

Critical Comparative Study of OPC Based & PPC Based Nominal Mix Concretes

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Abstract:

This paper deals with assessing suitability of PPC for making of nominal mix concrete as per provisions in clause no. 9.3, table 9, p. no.23 of I.S. 456 -2000. For an internal study at Maharashtra Engineering Research Institute Nashik, three types of concrete specimens were cast in the laboratory with three nominal mix proportions (as per clause no. 9.3, table 9, p. no.23 of I.S. 456 -2000) using OPC 43 conforming to IS 8112 – 1989. Likewise, exactly three similar types of concrete specimens were cast in the laboratory with three similar nominal mix proportions (as per clause no. 9.3, table 9, p. no.23 of I.S. 456 -2000) using PPC conforming to IS 1489 (Part 1) - 1991. Apart from this, two more concrete specimens of higher grades were cast in the laboratory using OPC 43 as the binder. Likewise, exactly two similar concrete specimens of higher grades with similar mix proportions were cast in the laboratory using PPC as the binder. Thus, equal opportunity was given to OPC 43 & PPC for all five sets of concrete specimens. Compressive strengths at various ages were observed for each concrete specimen. Also, flexural strength at 28th day was observed for every concrete specimen. Comparative study reveals that PPC is not suitable for making of nominal mix concrete as per present norms of I.S. 456 because PPC is not producing the concrete of the desired/required strength. Hence, the relevant norms of I.S. 456 – 2000 need amendments.

Keywords: OPC, PPC, Cement, Concrete, IS 456-2000.

Introduction

Generally, Design mix concrete is preferred to nominal mix concrete. Design mix concrete is not only reliable but economical also. But, the process of concrete mix design is tedious & expensive. Hence in practice, the design mix concrete is used only for special works where quantities are large & grades are high. Nominal mix concrete is used for common works where quantities are small & the grades are low ie up to M20. Considering all these facts, norms are mentioned in I.S. 456 – 2000 (Indian standard code of practice for plain & reinforced concrete) for making of nominal mix concrete up to grade M20.(6)

Literature Review of I.S. 10262 - 2009

Various guidelines mentioned in the code are studied and illustrative examples mentioned in annexure A & B are also studied. As mentioned in the annexure A, the required quantity of OPC is 350

kg for 1 m³ of the concrete having grade M40. As mentioned in the annexure B, the required quantity of OPC is 270 kg along with 115 kg of fly ash for 1 m³ of the concrete having grade M40. But 270 kg of OPC along with 115 kg of fly ash is nothing but about 375 kg of PPC & 10 kg of fly ash (as per IS 1489 part 1 – 1991)(10). Thus on basis of this study, it is observed that the required mass of PPC is more than the required mass of OPC for the same grade of concrete having other parameters exactly same and other ingredients in almost same quantity.

After thoroughly studying the illustrative examples in Annex A & B, it is specifically mentioned here that for the same grade of concrete (having other ingredients in the same quantity), cement requirement is about 10 % more in case of PPC as compared to OPC. Hence the same logic should also be applicable to nominal mix concrete.

History of the I.S. Code 456

i) After independence, the first code of practice for plain & reinforced concrete (I.S. 456) was adopted by The Indian Standard Institution on 23.02.1957. As per clause 4.1 of this code, the cement to be used was OPC or Rapid hardening portland cement or Blast furnace cement or High alumina cement. Nominal mix proportions of the concrete (on volumetric basis) were given in table I of this code.(3)

ii) The code was revised in 1964. However as per clause 4.1 of this code, there was no change in the types of cement to be used. Nominal mix proportions of the concrete (on volumetric basis) were given in table 3 for various grades such as M10, M15, M20 & M25. The table is narrated as below.(4)

Table 1: Nominal mix proportions on volumetric basis (1964)

