International Journal of Civil Engineering and Technology (IJCIET)
Volume 8, Issue 10, October 2017, pp. 1695–1703, Article ID: IJCIET_08_10_170
Available online at http://http://iaeme.com/Home/issue/IJCIET?Volume=8&Issue=10
ISSN Print: 0976-6308 and ISSN Online: 0976-6316

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THE STANDARD DEVIATION IN CUBE STRENGTH RESULTS OF SELF-COMPACTING CONCRETE OF M40 GRADE USING QUARRY DUST AS FINE AGGREGATE AND FLY ASH POWDER AS FILLER

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ABSTRACT

The reduction in the sources of natural sand and the requirement for reduction in cost of construction has led to an urgent need to identify a substitute for river sand. Quarry dust, which is a by product from the granite crushing processes in quarrying activity, is available abundantly and economically. This paper presents the study on the effect of replacing sand by quarry dust by 100% on the strength properties of self compacting concrete for M40 grade and also to find standard deviation in cube strength results. About 35 % of quarry dust powder having size between 600 micron to 300 micron. The results indicated that the standard deviation and coefficient of variation of cube test results for Mix 1, 2, 3 and 4 showed a variation between 3 MPa and 7.5 MPa and between 5% and 13% respectively. Lower cement content showed less standard deviation in compressive strength as compared to higher cement content. An average strength of 55.4 MPa of 31 cubes of Mix 2 has shown a standard deviation of 7.41 MPa and coefficient of variation of 13.4%.

Key words: Fly Ash, Cube Strength

Cite this Article: Dr. K. Balakrishna Rao and Shaikh Mohammed Ibrahim, The Standard Deviation In Cube Strength Results of Self-Compacting Concrete of M40 Grade Using Quarry Dust as Fine Aggregate and Fly Ash Powder as Filler, International Journal of Civil Engineering and Technology, 8(10), 2017, pp. 1695–1703.
http://iaeme.com/Home/issue/IJCIET?Volume=8&Issue=10

1. INTRODUCTION

SCC portrays one of the most prominent growths in concrete technology. The use of SCC is increasing nowadays due to elimination of consolidation work which reduces the efforts, duration of construction and therefore, improving the productivity. It reduces noise during casting and creates better working conditions [1]. According to EFNARC Guidelines, the difference between SCC and conventional concrete is the incorporation of mineral admixtures like fly ash, limestone powder and granulated blast furnace slag. Compressive strength increases with the increase in fly ash in concrete [2]. The compressive strength of SCC specimens incorporating with only quarry dust powder was more than the SCC specimens incorporating with silica fume plus quarry dust powder or fly ash alone [1].

The reduction in the sources of natural sand and the requirement for reduction in cost of construction has led to an urgent need to identify a substitute for river sand. Quarry dust, (QD)which is a by-product from the granite crushing processes in quarrying activity, is available abundantly and economically. The use of quarry dust as fine aggregate has made this useless material into a worthy resource/use [3]. The compressive strength of concrete cubes using QD as replacement for sand from 0% to 100% in steps of 10%at age of 28 days showed increase in compressive strength, split tensile strength and flexural strength of concrete [4].The incorporation of granite fines required a higher dosage of superplasticizers for similar yield stresses and other rheological properties [5].The chloride permeability in SCC specimens incorporating quarry dust powder or fly ash was moderate and it was low in the specimens incorporating silica fume plus quarry dust powder[6].

The compressive strength properties of M20 and M25 concrete containing quarry dust of varying fineness modulus and observed that the quarry dust concrete specimens of fineness 2.947 and 5.09 show almost same strength as that of control concrete for 1:3 proportion but as the fineness increases there is about 26% reduction in strength [8].

The present experimental program consists of studying the effect of replacing sand by quarry dust by 100% on the strength properties of self-compacting concrete for M40 grade and also to find standard deviation in cube strength results.

2. EXPERIMENTAL INVESTIGATION

2.1. Materials

The cement used in this study was 43 grade ordinary Portland cement. Coarse aggregates of size 20mm down and class F fly ash of specific gravity 2.134 procured from Raichur thermal power station, Karnataka, India was used. Polycarboxylic ether (PCE) based chemical admixture is added. Quarry dust of size 4.75mm passing and 300 microns retained were taken.

