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Effect of Replacement of Natural Sand by Grit on Workability of Concrete

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Abstract - Globally the construction industry is facing a major difficulty in obtaining natural river sand for making concrete. At national level the scenario is not different than global problem of natural sand. Day by day the sources of natural sand is depleting at a very fast rate and at the other end requirement of concrete is increasing tremendously due to infrastructure developments taking place worldwide. Government has also taken a serious note of the depleting sources of natural sand and is taking a corrective step to protect the environment. River sand is expensive because it is rare to find at every location, at the same time it is required to be transported from long distances ultimately increasing its final cost. Environmental issues and other constraints pose difficulties in availability and use of river sand. To cope up with this global problem and to reduce the pressure on natural resources, one of the alternatives is to replace the natural sand partially or fully by other such materials without compromising the quality of concrete. This has led to a search for different substitute materials for natural sand. Either partial or full replacement of natural sand by other alternative materials like grit, stone dust, manufactured sand, foundry sand or other such materials are being researched. One of the easily available materials is grit which can be obtained from stone crushers and can be used as a substitute material to natural river sand. Natural sand plays an important role in the performance behaviour of concrete which directly affects the mix design. Natural sand is rounded and smooth which improves the workability of concrete. However, the grit is angular and rough which adversely affects the workability. There is a challenge before construction industry to use such material without compromising on properties of concrete. In this paper an attempt has been made to propose a mix proportion for producing concrete using grit as a substitute material to natural sand. The experimental work was carried out to study the effect of grit on workability characteristics of concrete. The results obtained from the study shows that grit can be used successfully by partially replacing the natural sand thus effectively reducing the load on environment.

Key words: Concrete, Natural sand, Grit, workability

I. Introduction

Concrete is the second largest consumable material after water. The use of concrete is increasing tremendously due to infrastructure developments taking place worldwide. India consumes 450 million cubic meter of concrete per annum which is approximately 1 ton per Indian. The consumption is much more for the developed nations than the Indian continent. The use of concrete in India is due to infrastructure growth such as new highways, railway projects, airports, docks and harbours, power projects, dams, etc. For production of concrete, 70-75% aggregates are required. Out of this 60-67% is coarse aggregate and 33-40% is fine aggregate. Rising demand of construction sector cannot be fulfilled by natural sand as it is scarce and hence it is highly expensive. It takes millions of years to form natural sand. This bleak condition creates large demand for alternative materials and makes the use of grit inevitable. Natural sand contains excessive silt and the grading is not proper whereas grit is free from organic impurities and meets the requirement of gradation. The gradation of grit can be tailor-made whereas it is difficult to get particular sizes and hence the grading of natural sand. The major target before a Civil Engineer is to produce a good quality concrete. One of the properties required to produce a good quality concrete is its workability. Workability plays an important role in the production of concrete. Workability depends on many factors; one such factor is the shape and size of fine aggregate. Natural sand is normally of round shape and with smooth surface, whereas grit is angular and have rough surface. The main difficulty in achieving desired workability of concrete with use of grit is shape and surface of grit. The use of grit in concrete reduces the workability of concrete; hence the proportioning of ingredients of concrete is an important task. An attempt has been made by conducting experiments to study the workability characteristics of concrete produced by using grit.

II. Material and Methodology

II (A) Experimental program

The aim of this work is to study the behaviour of the concrete by using grit as a replacement of natural sand. In this work study has been done on the trial mixes in which the natural sand has been replaced by grit. After carrying out trials a mix for 100% replacement of natural sand is achieved for M 20 grade of concrete. For different concrete mixes slump values were found and comparison is done in terms of workability. For designing the M 20 grade of concrete W/C ratio of 0.50 is taken which is further modified up to 0.55 for meeting the value of required workability. For the assessment of gradation, sieve analysis of natural sand as well as grit is conducted. For the assessment, mix designs were made using natural sand and grit. The tests were conducted on the trials

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made from using natural sand, grit and combination of grit and fly ash with varying amount of cement, Coarse aggregate and water. In some mixes the admixtures are added for improving workability of concrete. Table 1.1 shows the comparative properties of natural sand and grit.

