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RESEARCH ARTICLE

Compressive and Flexural Strengths of Concrete using Stone Dust and Recycled Aggregate as Partial Replacement of Natural Aggregate

Shahbaz Shamim*, Vikas Srivastava and V.C. Agarwal
Dept. of Civil Engineering, Sam Higginbottom Institute of Agriculture Technology
and Sciences (Deemed University), Allahabad-211007, India
shahbazshamim91@gmail.com*; +91 8005319550

Abstract

Plain cement concrete is made by mixing cement, fine aggregate, coarse aggregate, water and admixture in appropriate proportion. The main constituents of concrete such as sand, stone and water are naturally available. These resources of natural aggregates (sand, stone) are limited and day-by-day the dependency on them must be minimized. The aim of this study was to investigate the possibility of using stone dust as partial replacement of fine aggregate and recycled aggregate as partial replacement of coarse aggregate. In the present study, cubes and beams were cast to determine the compressive and flexural strength of concrete made using stone dust and recycled aggregate as replacement of natural aggregate. Concrete of M25 grade was designed for a w/c ratio of 0.48 for the replacement of 10% coarse aggregate with recycled coarse aggregate and replacement of 50, 60 and 70% of fine aggregate (sand) with stone dust. The test results indicate that stone dust can effectively been used as partial replacement of fine aggregate in concrete. It is found that the compressive and flexural strengths of concrete increase on use of stone dust. It is observed that the compressive strength of concrete made using 10% recycled aggregate and 60% stone dust as replacement of coarse aggregate and fine aggregate respectively, is about 11% more than that of referral concrete at 28 d. However, the replacement of fine aggregate by stone dust improved considerably the flexural strength of concrete especially at 28 d.

Keywords: Concrete, compressive strength, flexural strength, stone dust, fine aggregate.

Introduction

Concrete is the prime construction material used in practice. No construction can be dreamed without use of concrete. Constituent of concrete is binding material, aggregate (fine and coarse) and water. Aggregates are naturally available and depleting day-by-day due to over exploitation for the sake of developmental activities. Owing to growing demand, aggregate will not be available in plenty in near future as their stock is limited. It is worthwhile to seek alternative for naturally available aggregates. Search of supplementary material is thirst area for researchers to workout scope and suitability of alternative material to relieve the burden over natural resources up to some extent. Owing to growing construction activities and renovation of structures, demolition wastes are produced in large quantities which are kept in abundance in low lying area or at disposal sites. The land, over which demolition wastes are disposed, deprives the further land use forever for other purposes. Demolition waste, after pulverization in appropriate size can effectively be used as partial replacement of natural coarse aggregate in concrete with some modification, if required. Stone dust is a waste material generated in process of crushing of natural aggregate in required size.

Large quantity of stone dust is available near crusher plants as it is kept in abundance. Being a worth less material, stone dust can be used in concrete as replacement material of fine aggregate with proper investigation. Nagabhusana and Bai (2011) reported that crushed stone powder can be effectively used to replace natural sand without reduction in the strength of concrete at replacement level up to 40%. Pofale and Quadri (2013) reported that compressive strength of concrete (M25 and M30) made using crusher dust increased at all the replacement level between 30-60% at an interval of 10%. However, maximum increased strength is observed at a replacement level of 40%. Sukesh *et al.* (2013) reported that compressive strength of concrete made using quarry dust is slightly higher than that of conventional concrete. Kumar *et al.* (2013) reported that there is an increase in strength in concrete containing quarry rock dust (10-12%) more than that of similar mix of conventional concrete. Reddy (2010) reported that stone dust can be used in place of natural sand in concrete. He concluded that by using stone dust as total replacement of natural sand in concrete, higher strength can be achieved. Ilangovan *et al.* (2008) concluded that replacement of natural sand with quarry rock dust as full replacement in concrete is possible.

Table 1. Properties of cement.