Grade of concrete	Total quantity of dry aggregates by volume per 50 kg of cement (Liter)	Quantity of water per 50 kg of cement (Liter)
M10	300	34
M15	220	32
M20	160	30
M25	100	27

NOTE :- Generally, average density of aggregates (in natural condition) is 1.5 kg/L. So, the quantities of aggregates for M10, M15, M20 & M25 would be 450, 330, 240 & 150 kg respectively.

iii) The code was again revised in 1978. As per clause 4.1 of this code, the cement to be used could be any of the following(5)

- OPC or Low heat portland cement
- Rapid hardening portland cement
- Portland slag cement
- PPC (Portland pozzolana cement)
- High strength OPC

f) Hydrophobic cement

Nominal mix proportions of the concrete (on mass basis) were given in table 3 for various grades such as M5, M7.5, M10, M15 & M20. The table is narrated as below.

Table 2: Nominal mix proportions on weight basis (1978)

Grade of concrete	Total quantity of dry aggregates by volume per 50 kg of cement (kg)	Quantity of water per 50 kg of cement (kg)
M5	800	60
M7.5	625	45
M10	480	34
M15	350	32
M20	250	30

NOTE :- Comparing ii) & iii), it is observed that there is no much difference in the nominal mix proportions for M10, M15 & M20. But, in this newly revised code, almost all types of cements were incorporated in the list of cement to be used. Hence, achieving the desired/required grade of concrete is doubtful due to incorporation of new type of cements whose binding capacity is less than the binding capacity of OPC. However it is recommended that they are to be used in the same quantity.

iv) The code is again revised in 2000. As per clause 5.1 of this code, some more types are added in the list of cement to be used. Nominal concrete mix proportions are given in the clause no. 9.3, table 9, p. no.23. It is observed that there is no change in the proportions except for M15 where 330 kg of the aggregate is to be used for 50 kg of cement instead of previously mentioned quantity i.e. 350 kg. So achieving the required grade of concrete is more doubtful due to incorporation of various types of cements & still using them in the same quantity.

Methodology for Experimental Study

For effective comparison, equal opportunity was provided to each type of cement i.e. OPC 43

conforming to IS 8112 - 1989 and PPC conforming to IS 1489 (Part 1) - 1991 & their performances were noted in terms of compressive and flexural strengths (9). Hence, taking all other ingredients in same quantity (natural sand, coarse aggregates & water), one mix was cast using OPC and the other mix was cast using PPC. Total 3 sets of mixes were cast (one each for M10, M15 & M20) using OPC & other 3 using PPC, as per the specifications give in table no. 9 of I.S. 456 - 2000. Apart from these, two more concrete specimens of higher grades were cast in the laboratory using OPC & the other two using PPC.

Nominal concrete mix proportions were adopted in totality for M10 & M15 grades, as per guidelines in the clause no. 9.3, table 9, p. no. 23 of IS 456 – 2000. Quantity of water used for M20 grade concrete was kept less than the maximum allowable limit. Proportions & properties of all concrete grades referred above are mentioned in table no. 2. Electrically operated tilting type batch mixer was used for concrete mixing. Concrete cube specimens were compacted using table vibrator.(2,6,7)

Computation of Target Mean Compressive Strength

(As per guidelines in clause no. 3.2, IS 10262 - 2009)

$$f'_{ck} = f_{ck} + 1.65 s$$

f'_{ck} = Target mean compressive strength @ 28 days in N/mm^2

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

s = Standard deviation in N/mm^2

Assume, $s = 3.5$ for M10 & M15

$s = 4.0$ for M20 & M25.

