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Concrete Mix Design with Portland Pozzolana Cements

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The Indian standard IS:456-2000 recommends the use of Portland pozzolana cement formerly known as blended cement as well as mineral admixtures for concrete mixes provided that there are satisfactory data on their suitability, such as performance test on concrete containing them. In the present paper concrete mix design with blended cement is presented based on relevant latest I.S. codes.

I. Introduction

Concrete is a widely used structural material consisting essentially of a binder and a mineral filler. It has the unique distinction of being the only construction material actually manufactured on the site, or in a RMC plant.

Concrete has become an indispensable construction material. In the present scenario concrete has crossed the stage of four component system i.e. cement, water, coarse aggregate and fine aggregate. It can be combination of more number of ingredients such as fly ash, ground granulated blast furnace slag, silica fume, rice husk ash and admixtures etc. are generally used in concrete production in practice which depends upon the requirement and the availability of the expertise.

The fundamental requirement of a concrete mix is that it should be satisfactory both in the fresh as well as in the hardened state, possessing certain minimum desirable properties like workability, strength and durability. Besides these requirements it is essential that the concrete mix is prepared as economically as possible by using the least possible amount of cement content per unit volume of concrete, with due regard to the strength and durability requirements. Since concrete is produced by mixing several discrete material, the number of variables governing the choice of mix design are necessarily large. However continuous research work in this field by various investigators, has helped to identify the major parameters controlling the proportions of ingredients in the mix.

Principle of Mix Design

The basic principle which is generally used for mix design for proportioning mixes is Abram's law for strength development. According to this law, for any given conditions of test the strength of workable concrete mix is dependant only on the water-cement ratio. Lesser the water-cement ratio in a workable mix greater will be its strength. From practical considerations compressive strength is taken as an index of acceptability. Mix proportioning is normally carried out for a specific characteristic compressive strength requirements ensuring that the mix so proportioned should satisfy the workability requirements without segregation and bleeding of concrete.

Data For Mix Design

The following data are required for mix design:

- Grade designation
- Type of cement
- Maximum nominal size of aggregate
- Minimum cement content
- Maximum water-cement ratio
- Workability
- Maximum cement content
- Any admixture used
- Exposure conditions (as per IS: 456)
- Method of transportation and placing of concrete

Mix Design Procedure

i. Target mean strength

$F_t = f_{ck} + 1.65 \times S$

Where,

F_t = Target mean strength at 28 days in N/mm^2

f_{ck} = Characteristic compressive strength at 28 days in N/mm^2

S = Standard deviation

ii. Selection of water-cement ratio

Table 3: Environmental Exposure Conditions (Clauses 8.2.1 and 35.3.2		
SI. No.	Environment	Exposure Conditions
i)	Mild	Concrete surfaces protected against weather or aggressive conditions, except those situated in coastal area.
ii)	Moderate	Concrete surfaces sheltered from severe rain or freezing whilst wet Concrete exposed to condensation and rain Concrete continuously under water Concrete in contact or buried under non-aggressive soil/ground water Concrete surfaces sheltered from saturated salt air in coastal area
iii)	Severe	Concrete surfaces, exposed to severe rain, alternate wetting and drying or occasional freezing whilst wet or severe condensation. Concrete completely immersed in sea water Concrete exposed to coastal environment
iv)	Very severe	Concrete surfaces exposed to sea water spray, corrosive fumes or severe freezing conditions whilst wet Concrete in contact with or buried under aggressive sub-soil/ground water
v)	Extreme	Surface of members in tidal zone Members in direct contact with liquid/solid aggressive chemicals

This ratio should be selected based upon the relationship between target mean compressive strength of concrete and Compressive strength of cement. IS: 10262-1982 fig. 2 gives the values of water-cement ratio for various cements. The water-cement ratio can also be taken from table (5) of IS:456-2000 for particular environmental exposure conditions as starting point. The supplementary cementitious material that is mineral admixtures shall also be considered in water-cement ratio calculations.

The above selected water-cement ratio should be checked against limiting water–cement ratio for the requirement s of durability and the lower of the two will be adopted.

Table 5: Minimum Cement Content, Maximum Water-Cement Ratio and Minimum Grade of Concrete for Different Exposures with Normal Weight Aggregates of 20 mm Nominal Maximum Size
Clauses 6.1.2, 8.2.4.1 and 9.1.2)

SI. No.	Exposure	Plain Concrete			Reinforced Concrete		
		Minimum Cement Content kg/m^3	Maximum Free Water-cement Ratio	Minimum Grade of Conrete	Minimum Cement Content kg/m^3	Maximum Free Water-cement Ratio	Minimum Grade of Conrete
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Mild	220	0.60	-	300	0.55	M 20
ii)	Moderate	240	0.60	M 15	300	0.50	M 25
iii)	Severe	250	0.50	M 20	320	0.45	M 30
iv)	Very severe	260	0.45	M 20	340	0.45	M 35
v)	Extreme	280	0.40	M 25	360	0.40	M 40

Notes

1. Cement content prescribed in this table is irrespective of the grades of cement and it is inclusive of additions mentioned in 5.2. The additions such as fly ash or ground granulated blast furnace slag may be taken into account in the concrete composition with respect to the cement content and water-cement ratio if the suitability is established and as long as the maximum amounts taken into account do not exceed the limit of pozzolona and slag specified in IS 1489 (Part 1) and IS 455 respectively.

