.
3. Partially crushed gravel or stone obtained as a product of the blending of above two types.

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All in aggregates:- sometimes combined aggregates are available in nature comprising different fractions of fine & coarse aggregates, which are known as all in aggregates. The all in aggregates are not generally used for making high quality concrete.

Single size aggregate:- Aggregates comprising particles falling essentially within a narrow limit of size fractions are called single size aggregate. For ex- a 20mm single size aggregate means an aggregate most of which passes through a 20mm IS sieve & the major portion of which is retained in 10 mm IS sieve.

(3) Classification According to shape:-

The particle shape of aggregate influence the properties of fresh concrete more than those of hardened concrete. Depending upon the particle shape, the aggregate may be classified as rounded, irregular or partly rounded, angular or flaky.

Rounded aggregate:- The aggregate with rounded particle (river or seashore gravel) has minimum

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ranging from 32 to 33%. It gives minimum ratio of surface area to the volume, thus requiring minimum cement paste to make good & hence the development of the bond is poor, making it unsuitable for high strength concrete & pavements.

Irregular Aggregates :- The aggregate having partly rounded particles ha higher % of voids ranging from 35 to 38%. It requires more cement past having a given workability. The interlocking between particles through batter than that obtained with the rounded aggregates. is inadequate for high strength concrete.

Angular Aggregates :- The aggregates with sharp, angular & rough particles has maximum % of voids ranging from 38-40 The interlocking between the particles good, there by providing a good bond. The aggregates requireds more cement paste to make workability concrete of high strength than that required by rounded particles The angular aggregates is suitable for high strength concrete & pavments subjected to tension.

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Flaky & Elongated Aggregates :- An aggregate is called flaky when it's least diamension (thickness) is less than three-fifth (3/5) of it mean diamension. The mean diamension of the aggregate is the average of sieve size through which the particles pass & are retained, respectively. The particles is said to be elongated when it's greatest diamension (length) is greater than nine fifth of it's means diamension.

(4) Classification Based on unit weight :-
The aggregates can also be classified according to their unit weight as normal weight, heavyweight, & light weight aggregates.

Normal-weight Aggregates :- The commonly used aggregates that is sand & gravel crushed rocks such as granite, basalt sandstone & limestone & brick ballast etc. which have specific gravities between 2.5 & 2.7 produce concrete with unit weight ranging from 23 to 26 KN/m^3 & crushing strength at 28 days between 15 to 40 mpa are called normal weight concrete.

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Heavyweight or high density Aggregate:
Some heavy weight or high density aggregates such baryte (sg 4.0-4.6), ferro-phosphorus (sg: 5.8-6.8), goethite magnetite (sg 4.2-5.2) de greased scrap iron & iron shots (sg. 6.2-7.8) are used in the manufacture of heavy weight concrete which more effective as a radiation shield.

In general, selection of an aggregates is determine by physical properties, availability & cost, high-density aggregates should be reasonable free of fine material, oil & foreign substance that may affect either the bond of paste to aggregate particle or the hydration of cement for good workability, maximum density & economy, aggregate should be roughly cubical in shape & free from excessive flat or elongated particles.

Light weight Aggregate:- The light weight aggregate having unit weight up to 12 KN/m³ are used to manufacture the structural concrete & masonary blocks for reduction of the self-weight of the structure. These aggregates can be either natural, such

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dolomite, pumice, volcanic cinder etc. or manufactured such as bloated clay sintered fly ash or foamed blast furnace slag. in addition to reduction in the weight the concrete produced by using light weight aggregate provides better thermal insulation & improved fire resistance.

→ The main requirement of the lightweight aggregate is its low density some specification limit the unit weight to 12 kN/m^3 for fine aggregate & approximately 10 kN/m^3 for coarse aggregate for the use in concrete.

Characteristics of Aggregates

The properties & performance of concrete are dependent to a large extent on the characteristics & properties of the aggregates themselves

→ In general, an aggregates to be used in concrete must be clean, hard, strong properly shaped & well graded,

→ The aggregates must possess chemical stability, resistance to abrasion & the freezing & thawing. The should not contain deleterious material may cause physical or chemical changes, such as

cracking, swelling softening or leaching.
→ The properties of aggregates for concrete are discussed under the following heads.

1. strength of aggregate: — The resistance of an aggregate to compressive load may be defined as the crushing strength of aggregates. The compressive strength of the concrete mix is greatly influenced by the strength of aggregate. To have an index about the crushing strength of aggregates the the crushing strength test may be carried out.

2) particle size (size of Aggregate)
The size of aggregate greatly influences the properties of concrete in the plastic & hardened stage. It also governs the quantity of cement paste required & hence the economy of concrete. larger the size of size of coarse aggregates, lesser is the surface area, hence lesser is the quantity of fine aggregate & cement required.

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(3) Shape of aggregate :- Aggregates both natural & crushed are available in all types of shape. One can seldom find aggregates which are indentical to each other in shape & size. The shapes of aggregate can be broadly classified as rounded, irregular, cubical, flaky, elongated.

(4) Surface Texture Surface texture illustrates the nature of the surface of the aggregates. The surface texture influences the bond between the aggregate & cement. The rough texture of the aggregate provides a higher surface area for a given volume. Aggregates with smooth surfaces develop a poor bond. Crushed aggregates have a rough texture & give a good mechanical bond with cement. If the crushing value of the aggregates is high, the compressive strength will depend on the bond created by the cement paste between the aggregates

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(5) Specific gravity :- The specific gravity of the aggregate generally is indicative of it's quality. A low specific gravity may indicate high porosity & therefore result in poor durability & low strength.

(6) Bulk density :- The bulk density or unit weight of an aggregate provide important information regarding the shape & grading of aggregate. The bulk density of aggregate is defined as the mass of the material in a given volume & expressed in kg/l. It depends on how densely the aggregate is packed in the mold.

(7) The soundness of Aggregates :- The soundness may be defined as the ability of the aggregate to resist excessive changes in volume due to change in environmental conditions like freezing & thawing, alternate wetting & drying & thermal changes.

→ Aggregate is said to be unsound when the volume changes result

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in the deterioration of concrete, unsound aggregates may result in local scaling to extensive surface cracking and may seriously disintegration of hardened concrete mix.

Grading of aggregates

The particle size distribution of an aggregate as determined by sieve analysis is termed grading of the aggregate.

→ The particles size distribution of a mass of aggregate should be such that the smaller particles fill the voids between the larger particles.

→ The proper grading of an aggregate produces dense concrete & need less quantity of fine aggregate & cement paste. It is therefore essential that the coarse & fine aggregates be well graded to produce quality concrete.

→ The grading of an aggregate is expressed in terms of percentages (%) by weight retained on or passing through a series of sieves taken in order

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80mm, 40mm, 20mm, 10m, 4.75 m for coarse aggregates & 10mm, 4.75mm 2.36 mm, 1.18 mm, 600 microns, 300 microns & 150 microns for fine aggregates.

→ The grading of the aggregates affects the workability which, in turn, control the water & cement requirements segregation, & influences the placing & finishing of concrete.

Quality of mixing water

The water used for the mixing & curing of concrete should be free form injurious amount of deleterious materials. The unwanted situation, leading to the distress of concrete. has been found to be a result of among other, the mixing & curing water being of in-appropriate quality.

→ potable water from the sources is generally considered satisfactory of mixing concrete.

→ In the case doubt about the suitability of water, particularly on remote area or where water

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water is derived from sources not normally utilized for domestic purpose water should be tested.

Curing of water

→ The use of water in curing the concrete is intended to penetrate the concrete.

→ no added water will be needed as a part of curing process except in circumstanes.

(i) when the water-cement ratio is less than 0.4.

(ii) when the concrete is produced using expansive cement even at a water ~~in the mixture~~ cement ratio of 0.48.

→ The water which is satisfactory for mixing concrete can also be used for curing.

→ It is generally recommended that the seawater should not be used as mixing water for hydraulic cement concrete works containing corrodible embedded ferrous metals, particularly in the tropics.

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→ However, under unavoidable circumstances it may be used for making a curing in plain concrete after evaluation of possible disadvantages & consideration of use of appropriate cement system.

Function of Admixture

Some of the important purposes for which the admixture should be used are the following:

→ To accelerate the initial set of concrete. i.e to speed up the rate of development of strength of early ages.
→ To enhance the workability.
→ To improve the penetration & pumpability of concrete.
→ To reduce the segregation in grout & concrete mixtures.
→ To increase the strength of concrete by reducing the water content & by densification of concrete.
→ To reduce the resistance of chemical attack.

-> To reduce the heat of hydration.
-> To increase the bond between old & new concrete surface.
-> To enhance the bond of concrete to the steel reinforcement.
-> To produce non-skid wearing surfaces.

Classification of Admixture

The admixture may be broadly classified as belonging to the general category & specialty category. According to the function or characteristic effects produced by them.

(1) General purpose admixture
The commonly used admixture of this category are,
(a) accelerating admixture.
(b) retarding admixture.
(c) air-entraining admixture.
(d) water-reducing admixture.

2) Specialty category Admixture,
The admixture of this category are.

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(a) grouting admixture.
(b) air - detraining admixture.
(c) gas - forming "
(d) corrosion inhibiting "
(e) shrinkage reducing "
(f) water or damp - proofing "
(g) bonding "
(h) concrete surface hardening "
(i) coloring admixtures.
(j) fungicidal, germicidal & insecticidal admixture.

(1) Accelerating Admixture or Accelerator
An admixture used to speed up the initial set of concrete is called an accelerator.
- These are added to concrete either
(i) to increase the rate of hydration of hydraulic cement & hence ~~the~~ to increase the rate of development of strength.
(ii) to shorten the setting time.

* An increase in the rate of early strength development may help in

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(ii) earlier removal of forms.
(iii) reduction of required period of curing.
(iv) earlier placement of structure service.

→ Accelerating Admixture are also used when the concrete is to be placed at low temperature.

→ The benefits of Reduced time of setting may include
(i) early finishing of surface.
(ii) reduction of pressure on forms or of period of time during which the form are subjected to hydraulic pressure.

(2) Retarding Admixture or Retarder
→ The set retarding admixture slow down the initial rate of hydration of cement or prolong the setting of the cement paste in concrete.
→ They are used primarily to offset the accelerating & damaging effect of high temperature & to keep concrete workable during the

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entire placing period which should be sufficiently long so that the succeeding lifts can be placed without the development of cold joint or discontinuities in a structural unit.

→ They are also used in grouting oil well.

⇒ Retarders delay setting of cement either by forming a thin coating on the cement particles & thus slowing down their dissolution in and reaction with water or by increasing the intra-molecular distance of reacting silicates & aluminates from water molecules by forming certain transient compound in the system.

3) Air entraining Admixture

→ Air-entraining Admixture help to incorporate a controlled amount of air, in the form of millions of minute non-coalescing bubbles distributed throughout the body of concrete, during mixing, without significantly altering

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the setting or the rate of hardening of ~~come~~ concrete.

→ It is generally recognized that a proper amount of entrained air results in improved properties of plastic concrete like workability, easier placing & finishing, increased durability, better resistance to frost action & reduction in bleeding & segregation.

→ The air voids present in concrete are classified as entrained air & entrapped air.

→ entrained air is intentionally incorporated in the form of minute spherical bubbles referred above

→ whereas entrapped air is in the form of voids occurring in the concrete due to sufficient or poor compaction.

→ Entrapped air voids may be any shaped & size, non-uniformaly distributed along the contours of aggregate surface.

