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Properties Evaluation of Carbon-Sink Concrete

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Abstract: Concrete is extensively used in the construction industry due to its high strength and endurance. However its also a major source of greenhouse gas emissions, both directly and indirectly. The objective of this research work is to limit it, by developing a cement mortar mix that can use material other then cement without affecting strength and life span of concrete structures. As the calcination process can not be replaced. Therefore to reduce the atmospheric CO_2 production, Sodium Zeolite is added to conrete mix in amount of 0%, 5%, 10% and 15% by weight of cement to mortar which would help reduce its CO2 signature. Moreover, cement mortar has heavy weight and has higher compressive strength. Therefor efforts are made to use such material to make mortar lighter and to have comparable binding strength. The compression tests were perforemed on four different composition samples with varying percentages of Sodium Zeolite to investigate its effectiveness.

Keywords— Cement Mortar, Sodium Zeolite, Compressive Strength.

I. INTRODUCTION

Concrete is used in abundance on earth after water, however, it use causes greenhouse effect due to emission of gases both directly and indirectly [1].The direct emission of CO2 occurs during process called calcination that occurs through chemical process in which CaCO3 is converted into CaO and CO2, however indirect emission is due to the burning of fuels to heat the kiln [1]. To reduce the atmospheric imbalance as well as global warming, we need to design blocks that can absorb CO2. Zeolite is a material, which absorb CO2 after adding it to cement due to its sieve like structure and catalytic behaviour (ref). This will help cement absorbing specific amount of CO2 and thus it can minimize the amount of CO2 in atmosphere [2]. Moreover Zeolite replaced in place of cement will help reduce CO2 emission during calcination . The second major problem is the higher thermal conductivity of concrete, which can be decreased by adding some insulating material like polystyrene beads. This arrangement decreases the concrete density, thus reduces the weight of structural members. Addition of polystyrene beads inturn increases sound proofing and insulation properties of these blocks as well as make them energy efficient as environment head load will have less impact on them [3]. Emissions of CO2 varies, and it depends on the production of cement, range may be from 0.73 to 0.99 per ton, where more than half of its total amount is released during its production. Many materials like supplementary cementitious material (SCM) or fly ash are substituted in concrete. Probably the most common material used is zeolite. This decreases the consumption of cement in concrete which in turn reduces the CO2 emissions in cement industries. Natural zeolite as volcano or volcanic sediment material having 3D frame has a structure divided into extremely small channels and pores, which can help in CO2 absorption in the later stages due to its sieve like structure. In this study, we will describe the feasibility of adding zeolite and polystyrene beads as partial replacement in concrete production, which will help us to generate ecofriendly material in building [4].

The CO_2 released during calcination process contributes to about 2.4% of global CO_2 emissions. [5, 6]. Martin Keppert et al [7] added zeolite up-to 20 % and considered it optimum level in concrete. Meysam at al [8] studies show that appropriate amount of zeolite as supplementary cementitious material is 15 % for improved durability and strength of concrete.
Zeolite is used as an aggregate in concrete in different quantities. Adding zeolite decreases the strength of concrete but it also reduces the weight of concrete to some extent [9]. In this research the effect of zeolite with varying amount in the concrete in place of cement to investigate mechanical properties like compressive strength of concrete. The results show that Compressive decreases depending on zeolite quantities.

Experimental Setup

Selection of mix proportion

To investigate the effectiveness of zeolite's cementing properties, various amounts of zeolite were used in place of cement in cement mortar cube of ratio of 1:2.75 as Cement : Fine Aggregates according to ASTM C109 [10]. In this study we replaced cement with zeolite by proportion of 0%, 5%, 10% nad 15% by weight as shown in table 1.

Table 1: Mix propotioning

S.No	Notation	Percentage of Zeolite	Reference ratio
1	A	0	1:2.75 (C:F.A) with W/C of 0.485
2	B	5	1:2.75 (C:F.A) with W/C of 0.485
3	C	10	1:2.75 (C:F.A) with W/C of 0.485
4	D	15	1:2.75 (C:F.A) with W/C of 0.485

Preparation of Zeolite concrete

The raw materials required for zeolite concrete are the same except the Sodium Zeolite. Sodium Zeolite can be obtained from the local market in powdered form as illustrated in the figure 1, which is available in both natural and artificial form. The required amount of zeolite is then mixed with fine aggregates thoroughy and added to the cement and mixed properly as required.

Specimen preparation

Inorder to evaluate the strength performance of zeolite in place of cement, specimen were prepared with dimensions of 2 inches cube according to the standards of ASTM C 109. For each composition illustrated in table 1, three 2 inch cubes were casted as given in figure 2. These specimen were cured for 28 days in curing tank and allowed to test under UTM with 200 ton capacity and ±0.05 ton

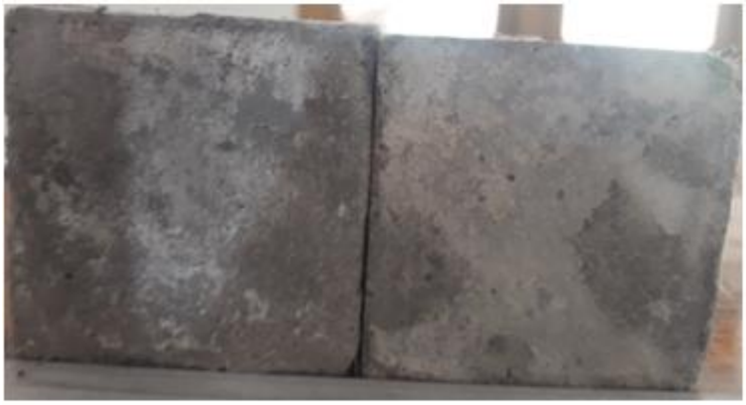

Figure 1: Test samples

Figure 2: Zeolite powder

Figure 3: Sand and Zeolite mixing through mechanical vibrator

Figure 4: Test Samples for compression analysis

Testing

To investigate the binding capacity of Zeolite used in concrete, samples were prepared according to the strict guidelines of ASTM C 170 [ ]. According to the specifications specimen dimensions of 50 mm by 50 mm by 50 mm were prepared in cubic (two inch each) molds at concrete lab for the prescribed test.

