Crushed stone waste as fine aggregate for concrete

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The suitability of crushed stone dust waste as fine aggregate for concrete has been assessed by comparing its basic properties with that of conventional concrete. Two basic mixes were chosen for natural sand to achieve M 20 and M 30 grade concrete. The equivalent mixes were obtained by replacing natural sand by stone dust partially and fully. Test results indicate that crushed stone dust waste can be used effectively to replace natural sand in concrete. Concrete made with this replacement can attain the same compressive strength, comparable tensile strength, modulus of rupture and lower degree of shrinkage as the control concrete.

Conventionally concrete is a mix of cement, sand and aggregate. Continuous research efforts have established concrete as a versatile material; concrete required for extensive construction activity can always be made available, since all the ingredients of concrete are of geological origin. In the production of concrete, granite/basalt stones and river sand are used as coarse and fine aggregate, respectively. Although these materials are usually available, at some places it is economical to substitute these materials by locally available ones. River sand which is most commonly used as fine aggregate in the production of concrete and mortar poses the problem of acute shortage in many areas. At the same time increasing quantity of crushed stone dust is available from crushers as waste. The disposal of this dust is a serious environmental problem. If it is possible to use this crushed stone dust in making concrete and mortar by partial/full replacement of natural river sand, then this will not only save the cost of construction but at the same time it will solve the problem of disposal of this dust.

For satisfactory utilisation of this alternative material, the various phases of examination have to be:

- technical feasibility
- durability of processed concrete
- economic feasibility.

With the ongoing research being done to develop appropriate technology and field trials to monitor the performance and assessment of economic feasibility, the use of this alternative material will become more viable.

There has been inadequate utilisation of large quantities of crushed stone as alternative material left out after crushing of rock to obtain coarse aggregate/ballast for concrete. Crushed stone dust does not satisfy the standard specification of fine aggregate in cement mortar and concrete. Efforts have been made to replace river sand by rock dust. Nagaraj *et al* have studied the effect of rock dust and pebble as aggregate in cement and concrete[1]. They found that crushed stone dust could be used to replace the natural sand in concrete. Babu studied the performance of quarry waste as fine aggregate in concrete[2]. Shukla *et al* investigated the behaviour of concrete made by partial/full replacement of river sand by crushed stone dust as fine aggregate and reported that 40 percent sand can be replaced by crushed stone dust without affecting the strength of concrete[1]. Pofale and Kulkarni investigated the behaviour of concrete mixes with natural sand partially and fully replaced by crushed stone powder (basalt) from aggregate crushing plant waste[1]. It is reported that crushed stone powder is feasible and practicable in plastic and cohesive mixes. Venugopal *et al* examined the effect of rock dust as fine aggregate in cement and concrete mixes[5]. They have suggested a method to proportion the concrete using rock dust as fine aggregate. Shukla and Sachan reported results of an experimental investigation in which stone dust is used to replace natural sand in concrete mixes[6]. It was observed that 40 percent dust can be used to replace natural sand without affecting strength of concrete mixes.

Research significance

The manufacture of coarse aggregate by crushing rock ballast produces large amount of crushed stone dust as waste material. This poses a serious disposal problem. In many regions of India, acres of land have become barren due to disposal of crushed stone dust on it. This study is mainly directed towards exploring the possibility of making effective use of the discarded crushed stone dust in concrete. The test results generated through a well planned and carefully executed programme indicate good prospects of utilising this crushed stone dust as a partial replacement of river sand in making quality concrete.

Experimental programme

Materials

The cement used for the investigation was 43 grade ordinary portland cement (OPC). The initial and final setting times were 45 and 300 minutes respectively; the 3-day and 7-day compressive strengths were 19.2 N/mm^2 and 26.04 N/mm^2.

Crushed granite aggregate having nominal size of 20 mm was used as coarse aggregate. Sand collected from nearby river was used without any refinement. Crushed stone dust procured from a crusher in Goramachia (Jhansi) was used. Stone dust was used as procured from the crusher. The fine aggregates used were 100 percent river sand, a mix of 80 percent river sand and 20 percent crushed stone dust and 60 percent river sand and 40 percent crushed stone dust. The sieve analysis results on random samples for these fine aggregates are indicated in *Table* 1.

