CONCRETE TECHNOLOGY

MODULE - 4

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MIX - DESIGN

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

FACTORS AFFECTING THE CHOICE OF CONCRETE MIX DESIGN.

1. **Compressing strength of concrete →**

The mean compressive strength (fcm) required at a specific age, usually 28 days, determines the nominal water-cement ratio of mix. The concrete compressive strength of fully compacted concrete is inversely proportional to the water-cement ratio.

2. **Workability of concrete →**

* Concrete workability for satisfactory placement and compaction depends on the size and shape of the section to be concreted, the amount and spacing of reinforcement and concrete transportation, placement and compaction technique.
* Additionally, use high workability concrete for the narrow and complicated section with numerous corners.
* Frequently, slump test values used to

evaluate concrete workability in

3. Durability of Concrete →

* The ability of the concrete to withstand harmful environment conditions termed as concrete durability.
* High strength concrete is generally more durable than low strength concrete.
* In the situations when the high strength is not necessary but the conditions of exposure are such that high durability is vital, the durability requirement will determine the utilized water-cement ratio.
* Concrete durability decreases with the increase of w/c ratio.

4. Maximum nominal size of aggregate →

* Reinforcement spacing controls maximum aggregate size.
* Aggregate size is inversely proportional to cement requirement for water-cement ratio. This is because workability is directly proportional to size of aggregate.
* The compressive strength tends to increase with the decrease in size of aggregate. Smaller aggregate size offers greater surface area for bonding with mortar mix that give higher strength.

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5. Grading and type of aggregate →

* Well graded fine and coarse aggregate produce a dense concrete because of the achievement of ultimate packing density.
* If available aggregate which obtained from natural source, does not confirm to the specified grading, the proportioning of two or more aggregate becomes essential.
* For specific workability and water to cement ratio, type of aggregate affects aggregate to cement ratio.

6. Quality control at site →

* The variation in strength results from the variations in the properties of the mix ingredients, in addition to lack of control of accuracy in batching, mixing, placing, curing and testing.
* Finally, the lower the difference between the mean and minimum strengths of the mix lower will be the cement - content required. The factor controlling this difference is termed as quality control.

DURABILITY OF CONCRETE

The durability of cement concrete can be defined as its ability to resist weathering action, chemical attack, abrasion or any

Other process of deterioration...

Factors affecting durability of concrete

1. Cement Content → Quantity of cement used in concrete mix will also be a factor affecting durability of concrete.

* If cement content used is lower than the required, then water cement ratio becomes reduced and workability also reduced.
* Adding more water to this mix results in formation capillary voids which will make Concrete as permeable material.

2. Aggregate Quality → Use of good quality aggregates in concrete mix will surely increase the durability of hardened concrete.

* The shape of aggregate particles should be smooth and round. Flaky and elongated aggregates effects the workability of fresh concrete.
* For better bond development between ingredients rough textured angular aggregates are recommended but they require more Cement content.
* Aggregate should be well graded to achieve dense concrete mix.

3) Water Quality → Portable water is recommended for making concrete.

* PH of water shall be in the range of 6 to 8.
* Water should be clean and free from oils, acids, alkalies, Organic materials etc.

4) Concrete Compaction → While placing concrete, it is important to compact the placed concrete without segregation

* Improperly compacted concrete contain number of air voids in it which reduces the concrete strength and durability.

5. Curing Period → Proper curing in initial stages of concrete hardening result in good durability of concrete.

* Improper curing leads to formation of cracks due to plastic shrinkage, drying shrinkage, etc, thereby durability decreases.

6) Permeability →

* Permeability of water into concrete expand its volume and lead to formation of cracks and finally disintegration of concrete occurs.
* To prevent permeability, lowest possible water cement ratio must be recommended.
* Use of Pozzolanic materials also helps to reduce permeability by filling capillary cavities.

Other factors affecting durability of concrete are :-

* Moisture
* Temperature effects
* Abrasion
* Carbonation
* Alkali Aggregate Reaction.
* Sulfate attack.

TYPES OF DURABILITY

1) Physical Durability → It is against the following actions.

* Freezing and thawing action.
* Percolation / Permeability of water.
* Temperature stresses i.e. high heat of hydration

2) Chemical Durability → It is against the following actions

* Alkali Aggregate Reaction.
* Sulphate Attack.
* Chloride Ingress
* Delay Ettringite formation.
* Corrosion of reinforcement.

QUALITY CONTROL OF CONCRETE

To add more strength and make the building structure long-lasting, the quality concrete is important.

Quality control in Concrete Construction

* Mechanical properties of the reinforcement to be utilized.
* Dimension of the reinforcement.
* Positioning of the reinforcement in construction prior to pouring of concrete.
* Positioning of Pre-stressing ducts.
* Properties of the concrete mix design to be applied in the structure.
* Control of the coarse aggregates and fine aggregates getting into the concrete.
* Mixing of the concrete
* Transmission of the concrete to the construction site.
* slump of the concrete
* Pouring of the concrete
* Control of adding water
* Vibration / Compaction of concrete.

