International Journal of Latest Trends in Engineering and Technology
Vol.(13)Issue(1), pp.015-021
DOI: http://dx.doi.org/10.21172/1.131.04
e-ISSN:2278-621X

EXPERIMENTAL STUDY ON PROPERTIES OF QUARTZITE AS UNCONVENTIONAL MATERIAL FOR COARSE AGGREGATE

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Abstract- Concrete is most commonly and widely used material in infrastructure development. Coarse aggregate is major ingredient of concrete which constitutes to about 60 to 70% in terms of volume of Concrete. The cost of coarse aggregate is increasing day by day due to its limited availability and large demand. In the present work, Quartzite is used as an alternate material to coarse aggregate and has studied various engineering and mechanical properties. Experimental studies were performed on plain cement concrete by replacing coarse aggregate up to 100% and durability studies were performed by 100% replacement of coarse aggregate. The mix design and test methods are followed in accordance with the Bureau of Indian Standards. The optimum percentage of quartzite replacement to coarse aggregate is found at 20%.The compressive strength increased at 20% and compressive strength at 100% replacement was found to be 53.2 N/mm2 and 48.8 N/mm2.The concrete made with quartzite performed well in terms of compressive strength and showed higher performance for 28,60,90,120 days than conventional concrete when exposed to sea water, acid exposure and temperature effect and showed satisfactory performance when exposed to sulphate exposure. The overall performance of quartzite is reasonably good when exposed to various weathering conditions and the same can be replaced as coarse aggregate in concrete.
Keywords – Quartzite, Coarse Aggregate, Compressive Strength, Acid Exposure, Temperature Effect, High Performance Concrete.

1. INTRODUCTION

Construction industry is one of the major consumers of natural resources and produces quantities of the waste materials. Infrastructure development in the developing countries increased the utilization of aggregate from the quarries leading to depletion of the natural resources. Large quantities of waste from various process industries are dumped into the landfill sites without any preprocessing. These enter into the ecosystems and create lot havoc. Utilization of the waste material as replacement of aggregate would reduce stress on the natural resources. The Coarse aggregate occupies 60-70% of the concrete volume. The rheological and mechanical properties of the aggregate play a vital role in concrete structures. Mineral properties of the aggregate determine the strength and durability properties of the concrete mix. Development of composite concretes using various admixtures increased the strength properties. The utilization of the waste materials reduces the density of the concrete. Scientific methods should be developed for the utilization of various alternate aggregates. Waste generated from Sanitary Ceramics, Marble dust, lime stone, crushed oil palm shell, copper slag, oil palm, corn cob, rice husk, construction and demolition, scrap tyre rubber, coconut shell, palm kernel were used as coarse aggregate replacement materials by different researchers in development of high strength concrete.

2. LITERATURE REVIEW

Almesfer et.al (2014) had replaced coarse aggregate with Waste Glass in which he had observed that the compressive strength trend at 28 days with the addition of Waste Glass significantly decreasing the compressive strength for all concrete mixes. This decrease in compressive strength is due to the high brittleness of glass leading to cracks which result in incomplete adhesion between the waste glass and cement paste, while the poor geometry and reduced specific gravity of glass leads to a heterogeneous distribution of aggregates.

Medina et al.(2012) said that coarse sanitary ware aggregates has higher water absorption than coarse natural aggregates. The results reported, respectively 0.6% and 0.2%, showed that these properties are very similar for recycled and natural aggregates. They stated that the bulk density is higher for coarse natural aggregates (2630 kg/m3) than for coarse recycled ceramic aggregates (2390 kg/m3).

Senthamarai et.al (2011) had said that the slump values are increased by replacement of coarse natural aggregates with coarse recycled ceramic aggregates. The authors had said that this result is due to the lower water absorption and smooth surface texture of the ceramic aggregates.

Rashida et.al (2009) had replaced coarse aggregates with crushed bricks in which he had concluded that when compared to the natural coarse aggregate in concrete there was a drastic reduction in compression strength due to increase in water cement ratio and the rate of this strength reduction is higher for lower water-cement ratio.

