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"An Experimental Investigation on Partial Replacement of Cement with Magnesium Carbonate on Performance of Concrete"

R.S. Chikkanagoudar[1], Deepak L S, Darshan K Jain[2], Kruthika T P[2], Maruthi R[2].

[1]*Assistant Professor, Dept. of Civil Engineering, BIET, Davanagere*
[2]*UG Students, Dept. of Civil Engineering, BIET, Davanagere*

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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. Magnesium carbonate powder has some similar characteristics of cement. Using Magnesium carbonate powder in concrete can reduce the cost of concrete and may increase the strength to some extent.*

In the present work, cement is partially replaced by various percentages of Magnesium Carbonate (0%, 5%, 10%, 15%, 20% and 25%) in concrete. The effect of Magnesium Carbonate on strength properties of concrete for M40 grade mix is studied. IS: 10262 (2019) is used to carry out the Mix Design. Slump and compaction factor are determined to measure workability. For various mixes of concrete, Compression, Split tensile and Flexural strengths are determined.

The workability of concrete increase with the increase in Magnesium Carbonate replacement level. The maximum compressive strength is observed in the range of 10-15% of Magnesium Carbonate addition, maximum flexure strength is observed at 20-25% of Magnesium Carbonate addition and the maximum split tensile strength is observed at 10-15% of Magnesium Carbonate addition.

Key Words: *CO_2. Carbon capturing system (CCS), Magnesium Carbonate, CO_2 emission, split tensile strength, compressive strength and flexural strength.....*

1. INTRODUCTION

Cement and concrete are the basic substances in construction and Civil engineering, and its leading role for the economic growth of our country has been well appreciated. Its production, however, is a highly energy- and resource-consuming one, and emits a large amount of carbon dioxide. Recent awareness on environmental issues drives our concern for energy-saving and environment friendly methods such as low CO_2 emission technologies. . At the same time, cement industries worldwide are involved in various methods for the reduction of carbon dioxide; introduction of high-efficiency equipments, utilizing alternate fuels, uses of blended cement, and adopting **"carbon capture and storage (CCS) techniques"**. Domestically, typical studies for reduction of carbon dioxide focus on mixed cement with the addition of pozzolan materials such as slag or fly ash, and on the development of sinter less cement without using any ordinary Portland cement (OPC).

By the effective utilization of Magnesium carbonate powder, the objective of reduction of cost of construction can be met. An attempt has been made to explore the possibility of using Magnesium carbonate as a replacement material for cement. M40 grade concrete specimens were made by replacing 5, 10, 15, 20 and 25% of cement with Magnesium carbonate powder. The Compressive, Split tensile and Flexural strength of the specimens were found on the 70th days. Optimal replacement percentage of Magnesium carbonate was determined.

2. Literature Review

[1]**Kamal M.M**, et al (2012) evaluated the bond strength of self compacting concrete mixes containing Magnesium carbonate. Either silica flume or fly ash was used along with Magnesium carbonate 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 Magnesium carbonate increased. All SCC mixes containing Magnesium carbonate 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. It has reported that the shear strength of RC beams were better than that of the conventional SCC without Magnesium carbonate.

[2]**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 Magnesium carbonate powder. It is observed that high volume fly ash self compacting concrete made 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 MgCO3 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.

[3]**Bhavin K, et al** (2013) presented the details of the investigation carried out on paver blocks made with cement, Magnesium carbonate block and different percentages of polypropylene fibres. It is reported that the addition of 0.3% and 0.4% of polypropylene fibers improved the abrasion resistance and flexural strength of paver block.

[4]**Salim Barbhuiya** (2011) carried out an investigation to explore the possibilities of using Magnesium carbonate powder for the production of SCC. Test results indicated that it is possible to manufacture SCC using fly ash and Magnesium carbonate powder. The mix containing fly ash and Magnesium carbonate 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 (EFN ARC) guidelines for making SCC. Compressive strengths of SCC with 75% fly ash and 25 % Magnesium carbonate powder were found to be satisfactory for structural applications.

