EFFECT OF CRUSHER FINES ON STRENGTH AND WORKABILITY OF CONCRETE

Harish Choudhary[1], Arham Siddique[2], Saha Dauji[3]

1. CED, NFC-Kota, India
2. CED, NFC,Kota, India & Homi Bhabha National Institute, India
3. Bhabha Atomic Research Centre, India & Homi Bhabha National Institute, India

ABSTRACT. Failure of concrete structures, especially under seismic loads, focuses our attention to the quality of concrete at construction sites in India. Even with good quality control procedures there are instances when deleterious materials get inadvertently mixed with concrete and result in adverse effects on the concrete properties. The nature of these contaminants varies for different locations, and so does their effects on the concrete properties. At a particular construction site of an important infrastructure facility in India, both coarse and fine aggregates were being used from crusher. Thus, there existed high possibility of crusher fines being included in the mix either as coating on the coarse aggregates or as loose particles along with fine aggregates. The effects of these contaminants on the properties of fresh and hardened concrete were studied and the preliminary results would be presented in the paper. This would help in evaluation of the possible causes for any future distress in these concrete structures.

Keywords: Deleterious Materials, Quality, Concrete, Construction, Crusher Fines

Mr Harish Choudhury, is Scientific Officer in Nuclear Fuel Complex, Kota, India. His research interests include construction methodologies, quality assurance and control in construction, and concrete technology. He is presently pursuing his Masters Project with Homi Bhabha National Institute.

Mr Arham Siddique, is Scientific Officer in Nuclear Fuel Complex, Kota, India. His research interests include structural dynamics, construction methodologies, quality assurance and control in construction, and concrete technology.

Dr Saha Dauji is Scientific Officer in Nuclear Recycle Board, Bhabha Atomic Research Centre, India and affiliated to Homi Bhabha National Institute. His research interests include oceanography, data driven models in civil applications, structural analysis, and health assessment of concrete structures.

INTRODUCTION

Concrete is the second most consumed material in the world after water. Like India, many other developing countries are rapidly growing in construction and infrastructure segment. This growth in construction industry in past decade has increased the demand for concrete and its constituent material. Concrete is mainly made up of cement, coarse aggregate and fine aggregate. A high quality control is obtained on cement because of decades of experience gained in manufacturing cement. Coarse aggregates are generally extracted by stripping and blasting, crushed, washed and graded to requirement. A good quality control is hence maintained in manufacturing of coarse aggregates. Earlier decade, fine aggregate was mined directly from river and its banks. Since its source was natural, meeting quality control and gradation requirement was difficult. Moreover, fine aggregates posses a threat to river ecology and environment. It disturbs the biodiversity of river on a broader aspect. Because of its immense drawback to environment and protest against mining of river sand, a ban on river sand is called by many state government and environment ministry in country.

This paved the necessity to develop high power and technology crusher to produce fine aggregates of required grading. Over exploitation of river sand and ban on dredging of river sand has pushed concrete technologists to use manufactured sand. In present scenario, many places around the world aggregates (both coarse and fine) are manufactured with available and blasted rocks of desired strength and durability. Rocks and boulders when crushed, produce rock sizes, aggregates and fines of variety of sizes. Crushed material are then screened through sieves of designated sizes. During sieving of coarse aggregate, it is possible that crusher fines of size smaller than 75µm is adhered to surface of aggregates. This manufactured fine aggregate is washed to remove the crusher fines before being use in concrete.

Crusher fines is a fine material formed during the process of comminution of rock into crushed stone or, less frequently, of gravel into crushed fine aggregate. In a properly laid out processing plant, this dust should be removed by washing. Other soft or loosely adherent coatings can also be removed during the process of the washing aggregate. Well-bonded coatings cannot be so removed but, if they are chemically stable and have no deleterious effect, there is no objection to the use of aggregate with such a coating, although shrinkage may be increased [7]. However, aggregates with chemically reactive coatings, even if physically stable, can lead to serious trouble.

Crusher fines may be present in the form of loose particles not bonded to the coarse aggregate. Fines should not be present in excessive quantities because, owing to their fineness and therefore large surface area, fines increase the amount of water necessary to wet all the particles in the mix.

