Experimental Study on the Utilization of Waste Material as Alternate Coarse Aggregate in the Sustainable RC Construction with Special Reference to Rajasthan Region

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ABSTRACT: Rajasthan is one of the biggest exporter of Marble, Limestone and Granite i.e. the state suffice more than 90% demand of the building material in the country [3]. Makrana marble manufactured from Rajasthan being the most famous and widely used. Also, limestone is the major ingredient in the cement manufacturing industry which is imported mainly from Rajasthan. Granite is known for its strength is also used widely as building material.

But during the quarrying of these rocks there is humongous waste produced in the form of dust and broken sheet pieces which is very difficult to dispose off and causes nuisance to the environment as well as cause health problems to the nearby habitants. This experimental study will mainly focus on finding the engineering as well as mechanical properties of waste produced during the quarrying of these rocks and their utilization as the building material.

INTRODUCTION

Concrete is the second most utilized material by the mankind after water. Although there are various emerging alternatives to concrete yet concrete remains the preferable among them all. The prime reason of this is the vast research and utilization that has been already carried out from ages on this binding material. Concrete is a blend of fines, coarse aggregate and cement mixed in fixed proportion either by volume or by weight as per the requirement and design constraint.

Just as concrete remains the most utilized and researched binding material, aggregates made of crushing sedimentary rock like limestone is the most commonly used coarse aggregate in the reinforced structure. As ever growing population has multifold the mining, production and procurement of limestone in the recent decade the attention is driven towards the other alternatives available in abundance in the environment. According to a report published by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH on Material Consumption Patterns in India says "The housing stock in India has been increasing at a remarkable pace, from 250 million units in 2001 to 330 million units in 2011. However, given the strong demand drivers – population, urbanization and income growth – the under supply of housing is becoming acute, especially in mega cities."

LIMITATION OF AGGREGATES- ECONOMICAL ASPECT

The construction industry prefers sedimentary rocks like limestone to be used as aggregates due to its durability. Limestone is the most extracted mineral in the country with its main source of supplier is Rajasthan and cement industry serves as the principal user of this rock material. However, India has large deposits of limestone but the deposits are concentrated only in few states in India and it is estimated to last for next 30-35 years. In the same report published by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH on Material Consumption Patterns in India says "It is clear that the Indian construction industry is likely to face serious material supply problems if the predicted growth in demand continues. Supply bottlenecks are already starting to affect prices and construction schedules in some parts of the country."

Due to the shortage of limestone in future construction sector in particular will be vulnerable to price shocks, since material costs account for roughly 2/3rds of the total cost of a typical building. Therefore, a strong emphasis is given on resource efficiency and also in use of alternate and secondary materials for the Indian construction industry to move forward.

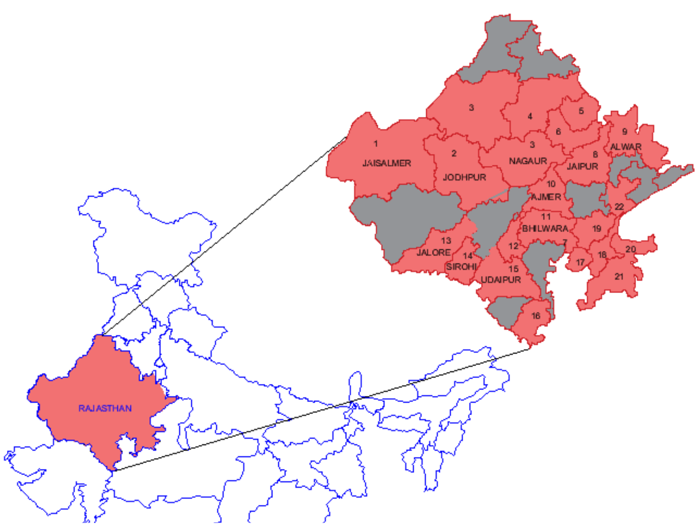
USE OF MARBLE AND GRANITE WASTE- ENVIRONMENTAL ASPECT

Rajasthan is being the biggest supplier of construction aggregate in India has abundance of good quality of marble, dolomite and granite. As marble is being used from over many centuries in construction of monuments due to its high compressive strength and availability. During quarrying a lot of marble waste are produced and due to the lack of proper waste management plan tons of waste are being dumped on open lands causing major threat to the environment in Rajasthan and in nearby areas of the state. Thus these waste can be further utilized as coarse aggregate in the building construction. Another such material is granite which is also known for its strength and non-porous characteristic. Thus this make it a preferable material to be utilized as coarse aggregate. Waste produced after the quarrying of marble and granite is tremendous as the state of Rajasthan has 20 out of 33 districts where these rock deposits are present in one form or other. Thus, authorities are finding it gruesome to dispose the waste produced by the quarrying and cutting of these rocks.

Using marble and granite waste as coarse aggregate can be considered as an initiative towards sustainable development goals unanimously agreed by the leaders of the world.

Figure 1 Dumping of Marble dust

This paper is an initiative towards reducing the generated waste by the manufacturing industries and promoting the gainful utilization of these waste as the building material for the sustainability of the environment.



Makrana is famous for its pure white Marble

Jhiri mine Alwar: Dolomite

Jalor, also called as granite city

Bajla Kabra mine Ajmer: Dolomite

Figure 2 Map of Rajasthan showing various states which are rich in Marble, Dolomite and Granite

UTILIZATION OF MARBLE AND GRANITE WASTE- STRUCTURAL ASPECT

As coarse aggregate occupies around 70-75% of the volume of hardened concrete mass. Aggregate has a considerable contribution on the physical and engineering property of the concrete like they impart permeability, surface texture, strength and durability. The use of aggregate also considerably improves both the volume, structural stability and the structural durability of the resulting concrete. They act as an economical filler which is much cheaper than cement. The maximum economy in the production and structural strength of concrete can be obtained by using as much aggregate as possible. Thus the properties of the coarse aggregate by and large effect the structural performance, durability and design life of the building.

