

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 1, January 2015

Efficacy of Established Standard Deviation on M30 Grade Concrete

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ABSTRACT: Concrete is a very common construction material and only design mix concrete is permitted for M25 and higher grade. For this study, M30 grade concrete mix was designed by using 53 grade ordinary Portland cement (OPC)¹, 20 mm angular graded aggregate of nominal size and zone III river sand². Based on guidelines of IS 456 : 2000 and IS 10262 : 2009, assumed standard deviation (SD) was used for calculating target mean. From final mix concrete, samples were tested and result of 32 samples were analysed and established SD was calculated. Value of established SD was found 2.43 N/mm² against the assumed standard deviation 5.0 N/mm². Corresponding to the established SD, water cement ratio was 0.4725 and cement content in the proportioned mix was reduced by 31.98 kg/m³ of concrete.

KEYWORDS: Concrete, M30 grade concrete, Cement content, Standard deviation,

I. INTRODUCTION

Concrete is used in various construction activities and its basic ingredients are cement, fine aggregate (sand), coarse aggregate, water and admixtures, if any. By using cement and locally available ingredients, concrete is produced at construction site or at suitable industrial plants. The ingredients are mixed in known proportion same is finalised by two ways: based on tradition ratio and as per design of concrete mix. Design mix concrete proportion is finalised by codal provisions, considering properties of ingredients, quality control of concrete production and other specific requirements. For design mix, target strength is estimated for probability factor corresponding to 5% failure of test results and assumed standard deviation (SD) for particular grade of concrete^{3,4}. For the same target strength, concrete mix is designed and minimum 30 samples from fresh concrete are taken and cubes are made, cured and tested at 28 days⁵. Standard deviation is established from the test results samples and this is brought up-to-date after every change of mix proportioning, materials used and changes in concrete production system. Standard deviation is established by using even using less than 30 sample results and in such cases SD should be multiplied by factors 1.16, 1.08, 1.03 and 1.0 for 15, 20, 25 and 30 or more samples respectively⁶. Marcia (1997) discussed optimisation of concrete mixtures by statistical methods and found the residual standard deviation 3.39 N/mm² for 36 samples⁷. Concrete required for a plain concrete pavement constructed in North Dakota for specified compressive of 35 MPa at 28 days, the standard deviation of 2.0 N/mm² is reported for particular producer⁸. Malagavelli et.al (2012) studied strength of concrete by using four different types of super plasticizers and found established SD within the range of 0.73 to 3.41 N/mm² for concrete samples with plasticisers and 1.33 N/mm² for concrete samples without super plasticiser⁹.

In absence of established standard deviation, assumed standard deviation given in Table 8 of IS 456 : 2009 is used for target strength calculation. The values of assumed standard deviations are 3.5 N/mm² for M10 and M15 grade concrete, 4.0 N/mm² for M20 and M25 and 5.0 N/mm² for M30 and higher grade concrete. In absence of appropriate quality control measures, the values of assumed SD are increased by 1 N/mm² and these SD values are used for designing up

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to M55 grade concrete mixes. Based on the adequate past records for a similar grade of concrete, justifying the designer, an appropriate value of SD, different than that of given in Table 8, is also permissible.

For the given set of ingredients in concrete mixes, cement content increases in higher grade of concrete. Due to increase in heat of hydration, increased risk of cracking due to drying and shrinkage in thin sections, early thermal cracking and increased risk of damage due to alkali silica reactions, maximum use of ordinary Portland cement (OPC) in concrete is limited to 450 kg/m^3 (sub section 8.2.4.2 IS 456 : 2000). Accordingly, in higher strength concrete, cement content is to be maintained within permissible limit by adopting appropriate measures without compromising strength and durability parameters. Initially for designing concrete mix of a given characteristic strength, target strength is determined adopting assumed standard deviation. By observing good quality control measures for producing homogeneous concrete mix, established standard has lower value. Based on established SD values, target strength reduces and in turn resulting increase in w/c and decrease in cement content for the same grade of concrete.

