Utilization of Quartzite as Fine Aggregate in Concrete

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Abstract

Increase in construction activities have led to an increase in demand for the various raw materials used in concrete, especially river sand which is conventionally used as fine aggregate. Due to increase in mining process, the availability of this river sand is becoming scarce and expensive. There is a requirement for reduction in the cost of concrete production has resulted in the increased need to identify substitute material to sand as fine aggregates in the production of concrete. This study was conducted to investigate the effect of quartzite as replacement to fine aggregate in concrete of M30 grade. The fine aggregate was replaced with six different percentages (0%, 10%, 20%, 30%, 50% and 100 %) of quartzite by weight. Laboratory tests are conducted and performance of quartzite concrete is determined by the workability, density and compressive strength tests. The results indicated that the effectiveness of quartzite sand as 100% replacement material to fine aggregate, without affecting the desired strength.

Keywords: *Quartzite, Concrete, Workability, Fine Aggregate*

I. Introduction

Throughout the world, every construction field requires huge quantity of raw materials such as cement, sand, coarse aggregate for the production of concrete. In fact, sand is a key ingredient of concrete, which is being rapidly extracted from river beds causing an ecological imbalance and depletion of natural sand deposits. With the extraction of natural sand deposits the world is over drying up, and there is an acute need for a product that matches the properties of natural sand in concrete (Bahoria et al., 2013). In the last 15 years, it has become clear that the availability of good quality natural sand is quite decreasing. Environmental concerns are also being raised against uncontrolled extraction of natural sand. The developing country like India is facing shortage of good quality natural sand (Akshay et al 2014) Due to this demand and scarcity, natural sand is becoming a very costly and expensive material. The use of alternative constituents in construction materials is now a global concern (Kamala et al., 2012). By viewing to these consequences, it is found that there is a need to find an alternative material to replace the natural river sand. Now-a-days, sustainable infrastructural growth requires the alternative material that should satisfy technical requisites of fine aggregate as well as it should be available locally in large amount.

II. Objective and Scope

The main objective of this experiment is to study the technical feasibility of quartzite sand in the production of concrete and this paper presents the results of investigation carried out to evaluate the mechanical properties of concrete mixtures in which fine aggregate (sand) was replaced with quartzite sand for M30 grade concrete. Fine aggregate (sand) is replaced with six different percentages (0%, 10%, 20%, 30%, 50%, and 100%) of quartzite sand by weight. Laboratory tests are performed to determine the Specific gravity, Gradation of aggregates, Bulk density, workability and compressive strength of concrete. The results indicated a significant improvement in the strength properties of normal concrete by the replacement of fine aggregate with quartzite sand and it can be effectively used in the structural concrete.

Iii. Literature review

Diogo Silva et al. (2014) studied on the mechanical performance of structural concrete containing fine aggregates from waste generated by marble quarrying industry .They reported that incorporation of secondary marble fine aggregates negatively influenced the workability of concrete. There is a decrease in the value of compressive strength with an increase in the replacement ratio of secondary marble fine aggregates.
Jared R. Wright et al. (2014) studied the use of glass cullet as a 100% sand replacement in Portland cement concrete system. They showed that glasscrete mixtures need a lower w/cm to match the 28 days compressive strength of conventional concrete and also these mixtures require less super plasticizer to achieve same slump compared with natural sand concrete.
K. Kayathri et.al. (2014) described the effect of copper slag, fly ash and granite powder as a partial replacement in fine aggregate. They showed that the compressive strength of various mixes of copper slag, granite powder, fly ash fiber in concrete at 28 days is 51.8N/mm^2 where as for the conventional concrete it is about 33 N/mm^2.
Akshay C. Sakh et al. (2014) explained about numerous trends in replacement of natural sand with different alternative materials. They emphasized on the physical and mechanical properties of concrete prepared with various alternative materials.
Gunalaan Vasudevan et al. (2013) presented a report on the performance of using waste glass powder in concrete as a replacement of cement. The density of concrete will get lighter than the standard concrete mix with increase in the replacement of material.
R. Kamala et al. (2012) demonstrated the reuse of solid wastes from building demolition by partial replacement substitute to conventional coarse aggregate. The workability of crushed tile aggregate is equilibrium of fluidity, deformability, filling ability and resistance to segregation. Further increase in the addition up to 40% replacement of coarse aggregate the strength decreases.
J. Silva et al. (2010) tried to prove the technical feasibility of replacing fine aggregate with crushed red-clay waste from a brick factory. They concluded that the results are very promising up to a replacement ratio of sand with ceramic waste of at least 20%.