3. Materials

3.1 Cement

Ordinary Portland cement (OPC) 43 grade with specific gravity 3.015, conforming to IS: 8112-1989 is used in the present experimental research work. Brand name of the cement is ACC cement.

Table 1: Physical properties of cement

Material property	Results obtained	Permissible limits as per IS 8112-1989
Specific gravity	3.08	3.00-3.15
Standard consistency	30 %	Less than 34%
Initial setting time	180 minutes	More than 30 minutes
Final setting time	369 minutes	Less than 600 minutes

Table 2: Chemical properties of cement

Chemical composition	Percentage (%)
Lime CaO	62
Silica SiO_2	22
Alumina Al_2O_3	05
Calcium Sulphate $CaSO_4$	04
Iron Oxide Fe_2O_3	03
Magnesia MgO	02
Sulphur trioxide S_2O_3	01
Alkalies	01
TOTAL	100

3.2 Magnesium Carbonate

Magnesium silicate (forsterite (Mg_2SiO_4)) is a carbonate material composed of magnesium carbonate $MgCO_3$. The term is also used to describe the sedimentary carbonate rock olivine. Olivine is composed predominantly of the mineral magnesium silicate with a stoichiometric ratio of 50% or greater content of magnesium, often as a result of digenesis. Forsterite is a rock forming mineral which is noted for remarkable wettability and dispersibility as well as moderate oil and plasticizers absorption. Forsterite has good weathering resistance.

Figure 1: Magnesium Carbonate

Table 3: properties of Magnesium Carbonate

Sl. no.	Properties	Magnesium carbonate powder
1.	Formula	$MgCO_3$
2.	Specific gravity	3.3
3.	Color	White and grey
4.	Tenacity	Nil
5.	Crystal system	Finer
6.	Sieve analysis	Zone-3
7.	Moisture content	Nil

3.3 Fine aggregate

Crushed or manufacturing sand shown in figure conforming to IS: 383-1970 of zone II and specific gravity 2.5 is used which was determined as per the method conforming to IS: 2386-1963 and the results gained comply with the code specifications. The sieve analysis results and specific gravity of FA are listed in table 4

Table 4: Properties of fine aggregate

IS sieve size	Cumulative-percentage passing of fine aggregates	Specifications for Zone-II as per IS:383-1970
10 mm	100	100
4.75 mm	99.5	90-100
2.36 mm	96	75-100
1.18 mm	74	55-90
600 µm	54	35-59
300 µm	10	8-30
150 µm	1.5	0-10
Pan	0	0
Specific gravity = 2.5		

3.4. Coarse aggregate

The angular crushed aggregates having size 20 mm and lesser size conforming to IS: 383-1970 with specific gravity 2.63, bulk density 1782 kg/m^3 and water absorption 0.54% was used in this experimental work of study. Specific gravity of coarse aggregate is determined using the method confirming to IS: 2386-1963.

3.5. Admixtures

Admixtures are those ingredients in concrete other than Portland cement, water, and aggregates that are added to the mixture immediately before or during mixing. Concrete should be workable, finish able, strong, durable, watertight, and wear resistant. These qualities can often be obtained easily and economically by the selection of suitable materials rather than by resorting to admixtures.

Super plasticizer

Super plasticizers are used to maintain high workability while at the same time to maintain strength. When concreting highly reinforced structures, concrete has to be able to flow freely. Super plasticizers can be used in such situations to increase the flow ability without compromising strength.

3.6. Water

Generally, quality of water for construction works is same as drinking water. This is to ensure that the water is reasonably free from such impurities as suspended solids, organic matter and dissolved salts, which may adversely affect the properties of the concrete, especially the setting, hardening, strength, durability, pit value, etc. The water shall be clean and shall not contain sugar, molasses or their derivatives, or sewage, oils, organic substances.