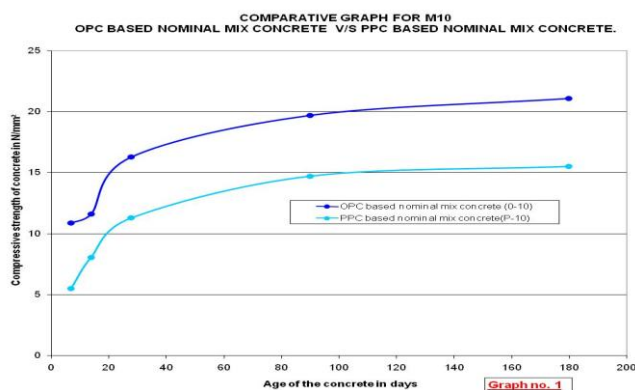
$s = 5.0$ for M30 to M55.

Table 3: Computation of Target Mean Compressive Strength(1)

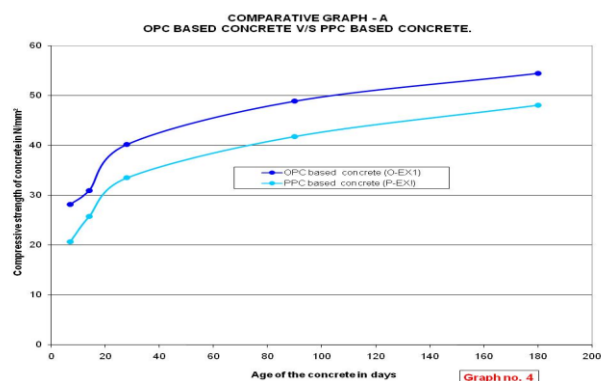
Grade of concrete	s (N/mm^2)	f_{ck} (N/mm^2)	f'_{ck} (N/mm^2)
M10	3.5	10	15.78
M15	3.5	15	20.78
M20	4.0	20	26.60
M25	4.0	25	31.60
M30	5.0	30	38.25
M35	5.0	35	43.25
M40	5.0	40	48.25

Sr. no. of the concrete mix	Notation mark of the concrete mix specimen	Quantities of various ingredients in kg.								Slump in mm	Flexural strength in N/mm ²	Compressive Strength of concrete in N/mm ²					Expected grade of concrete as per I.S. 456-2000	Observed grade of the concrete	Remarks
		Cement		Water	Coarse Aggregates			Fine aggregate (Natural sand)	Plasticizer (ml)			7 days	14 days	28 days	90 days	180 days			
		OPC 43	PPC	Litre	40 MSA	20 MSA	10 MSA												
1	O-10	50	-	34	106.67	106.667	106.667	160	-	0	3.07	10.87	11.6	16.29	19.7	21.09	M10	M10	
2	P-10	-	50	34	106.67	106.667	106.667	160	-	0	1.80	5.50	8.06	11.29	14.71	15.51	M10	M7.5	Not reliable
3	O-15	50	-	32	73.333	73.333	73.333	110	-	35	3.35	16.31	19.91	25.24	27.33	30.64	M15	M15	
4	P-15	-	50	32	73.333	73.333	73.333	110	-	30	2.70	9.02	11.38	15.91	24.35	26.25	M15	M10	Not reliable
5	O-20	50	-	26.110	55.555	55.555	55.555	83.33	-	65	4.70	21.42	27.33	32.22	39.47	42.07	M20	M25	
6	P-20	-	50	26.110	55.555	55.555	55.555	83.33	-	50	4.06	17.42	20.70	25.01	38.04	40.51	M20	M15	Not reliable
7	O-EX1	50	-	22.62	Nil	71.430	71.430	71.43	-	45	5.87	28.19	30.98	40.20	48.86	54.43		M30	
8	P-EX1	-	50	22.62	Nil	71.430	71.430	71.43	-	50	4.27	20.67	25.73	33.47	41.75	48.02		M25	
9	O-EX2	50	-	19.05	Nil	71.430	71.430	71.43	280	13	6.00	42.87	45.63	50.75	59.45	67.71		M40	
10	P-EX2	-	50	19.05	Nil	71.430	71.430	71.43	280	20	5.47	31.99	38.03	44.13	54.05	62.01		M35	