II. RELATED WORK

For M30 grade concrete, 53 grade ordinary Portland cement (OPC), 20 mm graded angular coarse aggregate of nominal size and river sand conforming to zone III were used. Specific gravity of coarse and fine aggregate was 2.78 and 2.706 respectively. Target strength calculated using assumed value of standard deviation with uncontrolled site condition was 39.90 N/mm^2 . For 25 – 50 slump value and severe exposure condition, proportion for trial mix I was calculated as per IS 10262 : 2009 and given as Appendix . Fresh concrete was made from the same proportion (Table – I) and slump value was found 30 mm. The mix proportion was designated as trial mix II and cubes were casted. Varying w/c $\pm 10\%$, proportions for trail mixes III and IV were calculated and cubes were casted from both mixes. After 28 days under water curing, cube samples from all trial mixes were tested and results were checked for acceptance criteria. Mean values for all three sets of samples were calculated and using these values graph was plotted. Corresponding to target strength, w/c for final mix was found from the same plot (Figure – 1) and using w/c as 0.473, final mix proportion was calculated. From final mix concrete proportion 33 cube samples were tested and validity of tests results, as per clause 15.4 of IS 456 : 2000, was checked. All tests results were valid and given in Table -2. Valid tests results of 32 samples were arranged in 8 groups of four non overlapping consecutive sample sets and results of all groups were checked for acceptance criteria based on provisions of table – 11, section 16.1 and 16.3 of IS 456 : 2000. Test results of all samples were satisfying the acceptance criteria for mean of the group of four cubes and individual strength requirement of each cube. From all 32 acceptable results, mean strength and established standard deviation were calculated (Table – 4). Using established SD, target strength was recalculated and for the same target strength w/c was calculated and concrete mix proportion was calculated again. Cement content for the same mix was found 393.63 kg/m^3 of concrete.

III. RESULT AND DISCUSSION

Average compressive strength of trail mix II, III and IV samples was 37.25 N/mm^2 , 30.25 N/mm^2 and 43.50 N/mm^2 respectively. For assumed SD, target strength was 39.9 N/mm^2 and the value of water cement ratio (0.437) for final mix was obtained from figure – 1. Cement content of final mix was 425.63 N/mm^2 . Compressive strength results of 33 samples were ranging between 32.89 N/mm^2 to 42.22 N/mm^2 (Figure – 2). Maximum and minimum values of mean strength of three cube sets were 35.407 N/mm^2 and 37.963 N/mm^2 from sixth and eighth set respectively. Upper and lower limit for validity for the same sets were 40.72 N/mm^2 and 30.10 N/mm^2 ; and 43.66 N/mm^2 and 32.27 N/mm^2 respectively. For acceptance criteria, highest and lowest values for four consecutive non overlapping samples were 35.47 N/mm^2 and 39.39 N/mm^2 for third and sixth group respectively. Minimum strength for a group of four consecutive non overlapping and individual samples were 34.13 N/mm^2 and 26 N/mm^2 respectively. Mean value and established standard deviation of 32 accepted sample results were 36.67 N/mm^2 and 2.43 N/mm^2 respectively. Using established SD, target strength reduced from 39.90 N/mm^2 to 35.64 N/mm^2 . For the same value of target strength, cement content was 393.65 kg/m^3 of concrete 8.12% saving in cement content.

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For optimal use of resources, final mix design proportion should be recalculated by using established standard deviation obtained from test results of samples from initial works.

REFERENCES

- [1] IS 12269 Specification for 53 Grade Ordinary Portland Cement, BIS, New Delhi – 110002, 987 (Reaffirmed 1999)
- [2] IS 383 Specification for Coarse and Fine Aggregates from Natural Sources for concrete, BIS, New Delhi – 110002, 1970 (Reaffirmed 2002)
- [3] IS 456 Plain and Reinforced Concrete - Code of Practice (Fourth Revision), BIS, New Delhi – 110002, 2000
- [4] IS 10262 Recommended Guidelines for Mix Design, BIS, New Delhi – 110002, 2009.
- [5] IS 516 Methods of Tests for Strength of Concrete, BIS, New Delhi – 110002, 1959 (Reaffirmed 1999)
- [6] ACI 318-95 / 318R-95 : 1995 Building Code Requirements for Structural Concrete and Commentary, American Concrete Institute, Farmington Hills, MI 4833, pp-44, 1995.
- [7] Marcia J. Samon, (1997), "Concrete Mixture Optimisation Using Statistical Mixture design Methods", International Symposium on High Performance Concrete, New Orleans, Louisiana, October 20-22, 1997, pp 230-244.
- [8] Portland Cement Association, "Design and Control of Concrete Mixtures(13th ed) (EB-001)", Chapter 9, pp166, 2012)
- [9] Malagavelli V. and Paturu N. R. "Strength and Workability Characteristics of Concrete by Using Different Super-plasticizers", International Journal of Materials Engineering 2012, 2(1): 7-11

APPENDIX

Concrete Mix Design for M₃₀ Grade Concrete

Stipulations for proportioning and test data for materials:

- | | | |
|---|---|---------------------------|
| a) Grade designation | : | M30 |
| b) Type of cement | : | OPC 53Grade |
| c) Maximum nominal size of aggregate | : | 20 mm |
| d) Minimum cement content | : | 320 kg/m ³ |
| e) Maximum water cement ratio | : | 0.45 |
| f) Workability | : | 25 - 50 mm (slump) |
| g) Exposure condition | : | severe |
| h) Degree of supervision | : | partially uncontrol |
| i) Type of aggregate | : | crushed angular aggregate |
| j) Maximum cement content | : | 450 kg/m ³ |
| k) Specific gravity of coarse aggregate | : | 2.78 |
| l) Specific gravity of fine aggregate | : | 2.701 |
| m) Specific gravity of cement | : | 3.15 |

Target strength (f_t) for mix proportioning

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

f_{ck} = characteristic compressive strength at 28 days, and
s = standard deviation.

$$\begin{aligned} \text{Target mean strength} &= 30 + 1.65 \times (5+1) \\ &= 39.90 \text{ N/mm}^2 \end{aligned}$$

Selection of water-cement ratio and water content

Value of maximum water-cement, 0.45 was selected for mix proportioning. For 20 mm graded angular aggregate of nominal size and 25 – 50 mm slump value, water content was 186 l/m³ of concrete.

Calculation of cement content and checking for minimum cement content

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For selected water cement ratio 0.45 and water content 186.0 l/m^3 of concrete, cement content was calculated as = $186/0.45 = 413.33 \text{ kg / m}^3$.

Cement content as above was higher than minimum cement content for severe exposure conditions within permissible range.

Proportion of volume of coarse aggregate and fine aggregate content

From IS 10262 : 2009, table no. 3, pg. 3, volume of coarse aggregate in all aggregate fraction corresponding to 20 mm size aggregate and fine aggregate (zone III) for water cement ratio 0.50 was found 0.64. For the selected case water-cement ratio as 0.45 adjustment was incorporated at the rate of ± 0.01 for every ± 0.05 change in water cement ratio. Adjusted proportion of volume of coarse aggregate for water-cement ratio of 0.45 was 0.65 and volume of fine aggregate was found as 0.35.

Mix Calculation

Volume of concrete in one cu m of concrete

$$= \frac{\text{mass of cement}}{\text{specific gravity of cement} \times 1000} \times \frac{1}{1000} = \frac{413.33}{3.15} \times \frac{1}{1000} = 0.131 \text{ m}^3$$

$$\text{Volume of water} = \frac{\text{mass of water}}{\text{specific gravity of water} \times 1000} \times \frac{1}{1000} = 186/1 \times 1/1000 = 0.186 \text{ m}^3$$

$$\begin{aligned} \text{Volume of all in aggregate (e)} &= 1 - (\text{volume of cement} + \text{vol. of water}) \\ &= 1 - (0.1312 + 0.186) = 0.683 \text{ m}^3 \end{aligned}$$

$$\begin{aligned} \text{Mass of coarse aggregate} &= e \times \text{volume of coarse aggregate} \times \text{sp.gr of coarse agg.} \times 1000 \\ &= 0.683 \times 0.65 \times 2.74 \times 1000 = 1216.42 \text{ kg/m}^3. \end{aligned}$$

$$\begin{aligned} \text{Mass of fine aggregate} &= e \times \text{volume of fine aggregate} \times \text{sp.gr. of fine agg.} \times 1000 \\ &= 0.683 \times 0.35 \times 2.706 \times 1000 = 646.86 \text{ kg/m}^3. \end{aligned}$$

Table – 1 Requirement of materials and their proportion for M30 grade concrete

Trial mixes	Ingredients	Water	Cement	Sand	CA
TM II	kg/m ³	186.00	413.33	646.66	1216.04
	Proportion	0.450	1.000	1.565	2.942
TM III	kg/m ³	186.00	375.76	674.88	1220.15
	Proportion	0.495	1.000	1.796	3.247
TM IV	kg/m ³	186.00	459.26	616.58	1206.55
	Proportion	0.405	1.000	1.343	2.627
Final mix	kg/m ³	186.00	425.63	638.19	1213.92
	Proportion	0.437	1.000	1.499	2.852
Final mix with established SD	kg/m ³	186.00	393.65	660.97	1218.67
	Proportion	0.473	1.000	1.679	3.096

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Table - 2 Validity of test results of samples (clause 15.5, IS 456 : 2000)