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3. PROPERTIES OF MATERIALS

Materials : Ordinary Portland cement of 53 grade confirming to IS 12269:1987 was used. It was tested for its physical properties as per IS 4031(part II):1988. The locally available river sand was used as fine aggregate in the present investigation. The sand was free from clayey matter, salt and organic impurities. The sand was tested for various properties like specific gravity bulk density etc., and in accordance with IS 2386:1963. Water used for casting was tested as per IS 3025. Machine crushed angular granite metal of 20mm nominal size from the local source was used as coarse aggregate. It was free from impurities such as dust, clay particles and organic matter etc. The physical properties of coarse aggregate were investigated in accordance with IS 2386:1963.Machine crushed angular quartzite metal of 20mm nominal size brought from the locally available quartzite quarry was used as alternative material for coarse aggregate. The physical properties of coarse aggregate were investigated in accordance with IS 2386:1963.

Figure 1. Quartzite

Specific Gravity: Specific gravity of cement, fine aggregate, coarse aggregate and quartzite had been found according to Indian standard code IS 2386:1963 part 3 in which three samples had been tested and the average value is reported.

Figure 2. Specific gravity apparatus

Fineness Modulus: Fineness modulus of coarse aggregate and quartzite had been tested according to Indian standard code IS 2386:1963 part 1using the standard IS sieves 40mm, 31.5mm, 25mm, 20mm, 16mm, 12.5mm, 10mm, 6.3mm and 4.75mm , graph had been plotted for both of them.

Figure 3. Sieve analysis apparatus

Durability Tests: Acid Exposure Hydrochloric acid (HCL) of 1% concentration was considered to berepresentative of aggressive sewer environments and 1% Hydrochloric acid (HCL) solution has been used in manylaboratory tests to investigate the acid resistance ofconcretes for sewer structures. Concrete cube 15× 15× 15 cm samples were immersed in1% Hydrochloric acid solution over 28, 60, 90 and 120 days and the sampleswere regularly investigated by visual inspection of surfacedeterioration, measuring mass change and testing loadbearingcapacity in compression.

Figure 4. Specimens of Acid Exposure

Sulfate Exposure: In this study, Magnesium sulphate, $MgSO_4$ and Sodium sulphate,Na_2SO_4 5% by mass of water solution is prepared .The compressive strength of cube specimens with dimensions of 15× 15× 15 cm which were preparedby the substitution of quartzite by coarse aggregate by weight were determined after the specimens were kept in 5% $Na_2SO_4$and $MgSO_4$ Sulphate solution. Then, the specimens were placed into sulphate solution and kept there for 28, 60, 90 and 120 days. Thespecimens were removed from sulphate solution after 28, 60, 90 and 120days, and then, the compressive strength and mass losses of thespecimens were determined.

Figure 5. Specimens of Sulphate Exposure

Sea Water: In this study, the concrete performance in sea water was determined by immersion of concrete cubes in sea water under laboratory conditions. The compressive strength of cube specimens with dimensions of 15× 15× 15 cm which were preparedby the substitution of quartzite by coarse aggregate by weight were determined after the specimens were sea water and kept there for 28, 60, 90, 120 days. Thespecimens were removed from sea water after 28, 60, 90, 120days, and then, the compressive strength and mass losses of thespecimens were determined.

Figure 6. Specimens of Sea water curing

4. RESULTS AND DISCUSSIONS

The physical and mechanical properties of quartzite and natural aggregates are represented in table 1. The specific gravity and fineness modulus of quartzite is 0.14%less than the coarse aggregate. The crushing and impact strength of quartzite is 10% more than natural aggregate. The physical properties of the materials used for casting cubes were reported in table 2. The experimental design for M30 grade concrete was performed as per IS Code of practice 10262:2009. The mix proportions for casting cubes for control mix and various mixes with replacement of coarse aggregate was reported in the table 3 and table 4. The surface texture, impact value, shape and size of the aggregate play a vital role in the development bond between the mortar paste and the aggregate. Quartzite has rough texture and semi angular shape. The results represent that the quartzite can be utilized as a replacement material for coarse aggregate. The crushing processes in producing the quartzite is key factor in producing aggregate with good particle size. The crushing methodology and impact crushers produce more angular shaped aggregate. This factor contributes to lower elongation and flakiness index which leads to better consistency in concrete mixes.

