JIPC - P -70

Jr. of Industrial Pollution Control 27(1)(2011) pp 43-49

CEMENT AND WATER SAVING WITH WATER REDUCERS

KAUSHAL KISHORE

Materials Engineer, Roorkee, U.K., India

Key words : CO2, Cement, Flyash, Water reducers, Mix design, Pollution

ABSTRACT

In the production of cement considerable amount of CO_2 is emitted in the atmosphere. With the use of water reducers same construction may be done with less cement. Thus les cement will be required to be produce by cement factories resulting less CO_2 will be emitted into the atmosphere. The paper gives method of mix design with water reducers.

INTRODUCTION

In India 0.93 kg of CO_2 is emitted in the production of one kg of cement. In the financial year 2009-10 India produces 200 million tonnes of cement. In the production of this cement 186 million tonnes of CO_2 was emitted in the atmosphere during financial year of 2009-10.

The availability of water in India per person per year in 1950 was 5177 cu.m. In the year 2009 it is reduces to 1700 cu.m.

If 50 million tonnes cement in making concrete uses water reducers 7500000 tonnes of cement can be saved. 3750000 kL of potable water will be saved and the saving of Rs. 3300 crores per year to construction industry. This amount is worked out after adjusting the cost of water reducers. Less cement used means less cement required to be produce by the cement factories resulting 6975000 tonnes of CO_2 will be prevented to be emitted to the atmosphere. These are worked out with an average saving of 15% cement and 15% water.

CO_2 emission is a global problem, but for India in addition to CO_2 it has problems of Air, Water, Soil, Food and Noise pollutions. Less densily populated countries may cope with these problems but for India it is of the top concern. The population figures of 2009 is, India 350 person per sq.km, China 132 person per sq.km and USA only 34 person per sq.km. The figures of 2006 CO_2 emissions are USA 658.60 tonnes per sq.km, China 611.76 tonnes per sq.km and India 459.35 tonnes per sq.km. Every one should contribute his or her efforts to save the environment from pollution. Those involved in the construction activities can contribute their share by proper design of concrete Mixes. This is best illustrated by the following examples.

TEST DATA FOR MATERIALS

1. The grading of fine aggregate, 10 & 20 mm aggregates are as given in Table 1. Fine aggregate is

Address for correspondence - New House No. - 571 (Old H.No. - 152/7A), Solani Puram, Behind Shiv Temple Malakpur, Roorkee - 247 667, Email : kkmengg@yahoo.co.in

MIX DESIGN DETAILS

1	Grad of Concrete	:	M-30
2	Cement	:	Three mixes are to be designed **MIX-A** With PPC (Flyash based) conforming to IS:1489-part-I-1991. 7 days strength 38.5 N/mm². Specific Gravity : 3.00 **MIX-B** With OPC-43- Grade conforming to IS: 8112-1989. 7 days strength 40.7 N/mm². Specific Gravity : 3.15 **MIX-C** With OPC of Mix-B and Fly ash conforming to IS:3812 (Part- I)-2003 Specific Gravity : 2.25 **Note :** Requirements of all the three mixes are the same. Fine Aggregate, Coarse Aggregate and Normal Super plasticizer are the same for all the three mixes.
3	Fly ash replacement	:	30% Fly ash is required to be replaced with the total cementitious materials.
4	Maximum nominal size of aggregates	:	20 mm Crushed aggregate
5	Fine aggregate	:	River sand of Zone-II as per IS:383-1970
6	Minimum cement content	:	320 kg/m3 including Fly ash
7	Maximum free W/C Ratio	:	0.45
8	Workability	:	50 mm slump
9	Exposure condition	:	Severe for RCC work
10	Method of placing	:	Site mixing
11	Degree of supervision	:	Good
12	Maximum of cement content (Fly ash not included)	:	450 kg/m³
13	Chemical admixture	:	Super plasticizer conforming to IS:9103-1999. With the given requirements and materials, the manufacturer of Normal Super plasticizer recommends dosages of 17 gm per kg of OPC, which will reduce 24% of water without loss of workability. For fly ash included cement dosages will be required to be adjusted by experience/ trials.

of zone-II as per IS:383-1970. 10 and 20 mm crushed aggregate grading are single sized as per IS: 383-1970.

