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IMPACT OF FLY ASH AND SILPOZZ AS ALTERNATIVE CEMENTITIOUS MATERIAL IN CRUSHER DUST CONCRETE

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ABSTRACT

In this study, an attempt is made to beneficially use of alternate materials in concrete without compromising its desired strength. M30 grade concrete was designed and used in this study. First two mixes were made by replacing 0% and 40% natural fine aggregate (NFA) with crusher dust (CD). Then at each replacement level of NFA, cement is replaced partially with fly ash (FA) and silpozz. The workability, compressive, split tensile and flexural strength of concrete mixes have been determined as per relevant Indian Standard codes. The test results indicate that the workability of concrete increases with FA content and decreases with addition of CD and silpozz. For strength characteristics, the results show that strength increases with increase in CD content and a gradual increase in strength occurs as the percentage of FA and silpozz increases. Ultimate strength is obtained when NFA is replaced with 40% CD and cement is replaced with 20% silpozz.

KEYWORDS: Crusher Dust, Compressive Strength, Flexural Strength, Split Tensile Strength.

In this modern time of globalization, the exponential growth in infrastructure sector has successfully overcome the challenge of rapid industrialization. To maintain this growth in the field of infrastructure, raw materials and related requisites are to be procured in abundance. Since the natural sources for raw materials are becoming scarcer by the day, it is our duty to find out the alternatives that can be used as efficiently as the naturals. As we know, concrete is the major component utilised in developing any kind of infrastructure, cement & sand being its two important ingredients. Lack of good quality of sand act as huddle in the progress of many infrastructure projects and extensive sand quarrying has also its own adverse environmental impact. So time has arrived where we need to search for a suitable replacement of sand in concrete from so many materials that are available as industrial or agricultural by-products that can be recycled as construction material.

When rocks are processed in crusher to produce aggregates of various sizes, the residue is called crusher dust (CD). Disposal of these CD is a difficult proposition as huge area of land is required for this purpose. There is always risk of pollution if these fine particles mingle with air/water. To overcome these problems and to find an economically viable alternative to Natural Fine Aggregate (NFA), we can use CD in concrete. It is also being successfully used in the field of road construction.

Similarly use of cement causes environmental pollution, which is one of its major drawbacks. Its production is not only energy consuming but also expensive. It is to be noted that during production of 1 MT of Portland cement, nearly 1 MT of CO_2 is released in to the atmosphere, which causes global warming.

On the other hand, disposal and stock piling of industrial by products such as blast furnace slag, fly ash (FA) and silpozz etc. are becoming difficult day by day. The only solution to these problems is to explore ways for replacement of Portland cement with these by-products so that consumption of cement will be less and at the same time these by-products will be disposed of efficiently. FA is broadly recognized as a cementitious material. If we properly substitute cement with this FA, we can improve workability as well as quality of concrete. Similarly, silica fume can efficiently be replaced with eco-friendly and low cost silpozz to enhance the strength and workability of concrete.

Some of the research papers in these fields are reviewed. Utmost compressive, tensile and flexural strength are achieved when NFA is replaced by 50% CD according to Balamurugan and Perumal [1]. With increase in percentage of dust content, Slump value decreases according to Celik and Marar [2]. They further concluded that CD can be put to use in place of NFA when by 50% giving additional strength. According to Eren and Marar [3] Water permeability is reduced with increasing content of CD. According to Jatale et al. [4], workability of concrete increases with increasing FA content. They further concluded that as compared to OPC concrete, FA concrete is more durable.

