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Investigation on strength, shrinkage and hydrogen ion concentration of magnesium binder blended cement concrete

G. Sugila Devi[1] and K. Sudalaimani[2]

[1]Department of Civil Engineering, Nadar Saraswathi College of Engineering and Technology, Theni 625531, Tamil Nadu, India
[2]Department of Civil Engineering, Thiagarajar College of Engineering, Madurai 625015, Tamil Nadu, India

Corresponding Author Email: sugiladevi.nscet@gmail.com

ABSTRACT

This research work is to investigate the strength, shrinkage and hydrogen ion concentration of concrete admixed with magnesium binder. The magnesium binder is manufactured through calcination process at a temperature of 1200 degree Celsius. The raw materials for the magnesium binder are magnesite (magnesium carbonate) and steatite (magnesium silicate). The calcined powder is also mixed with phosphate salt for better performance. The magnesium binder is replaced to cement in the proportion of 0% to 30% and the samples were tested in laboratory conditions from 1 day to 360 days for its strength. The shrinkage is tested until 130 days and the pH value is tested on 28 days hardened concrete samples. The results show that the magnesium binder replacement has refined effect on pore structures which attributed to the better performance in strength and shrinkage.

Keywords *: Magnesite; steatite; magnesium; shrinkage; strength; pH value; concrete*

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1. INTRODUCTION

Most Conventional methods of preparing thermally untreated / conventional Cement needs very high calcining or sintering temperature. Calcium carbonate usually used as source material for manufacturing cement emits high carbon into atmosphere. In this project, Steatite (magnesium silicate) and Magnesite (dead burned magnesium carbonate) are used to prepare magnesium-based pozzolanic powder which can effectively replace thermally untreated cement matrix and produce high performing concrete matrix. Disadvantage with regular Cement we use in our conventional construction methods is emission of CO_2 during its process and production which leads to higher Carbon Footprint whereas Magnesium based cement contains magnesium carbonate which has already undergone carbonation so emission of CO_2 gets reduced to low level [1,2]. Moreover, magnesium is highly combustible, so instead of heating at 1500° (Conventional Method) we need relatively less temperature as minimal as 700°-900° which in turn reduces our need for energy [3]. Over years, it has been a very steep rise in price of cement which has led to a hike in construction costs. India is having third largest reserves of Steatite and there is no import-export policy on same [4]. This is reason for which we get Steatite at a very cheap price, hence reducing overall cost of final product. Thus, main aim of project is to fabricate a substitute for conventional cement that is going to be relatively cheaper and environmental friendly, having similar properties and strength as that of Ordinary cement. Initially strength of Magnesium based cement is very less, but is approximately same as original cement that was produced in late 1800's which did not contain any kind of additives or pozzolana Material such as Aluminum oxide, ferric oxide, etc [6-8]. This has initiated scope for future work on Magnesium based cement as a complete replacement for Ordinary Portland Cement. The reaction looks to proceed through formation of MSH to talc, which had displacements of layers of microstructure formation and gave a reduced amorphous structure with increase of crystallinity. The early results also suggest that the Magnesium silicate hydrate gel also gave a X-ray powder patterns indicative of 2D crystals without any basal space, and had developed a specific area of 300 Sq m/g, and gave an exothermal effect at greater than 800°C . Innovative materials such as fly ash, silicon and fibers are used for making composites [9-12].

In this study first main material is magnesite, which is a mineral with chemical formula $MgCO_3$. Mixed with crystals of iron carbonate which possess a layered structure, monolayer's of carbonate groups alternate with magnesium monolayer's as well as or minerals such as presence and existence of iron carbonate monolayer's, traces of manganese, nickel and cobalt may also occur in tiny amounts [13,14]. The second material in this study is soap stone/Talc/Steatite is obtained as coarser form and then grinded in fine ball mills. Magnesite is obtained in powder form; both are mixed in desirable proportion and burnt and the clinkers are again grinded in ball mills to fine powder.