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Their size is large & may range from 0.01 to 1.0 mm or more

→ They are a source of weakness in the concrete in terms of strength & durability.

4) Water Reducing Admixture

→ Water Reducing Admixture enable a given fresh concrete mix to have higher workability without increasing the water content which results in faster rate of concrete placement.

→ easy placement in relatively poorly accessible location without vibration, true, shutter finish for highly reinforced concrete members & reduction in cement content.

→ Benefit of water reduction in hardened state of concrete ~~reduced permeability & cracking~~ are increased strength, density, durability volume stability, abrasion resistance reduced permeability & cracking.

→ The specific effect of water-reducing & set controlling admixture vary with the type of cement

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water - cement ratio, mixing tempera-
ture, ambient temperature & other
job conditions & therefore. it is
generally recommended that the
admixture used be adjusted to meet
the job conditions.

4) Properties of fresh concrete.

When concrete is its plastic state it is known as fresh concrete. fresh concrete can be easily moulded to a durable structural member. Following are the properties of fresh concrete.

① workability ② segregation
③ Bleeding ④ plastic shrinkage
⑤ setting ⑥ Temperature.
⑦ water cement ratio.

workability :- The term workability indicates the ease or difficulty with which the concrete is handled transported & placed. The amount of water present in concrete should be in the proper ratio

-> Generally a high water - cement ratio is required for good workability.

-> The concrete which is easy for handling & placing is a workable concrete.

-> There are various test to measure the workability of concrete mixture.

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The test such as (1) Flow test
(2) Compacting test
(3) Vee-Bee Consistency test
(4) Slump test.

Slump test:-

Concrete slump test or slump cone test is to determine the workability or consistency of concrete mix prepared at the laboratory or the construction site during the progress of the work.

→ Concrete slump test is carried out from batch to batch to check the uniform quality of concrete during construction.

→ The slump test is the most simple workability test for concrete involves low cost & provides immediate results.

Procedure for Concrete slump cone test:-

→ Clean the internal surface of mould & apply oil.

→ Place the mound on a smooth horizontal non-porous base plate.

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→ Fill the mould with the prepared concrete mix in 4 approximately equal layers.
→ Tamp each layer with 25 strokes of the rounded end of the tamping rod in a uniform manner over the cross section of mould. For the subsequent layer, the tamping should penetrate into the underlying layer.
→ Remove the excess concrete & level the surface.
→ Clean away the mortar or leaked out between the mould & the base plate.
→ Raise the mould from the concrete immediately & slowly in vertical direction.
→ Measure the slump as the difference between the height of the mould & that of height point of the specimen being tested.

Test Results

- True slump – True slump is the only slump that can be measured in the test. The measurement is taken between the top of the cone & the top of the concrete after the cone has been removed.
- Zero slump :- Zero slump is the indication of very low water-cement ratio which result in dry mixes. These type of concrete is generally used for road construction.
- Collapased slump :- This is an indication that the water-cement ratio is too high that is concrete mix is too wet or it is a high workability for which a slump test is not appropriate.
- Shear slump :- The shear slump indicates that the result is incomplete & concrete to be retested.

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Flow test of concrete.

- The flow test is performed to measure workability of concrete. In this test the workability of crete is measured by examining the flowing property of concrete. The flow test is a simple laboratory test. This test works on the principle of a Jolting of the standard mass of concrete and measured by flow of concrete. The flow of the concrete indicates the workability of the fresh concrete.

- The flow test is used to measure the workability of high or very high workable concrete, which eventually would exhibit the collapse of slump. It gives an idea about the quality of the concrete with respect to the consistency and cohesiveness. This workability test is quite simple to perform and is the best for the concrete which has a nominal maximum size of aggregate less than 38 mm.

Flow Test Apparatus

- Metal cone or Mould:- Mould is in the form of a frustum of a cone with a base diameter of 250 mm, upper surface diameter of 170 mm and 120 mm hight.

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The mould comes with handles for support.

- flow table
- Trowels
- Hand scoop
- Scale
- Tamping Rod.

Flow Test Procedure

- Clean all the gritty material or dust from the flow table and from inside the mould.
- Place the crone in the marked or middle portion of the flow table.
- Now pour the freshly mixed concrete in the mould in two layers, each layer should be tempted 25 times with tamping rod. If concrete overflows after tamping then level it with the help of a trowel, and excess concrete should be removed off from the table.
- Then, lift the mould vertically upward and let the concrete stand on its own without support.
- Thereafter the table is raised and dropped from 12.5 mm hight, 15 times in about 15 ~~seel~~ seconds.

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* It measures the diameter of the spread of concrete in about 6 directions and note down the average.

Result Calculation

The flow of concrete. The percentage increase in the average diameter of the spreading concrete over the base diameter of the mould is called the flow of concrete.

$$\text{flow } \% = \frac{\text{Spread diameter in cm} - 25}{25} \times 100$$

Compacting Test

The compacting test is used to calculate the degree of workability of fresh concrete with regard to the internal energy required for compacting the concrete perfectly.

→ This test will give the reasonably reliable assessment of the workability of concrete and the test require measurement of the weight of the partially and fully compacted concrete and also the ratio the partially compacted weight to the fully compacted weight.

The compacting factor lies between 0.8 to 0.92 for the normal range of concrete.

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Apparatus for compacting test

1. Compaction factor Machine
2. Weighing Machine and compacting Rod.
3. Mechanical vibrator or steel Trowel.

The apparatus consists of trowels, hand scoop which is 15.2 cm long, balance, and a rod of steel which is 1.6 cm diameter, 61 cm long rounded at one end.

The Procedure of compacting Test

There are following steps in the procedure as:-

1) By using the hand scoop, place the concrete sample gently on the upper hopper to its brim and level it and then cover the cylinder.

2) At the bottom of the upper hopper, open the trapdoor so that concrete falls into the lower hopper and with the rod, push the concrete sticking on its sides gently.

3) To fall into the cylinder below, open the trapdoor of the lower hopper and allow the concrete to fall.

4) By using trowels, cut off the excess of concrete above the top level of the cylinder and level it, then clean the outside of the cylinder.

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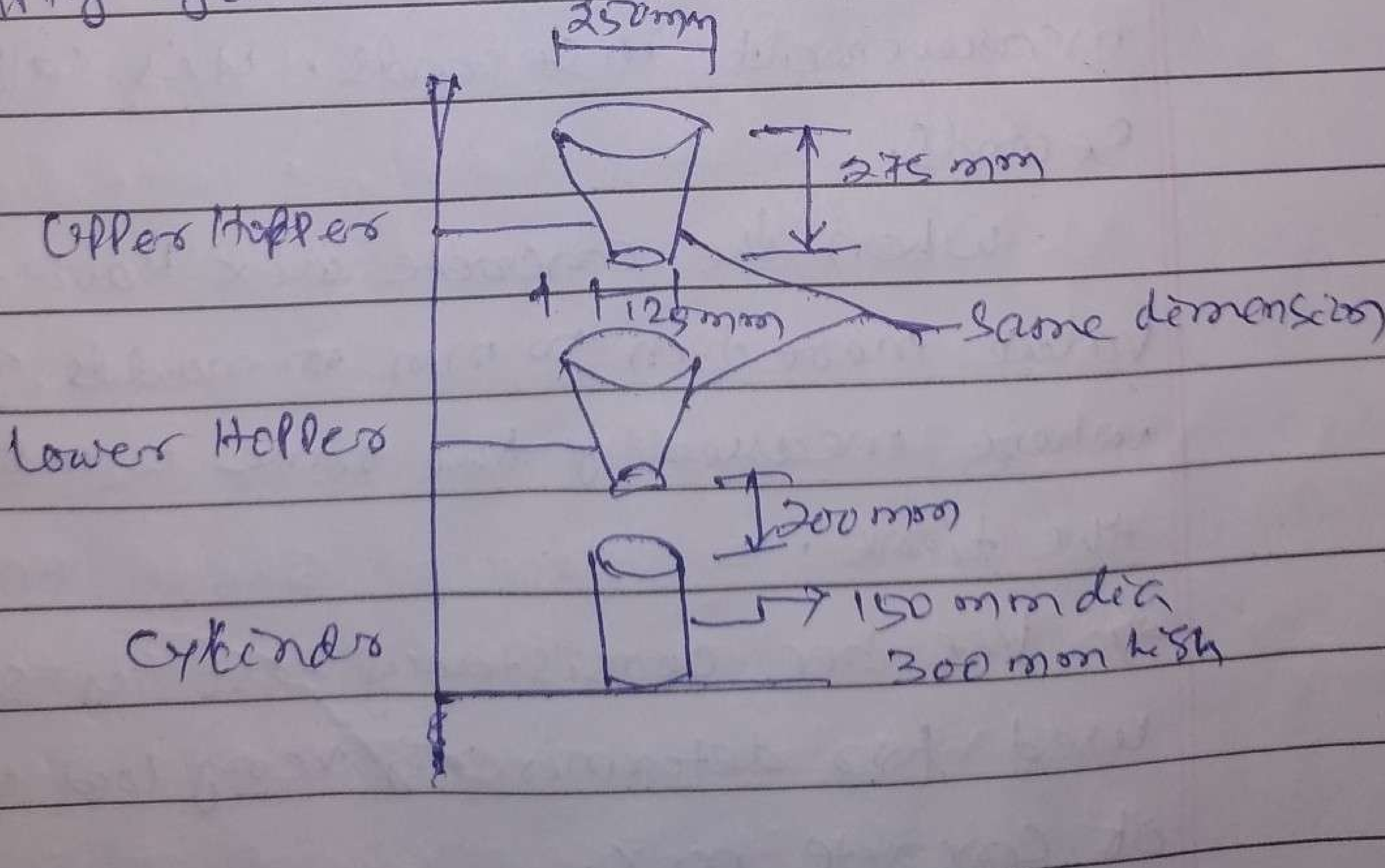
5). To the nearest 10g weight the cylinder with concrete and this weight is called the weight of partially compacted concrete as W1.

6) Empty the cylinder and then with the same concrete mix in layers approximately 5cm 5cm deep concrete mix in layers approximately 5cm deep refill it and to obtain full compaction, each layer has to be heavily rammed.

7) Level the top surface and then weigh the cylinder with fully compacted which is known as the weight of fully compacted concrete as W2.

8) Then as W, find the weight of the empty cylinder.



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Vee Bee Consistency Test

Vee bee consistency test is named after Sweden developers V Bahrmer and it is covered by IS : 1199-1959. It is used to determine workability of concrete using consistometer. It is usually performed on dry and fresh concrete and it is not suitable for very wet concrete.

Vee bee consistancy test carries out the relative effort measurement to change the mass of the concrete mix from one definite shape to another definite shape (from the slump conical shape to the cylindrical shape) by conducting vibration process. This effort is known as remoulding effort and the measurement of the effort is done by time measurement in seconds. It is called vee Bee seconds.

When the concrete mix having slump value more then 50 mm remoulds quicker where measuring the time is not possible the time.

→ Vee-bee consistency test is specially used for determining very low workability of concrete mix.

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Apparatus Required for vee bee consistency test
- Vee-Bee consistometer test apparatus.
- Sheet metal slump cone
- Stopwatch.
- Standard iron graduated rod.
- Weighing balance.
- Tamper (16 mm in diameter and 600 mm length)
- Trowels.
- Glass disc.
- cylindrical containers.

Vee Bee test machine (Apparatus)
Vee bee test machine (apparatus) consists of a vibrating table which is mounted on an elastic support. The vibrator is operated electrically. The length and width of a vibrating table are respectively 380 mm and 260 mm.

