Unit III

Proportioning of concrete mix.

Introduction:

Concrete is the most widely used man-made construction material and studies indicating that it will continue to be so in the years and decades.

Concrete mix design is termed as the process of selecting suitable ingredients of concrete determining their relative quantity with the main aim of producing a concrete of the required strength, durability and workability as economically as possible.
Principles of Mix proportioning:

Basic Considerations:
Design of concrete mixes involves determination of the proportion of the given constituents namely,

- Cement
- Water
- Course aggregates
- Fine aggregates

If any admixtures are added which would produce the concrete possessing specified properties in the fresh and hardened states with the maximum overall economy.

Workability is specified as the important property of concrete in the fresh state.

Compressive strength and durability are important for hardened state of concrete.
The following basic assumptions are made in design of plastic concrete mixes of medium strength:

* The compressive strength of concrete is governed by its water-cement ratio.

* For a given aggregate characteristic, the workability of concrete is governed by its water content.

For high strength concrete mixes of low workability, considerable interaction occurs between these two criteria and validity of such assumptions may become limited.

Moreover, there are various other factors which affect the properties of concrete are,

* Quality and quantity of cement,
* Water and aggregates,


Properties of concrete related to mix design:

Concrete has to have satisfactory properties both in the fresh and hardened states. While workability is the desirable property of fresh concrete, strength and durability are the most important properties of concrete in the hardened state.

The demand of satisfactory properties of concrete in the fresh and hardened state may often bring requirements in the material and mix proportions.

The important properties of concrete namely
* Workability
* Compressive and tensile strength.
* Durability.

Physical Properties of Materials Required for Mix Design.

The common ingredients of concrete are cement, fine and coarse aggregates and water.

By use of available materials for concrete making and their proportioning, concrete mixes are produced to have the desired properties in the fresh and hardened states, as situation demands.

Cement

Cement is by far the most important constituent of concrete, in that it forms the binding medium for the discrete ingredients.
Made up of naturally occurring raw materials and sometimes blended with industrial wastes, concrete comes in various types and chemical compositions.

**Aggregates:**

Aggregates which occupy nearly 70 to 75% volume of concrete are sometimes viewed as inert ingredients in more than one sense.

It is now well recognized that physical properties of aggregates substantially influence the properties and performance of concrete.

**Water:**

Water used for mixing and curing shall be clean and free from injurious amount of oils, acids, alkalies, salts, or other substances that may be deleterious to concrete or steel.
Types of Mixes:

The mix proportions shall be selected to ensure the workability of the fresh concrete and when concrete is hardened, it shall have the required strength, durability and surface finish.

The determination of the proportions of cement, aggregates and water required strengths shall be made as follows:

* By designing the concrete mix, such concrete shall be called design mix.

* By adopting nominal concrete mix, such concrete shall be called as Nominal mix concrete.

Nominal Mixes:

In the past specifications for concrete prescribed the proportions of
Cement, fine and coarse aggregates. These mixes of fixed cement-aggregate ratio which ensures adequate strength are termed as nominal mixes.

These offer simplicity and under normal circumstances, have a margin of strength above that specified. However, due to the variability of mix ingredients the nominal concrete for a given workability varies widely in strengths.

Design mixes:

The performance of the concrete is specified by the designer but the mix proportions are determined by the producer of concrete, except that the minimum cement content can be laid down.

This is most rational approach to the selection of mix proportions
with specific materials in mind possessing
more or less unique characteristics.

Standard mix:

The nominal mixes of fixed
cement-aggregates ratio by volume
very widely in strengths and may result
in under-rich mix or over-rich mix.

For this reason, the minimum
compressive strength has been included
in many specifications. These mixes are
treated as standard mixes.

Methods of concrete mix design:

* ACI mix design method,
* USBR mix design practice,
* British "I" method (DOE method)
* Mix design method according
to IS recommended Guidelines
or (BS 6109 Method of Mix design)
BIS Method & Mix design

The following points should be remembered before proportioning a concrete mix as per IS 10262:2009

* This method of concrete mix proportioning is applicable only for ordinary and standard concrete grades.
* The air content in concrete is considered as nil.
* The proportioning is carried out to achieve specified characteristic compressive strength at specified age, workability of fresh concrete and durability requirements.

Mix design examples:

Problem
Design of M20 concrete mix as per IS 10262:2009, concrete mix proportioning guidelines (First Revision).
The following are the design stipulations for proportioning:

i) Grade designation: M20

ii) Type of cement: OPC 43 grade conforming to IS 8112.

iii) Maximum nominal size of aggregates: 20mm

iv) Minimum cement content: 320 kg/m³

v) Maximum water cement ratio: 0.55

vi) Workability: 75mm (Slump)

vii) Exposure condition: Mild

viii) Degree of supervision: Good

ix) Type of aggregate: Crushed angular aggregates.

x) Maximum cement content: 450 kg/m³

xi) Chemical admixture: Not recommended.