At all age of curing, the strength of all concrete mixes prepared with different combination of silpozz and RHA is higher than control mix as per Panda and Prusty [5]. According to Pitroda et al. [6] Coal and thermal industry disposal cost can be saved with utilization of FA. It also leads to construction with ‘greener concrete’. But it is noticed that with addition

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of FA, percentage change in compressive as well as tensile strength decreases. Pradhan and Panda [7] concluded that addition of silpozz in concrete, as partial replacement of cement enhances the strength remarkably. According to Pofale and Quadri [8], at all replacement levels of NFA with CD, there is reduction of 1-6% in workability. They further concluded that compressive strength of concrete is increased up to 5-22% when NFA is substituted with CD. They also mentioned that when percentage replacement level of NFA with CD is 40%, maximum compressive strength is achieved. Compressive strength of concrete is increased considerably with addition of FA and but tensile strength is not that much affected by FA according to Sama et al. [9]. They further concluded that utilization of FA in concrete as the partial replacement of cement leads to a cost effective and environmental friendly product.

This study aims at utilization of FA and silpozz on the properties of concrete containing CD. To evaluate the fresh concrete properties, slump test was done and for hardened concrete properties, compressive, split tensile and flexural strength tests were done.

EXPERIMENTAL DETAILS

Materials

In this study, Ordinary Portland Cement, NFA, Natural Coarse Aggregate (NCA), CD, FA, Silpozz and potable water are used. OPC of grade 43 having specific gravity 3.15 grade is used. The physical properties of cement are obtained experimentally and the value specified by IS 8112:1989 [10] is presented in Table 1. Silpozz was supplied by N.K. Enterprises, Jharsuguda, which is having grey colour and specific gravity 2.3. Silpozz is the commercial name of amorphous silica which is produced from rice husk ash. Burning of rice husk under 700°c results in generation of amorphous ash that is known as amorphous silica. Particle size of silpozz is mostly 25 microns, pozzolanic in nature that contains more than 90% silica. FA of class F was supplied from Nava Bharat Ventures Ltd., Dhenkanal, Odisha. The chemical composition of OPC, FA and average batch analysis report of silpozz is given in Table 2. Sand is used as NFA which is passing through IS 4.75 mm sieve and having specific gravity 2.68 and conforming to zone II, was used in the present study. NCA were of 20 mm downgraded having specific gravity is 2.77. CD used was from a local crusher of zone I and having specific gravity 2.80. The physical properties of NFA, NCA and CD as per IS: 383-1970 [11] obtained experimentally is presented in Table 3. The residues obtained from different CD particles passing through different sieves are shown in Figure 1. Particle size gradation curve of NFA and CD is shown in Figure 2.

Figure 1: Residues of crusher dust passing through different Sieves

Figure 2: Silpozz and FA Samples

Table 1: Physical properties of cement (OPC-43 grade)

Characteristics	Test value	Value as per IS:8112-1989
Normal consistency, percent	32.5	NA
Specific gravity	3.15	3.15
Setting time, minutes		
Initial setting time	121	30 (min)
Final setting time	410	600 (max)
Compressive strength, Mpa		
3 days	30	23 (min)
7 days	43	33 (min)
28 days	51	43 (min)

Table 2: Chemical composition of OPC, FA and Silpozz

Oxide	OPC	FA	Silpozz
SiO_2	20.50	60.69	91.86
Al_2O_3	5.05	22.55	1.98
Fe_2O_3	2.99	3.52	0.58
CaO	62.00	0.007	1.03
MgO	2.07	0.005	0.67
SO_3	2.40	0.012	-
LOI	3.10	3.27	1.99
Carbon	-	-	0.79
Na_2O	-	-	0.14
K_2O	-	-	0.87
Others	-	-	0.87
Moisture	-	-	0.74

Table 3: Physical properties of Aggregates and CD

Characteristics	Test value (as Per IS:383-1970)		
	NFA	NCA	CD
Fineness modulus	2.76 (zone II)	6.93	3.37 (zone I)
Specific gravity	2.68	2.77	2.80
Water absorption	0.80	0.22	0.80