2.1.1. Coarse aggregate proportioning

Locally available crushed granite stones are used as coarse aggregate and it is taken in proportion of 60% of coarse aggregate passing 20mm and retained on 12.5mm and 40% of coarse aggregate passing 12.5mm and retained on 4.75mm. Table 1 shows the physical properties of coarse aggregate used in the present work.

Table 1 Properties of Coarse Aggregate

Specific Gravity	2.671
Bulk Density (Loose State)	1649 kg/m^3
Bulk Density (Compacted State)	1750 kg/m^3
Water Absorption	0.8%
Fineness Modulus	7

2.1.2. Quarry Dust proportioning

The quarry waste (quarry dust) available from local granite stone crushing industry (stone coarse aggregate producing industry) is used as fine aggregate in place of sand. Table 2 shows the properties of quarry dust. Table 3 shows the gradation of quarry dust. About 35 % of the sample having size between 600 microns to 300 microns.

Table 2 Properties of Quarry Dust

Specific Gravity	2.65
Bulk Density (Loose State)	1472 kg/m^3
Bulk Density (Compacted State)	1682 kg/m^3
Fineness Modulus	3.136

Table 3 Sieve Analysis of Quarry Dust

IS Sieve Size	Cumulative % Passing
10 mm	100
4.75 mm	99.8
2.36 mm	83
1.18 mm	61
600 micron	37
300 micron	4.4
150 micron	1.2
Lower Pan	0

2.1.3. Cement

Cement used was Ordinary Portland Cement 43 grade.

Table 4 Properties of cement

Specific Gravity	2.99
Standard Consistency	35%
Initial Setting Time	30 min
Final Setting Time	155 min

2.1.4. Superplasticizer

Auramix 300 Plus is used as superplasticizer in the present work. Table 5 shows properties of Auramix 300 Plus superplasticizer, which is based on polycarboxylic ether polymer with long lateral chains.

Table 5 Properties of Auramix 300 Plus

Appearance	Light yellow colored liquid
pH	Minimum 6.0
Volumetric mass @ 20 degree Celsius	1.08 ± 0.02 kg/liter
Chloride Content	Nil to IS:456
Alkali Content	Typically, less than 1.5g Na_2O equivalent / liter of admixture

2.2. Mix Design

To achieve the aim in the present work, EFNARC method is adopted [7] to design concrete mix of strength of M40. The EFNARC specification (EFNARC 2002) defines specific requirements for the SCC material, its composition and its application. Table 6 shows the mix proportions used in the present work. Four different mix proportions have been studied. From mix 1 to mix 4 the cement content has been decreased by 50 kg / m^3 and fly ash content increased by 50 kg/ m^3.

Table 6 Mix Proportion

Desig-nation	**Cement (kg/m^3)**	**Fly ash (kg/m^3)**	**Quarry Dust (kg/m^3)**	**Coarse aggregate (kg/m^3)**		**Water (Litres)**	**Super-plasticizer (kg)**	**W/P**
				20-12.5mm	12.5-4.75mm			
Mix1	350	250	745	419.4	279.6	190	0.0832	0.3167
Mix2	300	300	745	420	280	182.7	0.0742	0.3045
Mix3	250	350	745	409.54	273.03	182.7	0.0742	0.3045
Mix4	200	400	745	398.79	265.86	182.7	0.0742	0.3045

2.3. Samples

Ten cubes of150mm x150mm x 150mm, four cylinders of diameter 150mm and length 300 mm dimensions are casted for each mix. A total of 31 cubes of Mix 2 were casted on different days. The compressive strengths and split tensile at twenty-eight days are tested for all the mixes.

3. RESULTS AND DISCUSSIONS

3.1. Flow Properties

Table 7 shows flow properties of mix's 1 to 4. Mixes 1, 2, 3 and 4 satisfies the entire four flow properties tests (i.e. Slump, V-Funnel, L-Box and U-Box) and is within the range as mentioned in EFNARC guidelines (2002) [7].

Table 7 Flow Properties

Range	**650-800**	**2-5**	**6-12**	**0.8-1**	**0-30**
Designation	Slump (mm)	Slump T50cm (sec)	V-Funnel (sec)	L-Box	U-Box (mm)
Mix 1	695	3	9	0.89	10
Mix 2	672	4	9	0.91	20
Mix 3	795	2	8	0.928	5
Mix 4	760	3	8	0.9	10

3.2. Compression Behaviour

Table 8, 9, 10 and 11 shows the 28-day's average compressive strength, standard deviation and coefficient of variation of results of mix 1, mix 2, mix 3, and mix 4 respectively.