Test data for materials:

i) Cement used: OPC 43 grade conforming to IS 8112.

ii) Specific gravity of cement: 3.15

iii) Specific gravity of coarse aggregates: 2.68

iv) Specific gravity of fine aggregates: 2.65
iv) Water absorption

- Coarse aggregate: 0.6 x 1.0 x
- Fine : 1.0 x

v) Free (Surface moisture)

- Coarse aggregate: Nil (Absorbed moisture full)
- Fine : Nil

vi) Sieve analysis

- Coarse aggregate: conforming to table 2 of IS 383
- Fine: conforming to Zone-I of IS 383.

Target Strength for mix proportion:

\[ f_{ck}' = f_{ck} + 1.65s \]

where

- \( f_{ck}' \): Target average compressive strength at 28 days.
- \( f_{ck} \): Characteristic compressive strength at 28 days.
- \( s \): Standard deviation.

From Table 2 of IS 10262-2009, standard deviation, \( s = 4 N/mm^2 \).
Therefore target strength = 20 + (1.65 \times 4) = 26.60 \text{ N/mm}^2

Selection of water cement ratio

From Table 5 of IS 156 - 2000, maximum water cement ratio = 0.55 (mild exposure)

Based on experience adopt water cement ratio as 0.50

0.5 < 0.55
hence Ok.

Selection of water content

From Table 2 of IS 10262 - 2009
maximum water content = 186 litres (for 25mm - 50mm slump range and for 20mm aggregates)

Estimated water content for 75mm slump = 186 + \frac{3}{100} \times 186 = 191.6 \text{ litres}

Calculation of cement content

\text{Water cement ratio} = 0.50
Cement content = 191.6 \times 10.5 > 200 \text{ kg/m}^3
\text{Given)}

From Table 5 of IS 456 - 2000, minimum

\text{(15)}
Cement content for mild exposure condition = 300 kg/m$^3$ Hence ok.

Proportions of volume of coarse aggregates and fine aggregates.

From Table 3 of IS 10262:2009, volume of coarse aggregates corresponding to 20mm size aggregate and fine aggregate (Zone - I) for water-cement ratio of 0.50 = 0.60

Mix calculations:

The mix calculation per unit volume of concrete shall be as follows:

a) Volume of concrete = 1 m$^3$

b) Volume of cement = \( \frac{\text{Mass of cement}}{\text{Specific gravity of cement}} \times \frac{1}{1000} \)

c) Volume of water = \( \frac{\text{Mass of water}}{\text{Specific gravity of water}} \times \frac{1}{1000} \)

Volume of cement = \( \frac{383.16}{3.15} \times \frac{1}{1000} = 0.122 m^3 \)

Volume of water = \( \frac{172}{2} \times \frac{1}{1000} = 0.192 m^3 \)
d) Volume of all in aggregates \( z = a -(b+c) \)

\[ = 1 - (0.122 + 0.19) = 0.688 \text{ m}^3 \]

e) Mass of coarse aggregates = \( z \times \text{volume of C.A} \times \text{specific gravity of C.A} \times 1000 \)

\[ = 0.688 \times 0.6 \times 2.66 \times 1000 \]

\[ = 1103 \text{ kg}, \]

f) Mass of fine aggregates = \( z \times \text{volume of F.A} \times \text{specific gravity of F.A} \times 1000 \)

\[ = 0.688 \times 0.4 \times 2.65 \times 1000 \]

\[ = 727 \text{ kg}, \]

Mix proportion for Trial Number 1

- Cement = 283 kg/m³
- Water = 191.6 kg/m³
- Fine aggregates = 727 kg/m³
- Coarse \( w \) = 1103 kg/m³

Water cement ratio = 0.50

Aggregates are assumed to be in SSD. Otherwise, corrections are to be applied while calculating the water.
content. Necessary corrections are also required to be made in mass of aggregates. Trial mixes are studied in laboratory.

Problem:

Design a M40 grade concrete mix as per IS 10262:2009. The following are the design stipulations for proportioning:

a) Grade designation: M40
b) Type of cement: OPC 43 grade conforming to IS 8112.

C) Maximum nominal size of aggregates: 20mm
d) Minimum cement content: 320 kg/m³
e) Maximum water cement ratio: 0.45
f) Workability: 100 mm (slump)

I) Exposure conditions: Severe (for reinforced concrete)


J) Degree of supervision: Good.

K) Type of aggregates: Crushed angular aggregates.
1) Maximum cement content: 400 kg/m³
2) Chemical admixture type: superplasticiser.