This experimental study emphasizes on the use of waste produced by the quarrying of rocks in mines with special reference to marble, dolomite and granite. As not much is known about how these rock materials will act as a coarse aggregate in the building construction during partial or complete replacement from traditionally used aggregate. A detailed experiment based research is done in this paper to have a better understanding regarding the impact these rock materials as coarse aggregate.

AIMS AND OBJECTIVES

1. To establish the physical properties of Marble waste, Dolomite and Granite waste found in Mohammadpur area of Rajasthan.
2. To establish the engineering properties of Marble waste, Dolomite and Granite waste found in Mohammadpur area of Rajasthan.
3. Finally, to ascertain the suitability of the above mentioned rock aggregates in the building construction.

EXPERIMENTAL STUDY

The experimental study was intended to replace complete natural coarse aggregate with marble waste, granite waste and dolomite respectively in different grade of concrete. The cement used in this study was Ordinary Portland Cement-43 grade. Marble waste, granite waste and dolomite respectively were used as coarse aggregate with maximum nominal size of 20 mm and natural available sand was used as fine aggregate. The physical properties of Marble aggregate, granite aggregate and dolomite aggregates and fine aggregate (sand) are presented in Table 2 to Table 4 along with properties of cement used.

AREA OF STUDY

The area selected for the collection of marble waste, granite waste and dolomite was Mohammadpur area of Rajasthan. It is a village in the Mandawar tehsil, Alwar.

PHYSICAL PROPERTIES OF CEMENT AND AGGREGATES USED

a. Property of Cement Used

Cement Type	**Ordinary Portland cement**
Grade	43- Grade
Admixture Used	Nil

Table 1 Property of Cement Used

b. Property of Aggregates Used

1. **Marble**

Aggregate Type	Specific Gravity	Water Absorption(%)	Grading Zone
Natural Fine Aggregate	2.66	2.0	Zone II As per Table 4 of IS 383
Marble Coarse Aggregate	2.50	0.40	As per Table 2 of IS 383

Table 2 Property of Marble Aggregate Used

Granite

Aggregate Type	Specific Gravity	Water Absorption (%)	Grading Zone
Natural Fine Aggregate	2.66	2.0	Zone II As per Table 4 of IS 383
Granite Coarse Aggregate	2.75	0.50	As per Table 2 of IS 383

Table 3 Property of Granite Aggregate Used

2. **Dolomite**

Aggregate Type	:cific Gravity	Water Absorption (%)	Grading Zone
Natural Fine Aggregate	6		Zone II As per Table 4 of IS 383
Marble Coarse Aggregate	4		As per Table 2 of IS 383

Table 4 Property of Dolomite Aggregate Used

METHODOLOGY

In this experimental program different concrete mixes of Ordinary Portland Cement-43 grade with constant water-cement ratio of 0.45 were prepared as test specimens. The concrete was prepared by completely replacing the natural coarse aggregate by marble waste, granite waste and dolomite respectively. The mix design of M 10 to M 40 were casted and tested in Concrete Technology lab of School of Engineering & Technology of IFTM University, Moradabad. For determining compressive strength, three specimen of dimension 150 mm x 150 mm x 150 mm were casted and after 7-day and 28-day curing, their compressive strength was observed respectively. Flexure strength is observed by casting three beams of size 150 mm x 150 mm x 700 mm. Compaction factor tests was performed on fresh concrete to determine its workability.

RESULTS AND DISCUSSION

WORKABILITY

The compaction factor test as per IS 1199 (1999) was carried out for measurement of workability of concrete. The curve in Figure 3 to 4 shows change in workability by replacing of natural coarse aggregate by marble aggregate, granite aggregate and dolomite aggregate respectively.

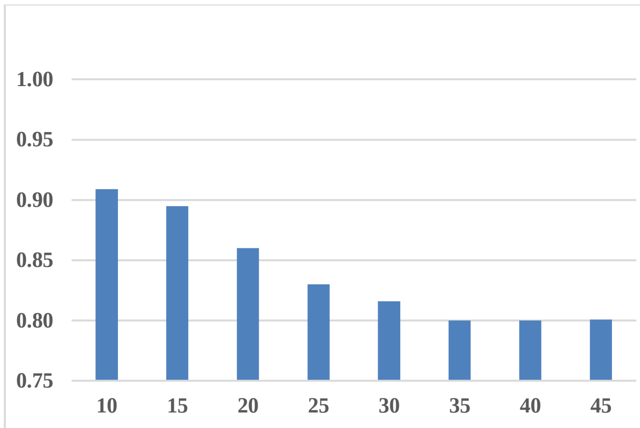


Figure 3 Result for compaction factor test of concrete with Natural aggregate

- **Marble waste**

The different grades of concrete were prepared by replacing coarse aggregate completely with marble waste. The below graphs compares the workability achieved by concrete with marble aggregate to concrete with natural aggregate.

From the Figure 4 it can be seen that, the workability of all the concrete mixes increased with increased in marble waste aggregate in the concrete mix. An increase in 7% in compaction factor was observed when conventional coarse aggregate was completely replaced by marble aggregate. The possible reason for the increase in workability of concrete mix containing portion of marble aggregate as coarse aggregate was due to the smooth surface and low water absorption of marble aggregate.