Procedure
1) The sheet metal slump cone is filled with four layers of concrete. Each layer of concrete is one fourth the height of the cone.
2) The sheet metal slump cone is placed inside the sheet metal cylindrical container that is placed in the consistometer.
3) The as described earlier is performed to find the test slump value (c.. m..

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4) The glass disc attached to the swivel arm is turned and placed on the top of the concrete in the slump cone placed inside the cylindrical container.

5) The electrical vibrator is switched on and at the same time a stop watch is started. The concrete is allowed to spread out on the sheet metal cylindrical container.

6) Until the slump ~~conic~~ conical shape of the concrete disappears and the concrete assumes a cylindrical shape, the vibration is continuedd. This can be decided by observing the glass disc from the top for disappearence of transperancy.

7) When the concrete fully changed to a cylindrical shape, immediately the stopwatch is switched off.

8) The time required for the shape of concrete to change from the slump cone shape to cylindrical shape in seconds is recorded. This time is expressed as vee bee degree or vee Bee seconds. It gives us the measure of workability of the fresh concrete.

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* This method is very suitable for very dry and harsh concrete whose slump value cannot be measured by stereo Slump Test; but the vibration is too vigorous for concrete with a slump value more than about 50mm.

Requirements of workability:-

The workability requirements for a concrete construction depends on

- → water cement ratio.
- → Type of construction work
- → method of mixing concrete.
- → Thickness of concrete section
- → Extent of reinforcement.
- → method of compaction
- → Distance of transporting
- → method of placement.

Production of concrete

Batching of materials

→ The process of measuring ingredients or materials to prepare concrete mix is known as batching of concrete.

→ Batching can be done by two methods volume batching & weight batching

→ Batching should be done properly to get quality concrete mix.

Methods of Batching concrete

1. volume Batching
2. weight Batching.

① volume Batching :- In volume batching materials are measured on the basis of volume. It is less precise methods of batching.

→ measurement boxes or gauge boxes of known volume are used to measure materials.

→ cement is taken in the form of bag where volume of one bag cement (50kg) is taken as 35 liters.

→ volume of Gauge box used is made equal to the volume of one bag of cement which is 35 literes of multiple thereof.

→ Gauge boxes are generally deeper & contains narrow top surface & they are made of [illegible]

→ volume of different sized fine aggregate & coarse aggregate are measured individually by these gauge boxes.

→ water is measured using water meter or water cans of known volume are used.

→ To make 1:1:2 ratio concrete mix according to volume batching, one should take one bag of cement (35 liters), 1 gauge box of fine aggregate (35 liters) & 2 gauge boxes of fine aggregates (70 liters). If the water cement ratio is 0.5 then half of the volume of cement which is 25 litres of water should be taken.

(2) weight Batching:-

→ In this method, materials are measured on the bases of weight. It is accurate methods of Batching.

→ weight batcher or other type of weighing equipment are used to measure weight of materials.

→ cement, fine aggregate, coarse aggregate & water are taken by weighing.

→ weigh batcheres used are available in two types namely mechanical weight batchere & electronic weigh batchares.

-> in mechanical weigh batcheres, weights are measured using spring x dial gauge arrangement x it is widely used equipment in weight batching.

-> in electronic weigh batcher, electronic scales & load cells supported by hoppers are used to measure the weight of ingredients of concrete.

-> weigh batchers available are may be manual or semi-automatic or fully automatic. manular type is used for small concrete production job while other two types are used for large concrete production.

-> In case of semi-automatic weigh batching, aggregate container gates are lifted manually & it is automatically closed after reaching required quantity in the weighing machine.

-> in fully automatic weight batcher, all the process will be done automatically. The benefit of this type equipment is, it also measures the moisture contents present in the aggregates & corrects the required quantity of water-cement with respect to moisture content of aggregate

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→ To prepare 1:1:2 concrete mix using weigh batching, measured quantity of materials are 50kg of cement, 50kg of fine aggregate & 100 kg of coarse aggregate.

~~concrete~~

mixing of concrete materials

concrete belong to a composite materials formed by cement, sand, coarse aggregate, water & chemical admixture (if necessary) to maintain the superior quality of concrete, the materials of the concrete should be be mixed properly so that the quality of concrete is not impacted.

→ A well-mixed concrete is formed on the basic of the following conditions.

* The color of the concrete should be consistent.
* Admixture of all concrete materials like cement, fine aggregate, coarse aggregate & water should be uniform.
* cement paste should wrap all the surface of the aggregate.
* segregation should not happen as soon as the mixing of concrete is completed.

mixing concrete is depended on the following 3 option.

(1) Hand mixing (mixing concrete devoid a mixer)

(2) machine mixing (mixing concrete with a mixer)

(3) Ready mix concrete.

(1) Hand mixing :— Hand mixing stands for the methods of mixing the different materials of concrete by hand. mixing concrete devoid of a mixer is suitable for small work. Mixing of materials is executed on masonry platform or flat iron sheet plates.

→ The hand mixing concrete is performed as follow:

* Expand the measured quantity of sand on the platform & then unload the cement on the sand.
* The sand & cement should be blended throughly with the help of shovels on the dry state.
* The measured amount of coarse aggregate should be extended & the mixture of sand & cement should spread on it and mixed in an exact manner.
* Depression is provided at the centre of the mixed materials.

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* Include 75% of required quantity of water on the depression & blend well by the shovels.
* Include the leftover amount of water & the mixing method should be carried on unless a uniform colour & consistency of concrete is procured. Time of mixing concrete should not be in excess of 3 minutes.
* The mixing platform should be washed at the end of the day's work.

machine mixing :- machine mixing is mostly suitable for bigger project where huge masses of concrete are necessary. The machine mixing can retain the persistent uniformity of concrete. Besides the machine mixing can significantly reduce the mixing time. ~~In recent~~ in recent time, different types of concrete mixer are available which run with petrol/ diesel or electricity.

→ The machine mixing is performed on the following ways.

* Initially, the concrete mixer should be drenched inside the drum.

* After that cement, sand & coarse aggregate should be arranged on the portable concrete mixer in desired ratio.
* The dry materials should be blended in mixing machine. After this exact quantity of water should be added slowly when the machine running.
* The concrete should be blended for minimum two minutes after placing all materials in the drum.
* If segregation occurs, the concrete should be remixed after unloading from the mixer.

Ready mix concrete: Read mix concrete (RMC) is developed in the factory or in a batching plant & supplied in a ready-to-use manner. The quality of the consequential concrete is superior as compared to the site mixed concrete.
→ less time is necessary for ready mix concrete as compared to site mixing (hand or machine mixing) & quantity of concrete is also greater then the site mixing.

Transportation of concrete:-

Transportation of concrete is an important activity in the production of concrete. The time taken in transit should be a design parameter as it depends on the initial setting time as well as the requirement of workability at the destination.

~~The~~

Methods of concrete transportation

The methods of transportation adopted at site should be decided in advance so that suitable admixture can be decided. The various prevalent methods of transportation are give below.

1. Mortar pan:- It is a labour intensive method & generally used for small work. There are no chances of segregation of concrete.

→ In hot weather, there is a substantial loss of water due to more exposure of concrete to environment.

(2) Wheel Barrow or Hand cart:— It is normally used on ground level i.e road construction & other similar structures.

→ segregation can occur if transportation is done on rough road, however this problem can be minimizes if pneumatic tyres are used.

(3) Bucket And Ropeway:— It is suitable for works in valley over high piers & long dam sites. Excessive free fall of concrete should be avoided to minimize segregation.

(4) Truck mixer and dumper:— It is an improved & better methods for long lead concreting. The concrete is covered with tarpaulin if it is transported in open trucks. If long distance is involved, agitator should be used.

(5) Belt conveyor:— It has limited application due to chances of segregation on steep slopes, roller point & changes in direction of belt. It also involves over exposure of concrete to environment.

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(6) Chute :- It is generally used for concreting on deep location. Care should be taken that slop should not be flatter than 1V : 2.5H otherwise concrete will not slide down. But workability should not be changed to suit the delivery by chute.

→ Technically it is not a very good method but it is extensively used on the field.

(7). Skip and Hoist :- It is a widely used method for high rise structure. concrete is fed onto the skip which travels vertically on rail like a lift. After discharging it is better to turn over the concrete before use to avoid segregation.

(8) pump and pipe line methods :-

It is the most ~~such~~ sophisticated methods particularly suitable for limited space or when a large quantity of concrete is ~~not~~ to be poured without cold joints. Pumping of concrete can be done @ 8 to 70 cubic meters per hour up to a horizontal distance of 300 meters

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vertical distance of 90 meter.

-> pipe dia is generally 8 to 20 cm & it is made of steel, plastic or aluminium.

-> The workability of pumped concrete should have a minimum of 40 to 100 mm of slump or 0.90 to 0.95 compacting factor.

-> At delivery point the workability may be reduced 25% due to compaction & this factor should be kept in mind while designing the mix.

(9) Transit mixer :- Transit mixer is one of the most popular equipment for transporting concrete over a long distance particularly on road mix concrete plant.

-> They are truck mounted having a capacity of 4 to 7 cubic meter.

-> There are two variation. In one mixed concrete is transported to the site by keeping it agitated all along at a speed varying between 2 to 6 revolution per minutes.

-> In other category, the concrete is batched at the central batching plant & mixing is done on the truck mixer either in transit or immediately prior to discharging concrete at site.

Placing of concrete:— concrete placement is an important process in the construction that determine the success of the structure & it's life.

→ Technical & environmental condition are taken into strict consideration while placing concrete.

→ The concrete is allowed to pass through different phase from the point it come out of the mixer till it complete as a finished concrete.

→ The concrete is transported, poured, vibrated, manufed, form removed & cured. Each of these phases must follow techniques that will come under good construction practice.

Procedure for placing concrete:—

(1) Planning for concrete placement.
(2) Formwork Requirements for concrete placement.
(3) Concrete placement in special conditions.
(4) Consideration in concrete placement layers.
(5) Consideration for segregation during concrete placement.

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(1) Planning for concrete placement :-

-> Before any concrete is placed the entire placing programme consisting of equipment, layout, proposed procedures & methods is planned & no concrete is placed until formwork is inspected & found suitable for placement.

-> Equipment for conveying concrete should be of such size & design as to ensure a practically continuous flow of concrete during depositing without segregation of materials considering the size of the job & placement location.

-> concrete is placed in it's final position before the cement reaches it's initial set & concrete is compacted in it's final position within 30 minutes of leaving the mixer & once compacting it should not be disturbed.

-> In all cases the concrete is deposited as nearly as practicable directly in it's final position & should not be re-handeld or caused to flow in a manner which may cause segregation, loss of materials, displacement of Reinforcement, shuttering or embedded inserts or impair it's strength,

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(2) Formwork Requirements for concrete placing :- The formwork must be rigid so that it does not get deformed under the pressure of placement of fresh concrete & water tight so the concrete does not leak out. For every new use of formwork, the surface have to cleaned & brushed.

→ The concrete reinforcement must be held properly in the formwork. Special care is taken where concrete is dropped from a height especially if reinforcement is in the way particularly in columns & thin wall.

→ concrete should be placed in the shuttering by shovels or other method & should not be dropped from a height more than one metre or handled in a manner which will cause segregation.

→ It is recommended to maintain the rate of concrete as constant as possible.