In view of the above, it is required to control the clay, silt and fine dust contents of aggregate used for production of concrete. IS: 383-2016 recommends the maximum quantity of deleterious material (shown in Table 1) when tested in accordance with IS:2386-1963.

Table 1 Limits of deleterious materials (IS:383-2016)

DELETERIOUS SUBSTANCE	METHOD OF TEST	FINE AGGREGATE PERCENTAGE BY WEIGHT, MAX		COARSE AGGREGATE PERCENTAGE BY WEIGHT, MAX	
		Uncrushed	Crushed	Uncrushed	Crushed
Materials finer than 75μ IS Sieve	IS : 2386 (Part 1)-1963	3.00	15.00	3.00	3.00

A good quality control check makes sure to limit the crusher fines within tolerance as specified by standards. But at a large concrete production site, where daily hundreds of cubic metres of concrete is produced, chances of crusher fines getting mixed with concrete mix is possible due to human or technical error. Hence, it is imperative to know the effect of crusher fines on properties of green and hardened concrete both. Workability of concrete is an important characteristic which addresses the properties of green concrete like consistency, flowability, segregation and compaction. Compressive strength of hardened concrete can be used to indirectly relate to durability of concrete. In the present study, an effort is made to study the effect of crusher fines on compressive strength and workability of concrete when fines are added at difference concentration substituting fines aggregate with specified percentage.

LITERATURE REVIEW

Kronlof (1994) found that that fine aggregate powder sharply reduces the water requirement in super plasticised concrete and increased strength at constant workability due to improved particle packing. Better workability is observed due to a consistent mix and increased durability because of decreased porosity [4]. Study on similar lines was performed by Ngugi et. al. (2006) in Namibia. The 13 sand samples were tested for silt and clay contents and organic impurities. These sand samples with varying impurities were used in making concrete mix and compressive strength of concrete was tested at 7, 14 and 28 days. With regard to compressive strength, 38% of the concrete cubes made from sand with varying sand impurities failed to meet the design strength of 25 MPa at the age of 28 days [7]. The effect of the addition of fines to normal-strength concrete at levels of up to 227 kg/m3 was studied in concrete mixtures prepared with constant workability (Katz & Baum, 2006). It was found that as long as workability can be controlled by reasonable amounts of admixture, the addition of fines improves concrete strength by as much as 30%, somewhat reduces the carbonation rate, and slightly increases the volume changes of fresh and hardened concrete. When high dosages of admixture were required to maintain workability due to the presence of large amounts of ultra-fine particles (less than ~5 micron), properties of the concrete were seriously affected (Katz & Baum, 2006) [3]. In another study made by Panchal et. al. (2015) showed that workability decreases with increasing content of quarry dust. Improvement in strength (compressive and flexural) was seen up to 40% content of quarry dust after which a drop in strength was observed [8]. Tejaswini et. al. (2016) studied the strength and durability for the various fines by replacement of the M-sand in concrete. They studied with variation of percentage of fines like 0%, 5%, 10%, 15% and 20% at constant workability. The strength studies such as compressive strength, flexural strength, Split tensile strength and durability tests such as water absorption, absorptivity, density, permeability test were done. The results are compared with the variation of fines in M-sand. It was found that percentage for about

5% fines gives more value for both the strength and durability parameters when compared to the other percentage of fines [10].

Research significance

An abundant literature is present on concrete with fine aggregates substituted by recycled concrete aggregate, blast furnace slag, fly ash, waste glass etc. Lesser is known about concrete where fine aggregates are replaced with crusher fines. Also, in the present work done, concrete strength at different percentage of fines are tested at constant workability. Moreover, lesser effort is made to study the variation of concrete strength at and around the limits specified by standard. Work is being performed by replacing quarry dust of different source at variable workability. In the present study, fines produced during the crushing of rocks and boulders was used to replace fine aggregate of mix design with used manufactured aggregates of same source. Hence, replacing the fine aggregates with crusher fines for different concentration at variable workability will give the variation in strength of concrete due to inadvertent addition of crusher fines in concrete mix.

EXPERIMENTAL PROCEDURE

Materials

- Cement

Type of cement is Portland Pozzolana cement fly ash (20% flyash) based. The properties of cement is shown in Table 2.