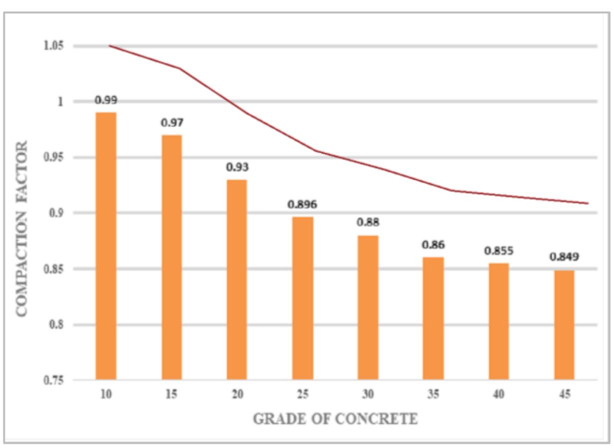


Figure 4 Result for compaction factor test of concrete with Marble aggregate

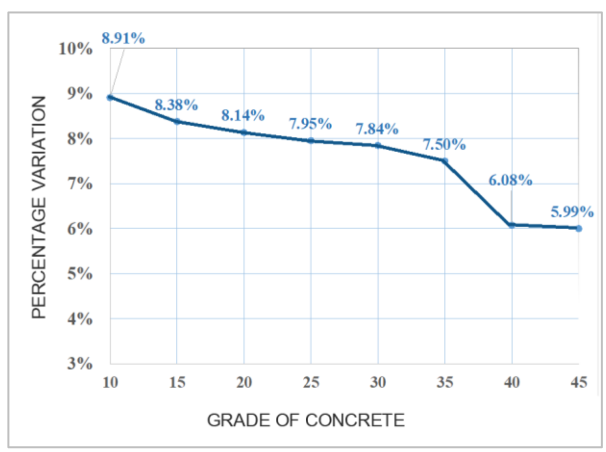


Figure 5 Percentage variation of workability of concrete with Marble aggregate and natural aggregate

- **Granite waste**

The different grades of concrete were prepared by replacing coarse aggregate completely with granite waste. The below graphs compares the workability achieved by concrete with granite aggregate to concrete with natural aggregate.

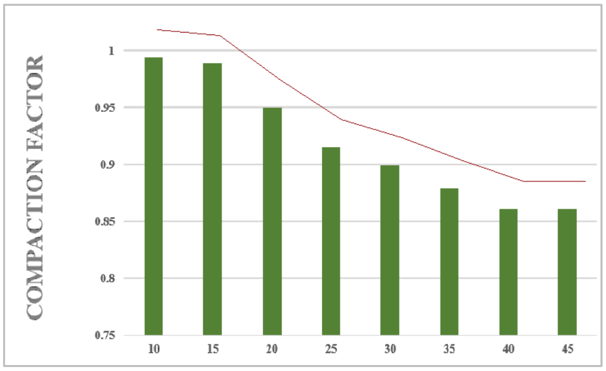


Figure 6 Result for compaction factor test of concrete with Granite aggregate

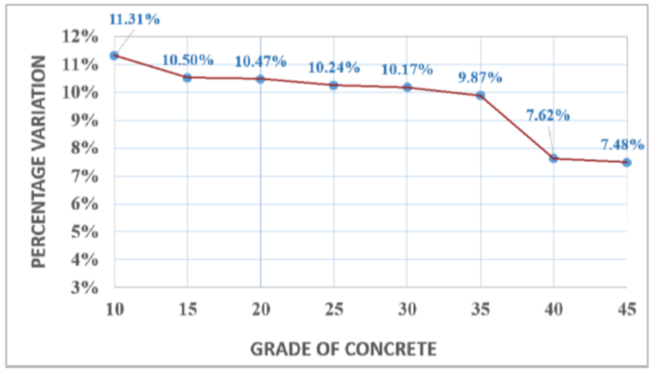


Figure 7 Percentage variation of workability of concrete with Granite aggregate and natural aggregate

From the Figure 6 it can be seen that, the workability of all the concrete mixes increased with increased in granite waste aggregate in the concrete mix. An increase in 5.5% in compaction factor was observed when conventional coarse aggregate was completely replaced by granite aggregate. This increase in workability of concrete mix containing granite aggregate was due to the smooth surface and low water absorption of marble aggregate.

Dolomite

Cube of dimension 150mmx150mmx150mm were casted for determining compressive strength and after 28-day curing their flexure strength is observed by casting prism of 150mm x150mmx700mm.

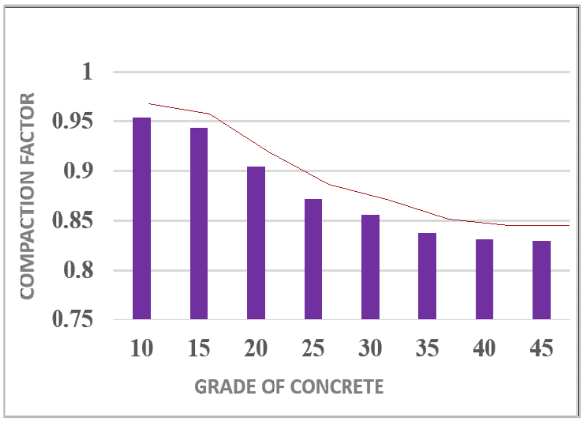


Figure 8 Result for compaction factor test of concrete with Dolomite aggregate

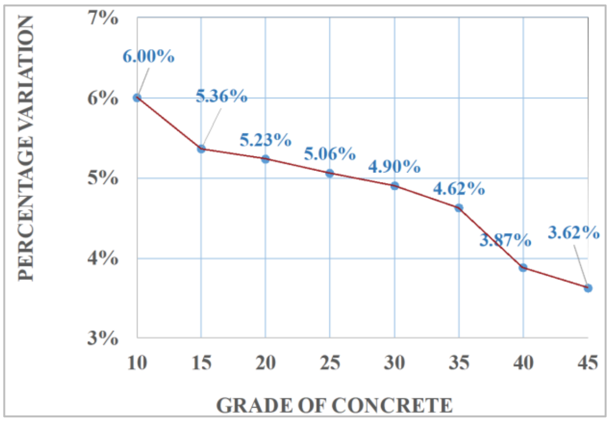


Figure 9 Percentage variation of workability of concrete with Dolomite aggregate and natural aggregate

From the Figure 8 it can be seen that, the workability of all the concrete mixes increased with increased in dolomite waste aggregate in the concrete mix. An increase in 4.7% in compaction factor was observed when conventional coarse aggregate was completely replaced by dolomite aggregate.