(3)

(3) concrete placement in special condition

→ concrete placed in restricted forms by barrows, buggies, cars, sort chutes or hand shoveling should be subjected to the requirement for vertical delivery of limited height to avoid segregation & should be deposited as nearly as ~~Beat~~ practicable in it's final position

→ for location where direct placement is not possible & in narrow forms suitable drop & elephant trunks to confine the movement of concrete is provided.

→ for hot or cold weather concreting the temperature of the concrete must be kept according to undergo effective placement so that the concrete does not dry out of freeze out before completing the placement & related procedures.

(4) consideration in concrete placement layers

→ concreting once started should be continuous until the pour is completed. concrete should be placed in successive horizontal layers of uniform thickness ranging from 150mm to 900mm.

→ The thickness of each layer should be such that it can be deposited before the previous ~~lay~~ layer has stiffened.

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→ Before pouring the next concrete layer, it is necessary to properly compact the below layer. every under lying layer will be responsive to the vibration above. These layer hence will knits together.

→ concrete placement has to be done rapidly as particable to prevent the formation of cold joints or planes of weakness between each succeeding layer within the pour. Cold joints are prominent in large pouring session. These type of pouring will require proper planning.

→ The bucket load or other unit of deposit should be spotted progressively along the face of the layer with such overlap as will facilitate spreading the layer to uniform depth & texture with a minimum of shovelling.

⑤ consideration for segregation during concrete placement:—

→ Any tendency to segregation should be corrected by shovelling stones into mortar rather than mortar onto stones. such a condition should be corrected by redesign of mix or other suitable means.

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→ The top surface of each pour & bedding planes should be approximately horizontal unless otherwise specified on drawings.

Compaction of concrete :- Compaction of concrete is an operation which fresh concrete is compacted on forms & make it encircle reinforcement & other embedded objects such as tubes on the mold.

→ There are various problems that might arise if compaction of concrete is not carried out properly such as honeycomb & trapped inside concrete paste.

→ moreover, poor compaction of concrete could to permeability problems & therefore steel corrosion & decreasing ultimate capacity of hardened concrete.

methods of compaction of concrete :-

→ concrete consolidation can be carried out either by hand or machines.

→ There are many factors that should be considered to choose compaction methods such as reinforcement quantities & spacing concrete paste consistency & formwork complexity.

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Hand compaction method :-

→ Reasonable workable & flowable concrete mixture are consolidated by hand employing a rod,

→ The bar should adequately reach the bottom of the form work & rode diameter need to compact concrete between reinforcement spacing & form works.

→ The concrete is tamped by the rod tool repeatedly to consolidated it. mixtures with low slump value could be consolidated by hand if superplasticizers are added to decrese slump and make the concrete workable.

→ Tools such as spade is used to provide good surface appearance and hitting form work ~~sides~~ sides make way to repel entrapped air out of the concrete.

→ Mechanical consolidation is not recommended to use if the mixture is designed to compact by hand to avoid segregation.

Mechanical compaction method :-

The mechanical consolidated method is capable and suitable for concrete mixtures wi... great amount of coarse aggregate content

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and low water to cement ratio in heavily reinforced structural elements. Different types of mechanical compaction methods are explained

① **shock or drop table** :- shock or drop table is used to consolidate extremely stiff low slump concrete in making precast units.

② **centrifugation** :- It is employed for compacting moderate to high slump mixtures in constructing poles, pipes & piles.

③ **vibration method of concrete compaction**

→ vibration method is probably the most extensively used technique for compacting concrete.

→ In this method internal friction between aggregate particles is eliminated for a short time & concrete mixtures behave like liquid & gravitational force will come into effect.

→ This lead to move entrapped air to move upward & the mixture will settle in the formworks.

→ when the vibration is stopped the internal friction is immediately developed again

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→ Either number of vibration per minute (vpm) or vibrations per second (Hertz) are used to express vibration.

* Compaction of concrete with vibrators is divided into the following types:

(a) Internal vibrator: — Internal vibrators which sometimes called spude or poker vibrators are usually applied to compact concrete in beams, wall, column & slab. Not only does vibrators performance is influenced by concrete workability but also by frequency, amplitude & head dimension of vibrators.

→ Generally vibrator head diameter is between 2-18 cm & the shape of head is cylindrical. As the head diameter of vibrators is increased the effective action area is rose, for instance radius action of vibrators with 4 cm head diameters is 15 cm while 45 cm is the radius action of vibrators with 8 cm head diameter.

→ Moreover, it is considerably significant to utilize internal vibrators correctly to achieve the best compaction.

→ Horizontal movement of vibrators should be avoided to prevent concrete segregation & lowering head of vibrators to the bottom of considered concrete layer & it should overlab previous layer by about 15 cm.

· Compacted concrete layer thickness is about the head length or 50cm.

→ Regarding using vibrators for compacting slab, the vibrator must be kept submerged in concrete & this can be done using it horizontally or at specific angle in addition to use 1.5 times the radius action as the distance to guarantee overlap previously adjacent vibrated layer.

→ Not only does the vibrator should be held steady but also keep in specific station for 5-15 second to obtain desirable consolidation.

(b) External vibrator :- There are two major types of external vibrator which are.

(1) Table or surface vibrator.
(2) form vibrator.

(1) Table or surface vibrator :- The table vibrator is widely suitable for compacting concrete surface such as floors & slab. It adequately consolidates slabs up to 20 cm thickness ~~[illegible]~~

(2) Form vibrator
→ The form vibrator is attached to the exterior face of mold or forms properly otherwise energy will be lost because of improper attachments.
→ moreover, form vibrator is the proper choice for compacting concrete in thin & heavily congested form consolidating stiff mixture & supplementary external vibrator.
→ form vibrator can be advantageous for constructing pipes, masonry units & other types of precast concrete.
→ However it is not recommended to employ form vibrator at the top of vertical forms such as a consequent of in & out

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movements so internal vibration is better to use in this case.

-> Form vibrator should be spaced properly to make uniform distribution of intensity above the form.

Results of improper vibrations of concrete :- There are various problems & defects that could arise when concrete is not vibrated adequately.

- Honeycomb
- Sand streaks
- Cold joints.
- Excessive amount of entrapped air voids that most of the times called bug holes.
- Subsidence cracking.
- Placement lines.

Curing of concrete :- curing of concrete is a method by which the concrete is protected against loss of moisture required for hydration & kept within the recommended temperature range.

-> Curing will increase the strength & decrease the permeability of hardened concrete.

-> Curing is also helps in mitigating thermal & plastic cracks, which can severely impact durability of structure.

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→ A curing practice involves keeping the concrete damp or moist until the hydration of concrete is complete & strength is attained.

→ curing of concrete should begin soon after initial setting time of concrete or formwork / shuttering is removed & must continue for a reasonable period of time as per the specified standards for the concrete to achieve its desired strength & durability.

→ It is important to make sure an uninterrupted hydration of PCC & RCC after concrete is placed & finished in it's position.

→ protecting measures are also required to control water loss from the concrete surface to prevent plastic shrinkage cracks.

~~methods of curing to~~

methods to cure concrete :-

Depending upon the site constraints, type of structure & other material parameters, different methods of curing are adopted at site.

→ methods of curing concrete fall into following categories.
(1) water curing
(2) membrane curing
(3) stream curing.

(1) water curing :- water curing prevents the water loss from the concrete surface by uninterrupted wetting of the exposed surface of concrete.
→ It's done by spraying or sprinking water or curing agents over the concrete surface to ensure that the concrete surface is continuously moist.

→ Moisture from the body of concrete is retained from evaporating and contribute to the strength-gain of concrete.
water curing methods are :-
* ponding
* sprinkling, fogging & mist curing.
* wet coverings.

(2) membrane curing :→ Membrane curing lessens moisture loss from the concrete surface by wrapping it with an impermeable membrane. curing compounds are wax, acrylic and water based liquids. These are sprayed over fresh concreting to create an impermeable membrane this will reduces the loss of wetness from the

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Membrane curing methods are :-

* Plastic sheeting
* Form work.

~~Steam~~ ~~curi~~

③ Steam curing :- ~~Steam~~ Steam curing keeps the surface moist and raises the temperature of concrete to quicken the rate of strength achievement. It is a process done to speed up the early hardening of concrete and mortars by subjecting it to steam and humidity.

→ This method is most commonly used for precast concrete plants where products are mass produced and the turnaround or striking time of the framework is very quick.

→ It is witnessed that at construction sites, curing of concrete is left to the decision and comfort of the unskilled manual worker. Site engineers and supervisors should put additional effort to guarantee that curing is not overlooked at site.

→ They should arrange for the essential resources to retain satisfactory levels of curing, by using best techniques available

Formwork :— A formwork is a temporary structure used as mold for the original structure.

→ There are different material available to construct the formwork.

→ Formwork material is selected depending upon many factor like cost, requirement, types of structure.

Different type formwork material :—

→ Different type form work materials are -

1. Timber 2. Plywood 3. Steel
4. Aluminium 5. Plastics
6. magnesium 7. fabric.

1. Timber as formwork material

→ Timber is the most commonly used material for formwork. Timber logs lumber etc. are used as bracing members from ancient times so the timber formwork is also called as traditional formwork.

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→ It is most economical material used formwork. ~~material~~ to

→ This is used in sites as formwork material for number of years so the method of constructing timber framework is well known to the worker.

2) ~~plywood~~ plywood as formwork material

→ plywood which is a manufactured product of timber is also used for formwork.

→ It consists number of veneer sheets or plies in layers.

→ Now a days, the used of plywood formwork increase especially for facing panels.

→ The reason behind it is that the plywood formwork provides smooth finish when compared to normal timber formwork.

→ Hence finishing cost may reduce by the use of plywood.

→ For formwork, special type of plywood called exterior plywood is used. The veneer sheets of exterior plywood are bonded with strong adhesive to make it watertight.

→ The plywood boards are available in thickness from 7 mm to 30

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→ In general plywood of size 1220×2440, A 18mm thick board are sufficient for most of the work.

→ For curved structures special types of plywood with sufficient thickness are available.

(3) Steel as formwork material :-

Steel can also be used as formwork material. It is very costly but it can be used for more number of times than other.

→ They provides excellent finish to the concrete surface.

→ For mass structure like dams, bridges, etc steel formwork is so strong & safe.

(4) Aluminium as formwork material:-

Aluminium formwork is used often for prefabricated formworks.

→ It is getting more popular because of it's light weight & good strength.

→ It requires fewer supports & ties.

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5) Plastics as formwork materials:-

→ plastic is another type of formwork material which is used for small concrete structure or for complex portions of the structure.

→ It is light in weight & durable for long periods.

→ For complicated concrete structure Glass Reinforced Plastics (GRP) & vacuum formed plastic are used.

6) magnesium as formwork material

→ magnesium is another metal element which is used for formwork.

→ magnesium is not directly used for formwork & is used with the combination of oxygen atoms which forms magnesium oxide, usually called magnesia or mgO

→ magnesium oxide boards or mgO ~~board~~ boards are famous in some countries because of their multiple applications.

→ mgO boards are available in required size & grades.

7) Fabric as formwork materials :-

-> Fabric formwork is the modern technology in construction sector.

-> Fabric can be mold into any required shapes which makes it more famous formwork for architectural purposes.

(6) Concrete mix design

⇒ Concrete mix design means determination of proportion of the concrete ingredient i.e. cement, water fine aggregate, coarse aggregate which would produce concrete possessing specified properties such as workability, strength & durability with maximum overall economy.

→ Standard mix for concrete in terms of ratio for concrete it depend on what strength you are trying to achive, but as a general guide a standard concrete mix would be 1 part cement to 2 parts sand & 4 parts aggregate.