IV. Experimental Investigation

a. *Materials used:*
Cement:

In the present study Ordinary Portland Cement of 53 grade confirming to IS: 12269-1987 was used. Its specific gravity is 3.15. The cement is tested as per the procedure given in the Indian standards IS 4031(1988).

Fine Aggregate:
Natural river sand conforming to zone II as per IS 383(1987) was used. It is free from clayey matter and organic impurities. Its specific gravity value is 2.59 and fineness modulus is about 2.38.

Coarse Aggregate:
Machine crushed angular granite metal of 20mm nominal size from the local source was used as coarse aggregate. The physical properties of coarse aggregate were investigated in accordance with IS 2386 -1963. Its specific gravity is 2.9.

Water:
Locally available water is used for mixing and curing which is free from oils, acids, alkalis, salts, organic materials.

Quartzite Sand:
Machine crushed finely graded quartzite sand obtained from locally available quartzite quarry (kothavalasa), is used in this investigation and its sample material is shown in the figure1 and the Physical Properties of Quartzite Sand are presented in Table.1.

Figure 1: Quartzite Sand

Table1: Physical Properties of Quartzite Sand

PHYSICAL PROPERTIES	
Color	whitish grey to red
Specific gravity	2.35
Bulk density	1700 Kg/m^3
Fineness modulus	3.034
Chemical composition	SiO_2 (96%)

b. Mix Design

(1) Mixture proportions:

The mix design for M30 grade was carried out based on the recommended guidelines in Indian Standards (IS 10262-1982). The basic assumption made in the Indian standard method for mix design is that the compressive strength of workable concrete is by and large governed by the water-cement ratio. In this method the water content and proportion of fine aggregate corresponding to a maximum size of aggregate are first determined from the reference values of workability, water-cement ratio, and the grading of fine aggregate. These values are then adjusted for any difference in workability, water/cement ratio and grading of fine aggregate in any particular case.
After conducting tests on trial mixes, the final mix proportion arrived at was 1:1.52:2.83 with water/cement ratio of 0.45 which is taken as a constant value during the entire work. The quantity of materials used are given in Table.2

Table 2: Mix Proportions

S.No	% Replacement	Cement (Kg/m^3)	F.A (Kg/m^3)	Q.Sand (Kg/m^3)	C.A (Kg/m^3)
1	0%	413.33	629.77	0	1169.57
2	10%	413.33	566.79	62.98	1169.57
3	20%	413.33	503.82	125.95	1169.57
4	30%	413.33	440.84	188.93	1169.57
5	50%	413.33	314.89	314.89	1169.57
6	100%	413.33	0	629.77	1169.57

Note: F.A- Fine Aggregate (River sand), Q.Sand- Quartzite Sand
C.A- Coarse Aggregate (gravel)

c. Casting, Curing and Testing Of Specimen:

Fine aggregate is replaced with six Percentages (0%, 10%, 20%, 30%, 50% and 100%) of Quartzite sand by weight. All the triple blended composites were mixed in the pan mixer. Three cubes are casted for the each combination and Continuous curing was maintained up to the age of 7 and 28 days. Mixing, casting, curing and testing were carried out as per the standard specifications. The compressive strength is determined and reported in this paper.

V. Test methods, results and discussions

a. Workability:

The workability is one of the physical parameters of concrete which affects the strength, durability and the appearance of the finished surface. The workability of concrete depends on the water cement ratio. If the water added is more which will lead to bleeding or segregation of aggregates. The test for the workability of concrete is given by the Indian Standard IS 1199-1959 which gives the test procedure using various equipments. In this case slump cone test and compaction factor tests are conducted for measuring the workability of concrete. Test results are reported in Table 3 and Table 4 respectively.