Table 4 : Mix proportions of concrete, Slump, Flexural strength & Compressive strengths(11)



Graph 1: Comparative graph for compressive strengths of M10 mixes

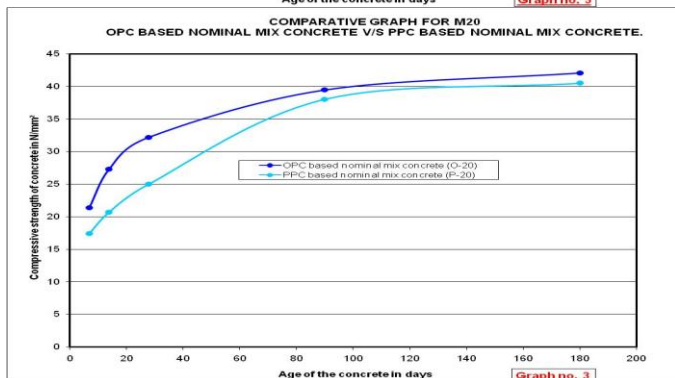
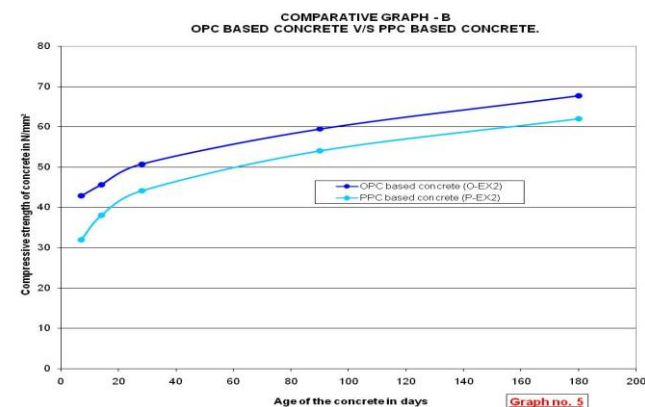
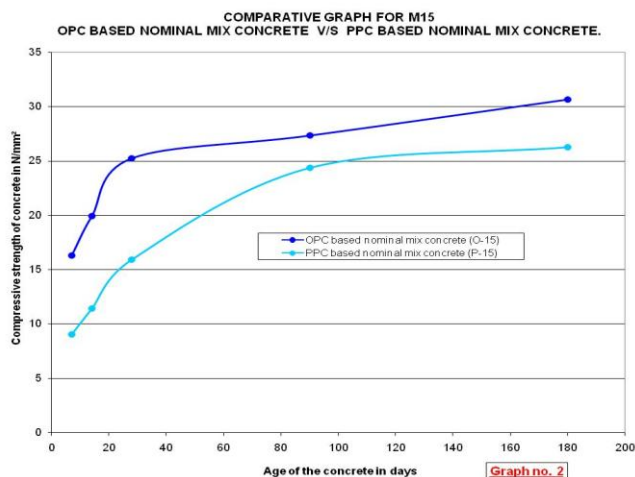


Conclusions and Recommendations

1. PPC (conforming to IS 1489 (Part 1) – 1991) based nominal mix concrete has shown (on an average) 21.18% less 28 days laboratory compressive strength as compared to OPC 43 (conforming to IS 8112–1989) based nominal mix concrete.
2. PPC based nominal mix concrete has shown (on an average) 20.40% less flexural strength as compared to OPC based nominal mix concrete.
3. Concretes cast by nominal mix proportions using PPC as a binder (as per provisions given in clause no. 9.3, table 9, p. no.23 of I.S. 456 -2000) does not yield the required strengths & hence such PPC based nominal mix concretes are not reliable.
4. The quantity of PPC should be 10 % more as compared to quantity of OPC for making of nominal mix concrete. The relevant clause no 9.3 & the table 9 of I.S. 456-2000 is to be amended immediately.

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