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RESEARCH ARTICLE

An Experimental Investigation on Stone Dust as Partial Replacement of Fine Aggregate in Concrete

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Abstract

Natural sand is most commonly used fine aggregate in concrete. Owing to acute shortage in many areas, cost and environmental factors, an alternative for the same is pondered. The aim of this study was to investigate the possibility of using stone dust as partial replacement of fine aggregate. A referral M25 concrete mix was used in the present investigation. The test results indicate that stone dust can be effectively used in partial replacement of fine aggregate in concrete. It is found that the compressive and flexural strengths of concrete increase on use of stone dust. The replacement level of the fine aggregate (30, 40, 50, 60 and 70%) by stone dust was investigated. It is observed that the compressive strength is not affected much by replacement up to 40%; however, the flexural strength at all ages improved significantly at all the replacement levels.

Keywords: Natural sand, fine aggregate, concrete, stone dust, partial replacement, flexural strength.

Introduction

Concrete is a mixture of binding material, coarse and fine aggregates and water. It is a versatile construction material due to its reasonable cost and easy availability of its constituents. Owing to increasing urbanization and other development activities in different sectors its consumption is increasing day-by-day. Increase in construction activities requires production of more and more quantity of concrete, which needs more and more natural river sand and coarse aggregate. During the process of production of coarse aggregate in crushing plants, a huge quantity of stone dust is produced which is considered worth less for any substantial use. This stone dust being a waste material can effectively be used in concrete making, as partial replacement of fine aggregate. The use of stone dust in concrete as partial replacement of fine aggregate will be an alternative material instead of conventional fine aggregate. This will result in conservation of natural resources (fine aggregate) up to some extent, besides helping in environment protection and disposal of stone dust in abundance. The presence of stone dust in sand increases the water demand and so the filler effect (Bonavetti *et al.,* 1993). Celik and Marar (1996) have reported that on increasing the dust content up to 10%, improved the compressive strength, flexural strength of concrete and drying shrinkage improved. However, the dust content exceeding 10% decreased the compressive strength, flexural strength and drying shrinkage gradually. They have also reported that impact resistance of concrete improved with the addition of 5% stone dust.

Attempts have been made to investigate the possibility of use of stone dust as partial replacement of sand in concrete. Due to its benefits such as useful disposal of this by-products, reduction in use of natural sand consumption as well as increasing the strength parameters and increasing the workability of concrete was noted (Jain *et al.,* 1999). The optimum dust content is found to be 10% for compressive strength and split tensile strength (Eren *et al.,* 2007). Increasing the dust content up to 30%, improved compressive strength of concrete and minimum absorption obtained when dust content was 20%. Dust content higher than 30% decreased the compressive strength and dust content more than 20% increased the absorption of the concrete (Hameed and Sekar, 2009). In the study of utilization of crushed stone waste in concrete it was concluded that adding 40% sand may be replaced by stone waste in concrete without compromising the quality of concrete (Sahu *et al.,* 2009). It is used for different activities in the construction industries such as road construction, manufacture of building materials, bricks, tiles and autoclave blocks. Every year 200-400 tons of stone dust is generated by the stone cutting plants and is dumped as waste leading to serious environmental and dust pollution. So it is necessary to dispose the stone dust waste quickly and efficiently. One of the possible uses lies in the construction industry (Patel and Pitroda, 2013). Aggregate is one of the main ingredients in concrete production. It accounts for about 75% of any concrete mix. The strength of the concrete produced depends on the properties of aggregate used (Sivakumar *et al.,* 2014).

Table 1. Properties of cement.

Properties	Experimental	Codal requirement[IS 1489 (Pt-1)-1991]
Normal consistency %	31.5%	-
Initial setting time	165 min	(Not less than 30 min)
Final setting time	215 min	(Not more than 600 min)
Soundness of cement (Le chatelier expansion)	0.75 mm	(Not more than 10 mm)
Fineness of cement (% retained on 90 µ IS sieve)	3.77%	10%
Specific gravity of cement	2.67	3.15
Compressive strength		
7 d testing	33.0	22 N/mm^2 (min)
28 d testing	43.2	33 N/mm^2 (min)

Table 2. Sieve analysis for fine aggregate.