Table 2 Properties of cement

SR NO.	TEST ON CEMENT	RESULT	ACCEPTANCE CRITERIA AS PER IS 1489 (PART 1): 2015	STANDARD FOR TESTS
1	Fineness	0.7%	10% max.	IS: 4031-1988 (Part 1)
2	Initial setting time	150 min	30 minutes min.	IS: 4031-1988 (Part 5)
3	Final setting time	225 min	600 minutes max.	IS: 4031-1988 (Part 5)
4	Soundness test	0.5%	10% max.	IS: 4031-1988 (Part 3)
5	Strength test (at 28 days)	58 MPa	33 MPa min	IS: 4031-1988 (Part 6)

- Aggregate

Source of aggregate is excavated hard rock of sandstone origin at Rawatbhata, Rajasthan civil work project. This rocks are crushed by crusher plant installed at site to make fine and coarse aggregate. The crusher plant produces coarse aggregate of 20mm and 10mm dia. This single sized 20mm and 10mm aggregates are graded in 60:40 ratio respectively to obtain a graded aggregate of 20mm nominal size confirming to codal specification. The fine aggregate is crushed sand meeting the gradation requirement of zone-II as per IS: 383-2016. These other properties of aggregates refer to the mechanical properties of aggregate required to confirm with IS: 383-2016. This mechanical property of aggregates mainly governs the strength of concrete. The test is performed as per the relevant Indian standard as shown in Table 3.

Table 3 Properties of Crushed aggregates

SR. NO.	TEST	RESULT	ACCEPTANCE CRITERIA AS PER IS 383: 2016	STANDARD FOR TESTS
1	Combined flakiness and elongation	6%	40% Max	IS: 2386 (Part 1)-1963
2	Crushing value	13%	30% Max	IS: 2386 (Part 2)-1963
3	Aggregate Impact value	16.5%	45% Max	IS: 2386 (Part 2)-1963
4	Aggregate abrasion value	23%	50% Max	IS: 2386 (Part 2)-1963

- Crusher fines

Crusher fines belong to the same source as of aggregates. These fines are obtained by drying and sieving (through 75µm Sieve) of washed out fines produced during crushing of aggregates.

Standard mix design

The trials for concrete mix design was done at site as per IS: 10262:2009 and mix design of concrete with grade M25 was obtained. The recipe for the standard mix which is also the control mix is given below in Table 4.

Table 4 Mix design of control mix

GRADE OF CONCRETE	W/C RATIO	QUANTITIES OF MATERIALS PER CUBIC METER OF CONCRETE						SLUMP (mm)
		Cement (kg)	Water (lit.)	Plasticizer (kg)	Sand (kg)	Coarse Aggregate (kg)		
						20mm	10mm	
M25	0.48	334	160	2	806	624	416	120

Mix Design With Deleterious Materials

Deleterious materials for the study are silt and clay present in fine aggregates. The Indian standard code limits for fines is 15% for crush fine aggregates, by weight. It is intended to study the variation in concrete properties around the code specified values. Thus, the experiment is designed as given in Table 5.

Table 5 Mix designs with deleterious materials

DELETERIOUS MATERIAL	CUBE MARK	PERCENTAGE OF DELETERIOUS MATERIAL W.R.T TO SAND	QUANTITIES OF MATERIALS PER CUBIC METER OF CONCRETE						
			Cement (kg)	Water (lit.)	Plasticizers. (kg)	Sand (kg)	Deleterious material (kg)	Coarse Aggregate (kg)	
								20mm	10mm
No deleterious material	CM	**Nil**	334	160	2	**806**	**Nil.**	624	416
Silt	S1	**5**	334	160	2	**766**	**40**	624	416
	S2	**10**	334	160	2	**726**	**80**	624	416
	S3	**15**	334	160	2	**685**	**121**	624	416
	S4	**20**	334	160	2	**645**	**161**	624	416
	S5	**25**	334	160	2	**604**	**202**	624	416

Casting of Cube Samples

The below statement covers the SOP adopted for casting of experiment cubes for the given study. Casting of cubes are done as per Indian Standard IS: 516-1959.

a. Preparation of materials
The cement samples are thoroughly mixed dry by hand so as to ensure the greatest possible blending and uniformity in the material. Aggregates for each batch of concrete is air dried before using in mix. Water is potable water and at room temperature.

