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Experimental Study on Properties of Concrete by Replacing Coarse Aggregate with Quartzite

Nalli Vijaya Chandra[1], K.V.V. Ramaraju[2]
[1]M. Tech (Structural Engineering), Department of Civil Engineering, Kakinada Institute of Technology And Science. Divili
[2]Asst.Professor and HOD C.E, Department of Civil Engineering, Kakinada Institute of Technology And Science. Divili

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 have 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, Concrete, Coarse Aggregate, Compressive Strength.

I. INTRODUCTION

A. General

Construction industry is one of the major consumers of natural resources and produces quantities of the waste materials (Silva et al., 2014). Infrastructure development in the developing countries increased the utilization of aggregate from the quarries leading to depletion of the natural resources (Paulo et al., 2009). 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 (Payam et al., 2014). Utilization of the waste material as replacement of aggregate would reduce stress on the natural resources (Paulo et al., 2009). 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 (Aquino et al., 2010). Development of composite concretes using various admixtures increased the strength properties (Mostafa et al., 2009). The utilization of the waste materials reduces the density of the concrete (Payam et al., 2014). Scientific methods should be developed for the utilization ofvarious alternate aggregates (Hobnob et al., 2011). 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 (Silva et al.,2014, Paulo et al.,2009,Payam et al.,2014,Aquino et al., 2010, Mostafa et al.,2009, Hebhoub et al.,2011,Alves et al.,2014,Medina et al.,2012,Olanipekun et al., 2006). Physical, Mechanical Workability, Strength and durability properties of the concrete were investigated under various curing and elevated temperatures.

B. Indian Scenario

According to Indian scenario, India is expected to grow with a huge population, which crosses china by the middle of this century. These population growth leads to two effects in which India is going to have unique advantage of having the biggest work force in the coming years and which leads to large scale developments over the coming years (Jose kurian 2013). Annually, the production of concrete is more than 10 billion tons and it is considered to be the most important building material. It has been predicted that the world‟s population will increase from the present-day 6–9 billion by the year 2050 and to 11 billion by the end of the century, which will result in a considerable increase in the demand for water, energy, food, river sources, common goods and services and also, the demand for concrete is expected to grow to approximately 18 billion tons a year by 2050. Consequently, the concrete industry is going to use a considerable amount of natural resources to produce cement and concrete (Shafigh et al., 2014, Jose kurian 2013).

India has focused on 12th Five Year plan on the growth of infrastructural facility such as roads and highways, railways, ports, power, communication, etc., and also investment of the order US 1 trillion is envisaged for this sector during the 12th plan. As we all know that concrete is the single most material that is used in this endeavor. In this situation to achieve the above goal there are several aspects of concrete , be it the production of constituent materials like cement, aggregate, fly ash, construction chemicals, concrete production and use, construction technologies, quality and durability, maintenance, sustainability, standardization, skill development, research and development, etc.(Jose kurian 2013)

II. LITERATURE REVIEW

A. Literature on Coarse Aggregate

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.

Literature on Acid Exposure

Thandavamoorthy et.al (2015) had used wood waste in replacement of coarse aggregate in concrete and performed acid attack on it.He had stated that the waste wood was replaced with different percentage levels and observed that the weight loss of wood aggregate concrete with 15% replacement level under acid attack was 30.38% greater than the control concrete.

Muthusamy et al.(2014) had replaced coarse aggregate with laterite aggregate in concrete and performed acid attack on it. He had stated that the laterite aggregate was replaced with different percentage levels concluded that integration of laterite aggregate up to 20% replacement would produce concrete behaving almost similar to plain concrete. However, replacement of 40 and 50% is not recommended since it would significantly affect the durability of concrete to acid attack.

Literature on Sulphate Exposure

Vijayalakshmi et al. (2013) had used granite industry waste in concrete and conducted strength and durability tests on it. He had said thatthe concrete cubes were immersed in solution containingNaSO4 and MgSO4 for the duration of 180 days and 365 days. The control mixtures showed10% and 30% reduction in compressive strength after 180 and365 days exposure respectively. However the concrete containing granite industry waste showed significant loss in the compressive strengthwhen compared to the control mixtures in addition the action ofsulphate increased when increasing the substitution rate.

