BEHAVIOUR OF CONCRETE ON THE USE OF QUARRY DUST TO REPLACE SAND – AN EXPERIMENTAL STUDY

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Abstract— **This experimental study presents the variation in the strength of concrete when replacing sand by quarry dust from 0% to 100% in steps of 10%. M20 and M25 grades of concrete are taken for the study keeping a constant slump of 60mm. The compressive strength of concrete cubes at age of 7 and 28 days is obtained at room temperature. Split tensile strength and flexural strength of concrete are found at the age of 28 days. From the test results it is found that the maximum compressive strength, tensile strength and flexural strength are obtained only at 50% replacement. This result gives clear picture that quarry dust can be utilized in concrete mixtures as a good substitute for natural river sand at 50% replacement with additional strength than control concrete.**

Keywords- Concrete, quarry dust, river sand, compressive strength.

I. INTRODUCTION

Concrete is the most widely used construction material today. The constituents of concrete are coarse aggregate, fine aggregate binding material and water. Rapid increase in construction activities leads to acute shortage of conventional construction materials. It is conventional that sand is being used as fine aggregate in concrete. For the past some years, the escalation in cost of sand due to administrative restrictions in India, demands comparatively greater cost at around two to three times the cost of quarry dust even in places where river sand is available nearby.

To achieve economy, it is proposed to study with the use of crusher powder, a quarry waste as an alternative material to replace sand by crusher powder. There was a remarkable increase in compressive strength of concrete with 20% replacement of sand with manufactured sand[1], 40% replacement is possible[2] and 50% replacement gave higher strength[3]. Quarry dust fine aggregate decreased the compressive strength due to deficient grading and excessive flakiness [4]. The w/c ratio and slump value increased with the replacement of sand [5]. Voids present in quarry dust mortar were lesser as compared to that of sand hence higher compressive strength [6]. A comparatively good strength is expected when sand is replaced partially or fully with or without concrete admixtures.

It is proposed to study the possibility of replacing sand with locally available quarry dust without sacrificing the strength and workability of concrete.

Coarse aggregate is an important material used in R.C.C work of all types of structures. This is obtained by crushing the stone boulders of size 100 to 150mm in the stone crushers. The aggregate is sieved and the sieved aggregates which is less than 4.75mm in size, used in building construction works is called quarry dust. This dust is heaped like a mountain near the stone crushers. The volume of the waste dust produced is increased day by day. The owners of the crushers find it difficult to clear the dust from the crusher units.

In highways department the quarry dust is used to sprinkle over the newly laid bituminous road as a binding material between the bitumen and coarse aggregate. The fine powder from quarry dust is mixed with cement and used in grouting works. The quarry dust is used in the manufacturing of hollow blocks. Some mosaic companies use quarry dust partly for sand. In telecommunication department the quarry dust is used to refill the excavated pits after laying the telephone cables.

II. PROPERTIES OF MATERIALS

A. Cement

The cement used for this project work is Birla Super 43-grade Portland pozzolana cement. The various properties of cement are tabulated in Table I.

TABLE I. PROPERTIES OF CEMENT

S.No	Description	Value
1	Normal Consistency	29.5%
2	Initial setting time	30 min
3	Final setting time	230 min
4	Specific Gravity	3.05
5	Fineness	6%

B. Aggregates

1) Coarse Aggregate: The crushed granite aggregate of size passing through 20mm and retaining on 12.5mm standard sieve is used as coarse aggregate. The various properties of coarse aggregate are presented in Table II.

TABLE II. PROPERTIES OF COARSE AGGREGATE

S.No	Description	Value
1	Specific Gravity	2.98
2	Fineness Modulus	6.36
3	Density	1.58 gm/cc

2) Fine Aggregate:

a) Sand*:* Sand collected from nearby river Thamirabarani is used for this project. The various properties of sand are tabulated in Table III.

TABLE III. PROPERTIES OF FINE AGGREGATE

S.No	Properties	Sand	Quarry dust
1.	Specific Gravity	2.53	2.57
2.	Fineness Modulus	3.08	2.41
3.	Void ratio	0.55	0.42
4.	Density	1.63	1.85

b) Quarry dust*:* Quarry dust an alternative for sand is collected from nearby quarry. The properties of quarry dust are tabulated in Table III.

C. Water

Potable water with pH value 7 is used for mixing and curing throughout the experiment.

III. EXPERIMENTAL INVESTIGATIONS

A. Mix proportioning

Two grades M20 and M25 having proportion 1:1.5:3 and 1:1:2 respectively are used by weight and w/c ratio is fixed according to the slump of 60mm. For this concrete mix, quarry dust is added for replacement of sand at 0% to 100% in step of 10%.