2. Properties of aggregates

Tests	Fine aggregate	10 mm aggregate	40 mm aggregate
Specific Gravity	2.65	2.65	2.65
Water Absorption %	0.8	0.5	0.5

3. Target strength for all A, B and C mixes

fck = fck + 1.65 x S
30 + 1.65 x 5
= 38.3 N/mm² at 28 days age

4. For Mix A and B free W/C ratio with crushed aggregate and required target strength of 38.3 N/mm² at 28 days from Fig. 1 Curve D found to be 0.45. Taking into the consideration of water in admixture, let it be 0.44. This is lower than specified maximum W/C ratio value of 0.45.

Note:
In absence of cement strength, but cement conforming to IS Codes, assume from Fig. 1 and 2.

Curve A and B	for OPC 33 Grade
Curve C and D	for OPC 43 Grade
Curve E and F	for OPC 53 Grade

Take curves C and D for PPC, as PPC is now being manufactured in minimum of 43 Grade of strength.

5. Other data's: The Mixes are to be designed on the basis of saturated and surface dry aggregates. At the time of concreting, moisture content of site aggregates are to be determine. If it carries surface moisture this is to be deducted from the mixing water and if it is dry add in mixing water the quantity of water required for absorption. The weight of aggregates are also adjusted accordingly.

DESIGN OF MIX-A WITH PPC

a) Free W/C ratio for the target strength of 38.3 N/mm ² as worked out is 0.44.
b) Free water for 50 mm slump from Table 2 for 20 mm maximum size of aggregate.

$$\frac{2}{3} X\,180 + \frac{1}{3} X\,210$$

= 190 kg/m³

From trials it is found that Normal Super plasticizer at a dosages of 20gm/kg of cement may reduce 24% water without loss of workability

Then water = 190 – (190 x 0.24) = 144.4 kg/m³
for trials say 145 kg/m³

c) PPC = 145/0.44 = 329.5 kg/m³
Say 330 kg/m³. This is higher than minimum requirement of 320 kg/m³

d) Formula for calculation of fresh concrete weight in kg/m³

U_M $10 \times G_a (100 – A) + C_M(1 – G_a/G_c) – W_M (G_a – 1)$

Where,
U_m = Wight of fresh concrete kg/m³
G_a = Weighted average specific gravity of combined fine and coarse aggregate bulk, SSD
G_c= Specific gravity of cement. Determine actual value, in absence assume 3.15 for OPC and 3.00 for PPC (Fly ash based)
A = Air content, percent. Assume entrapped air 1% for 40 mm maximum size of aggregate, 1.5% for 20 mm maximum size of aggregate and 2.5% for 10mm maximum size of aggregate. There are always entrapped air in concrete. Therefore ignoring entrapped air value as NIL will lead the calculation of higher value of density.
W_m = Mixing water required in kg/m³
C_m = Cement required, kg/m³

Note: The exact density may be obtained by filling and fully compacting constant volume suitable metal container from the trial batches of calculated design mixes. The mix be altered with the actual obtained density of the mix.

U_m = $10 \times G_a (100 – A) + C_m (1 – G_a/G_c) – Wm (G_a – 1)$
=10 x 2.65 (100 –1.5) + 330(1- 2.65/3.00)–145 (2.65 -1)
2409.6 kg/m³
Say 2410 kg/m3

e) aggregates = 2410 – 330 – 145 = 1935 kg/m³

f) Fine aggregate = From Table 3 for zone-II Fine aggregate and 20 mm maximum size of aggregate, W/C ratio = 0.44, 50 mm slump (Low Workability) found to be 34%.
Fine aggregate = 1935 x 0.34 = 658 kg/m³
Coarse aggregate = 1935 – 658 = 1277 kg/m³
10 and 20 mm aggregate are single sized as per IS: 383-1970. Let they be combined in the ratio of 1.2:1.8 to get 20 mm graded aggregate as per IS: 383-1970
10 mm aggregate = 510 kg/m³
20 mm aggregate = 767 kg/m³

g) Thus for M-30 Grade of concrete quantity of materials per cu.m. of concrete on the basis of saturated and surface dry aggregates:

Water	=	145 kg/m³
PPC	=	330 kg/m³
Fine Aggregate (sand)	=	658 kg/m³
10 mm Aggregate	=	510 kg/m³
20 mm Aggregate	=	767 kg/m³
Normal Super Plasticizer	=	6.6 kg/m³

MIX- B WITH OPC

a) Water = 190 – (190 x 0.24) = 144.4 kg/m³ say 145 kg/m³
b) OPC = 145/0.44 = say 330 kg/m³
c) Density
10 x 2.65 (100 – 1.5) + 330 (1 – 2.65/3.15) – 145 (2.65 – 1)
= 2423.5 kg/m³ say 2425 kg/m³
d) Total Aggregates = 2425–145 – 330 = 1950 kg/m³
Fine Aggregate = 1950 x 0.34 = say 663 kg/m³
Coarse aggregate = 1950 – 663 = 1287 kg/m³
10 mm Aggregate = 1287x1.2/3 = 515 kg/m³
20 mm Aggregate = 1287x1.8/3 = 772 kg/m³

e) Thus for M-30 Grade of concrete quantity of materials per cu.m of concrete on the basis of SSD aggregates are given below:

Water	=	145 kg/m^3
OPC	=	330 kg/m^3
Fine Aggregate (sand)	=	663 kg/m^3
10 mm Aggregate	=	515 kg/m^3
20 mm Aggregate	=	772 kg/m^3
Normal Super Plasticizer	=	5.610 kg/m3

MIX. C WITH OPC + FLYASH

With the given set of materials increase in cementitious materials = 12% ,Total cementitious materials = 330 x 1.12 = 370 kg/m^3

Materials		Weight	Volume (kg/m^3)
(m^3)			
OPC =	370 x 0.70	259/3150	0.0822
Flyash =	370x 0.30	111/2250	0.0493
Free Water =	145 x 0.95	138/1000	0.138
Normal Super Plasticizer =	7.5kg	7.5/1150	0.0065
Air =	1.5%		0.015
		Total =	0.291
Total Aggregates = 1–0.291			0.709
		=	1.00
Coarse Aggregate		1287/2650	0.4857
Fine Aggregate		=	0.709 – 0.4857 = 0.2233
	=	0.2233 x 2650 =	592 kg

Note:

1. Specific gravity of Normal Superplasticizer = 1.15
2. Addition of Flyash reduces 5% of water demand.

M-30 Grade of concrete quantity of material per cu.m of concrete on the basis of saturated and surface dry aggregates of Mix 'A', 'B' and 'c' are given below:

Materials	MIX.'A' with PPC	Mix.'B' with OPC	Mix.'C' withOPC +Flyash
Water kg/m^3	145	145	138
PPC kg/m^3	330	--	--
OPC kg/m^3	--	330	259
Flyash kg/m^3	--	--	111
Fine Agg. kg/m^3	658	663	592
10mm Agg. kg/m^3	510	515	515
20mm Agg. kg/m^3	767	772	772
Normal Super - plasticizer kg/m^3	6.6	5.61	7.5
W/Cementations ratio	0.44	0.44	0.373

Note :

1. For exact W/C ratio the water in admixture should also be taken into account.
2. The W/C ratio of PPC and OPC is taken the same assuming that the strength properties of both are the same. If it is found that the PPC is giving the low strength then W/C ratio of PPC have to be reduce, which will increase the cement content. For getting early strength and in cold climate the W/C ratio of PPC shall also be required to be reduced.
3. PPC reduces 5% water demand. If this is found by trial then take reduce water for calculation.
4. If the trial mixes does not gives the required properties of the mix, it is then required to be altered accordingly. However, when the experiences grows with the particular set of materials and site conditions very few trials will be required and a expert of such site very rarely will be required a 2nd trial.