4. Mix Design for M40 Grade Concrete

Mix Design is the process of choosing suitable ingredients of concrete and obtaining their relative quantities with the aim of generating an economical concrete of the required workability, strength and durability. In the present study, mix design is carried as per IS 10262(2019) guidelines for M40 grade concrete.

4.1 Mix proportioning

M40 grade concrete was designed using IS method of mix design. The mix proportion for M40 grade concrete is given in the following table 5.

Table 5: Mix proportioning of M40 Grade of concrete

Grade of concrete	Cement + $MgCO_3$	FA	CA	Water
Weights	483.16	645.028	1126.14	167.586
M40	1	1.51	2.65	0.38

4.2 Mix preparation and casting of specimens

1. As per computed weights the cementitious materials i.e. the cement, magnesium carbonate are mixed together homogeneously in dry state. Further, this mixture is blended with specifically calculated weight quantities of fine and coarse aggregates with essentially estimated amount of BASF and water in a mixing tray.
2. Quantity of concrete to be prepared in a batch is decided by number of specimens to be cast.
3. The moulds were cleaned in systematic way using a dry cloth and subsequently all faces of moulds were oiled in proper manner so that easy demoulding of concrete can be done at later stage.
4. The concrete was filled in the moulds in 3 layers. After filling up of each layer mixture is tamped using 16mm diameter tamping rod by giving sufficient compaction.
5. The moulds filled with mixture were placed on vibration table so, that mixture will get compacted thoroughly.
6. After compaction the surface was leveled with the help of the trowel.
7. Specimens were named before initial setting time.
8. After a period of 24 hours of casting, the specimens were taken out from moulds and are kept in water or open to atmosphere for respective type of curing for a period 7 days, 14 days and 28 days.
9. After an interval of 7days, 14days, 28 days of curing, the specimens were tested and results are recorded.

Figure 2. Dry mix of concrete

Figure 3. Wet mix of concrete

Figure 4. Casing of specimens

Figure 5. Compaction of specimens by using vibration machine.

4.3 Curing

During the hardening process, the specimens should be cured in a suitable environment such that good quality concrete is obtained. They are placed in the tank for curing as shown in Fig. 6.

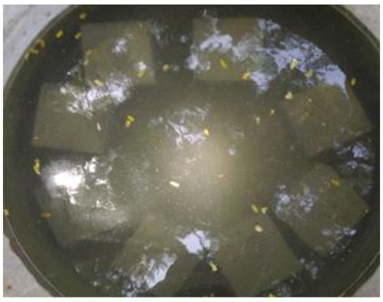

Figure 6. Curing of specimens

5. Results and Discussion

5.1 Compressive Strength on Cement Mortar

The following Table 6 represents the test results of Compressive strength of hardened cement mortar for addition of different percentages of Magnesium Carbonate which range from 5%, 10%, 15%, 20% and 25% by weight of cement.

Date of manufactured of cement: January 2020
Date of use of cement: March 2020

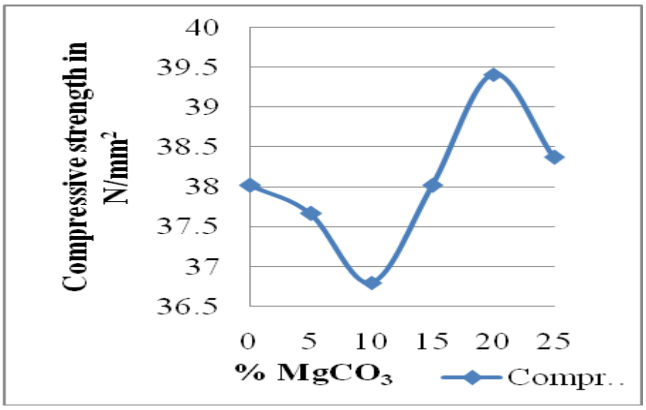

Figure 7 Variation of Compressive test strength of cement mortar

5.2 Tests on fresh concrete [Workability characteristics]:

The following Table 7 given below represents the test results on fresh concrete for slump, compaction factor, for addition of different percentages which range from 5%, 10%, 15%, 20% and 25% of Magnesium Carbonate by weight of cement. Figure 8 represents the variation of slump and Compaction factor results for different percentage replacement of cement by $MgCO_3$.