B. Casting of specimen

As the aggregate of size less than 20 mm and greater than 12.5 mm are used, cubes mould of 150x150x150 mm are used. Cylindrical moulds of size 150 mm diameter and 300 mm height are used for casting specimen for split tensile test. For flexural strength, beam moulds of size 500x100x100 mm of internal dimension are used. Moulds are removed after 24hours of casting and cured in water up to the date of testing.

IV. TESTING PROCEDURE

A. Fresh concrete workability

To determine consistency of concrete, Slump test was conducted with varying water content and a particular w/c is fixed according to the slump of 60mm from graph plotted. The various w/c for different proportions of sand with quarry dust is tabulated in Table IV

TABLE IV. WORKABILITY OF CONCRETE (SLUMP 60MM)

Fine aggregate Sand: Quarry dust	water cement ratio (w/c)	
	M20	*M25*
100:0	0.489	0.475
90:10	0.495	0.480
80:20	0.500	0.490
70:30	0.512	0.503
60:40	0.520	0.509
50:50	0.525	0.512
40:60	0.535	0.521
30:70	0.542	0.532
20:80	0.550	0.535
10:90	0.560	0.540
0:100	0.568	0.556

B. Compression test

The cube specimen was tested for compressive strength at the end of 7 days and 28 days. The specimen was tested after the surface gets dried. The load was applied on the smooth sides without shock and increased continuously till the specimen failed. The mean compressive strength is calculated and tabulated in Table V.

TABLE V. MEAN COMPRESSIVE STRENGTH OF CONCRETE (MPA)

Fine aggregate Sand: Quarry dust	M20		M25	
	7 days	*28 days*	*7 days*	*28 days*
100:0	18.37	22.00	21.33	28.58
90:10	18.45	22.22	22.22	29.18
80:20	19.25	22.52	22.76	29.33
70:30	19.67	24.30	23.25	29.48

Identify applicable sponsor/s here. *(sponsors)*

60:40	20.44	24.89	23.56	29.62
50:50	21.18	26.22	24.43	30.07
40:60	19.67	24.43	22.76	28.58
30:70	18.15	22.22	20.44	26.22
20:80	17.55	20.89	19.25	24.29
10:90	15.85	19.67	18.66	23.25
0:100	14.86	18.66	17.78	22.66

From the Figures 1 and 2, it is observed that the 7 days and 28 days compressive strength of concrete reached maximum value at 50% replacement.

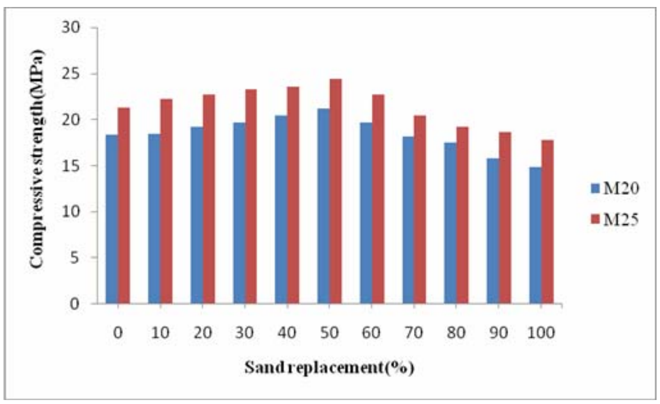

Figure 1. Compressive strength of concrete in 7 days.

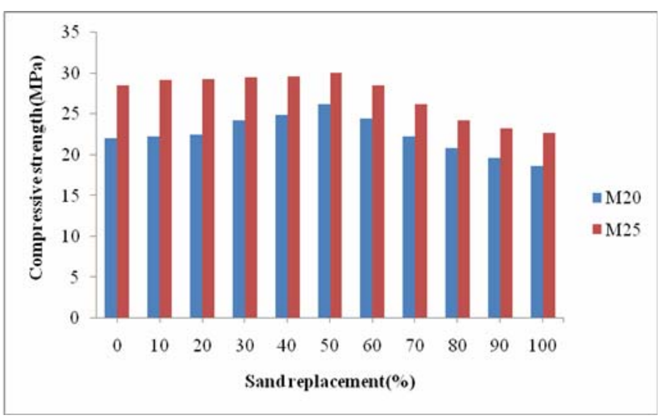

Figure 2. Compressive strength of concrete in 28 days.

C. Split tensile test

Split tensile test is also referred as "Brazilian Test". Placing a cylindrical specimen horizontally between the loading surfaces of a compression-testing machine and the load is applied till the cylinder failed along the vertical diameter.

$$\text{Tensile strength} = 2W / (\Pi\ DL)$$

The mean tensile strength is calculated and tabulated in Table VI.