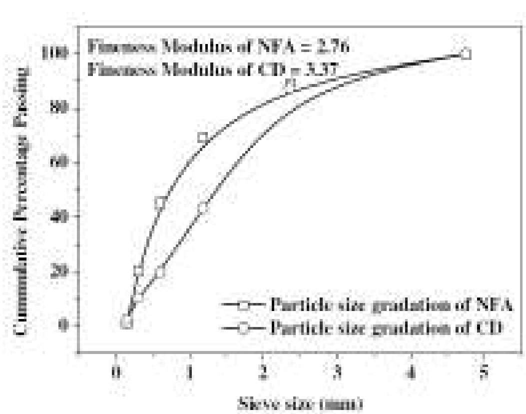

Figure 3: Particle size gradation curve of NFA and CD

Mixture Proportion

To acquire target mean strength, design mix of M30 grade of concrete was done as per IS: 10262-2009 [12]. Here the mix proportion 1:1.535:2.746 were taken in this experiment. In this study, total twelve mixes were prepared. Mixes have been tested in a constant w/b ratio i.e. 0.43 for cement concrete. First two different mixes of concrete mixtures were made by replacing 0 and 40% of NFA with CD. MCD indicate concrete mix with 0 and 40% replacement of NFA with CD, with w/b ratio 0.43. MCD0 indicates 0% CD, 100% cement, 100% NFA, and 100% NCA, MCD40 indicates 40% CD, 100% cement, 60% NFA and 100% NCA. Designation of mix proportion for their identification is done as per degree of replacement of different ingredients. Then total ten different mixes of concrete (5 in each percentage interval of replacement of NFA) were made. The sample MCD0F10S0 represents 0% replacement of NFA with CD, 10% replacement of cement with FA, and 0% replacement of cement with silpozzz. Similarly, MCD40F10S0 represents 40% replacement of NFA with CD, 10% replacement of cement with FA, and 0% replacement of cement with silpozz. The details of concrete mixture proportions along with identity are presented in Figure 4.

Casting and Testing of Specimen

The batching, mixing and casting of concrete was done properly. After the cementitious materials, such as OPC, FA, silpozz along with NCA, NFA and CD were weighed in different proportions as per test sampling to homogeneous mixture by placing them in the concrete mixer, specified quantity water as per w/b respective ratio was weighed and added to this mix and further mixed in the mixer till a uniform homogeneous mix is obtained. The mixing procedure is same for all the test samples. The workability of the mixed concrete was carried out immediately by the slump test. Test specimens were placed in moulds of specified size. 40 mm size needle vibrator was used for compacting the concrete specimens. The specimens were kept in the moulds for 24 hours. After removal from moulds, the specimens were placed in curing tank at normal temperature (27^{o}c-30^{o}c) using potable water for 7, 14, and 28 days.

The slump values of concrete mixtures were obtained experimentally with w/b ratio 0.43. In this study, cubes of size 150 mm × 150 mm × 150 mm, cylinders of size 100 mm diameter and 200 mm height and prisms of size 100 mm × 100 mm × 500 mm is used. Characteristics of the hardened concrete specimens were obtained by testing the specimens after specified curing time i.e. 7 days, 14 days and 28 days. The hardened concrete properties such as compressive strength for cubes, flexural strength for prisms and split tensile strength for cylinders were tested in the laboratory.

Table 4: Concrete mixture proportions

Mix Identity	Filler	Cementious materials per m^3 of concrete			NFA (Kg)	NCA (Kg)	CD (Kg)	Water (Kg)
		Cement (Kg)	Fly ash (Kg)	Silpozz (Kg)				
MCD0	0%	432	0	0	663	1187	0	185
MCD40	40%	432	0	0	398	1187	265	185
MCD0F10S0	0%	389	43	0	663	1187	0	185
MCD0F20S0	0%	346	86	0	663	1187	0	185
MCD0F0S10	0%	389	0	43	663	1187	0	185
MCD0F0S20	0%	346	0	86	663	1187	0	185
MCD0F10S10	0%	346	43	43	663	1187	0	185
MCD40F10S0	40%	389	43	0	398	1187	265	185
MCD40F20S0	40%	346	86	0	398	1187	265	185
MCD40F0S10	40%	389	0	43	398	1187	265	185
MCD40F0S20	40%	346	0	86	398	1187	265	185
MCD40F10S10	40%	346	43	43	398	1187	265	185