Properties	Experimental	Codal requirement[IS 1489 (Pt-1)-1985]
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 µm	348	630	63.0	37	35-59
300 µm	296	926	92.6	7.4	8-30
150 µm	60	986	98.6	1.4	0-10
Pan	12	998	100	0	0
Total = 287.4				Fineness modulas = 287.4/100 = 2.87	

However, they advice to carry out trial casting with quarry rock dust proposed to be used. Kujur *et al.* (2014) reported that fine aggregate can be replaced (up to 40%) by stone dust in concrete without compromising the strength. Singh *et al.* (2014) concluded that replacement of fine aggregate with stone dust does not affect the compressive strength up to the replacement level of 40% respective of curing period. Monish *et al.* (2013) reported that recycled aggregate can be used in concrete as partial replacement of coarse aggregate up to 30% with marginally compromise of compressive strength. However, up to 30% replacement of coarse aggregate with recycled aggregate compressive strength of same was comparable to conventional concrete. The present study is a part of an experimental program carried out to work out the suitability of possible use of recycled aggregate as partial replacement of fine aggregate.

Materials and methods

Methodology: Experimental investigation was conducted to get the strength of specimens (cubes and beams) made with the use of stone dust and recycled aggregates as partial replacement of fine aggregates and coarse aggregates respectively. 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 and recycled aggregates inclusion, cubes and beams of design mix M25 grade concrete were cast. The 100 mm cubes were tested for compressive strength and the beam of size (100 mm × 100 mm × 500 mm) were tested for flexural strength. The M25 mix proportion was (1:1.65:3) at w/c ratio of 0.48.

Cement: Portland Pozzolana Cement (PPC) of a single batch 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. However, a more or less similar test result of cement was reported by Sandeep *et al.* (2014) and kujur *et al.* (2014).

Fine aggregate: The fine aggregate used was locally available river sand, which was 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 are given in Table 3 and 4 respectively. The 20 and 10 mm aggregate were mixed in the ratio of 60:40. However, more or less similar test results of aggregates were reported by Sandeep *et al.* (2014) and kujur *et al.* (2014).

Stone dust: Stone dust was obtained 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.

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=6.4				

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	-
40 mm	-	-	-	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	4	4	0.4	99.6	100
2.36 mm	80	84	8.4	91.6	75-100
1.18 mm	336	420	42.0	58.0	55-90
600 µ	510	930	93.0	7.0	35-59
300 µ	70	1000	100.0	0	8-30
150 µ	-	-	-	-	0-10
Pan	-	-	-	-	0
Total cumulative % retained = 243.8, Fineness modulus=243.8/100=2.44.					

Mix design: The mix design was carried out as per the recommendations laid down in IS-10262-2009. 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 was 380 kg/m^3 satisfying the requirements of minimum cement content (300 kg).

Results and discussion

Compressive strength: The result of compressive strength with replacement of stone dust for 7 and 28 d are presented in Table 6 and its graphical representation is shown in Fig. 1. From the results, compressive strength of concrete with 60% replacement of stone dust and 10% replacement of recycled coarse aggregate have the highest 7 d and 28 d strength which reaches 23.5 N/mm^2 and 36.8 N/mm^2 respectively.

Results shows that with 60% replacement of fine aggregate with stone dust and 10% replacement of coarse aggregate with recycled coarse aggregate, the compressive strength of concrete increased by 10.05% at the age of 28 d compared to referral concrete. It can be seen that compressive strength is increased with addition of stone dust, but only at 60% further addition of stone dust resulted in decrease of the strength that is similar to the finding of kujur *et al.* (2014) and reported similar trend and concluded that optimum replacement level is 40%.

Flexural strength: 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.

Table 6. Compressive strength of different mixes.