2. MATERIALS AND TESTING METHODOLOGY

For this study commercially available 53 grade OPC is used as binder. Natural river sand in accordance to IS code is used. Natural blue metal based coarse aggregate of average size of 20mm is used as coarse aggregate. The potable water is used for mixing the concrete. Naturally available metamorphic magnesium carbonate (Magnesite), and naturally available metamorphic magnesium silicate is obtained and grinded to powder in ultrafine grinding ball mills. The properties of magnesite and steatite is given in Table 1. The ratio of magnesite to steatite is maintained as 3:1. The mixed powder of magnesite and steatite is placed in crucible and kept in muffle furnace for a temperature of 1200^0 Celsius for a period of 3 hours. Then the powder is again grinded using ultra fine ball mill. This sample is named as magnesium binder (MB). The properties of calcined magnesite and steatite (MB) is given in Table 2. Then after testing the MB sample is finalized to be the pozzolanic replacement. Then the MB powder is used as replacement to cement in normal M40 grade of concrete. The percentage replacement changes from 0% to 30%.

Table 1 (a). Properties of minerals used in this study

Physical Properties		
	Magnesite	**Steatite**
Sg	3.19	2.68
LoI (%)	46	3.25
Chemical Properties		
SiO_2	9.01%	64.56%
Al_2O_3	0.28%	0.23%
MgO	42.45%	32.85%
Fe_2O_3	0.59%	0.47%
CaO	0.42%	0.30%

Table 1 (b). Properties of Sintered Powder (MB)

Surface area (Sq m/Kg)	600
Particle Mean Dia (μm)	10 < 15
Specific Gravity	3.2

3. RESULTS AND DISCUSSIONS

The results on compressive strength and pH Value, is shown in Table2 and Table 3. Figure 1 and Figure 2 shows compressive strength of concrete and drying shrinkage in concrete. The discussion and observation are also made on the specimens with and without magnesium binder.

3.1 Compressive Strength:

The test results on compressive strength of concrete with and without magnesium binder is shown in Table 2 and Figure 1. The results show that replacement of magnesium binder with cement increases the strength of concrete. On 7 days maximum strength is attained on CS specimen and there is a reduction in strength throughout the specimens, and the least strength is observed in CSMB 30. On 14 days the maximum strength is observed on CSMB 10, the specimens up to 15% of MB replacement shows strength gain with respect to control specimen. The least strength on 14 days is observed in CSMB 30 which has 38% less strength when compared to that of control specimen. On 28 days the CSMB15 has the maximum strength gain of 7% and CSMB 30 has the maximum strength loss of 28% when compared to that control specimen. Similar to 28 days results, 56 days, 90 days, 180 days and 360 days shows maximum strength gain at CSMB 15 with 15%, 26%, 30% and 28% strength gain respectively. It is also observed that until 360 days the CSMB 30 is the only specimen which has strength loss. On 56 days and 90 days strength gain is observed till CSMB 20 specimens and on 180 days CSMB 25 also shows strength gain with respect to control specimen. The strength gain in the MB blended cement matrix based concrete system is due to the fine dispersion and due to the pozzolanic action rendered through the reactive silica present in the MB blended system [15,16].

Table 2. Compressive Strength of Concrete

Mix IDs	Compressive Strength in MPa						
	7 days	**14 days**	**28 days**	**56 days**	**90 days**	**180 days**	**360 days**
CS	30.24	35.57	38.25	39.19	40.81	41.25	42.90
CSMB-5	29.33	35.76	39.74	42.12	44.14	45.78	46.80
CSMB-10	27.94	35.82	40.25	43.86	47.53	48.95	49.23
CSMB-15	26.82	35.75	41.10	44.98	51.49	53.45	54.90
CSMB-20	21.77	30.24	36.43	44.15	46.59	48.76	50.26
CSMB-25	18.02	26.11	32.64	35.86	39.52	42.65	44.98
CSMB-30	14.42	22.18	28.43	34.76	36.37	39.65	42.76

Drying Shrinkage of Concrete

The concrete shrinkage and its results from Day 1 to Day 130 is shown in Figure 2. The results show that replacement of MB influences and reduces the shrinkage. The results show that on all the days the control specimen has higher shrinkage when compared to that of all the other specimens. The least shrinkage is observed on CSMB-15 on all the days. The specimens with 20% to 30% show little elevated shrinkage due to the reaction of magnesium which may

Induce the faster setting process [17]. The shrinkage in control specimen, 5% MB replacement and 10% MB replacement normalizes after 42 days. All the other specimens normalize after 28 days. This result shows that addition of MB has stabilized the shrinkage process in the concrete and this is attributed to the refinement of pores due to the physical and chemical action [18].