Test Data for Materials:

a) Cement used: OPC 43 grade conforming to IS 8112.

b) Specific gravity of cement: 3.15

c) Chemical admixture: Superplasticizer conforming to IS 9103.

d) Specific Gravity
   - Coarse aggregate: 2.74
   - Fine aggregate: 2.74

e) Water absorption
   - Coarse aggregates: 0.5%
   - Fine aggregates: 1.0%

f) Free Surface moisture
   - Coarse aggregate: Nil (absorbed moisture also nil)
   - Fine aggregate: Nil

7) Sieve analysis
   - Coarse aggregate: Conforming to Table 2 of IS 983
   - Fine aggregates: Conforming to Zone I of IS 983.
Target Strength for Mix Proportioning

\[ f'_{ck} = f_{ck} + 1.65 \sigma \]

where

- \( f'_{ck} \) = Target mean strength at 28 days.
- \( f_{ck} \) = Target mean strength at 28 days.
- \( \sigma \) = Standard deviation

From Table 1 of IS: 10262: 2009,
standard deviation \( \sigma = 5\text{ N/mm}^2 \) Therefore

Target Strength \( = 40 + 1.65 \times 5 = 48.25\text{ N/mm}^2 \)

Selection of water cement ratio:

From Table 5 of IS: 456: 2000,
maximum water cement ratio \( = 0.45 \)

Based on experience, adopt water cement ratio as 0.40.

0.4 \( < 0.45 \) Hence OK.

Selection of water content

From Table 2 of IS: 10262: 2009, maximum water content \( = 186 \text{ litres} \) (for 25 mm to 50 mm range and for 20 mm aggregates.)

Estimated water content for 100 mm slump

\[ = 186 + \left( \frac{15}{100} \right) \times 186 = 191 \text{ litres} \]

As super plasticizer is used the water content can be reduced upto 20%.
and above. Based on totals with SP,
water content reduction of 29% has
been achieved.

Hence the water content achieved
\[ \frac{197 \times 0.71}{0.40} = 140 \text{ litres} \]

Calculation of cement content

Water cement ratio = 0.40

Cement content = \[ \frac{140}{0.40} = 350 \text{ kg/m}^3 \]

From Table 5 of IS: 456: 2000, minimum
cement content for severe exposure
conditions = 320 kg/m^3

350 kg/m^3 > 320 kg/m^3 Hence OK.

Proportion of volume of coarse aggregate
and fine aggregate content:

From Table 3 of IS: 10262: 2009,
volume of coarse aggregate corresponding
to 20mm size aggregate and fine
aggregate (Zone-I) for water cement
ratio of 0.50 = 0.60.
For pumpable concrete these values should be reduced by 10%. Therefore:

Volume of coarse aggregates = \(20.62 \times 0.9\) = 0.56.

Volume of fine aggregates content = \(1 - 0.56 = 0.44\)

Mix calculations:

The mix calculations per unit volume of concrete shall be as follows:

a) Volume of concrete = 1 m³

b) Volume of cement = \(\frac{\text{Mass of cement}}{\text{specific gravity of cement}} \times \frac{1}{1000}\)

= \(\frac{350}{3.15} \times \frac{1}{1000}\) = 0.111 m³

c) Volume of water = \(\frac{\text{Mass of water}}{\text{specific gravity of water}} \times \frac{1}{1000}\)

= \(\frac{140}{1} \times \frac{1}{1000}\)

= 0.140 m³
4) Volume of chemical admixtures
(Super plasticizer - SP 2% by mass of cementitious material)

\[
\text{Volume} \times \frac{1}{\text{specific gravity}} = \frac{\text{Mass of chemical admixture}}{1000}
\]

\[
= \left[ \frac{17}{1.145} \right] \times \left[ \frac{1}{1000} \right] = 0.006 m^3
\]

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

\[
= 1 - (0.11 + 0.140 + 0.006) = 0.743 m^3
\]

6) Mass of coarse aggregates = \( Z \times \text{Volume of C.A} \times \text{Specific gravity of C.A} \times 1000 \)

\[
= 0.743 \times 0.56 \times 2.74 \times 1000 = 1140 kg
\]

7) Mass of fine aggregates = \( Z \times \text{Volume of F.A} \times \text{Specific gravity of F.A} \times 1000 \)

\[
= 896 kg
\]

Mix proportions for Trial Number 2

Cement = 350 kg/m^3
Water = 140 kg/m^3
Fine aggregate = 896 kg/m³
Coarse aggregate = 1140 kg/m³
Chemical admixtures = 7 kg/m³
Water cement ratio = 0.40

Aggregates are assumed to be in saturated surface dry condition. Otherwise, corrections are to be applied while calculating the water content. Necessary corrections are also required to be made in mass of aggregates.

\[ \times \times \times \]