Two basic concrete mixes designated as A (1 : 1.44 : 3.28; w/c = 0.50) and B (1 : 1.23 : 2.93; w/c = 0.45) were chosen for study. The mix proportions were obtained using IS code method of mix design to achieve M 20 and M 30 grade of concrete, with granite aggregate and 100 percent river sand as fine aggregate (referred to here as conventional concrete). The superplasticiser dosages used were 0.5, 1, 2 and 3 percent by weight of cement.

Preparation of specimens

The exact amounts of cement, sand, stone dust and coarse aggregate were weighed and then placed in a laboratory concrete mixer. The water was then added in required amount and workability of fresh concrete was measured by compacting factor method immediately after mixing. The test specimens were cast in steel moulds and compacted on a vibrating table. They were demoulded a day after casting. The specimens were cured in water until the test date.

Tests

For each batch of concrete, six 150-mm cubes were tested to determine the compressive strength, three at the age of 7 days and the remaining three at the age of 28 days. Three 100 mm x 100 mm x 400 mm size prisms were tested in flexure under three point loading to determine modulus of rupture, and three 150 mm x 300 mm cylinders were tested for splitting tensile strength both at 28 days.

Results and discussion

The effect of superplasticiser and partial replacement of stone dust on workability, compressive strength, modulus of rupture and splitting tensile strength are illustrated in *Figs* 1 to 4. It is clear from the figures that there is a significant increase in workability, compressive strength, modulus of rupture and split tensile strength. *Fig* 1 shows the variation of

Table 1: Details of sieve analysis for natural sand and stone

IS sieve designation	*Percentage passing*			
	River sand	*Stone dust*	*River sand (60 percent) + stone dust (40 percent)*	*River sand (80 percent) + stone dust (20 percent)*
10 mm	100.00	100.00	100.00	100.00
4.75 mm	100.00	99.00	99.50	99.60
2.36 mm	98.07	97.69	97.90	98.00
1.18 mm	42.83	67.19	52.00	46.81
600 micron	32.73	60.63	43.80	39.20
300 micron	4.30	30.74	14.50	11.10
150 micron	0.91	11.01	4.90	2.93
	Conforming to grading zone I of IS 383	Not conforming to any grading zone of IS 383	Conforming to grading zone II of IS 383	Not conforming to any grading zone of IS 383

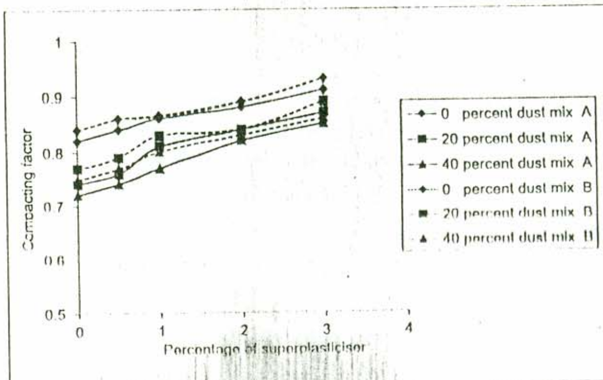
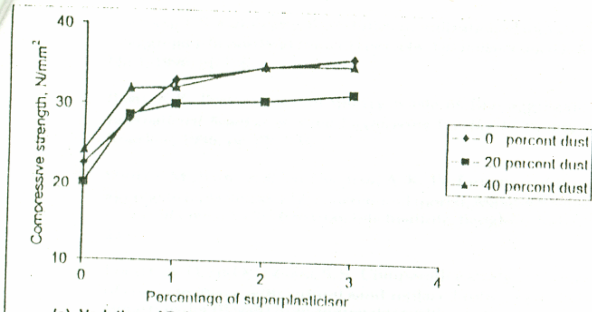
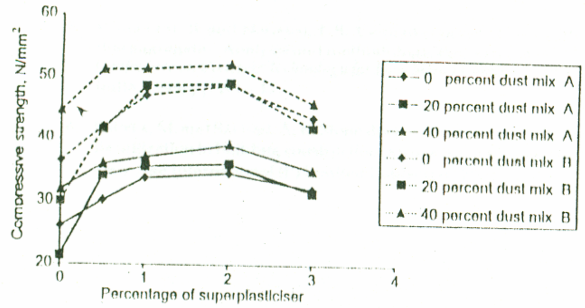


