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Experimental Investigation on partial Replacement of Cement with dolomite powder

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ABSTRACT:The main aim of this experimental investigation is to focus on the possibilities of utilizing dolomitepowder (DP) in cement and concrete production. 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 CO2 is released into 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 CO2. The reduction in the consumption of cement will not only reduce the cost of concrete but also the emission of CO2. Dolomite powder obtained by pulverising the sedimentary rock forming mineral dolomite 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%, 7.5%, 10% and 15% by weight of cement. The compressive and split tensile strength of concrete with dolomite powder was compared with those of the reference specimens. The results indicate that replacement of cement with dolomite powder increases the compressive and split tensile strength of concrete.

KEYWORDS: Dolomite Powder, Mix Design, Compressive Strength, Split Tensile Strength

I. INTRODUCTION

The concrete is one of two largest producers of carbon dioxide (CO_2), creating up to 5% of worldwide man-made emissions of this gas, of which 50% is from the chemical process and 40% from burning fuel. The carbon dioxide CO_2 produced for the manufacture of one tonne of structural concrete (using ~14% cement) is estimated at 410 kg/m^3 (~180 kg/tonne @ density of 2.3 g/cm^3) (reduced to 290 kg/m^3 with 30% fly ash replacement of cement). The CO_2 emission from the concrete production is directly proportional to the cement content used in the concrete mix; 900 kg of CO_2 are emitted for the fabrication of every ton of cement, accounting for 88% of the emissions associated with the average concrete mix. Cement manufacture contributes greenhouse gases both directly through the production of carbon dioxide when calcium carbonate is thermally decomposed, producing lime and carbon dioxide, and also through the use of energy, particularly from the combustion of fossil fuels.

One area of the concrete life cycle worth noting is the fact that concrete has a very low embodied energy relative to the quantity that is used. This is primarily the result of the fact that the materials used in concrete construction, such as aggregates, pozzolans, and water, are relatively plentiful and can often be drawn from local sources. This means that transportation only accounts for 7% of the embodied energy of concrete, while the cement production accounts for 70%. With a total embodied energy of 1.69 GJ/tonne concrete is lower than any other building material besides wood. It is worth noting that this value is based on mix proportions for concrete of no more than 20% fly ash. It is estimated that one percent replacement of cement with fly ash represents a .7% reduction in energy consumption. With some proposed mixes containing as much as 80% fly ash, this would represent a considerable energy savings.

One reason why the carbon emissions are so high is because cement has to be heated to very high temperatures in order for clinker to form. A major culprit of this is alite (Ca_3SiO_5), a mineral in concrete that cures within hours of pouring and is therefore responsible for much of its initial strength. However, alite also has to be heated to 1,500 °C in the clinker-forming process. Some research suggests that alite can be replaced by a different mineral, such It has a roasting temperature of 1,200 °C, which is significantly lower than that of alite. Furthermore, belite is actually stronger once concrete cures. However, belite takes on the order of days or months to set completely, which leaves concrete weak for an unacceptably long time. Current research is focusing on finding possible impurity additives, like magnesium, that might speed up the curing process. It is also worthwhile to consider that belite takes more energy to grind, which may make its full life impact similar to or even higher than alite.

Another approach has been the partial replacement of conventional clinker with such alternatives as fly ash, bottom ash, and slag, all of which are by-products of other industries that would otherwise end up in landfills. Fly ash and bottom ash come from thermoelectric power plants, while slag is a waste from blast furnaces in the ironworks industry. These materials are slowly gaining popularity as additives, especially since they can potentially increase strength, decrease density, and prolong durability of concrete.

II.LITERATURE SURVEY

Kamal M.M, (2012) evaluated the bond strength of self compacting concrete mixes containing dolomite powder. 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. 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. For all levels of cement replacement, concrete achieved superior performance in the fresh and hardened states when compared with the reference mixture.
Bhavin K, (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.

III.MATERIAL AND METHODOLOGY

3.1MATERIALS

CEMENT: ordinary portland cement (opc) of 43 grade was used throughout the course of the investigation. The physical properties of the cement as determined from various tests conforming to Indian Standard IS: 1489:1991.
DOLOMITE POWDER was collected from the dolomite powder manufacturing factory. It was sieved by IS-90 micron sieve before mixing in concrete.Dolomite is a carbonate material composed of calcium magnesium carbonate CaMg (CO3)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.

Advantages of Dolomite Powder

- Dolomite has good weathering resistance
- Higher degree of purity, wet ability and whiteness.
- Dolomite is popular for its shear and compressive strength.
- Fire resistive and solid.
- Long lasting life and stiffness.