Table 1 Physical Characteristic of Ingredients

Sample Number	Properties	Natural Aggregate	Quartzite
1	Specific Gravity	2.72	2.68
2	Fineness Modulus	7.87	7.04
3	Crushing Value	26.2%	36.2%
4	Impact Value	27.5%	34.40%

Table 2Material Properties for concrete mix

Properties	Values
Specific gravity of cement	3.1
Specific gravity of water	1
Specific gravity of sand(FA)	2.59
Specific gravity of coarse aggregate(CA)	2.9
Fineness modulus of sand(FA)	2.38
Fineness modulus of coarse aggregate(CA)	7.87
Water/cement ratio for 53 Grade cement	0.45
Fineness modulus of Quartzite	7.04
Specific gravity of Quartzite	2.68

Mix Design for M30 Grade Concrete IS 10262:2009:
Mix Proportions:
Ratio =1:1.5:2.8
Water = 186lts
Coarse aggregate = 1169.577 kg
Cement = 413.33 kg,
Fine aggregate = 629.77 kg
Water-cement ratio =0.45

Grade of concrete	Slump(mm)	Quantities per m³ of Concrete (Kg)		
		Water(L)	Cement	Sand (FA)
M30	0 to 25	186	413.33	629.773
	25 to 50	197	438.133	667.277
	50 to 75	208	462.933	705.046
	75to 100	219	487.733	742.817

Table 4Coarse Aggregate Proportions

Slump in mm	Percentage Replacement of Coarse Aggregate									
	0	10		20		30		50		100
	CA	CA	QU	CA	QU	CA	QU	CA	QU	QU
0 to 25	1169.5	1052.6	116.9	935.66	233.9	818.7	350.8	584.7	584.7	1169.5
25 to 50	1239.9	1115.9	123.9	991.9	247.9	867.9	371.9	619.9	619.9	1239.9
50 to 75	1310.1	1179.2	131.4	1048.3	262.1	917.1	393.1	655.3	655.1	1310.1
75to 100	1380.2	1242.2	138.1	1104.2	276.1	966.1	414.2	690.1	690.1	1380.2

Workability of fresh concrete is carried out for different replacement levels from 0% to 100% respectively .we had conducted three different tests slump test, compaction factor test and vee-bee consistometer test in which the corresponding values are tabulated as follows:

Table 5Workability of Fresh Concrete Results

S. No	Type of mix	Slump test in mm	Compaction factor	Vee-bee degrees(sec)
1	0%	75	0.96	1.5
2	10%	74	0.94	1.5
3	20%	73	0.94	1.5
4	30%	72	0.94	1.8
5	50%	69	0.94	1.8
6	100%	65	0.92	1.8

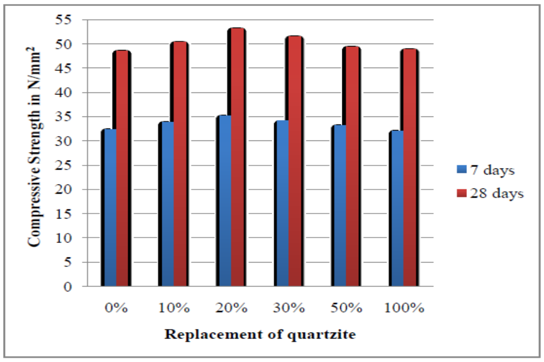

Figure 18Compressive strength development Vs. Percentage Replacement of Quartzite

Table 6 Compressive strength

Percentage replacement of Quartzite	7 Days Strength in N/mm^2	28 Days Strength In N/mm^2
0%	33.2	48.5
10%	34.1	50.3
20%	35	53.2
30%	34.5	52.8
50%	34.3	49.1
100%	33.1	48.8

4.3.1 28 Days Test Results

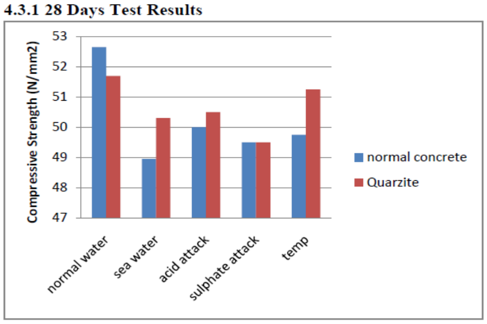

Figure 19Variation of Compressive strength with different exposure @28 days

Compression Strength Results

Table 7 28 Days Test Results

Type	Normal concrete strength in N/mm^2	Quartzite concrete strength in N/mm^2
Normal water	52.65	51.7
Sea Water	48.95	50.3
Acid Curing	50	50.5
Sulphate curing	49.5	49.5
Temperature	49.75	51.25