Hanifi 2010 had used barite as replacement of coarse aggregate in concrete and durability studies on it. He had said that the compression strength of natural aggregate and barite concretes was reduced when exposed to sulphate solution. He had concluded that after exposure of sulphate solutions for six months barite concrete performed well than the normal concrete

Hanifi et al. (2008) had used granite and marble in concrete and performed durability studies on it. He had stated that the results show that therelative compressive strengths of all concretes decrease withincreasing exposure to sulphate solutions. For control specimens, the compressive strength reduction was higher in sulphate solution than those of Marble and Granite concretes. Marble concrete exhibited greater sulphate resistance than allthe others.

Literature on Temperature Effect

Correia et al. (2014) had used plastic waste aggregates in concrete and conducted temperature effect on it. He had concluded that results indicate an increase of the compressive strength degradation with the replacement of natural aggregates byplastic waste aggregates. The higher degradation of plastic waste concrete stems from the thermal decomposition of plasticaggregates, which results in a higher increase of concrete porosity with large voids, hence in higher reduction of compressivestrength.

Shi Cong Kou et al. (2014) had performed exposure to elevated temperatures wit replacement of coarse aggregate with recycled aggregate. He had stated that the concretes were exposed separately to 3000C, 500 0C and 800 0C, theresults show that the concretes made with recycled aggregates suffered less deteriorations in mechanicaland durability properties than the concrete made with natural aggregates after the high temperatureexposures. The relative residual compressive strength of concrete made with recycled aggregates was higher than that of the concrete prepared with naturalaggregates for all types of binders used.

III. RESULTS AND DISCUSSIONS

Mix Design for M30 Grade Concrete IS 10262:2009

1) *Step 1:* Design Stipulations for Proportioning
   a) Grade designation: M30
   b) Type of cement: OPC 53 grade (KCP Cement) conforming IS: 12269
   c) Maximum nominal size of aggregate: 20mm
   d) Maximum water-cement ratio: 0.4
   e) Workability: 50mm (slump
   f) Exposure condition: Mil
   g) Specific gravity of cement: 3.0
   h) Specific gravity of fine aggregate: 2.6
   i) Zone of fine aggregate: II

2) *STEP 2:* Target Mean Strength

The target mean strength is calculated according to the IS 10262:2009 codeprovisions is

$$f'ck = fck + 1.65s$$
$$= 30 + (1.65 \times 5)$$

Where;

$=38.25 N/mm^2$

f 'ck = target average compressive strength at 28 days, fck = characteristic compressive strength at 28 days, ands = standard deviation.

From Table I of IS 10262:2009 standard deviation(s)=5 N/mm2

3) *STEP 3:* Selection of Water Content

Based on experience, maximum water-cement ratio = 0.45 is adoptedHence ok.

From Table 2, maximum water content for 20 mm aggregate =186 litres(For 25 to 50 mm slump range).

4) *STEP 4:* Calculation of Cement Content

Water-cement ratio = 0.45

Cement content = 186/0.45 =413.33kg/m^3

From Table 5 of IS 456, minimum cement content for „Mild" exposure condition =320kg/m3

413.33 kg/m3 > 320 kg/m3, hence ok.

5) *STEP 5:* Proportion of Volume of Coarse and Fine Aggregate

From Table 3 of IS 10262:2009, volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate for water-cement ratio of 0.50 =0.60.

In the present case water-cement ratio is 0.45. Therefore, volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the water- cement ratio is lower by 0.10, the proportion of volume of coarse aggregate isincreased by 0.02 (at the rate of -/+ 0.01 for every ± 0.05 change in water-cement ratio).

Therefore, corrected proportion of volume of coarse aggregate for the water-cement ratio of 0.45 = 0.65.Volume of fine aggregate= (1-0.65) =0.35.