→ For foundation a mix of 1 part cement to 3 parts sand to 6 parts aggregates can be used.

→ The main aim of the concrete mix design is to find out the desired proportion of each ingredients which are cement, coarse aggregate, fine aggregates, water etc. to obtain the required properties of resulting mix.

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Requirements of concrete mix design

The requirements which form the basis selection & proportioning of mix ingredients are.

(a) The minimum compressive strength required from structural consideration.

(b) The adequate workability necessary for full compaction with the compacting equipment available.

(c) maximum water-cement ratio & or maximum cement content to give adequate durability for the particular site conditions.

(d) maximum cement content to avoid shrinkage cracking due to temperature cycle in mass concrete.

Types of mixes

Standard mixes: — The nominal mixes of fixed cement - aggregate ratio vary widely in strength & may result in under or over rich mixes. for this reason, the minimum compressive strength has been included in many specification, These mixes are termed standard mixes.

IS 456-2000 has designated the concrete mixes into a number of grades as m10, m15, m20, m25, m30, m35 & m40.

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→ in this designation the letter M refers to the mix & the number to the specified 28 day cube strength of mix in N/mm^2.

Nominal mixes

⇒ These mixes to fixed cement aggregate ratio which ensures adequate strength are termed nominal mixes. These offer simplicity & under nominal circumstances have a margin of strength above that specified. However due to the variability of mix ingredients the nominal concrete for a given workability varies widely in strength.

Designed mixes:— In these mixes the performance of the concrete is specified by the designer but the mix proportions are determined by the producer of concrete, except that the minimum cement content can be laid down. This is most rational approach to the selection of mix proportion with specific materials in mind possessing more or less unique characteristics. The approach results in the production of concrete with the appropriate properties most economically. However, the designed mixed does not serve as a guide since this does not guarantee the correct mix proportions for the specified performance.

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Basic considerations for concrete mix design :-

→ The concrete mix design is a process of selecting suitable ingredients for concrete & determining their proportion which would produce, as economically as possible.

→ a concrete that satisfies the job requirements i.e. concrete having a certain minimum compressive strength, workability & durability.

→ The proportioning of the ingredients of the concrete is an important phase of concrete techonology as it ensures quality & economy.

→ The proportioning of concrete mixes is accomplished by the use of certain empirical relations which afford a reasonable accurate guide to select the best combination of the ingredients so as to achive the desired properties. The design of plastic concrete of medium strengths can be based on the following assumptions.

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(7) The compressive strength of concrete is governed by it's water-cement ratio

(8) For the given aggregate characteristics, the workability of concrete is governed by it's water content.

Factors influencing the choice of mix proportions:

According to IS:- 456- 2000 & IS: 1343-1980, the design of concrete mix should be based on the following factors.

1. Grade designation.
2. Type & grade of cement.
3. maximum nominal size of aggregate
4. Grading of combined aggregate.
5. water - cement ratio.
6. workability.
7. Durability.
8. Quality control.

Inspection & Quality control of concrete

Quality control of concrete :- Quality of concrete construction on site can be accomplished in three distinct stages as follow.

1) Quality control before concreting
2) Quality control during concreting
3) Quality control after construction.

Stage-1 (Quality control Before concreting)

This stage of quality control consists of two steps.

1- Checking of specification requirements regarding excavation, forms, reinforcement & embedded fixtures etc.
2- Control test on concrete ingredient (i.e. on cement, aggregate & water)

Cement :- Quality of cement is ascertained by making compressive strength test on cement cubes.

However for effective control cement :-

-> should be tested initially once for each source & subsequently once for every two months.

-> Should be protected from moisture

-> Should be retested after 3 months of storage, if long storage in unavoidable.

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→ should be rejected if large lump are found in cement bags.

Aggregate :- concrete aggregates should conform to specified value as per standard specification.

⇒ The quality of concrete is affected by different physical & mechanical properties of aggregage i.e. shape, grading, durability, specific gravity & water absorption etc.

-> these properties of aggregate should be tested before using it for concrete production.

-> The quantity of deleterious materials & organic impurities should also be tested.

-> Bulking of sand is also important property in several ways. It gives wrong results when volume batching is done. It increase water cement ratio which in turn redues strength.

For effective control aggregate.

-> Are required to be tested once initially for approval of source.

-> should subsequently be tested once or twice daily for moisture content & allowance should be made for moisture content of aggregate.

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Water:— The quality of water should be checked for requirement as specified in respective standard.

-> chemical analysis shall be conducted for approval of source.

-> In case of suspended impurities, it is necessary to store water for some time to allow them to settle down.

-> In case of doubt concrete cubes made with this water are tested.

-> Average 28 days compressive strength of at least three cubes or cylinder of specified size, prepared with water proposed to be used shall not be less than 90% of the average strength of three similar concrete cubes prepared with distilled water.

Stage-2 Quality control During concreting

Careful supervision during concrete manufacture is necessary for all concreting operation such as batching mixing, transporting, laying, compacting & curing.

Following precaution should be taken during concreting operation

-> The concrete mix should be designed in the laboratory with the materials to be used on site

→ As far as possible concrete should be batched by weight. If weight batching is not possible, then volume batching may be permitted through proper supervision in the presence of engineer in charge.

→ During mixing the, mixer should be charged to its full capacity; The materials should be fed in proper sequence.

→ The speed of the mixer should be range from 15 to 20 revolution per minute. The mixing time should not be less than 2 minutes in any case. Segregation should be avoided while unloading the concrete from the mixer.

→ Workability of concrete is an important property of concrete while concrete is in its fresh state. Therefore slump test or compaction factor test should be performed to check workability of concrete. About three tests should be carried out for every 25 m^3 of concrete.

→ Care should be taken so that no segregation takes place during transportation of concrete.

→ Concrete should not be dropped from a height of more then 1m. If the drop height exceeds 1m chutes should be used

→ To avoid rehandling of concrete it should be placed at its final position as far as possible.

→ Vibrators should be used for compacting concrete. The insertion spacing of internal vibrators should not be more than 0.6m. It should be drawn out slowly so that no holes remain in the concrete. The frequency of vibrator should not be less than 7000 cycles/minutes.

→ Curing should be done for a specified period so that concrete develops requisite strength. Concrete should be covered with hessian as soon as it becomes hard.

→ The formwork should correspond to final form of the structure. It should be checked before concreting is started. The inside of the forms should be cleaned & oiled. The forms should be removed after the specified period.

→ Concrete should be protected from hot & cold wheather at early ages. Concreting should not be done at temperature 4.5°C & above 40° in very hot wheather water & aggregate should be cooled. Retarders of approved quality can be used.

→ In very cold weather water & aggregates should be heated. Accelerators of approved quality can also be used.

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Stage-3 Quality control After construction :- once the concrete is laid & compacted, compression tests are made on the cubes made out of this concrete. For ordinary concrete, cubes are made out of the concrete made at work site.

-> The hardened concrete has to be checked for trueness in dimension, shape & size as per design specification. General surface appearance of concrete should also be checked. Dimensions are ascertained by different measurements.

-> Reinforcement should have adequate concrete cover & if the reinforcement is visible on part of a structure, the part should be rejected or necessary actions should be taken accordingly.

-> Concrete strength is normally to be ascertained from cube or cylinder samples tested at 28 days. In case the strength obtained is less than the specific minimum, one or more of following steps may be taken.

* Load test & measurement of deflection & or strain (the quality of the structure can then be ascertained by calculating back the concrete strength)

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* cutting cores from the structure & testing them for strength.
* Non destructive test like schmidt rebound hammer or ultrasonic pulse velocity test. These test give only a very rough idea & are primarily used to ascertain the uniformity of construction.
* chemical analysis of hardened concrete.

quality control:-

The quality control is a corporate dynamic program to assure that all the aspects of material, equipment & workmanship are well looked after.

→ the quality control should have conformity to the specification. no more, no less. for the manufacturer of the concrete, the quality control process will involve material personnel equipment & workmanship in all stage of concreting

→ The concrete is generally produced in batches at the site with the locally available materials of variable characteristics. It is therefore likely to vary from one batch to the other. The magnitude of this variation is depending upon several factor like

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① The variation of quality of constituent materials.
② variation in the mix proportion
③ variation in the quality of batching & mixing.
④ The quality of overall workmanship & supervision at the site.

moreover concrete undergoes a number of operation like transportation, placing compacting & curing. During these operation, considerable variation occur partly due to the quality of the plant available & partly due to the difference in the efficiency of the techniques used.

→ Hence, there is no attributes to define, the quality of concrete under such situation, the concrete is treated as good, poor or fair, Hence it is necessary to judge the concrete based on the performance characteristic i.e. economic, safety, aesthetics, durability & other factors.

The main aim of quality control of concrete is to reduce the above variation & produce uniform material providing the characteristics

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desirable for the goals.

Factors causing variation on the quality of concrete:– The following are the three main factor that affect the quality of concrete.

① personal factors.

② materials, Equipment & workmanship

③ field control factor.

personal factors:– The success of the quality control plan is the availability of experienced. knowledgeable & trained workers at all the levels. The designer & specification writer should have the knowledge of the construction operation as well.

③ materials, Equipment & workmanship:–

→ For the uniform quality of concrete, the ingredient (particularly the cement) should preferably be used from a single source.

→ when ingredients from different sources are used the strength & other characteristics of the material are likely to change & therefore these materials should be used only after the proper evaluation & testing.

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→ Aggregates should be well graded, free from deleterious substance. Grading, maximum size, shape & moisture content of aggregate are the major sources of variability.

→ Equipment used for batching, mixing & vibration should be the right capacity, weight batcher should be frequently checked for their accuracy. weigh-batching of materials is always preferred to volume batching.

→ The vibrators should have the required frequency & amplitude of the vibration.

→ The fresh concrete should be handled, transported & placed in such a manner that it does not get segregated. The time interval between the mixing & placing the concrete should be reduced to the minimum as possible.

→ The expected targets of strength, impermeability & durability of concrete can be achieved only by thorough & adequate compaction.

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→ 1% of air content left in concrete due to incomplete compaction can lower the compressive strength by nearly 5%. adequate curing is essential for handling & development of strength of the concrete.

→ Long-term compressive strength of concrete moist cured for 3 days or 7 days will be about 60% or 80% respectively. given the concrete is cured for 28 days or more.

Field control:— The field control i.e inspection & testing, is an important factor to be considered for quality control. concrete should be tested at it's fresh & hardened stage to assess their strength.

→ Accelerated strength tests by which a reliable idea about the potential 28 day strength can be obtained within few hours are effective control tools.

Mixing of concrete as per IS 456

IS 456-2000 recommends that mixing should be done in a mechanical mixer.

→ The mixing should be continued till all the materials are uniformly distributed on the mixer & the end product is of consistent colour.

→ mixing time should be atleast 2 min.

→ concrete should never be mixed just on the ground. otherwise dirt will also get mixed in.

→ while mixing the raw material cement, & sand should be intimately mixed first, then coarse aggregate

→ water is added last & the mixture should be turned over until a uniform colour is obtained all around.

Transporting of concrete as per IS 456-2000

→ Transporting the concrete mix defined as the transferring of concrete from the mixing plant to the construction site.

→ As a general rule of thumb 30 To 60 minutes of transportation are acceptable on small jobs. (PCC work)

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→ At a central or portable Ready-mix plant, concrete should be discharge from Truck mixer within 2 hours.
→ If non agitating transporting equipment is used this time is reduce to 1 hours.