Table 7 Tests result on workability

% of $MgCO_3$	Slump value In mm	Compaction factor
0	103	0.934
5	110	0.935
10	125	0.945
15	134	0.943
20	143	0.948
25	145	0.950

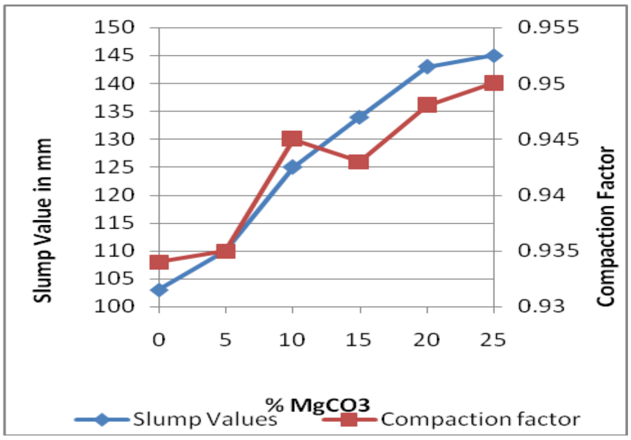

Figure 8 Variation of slump value and Compaction factor results for different percentage replacement of Cement by $MgCO_3$

5.3 Tests on Hardened concrete

5.3.1 Compressive strength results

The following graph figure 9 represents the compressive strength results for different percentage of Magnesium carbonate replaced by weight of cement ranging from 5%, 10%, 15%, 20% and 25%.

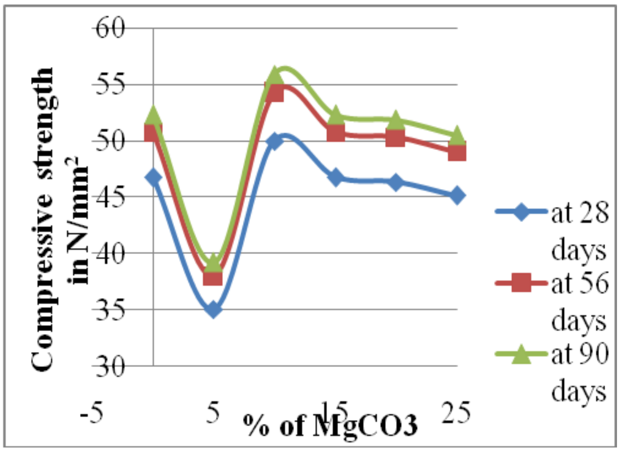

Figure 9 Result of Compressive strength of concrete specimen

5.3.2 Split Tensile Strength

The following figure 10 represents the results of split tensile strength for replacement of different percentage of mineral admixtures (Magnesium carbonate) ranging from 0, 5, 10, 15, 20 and 25% by weight of cement.

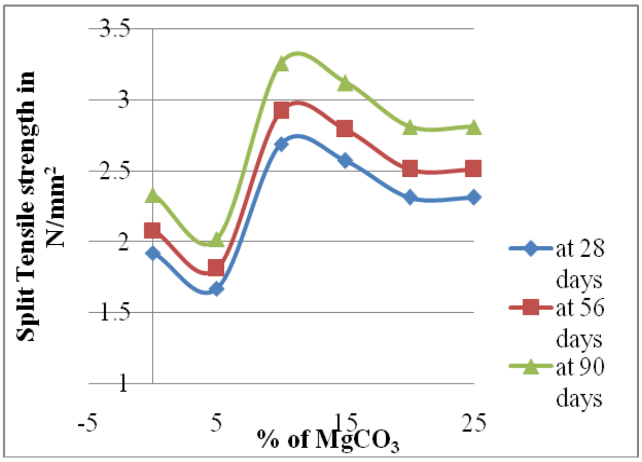

Figure 10: Results of split tensile strength of concrete specimen

5.3.3 Flexural strength test

The following figure 11 represents the results of flexural strength for addition of different percentage of mineral admixtures (Magnesium carbonate) ranging from 0, 5, 10, 15, 20 and 25% by weight of cement.