2. Minimum grade for plain concrete under mild exposure condition is not specified.

Selection of water content

The water content i.e. the quantity of maximum mixing water per unit volume of concrete may be determined from the following table:

Table: Maximum water content per cubic meter of concrete

S.No.	Nominal maximum size of agg.	Maximum water content
1.	10 mm	208 kg
2.	20 mm	186 kg
3.	40 mm	165 kg
The above table is for angular coarse aggregates and for 25 to 50mm slump range.		

iii.

Note:

a. The water estimates can be reduced by approximately 10 kg for sub-angular aggregates, 20 kg for gravel with some crushed particles & 25 kg for rounded gravel to produce same workability.
b. For desired workability (other than 25 to 50mm slump range) the required water content may be increased by about 3 percent for every additional 25mm slump or alternatively by use of chemical admixtures.
c. Water reducing admixtures usually decrease water content by 5 to 10 percent and 20 percent and above respectively at appropriate dosages.

iv. Cementitious material content

This may be calculated from the free water-cement ratio and the quantity of water per unit volume of concrete. The cementitious material content so calculated shall be checked for minimum content for the durability requirements and the greater of the two values adopted. The maximum cement content shall be as per IS: 456-2000.

v. Proportioning of coarse aggregate content

For a water-cement ratio of 0.5 approximate values of aggregate volume is given in the following table.

Table: Volume of coarse aggregate per unit volume of total Aggregate for different Zones of Fine Aggregate

S, No.	Nominal Maximum Size of Aggregate	Volume of Coarse Aggregate* per unit Volume of Total Aggregate for Different Zones of Fine Aggregate			
	mm	Zone IV	Zone III	Zone II	Zone I
1	2	3	4	5	6
i)	10	0.50	0.48	0.46	0.44
ii)	20	0.66	0.64	0.62	0.6
iii)	40	0.75	0.73	0.71	0.69
*Volumes are based on aggregates in saturated surface dry condition.					

Note:

a. Adjust volume of coarse aggregate for decrease in w/c ratio by 0.05 the increase in coarse aggregate by 1%.
b. For more workable concrete such as pumped concrete etc the above estimated coarse aggregate content may be reduced by up to 10%.

vi. Determination of Fine Aggregate Content:

This is obtained by finding out the absolute volume of cementitious material; water and the chemical admixture by dividing their masses to their specific gravity, multiplying by 1/1000 subtract the results of this summation from unit volume.

The above obtained values are distributed into coarse and fine aggregate fractions by volume in accordance with coarse aggregate fractions.

The coarse and fine aggregates contents are then determined by multiplying with their respective specific gravities and multiplying by 1000.

vii. Trial Mixes

The trial mixes shall be made and cubes be tested, if any discrepancies may be observed during concrete making it should be taken into considerations and more trial mixes be prepared and finally the mix which provides sufficient information, including the relationship between compressive strength, water cement ratio and slump, from which the mix proportions for field trials may be arrived at. The concrete for field trials shall be produced by methods of actual concrete production.

viii. Example

Grade of Designation	M-25
Type of Cement	PPC confirming to Is1489 – Part I
Maximum Nominal Size of Aggregate	20 mm
Minimum Cement Content	300 kg
Maximum water cement ratio	0.5
Workability	60 mm slump
Type of Aggregate	Crushed Angular aggregate
Maximum Cement Content	450 kg/m^3
Chemical Admixtures	Fosroc (as supplied)

Sieve Analysis of Coarse Aggregate						
IS sieve No	Analysis of Coarse Aggregate Fraction, % passing		Percentage of Different Fractions			Remarks
	I	II	I	II	Combined	
			30%	70%	100%	
20mm	81	100	24.3	70	94.3	Conforming to Table: 2 of IS383
10mm	0.8	47	.24	32.9	33.14	
4.75mm	0	4.4	0	3.08	3.08	
2.36mm	-	-	-	-	-	

IS sieve No	Percentage passing	Remarks
4.75mm	100	Conforming to Zone IV Table 4 of IS383
2.36mm	98.5	
1.18mm	96	
600 µm	85	
300 µm	3	
150 µm	0	

Target Mean Strength $F_t = f_{ck} + 1.65\ S$

$= 25 + 1.65 * 4.0$

$= 31.6\ N/mm^2$

The mix proportions obtained for above materials are:

Water : Cement : Sand : Aggregate = 184.5 lits: 410 kg: 606 kg : 1176 kg

w/c ratio = 0.45, 1 : 1.478 : 2.868

Admixture dose = 0.25 % of weight of cement in terms of volume of admixture.

Cube strength after 7 days = 24.0 N/mm^2, 20.88 N/mm^2, 22.22 N/mm^2

Average Value = 22.36 N/mm^2

Cube strength after 28 days = 31.11 N/mm^2, 34.66 N/mm^2, 31.11 N/mm^2

Average Value = 32.29 N/mm^2

II. Conclusions

The concrete mix produced with blended cements (PPC Cement) possesses nearly same quality as of OPC except with adjustments in water cement ratio as such the heat of hydration of PPC is lower than OPC the

cement content obtained is slightly higher for blended cements. Hence, it is concluded that with proper quality control and supervision at site, the effectiveness of concrete produced with blended cements will be increased. It will also satisfy the requirements of workability, strength and durability.

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