COMPRESSIVE STRENGTH

The concrete cube specimens were cast and tested as per IS 516 (1999). The specimens were tested at 7 and 28 days of curing age and the results are presented below. It can be seen that, the use of marble aggregate resulted in increase in compressive strength. This increase was prominent in 7 days and 28-days strength. The compressive strength test results of concrete for M 10, M 15, M 20, M 25 grade are shown in table 7. It presents the comparison of 7-day compressive strength (mean).

Table (a) 7 Days cube compressive strength (N/mm²) of concrete

Grade of Concrete	Average Compressive Strength of OPC Natural Aggregate (N/mm²)
M 10	6.7
M 15	10.0
M 20	13.3
M 25	16.7
M 30	20.0
M 35	23.3
M 40	26.7
M 45	30.0

Table (a) 28 Days cube compressive strength (N/mm²) of concrete

Grade of Concrete	Average Compressive Strength of OPC Natural Aggregate (N/mm²)
M 10	10
M 15	15
M 20	20
M 25	25
M 30	30
M 35	35
M 40	40
M 45	45

MARBLE

Table (a) 7 Days cube compressive strength (N/mm²) of concrete

Grade of Concrete	Average Compressive Strength Marble Aggregate (N/mm²)
M 10	7.45
M 15	12.30
M 20	18.16
M 25	22.85
M 30	27.70
M 35	32.89
M 40	36.41
M 45	41.20

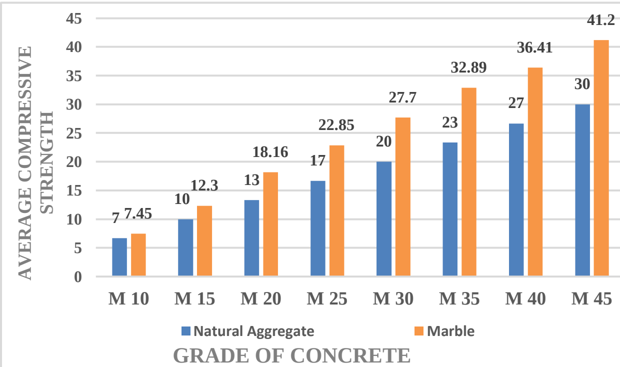


Figure 10 Average Compressive strength of Marble aggregate and Natural aggregate

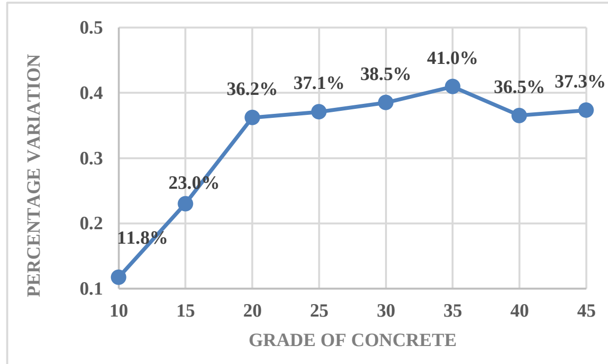


Figure 11 Percentage variation of compressive strength of concrete with marble aggregate and natural aggregate

Table (a) 28 Days Cube compressive strength (N/mm²) of Concrete

Grade of Concrete	Average Compressive Strength Marble Aggregate (N/mm²)
M 10	11.9
M 15	19.8
M 20	28.3
M 25	36.3
M 30	44.1
M 35	52.8
M 40	56.3
M 45	63.7

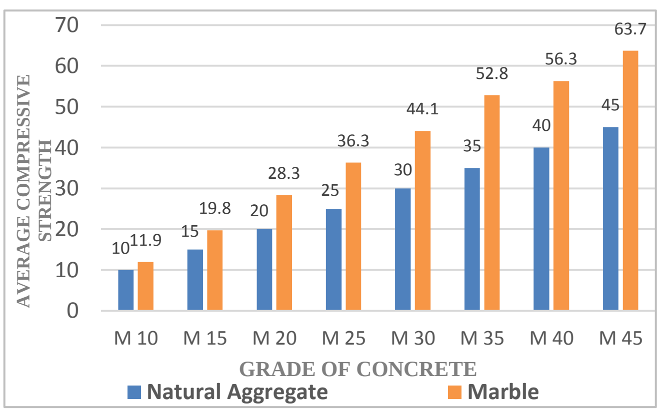


Figure 12 Result for compressive test of concrete with Marble aggregate

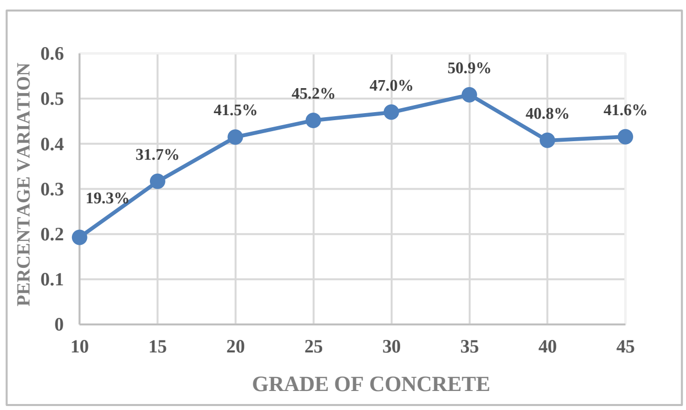


Figure 13 Percentage variation of compressive strength of concrete with Marble aggregate and Natural Aggregate

The compressive strength test results of concrete for M 10, M 15, M 20, M 25 grade are shown table. It presents the comparison of 28-day compressive strength (mean). The compression load was applied at a rate of 3kN/s using a compression machine of the capacity of 2000 kN.