CONCLUSION

1. For M-30 Grade concrete having same material and requirement, but without water reducer, the PPC and OPC required will be 190/0.45 = 422kg/m^3
2. With the use of superplasticizer the saving in cement is 92 kg/m^3 and water 45 lit/m3 for PPC and OPC.
3. In the Fly ash concrete the saving in cement is 163 kg/m^3 and water 52 lit/m^3 including utilization of 111 kg/m^3 of fly ash witch is a waste material.
4. If 50 million tonnes cement in making concrete uses Water Reducers 7500000 tonnes of cement can be saved. 3750000 KL of potable water will be saved and the saving of Rs. 3300 crores per year to the construction Industry. 6975000 tonnes of CO_2 will be prevented to be emitted to the atmosphere. The

Table 1. Grading of aggregates

IS Sieve designation	Percentage passing		
	Fine aggregate	Crushed aggregate	
		10 mm	20 mm
40 mm	--	--	100
20 mm	--	--	100
12.5 mm	--	100	--
10 mm	100	85	4
4.75 mm	99	5	0
2.36 mm	88	0	
1.18 mm	74		
600 Micron	43		
300 Micron	24		
150 Micron	6		

Table 2. Approximate free-water content (kg/m3) required to give various levels of workability for non-air-entrained (with normal entrapped air) concrete.

Maximum size of aggregate (mm)	Type of aggregate	Slump (mm) Degree of workability vary low	25-75 Low	50-100 Medium	100-180 High
10	Uncrushed Crushed	150	205	220	240
	Crushed	180	235	250	265
20	Uncrushed Crushed	140	180	195	210
	Crushed	170	210	225	245
40	Uncrushed Crushed	120	160	175	190
	Crushed	155	190	205	220

Note : When coarse and fine aggregate of different types are used, the free water content is estimated by the expression.

$$\underline{\overset{2}{W_f}} + \underline{\overset{1}{W_c}}$$

Where, Wf = Free water content appropriate to type of fine aggregate
And Wc = Free water content appropriate to type of coarse aggregate.

Table 3. Proportion of fine aggregate (percent) with 10mm and 20mm maximum sizes of aggregates and with different workability.

Grading Zone of F.A	W/C Ratio	10 mm aggregate Workability				20 mm aggregate Workability			
		VL	L	M	H	VL	L	M	H
I	0.3	43-53	46-56	49-60	54-67	32-39	35-42	39-47	44-53
	0.4	46-56	48-58	51-62	57-69	34-42	37-45	41-49	46-56
	0.5	48-58	50-61	53-65	59-72	37-45	39-47	43-52	48-59
	0.6	50-61	52-63	56-68	62-75	39-47	41-50	45-54	50-61
	0.7	52-64	55-66	58-70	64-77	41-50	44-53	47-57	53-64
II	0.3	36-43	37-46	40-49	44-54	27-32	28-35	32-39	35-44
	0.4	37-46	39-48	42-51	46-57	28-34	30-37	33-41	37-46
	0.5	39-48	41-50	44-53	47-59	30-37	32-39	35-43	39-48
	0.6	41-50	42-52	45-56	49-62	32-39	34-41	36-45	41-50
	0.7	42-52	44-55	47-58	51-64	34-41	36-44	38-47	43-53
III	0.3	29-36	32-37	33-40	37-44	23-27	24-28	27-32	30-35
	0.4	31-37	33-39	35-42	38-46	24-28	26-30	28-33	31-37
	0.5	32-39	34-41	36-44	40-47	25-30	27-32	29-35	33-39
	0.6	34-41	36-42	38-45	42-49	27-32	29-34	31-36	35-41
	0.7	35-42	37-44	39-47	43-51	28-34	30-36	32-38	36-43
IV	0.3	26-29	27-32	29-33	32-37	19-23	21-24	23-27	26-30
	0.4	27-31	29-33	30-35	34-38	21-24	22-26	24-28	28-31
	0.5	28-32	30-34	32-36	35-40	22-25	24-27	26-29	29-33
	0.6	30-34	31-36	33-38	36-42	23-27	25-29	27-31	30-35
	0.7	31-35	32-37	35-39	37-43	25-28	26-30	28-32	32-36

Table 4. Proportion of fine aggregate (percent) with 40 mm maximum sizes of Aggregates and with different workability.