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Dolomite is a rock forming mineral which is noted for remarkable wettablity and dispersibility as well as moderate oil and plasticizers absorption. Salient features of natural dolomite are shown in Table:1

Table:1 Salient features of natural dolomite

Sl.No	Property	Dolomite Powder
1	Formula	CaMg(CO3)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

COARSE AGGREGATES are those chemically inert materials which when bonded by cement paste form concrete. Aggregates influence the strength of concrete to great extent. The properties of concrete are directly related to those of its constituents and as such aggregate used in a concrete mix should be hard, strong, dense, durable, and free from lumps of clays, loam, vegetable and other such foreign matter. The presence of all such debris prevents adhesion of cement on the surface of aggregates and hence reduces the strength of concrete.

FINE AGGREGATES (M-SAND) the material which passed through I.S. Sieve No. 480 (4.75mm) is termed as fine aggregates. Function of fine aggregates is to make concrete dense, by filling voids of coarse aggregates, reduces the shrinkage of cement and makes an economical mix. Natural sand or crushed stone dust is used as a fine aggregate in concrete mix. Sand may be obtained from sea, river, lake or pit, but when used in a concrete mix, it should be properly washed and tested to ascertain that total percentage of clay, silt, salts and other organic matter does not exceed specified Limit.

3.2. METHODOLOGY

- Mix design for self compacting concrete (SCC) are made using the properties constituents of concrete. Grade of concrete is taken as M30 and the mix design are done as per IS:10262-2009 and IS: 456-2000 for different dolomite powder percentage replacing of cement, using M-sand as fine aggregate. All mixtures are prepared for room temperature.
- Test specimens of prescribed mix designs are done and allowed them to cure in water for 7, 14 and 28days at room temperature.
- Finally, tests on Compressive Strength, Split Tensile Strength on 7^{th} ,14^{th},and 28^{th} day respectively.

IV.INITIAL INVESTIGATIONS

The basic properties of materials like specific gravity (cement, coarse aggregates, fine aggregates),fineness of cement, standard consistency of cement etc are shown in **Table:2.**

Table: 2 Basic Properties of Materials

Sl. No	Test Conducted	Results	IS code
1	Specific Gravity of Cement (OPC 53)	3.15	IS 12269:1987
2	Specific Gravity of Fine Aggregates	2.58	IS 2720:1980-Part 3

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3	Specific Gravity of Coarse Aggregates	2.69	IS 2386:1963-Part 4
4	Specific Gravity of Dolomite powder	2.84	IS 3812:2003
5	Standard Consistency of cement	29%	IS 4031:1991-Part 4
6	Fineness Modulus of Cement	91%	IS 4031:1996
7	Initial Setting time of Cement	33 mins	IS 4031:1988-Part 5
8	Bulk Density of Fine Aggregates	1628 kg/m^3	IS 2386:1963-Part 4
9	Bulk Density of Coarse Aggregates	1550 kg/m^3	IS 2386:1963-Part 4
10	Water Absorption of Fine Aggregates	1.9%	IS 2386:1963-Part 4
11	Water Absorption of Coarse Aggregates	0.5%	IS 2386:1963-Part 4
12	Fineness Modulus of Fine Aggregates	3.09	IS 2386:1963-Part 5
13	Impact Value	28%	IS 2386: 1963-Part 4

4.1 SIEVE ANALYSIS OF COARSE AGGREGATES

After the material has been sieved, remove each tray, weigh each size, and record each weight to the nearest 0.1 g. Be sure to remove any aggregate trapped within the sieve openings by gently working from either or both sides with a trowel or piece of flat metal until the aggregate is freed. Banging the sieve on the floor or hitting the sieve with a hammer will damage the sieve. The final total of the weights retained on each sieve should be within 0.3% of the original weight of the sample prior to grading. Particles larger than 3 in. (75 mm) should be hand sieved. When passing large stones through sieves, do not force the aggregate through the sieve openings. The sieve analysis of coarse aggregates are shown in **Table:3**

I.S Sieve Size	Particle Size (mm)	Weight of Coarse aggregates Retained (grams)	Percentage Weight Retained	Cumulative Percentage Weight Retained (a)	Percentage Fineness (100-a)
20mm	20.000	240.0	08.000	08.00	92.00
10mm	10.000	1960	65.330	73.33	26.67
4.75mm	04.750	770.0	25.660	98.99	1.010
2.36mm	02.360	8.700	00.290	99.28	0.720
600micron	00.600	5.100	00.170	99.45	0.550
75micron	00.075	7.700	00.250	97.70	0.300
pan		8.500	00.283	100.0	0.000

Table:3 Sieve Analysis of Coarse Aggregates

4.2 SIEVE ANALYSIS OF FINE AGGREGATES

- The test sample is dried to a constant weight at a temperature of 110 + 5^{o}C and weighed.
- The sample is sieved by using a set of IS Sieves
- On completion of sieving, the material on each sieve is weighed
- Cumulative weight passing through each sieve is calculated as a percentage of the total sample weight
- Fineness modulus is obtained by adding cumulative percentage of aggregates retained on each sieve and dividing the sum by 100.The sieve analysis of Fine aggregates are shown in **Table:4**.