Mix 1 shows an average strength of 58.03MPa, and standard deviation and coefficient of variation of the results as 7.485MPa and 12.89% respectively. Mix 2 shows an average strength of 55.4 MPa, and standard deviation and coefficient of variation of the results as 7.41 MPa and 13.37% respectively. Mix 3 shows an average strength of 52.58 MPa, and standard deviation and coefficient of variation of the results as 2.52 MPa and 4.79% respectively. Mix 4 shows an average strength of 45.74 MPa, and standard deviation and coefficient of variation of the results as 3.08 MPa and 6.73% respectively.

As the cement content increases the compressive strength also increases. The increase in cement content from 200 kg/m^3 to 350 kg/m^3, 250 kg/m^3 to 350 kg/m^3 and 300 kg/m^{3}to 350 kg/m^3 has shown 26.87%, 10.36% and 4.74% increase in 28 days average compressive strength. An average strength of 55.4MPa of 31 cubes of Mix 2 has shown a standard deviation of 7.41 MPa and coefficient of variation of 13.4%.

The standard deviation and coefficient of variation of cube test results for Mix 1, 2, 3 and 4 showed a variation in compressive strength between 3MPa and 7.5MPa and between 5% and 13% respectively. Table 12 shows lower the cement content (200 kg/m^3 and 250 kg/m^3) standard deviation is less as compared to higher cement content (300 kg/m^3 and 350 kg/m^3).

Table 8 28 Days Compressive Strength of Mix 1

Sample No.	**Crushing Strength (x) MPa**	**Average Strength** $\bar{x} = \frac{\sum x}{n}$	**Deviation** $(x-\bar{x})$	**Square of Deviation** $(x-\bar{x})^2$
1	69.2	58.03	11.17	124.7689
2	65.5		7.47	55.8009
3	54.1		-3.93	15.4449
4	47.2		-10.83	117.2889
5	55.2		-2.83	8.0089
6	62.5		4.47	19.9809
7	50.4		-7.63	58.2169
8	54		-4.03	16.2409
9	67		8.97	80.4609
10	55.2		-2.83	8.0089
			Total	504.221
Standard Deviation of Mix 1 = 7.485 MPa Coefficient of Variation = 12.89%				

Table 9 28 Days Compressive Strength of Mix 2

Sample No.	**Crushing Strength (x) MPa**	**Average Strength** $\bar{x} = \frac{\sum x}{n}$	**Deviation** $(x - \bar{x})$	**Square of Deviation** $(x - \bar{x})^2$
1	42		-13.4	179.56
2	62.7		7.3	53.29
3	50.3		-5.1	26.01
4	61.2		5.8	33.64
5	66		10.6	112.36
6	62.4		7	49
7	58.9		3.5	12.25
8	63.4		8	64
9	60.4		5	25
10	64.8		9.4	88.36
11	57.4		2	4
12	52.6		-2.8	7.84
13	61.2		5.8	33.64
14	60.2		4.8	23.04
15	49.7	55.4	-5.7	32.49
16	61.8		6.4	40.96
17	42.7		-12.7	161.29
18	55.9		0.5	0.25
19	62.7		7.3	53.29
20	52.5		-2.9	8.41
21	49.6		-5.8	33.64
22	60.4		5	25
23	48.7		-6.7	44.89
24	51.6		-3.8	14.44
25	42.2		-13.2	174.24
26	55.3		-0.1	0.01
27	51.4		-4	16
28	57.1		1.7	2.89
29	67.1		11.7	136.89
30	62.6		7.2	51.84
31	67.2		11.8	139.24
			Total	1647.76
Standard Deviation of Mix 2 = 7.41 MPa Coefficient of Variation = 13.37%				

Table 10 28 Days Compressive Strength of Mix 3

Sample No.	Crushing Strength (x) MPa	Average Strength $\bar{x} = \frac{\Sigma x}{n}$	Deviation $(x-\bar{x})$	Square of Deviation $(x-\bar{x})^2$
1	55.5	52.58	2.92	8.5264
2	55.4		2.82	7.9524
3	49.7		-2.88	8.2944
4	50.6		-1.98	3.9204
5	51.3		-1.28	1.6384
6	49.2		-3.38	11.4244
7	53.1		0.52	0.2704
8	54.7		2.12	4.4944
9	55.4		2.82	7.9524
10	50.9		-1.68	2.8224
			Total	57.296
Standard Deviation of Mix 3 = 2.52MPa Coefficient of Variation = 4.79%				