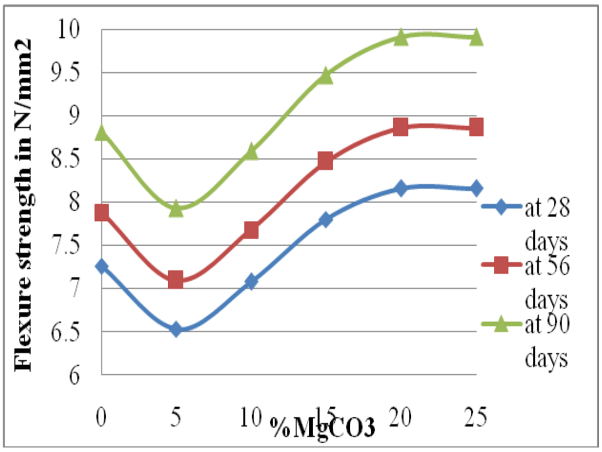

Figure 11 Result of flexural strength of concrete specimen

Table 8: Test results of flexural strength test

% of $MgCO_3$	Flexural strength in N/mm²			
	at 70 days	at 28 days *	at 56 days *	at 90 days *
0	8	7.26	7.88	8.81
5	7.2	6.53	7.09	7.93
10	7.8	7.08	7.68	8.59
15	8.6	7.8	8.47	9.47
20	9	8.16	8.86	9.91
25	9	8.16	8.86	9.91

* Test on beams done for 70 days has been interpolated to 28, 56 and 90 days

Relation between Flexural strength and Split tensile strength

From CEB-FIP Model code 1990; clause no 2.1.3.3 Tensile strength and Fracture properties

Table 9 Value of split tensile strength

% of $MgCO_3$	flexural strength from test conducted in n/mm²	Split tensile strength in n/mm²
0	8	5.33
5	7.2	4.8
10	7.8	5.2
15	8.6	5.73
20	9	6
25	9	6

5.4 Discussions of results

1. From the results obtained on fresh concrete, workability increase with increase in magnesium carbonate content both terms of slump and compaction factor.
2. There is rise in compressive strength at 10-25% (5 to 25% with 5% interval) Magnesium Carbonate replacement level.
3. There is rise in flexural strength at 15- 25% (5 to 25% with 5% interval) Magnesium Carbonate replacement level.

4. There is rise in split tensile strength at 10-25% (5 to 25% with 5% interval) Magnesium Carbonate replacement level.

6. CONCLUSIONS

1. The workability of concrete increase with the increase in Magnesium Carbonate replacement level.
2. The optimum percentage of Magnesium Carbonate addition at which the study indicates maximum compressive strength is observed to be in the range of 10 to 15 percent.
3. The optimum percentage of Magnesium Carbonate addition at which the study indicates maximum flexural strength is observed to be in the range of 20 & 25 percent.
4. The optimum percentage of Magnesium Carbonate addition at which the study indicates maximum split tensile strength is observed to be in the range of 10 & 15percent.
5. Split tensile and flexural strength values for various percentage of Magnesium Carbonate addition show to satisfy the stipulation as per code.
6. Magnesium carbonate is better performing in split tensile strength and flexural strength when compared to GGBS, Fly Ash with GGBS and Recron 3s fibers addition in to the concrete.
7. From the "CEB-FIP MODEL CODE 1990" the relationship between flexure and split tensile strength is acceptable at range of 10-25% (5 to 25% with 5% interval).

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