6) *STEP 6:* Trail Mix Calculations

The mix calculations per unit volume of concrete shall be as follows:

   a) Volume of concrete = 1 m^3
   b) Volume of cement =(Mass of cement/Specific gravity ofcement)×(1/1000)
   = (413.33/3.07) × (1/1000) = 0.135 m^3
   c) Volume of water = (Mass of water /Specificgravity ofwater)×(1/1000)
   = (186/1) × (1/1000) =0.186 m^3

d) Volume of all aggregate = a-(b+c)
= 1-(0.135+0.186) = 0.679 m^3

e) Mass of coarse aggregate = d× volume of coarse aggregate ×specificgravity×1000
=0.679×0.65×2.65×1000
=1169.577kg

f) Mass of fine aggregate = d× volume of fine aggregate ×specificgravity×1000
=0.679×0.35×2.65×1000 =629.77 kg

Mix Proportions

Ratio	=1:1.5:2.8
Cement	= 413.33 kg
Water	= 186lts
Fine aggregate	= 629.77 kg
Coarse aggregate	= 1169.577 kg
Water-cement ratio	=0.45

Table 3Mix Proportions

Grade of concrete	Slump(mm)	Quantities per mt 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

		Percentage Replacement of Coarse Aggregate								
Slump in mm	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

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

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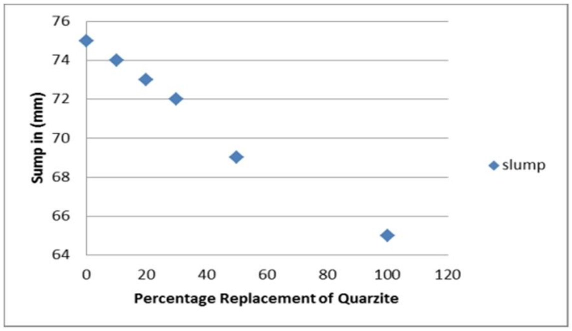


Figure 17 Slump vs. Percentage replacement of quartzite content

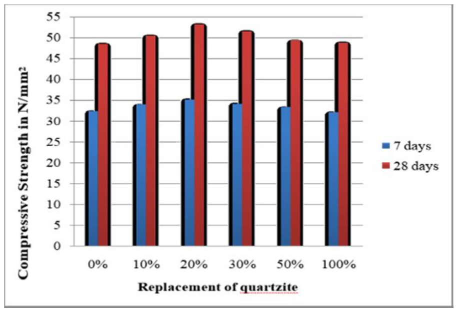


Figure Compressive strength development Vs. Percentage Replacement ofQuartzite

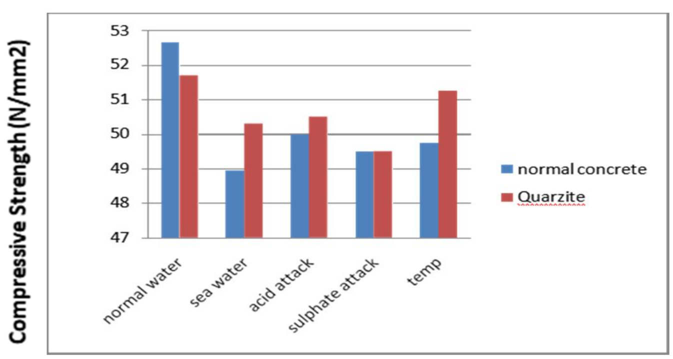
Figure represents the seven day and twenty eighth day variation of compressive strength for various percentage replacement of coarse aggregate with quartzite. The compressive strengths for both seven days and twenty eight days increase with the increase in replacement of quartzite.

A. *Compressive Strength*

Percentage replacement of Quartzite	7 Days Strengthin N/mm^2	28 Days StrengthIn 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

B. *Water Absorption and Density of Aggregates*

The values reported are 6.1% and 0.7%, respectively. Regarding the bulk density, they stated that the bulk density is lower for the coarse recycled brick aggregates (2.21 kg/m3) than for coarse natural aggregates (2.66 kg/m3).