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Table:4 Sieve Analysis of Fine Aggregates

I.S Sieve Size	Particle Size (mm)	Weight of soil Retained (kg)	Percentage Weight Retained	Cumulative Percentage Weight Retained (a)	Percentage Fineness (100-a)
4.75mm	4.75	0	0	0	100
2.36mm	2.36	.068	6.8	6.8	93.2
1.18mm	1.18	.224	22.4	29.2	70.8
600micron	.5	.130	13.0	42.2	57.8
300micron	.3	.204	20.4	62.6	37.4
150micron	.15	.154	15.4	78.0	22
75micron	.075	.126	12.6	90.6	9.4
Pan		.094	9.4	100	0
				Total Percentage Fineness	309.4

V. MIX DESIGN

Step-I **Data Selected**

Grade : M35

Type of cement : OPC 53
Maximum size of aggregate : 20mm
Maximum water cement ratio : 0.45
Workability : 75mm slump
Exposure condition : very severe
Method of concrete placing : normal
Degree of supervision : good
Chemical admixture type : super plasticizer
Specific gravity of cement : 3.15
Specific gravity of coarse aggregate : 2.69
Specific gravity of fine aggregate : 2.58
Specific gravity of admixture : 1.06
Specific gravity of water : 1.00

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Specific gravity of dolomite powder : 2.84
Initial water content in fine aggregate : 1.9%
Initial water content in coarse aggregate : 0.5%

Step-II. **Target mean strength**

F'ck=fck+1.65s Wheref'ck= target average compressive strength at 28days,
fck= characteristic compressive strength at 28 days, and
s= standard deviation.
From table 1, standard deviation, s= 5 N/mm^2.
Therefore, target mean strength=35+ (1.65*5) = 43.25 N/mm^2.

Step-III selection of water-cement ratio:

From table 5 of IS: 456, maximum water-cement ratio is 0.45.
Based on experience, adopt water-cement ratio as 0.42.
0.42<0.45, hence ok.

Step-IVselection of water content:

From table 2, maximum water content for 20mm aggregate
= 186 litres (for 25 to 50mm slump range)
Estimated water content for 75mm slump = 186+ (3/100*186)
=191litres
As super plasticizer is used, the water content can be reduced up to 20% and above
Let's assume, water content is reduced by 16%.
Therefore water content is reduced by = 191*0.16 =32litres
Water content = 191-32= 159litres.

Step-Vcalculation of cement content:

Water cement ratio = 0.42
Cement content = 159/.42= 379.57kgs/m^3 $_{approx.}$380kgs/m^3
From table 5 of IS: 456, minimum cement content for "very severe" exposure condition = 340kg/m^3.
380kg/m^3> 340kg/m^3, hence OK.

Step--VI. **calculation proportion of coarse aggregate and fine aggregate content:**

From table 3, volume of coarse aggregate corresponding to 20mm size aggregate and fine aggregate (zone 2) for water cement ratio of 0.5= 0.62.
In present case water cement ratio is 0.42. Therefore, volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the water cement ratio is lower by 0.08, the proportion of volume of coarse aggregate is increased 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 0.42 =0.632.
Volume of fine aggregate content = 1-0.632 = 0.37

Step-VIIMix Calculations:

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

- Volume of concrete= 1m^3.
- Volume of cement=(mass of cement/specific gravity of cement)*(1/1000) =(380/3.15)*(1/1000)= 0.12m^3
- Volume of water=(mass of water/specific gravity of water)*(1/10002)=(159/1)*(1/1000)= 0.159m^3
- Volume of chemical admixture(@1.5% by mass of cementatious material)= (mass of chemical admixture/specific gravity of admixture)*(1/1000)= (1.5*380/1.06)*(1/1000)= 0.00537m^3
- Volume of all in aggregates= [a-(b+c+d)]= [1-(0.12+0.159+0.00537)]= 0.717m^3
- Mass of coarse aggregate= e*volume of coarse aggregate*specific gravity of coarse aggregate*1000= 0.717*0.632*2.69*1000= 1218.95kgs
- Mass of fine aggregate= e*volume of fine aggregate*specific gravity of fine aggregate*1000= 0717*037*2.58*1000= 684.44kgs
- Mass of chemical admixture= (1.5/100)*380 = 5.7kgs

Step-IXsight corrections:

Initial moisture content in fine aggregate = 1.9%
Initial water content in coarse aggregate = 0.5%

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Mass of fine aggregate = 684.44-(684.44*1.9/100) = 671.43kgs
Mass of coarse aggregate = 1218.95-(1218.95*0.5/100) = 1212.85kgs
Total water content = 159+20 = 179 litres.