After mixing:- concrete shall be transporting to the formwork as rapidly as possible by methods which will prevent the segregation or loss of any of the ingredients.

Care → main objective is transporting concrete is ensure that the water-cement ratio, slump or consistency, Air content & Homogeneity are not modified from their intended stages.
→ During Hot & cold wather, concrete shall be transported in deep containers other suitable method to reduce the loss of water by evaporation in hot weather & heat loss in cold weather may also be adopted.

Placing of concrete as per IS 456-2000
→ The concrete shall be deposited as nearly as practicable in it's final position to avoid Rehandling.
→ The concrete shall be placed & compacted before initial setting of concrete is started & should not be subsequently distrubed.

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→ methods of placing should be such as to preclude segregation.

Care → placing should be taken to avoid displacement of reinforcement or movement of formwork.

Free fall of concrete → As a general guidance the permissible free fall of concrete may be taken as 1.5 m

curing of concrete as per IS 456-2000

→ curing concrete is defined as the process of ~~maintaing~~ maintaing the moisture & temperature condition of concrete for hydration reaction to normally, so that concrete develop hardened properties over time.

→ The main components which needs to be taken care are moisture heat & time during curing process.

→ curing is the process of preventing the loss of moisture from the concrete which maintaing a satisfactory temperature effect.

~~P~~Preventions → The prevention of moisture loss from the concrete is particularly important if the water cement ration is low.

(a) If the cement has high rate of strength Development.

(b) If the concrete containg granulated blast furnance & fule Ash.

Then, the curing should also prevent the development of high temperature gradients within the concrete.

Different concepts of curing

(a) moist curing → surface of concrete shall be kept continously in damp or wet contion by covering with layers of materials like sacking a canvas etc

→ It shoud be kept contantly wet for at least 7 days from the date of placing concrete.

→ For ordinary portland cement: → In case ~~for~~ of ordinary portland cement at least 10 days where mineral admixture or blended cement are used

→ The period of curing shall not be less than 10 days for concrete exposed to dry & hot weather conditions.

→ In case of concrete where mineral admixtures of Blended cement are used. It is Recommended that above minimum period may be extended to 14 days.

(b) Membrane curing: — Approved curing compounds may be used in place of moist curing with the permission of the Engineer-Incharge.

→ Such compounds shall be applied to all exposed surface of the concrete as soon as possible after the concrete has set.

→ Impermeable membrane such as polythylene sheeting covering closely the concrete surface may also be used to provide effective against evaporation.

→ For the concrete containing portland and pozzolana cement, portland slag cement or mineral admixture period of curing may be increased.

Durability of concrete as per IS 456-2000

→ For a long time concrete was considered to be very durable material requiring little or no maintenance.

→ Emphasis was mostly on compressive strength of concrete. However ~~deterioration during th~~ many structures world over have shown deterioration during the last 60-70 years.

→ lot of studies has been carried out. Exposure conditions also have been found to play a vital role on the durability of concrete.

→ According to IS 456-2000 has been amended. It has been amended further based on experience on other countries.

→ One of the main reasons for deterioration of concrete, is the component materials used in the manufacture of concrete, method of manufacture, placing, compacting & curing, environmental condition, loading pattens, various pollutants like carbon dioxide, chemical that have pervaded the environment.

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→ soils & subsoil water in certain location in India have deleterious chemical & salts which will affect the durability of concrete.

Factors affecting durability:-

→ Durability as per IS 456-2000 durable concrete is one that performs satisfactorily in the working environment during the anticipated exposure condition during it's service life

→ It is the ability to resist weathering action, chemical attack, abrasion or any other process of deterioration which will alter the original form & quality.

→ The materials & mix proportion specified & used should be such as maintain it's integrity & if applicable, to protect embedded metal from corrosion.

→ Durability to a great extent is influenced by it's permeability to ingress of water, oxygen, carbon dioxide, chloride, sulphate, & other potentially deleterious substance,

→ impermeability is greatly governed by the constituents, [illegible] in making concrete.

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Factors influencing durability :-

- → The environment (rain, heat, cold, frozen snow)
- → The cover to the embedded steel.
- → The type & quality of constituent materials.
- → The cement content & water/cement ratio of the concrete.
- → Workmanship, to obtain full compaction & efficient curing.
- → The shape & size of the members.
- → Permeability & abrasion.

Types of durability condition

External

Physical	Chemical
• Freezing & Thawing	• Alkali aggregate reaction
• Percolation & permeability	• Sulphate attack.
• Temperature stress (High heat of hydration)	• Chloride ingress
	• Delayed ettringite formation (DEF) (DCF)
	• Corrosion of reinforcement.

Cause :- Extreme weather conditions, extreme temperature, extreme humidity, Abrasion, Electrolytic action. Attack by natural or industrial liquid/gass

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internal

physical

Volume changes due to different thermal properties of aggregates & cement paste

- Frost action

chemical

- Alkali silica reaction
- Alkali silicate reaction
- Alkali carbonate reaction.

5) properties of hardened concrete:-

Flexural strength of concrete:-

Flexural strength is one measure of the tensile strength of concrete. It is a measure of an unreinforced concrete beam or slab to resist failure in bending.

-> It is measured by loading 6x6 inch (150mmx150mm) concrete beam with a span length of at least 3 times the depth.

-> The flexural strength is expressed as modulus of Rupture (MR) in psi (mpa) & is determined by standard test methods ASTM C 78 (third-point loading) or ASTM C 293 (center-point loading).

-> flexural MR is about 10 to 20 % of compressive strength depending on the type, size & volume of coarse aggregates used. However, the best correlation for specific materials is obtained by laboratory tests for given materials & mix design. The MR determined by third-point loading is lower than the MR determined by center-point loading sometimes by as much as 15%.

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stress-strain & elasticity:-

Fig-1

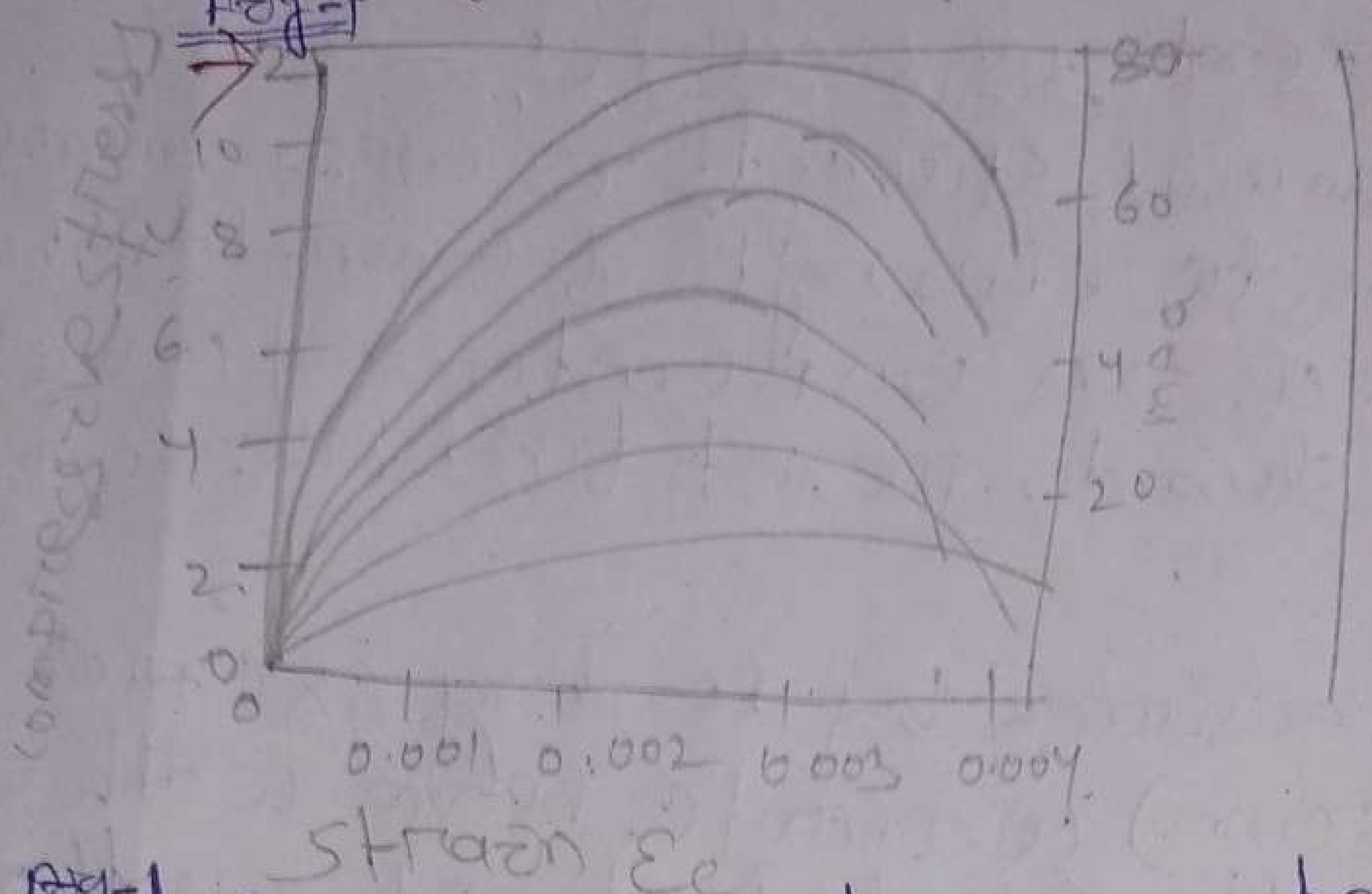
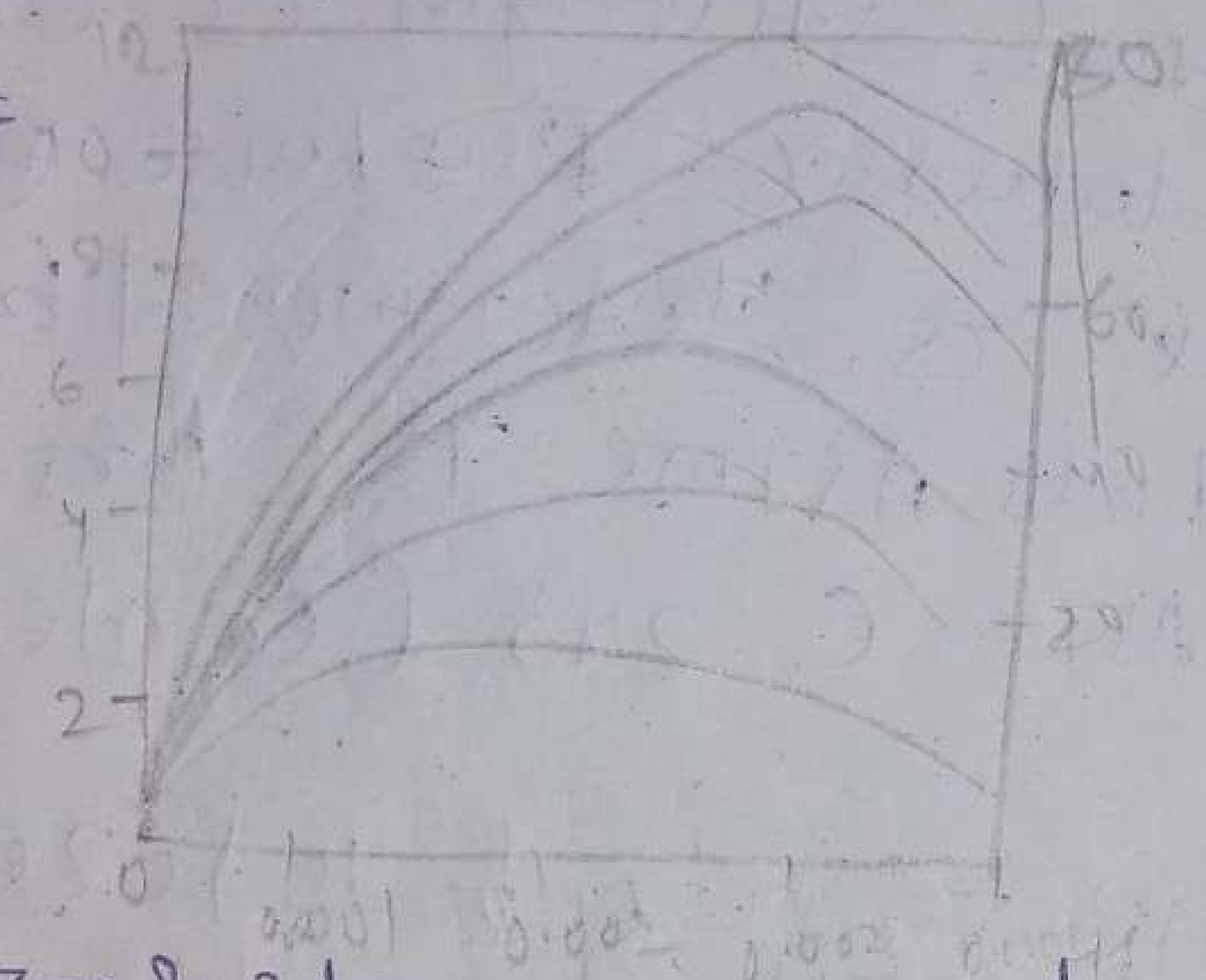