b. Proportioning
The proportion of the material is done by weight per cubic meter of concrete. Weigh batching is used for proportioning.

c. Mixing
The sequence of loading material is as per IS 516-1959. The period of mixing is kept no less than 2 minutes after all the materials are in the drum and is continued till the resulting concrete is uniform in appearance.

d. Casting of cubes
Each sample consist of three cube test specimens of 150×150×150mm size confirming to IS: 10086-1982. The average strength of three test specimens is taken as compressive strength of sample.

e. Compacting

The concrete is filled into the mould in layers approximately 5cm deep. 35 strokes per layer is given with tamping rod.

f. Cube identification.
The cubes after initial setting was labelled with permanent marker with mark as show in Table 5 and date of casting.

g. Curing
The test specimens are stored in a place, free from vibration and away from direct sunlight for 24±1/2 hours form the time of addition of water to the dry ingredients. After this period, the specimens are marked and removed from the moulds and it is submerged in clean, fresh water. The water or solution in which the specimens are submerged is renewed every seven days.

Testing of green and hardened cube samples

Casting of cubes are done as per Indian Standard IS: 516-1959. The concrete strength is evaluated as per IS: 516-1959 and slump of green concrete is evaluated as per IS: 1199-1959.

RESULTS AND DISCUSSION

Slump Value

Table 6 shows the results of the concrete slump value depending upon the different percentage if crusher fines replace the fine aggregate in standard mix. With reference to results of slump cone test as shown in Table 6, it can be inferred that green concrete losses its workability as the quantity of silt is increased in mix. The result of decreasing workability can be attributed to constant water cement ratio and admixture dose maintained for all mix design. Increasing the percentage of crusher fines increases the surface area required for water to wet the surface of aggregates. Hence concrete will become unworkable, harsh and difficult to handle and place at site. Low workability will lead to poor compaction, honey combing, air voids, less dense concrete and lesser flowability.

Table 6 Summary of slump value of green concrete

Mix	CM	S1	S2	S3	S4	S5
Slump (mm)	140	120	110	105	95	75

Figure 1 represent a graphical representation of decrease in workability with increase in percentage fines from 0 to 25 percent of fine aggregate.

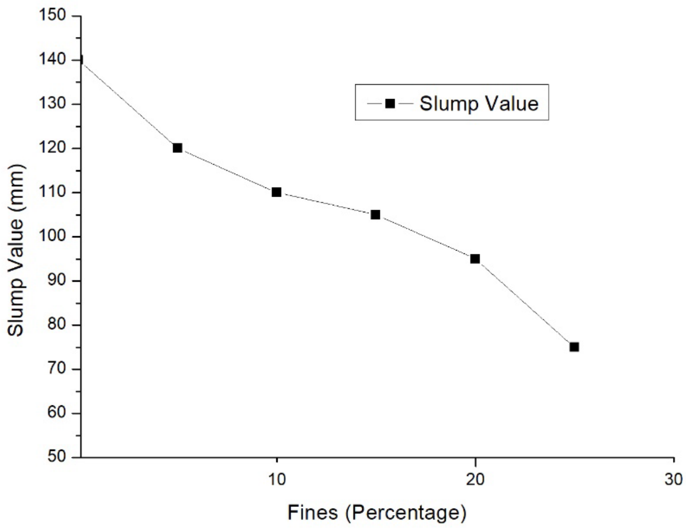

Figure 1 Variation of slump value at different percentage of fines

Compressive Strength

The test results for compressive strength of concrete mixes at different percentage of fines and ages is summarised in Table 7. A comparative graph of compressive strength of hardened concrete for all mixes is made against age of concrete. Interpretation of results show increase in compressive strength of S1(5% fines) Mix. The reason for increase in compressive strength can be attributed to improvement in packing of concrete and improved density. Crusher fines fills the smaller voids present in the gradation of fine and coarse aggregates. More water is consumed in wetting the surface and free water present in mix reduces. This reduced the voids produced due to presence of free water. An increase of about 4.5 percent in strength is observed compared to standard mix design strength. Referring to Figure 2, strength of concrete falls below the standard mix design for fines 10 percent and above. These reduction in strength of concrete is due to loss in workability to a level concrete is not even workable to place and compact. The harshness and less workability of mix increases the void ratio of concrete making it less dense. Another reason for decrease in strength can be attributed suggested as a lot of water is used to wet the surface of crusher fines and aggregates, the water cement ratio required for hydration of cement is disturbed and hence reducing the strength of concrete. A decrease in compressive strength at 91 days of about 11.5%, 16.4%, 22.6% and 26.7% for S2, S3, S4 and S5 concrete mix respectively.

