IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 2 Issue 4, April 2015.
www.ijiset.com
ISSN 2348 – 7968

# Effect of Replacement of Cement with Dolomite Powder on the Mechanical Properties of Concrete

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### Abstract

Cement is one of the most important constituents of concrete. Most of the properties of concrete depend on cement. Cement is manufactured by calcining argillaceous and calcareous materials at a high temperature. During this process, large amount of $CO_2$ is released in to the atmosphere. India is the second largest producer of cement in the world. It is estimated that the production of one ton of cement results in the emission of 0.8 ton of $CO_2$. The reduction in the consumption of cement will not only reduce the cost of concrete but also the emission of $CO_2$. Dolomite powder obtained by powderising the sedimentary rock forming mineral dolostone can be used as a replacement material for cement in concrete up to certain percentage. Dolomite powder has some similar characteristics of cement. Using dolomite powder in concrete can reduce the cost of concrete and may increase the strength to some extent. This paper examines the possibility of using dolomite powder as a partial replacement material to cement. The replacement percentages tried were 0%, 5%, 10%, 15%, 20% and 25% by weight of cement. The compressive, split tensile and flexural strengths of concrete with dolomite powder were compared with those of the reference specimens. The results indicate that replacement of cement with dolomite powder increases the compressive, split tensile and flexural strengths of concrete.

***Keywords:*** Dolomite Powder, Compressive strength, Split tensile strength, flexural strength.

## 1. Introduction

Concrete is the basic civil engineering material used in most of the civil engineering structures. Many materials are used to manufacture good quality concrete. Cement, fine aggregate, coarse aggregate, mineral admixtures, chemical admixtures and water are the constituents of concrete. Cement is the most important constituent material, since it binds the aggregates and resists the atmospheric action. However, manufacturing of cement emits about 0.8 ton of $CO_2$ in to atmosphere for every ton of cement manufactured. Dolomite is a carbonate material composed of calcium magnesium carbonate **CaMg $(CO_3)_2$.** Dolomite is a rock forming mineral which is noted for its remarkable wettability and dispersibility. Dolomite has a good weathering resistance. Dolomite is a preferred for construction material due to its higher surface hardness and density. Asphalt and concrete applications prefer dolomite as a filler material due to its higher strength and hardness. By the effective utilization of dolomite powder, the objective of reduction of cost of construction can be met. An attempt has been made to explore the possibility of using dolomite as a replacement material for cement. $M_{20}$ grade concrete specimens were made by replacing 5, 10, 15, 20 and 25% of cement with dolomite powder. The Compressive, Split tensile and Flexural strength of the specimens were found on the $7^{th}$ and $28^{th}$ days. Optimal replacement percentage of dolomite was determined.

## 2. Literature Review

**Kamal M.M, et al (2012)** evaluated the bond strength of self compacting concrete mixes containing dolomite powder. Either silica flume or fly ash was used along with dolomite powder to increase the bond strength considerably. Seven mixes were proportioned and push-out test was carried out. The variation of the bond strength for different mixes was evaluated. The steel concrete bond adequacy was evaluated based on normal bond strength. The result showed that the bond strength increased as the replacement of Portland cement with dolomite powder increased. All SCC mixes containing dolomite powder up to 30 % yielded bond strength that is adequate for design purpose. The availability of this type of concrete provided unique merits for faster construction. They reported that the shear strength of RC beams were better than that of the conventional SCC without dolomite powder.

**Deepa Balakrishnan S and Paulose K.C (2013)** carried out an investigation on the workability and strength characteristics of self compacting concrete containing fly ash and dolomite powder. They made high volume fly ash self compacting concrete with 12.5percent, 18.75percent, 25percent and 37.5percent of the cement (by mass) replaced by fly ash and 6.25percent, 12.5percent and 25percent of the cement replaced by dolomite powder. The test results for acceptance characteristics of self compacting concrete such as slump flow test, J-ring test, V-funnel test and L-box test were presented. The mixes were then tested for other mechanical properties like, cube compressive strength at 7th day, 28th day and 90th day, cylinder compressive strength at 28th day, split tensile strength, and flexural strength at 28th day. For all levels of cement replacement, concrete achieved superior performance in the fresh and hardened states when compared with the reference mixture.