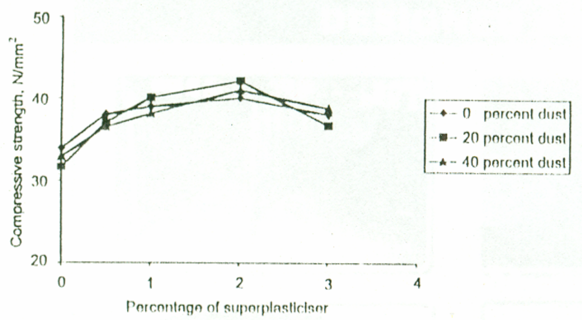
Fig 1 Variation of compacting factor with superplasticiser content for mix A and mix B



(a) Variation of 7-day compressive strength with superplasticiser content for mix A



(b) Variation of 28-day compressive strength with superplasticiser content for mix A and mix B



(c) Variation of 180-day compressive strength with superplasticiser content for various mixes

Fig 2 Variation of compressive strength with superplasticiser content for various mixes

compacting factor with dosages of superplasticiser. It was noticed that addition of stone dust decreases the workability of concrete mixes significantly. This is due to the reason that, stone dust is used as it is procured from the crusher and contains a larger portion of fine particles, which is evident from the sieve analysis result also. The workability of mixes made by using stone dust can be increased by addition of superplasticiser. From *Fig* 1 it can be observed that the workability level of 100 percent sand without superplasticiser can be obtained by using 40 percent stone dust and 2 percent superplasticiser. *Figs* 2 *(a)*, *(b)* and *(c)* show the variation of compressive strength with percentage of superplasticiser after 7 days, 28 days and three months curing, for mix A. It can be seen from the graphs that replacement of sand by stone dust does not affect the strength. Addition of superplasticiser increases the strength of concrete mixes.

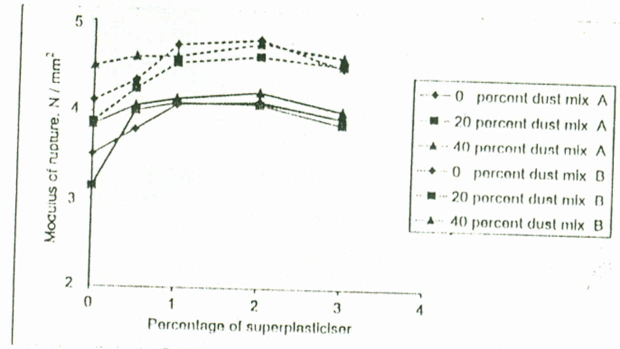


Fig 3 Variation of moudulus of rupture with superplasticiser content for mix A and mix B

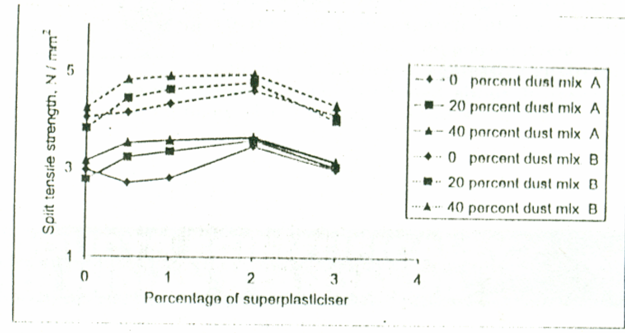


Fig 4 Variation of split tensile strength with superplasticiser content for mix A and mix B

Fig 2*(b)* also shows the variation of 28 day compressive strength for mix B with the percentage of superplasticiser. From the figure it is evident that the behaviour of mix B is similar. *Figs* 3 and 4 show the variation of modulus of rupture and split tensile strength for mix A and mix B, with the percentage of superplasticiser. It can be observed that replacement of sand by stone dust increases the modulus of rupture and split tensile strength of both the mixes.

Conclusions

The following conclusions can be drawn from the results of this study.

(i) There is a significant increase in compressive strength, modulus of rupture and split tensile strength for both the concrete mixes when sand is partially replaced by stone dust.

(ii) The workability of the concrete mixes decreased with an increase in percent of stone dust as partial replacement of sand.

(iii) The workability of concrete mixes increased with an increase in percent of superplasticiser.

It can be concluded that if 40 percent sand is replaced by stone dust in concrete, it will not only reduce the cost of concrete but at the same time will save large quantity of natural sand and will also reduce the pollution created due to the disposal of this stone dust on valuable fertile land.

Reference

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