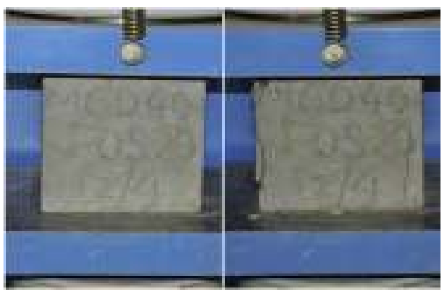

Figure 4: Cube specimen before and after failure

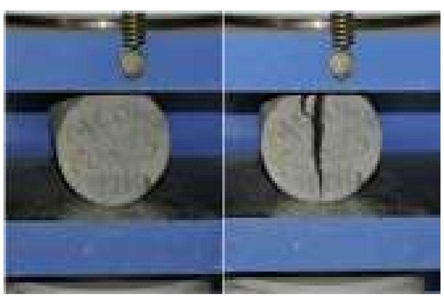

Figure 5: Cylinder specimen before and after failure

Figure 6: Prism specimen before and after failure

RESULTS AND DISCUSSION

The test results are presented along with their graphical plots and discussions.

Fresh Concrete Test Results

The concrete mixes were prepared in different proportion and the fresh concrete test is conducted after the mixing. It is observed that in the control specimen i.e. MCD0, the slump value was 35 mm. But when sand is replaced with 40% 0f CD, the slump was 18 mm. So, it is concluded that workability decreases with increase in CD content. In the absence of CD, when cement is replaced with 10% and 20% FA, the slump values were 38 mm and 39 mm respectively. But when sand is replaced with 40% of CD and cement is replaced with 10% and 20% FA, the slump values were same in both the cases i.e 25 mm. So, it is concluded that presence of FA increases workability. But in the presence of CD, FA content decreases the workability. In the absence of CD, when the cement is replaced with 10% and 20% silpozz, the slump values were 12 mm and 6 mm respectively. But when sand is replaced with 50% of CD and cement is replaced with 10% and 20% of silpozz, the slump values were 2 mm and zero. So, it is concluded that presence of silpozz decreases workability. In the absence of CD, when cement is replaced with combination of 10% FA and 10% of silpozz, the slump value was 35 mm. But when sand is replaced with 40% of CD and cement is replaced with combination of 10% FA and 10% of silpozz, the slump value was 24 mm. So, it is concluded that with combination of FA and silpozz, the workability is not so significant.

Compressive Strength Test Results

Nine numbers of cubes were cast for each mix and each three cubes were tested after 7, 14 and 28 days of curing. Figures 7-8 show the plot between the compressive strength in MPa and age in days for concrete without CD and with CD.