Cube designation	Replacement of stone dust (%)	Replacement of recycled aggregate (%)	Average compressive strength (N/mm^2)	
			7 d	28 d
A1	0	0	25.9	33.1
A2	50	10	17.9	30.7
A3	60	10	23.5	36.8
A4	70	10	21.5	33.8

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

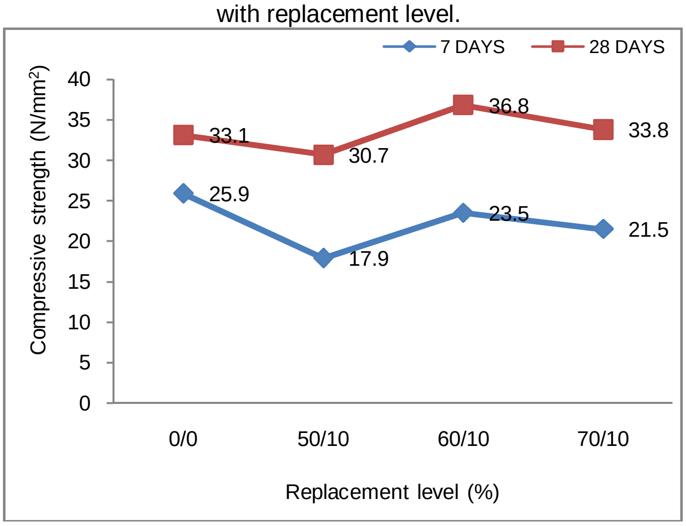
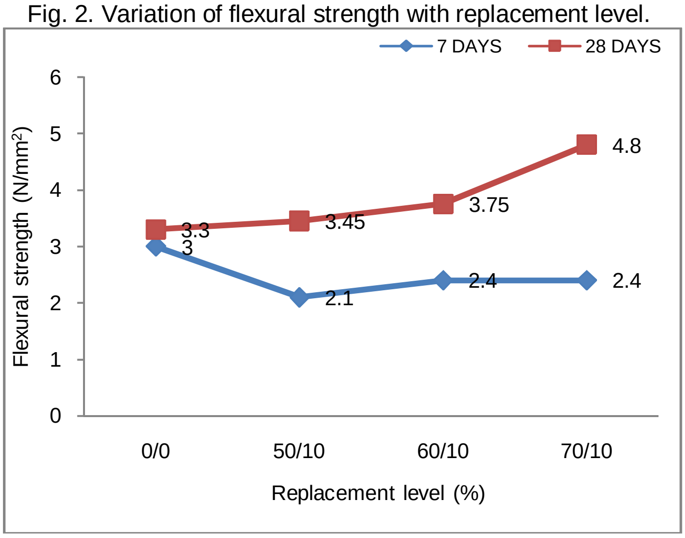


Table 7. Flexural strength of different mixes.

Cube designation	Replacement of stone dust (%)	Replacement of recycled aggregate (%)	Flexural strength (N/mm^2)	
			7 d	28 d
C1	0	0	3	3.3
C2	50	10	2.1	3.45
C3	60	10	2.4	3.75
C4	70	10	2.4	4.8

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



It was 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 concrete. Results shows that with partial replacement of stone dust with 50, 60 and 70% and 10% recycled coarse aggregate, flexural strength increased by 4.35, 12 and 31.25% at the age of 28 d respectively as compared to referral concrete. It is makeable that 7 d curing for different strength ratios decreases but for the same ratio for 28 d strength increases. Sandeep *et al.* (2014) reported similar finding that the addition of stone dust improves the flexural strength at 28 d.

Conclusion

From the above study, the following conclusions are obtained:

1. Compressive strength of concrete made using 10% recycled aggregate and 60% stone dust as replacement of coarse aggregate and fine aggregate respectively, is about 11% more than that of referral concrete at 28 d. However, compressive strength at 10% recycled aggregate and 70% stone dust is marginally than that of conventional concrete.
2. The compressive strength of 60% stone dust and 10% RCA sample is in close proximity of the referral concrete. Thus, it can be concluded that stone dust up to 60% with 10% recycled concrete aggregate is satisfactory for use.
3. Results shows that with partial replacement of stone dust with 50, 60 and 70% and 10% recycled coarse aggregate, flexural strength increased by 4.35, 12 and 31.25% at the age of 28 d as compared to referral concrete whereas, with 70% replacement of stone dust and 10% replacement of recycled coarse aggregate there is an increase in flexural strength by 31.25% at the age of 28 d compared to referral concrete.

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