Compressive strength of granite

Table: Cube compressive strength of concrete after 7 days

Grade of Concrete	Average Compressive Strength Granite Aggregate (N/mm²)
M 10	7.87
M 15	12.34
M 20	17.23
M 25	21.67
M 30	26.21
M 35	30.90
M 40	36.20
M 45	38.10

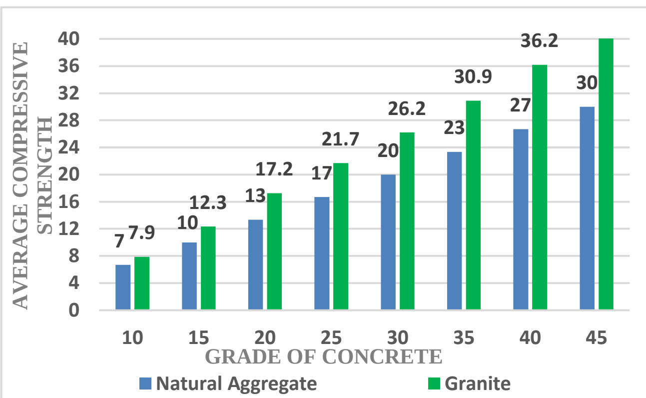


Figure 14 Result for compressive test of concrete with Marble aggregate

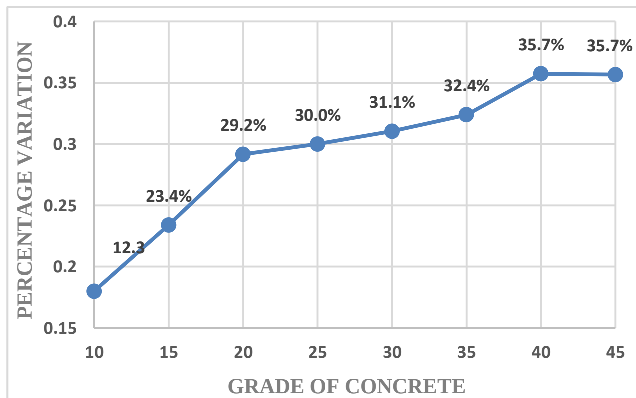


Figure 15 Percentage variation of compressive strength of concrete with Marble aggregate and Natural Aggregate

Table: Cube compressive strength of concrete after 28 days

Grade of Concrete	Average Compressive Strength Granite Aggregate (N/mm²)
M 10	12.60
M 15	19.10
M 20	27.00
M 25	34.00
M 30	40.80
M 35	48.40
M 40	55.40
M 45	62.50

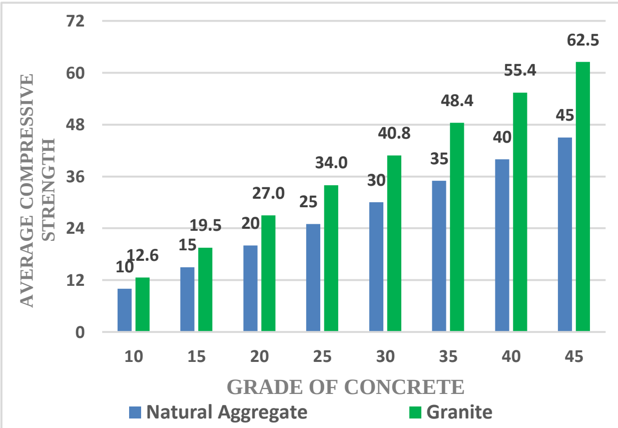


Figure 16 Result for compressive strength test of concrete with Marble aggregate

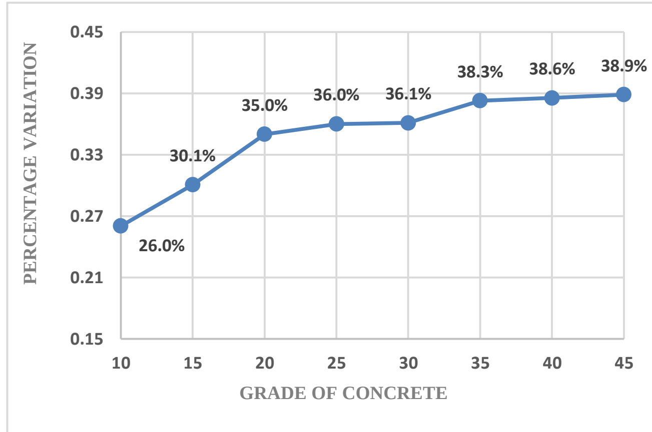


Figure 17 Percentage variation of compressive strength of concrete with Marble aggregate and Natural Aggregate

DOLOMITE

Compressive Strength

Table: Cube compressive strength of concrete after 7 days

Grade of Concrete	Average Compressive Strength Granite Aggregate (N/mm²)
M 10	7.80
M 15	12.13
M 20	17.10
M 25	21.70
M 30	23.92
M 35	28.12
M 40	32.35
M 45	36.62

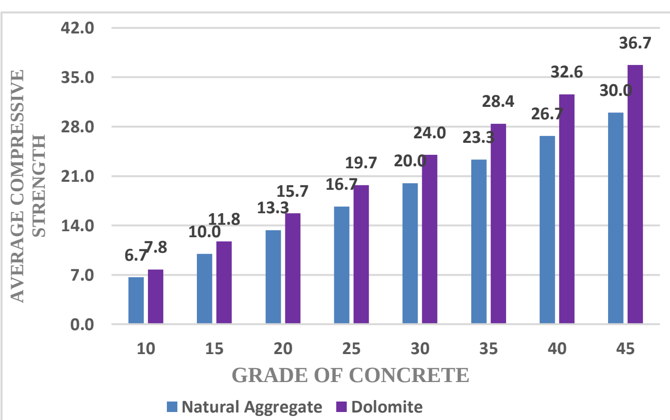


Figure 18 Result for compressive strength test of concrete with dolomite aggregate