TABLE VI. TENSILE STRENGTH OF CONCRETE (MPA)

Fine aggregate Sand: Quarry dust	28 days	
	***M*$_{20}$**	***M*$_{25}$**
100:0	2.80	3.17
90:10	2.90	3.29
80:20	3.10	3.35
70:30	3.25	3.44
60:40	3.30	3.58
50:50	3.40	3.63
40:60	3.15	3.56
30:70	3.00	3.40
20:80	2.85	3.36
10:90	2.70	3.20
0:100	2.60	3.03

From the Figure 3, it is observed that the increase in the 28 days tensile strength of concrete reached the maximum value at 50% replacement of sand by quarry dust.

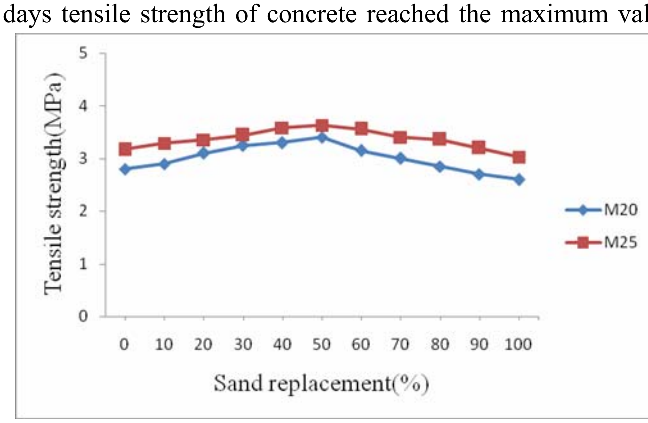

Figure 3. Mean Tensile strength of concrete (MPa).

D. Flexure test

The flexural strength of the concrete was determined by using loading frame. The loading is done using hydraulic jack on the beam and the load applied is measured using the proving ring. The span of the beam adopted is 450 mm and central concentrated load was applied.

Flexural strength = 1.5Wl / bd2

The mean flexural strength is calculated and tabulated in Table VII.

TABLE VII. FLEXURAL STRENGTH OF CONCRETE (MPA)

Fine aggregate Sand: Quarry dust	28 days	
	M_{20}	M_{25}
100:0	3.30	3.66
90:10	3.40	3.78
80:20	3.60	3.84
70:30	3.72	3.92
60:40	3.78	4.05
50:50	3.88	4.10
40:60	3.65	4.03
30:70	3.50	3.88
20:80	3.36	3.85
10:90	3.22	3.70
0:100	3.10	3.54

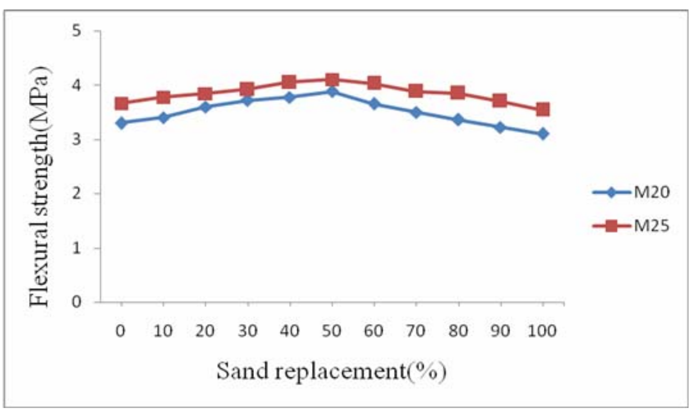

Figure 4. Flexural strength of concrete (MPa).

From the Figure 4, it is observed that the 28 days flexural strength of concrete reached maximum value at 50% replacement.

E. Flexure test on RCC beam

Concrete is weak in tension. To increase the tensile strength, steel was introduced in concrete members. In the reinforced concrete members, the reinforcement resists the tension produced in the concrete and hence they play a vital role in maintaining the tensile stress. Apart from loading some of the reasons for tensile stresses development in concrete are drying shrinkage, rusting of steel reinforcement and temperature variation.

To cast the specimen for RCC beam, moulds of 100mm breadth 150mm thick and length 1000mm were used. Two numbers of 10 mm diameter bars were used as main bars and two numbers of 10 mm diameter bars were used as hanger bars. Two legged 8mm diameter vertical stirrups @ 150 mm spacing were provided as shear reinforcement.

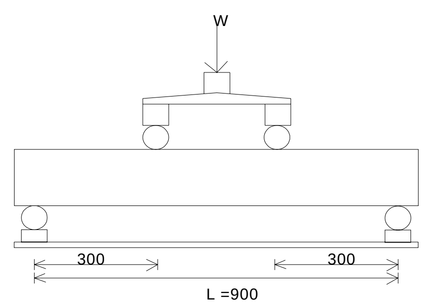

Figure 5. Loading for flexure test on RCC beam

Fresh concrete was prepared with replacement of sand by quarry dust from 0% to 100% at increments of 10%. Water was added as per the w/c ratio mentioned in the Table IV. The specimens were cast after placing the reinforcement properly inside the mould and the concrete filled in the mould in layers with proper compaction to each layer. After 24 hours the specimens were demoulded and immersed in water for curing. The specimens were cured for 28 days and placed horizontally between two roller supports of the bending table in the Universal testing machine with unsupported length 900mm as in Fig. 6. Concentrated loads were applied at one third points until failure has occurred. Flexural strength of reinforced Concrete beam was calculated and the values are presented in Table VIII.