Sieve size	Weight retained (g)	Cumulative weight retained	Cumulative % weight retained	Passing %	Standard % weight passing for zone II
4.75 mm	-	-	-	100	100
2.36 mm	50	50	5.0	95	75-100
1.18 mm	232	282	28.2	71.8	55-90
600 µ	348	630	63.0	37	35-59
300 µ	296	926	92.6	7.4	8-30
150 µ	60	986	98.6	1.4	0-10
Pan	12	998	100	0	0
Total = 287.4				Fineness modulas = 287.4/100 = 2.87	

In the present study, an attempt is made to explore the possibility use of stone dust in concrete, as partial replacement of fine aggregate. An experimental program was conducted to determine the effect of stone dust on compressive and flexural strength of concrete. The replacement level of fine aggregate varied between 30-70% at an interval of 10%.

Materials and methods

Experimental design: An experimental investigation was conducted to get the strength of specimen (cube and beam) made with the use of stone dust in partial replacement of fine aggregate. The strength of conventional concrete and other mixes were determined at the end of 7 and 28 d of moist curing. To study the effect of stone dust inclusion, cubes and beams of a design mix M25 grade concrete were cast. The 100 mm cubes were tested for compressive strength and the beam of size (500 mm × 100 mm × 100 mm) were tested for flexural strength. The M25 mix proportion was 1:1.65:3 at w/c ratio of 0.48.

Cement: In the present study, Portland Pozzolana Cement (PPC) of Prism brand of a single lot was used throughout the investigation. The physical and chemical properties of PPC as determined are given in Table 1. The cement satisfies the requirement of IS: 1489:1985.

Fine aggregate: The fine aggregate used was locally available river sand, which passed through 4.75 mm. Result of sieve analysis of fine aggregate is given in Table 2. The specific gravity of fine aggregate is 2.43 and fineness modulus is 2.87.

Coarse aggregate: Two aggregate sizes (20 and 10 mm) were used in this investigation. The specific gravity of coarse aggregate was 2.72 for both the fractions. Result of sieve analysis of 10 and 20 mm coarse aggregate is given in Table 3 and 4 respectively. The 20 and 10 mm aggregate were mixed in the ratio of 60:40.

Stone dust: Stone dust was collected from local stone crushing units of Mirzapur, Vindhyachal Road, Uttar Pradesh. It was initially dry in condition when collected, and was sieved before mixing in concrete. Result of sieve analysis of stone dust is given in Table 5. Specific gravity of stone dust was 2.50 and Water absorption was 0.5%.

Water: Potable water was used for mixing and curing.

Mix design: The design mix proportion of 1:1.65:3 at W/C ratio of 0.48 were used for M25 grade of concrete and the cement content were 380 kg/m^3 satisfying the requirements of IS-10262-2009.

Results and discussion

The compressive strength of concrete mixes at different replacement levels of fine aggregate with stone dust at 7 and 28 d is presented in Table 6 and its graphical representation is shown in Fig. 1. It is observed that up to 30% replacement level both at 7 and 28 d, the strength is decreased; but at 40% replacement, the 28 d strength is increased while the 7 d strength is decreased marginally. At 7 d, the compressive strength is decreased by 4.6% as compared to the referral concrete.

Table 3. Sieve analysis for coarse aggregate of 10 mm size.

Sieve size	Weight retained (g)	Cumulative weight retained	Cumulative % weight retained	Passing %
20 mm	-	-	-	100
10 mm	1680	1680	56	44
4.75 mm	865	2545	84.83	15.17
2.36 mm	453	2998	100	-
1.18 mm	0	2998	100	-
600 µ	0	2998	100	-
300 µ	0	2998	100	-
150 µ	0	2998	100	-
Fineness modulus = 640.83/100=6.40				

Table 4. Sieve analysis for coarse aggregate of 20 mm size.

Sieve size	Weight retained (g)	Cumulative weight retained	Cumulative % weight retained	Passing %
40 mm	-	-	-	100
20 mm	290	290	9.66	90.34
10 mm	2494	2784	92.8	7.2
4.75 mm	214	2998	100	-
1.18 mm	0	2998	100	-
600 µ	0	2998	100	-
300 µ	0	2998	100	-
150 µ	0	2998	100	-
Fineness modulus = 602.46/100=6.024				

Table 5. Sieve analysis for stone dust.