Starting Point of Quality control.

It starts in the production of material that is applied in concrete. (sampling and testing)

* Portland Cement
* Pozzolana
* Coarse and fine aggregate.

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QUALITY CONTROL PROCEDURE

It proceeds in the following steps :-

* Handling and stockpiling.
* Batching and mixing
* sampling and testing fresh concrete.
* Transporting and positioning the freshly mixed concrete.

TESTS FOR CHECKING CONCRETE QUALITY

TESTS ON FRESH CONCRETE

* The slump test
* The compacting factor test.

TESTS ON HARDENED CONCRETE

* Compression test.
* Tensile strength test
* Flexural strength test.

Advantages of quality control in concrete

(i) It is the rational use of available resources after testing their characteristics resulting in the reduction of material cost.

(ii) Quality control reduces the maintenance cost.

(iii) In the absence of quality control at the site, the designer may be tempted to over design to minimise the risk. This will result in more cost.

Statistical Quality of Concrete

Statistical quality control method provides a scientific approach to the concrete designer to understand the realistic variability of the materials so as to lay down design specifications with proper tolerance to cater for unavoidable variations. The acceptance criteria are based on statistical evaluation of the test result of samples taken at random during execution. By devising a proper sampling plan it is possible to ensure a certain quality at a specified risk. Thus the method provides a scientific basis of acceptance which is not only realistic but also restrictive as required by the design requirements for the concrete construction.

COMMON TERMINOLOGIES

a) **Mean strength** → This is the average strength obtained by dividing the sum of strength of all cubes by the number of cubes.

where $\bar{x} = \frac{\sum x}{n}$ = mean strength

$\sum x$ = sum of the strength of cubes

n = number of cubes.

b) **Variance** → This is a measure of variability or difference between any single observed data from the mean strength.

Variance $= x - \bar{x}$.

c) **Standard deviation** → This is the root mean square deviation of all the results. This is denoted by s or σ.

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

where,

σ = standard deviation
n = number of observations
x = Particular value of observations
$\bar{x}$ = mean strength.

d) **Coefficient of variation** → It is an alternative method of expressing the variation of results. It is a non-dimensional measure of variation obtained by dividing the standard deviation by the arithmetic mean and is expressed as:

$$v = \frac{s}{\bar{x}} \times 100$$

where; v = coefficient of variation

ACCEPTANCE CRITERIA

COMPRESSIVE STRENGTH

The concrete is deemed to comply with the compressive strength requirements when both the following conditions are met :-

SPECIFIED GRADE (1)	MEAN OF THE GROUP OF 4 NON-OVER-LAPPING CONSECUTIVE TEST RESULTS IN N/mm^2 (2)	INDIVIDUAL TEST RESULTS IN N/mm^2 (3)
M 15	$> f_{ck} + 0.825 \times$ established standard deviation (rounded off to the nearest $0.5\ N/mm^2$) or $f_{ck} + 3\ N/mm^2$ whichever is greater	$> f_{ck} - 3\ N/mm^2$
M 12	$> f_{ck} + 0.825 \times$ established standard deviation (rounded off to the nearest $0.5\ N/mm^2$) or $f_{ck} + 3\ N/mm^2$ whichever is greater	$> f_{ck} - 3\ N/mm^2$

The mean strength determined from any group of four consecutive test results complies with the appropriate limits in column 2 of table given above.

Any individual test result complies with the appropriate limits in column 3 of table given above.

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FLEXURAL STRENGTH

When both the following conditions are met, the concrete complies with the specified flexural strength.

The mean strength determined from any group of four consecutive test results exceeds the specified characteristic strength by at least 0.3 N/mm^2.

The strength determined from any test result is not less than the specified characteristic strength less 0.3 N/mm^2

PROPORTIONING OF CONCRETE MIXES BY VARIOUS METHODS

1. American Method of Mix design. (ACI)

The American Concrete Institute (ACI) method is based on the fact that for a given maximum size of aggregate the water content in kilogram per cubic metre of concrete determines the workability of concrete mix, usually independent of the mix proportions.

(a) The method makes use of the established fact, that over a considerable range of practical proportions, fresh concrete of given slump and containing a resonably well graded aggregate of given maximum size will have practically a constant total water content regardless of variations in water/cement ratio and cement content, which are necessarily interrelated.

(b) It makes use of the relation that the optimum dry rodded volume of coarse aggregate per unit volume of concrete depends on its maximum size and the fineness modulus of the fine aggregate. The effect of angularity is reflected in the void content, thus angular coarse aggregates require more mortar than rounded coarse aggregate.

(c) Irrespective of the methods of compaction, even after complete compaction is done, a definite percentage of air remains which is inversely proportional to the maximum size of the aggregate.