Table 3: Slump Test

Concrete mix	Slump in mm
0%	70
10% QS	55
20% QS	35
30% QS	25
50% QS	22
100% QS	0

Note: QS- Quartzite Sand

The workability of concrete for six mixes was studied and the slump values are furnished in Table 2. The variation in slump values for concrete mixes of different % replacement with Quartzite sand are found to be quite decreasing when compared to the normal concrete mix. It also shows that the slump value decreases with the increase in percentage of quartzite sand in the concrete mix. However, concrete mixes were tested for compaction factor value.

Table 4: Compaction factor test

Concrete mix	Compaction factor value
0%	0.96
10% QS	0.92
20% QS	0.88
30% QS	0.83
50% QS	0.79
100% QS	0.61

Compaction factor test is very useful for low workability concrete mixes as normally used when concrete is to be compacted by vibration. For normal concrete it is showing a higher value of workability, as the % of replacement is increasing there is decreasing tendency, this may be due to the void filling action of the quartzite sand as it is finer than the river sand, which gives a high cohesion to the mix. Quartzite sand consumes higher amount of water to achieve the required workability in concrete. Compaction factor values show that for 100% replacement with quartzite sand, the concrete mix represented a medium workability as per the recommendations of IS 1199-1959.

b. bulk density of aggregate:

Bulk density is the weight of a material in given volume and is affected by several factors, including the amount of effort introduced in filling the measures. It is performed in accordance of IS: 2386 (part III- 1963). The loose bulk density measures the volume that the aggregate will occupy in concrete. The loose and compacted bulk density values aggregates are given in Table.5.

Table5: Loose and Compacted Bulk Densities

Material	Loose Bulk Density (Kg/M^3)	Compacted Bulk Density (Kg/M^3)
Fine aggregate(Sand)	1560	1700
Coarse aggregate	1476	1722
Quartzite sand	1401	1660

It is observed that, the loose and compacted bulk density values of Quartzite sand are less when compared to natural sand. J. Silva et al. (2010) found that the bulk density substantially decreased, almost linearly, as the primary aggregate (sand) was replaced with brick waste. This was because the bulk density of the brick waste is generally lower than that of sand.
The density of Recycled plastic concrete (RPC)-20 decreases by 3% compared with that of normal concrete because the density of plastic is less than that of sand which was stated by Feng Liu et al. (2014).

c. Compressive strength test:

Cube specimens of 150 mm× 150 mm × 150 mm for M30 grade of concrete were casted and tested under compressive loading. All the specimens were tested in saturated surface dry condition, after wiping out the surface moisture. For each mix combination, three identical specimens were tested at the age of 7 and 28days. The compressive strength was calculated as per IS: 516 (1959), and values are presented in the figure 2 and figure 3 as below.

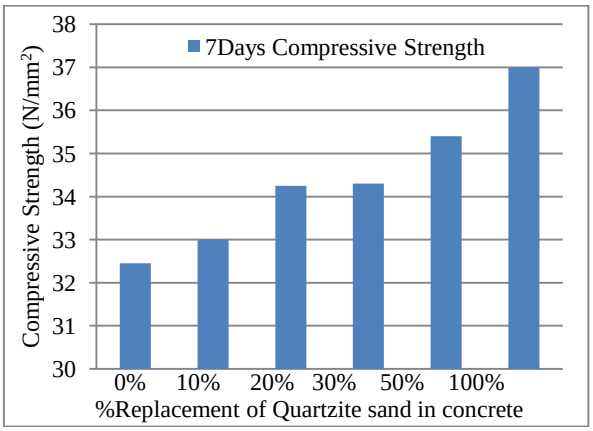

Figure.2: Compressive Strength with% Replacement Levels of Quartzite Sand (7 Days)

Figure.2 represents the variation in 7days Compressive Strength of normal concrete with Quartzite Sand concrete. The average Compressive strength of normal concrete at the age of 7days is about $32.45N/mm^2$. It is observed that with the addition of Quartzite sand in various proportions as a replacement to fine aggregate i.e., with 10% and 20% replacement, the compressive strength is increased to $33N/mm^2$ and $34.25N/mm^2$, but less early strength gain in concrete is observed at 7days. Craig Polley et al. (1998) noted that a strength gain was slow initially and a satisfactory result is obtained up to 20% replacement of natural fine aggregates with waste glass.