X. mix proportions: Cement = 380kg/m^3,Water = 179kg/m^3,Fine aggregates = 672kg/m^3,Coarse aggregate = 1213kg/m^3,Chemical admixture = 5.7kg/m^3,Water-cement ratio= 0.42 .**Table:5** shows the final mix proportions. The mix proportions are shown in **Table:5**

Table:5 Mix Proportions

Cement	Water	Coarse Aggregates	Fine Aggregates	Chemical Admixture
1	3.192	1.768	0.015	0.42

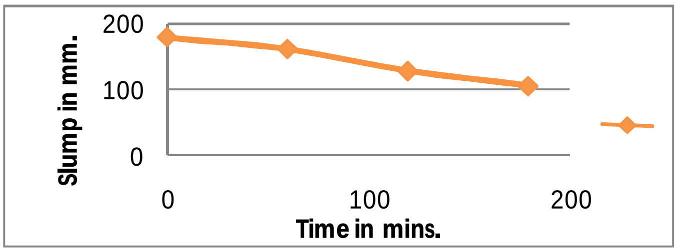
VI.WORKABILITY TEST ON CONCRETE

6.1 SLUMP CONE TEST

To obtain a representative sample, take samples from two or more regular intervals throughout the discharge of the mixer or truck. Do not take samples at the beginning or the end of the discharge.

Dampen inside of cone and place it on a smooth, moist, non-absorbent, level surface large enough to accommodate both the slumped concrete and the slump cone. Stand or, foot pieces throughout the test procedure to hold the cone firmly in place**. Fig:1** shows the slump flow v/s time. According to the results slump flow reduces with time.

Fig:1Slump Flow



VII. TEST RESULTS OF HARDEN CONCRETE TESTS

7.1. COMPRESSIVE STRENGTH

The cube compressive strength of concrete was determined by conducting test on 150mm x 150mm x 150mm cube specimens at 7,14 and 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. The compressive strength results are shown in **Fig:2**.According to the results compressive strength is maximum for 7.5% addition of dolomite powder and further addition will results in the reduction of compressive strength.

7.2. 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. The Tensile strength results are shown in **Fig:3**.According to the results tensile strength is maximum for 7.5% addition of dolomite powder and further addition will results in the reduction of tensile strength.

Fig:2 Compressive Strength Values

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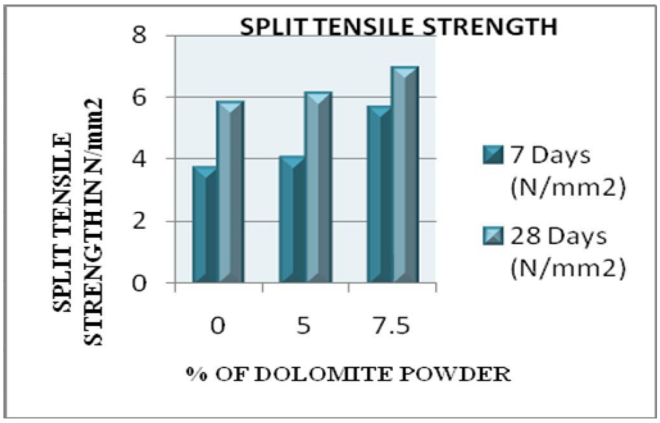
Fig:3Tensile strength values



VIII.CONCLUSION

The Compressive strength of Cubes are increased with addition of dolomite powder up to 15% replaced by weight of cement and further any addition of dolomite powder the compressive strength decreases. The Split Tensile strength of Cylinders are increased with addition of dolomite powder up to 15% replaced by weight of cement and further any addition of dolomite powder the Split Tensile strength decreases. We found out the optimum percentage for replacement of dolomite powder with cement and it is 7.5% cement for both cubes and cylinders**.** We have put forth a simple step to minimize the costs for construction with usage of dolomite powder which is freely or cheaply available.We have also stepped into a realm the environmental pollution by cement production; being our main objective as Civil Engineers.

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