Flexural strength = WL/bd^2

where W - Ultimate load
L - Unsupported length of the beam
b - Breadth of the beam
d - Depth of the beam\

Figure 6. Flexure test on RCC beam- Experimental setup

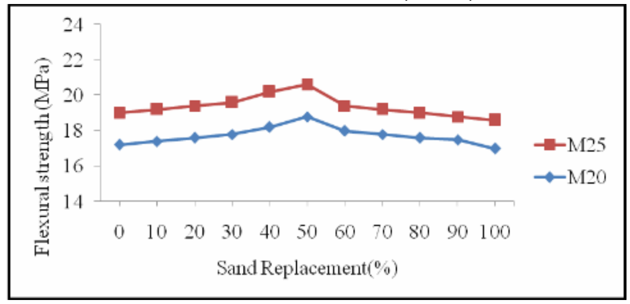

Figure 7. Flexural strength of RCC beam

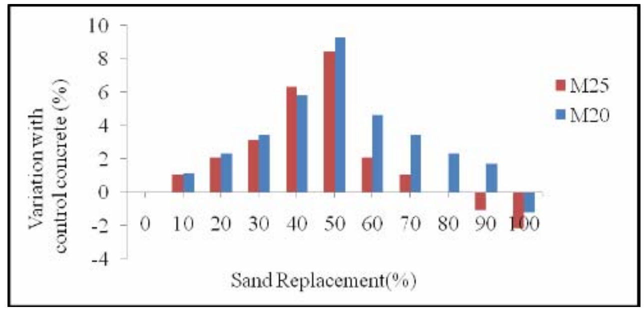

Figure 8. Variation in flexural strength (%) of RCC beam

TABLE VIII. FLEXUREL STRENGTH OF RCC BEAM (MPA)

Fine aggregate Sand: Quarry dust	Flexural strength (MPa)		% of variation with respect to control concrete	
	M20	*M25*	*M20*	*M25*
100:0	17.20	19.0	0	0
90:10	17.40	19.2	1.17	1.06
80:20	17.60	19.4	2.33	2.11
70:30	17.80	19.6	3.49	3.16
60:40	18.20	20.2	5.82	6.32
50:50	**18.80**	**20.6**	**9.31**	**8.43**
40:60	18.00	19.4	4.66	2.11
30:70	17.80	19.2	3.49	1.06
20:80	17.60	19.0	2.33	0
10:90	17.50	18.8	1.75	-1.06
0:100	17.00	18.6	-1.17	-2.11

From Figure 7, it is observed that the flexural strength of RCC beam is maximum at 50% sand replacement by quarry dust. From Table VIII, the value of this maximum flexural strength is found to be 18.8 MPa and 20.6 MPa with the percentage of increase in strength compared with control concrete of 9.31 and 8.43 for M20 and M25 concrete respectively. Figures 8 represents the variation in flexural strength compared with control concrete of M20 and M25 concrete RCC beams with sand replacement. From that it is observed that quarry dust can be comfortably used for replacing sand upto 80% without any reduction in strength compared to control concrete.

Flat and elongated aggregate particles should be avoided (or) limited to 15% by mass of total aggregates. Quarry dust often contains flat and elongated particles require an increase in mixing water and thus it affect the flexural strength of concrete if the water cement ratio is not adjusted.

V. CONCLUSION

From the above discussion it is concluded that:

- Concrete acquires maximum increase in compressive strength at 50 % sand replacement. When compared with concrete with only river sand, the amount of increase in strength is 19.18% and 5.21% for M20 and M25 respectively.
- Split tensile strength is maximum at 50 % replacement of natural sand by quarry dust. The percentage of increase with control concrete is 21.43 and 14.51 for M20 and M25 respectively.
- Maximum flexural strength is also at 50 % replacement. The percentage of increase compared with control concrete is 17.58 and 12.02 for M20 and M25 respectively.
- Maximum flexural strength of RCC beam is obtained at 50% sand replacement by quarry dust. The percentage of increase in strength compared with control concrete is 9.31 and 8.43 for M20 and M25 concrete respectively.

The derivation gives clear picture that quarry dust can be utilized in concrete mixture as a quality substitute instead of river sand to a high strength at 50% replacement.

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