No significant variation is observed on rate of gain of strength for different mixes. A significant strength gains of about 7% to 12% is observed from 28 days to 91 days. The presence of blended cement i.e fly ash based is responsible for significant later strength gains.

Table 7 Summary of compressive strength of hardened concrete

MIX	AVERAGE STRENGTH				
	@7 days	@14 days	@28 days	@63 days	@91 days
CM	31.08	38.27	42.89	47.45	48.71
S1	33.36	39.51	44.25	48.70	50.92
S2	30.12	38.10	40.98	43.53	45.07
S3	29.73	34.50	38.89	40.68	42.58
S4	28.44	30.55	36.70	38.06	39.39
S5	26.89	29.17	34.41	36.24	37.30

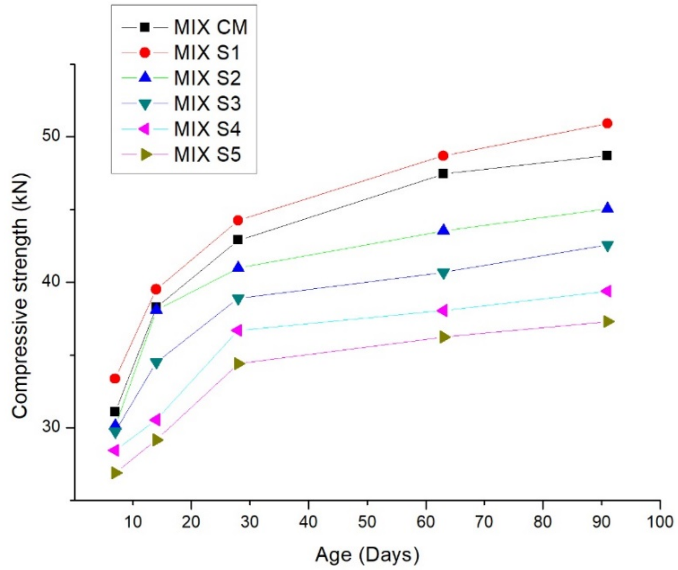

Figure 2 Compressive strength values at different ages

Figure 3 shows graphical comparative representation of compressive strength of concrete of various mixes at same age. A minor strength gain is seen for S1 mix. A sharp fall of 11.5 percent is witnessed in compressive strength from S1 to S2 at age of 91 days.

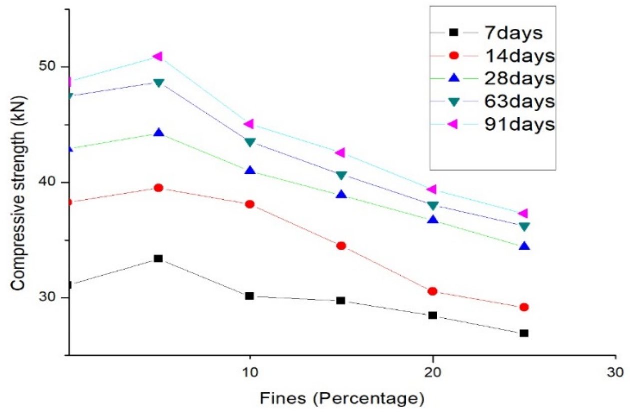

Figure 3 Compressive strength values against percentage fines

CONCLUSION

Decrease in workability is observed as percentage fines increases. 14 percent to 50 percent decrease in slump value is seen for S1 Mix (5% fines) and S5 Mix (25% fines) respectively.

A 4.5 percent increase in compressive strength is observed for S1 Mix (5% fines).

Compressive strength reduces to the order of 22.6 percent on increasing fines percentage up to 25 percent.

A sharp decrease in compressive strength is observed from S1 Mix to S2 Mix. The decrease is of the order of 11.5 percent.

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