4.3.2 60 Days Test Results

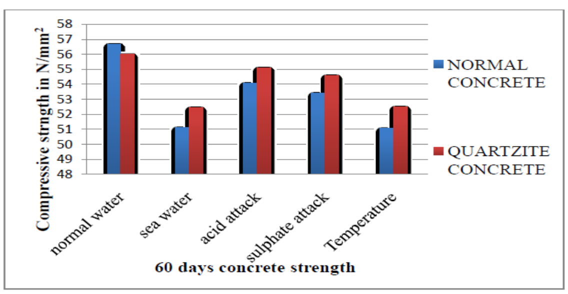

Figure 20Variation of Compressive strength with different exposure @60 days

Compression Strength Results

Table 8 60 Days Test Results

Type	Normal concrete strength in N/mm^2	Quartzite concrete strength in N/mm^2
Normal water	56.65	56
Sea Water	51.1	52.45
Acid Curing	54.05	55.1
Sulphate curing	53.4	54.6
Temperature	51.05	52.5

4.3.390 Days Test Results

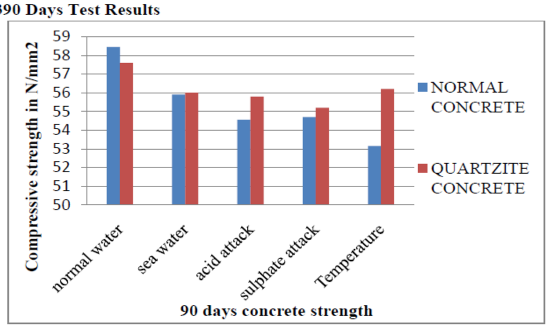

Figure 21Variation of Compressive strength with different exposure @90 days

Compression Strength Results

Table 9 90 Days Test Results

Type	Normal concrete strength in N/mm^2	Quartzite concrete strength in N/mm^2
Normal water	58.25	57.4
Sea Water	55.9	56
Acid Curing	54.35	55.6
Sulphate curing	54.7	55.2
Temperature	53.15	56.2

4.3.4120 Days Test Results

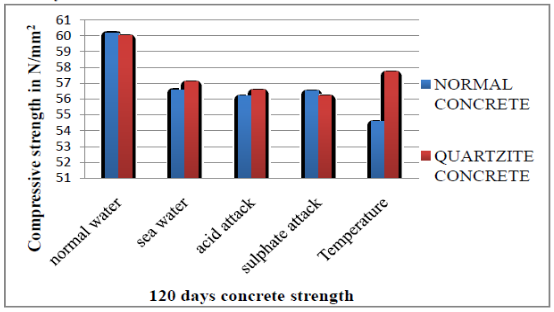

Figure 22Variation of Compressive strength with different exposure @120 days

Compression Strength Results

Table 10 120 Days Test Results

Type	Normal concrete strength in N/mm²	Quartzite concrete strength in N/mm²
Normal water	60.2	60
Sea Water	56.6	57.1
Acid Curing	56.2	56.55
Sulphate curing	56.5	56.2
Temperature	54.41	57.5

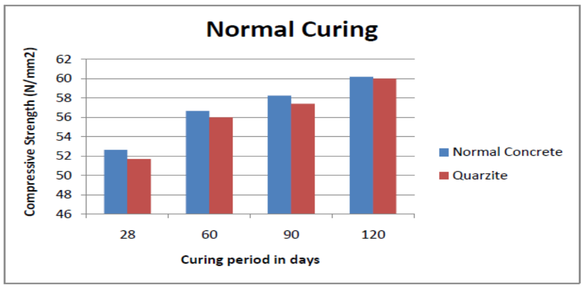

Figure 23Compressive strength Vs. Normal and Quartzite concrete cured in Normal water

Table 11 Normal Water Curing Results

No of days	Normal concrete strength in N/mm²	Quartzite concrete strength in N/mm²
28 days	52.65	51.7
60 days	56.65	56
90 days	58.25	57.4
120 days	60.2	60

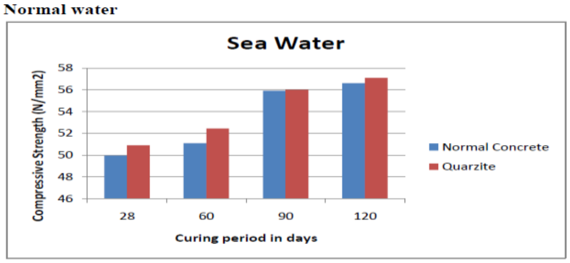

Figure 24Compressive strength Vs. Normal and Quartzite concrete cured in Seawater

Table 12 Sea Water Curing Results

No of days	Normal concrete strength in N/mm²	Quartzite concrete strength in N/mm²
28 days	48.95	50.3
60 days	51.1	52.45
90 days	55.9	56
120 days	56.6	57.1