Table 11 28 Days Compressive Strength of Mix 4

Sample No.	Crushing Strength (x) MPa	Average Strength $\bar{x} = \frac{\Sigma x}{n}$	Deviation $(x-\bar{x})$	Square of Deviation $(x-\bar{x})^2$
1	44.7	45.74	-1.04	1.0816
2	42.8		-2.94	8.6436
3	44.1		-1.64	2.6896
4	44.4		-1.34	1.7956
5	48.6		2.86	8.1796
6	46.8		1.06	1.1236
7	40.3		-5.44	29.5936
8	49.8		4.06	16.4836
9	49.7		3.96	15.6816
10	46.2		0.46	0.2116
			Total	85.484
Standard Deviation of Mix 4 = 3.08 MPa Coefficient of Variation = 6.73%				

Table 12 Influence of Cement Content on Strength Properties

Mix	Cement Content (kg/m^3)	Fly Ash Content (kg/m^3)	Average Strength (MPa)	Standard Deviation (MPa)
1	350	250	58.03	7.485
2	300	300	55.4	7.41
3	250	350	52.58	2.52
4	200	400	45.74	3.08

3.3. Split Tensile Strength

Table 13 shows 28 days split tensile strength test conducted on four mix's 1, 2, 3 and 4. As the cement content increases the split tensile strength of concrete also increases. Different concrete mixes studied with cement content of 200 kg/m^3, 250 kg/m^3, 300 kg/m^3 and 350 kg/m^3 gave 28 days split tensile strength of 2.525 MPa, 3.20 MPa, 3.93MPa and 3.59 MPa respectively.

From table 13 it is clear that concrete with cement content of 250 kg/m^3 gave strength of 3.2MPa, which was found to be 26.98% more than the concrete with cement content of 200 kg/m^3; concrete with cement content of 300 kg/m^3 gave strength of 3.93MPa, which was found to be 55.95% more than the concrete with cement content of 200 kg/m^3 and concrete with cement content of 350 kg/m^3 gave strength of 3.59MPa, which was found to be 42.46% more than the concrete with cement content of 200 kg/m^3. From the above discussion it can be concluded that the increase in cement content from 250 kg/m^3 to 350 kg/m^3 has shown 12% increase in split tensile strength.

Table 13 28 Days Split Tensile Strength of SCC Mixes

Designation	28 days Split Tensile Strength (MPa)	Average of 28 Days Split Tensile Strength (MPa)	Comparison with Mix 4
Mix 1 C350	3.14	3.59	42.46% more
	3.97		
	3.5		
	3.78		
Mix 2 C300	2.73	3.93	55.95% more
	4.42		
	4.64		
	3.93		
Mix 3 C250	3.024	3.2	26.98% more
	3.74		
	2.58		
	3.47		
Mix 4 C200	2.24	2.52	-
	2.89		
	2.42		
	2.54		

4. CONCLUSIONS

Based on the result presented in this paper, the following conclusions can be drawn:

- The standard deviation and coefficient of variation of cube test results for Mix 1, 2, 3 and 4 showed a variation between 3MPa and 7.5MPa and between 5% and 13% respectively.
- Lower cement content showed less standard deviation in compressive strength as compared to higher cement content.
- An average strength of 55.4 MPa of 31 cubes of Mix 2 has shown a standard deviation of 7.41 MPa and coefficient of variation of 13.4%.

- The increase in cement content from 200 kg/m^3 to 350 kg/m^3, 250 kg/m^3 to 350 kg/m^3 and 300 kg/m^3 to 350 kg/m^3 has shown 26.87%, 10.36% and 4.74% increase in 28 days average compressive strength.
- Different concrete mixes studied with cement content of 200 kg/m^3, 250 kg/m^3, 300 kg/m^3 and 350 kg/m^3 gave 28 days split tensile strength of 2.525 MPa, 3.20 MPa, 3.93MPa and 3.59 MPa respectively. The increase in cement content from 250 kg/m^3 to 350 kg/m^3 has shown 12% increase in split tensile strength.

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