(d) It assumes that the optimum ratio of bulk volume of coarse aggregate to the total volume of concrete depends only on maximum size of coarse aggregate on the grading of fine aggregate.

2) Graphical Method of Mix Design:

The aggregates to be mixed together are sieved and their percentage passing through standard sieves for fine aggregate sieve 4.75 mm, 2.36 mm, 1.18 mm, 600 micron, 300 micron and 150 micron are used. For coarse aggregate maximum size allowed such as 38 mm, 19 mm, 9.5 mm, 4.75 mm 2.36 mm sieve used.

PROCEDURE

1. The percentage passing through each sieve of the coarse and fine aggregate or two fractions of coarse aggregate which are to be mixed to obtain the desired grading curve are noted along the two opposite vertical sides of a square from top to bottom. The points corresponding to the same sieve size are joined by the straight lines. If the sieve size does not exist on any of the vertical axis, then the line should be joined to the 100% point on the left hand axis and 0% point on the right hand axis.

2. Now a vertical line is drawn through the point of intersection of the line joining the same sieve size point and the horizontal line representing the correct percentage of aggregate smaller than the desired sieve as the vertical line drawn from the appropriate point along the scale at the top of the diagram and the combined grading is given by the intersection of this line and sieve size lines joining the pairs of points.

3. A horizontal line is drawn through 41% line parallel to X-axis.

4. A vertical line through the point of inter-section of line joining the percentage of 4.75 mm line is drawn and a horizontal line of 41% intersecting all lines

5. Measure the corresponding percentages indicated by these points of inter-section. These will be the percentages of each fraction. These percentages ~~are sta~~

6. Now, combine two fractions of coarse aggregate. In this case the percentage passing through 19.0 or (20) mm sieve size is taken as the criterion. The percentages passing each sieve are marked along the two opposite sides of the square. The points corresponding to the same sieve are joined by straight lines.

Now a vertical line is drawn through the point where the line joining the 19.0 mm value intersect the horizontal line representing the correct percentage of aggregate smaller than 19.0 mm as in ~~ca~~ 39%.

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3) Mix Design by Indian Standard Method.

The method of mix design consists of determining the followings: -

(a) Water content.
(b) Percentage of fine aggregate corresponding to the maximum nominal size of aggregate for the reference value of workability.
(c) Water - cement ratio
(d) Grading of fine aggregate.

BIS METHOD OF MIX DESIGN

PROCEDURE

1. Calculation of target strength of concrete.
2. Selection of water-cement ratio.
3. Determination of aggregate air content.
4. Selection of water content for concrete.
5. Selection of cement content for concrete.
6. Calculation of aggregate ratio.
7. Calculation of aggregate content for concrete.
8. Trial mixes for testing concrete mix design strength.

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Step 1 : Calculation of Target Strength of Concrete.

Target strength is denoted by ft which is obtained by characteristic compressive strength of concrete at 28 days (fck) and value of standard deviation (s)

$$f_t = f_{ck} + 1.65\ s$$

Step 2 : Selection of Water-cement Ratio

Ratio of the weight of water to weight of cement in the concrete mix is water-cement ratio. It is the important consideration in concrete mix design to make the concrete workable. Water cement ratio is selected from the below curve for 28 days characteristic compressive strength of concrete.

Step 3 : Determination of Aggregate Air Content

Air content in the concrete mix is determined by the nominal maximum size of aggregate used.

Step 4 : Selection of Water Content for Concrete.

Select the water content which is useful to get required workability with the help of nominal maximum size of aggregate.

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Step-5 Selection of cement content for concrete

Water - cement ratio is determined and quantity of water is determined. So, we can easily calculate the quantity of cement from these two conditions. The greater of the two values is decided as quantity of cement content.

Step-6 Calculation of Aggregate Ratio

For the given nominal maximum size of aggregate, calculate the ratio of volumes of coarse aggregate and volume of total aggregates for different zones of fine aggregates

Step-7 Calculation of Aggregate Content for Concrete

Mass of fine aggregate is calculated from below formula.

$$V = \left[W + \frac{C}{G_c} + \left(\frac{1}{(1-P)} \times \frac{F.A}{G_f} \right) \right] \times \frac{1}{1000}$$

Mass of coarse aggregate is calculated from below formula.

$$V - \left[W + \frac{C}{G_c} + \left(\frac{1}{P} \times \frac{C.A}{G_{ca}} \right) \right] \times \frac{1}{1000}$$

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where V = Volume of concrete
W - Water content
C = Cement content
Gc = Sp. Gravity of cement
P = aggregate ration obtained
F.A & C.A = masses of fine and coarse aggregates
Gf & Gca - Sp. Gravities of fine and coarse aggregates.

Step 8: Trial mixes for testing concrete Mix design Strength

Based on the values a trial test is conducted by making at least 3 cubes of 150 mm size as per standards. Test that cubes and verify whether the required strength is gained or not. If not redesign the mix with proper adjustments until required strength of cube occurs.