Specimen No.	Failure Load	Compressive strength	Mean of three samples	Range of test result (±15%)N/mm ²		Remarks for test result
	(kN)	(N/mm ²)	N/mm ²	Maximum	Minimum	
1	860	38.22	37.33	42.93	31.73	Valid
2	740	32.89				
3	920	40.89				
4	800	35.56	36.30	41.74	30.85	
5	810	36.00				
6	840	37.33				
7	830	36.89	36.00	41.40	30.60	
8	840	37.33				
9	752	33.78				
10	820	36.44	36.15	41.57	30.72	
11	800	35.56				
12	820	36.44				
13	760	34.78	36.85	42.38	31.32	
14	910	38.44				
15	840	37.33				
16	750	33.33	35.41	40.72	30.10	
17	840	37.33				
18	800	35.56				
19	755	34.33	37.37	42.98	31.76	
20	800	35.56				
21	950	42.22				
22	905	39.56	37.96	43.66	32.27	
23	790	35.11				
24	900	39.22				
25	850	37.78	36.30	41.74	30.85	
26	840	36.78				
27	755	34.33				
28	820	36.44	36.67	42.17	31.17	
29	890	38.78				
30	840	34.78				
31	755	36.00	36.52	42.00	31.04	
32	820	37.33				
33	815	36.22				

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Table - 3 Acceptance criteria of valid results of samples (table - 11, Clauses 16.1 and 16.3, IS 456 : 2000)

Sl no.	Failure load	Compressive strength	Mean of the group of 4 non-overlapping consecutive four sample result (N/mm ²)	Acceptance criteria for range of mean strength of four non overlapping consecutive samples (N/mm ²)		Individual test result, (f _{ck} - 4) (N/mm ²)	Remark
	(kN)	(N/mm ²)		Maximum (f _{ck} + 0.825 * SD)	Minimum (f _{ck} + 4)		
1	860	38.22	36.89	34.125	34	26	OK
2	740	32.89					
3	920	40.89					
4	800	35.56					
5	810	36.00	36.89	34.125	34	26	OK
6	840	37.33					
7	830	36.89					
8	840	37.33					
9	752	33.42	35.47	34.125	34	26	OK
10	820	36.44					
11	800	35.56					
12	820	36.44					
13	760	33.78	36.22	34.125	34	26	OK
14	910	40.44					
15	840	37.33					
16	750	33.33					
17	840	37.33	35.50	34.125	34	26	OK
18	800	35.56					
19	755	33.56					
20	800	35.56					
21	950	42.22	39.39	34.125	34	26	OK
22	905	40.22					
23	790	35.11					
24	900	40.00					
25	850	37.78	36.28	34.125	34	26	OK
26	840	37.33					
27	755	33.56					
28	820	36.44					
29	890	39.56	36.72	34.125	34	26	OK
30	840	37.33					
31	755	33.56					
32	820	36.44					

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Table 4 Standard deviation calculation

Sample No.	Failure Load	Compressive strength	Average	Deviation	Square of Deviation
	(kN)	(N/mm ²)			
		$X_{\text{individual}}$	X_{mean}	$(X_{\text{individual}} - X_{\text{mean}})$	$(X_{\text{individual}} - X_{\text{mean}})^2$
1	860	38.22	36.67	1.55	2.40939383
2	740	32.89		-3.78	14.2968012
3	920	40.89		4.22	17.7990235
4	800	35.56		-1.11	1.24198642
5	810	36.00		-0.67	0.4489000
6	840	37.33		0.66	0.44001111
7	830	36.89		0.22	0.04791235
8	840	37.33		0.66	0.44001111
9	752	33.42		-3.25	10.5480605
10	820	36.44		-0.23	0.05087531
11	800	35.56		-1.11	1.24198642
12	820	36.44		-0.23	0.05087531
13	760	33.78		-2.89	8.36494938
14	910	40.44		3.77	14.2464309
15	840	37.33		0.66	0.44001111
16	750	33.33		-3.34	11.1333444
17	840	37.33		0.66	0.44001111
18	800	35.56		-1.11	1.24198642
19	755	33.56		-3.11	9.6997642
20	800	35.56		-1.11	1.24198642
21	950	42.22		5.55	30.8271716
22	905	40.22		3.55	12.6182827
23	790	35.11		-1.56	2.43013457
24	900	40.00		3.33	11.0889000
25	850	37.78		1.11	1.2271716
26	840	37.33		0.66	0.44001111
27	755	33.56		-3.11	9.6997642
28	820	36.44		-0.23	0.05087531
29	890	39.56		2.89	8.32643086
30	840	37.33		0.66	0.44001111
31	755	33.56		-3.11	9.6997642
32	820	36.44		-0.23	0.05087531
Total		1173.42	Total	182.723714	
Mean		36.67	Established SD	2.4278207	

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