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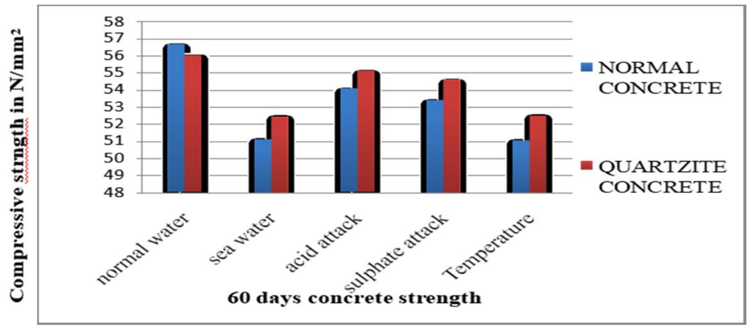
C. Figure 19Variation of Compressive strength with different exposure @28 days

A graph was plotted with compressive strength on the ordinate and different curing conditions on abscissa. The cubes were cured for a period of 28 days in normal water,seawater, acid attack, sulphate attack and temperature. From the above results, it is observed that the compressive strength of quartzite concrete is reduced by 1.8 % compared to conventional concrete. In comparison with normal curing, the compressive strength of conventional concrete is reduced by 7.0%, 5.3%, 5.98%, 5.50%, when exposed to sea water, acid exposure, sulphate exposure and temperature exposure respectively.

Type	Normal concrete strength in N/mm²	Quartzite concrete strength in N/mm²
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

Compression Strength ResultsTable 7 28 Days Test Results



60 Days Test Results

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

A graph was plotted with compressive strength on the ordinate and different curing conditions on abscissa. The cubes were cured for a period of 60 days in normal water,seawater, acid attack, sulphate attack and temperature. The concrete cubes werecasted using natural aggregate and quartzite with 100% replacement. For 60 days curing, compressive strength of concrete made with normal water is 56.65N/mm^2 and 56N/mm^2, with sea water is 51.1N/mm^2 and 52.45 N/mm^2, with acid curing is 54.05 N/mm^2 and 55.1 N/mm^2, with sulphate curing is 53.4 N/mm^2 and 54.6 N/mm^2 and temperature effect of 250°C for 1hour duration is 51.05 N/mm^2 and 52.5 N/mm^2 wereobserved for control mix and 100% quartzite replacement.

Type	Normal concrete strength in N/mm²	Quartzite concrete strength in N/mm²
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

Compression Strength ResultsTable 8 60 Days Test Results

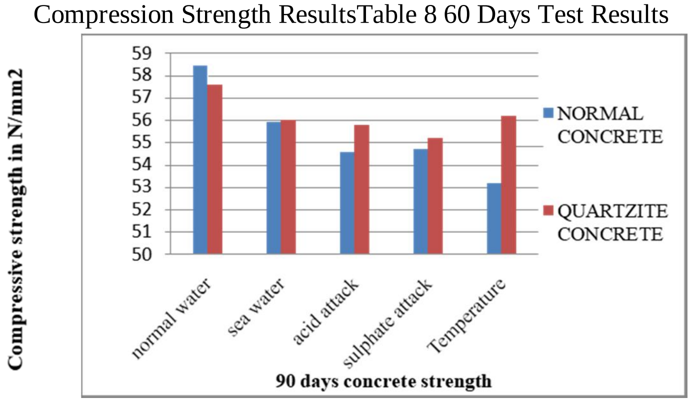


Figure 21Variation of Compressive strength with different exposure @90 days

A graph was plotted with compressive strength on the ordinate and different curing conditions on abscissa. The cubes were cured for a period of 90 days in normal water,seawater, acid attack, sulphate attack and temperature.

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

Compression Strength ResultsTable 9 90 Days Test Results

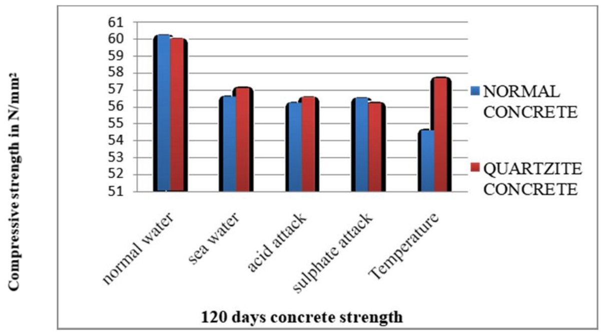


Figure 22Variation of Compressive strength with different exposure @120 days

A graph was plotted with compressive strength on the ordinate and different curing conditions on abscissa. The cubes were cured for a period of 120 days in normal water, seawater, acid attack, sulphate attack and temperature.