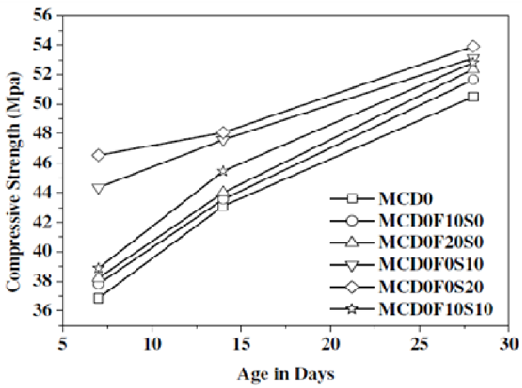

Figure 7: Compressive Strength vs. Age in Days for concrete without CD

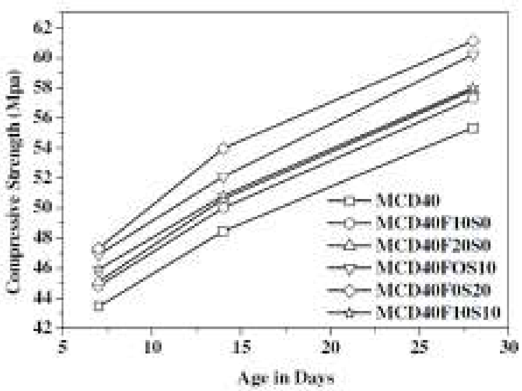

Figure 8: Compressive Strength vs. Age in Days for concrete with 40% CD

It is observed that the compressive strength of concrete mix with 40% replacement of NFA with CD increases upto 17.85%, 12.43% and 9.62% at 7, 14 and 28 days respectively as compared to control specimen. Whereas in concrete mix with 40% CD and with 20% replacement of cement with FA, the compressive strength increases upto 22.38%, 17.40%, 14.59% at 7, 14 and 28 days respectively. In concrete mix with 40% CD and with 20% replacement of cement with silpozz, the compressive strength increases upto 28.38%, 25.22%, 21.05% at 7, 14 and 28 days respectively. In presence of 40% CD and with 20% replacement of cement with combination of 10% FA and 10% silpozz, the compressive strength increases upto 24.86%, 17.91%, 14.89% at 7, 14 and 28 days respectively as compared to control specimen. The compressive strength of all concrete mixes with and without CD and with cementitious material is giving higher value of compressive strength as compared to control specimen.

Split Tensile Strength Test Results

Nine numbers of cylinders were cast for each mix and each three cylinders were tested after 7, 14 and 28 days of curing. Figures 9-10 show the plot between the split tensile strength in MPa and age in days for concrete without CD and with CD.

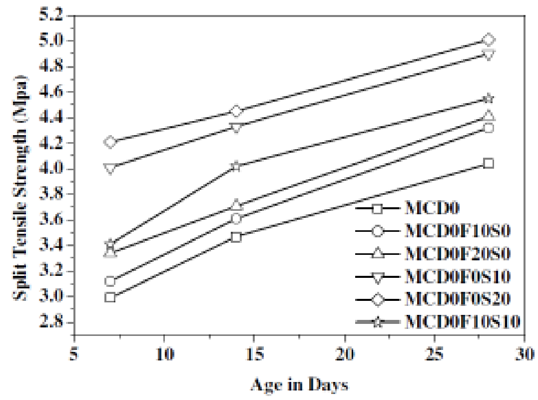

Figure 9: Split Tensile Strength vs. Age in Days for concrete without CD

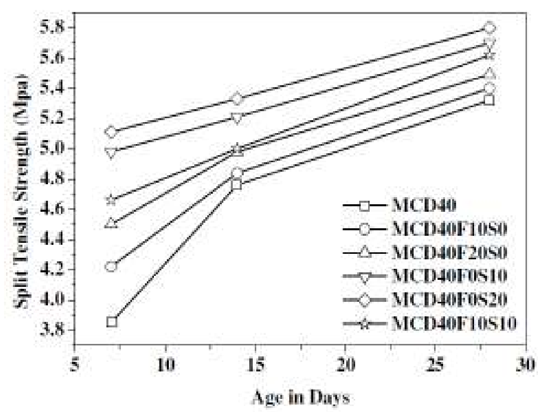

Figure 10: Split Tensile Strength vs. Age in Days for concrete with 40% CD

It is observed that the split tensile strength of concrete mix with 40% replacement of NFA with CD increases upto 28.76%, 37.17% and 31.68% at 7, 14 and 28 days respectively as compared to control specimen. Whereas in concrete mix with 40% CD and with 20% replacement of cement with FA, the split tensile strength increases upto 50.50%, 43.51% and 35.89% at 7, 14 and 28 days respectively. In presence of 40% CD with 20% replacement of cement with silpozz, the split tensile strength increases upto 70.90%, 53.60% and 43.56% at 7, 14 and 28 days respectively. In presence of 40% CD with 20% replacement of cement with combination of 10% FA and 10% silpozz, the split tensile strength increases upto 55.85%, 44.09% and 39.10% at 7, 14 and 28 days respectively as compared to control specimen. The split tensile strength of all concrete mixes with and without CD and with cementitious material is giving higher value as compared to control specimen.