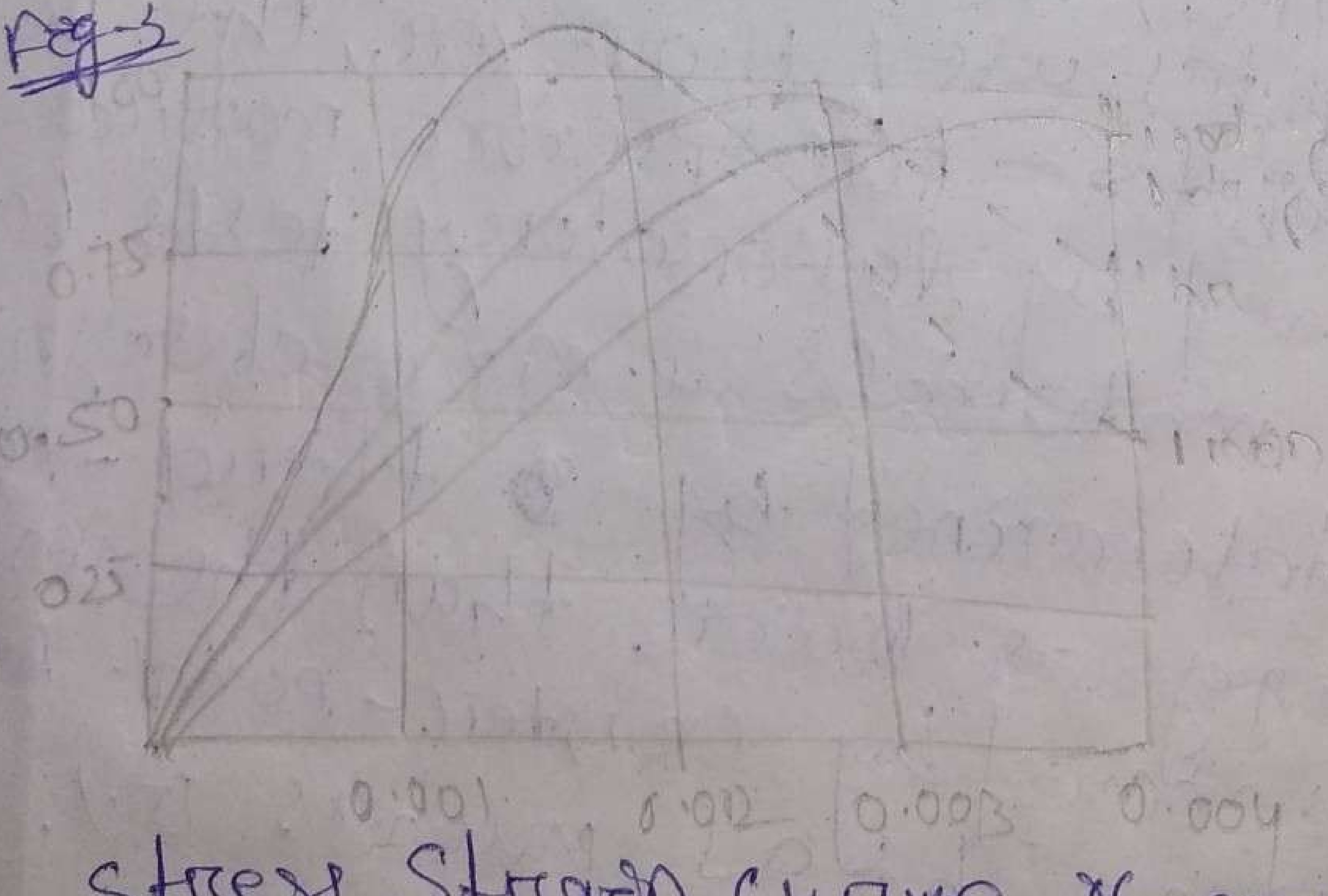
Fig-1 set of stress stain curve for normal density concrete.

Fig-2



stress strain curve for lightweight concrete

Fig-3



stress strain curve of concrete varied Based on speed of testing.

→ Stress strain curve of concrete 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 - strain curve for concrete

Fig-1 and fig. 2 shows strain stress curve for normal weight and light weight concrete, respectively. There is a set of curves on each figure which represents the strength of the concrete. So, higher curves show highers concrete strength. fig. 3 shows how the shape of concrete stress strain curve changes based on the speed loading. Despite the fact that, speed of testing and concrete density influences the ~~loading~~ shape of the stress - strain curve, but it can be noticed that, all curves show nearly the same character. i.e. they undergo the same stages under loading. various portions of concrete stress stain curve are discussed.

1. Straight or Elastic portion.

Initially, all stress strain curves (fig. 1 and fig. 2) are fairly straight; stress and strain are proportional. with the stage, the material should be able to retain its original shape if the load is removed.

The elastic range of concrete stress stain curve continues up to 0.45 fc (maximum concrete compressive strength). The slope of elastic part of stress stain curve is

modulus of elasticity.

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The modulus of elasticity of concrete increases as its strength is increased. ACI code provides equations for computing concrete modulus of elasticity.

2. Peak point or maximum compress stress point.

The elastic range is exceeded and concrete begin to show plastic behavior (Nonlinear), when a load is further increased. After elastic range, the curve starts to horizontal; and reaching maximum compress stress (maximum compressive strength). For normal weight concrete, the maximum stress is realised at compressive strain ranges from 0.002 to 0.003. However, its light weight concrete, the maximum stress reached at strain range from 0.003 to 0.035. The higher results of strain in both curves represent larger strength.

For normal weight concrete, the ACI code specified that, a strain of 0.003 is maximum strain that concrete can reach and this value used for design of concrete structural element. However, the European code assumes concrete can reach a strain of 0.035, and hence this value is used for the design of concrete structural element.

3. Descending portion.

After reaching maximum stress, all the curves show descending trend. The characteristics of the stress strain curve in descending part is based on the method of testing. Long stable descending part is achieved if special testing

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procedure is employed to guarantee a constant strain rate while cylinder resistence is decreasing
However if special testing procedure part is achieved ~~to~~ if special testing procedure is employed to guarantee a constant strain rate while cylinder resistence is decreasing. ~~Howev~~

If special testing procedure is not followed, then unloading after peak point would be ~~...~~ and the descending portion of the curve would not be the same.

Permeability of concrete.

def^n :→ The ability of a given concrete to permit liquids ~~to~~ or gases to pass through.

→ Permeability is a measure of the amount of water, air and others ~~..~~ substances that can enter the concrete matrix. concrete ~~...~~ contains pores that can allow these substances to enter or depart. Permeability of concrete can be a primary reason for concrete deterio-ration due to reinforcing steel corrosion and other deteriorating mechanism. ~~...~~

Permeability also refers to 'porous' slabs used to drain pavements, side walks, and parking areas of water, eliminating the need for drainage slope, structures and piping. This technology - 'sometimes called "no fines concrete". is gaining popularity again with the desire to reduce surface run-off from pavements, side walks, and parking areas.

Factors Affecting Permeability

→ Water/cement ratio:-

→ For the pastes hydrated to the same degree, the permeability is lower with lower water/cement ratio or higher cement content.

→ Properties of cement.

→ The permeability of concrete is affected also by the properties of cement. For the same water/cement ratio, coarse cement tends to produce a paste with higher porosity of cement than a finer cement. In general, higher the strength of cement paste, the lower will be the permeability.

→ Aggregate. The permeability of aggregate affects the behavior of the concrete. If the aggregate has a very low permeability its presence reduces the effective area over which flow can take place.

→ For a given water/cement ratio, greater the maximum size of aggregate greater is the permeability. This is because of the relatively larger voids, well graded aggregate reduces the permeability.

Concrete Shrinkage

→ Concrete is subjected to changes in volume either autogenous or induced. Volume change is one of the most detrimental properties of concrete, which affects the long-term strength and durability. To the practical engineer, the aspect of volume change in concrete is important from the point of view that it causes unsightly cracks in concrete and called shrinkage.

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→ Concrete Shrinkage is the change in length per unit length and is, therefore, a dimensional number expressed as percent shrinkage is time dependent and its value includes plastic shrinkage, autogenous shrinkage, drying shrinkage, and carbonation shrinkage usually quantified in terms of micro strain which is equal to 1x10^-6 in/in or 1x10^-6 m/m.

Types of Shrinkage in Concrete

To understand this aspect more closely, Shrinkage can be classified in the following way.

(a) Plastic Shrinkage in concrete.

(b) Drying Shrinkage in concrete.

(a) Plastic Shrinkage

→ Plastic Shrinkage is ~~const~~ contraction in volume due to water movement from the concrete while still in the plastic state, or before it sets. This movement of water can be during the hydration process or from the environmental conditions ~~to~~ leading to evaporation of water that resides on the surface on the wet concrete. So the more the concrete bleeds, the greater the plastic shrinkage should be plastic shrinkage is proportional to cement content and therefore, inversely proportional to the w/c ratio.

→ Concrete Shrinkage of this type manifests itself soon after the concrete placed in the forms while the concrete is still in the plastic state. Loss of water by evaporation from the surface of concrete or by the absorption by aggregate or ~~Sub~~ sub grade, is believed to be the reasons of plastic shrinkage.

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(b) Drying Shrinkage

Just as the hydration of cement is an ever lasting process, the drying shrinkage is also an ever lasting process when concrete is subjected to drying conditions. The drying shrinkage of concrete is analogous to the mechanism of drying of timber specimen. The loss of free water contained in hardened concrete, does not result in any appreciable dimension change.