Grading Zone of F.A	W/C Ratio	40 mm aggregate Workability VL	L	M	H
I	0.3	27-33	29-35	33-39	38-46
	0.4	29-35	31-38	35-42	41-49
	0.5	31-38	33-41	37-44	43-52
	0.6	33-41	36-43	39-47	45-54
	0.7	36-44	38-46	42-50	47-57
II	0.3	22-27	23-29	27-33	31-28
	0.4	24-29	25-31	28-35	32-41
	0.5	25-31	27-33	30-37	34-43
	0.6	27-33	29-36	32-39	36-45
	0.7	29-36	31-38	34-42	38-47
III	0.3	18-22	20-23	22-27	26-31
	0.4	20-24	21-25	24-28	27-32
	0.5	21-25	23-27	25-30	29-34
	0.6	23-27	24-29	27-32	30-36
	0.7	24-29	26-31	29-34	32-36
IV	0.3	16-18	18-20	19-22	22-26
	0.4	17-20	19-21	20-24	24-27
	0.5	18-21	20-23	22-25	25-29
	0.6	20-23	22-24	23-27	26-30
	0.7	21-24	23-26	25-29	28-32

VL = Very low workability; L = Low workability – slump 25-75 mm ;
M = medium workability – slump 50-100 mm ; H = High workability- slump 100-180 mm

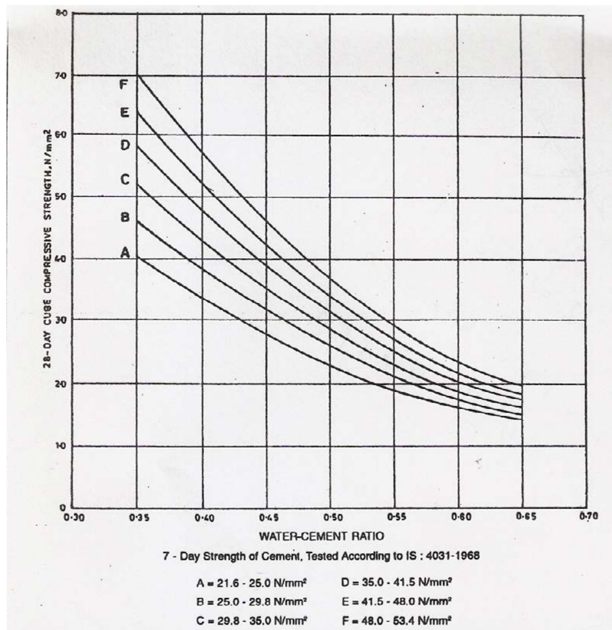

Fig. 1 Relation between free water / cement ratio and concrete compressive strength for different cement stremgth using crushed aggregate

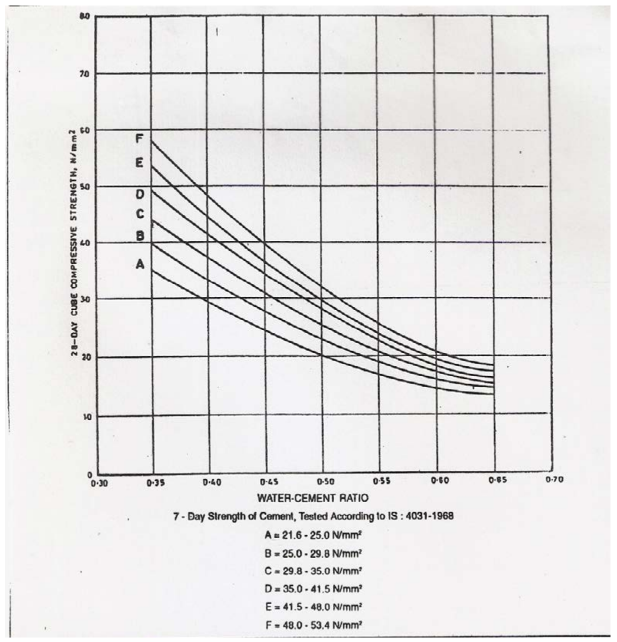

Fig. 2 Relation between free water / cement ratio and concrete compressive strength for different cement stremgth using uncrushed aggregate

benefits in the uses of water reducers not limited to this. When water reduces shrinkage and porosity of concrete are reduces which provides the durability to concrete structures.