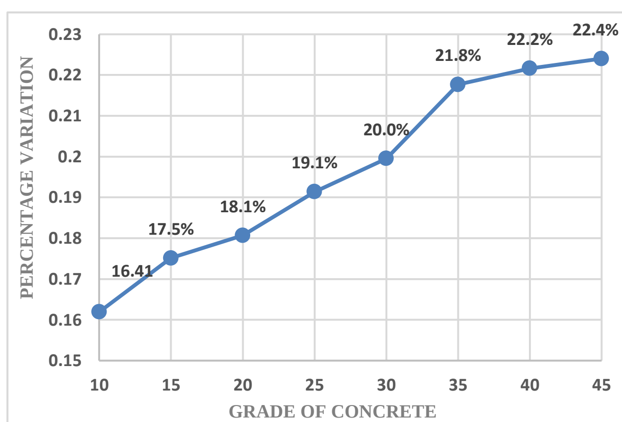


Figure 19 Percentage variation of compressive strength of concrete with dolomite aggregate and Natural Aggregate

Table: Cube compressive strength of concrete after 28 days

Grade of Concrete	Average Compressive Strength Granite Aggregate (N/mm²)
M 10	11.90
M 15	18.10
M 20	24.20
M 25	31.30
M 30	38.10
M 35	44.50
M 40	51.10
M 45	57.60

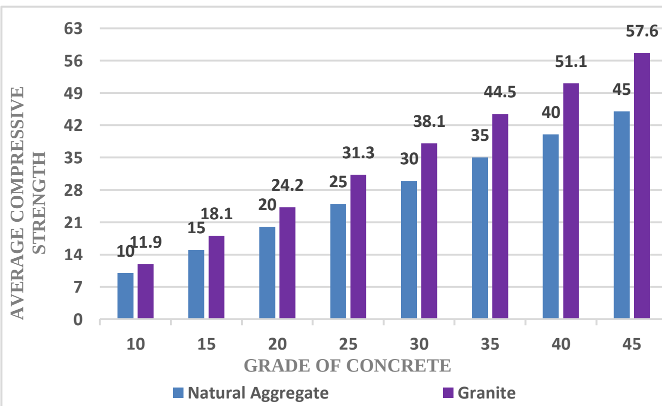


Figure 20 Result for compressive strength test of concrete with Dolomite aggregate

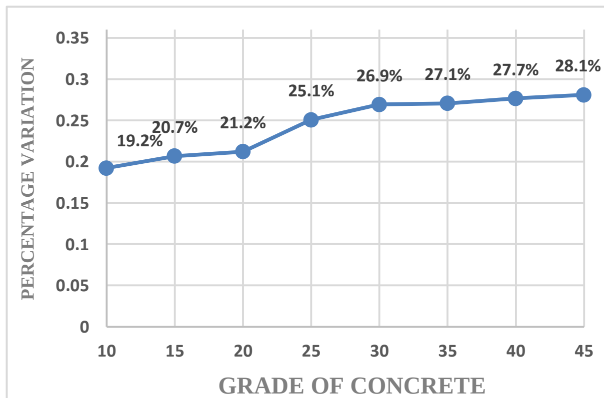


Figure 21 Percentage variation of compressive strength of concrete with Dolomite aggregate and Natural Aggregate

FLEXURAL STRENGTH

The compressive strength test results of concrete for M 10, M 15, M 20, M 25 grade are shown in table 7. It presents the comparison of 7-day compressive strength (mean).

- **MARBLE**

2. Flexural strength

Flexural strength formula(R) = $3PL/2BD^2$

Flexural strength for different grades of concrete on 7 day and 28 day of curing.

Table 2.1 (a) 7 days of Flexural strength

Grade of Concrete	Average Flexural Strength Marble Aggregate (N/mm²)
M 10	1.79
M 15	2.60
M 20	2.60
M 25	2.90

M 30	3.13
M 35	3.40
M 40	3.64
M 45	3.87

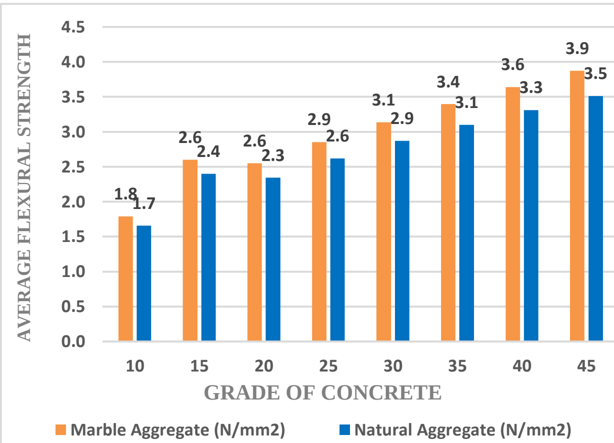


Figure 22 Result for flexural test of concrete with Marble aggregate

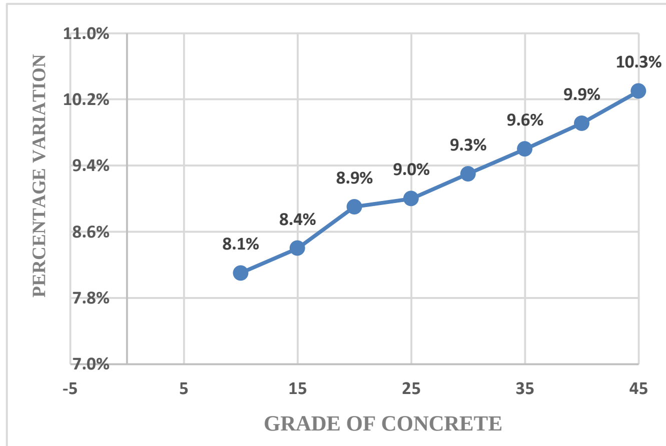


Figure 23 Percentage variation of flexeral strength of concrete with Marble aggregate and Natural Aggregate