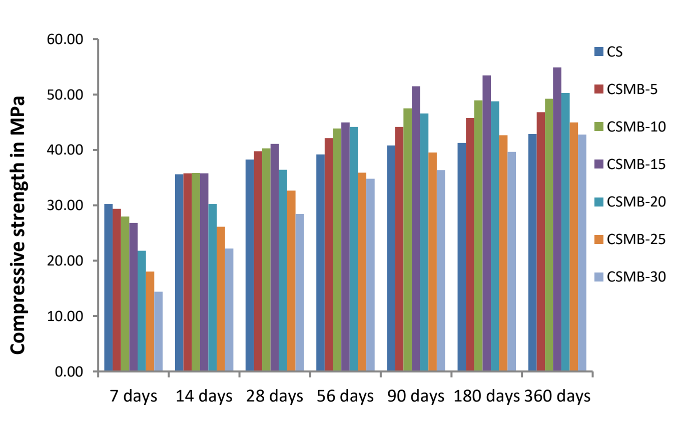

Figure 1 Compressive strength of concrete

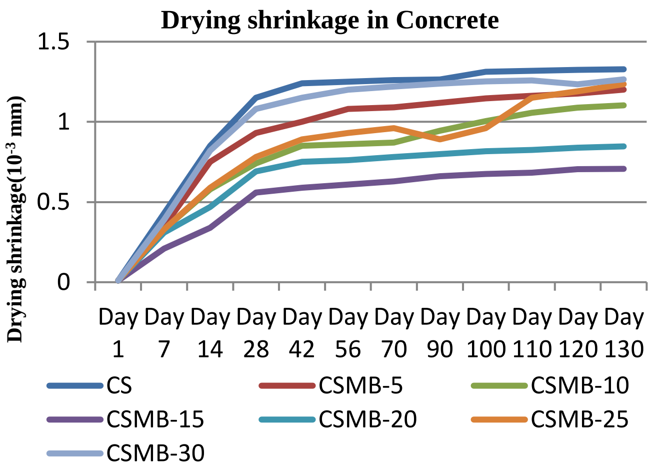

Figure 2. Drying shrinkage in concrete

Hydrogen Ion Concentration (pH Value)

The results of hydrogen ion concentration (pH Value) on 28days hardened concrete are shown in Table 3. The replacement of MB has increased the alkalinity of the concrete. The results show that the pH value starts from 11.52 and progresses toward 13.12. Even though the pH value is within the safe limit, the alkalinity increases due to the residual hydroxides which were evolved as a part of mixing process in concrete [19]. The values of pH show that the addition of MB can be useful in providing high alkaline concrete which can be used as a high durable concrete.

Table 3. pH Value of 28 days hardened concrete

Mix IDs	Average pH value
CS	11.52
CSMB-5	11.74
CSMB-10	12.32
CSMB-15	12.34
CSMB-20	12.56
CSMB-25	12.94
CSMB-30	13.12

CONCLUSION

From the research on the concrete with and without replacement of MB the following conclusions were made.

1. The compressive strength of MB blended cement-based concrete has slow attainment, the strength gain is minimum during initial ages and as the day progress, the strength attainment has been observed good on all the days. On 360 days almost 30% replacement of MB has similar strength like control specimen.
2. The results of compressive strength show that the 15% of MB replacement shows higher strength gain during and above 28 days.
3. The drying shrinkage is drastically controlled through the addition of MB. The 15% replacement of MB shows controlled shrinkage while 20% to 30% shows shrinkage lesser than control specimen but not as controlled as 15% replaced specimen.
4. Most of the shrinkage values get normalized on 42 days for samples until 10% replacement and after which the shrinkage normalizes on 28 days.
5. The pH values show that the replacement of MB to cement increases the alkalinity and shows concrete with alkalinity within the safe range.
6. Through the study it is concluded that the MB can be replaced up to 20% effectively to cement and the best value can be obtained from 15% replacement.

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