Table no. 1 General properties of Natural Sand and Grit

S.N.	Property	Natural Sand	Grit
1	Shape	Spherical	Cubical
2	Grading	Cannot be controlled	Can be controlled
3	Specific Gravity	2.6 to 2.8	2.5 to 2.9
4	Water Absorption	2 to 3%	3 to 4%
5	Ability to hold moisture	Up to 7%	Up to10%

II (B) Materials

The following paragraphs explain the details of materials used for conducting the experiments. The natural sand was obtained from nearby river, whereas coarse aggregate and grit was obtained from local crusher. A total of 7 concrete samples with different proportions were studied to find the workability characteristics of concrete.

II (B-1) Cement

In this experimental work OPC 53 grade cement was used. The tests conducted on the cement were fineness test conforming to IS 12269 : 1987, standard consistency test, compression test conforming to IS 650 : 1991. Table no. 2 shows the test results of cement used for producing concrete.

Table no. 2 Test results of cement

S.N.	Test	Result
1	Soundness (Le Chatelier)	8 mm
2	Initial setting time	50 minutes
3	Final setting time	560 minutes
4	Compressive strength (28 days)	51 MPa
5	Fineness	235 m^2/kg

II (B-2) Natural sand and grit

For the present work four types of fine aggregate are used for making concrete which includes natural sand and three different samples of grit. Initially, trials were carried out on the mix made from the natural sand which is free from the organic impurities. Following which trials were made by replacing natural sand by three different samples of grit. The sieve analysis was conducted for determination of gradation of natural sand as well as grit. For sieve analysis 1 kg of material was taken and sieved through sieves which were mounted one over another in decreasing order of their sizes i.e. 4.75 mm, 3.35 mm, 2 mm, 600 micron, 90 micron and grading pattern was found. Results of sieve analysis for natural sand are shown in table no. 3. Whereas, table no. 4 shows the results of sieve analysis for grit. Table no. 5 shows the test results of fineness modulus and specific gravity of natural sand and grit samples used in the experimental work.

Table no. 3 Sieve analysis of natural sand

S. N.	Sieve sizes	Retained (gm)	Retained (%)	Cum. (%)	% Passing
1	4.75 mm	29.5	2.95	2.95	97.05
2	3.35 mm	19.1	1.91	4.86	95.14
3	2.36 mm	26.1	2.61	7.47	92.53
4	2.00 mm	30.1	3.01	10.48	89.52
5	1.0 mm	145.2	14.52	25	75
6	600 µ	125.3	12.53	37.53	62.47
7	90 µ	611.5	61.15	98.68	1.32
8	Pan	11.9	1.19	99.87	0.13

Table no. 4 Sieve analysis of grit (sample 1)

S. N.	Sieve sizes	Retained (gm)	Retained (%)	Cum. (%)	% Passing
1	10 mm	5.0	0.5	0.5	99.5
2	4.75 mm	82.3	8.23	8.73	91.27
3	2.36 mm	292.1	29.21	37.94	62.06
4	1.18 mm	299.3	29.93	67.87	32.13
5	600 µ	93	9.3	77.17	22.83
6	300 µ	70.9	7.09	84.26	15.74
7	150 µ	73.2	7.32	91.58	8.42
8	Pan	84.9	8.49	100.07	- 0.07

Table no. 5 Test results of fine aggregate

S.N.	Test	Results			
		Natural sand	Grit (sample 1)	Grit (sample 2)	Grit (sample 3)
1	Specific gravity	2.66	2.6	2.35	2.52
2	Fineness modulus	2.86	4.68	4.57	4.51

II (B-3) Coarse aggregate

Coarse aggregate occupies the maximum volume in concrete, hence it is plays an important role in performance of concrete. It occupies nearly 70 to 80 percent by volume of the concrete and hence their properties are vital. Plastic and hardened concrete properties are largely depends upon the type of coarse aggregate. In this work coarse aggregate conforming to IS 383 : 1970 was used having maximum size of aggregate of 20 mm. the particle size of coarse aggregate varied from 4.75 mm to 20 mm.

II (B-4) Super plasticizer

In the present investigation Conplast SP 430 super plasticizing admixture was used, which complies with IS 9103 : 1999. Conplast SP 430 is based on sulphonated

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naphthalene polymers and is supplied as a brown liquid instantly dispersible in water. It has been specially formulated to give high water reduction up to 25% without loss of workability. Its specific gravity is 1.145 (at 30 °C) and chloride content is Nil. Air entrainment is approximately 1%.