**Bhavin k, et al (2013)** presented the details of the investigation carried out on paver blocks made with cement, dolomite block and different percentages of polypropylene fibres. They reported that addition of 0.3% and 0.4% of polypropylene fibres improved the abrasion resistance and flexural strength of paver block.

**Salim Barbhuiya (2011)** carried out an investigation to explore the possibilities of using dolomite powder for the production of SCC. Test results indicated that it is possible to manufacture SCC using fly ash and dolomite powder. The mix containing fly ash and dolomite powder in the ratio 3:1 was found to satisfy the requirements suggested by the European Federation of Producers and Contractors of Specialist Products for Structures (EFNARC) guidelines for making SCC. Compressive strengths of SCC with 75% flyash and 25% dolomite powder was found to be satisfactory for structural applications.

## 3. Experimental Investigation

### 3.1 Materials used

**Cement**

Cement is a binder, a substance that sets and hardens independently, and binds other materials together. Many types of cements are available in the market. The commonly used cement is Portland cement. Portland cement of 53 grade was used for the investigation. The specific gravity of Portland cement was 3.15.

**Coarse aggregate**

The coarse aggregate is the largest component of concrete. It is chemically a stable material. Presence of coarse aggregate reduces the drying shrinkage and other dimensional changes occurring on account of movement of moisture. Hard broken granite stones were used as coarse aggregate in concrete. Size of coarse aggregate used in the investigation was 10mm. The specific gravity of the coarse aggregate was found to be 2.68.

**Fine aggregate**

The most important function of the aggregate is to assist in producing workability and uniformity in mixture. The fine aggregate also assists the cement paste to hold the coarse aggregate particle in suspension. This action promotes plasticity in the mixture and prevents the possible segregation of paste and coarse aggregate. It should be durable, clean and be free from organic matters. It should not contain any appreciable amount of clay balls and harmful impurities such as alkalis, salt, coal, decayed vegetation etc. River sand was used as fine aggregate. The specific gravity of sand was found to be 2.56.

**Water**

Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement. The water, which is used for making concrete should be clean and free from harmful impurities like oil, alkalis, acids etc. Water for making concrete should have pH between 6 and 8. Locally available drinking water was used in this work.

**Dolomite**

Dolomite is a carbonate material composed of calcium magnesium carbonate **$CaMg(CO_3)_2$.** The term is also used to describe the sedimentary carbonate rock dolostone. Dolostone (dolomite rock) is composed predominantly of the mineral dolomite with a stoichiometric ratio of 50% or greater content of magnesium replacing calcium, often as a result of digenesis. Dolomite is a rock forming mineral which is noted for remarkable wettablity and dispersibility as well as moderate oil and plasticizers absorption.

Dolomite has good weathering resistance. The properties of the dolomite powder are given in Table 1.

Table 1: Properties of Dolomite Powder

| S.No | Property | Dolomite Powder |
|---|---|---|
| 1 | Formula | $CaMg(CO_3)_2$ |
| 2 | Specific gravity | 2.85 |
| 3 | Color | white, grey to pink |
| 4 | Tenacity | Brittle |
| 5 | Moisture content (%) | Nil |
| 6 | Crystal system | Trigonal |
| 7 | Sieve analysis | Zone III |

### 3.2 Details of concrete mix

In the present investigation, $M_{20}$ mix was designed as per the guidelines given in IS 10262:2009. The water cement ratio adopted was 0.48. The quantities of cement, fine aggregate and coarse aggregate required for 1m$^3$ of concrete are 399.13 kg, 526.56 kg, 1221.81 kg respectively.

### 3.3 Test Results

#### Compressive Strength

The cube compressive strength of concrete was determined by conducting test on 150mm x 150mm x 150mm cube specimens at 7 days, 28 days of curing. After curing, three cube specimens were tested on a compression machine. The specimens were tested in the compression testing machine of 2000kN capacity. After keeping the specimens on the compression testing machine, the load was applied at a uniform rate of 140kg/cm$^2$/min until the failure of the specimen. The average value of the three results was taken as the compressive strength. The compressive strength of concrete gives an idea about the overall quality of concrete. The compression testing machine used is shown in Fig 1.