Table 2.1 (a) 28 days of Flexural strength

Grade of Concrete	Average Flexural Strength Marble Aggregate (N/mm²)
M 10	2.7
M 15	3.3
M 20	3.9
M 25	4.3
M 30	4.8
M 35	5.2
M 40	5.6
M 45	6.0

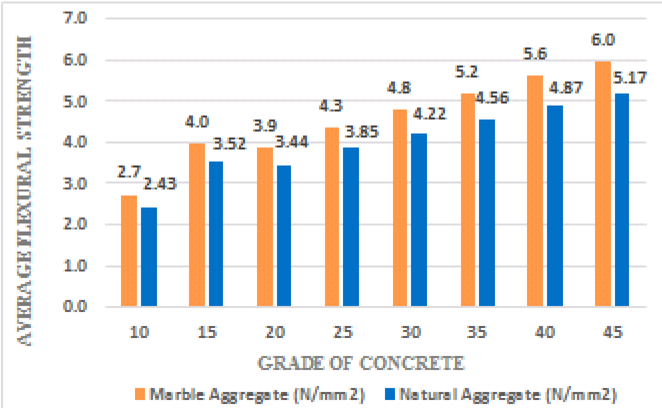


Figure 24 Result for flexural test of concrete with Marble aggregate

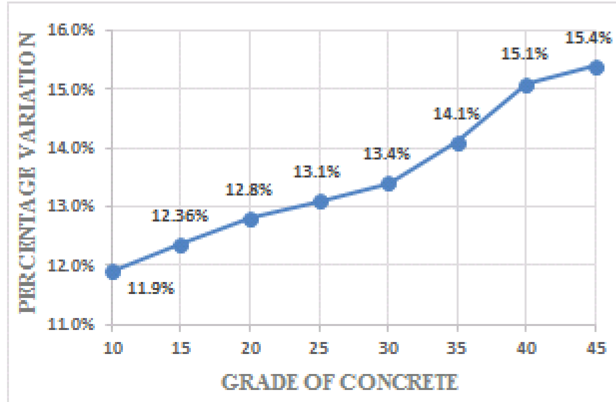


Figure 25 Percentage variation of flexural strength of concrete with Marble aggregate and Natural Aggregate

- **GRANITE**
  Flexural strength

Table: Flexural strength of concrete after 7 days

Grade of Concrete	Average Flexural Strength Marble Aggregate (N/mm²)
M 10	1.77
M 15	2.57
M 20	2.51
M 25	2.82
M 30	3.09
M 35	3.35
M 40	3.58
M 45	3.80

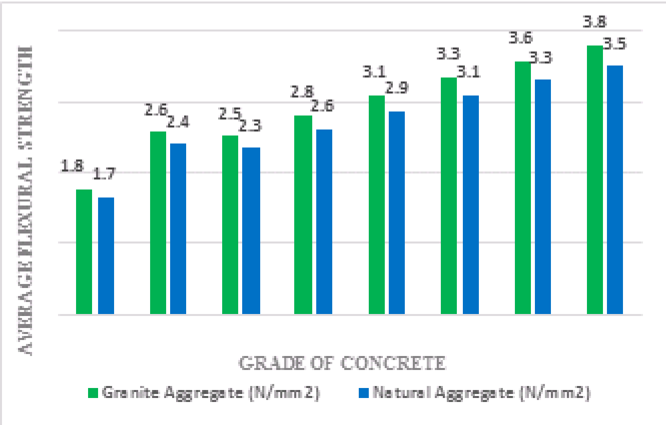


Figure 26 Result for flexural test of concrete with granite aggregate

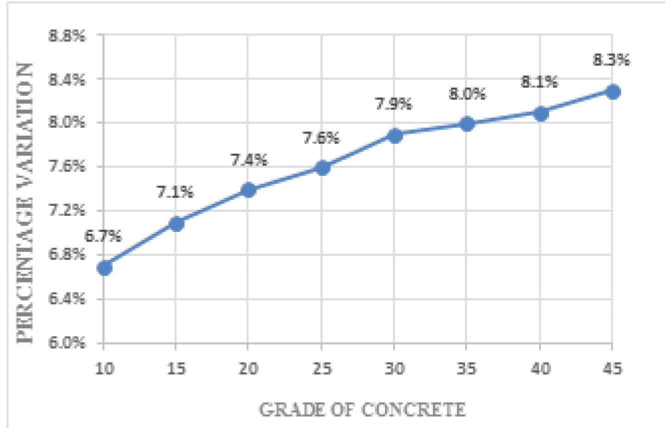


Figure 27 Percentage variation of flexural strength of concrete with granite aggregate and Natural Aggregate

Table: Flexural strength of concrete after 28 days

Grade of Concrete	Average Flexural Strength of Marble Aggregate (N/mm²)
M 10	2.6
M 15	3.8
M 20	3.7
M 25	4.2
M 30	4.6
M 35	5.0
M 40	5.4
M 45	5.7