It is the loss of water held in gel ~~pores~~ pores that causes the change in the volume. Under drying conditions, the gel water is lost progressively over a long time, as long as the concrete is left in drying conditions. Cement paste shrinks more than mortar and mortar shrinks more than concrete. Concrete made with smaller size aggregate shrinks more than concrete made with bigger size aggregate. The magnitude of drying shrinkage is also a function of the fineness of gel. The finer the gel the more is the shrinkage.

Durability of Concrete

Defn :→

→ A durable concrete is one that performs satisfactorily in the working environment during its anticipated exposure conditions during service.

→ Durability of concrete is its ability to resist weathering action, chemical attack, abrasion or any other process of deterioration.

→ When exposed to environment durable concrete is likely to retain its original form, quality and serviceability during its lifetime.

→ Durable concrete envisage limits for maximum water cement ratio, minimum cement content, cover thickness, types of cement and presence of amount of chloride and sulphates in concrete.

8.7.3 Causes of Lack of Durability

The factors affecting the durability may be external or internal causes. The external causes may be physical, chemical and mechanical which are grouped in the following categories:

1. Environmental, such as occurence of extreme temperatures, abrasion and electrostatic actions.
2. Chemical attack by natural or industrial liquids and gases.

The internal causes include the following:

1. Alkali-aggregate reaction.
2. Volume changes due to difference in thermal properties of the aggregate and cement paste.

The common forms of chemical attack are: (i) leaching out of cement, (ii) carbonation, (iii) chloride-ion penetration, (iv) sulfate attack, (v) marine environment and (vi) natural slightly acidic water. The resistance to these attacks varies with the type of cement and increases in order: OPC and RHC; Portland blast furnace cement or low heat cement; sulfate resisting Portland cement, pozzolanic cement and super sulfated cement.

Chloride-ion Penetration The chloride ions present in the concrete can have harmful effect on concrete as well as on the reinforcement. In the first case, chloride ion penetration results in concrete swelling of 2 to 2.5 times larger than that observed with water penetration. This causes slight reduction of concrete strength. In the second case, presence of chloride ions near the reinforcement steel makes it vulnerable to corrosion. If the hydroxide to chloride ratio near the reinforcement steel drops below 0.3, the passivation is destroyed and corrosion is inevitable. This aspect has been discussed in details in Chapter 15. Chlorides have therefore to be prevented from entering into the concrete.

As per IS:456–2000, the amount of chlorides permitted in concrete so far as corrosion of reinforcements is concerned is limited to acid-soluble chloride contents of 0.4 and 0.6 kg/m^3 of concrete in pre-stressed and reinforced concretes, respectively, at the time of placing concrete. Some of the chloride present in the concrete materials can become chemically fixed by reactions with C_3A compound of the Portland cement forming calcium chloro-aluminate hydrate. This not only explains the good performance of Portland cement containing high amounts of calcium aluminate, but also advocates such cements as a solution to the problem. It is not advisable to use sulfate-resisting cements in an environment where excessive chlorides are present as they have low C_3A content and therefore less ability to form calcium chloro-aluminate hydrate. Reduction in *water–cement ratio* which reduces permeability and hence chloride ion penetration into concrete to a considerable extent prevents corrosion of steel.

It is also recommended to use *blended cements* containing pozzolanic materials or slag, as the chloride diffusion through the pastes of these cements is at a very slow rate as compared to OPC and *sulfate-resisting cements*. A cement with 65 per cent slag is most suitable while sulfate-resisting cement is least suitable in chloride environment. In case the pozzolanic material is present a content of 33 per cent is considered to be very effective in reducing the chloride diffusion into concrete. However, percentage of replacement of cement by pozzolana being restricted to 25 per cent in IS: 1489–1991 and slag being restricted to 65 per cent in IS: 455–1989, a concrete with desirable performance can be produced using pozzolana or slag as *mineral additive*. Therefore, it is possible to use higher percentage of such materials in a very aggressive environment wherein high proportions of chloride are present.

Carbonation

Alkalinity of concrete Concrete is an alkaline substance and provides excellent protection to reinforcement embedded inside. The *alkaline environment* forms a protective oxide film which passivates the steel and protects it from *corrosion*. Concrete initially has a pH value of about 12 to 13. Due to leaching, carbonation and defective construction practices the pH value drops rapidly. Once pH value of concrete in the *covercrete* drops below 10, corrosion of steel reinforcement is inevitable and therefore concrete durability is at stake. This is however dependent on the quality of concrete and its *porosity* mainly in the cover area. A dense good quality concrete offers good protection to steel embedded in it. It is also essential to produce concrete using low *water–cement ratio* so that it has minimum unblocked capillary pores. Since the concretes of higher strength have lower *water–cement ratio* they are preferred.

Process of carbonation As discussed in Section 8.4.3 the carbon dioxide present in the atmosphere reacts in the presence of water with the concrete surface and concrete gets carbonated or in other words turns acidic. This chemical reaction starts at the surface and gradually proceeds inside the concrete mass and is generally measured as *depth of carbonation*. As hydrated calcium silicates and aluminates are less stable than calcium carbonate, concrete carbonation cannot be avoided. In the cracked portion, carbonation penetrates inside along the cracks as can be seen in Fig. 8.26(a).

Advantages and disadvantages of carbonation Carbonation of concrete improves several characteristics of ordinary concrete but can also affect the durability of reinforced concrete significantly. If the concrete is dense and well compacted, carbonation reduces the total porosity, specific surface of cement pastes as well as water permeability which in turn increases resistance to sulfate and aggressive chloride-ion penetration. However, in reinforced concrete these beneficial effects are accompanied by large decrease in alkalinity or drop in pH value.

On carbonation, the concrete loses its pH value from around 13.5 to 8.3. Therefore, steel is no longer passivated by the alkaline concrete around it. Oxidation of reinforcement steel therefore takes places in the presence of moisture and oxygen, and corrosion (rusting) occurs. The corrosion increases the volume of steel and ultimately results in *cracking* and *spalling* concrete.

Chlo...

Sulfate Resistance on Durability of Concrete.

A sulfate attack is one of the deterioration methods of concrete. This process can be initiated without any influence on the environment or with the support of the environment. The increase in the volume of the concrete causes cracking.

→ Generally, the sulfate related stresses are developed in the surface of the concrete reffered to as external sulfate attack.

→ It causes by the reaction of the sulfates contained in the groundwater or soil reacting with the cementitious paste is concrete.

→ Though deterioration starts at the contract face it develops further.

→ The chemical reaction creates very high tensile stresses and it causes cracking and disintegration of concrete.

→ Porous concrete attacked then the low permeable concrete in general.

8.9 ACID ATTACK

Concrete structures are also used for storing liquids, some of which are harmful for concrete. In industrial plants, concrete floors come in contact with liquids which damage the floor as is seen in Fig. 8.26(b). In damp conditions SO_2 and CO_2 and other acid fumes present in the atmosphere affect concrete by dissolving and removing part of the set cement. In fact, no Portland cement is acid resistant. Concrete is also attacked by water containing free CO_2. Sewerage water also very slowly causes deterioration of concrete.

8.10 EFFLORESCENCE

The water leaking through cracks or faulty joints or through the areas of poorly compacted porous concrete, dissolves some of the readily soluble calcium hydroxide and other solids, and after evaporation leaves calcium carbonate as white deposit on the surface as shown in Fig. 8.26(c). These deposits on the surface of concrete resulting from the leaching of calcium hydroxide and subsequent *carbonation* and evaporation, are termed *efflorescence*. Unwashed seashore aggregate, gypsum and alkaline aggregate also cause efflorescence. Many kinds of salts have been detected in samples of efflorescences.

8.11 FIRE RESISTANCE

In general, concrete has good properties with respect to fire resistance, i.e., the period of time under fire during which concrete continues to perform satisfactorily is relatively high and no toxic fumes are emitted. The length of time over which the structural concrete preserves structural action is known as *fire rating*. Under sustained exposure to temperature in excess of 35°C along with the condition that a considerable loss of moisture from concrete is allowed leads to decrease in strength and in *modulus of elasticity*. The loss of strength at higher temperatures is greater in saturated than in dry concrete. Excessive moisture at the time of fire is the primary cause of *spalling* as shown in Fig. 8.26(d). In general, moisture content of concrete is the most important factor determining the structural behaviour at higher temperature.

Leaner mixes appear to suffer a relatively lower loss of strength than rich ones. Flexural strength is affected more than compressive strength. The loss of strength is considerably lower when the aggregate does not contain silica, e.g., concrete made with limestone, *crushed brick* and *blast-furnace-slag aggregate*. Low *conductivity* of concrete improves its fire resistance, and hence a *lightweight concrete* is more fire resistant than ordinary concrete. The calcined material aggregate having a low density leads to a good fire resistance of concrete. Due to *endothermic* nature of carbonate aggregate during calcination at high temperature, heat is absorbed and further temperature rise is delayed. For example, dolomite gravel leads to a good fire resistance of concrete.

The data on the variation of strength of concrete upon heating obtained experimentally are generally conditional. The data obtained by generalizing the results

Formwork—Stripping forms

These are some injuries that workers have experienced while stripping formwork.

1. A worker strained the tendon in his left forearm while stripping and moving forms.
2. A worker fell six feet from a scaffold platform and severely injured his leg.
3. A worker was struck by a piece of plywood, which hit his hard hat and twisted his head.

Explain dangers

Formwork stripping is one of the most dangerous operations in concrete work.

Hazards can include the following.

FALLS

- Panels and other materials could fall and strike workers during stripping.
- Stacked materials could fall and strike workers.
- Workers could fall when formwork breaks free or if forms are being stripped at dangerous heights.
- Materials could fall to lower levels and injure workers or pedestrians.
- Poor housekeeping can cause slips and trips.

STRUCK-BYS

- Workers could be struck by loose concrete, rubble, debris, or over-pour left on columns, walls, and other structures. These hazards could also result in eye injuries.
- Sharp edges on formwork, protruding nails, snap ties, conduit, and bolts can cause pinches, cuts, scrapes, abrasions, and other injuries.
- Protruding rebar can cause cuts, abrasions, and impalement.

MSDs

- Workers can injure their joints, muscles, and bones from reaching, prying, pulling, pushing, lifting, and carrying heavy forms, panels, and other components.

Identify controls

- Maintain signs and barriers to prohibit unauthorized entry into the stripping area.
- Ensure that exposed rebar is properly capped to avoid cuts, abrasions, and impalement.
- If guardrails must be removed, make sure everyone working in the area uses a fall protection system. Don't take shortcuts.
- Only strip what you can clean up during the same work shift.
- Ensure bracing is sufficient before breaking formwork from concrete.
- Never climb partially stripped formwork to reach high areas. Use a work platform.
- Make sure that work platforms are fully planked and have proper guardrails—including toe boards—for work over 2.4 metres. Planks for work platforms less than 2.4 metres high must be at least 460 millimeters wide.
- Never lean material against the wall. Place it neatly on the ground in a stable position.
- Never throw stripped material to the ground from a work platform. Always lower it by passing it to a co-worker or using another safe method.
- Ensure the stripping area is clean to avoid slips and trips. Inspect columns, walls, and other structures and remove any loose concrete or debris.
- When stripping, always wear gloves and safety eyewear to protect against cuts, pinches, scrapes, and injuries from debris.
- Never alter tools.
- Use carts or cradles to move material.
- Never strip forms unless you have verified that the concrete strength is sufficient.

Demonstrate

Take the crew to an area where stripping will be done. Highlight some of the hazards and identify the controls that will be used, such as signs and barriers, methods for lowering material, and proper stacking and storage of stripped material.