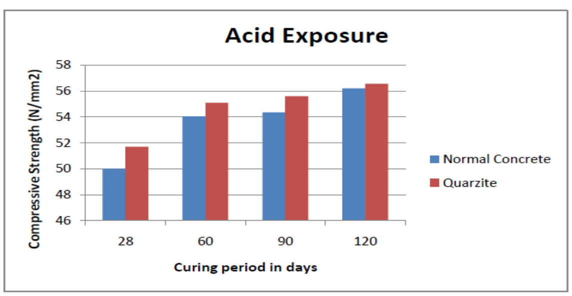

Figure 25Compressive strength Vs. Normal and Quartzite concrete cured in Acid Solution

Table 13 Acid Exposure Curing Results

No of days	Normal concrete strength in N/mm²	Quartzite concrete strength in N/mm²
28 days	50	51.7
60 days	54.05	55.1
90 days	54.35	55.6
120 days	56.2	56.55

4.3.8 Sulphate Exposure

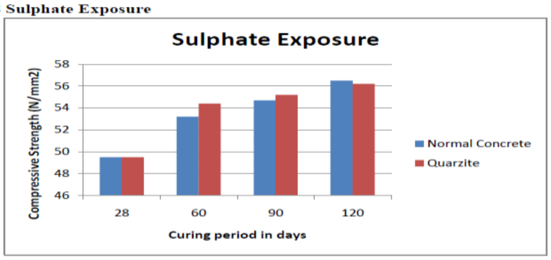

Figure 26Compressive strength Vs. Normal and Quartzite concrete cured in Sulphate Solution

Table 14 Sulphate Exposure Curing Results

No of days	Normal concrete strength in N/mm²	Quartzite concrete strength in N/mm²
28 days	49.5	49.5
60 days	53.2	54.4
90 days	54.7	55.2
120 days	56.5	56.2

4.3.9Temperature Effect

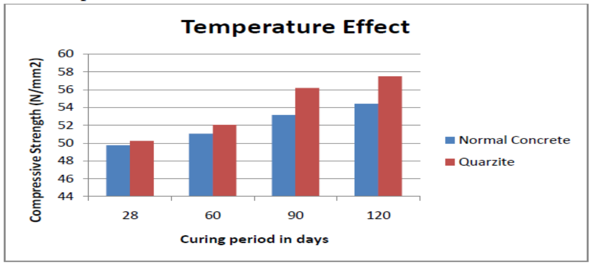

Figure 27Compressive strength Vs. Normal and Quartzite concrete at temperature effect of 250^{0}c

Table 15 Temperature Effect.

No of days	Normal concrete strength in N/mm²	Quartzite concrete strength in N/mm²
28 days	49.75	51.25
60 days	51.05	52.5
90 days	53.15	56.2
120 days	54.41	57.5

5. CONCLUSION

From the present study, the following conclusions are drawn.

The specific gravity and fineness modulus of quartzite is similar to conventional coarse aggregate.

The crushing strength and impact strength of quartzite is about 15% higher than conventional aggregate.

It is observed that the slump of concrete reduced at constant rate by increasing the quartzite percentage.

The optimum percentage of quartzite replacement to coarse aggregate is 20% and the compression strength increased to 10% at this replacement percentage.

The concrete made with quartzite performed well in terms of compressive strength when compared to conventional concrete when exposed to sea water and showed higher performance for 28 days and 60 days (2.63% and 2.57%) and almost similar results for 90 and 120 days (0.17% and 0.87%) with conventional concrete.

In acid exposure, the concrete made with quartzite performed well in terms of compressive strength when compared to conventional concrete. It is observed that the compressive strength of quartzite concrete showed higher performance for 28,60,90 and 120 days (0.97%,1.90%,2.24% and 0.61%)than conventional concrete.

The compressive strength of concrete made with quartzite and strength of conventional concrete is equal at 28 days curing and the quartzite concrete performed better at 60 days and 90 days (2.19% and 0.9%)curing and strength is nominally decreased at 120 days (0.53%)curing than conventional concrete when it is exposed to sulphate exposure.

When the concrete made with quartzite exposed to high elevated temperature of 2500c performed well in terms of compressive strength when compared to conventional concrete and it is observed that the compressive strength of quartzite concrete showed higher performance for 28,60, 90 and 120 days (3.17%,2.76%,5.42% and 5.35%)than conventional concrete. This performance against temperature is due to refractory property of quartzite.

Overall, the performance of quartzite is reasonably good when exposed to various weathering conditions and the same can be replaced as coarse aggregate in concrete.

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