Type	Normal concrete strength in N/mm^2	Quartzite concrete strength in N/mm^2
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

Compression Strength Results Table 10 120 Days Test Results

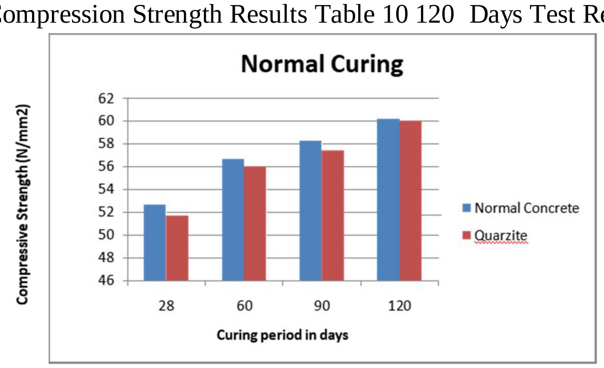


Figure 23Compressive strength Vs. Normal and Quartzite concrete cured inNormal water

A graph was plotted with compressive strength on the ordinate and number of curing days on abscissa. The cubes were cured for a period of 28, 60, 90 and 120days in normal water. The concrete cubes were casted using natural aggregate and quartzite with 100% replacement.

Compressive strength

Table 11 Normal Water Curing Results

No of days	Normal concrete strength in N/mm^2	Quartzite concrete strength in N/mm^2
28 days	52.65	51.7
60 days	56.65	56
90 days	58.25	57.4
120 days	60.2	60

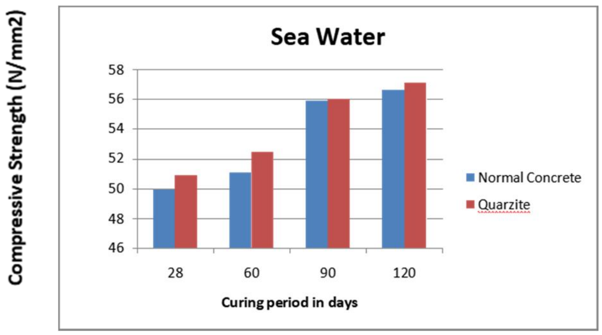


Figure 24Compressive strength Vs. Normal and Quartzite concrete cured inSeawater

A graph was plotted with compressive strength on the ordinate and number of curing days on abscissa. The cubes were cured for a period of 28, 60, 90 and 120 days in normal water. The concrete cubes were casted using natural aggregate and quartzite with 100% replacement. For 28 days curing compressive strength of 48.95N/mm^2 and 50.3N/mm^2 were observed for control mix and 100% quartzite replacement. For60days curing compressive strength of 51.1N/mm^2 and 52.45N/mm^2 were observed for control mix and 100% quartzite replacement. For 90 days curing compressive strength of 55.9N/mm^2 and 56N/mm^2 were observed for control mix and 100%quartzite replacement. For 120 days curing compressive strength of 56.6N/mm^2 and 57.1N/mm^2 were observed for control mix and 100% quartzite replacement.

Compressive strength

Sea Water Curing Results

No of days	Normal concrete strength in N/mm^2	Quartzite concrete strength in N/mm^2
28 days	48.95	50.3
60 days	51.1	52.45
90 days	55.9	56
120 days	56.6	57.1

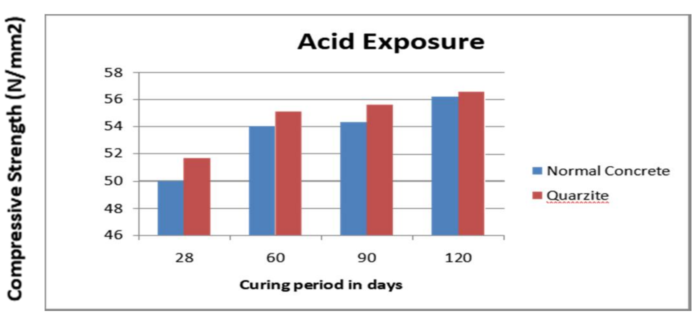


Figure 25Compressive strength Vs. Normal and Quartzite concrete cured in AcidSolution

A graph was plotted with compressive strength on the ordinate and number of curing days on abscissa. The cubes were cured for a period of 28, 60, 90 and 120 daysin normal water. The concrete cubes were casted using natural aggregate and quartzitewith 100% replacement. For 28 days curing compressive strength of 50N/mm^2 and 51.7N/mm^2 were observed for control mix and 100% quartzite replacement.