Flexural Strength Test Results

Nine numbers of prisms were cast for each mix and each three prisms were tested after 7, 14 and 28 days. Figures 11-12 show the plot between the flexural strength in MPa and age in days for concrete without CD and with CD respectively.

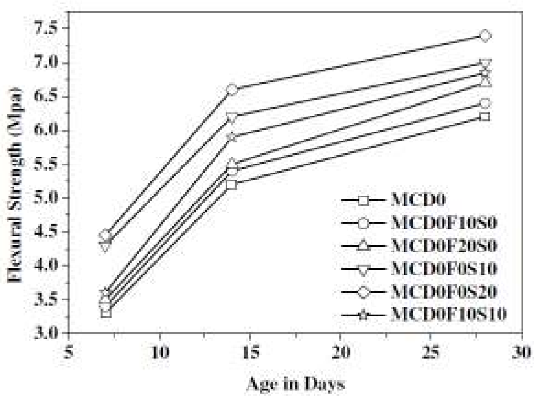

Figure 11: Flexural Strength vs. Age in Days for concrete without CD

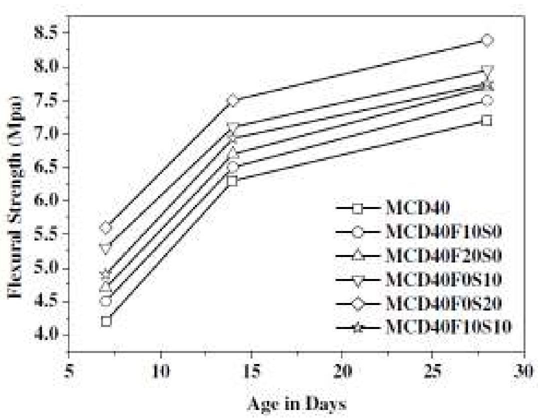

Figure 12: Flexural Strength vs. Age in Days for concrete with 40% CD

It is observed that in comparison to control mix, with 40% replacement of NFA with CD, the flexural strength increases upto 27.27%, 21.15% and 16.12% at 7, 14 and 28 days respectively. Whereas the concrete mix, in presence of 40% CD with 20% replacement of cement with FA, the flexural strength increases upto 42.42%, 28.84% and 24.19% at 7, 14 and 28 days respectively. In presence of 40% CD, with 20% replacement of cement with silpozz, the flexural strength increases upto 69.69%, 44.23% and 35.48% at 7, 14 and 28 days respectively. In presence of 40% CD with 20% replacement of cement with combination of 10% FA and 10% silpozz, the flexural strength increases upto 48.48%, 23.26% and 25% at 7, 14 and 28 days respectively as compared to control specimen. The flexural strength of all concrete mixes with and without CD and with cementitious material is giving higher value as compared to control specimen.

CONCLUSION

Based on the above studies the following Conclusions may be drawn.

1) Workability of concrete is indirectly proportional to CD content.
2) With respect to control specimen, in the absence of CD, workability increases when the cement is replaced with FA starting from 10% up to 20%. But in the presence of CD, FA decreases the workability.
3) At all replacement levels of NFA with CD, the workability of concrete decreases with respect to control specimen when the cement is replaced with silpozz starting from 10% upto 20%.
4) With respect to control specimen, the rate of increase in workability is not so significant when cement is replaced with the combination of 10% of FA and 10% of silpozz.
5) At all replacement levels of NFA (0 and 40%) with CD, compressive strength, split tensile strength and flexural strength increases with respect to control specimen when the cement is replaced with FA starting from 10% up to 20%.
6) With respect to control specimen, at all replacement levels of sand with CD, when the cement is replaced with silpozz starting from 10% up to 20% the compressive, split tensile and flexural strength increases remarkably.
7) With respect to control specimen, when cement is replaced with the combination of 10% of FA and 10% of silpozz, the compressive, split tensile, flexural strength increases significantly.
8) NFA can be replaced with CD up to 40% with increase in strength.

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