Sieve size	Weight retained (g)	Cumulative weight retained	Cumulative % weight retained	Passing %	Standard % weight passing for zone II
4.75 mm	-	-	-	100	100
2.36 mm	17	17	1.7	98.3	75-100
1.18 mm	161	178	17.8	82.2	55-90
600 µ	196	374	37.4	62.6	35-59
300 µ	399	773	77.4	22.6	8-30
150 µ	202	975	97.5	2.5	0-10
Pan	20	995	100	0	0
Total cumulative % retained = 232, Fineness modulus=232/100=2.32.					

Table 6. Compressive strength of different mixes.

Cube designation	Average compressive strength (N/mm^2)		% replacement of fine aggregate
	7 d	28 d	
A1	25.9	33.1	0
A2	25.1	32.5	30
A3	24.7	34.7	40
A4	21.6	31.5	50
A5	20.4	30.8	60
A6	18.7	29.9	70

At 28 d, the compressive strength is increased by 4.8% as compared to the referral concrete. The flexural strength of specimen was determined at 7 and 28 d (Table 7). The variation of flexural strength with replacement level is shown in Fig. 2. It is observed that the flexural strength increases marginally at 7 d with replacement level. However at 28 d, the flexural strength increases significantly with replacement level as compared to the referral.

Fig. 1. Variation of compressive strength with replacement level.

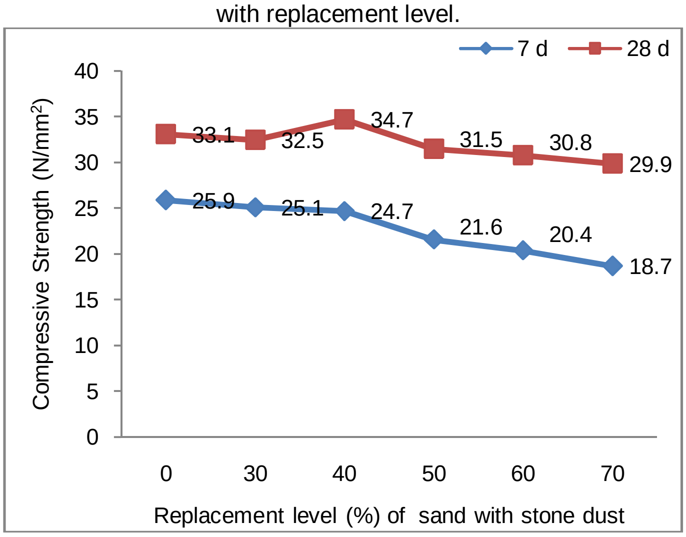
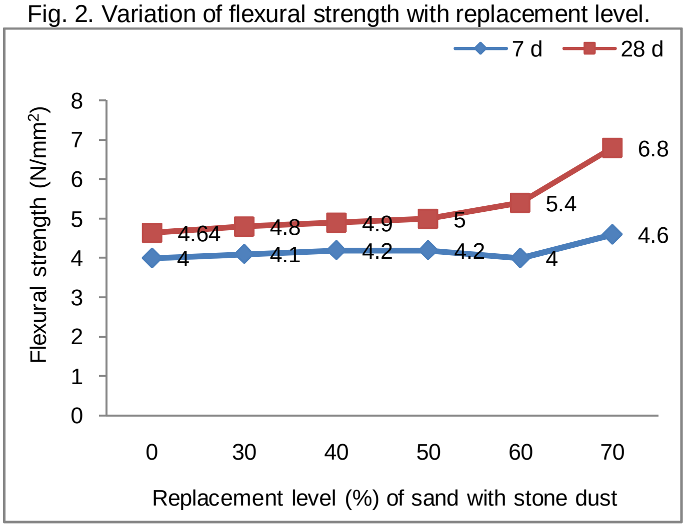


Table 7. Flexural strength of different mixes.

Beam designation	Average compressive strength (N/mm^2)		Replacement level (%) of sand
	7 d	28 d	
C1	4.00	4.64	0
C2	4.10	4.80	30
C3	4.20	4.90	40
C4	4.20	5.00	50
C5	4.00	5.40	60
C6	4.60	6.80	70

Fig. 2. Variation of flexural strength with replacement level.



The maximum gain in flexural strength is obtained at 70% replacement level and is 13 and 31.7% at 7 and 28 d respectively as compared to the referral.

Conclusion

From the above study, the following conclusions were obtained:

1. Replacement of fine aggregate with stone dust does not affect the compressive strength up to the replacement level of 40%, irrespective of the number of days.
2. The replacement of fine aggregate by stone dust improved the flexural strength considerably especially at 28 d.

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