Fig. 1 Compression Testing Machine

#### Split Tensile Strength

Tensile strength of concrete greatly affects the extent and size of cracking in concrete. Tensile strength of concrete is less when compared with its compressive strength. Cylinders of diameter 150mm and height 300mm were used to determine the split tensile strength. After curing, the specimens were tested on the compression testing machine of 2000kN capacity.

#### Flexural Strength

The determination of flexural tensile strength is essential to estimate the load at which concrete members may crack. The flexural tensile strength at failure is called modulus of rupture. The knowledge of modulus of rupture is useful in the design of pavement slabs, airfield runways, finding deflection and crack width as flexural tension is critical in these cases. Prisms of size 100 mm X 100 mm X 500mm were used to determine the flexural strength. Two point loading was adopted for finding the flexural strength. The specimens were tested in a Universal Testing Machine (UTM) of capacity 1000kN. The test setup is shown in Fig 2.

ISSN 2348 – 7968


Fig. 2 Universal Testing Machine

The values of the compressive, split tensile and the flexural strengths are given in Table 2, Table 3 and Table 4 respectively for $M_{20}$ grade of concrete.

Table 2: Compressive Strength of $M_{20}$ Concrete at 7th & 28th Days

| S.No | % Replacement of cement with dolomite powder | Compressive Strength ($N/mm^2$) | | | |
|---|---|---|---|---|---|
| | | 7th day | % Variation * | 28th day | % Variation * |
| 1 | 0 | 16.15 | - | 28.30 | - |
| 2 | 5 | 17.56 | 8.73 | 29.56 | 4.45 |
| 3 | 10 | 18.14 | 12.32 | 31.24 | 10.39 |
| 4 | 15 | 17.96 | 11.21 | 25.72 | -0.09 |
| 5 | 20 | 15.56 | -3.65 | 23.07 | -18.48 |
| 6 | 25 | 13.27 | -17.83 | 18.48 | -34.70 |

* - Negative sign indicates a reduction in strength with respect to the reference specimen

Table 3: Split Tensile Strength $M_{20}$ Concrete at 7th & 28th days

| S.No | % Replacement of cement with dolomite powder | Split Tensile Strength ($N/mm^2$) | | | |
|---|---|---|---|---|---|
| | | 7th day | % Variation * | 28th day | % Variation * |
| 1 | 0 | 1.53 | - | 3.04 | - |
| 2 | 5 | 1.91 | 24.84 | 3.29 | 8.22 |
| 3 | 10 | 2.33 | 52.29 | 3.72 | 22.37 |
| 4 | 15 | 2.76 | 80.39 | 4.25 | 39.80 |
| 5 | 20 | 2.48 | 62.09 | 2.76 | -9.21 |
| 6 | 25 | 1.40 | -8.50 | 1.93 | -36.51 |

* - Negative sign indicates a reduction in strength with respect to the reference specimen

Table 4: Flexural Strength of $M_{20}$ Concrete at 7th & 28th days

| S.No | % Replacement of cement with dolomite powder | Flexural Strength ($N/mm^2$) | | | |
|---|---|---|---|---|---|
| | | 7th day | % Variation * | 28th day | % Variation * |
| 1 | 0 | 4.80 | - | 7.20 | - |
| 2 | 5 | 5.28 | 10 | 7.80 | 8.33 |
| 3 | 10 | 5.80 | 20.83 | 8.48 | 17.78 |
| 4 | 15 | 4.96 | 3.33 | 6.40 | -11.11 |
| 5 | 20 | 3.44 | -28.33 | 5.04 | -30 |
| 6 | 25 | 2.68 | -44.17 | 4.56 | -36.67 |

* - Negative sign indicates a reduction in strength with respect to the reference specimen

The variations in the compressive strength, the split tensile strength and the flexural strength of $M_{20}$ concrete with respect to percentage replacement are shown in Fig 3, Fig 4 and Fig 5 respectively.