6. India is facing serious air, water, soil, food and noise pollution problems. Every efforts therefore are necessary to prevent pollution on top priority basis.

REFERENCES

IS : 383-1970. Specifications for coarse and fine aggregates from natural sources for concrete (second revision) BIS, New Delhi.

IS: 456-2000. Code of practice for plain and reinforced concrete (fourth revision), BIS, New Delhi.

IS: 9103-1999. Specification for admixtures for concrete (first revision) BIS, New Delhi.

IS: 8112-1989. Specifications for 43 Grade ordinary portland cement (first revision) BIS, New Delhi.

IS: 2386 (Part-III) 1963. Method of test for aggregate for concrete. Specific gravity, density, voids, absorption and bulking, BIS, New Delhi.

IS: 3812 (Part-I) 2003. Specification for pulverized fuel ash: Part-I for use as pozzolana in cement, cement mortar and concrete (second revision) BIS, New Delhi.

IS: 1489-Part-I 1991. Specifications for portland pozzolana cement (Part-I) Flyash based. (Third revision), BIS, New Delhi.

Kishore Kaushal, 1978. Design of concrete mixes with high-strength ordinary Portland cement. *The Indian Concrete Journal*. 103-104

Kishore Kaushal, 1986. Concrete mix design. *A Manual Published for Structural Engineering Studies*, Civil Engineering Department, University of Roorkee.

Kishore Kaushal, 1988. Concrete mix design based on flexural strength for air-entrained concrete. *Proceeding of 13th Conference on our World in Concrete and Structures, 25-26, August, 1988*, Singapore.

Kishore Kaushal, 1988. Concrete mix design. *Indian Concrete Institute Bulletin*. 27-40 and ICI Bulletin December, 1988 : 21-31.

Kishore Kaushal, 1988. Method of concrete mix design based on flexural strength. *Proceeding of the International Conference on Road and Road Transport Problems ICORT, 12-15 December, 1988*, New Delhi, pp. 296-305.

Kishore Kaushal, 1989. Mix design based on flexural strength of air-entrained concrete. *The Indian Concrete Journal*. 93-97.

Kishore Kaushal, 1989. Concrete mix design. *VIII All India Builders Convention 29-31, January, 1989*, Hyderabad, organized by Builders Association of India, Proceeding Volume pp. 213-260.

Kishore Kaushal, 1990. Concrete mix design containing chemical admixtures. *Journal of the National Building Organization*. 1-12.

Kishore Kaushal, 1991. Concrete mix design for road bridges. *Indian Highways*. 19 (11) : 31-37

Kishore Kaushal, 1991. A Concrete Design. *Indian Architect and Builder*. 54-56

Kishore Kaushal, 1992. Mix design for pumped concrete. *Journal of Central Board of Irrigation and Power*. 49 (2) : 81-92.

Kishore Kaushal, 1995. Concrete mix design with fly ash. *Indian Construction*. 16-17.

Kishore Kaushal, 1995. High-strength concrete. *Civil Engineering and Construction Review*, March, 1995, pp. 57-61.

Kishore Kaushal, 1995. High-strength concrete. *Bulletin of Indian Concrete Institute*. 51 : 29-31

Kishore Kaushal, 1996. Mix design of polymer-modified mortars and concrete. *New Building Materials & Construction*. 19-23.

Kishore Kaushal, 1996. Concrete mix design simplified. *Indian Concrete Institute Bulletin*. 56 : 25-30.

Kishore Kaushal, Concrete mix design. *A Manual* Published by M/S Roffe Construction Chemicals Pvt. Ltd., Mumbai, pp. 1-36

Kishore Kaushal, 1997. Concrete mix design with fly ash and superplasticizer. *ICI Bulletin* 59 : 29-30

Kishore Kaushal, 2006. Mix design for pumped concrete. *CE & CR*. 44-50.