Compressive strength

Table 13 Acid Exposure Curing Results

No of days	Normal concrete strength in N/mm^2	Quartzite concrete strength in N/mm^2
28 days	50	51.7
60 days	54.05	55.1
90 days	54.35	55.6
120 days	56.2	56.55

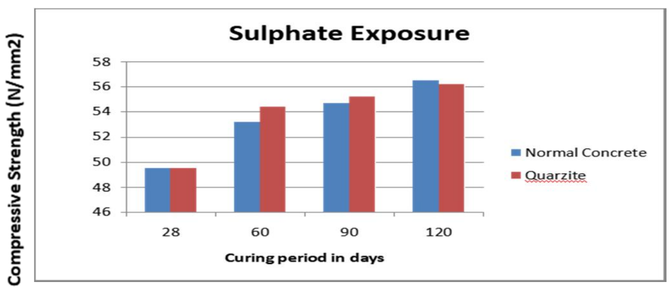


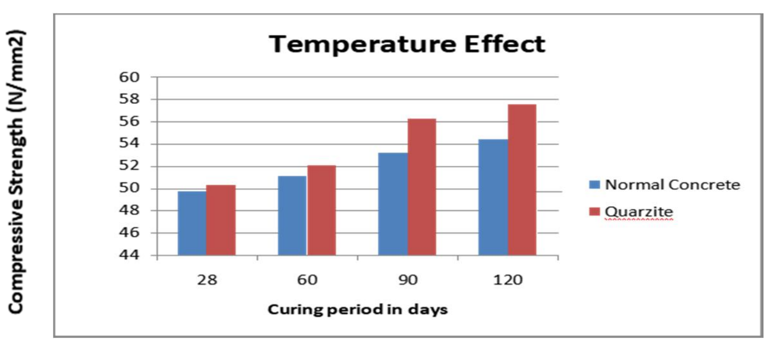
Figure 26Compressive strength Vs. Normal and Quartzite concrete cured inSulphate Solution

A graph was plotted with compressive strength on the ordinate and number of curing days on abscissa. The cubes were cured for a period of 28, 60, 90 and 120 daysin normal water. The concrete cubes were casted using natural aggregate and quartzitewith 100% replacement. For 28 days curing compressive strength of 49.5N/mm^2 and 49.5N/mm^2 were observed for control mix and 100% quartzite replacement. For 60days curing compressive strength of 53.2N/mm^2 and 54.4N/mm^2 were observed for control mix and 100% quartzite replacement.

Compressive strength

Table 14 Sulphate Exposure Curing Results

No of days	Normal concrete strength in N/mm^2	Quartzite concrete strength in N/mm^2
28 days	49.5	49.5
60 days	53.2	54.4
90 days	54.7	55.2
120 days	56.5	56.2



A graph was plotted with compressive strength on the ordinate and number of curing days on abscissa. The cubes were cured for a period of 28, 60, 90 and 120 days in normal water. The concrete cubes were casted using natural aggregate and quartzite with 100% replacement.

Table 15 Temperature Effect.

No of days	Normal concrete strength in N/mm^2	Quartzite concrete strength in N/mm^2
28 days	49.75	51.25
60 days	51.05	52.5
90 days	53.15	56.2
120 days	54.41	57.5

IV. CONCLUSION

From the present study, the following conclusions are drawn.