ISSN 2348 – 7968

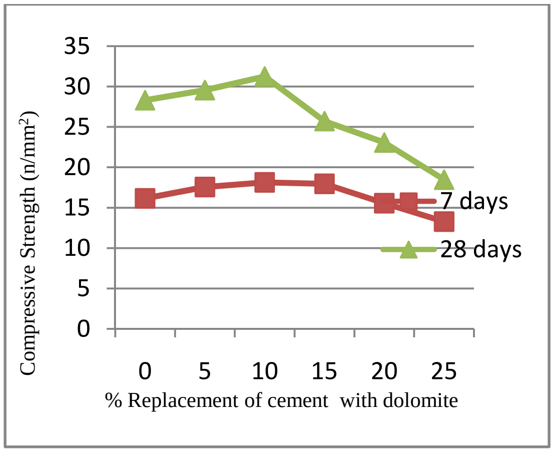


Fig. 3 Compressive Strength of $M_{20}$ Concrete at $7^{th}$ & $28^{th}$ days

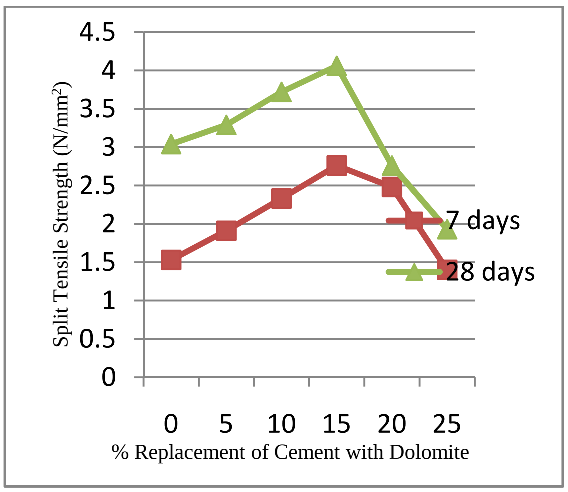


Fig. 4 Split tensile strength of $M_{20}$ Concrete at $7^{th}$ & $28^{th}$ days

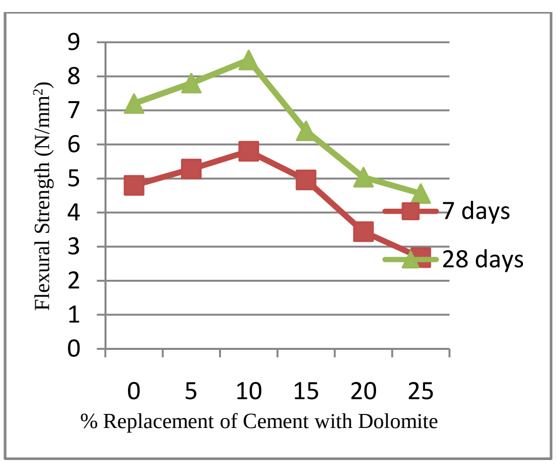


Fig. 5 Flexural Strength of $M_{20}$ Concrete at $7^{th}$ & $28^{th}$ days

From the tables and figures, it can be seen that dolomite powder improves the compressive strength, the split tensile strength and the flexural strength of concrete up to certain replacement percentage. As the percentage replacement of cement with dolomite powder increases, the compressive, the split tensile and the flexural strengths increase, reach a maximum value and then decrease. The maximum compressive and flexural strengths are obtained when the replacement percentage is 10. In case of split tensile strength, the optimal replacement percentage is 15. The maximum compressive strength obtained at 10% replacement was found to be 31.24 N/mm$^2$. The split tensile strength of concrete with dolomite powder increased up to 15% and then it decreased. The maximum split tensile strength at 15% replacement was 4.25 N/mm$^2$.The flexural strength of concrete with dolomite powder increased up to 10% and then it decreased. The maximum flexural strength at 10% replacement was 8.48 N/mm$^2$.

## 4. Conclusions

Replacement of cement with dolomite powder is found to improve the strength of concrete. The optimal replacement percentage of cement with dolomite powder is found to be 10% and at this replacement level, the maximum increase in the 28$^{th}$ day compression and flexural strength were found to be 10.4% and 17.8% respectively. In case of split tensile strength, the optimal replacement is 15% and at this replacement level, the percentage increase in split tensile strength was found to be 39.8%. Use of dolomite powder decreases the cost of concrete. since the cost of dolomite is less than that of cement. The reduction in the consumption of cement will reduce the emission of green house gas.

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