II (B-5) Water

Water plays an important role in modifying the plastic and hardened properties of concrete. It reacts with cement and helps in setting and hardening the cement by evolving heat of hydration. The workability of concrete directly depends on the water-cement ratio and hence the quantity of water used for making concrete. The water-cement ratio affects directly the workability and strength of hardened concrete. For making the concrete potable water was used.

II (C) Mix design of concrete

Concrete mix was designed in accordance with IS 456 : 2000 and IS 10262 : 1982. A total of four concrete mix were designed to obtain M 20 grade of concrete. Out of the four concrete mix, one mix was prepared from 100% natural sand and the other three mix were by replacement of natural sand with grit. Table no. 6 shows the proportions of ingredients for different mix of concrete:

Table no. 6 Concrete mix proportions for M 20 grade (kg/m^3)

S.N.	Materials	Cement	Water	Sand (fine aggregate)	Coarse Aggregate
1	Quantity	394.32	197.9	635.74	1147.45
2	Proportion	1	0.50	1.6	2.90

Table no. 7 Trial Mix Design for replacement of natural sand by grit (Sample 1) (kg/m^3)

S.N.	Cement	w/c ratio	Fine aggregates		Coarse aggregates	Super-Plasticizer	Fly ash
			Natural sand	Grit (sample1)			
1	340	0.50	662.34	-	1155.42	-	-
2	325	0.50	-	652.6	1116.8	-	-
3	370	0.50	-	696.5	1114.8	0.60%	-
4	330	0.55	-	541.00	1085	0.80%	132
5	330	0.55	-	568.058	1085	0.80%	99

Table no. 8 Trial Mix Design for replacement of natural sand by grit (Sample 2, 3) (kg/m^3)

S.N.	Cement	w/c ratio	Fine Aggregates		Coarse aggregates	Super--plasticizer	Fly ash
			Sample 2	Sample 3			
1	330	0.55	548.8	-	1080.35	0.80%	99.06
2	330	0.55	-	583.92	1080.00	0.80%	99.06

Based on the results of 1st trial mix, adjustments were made for the further trial mix. Each trial mix was designed to obtain a target mean strength of 26.6 N/mm^2. Different concrete mix were designed with a variable water-cement ratio and cement content varying from 330 kg/m^3 to 370 kg/m^3.

III. Results and Tables

III (A) Measurement of workability

The 1st trial mix of concrete tested had a water-cement ratio of 0.50 with 100% natural sand as fine aggregate. The workability measured on a slump cone for this 1st trail mix was 50 mm. The compressive strength obtained for the 1st trail was more than the desired target mean strength. Hence a 2nd trail mix of concrete with natural sand was made by reducing cement content and as expected the required target mean strength was achieved. The 3rd trial mix was made with replacement of natural sand by grit with an increased water-cement ratio of 0.55. For this sample of concrete mix the observed slump was shear slump. So the 4th trial was carried out with addition of SP-430 super plasticizer. The concrete obtained was honeycombed for this mix and it became difficult to finish the concrete in cubes. To improve the workability and ease in finishing the concrete, mix was designed for another trial with addition of fly ash. The difficulty in achieving a smooth finish and target workability was achieved by addition of 30% fly ash and 0.8% SP 430 super plasticizer. Table no. 9 shows the workability of concrete obtained for different mix.

Table no. 9 Workability results of various mixes

S.N.	W/C ratio	Fine Aggregate	Admixture	Workability (mm)
1	0.50	Natural sand	-	50
2	0.50	Natural sand	-	40
3	0.55	Grit (sample 1)	-	50
4	0.55	Grit (sample 1)	0.8% SP 430	100
5	0.55	Grit (sample 1) + 40% Fly ash	0.8% SP 430	110
6	0.55	Grit (sample 2) + 30% Fly ash	0.8% SP 430	150
7	0.55	Grit (sample 3) + 30% Fly ash	0.8% SP 430	150
8	0.55	Grit (sample 1)	0.8% SP 430	30

IV. Conclusion

Natural sand as fine aggregate in concrete plays an important role in modifying the workability characteristics of concrete. However, the sources of natural sand are depleting day-by-day and it becomes essential to find other alternative materials which can be used as replacement of natural sand. One such material which can be used as replacement of natural sand is grit. According to the findings of this present work, due to the irregular particle shape of the grit and

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limitations imposed by code on water-cement ratio, achieving a good workable concrete without super plasticizer was practically difficult. From the study carried out, it can be concluded that concrete of M 20 grade can be produced by 100% replacing natural sand with grit in presence of fly ash and super plasticizer.

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