1) The specific gravity and fineness modulus of quartzite is similar to conventional coarse aggregate.
2) The crushing strength and impact strength of quartzite is about 15% higher than conventional aggregate.
3) It is observed that the slump of concrete reduced at constant rate by increasing thequartzite percentage.
4) The optimum percentage of quartzite replacement to coarse aggregate is 20% and the compression strength increased to 10% at this replacement percentage.
5) 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.
6) 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.
7) 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.
8) When the concrete made with quartzite exposed to high elevated temperature of 250^0c 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.
9) 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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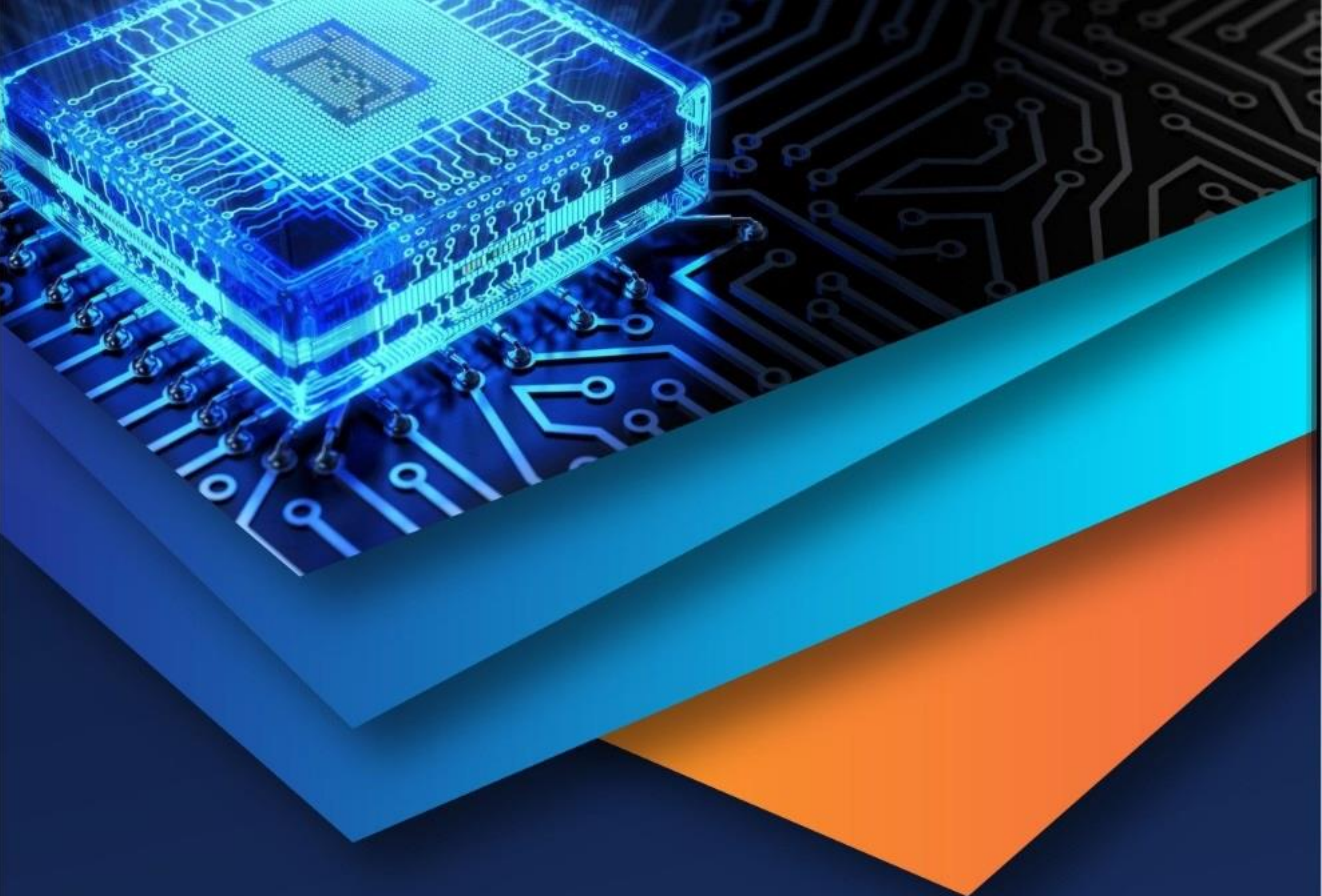

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