Further increase in the replacement of quartzite sand showed an increasing trend in Compressive Strength of concrete and for 100% replacement of quartzite sand, the maximum compressive strength of 37 N/mm^2 is achieved which is 14.02% more than that of normal concrete.

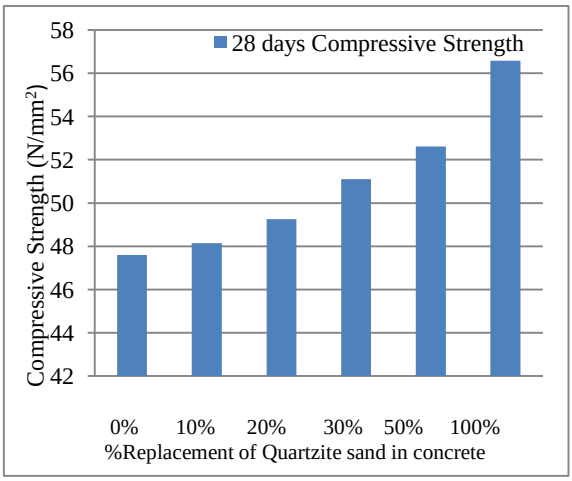

Figure.3: Compressive Strength with% Replacement Levels of Quartzite Sand (28 days)

Figure.3 represents variation in 28days Compressive Strength of normal concrete with different %replacement of Quartzite Sand concrete. The average Compressive strength of normal concrete at the age of 28days is about 47.6N/mm^2. With 10% inclusion of quartzite sand in the concrete, the early strength development is found to be high of about 48.14N/mm^2.An increase in the Compressive Strength is observed up to full 100% replacement of Quartzite sand in concrete.

For 100% replacement of quartzite sand, the maximum compressive strength of about 56.58 N/mm^2 is achieved which is 18.86% more than that of normal concrete at 28 days. Jafar Bolouri Bazaz et al. (2012) stated that compressive strength of concrete made with crushed brick as substitute to fine aggregate is about 21.5 N/mm2 which is relatively low in comparison with ordinary concrete can be used in non structural purpose. Abdullahi. M (2012) reported that normal strength concrete made with river gravel and granite aggregate had similar compressive strength where as concrete made with quartzite aggregate achieved a somewhat higher strength. When natural sand was replaced with Quartzite sand, there is an increase in the compressive strength. This is due to low friction of quartzite sand, proper inter locking of particles during compaction results in gain of strength. Quartzite sand concrete shows a smooth surface finishes which is not observed with natural river sand.

VI. Conclusions

This paper has presented an experimental study on utilization of quartzite sand as a replacement to fine aggregate in concrete. The following conclusions could be drawn.

1. In this study, it is observed that the overall strength of Quartzite sand concrete is higher and workability is lower when compared to the normal concrete
2. As the percentage replacement of Quartzite sand increases, the workability of the concrete is decreasing. This is due to the higher amount of water absorption by

the fines particles. Therefore, Quartzite sand has positively influenced the workability of concrete

3. The maximum compressive strength of Quartzite sand concrete at 7 days and 28 days are 37 N/mm^2 and 56.58 N/mm^2 respectively shows that the initial strength development is less at 7days and further increase in compressive strength is observed at 28 days.
4. For 100% replacement of fine aggregate by quartzite sand showed 14.02% increase in compressive strength at 7days and 18.86% increase in compressive strength at 28days.
5. Quartzite sand which is used for replacement of fine aggregate is having low bulk density and specific gravity than the natural river sand. Hence weight of concrete can be reduced.
6. Quartzite sand shows a good gradation and smooth surface finish which is not observed in natural sand.
7. Quartzite sand is found to be more suitable alternative material to river sand at reasonable cost. Hence 100% replacement of fine aggregate with Quartzite sand is acceptable in construction works.

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