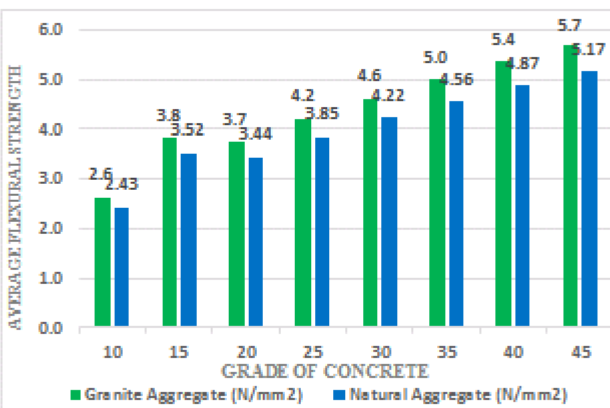


Figure 28 Result for flexural test of concrete with granite aggregate

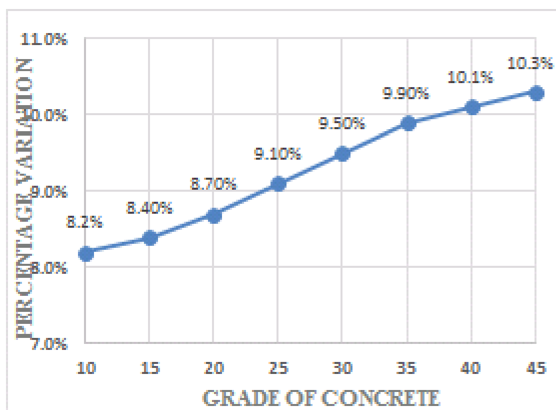


Figure 29 Percentage variation of flexural of concrete with granite aggregate and Natural Aggregate

DOLOMITE

Flexural strength

Table: Flexural strength of concrete after 7 days

Grade of Concrete	Average Flexural Strength Marble Aggregate (N/mm²)
M 10	1.7
M 15	2.5
M 20	2.4
M 25	2.7
M 30	3.0
M 35	3.2
M 40	3.4
M 45	3.6

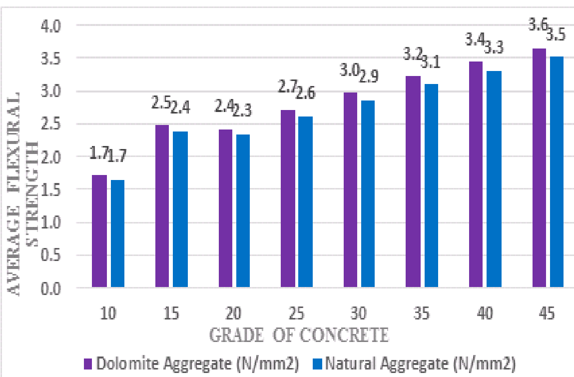


Figure 30 Result for flexural test of concrete with dolomite aggregate

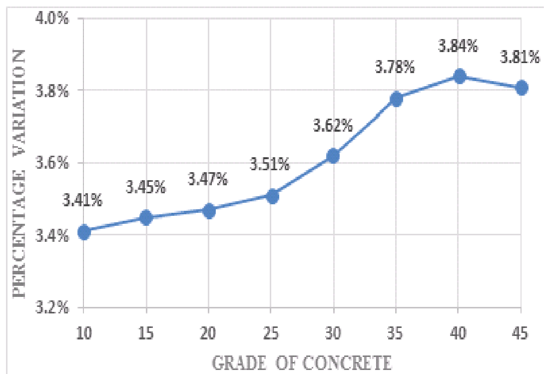


Figure 31 Percentage variation of flexural strength of concrete

Table: Flexural strength of concrete after 28 days

Grade of Concrete	Average flexural Strength Marble Aggregate (N/mm²)
M 10	2.6
M 15	3.8
M 20	3.7
M 25	4.2
M 30	4.6
M 35	4.9
M 40	5.3
M 45	5.6

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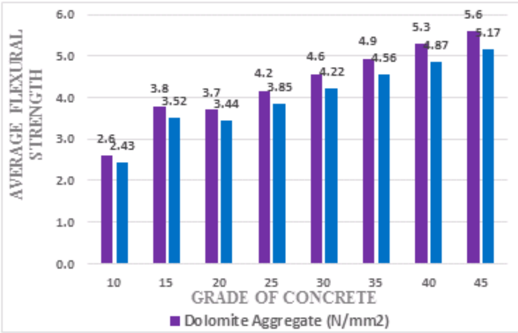

Figure 32 Result for flexural test of concrete with dolomite aggregate

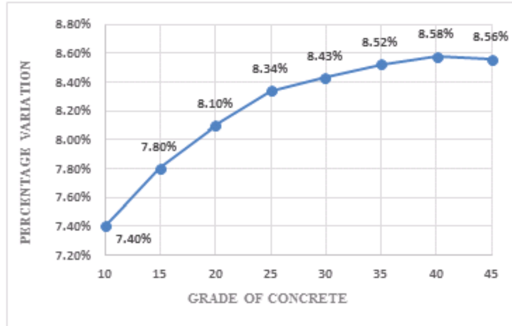

Figure 33 Percentage variation of flexural strength of concrete with dolomite aggregate and Natural Aggregate

CONCLUSIONS

In this study, the effect of replacing marble aggregate, granite aggregate and dolomite aggregate respectively on the properties of concrete were investigated and it can be concluded that

I. The fresh concrete property i.e. workability of all concrete mixes containing marble aggregate, granite aggregate and dolomite aggregate increased due to complete replacement of these aggregates in the design mix.

II. The maximum increase in the workability was seen during the complete replacement of natural aggregate with marble aggregate followed by granite and then dolomite. The possible reason for the increase in workability of concrete mix containing portion of marble aggregate as coarse aggregate was due to the smooth surface and low water absorption of marble aggregate.

III. Compressive strength of all concrete mixes containing marble aggregate, granite aggregate and dolomite aggregate shows upward trend. However, the increase in compressive strength was seen the most in the case of addition of marble aggregate in place of natural aggregate mainly because marble is known for its strength.

IV. Flexural strength of all concrete mixes containing marble aggregate, granite aggregate and dolomite aggregate also shows an increase. However, the increase in flexural strength was seen the most in the case of addition of marble aggregate in place of natural aggregate. `

It concludes that, the natural aggregates can be replaced by marble aggregate, granite aggregate and dolomite aggregate in concrete mixes. More studies will be required to use this waste material as construction material in concrete mixes

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