Four different types of samples were prepared to evaluate the strength gain/loss with different percentage of Zeolite content in the respective samples. The Zeolite was replaced inplace of cement in the concrete. Four samples A, B ,C and D were casted with A having 0% replacement of Zeolite and was the reference specimen. Type B having 5% Zeolite in place of cement, Type C having 10% Zeolite in place of cement and type D having 15% Zeolite in place of cement as given in table 1.

In addition to the samples preparation the samples that were casted in the cubic molds were then placed in the curing tank after 24 hours of casting for 28 days to properly cure and gain strength. After 28 days of curing the samples were taken out of the curing tank and were allowedfor omne day to get dry and the water could be removed from the samples to analyze the actual strength gain/loss. After dryingthe samples for one day, the specemen were then allowed to test for compression strength to investigate the strenth of the molds prepared with different percentages of Zeolite in place of cement under the universal testing machine (UTM) with ±0.5% accuracy. In order to have a uniform loading application during the test, plates were palced above and below the test specimen as illustrated in the figure 5.

Figure 5: Type B specimen during compression test

The load application were set to have an incriment of 0.2 ton per second. This slow andvancement of load will allow the investigator to properly notice the crake formation at an exact load points and analyze the crack propagation.

Results and discussions

Compression tests were performed on the specimen to investigate the binding dtrength effects of various percentage additions of Zeolite in place of cement to cement mortar after curing for 28 days according to ASTM C 109 guidelines. The samples were prepared by mixing a ratio of 1:2.75 as cement and fine aggregates. Keeping the sand ratio fixed and changed the cement with Sodium Zeolite at various percentages as inlisted in table 1 as type A, type B, type C and type D. The test samples were then subjected tocompression stress applied with UTM, results are given in the table 2 below.

It can be observed from the figure 6 below, which shows that specimen with 0% Zeolite addition called as reference mortar has high strength then all other specimen with some addition of Zeolite in place of cement into the mortar. The reference cement mortar had a strength of compression at 28 days curing to be 21.38 MPa and the lowest strength was observed in specimen type D as shown in figure 6.

Table 2: Strength vales of test samples in MPa

S.No	Strength-C100 (MPa)	Strength-C95 (MPa)	Strength-C90 (MPa)	Strength-C85 (MPa)
1	18.28	15.58	13.60	11.86
2	19.99	15.12	15.05	14.48
3	25.88	16.53	18.66	15.01

The compression strength of normal concrete ranges from 20 to 40 Mpa while the minimum strength range which is acceptable to be used in non-load bearing wall to be 4.14 MPa according to ASTM C 129 [11]. However, from research point of view, walls up to a height of five stories building, has been constructed of light-weight inter-locking blocks sections with designated cement mortar, having a cubic compressive strength of about 4.90 MPa [12]. In our findings, the maximum 28 days curing compressive strength achieved by mix ratio of type A is about 21.38 MPa, followed by a mixed ratio of type B, which is 15.74 MPa similarly the next two also have fulfill the minimum requirements ASTM. All samples of type A, B, C and D after 28 days compressive strength have fulfilled the minimum strength requirement for the non-load-bearing wall as per ASTM standards.

Table 3: Strength reduction of type B specimen

S.No	Type B Strength (MPa)	% Strength Reduction	Average Reduction (%)
1	15.58	14.76	
2	15.12	24.33	25.7
3	16.53	36.12	

It can be observed from the table 3, the replacement of ement with Sodium Zeolite has cause a reduction in the compressive strength of the cement mortar after 28 days curing of the test samples. For each of the test types three samples were tested under cpompression strength machine. At 5% replacement of cement with Sodium Zeolite the strength decreased by an average of 25.7% as shown in table 3.

Table 4: Strength reduction of type C specimen

S.No	Type B Strength (MPa)	% Strength Reduction	Average Reduction (%)
1	13.60	25.57	
2	15.05	24.71	26.06
3	18.66	27.90	

Similarly, with cement replacement of 10% and 15% with Sodium Zeolite, the strength was observed to be decreased by an average of 26.06% and 34.9% as illustrated in table 4-5. the strength decreased more after addition of Zeolite upto 15% as cement by weight. The reason behind this decrease in strength may be that the binding property of Sodium Zeolite is less then that of cement. This means that Zeolite has lower cementing properties then cement. Although, the strength of the mortar with and without Zeolite has high strength then the minimum strength required for the non-load bearing walls.

Table 5: Strength reduction of type D specimen

S.No	Type B Strength (MPa)	% Strength Reduction	Average Reduction(%)
1	11.86	35.14	
2	14.48	27.57	34.9
3	15.01	42.00	

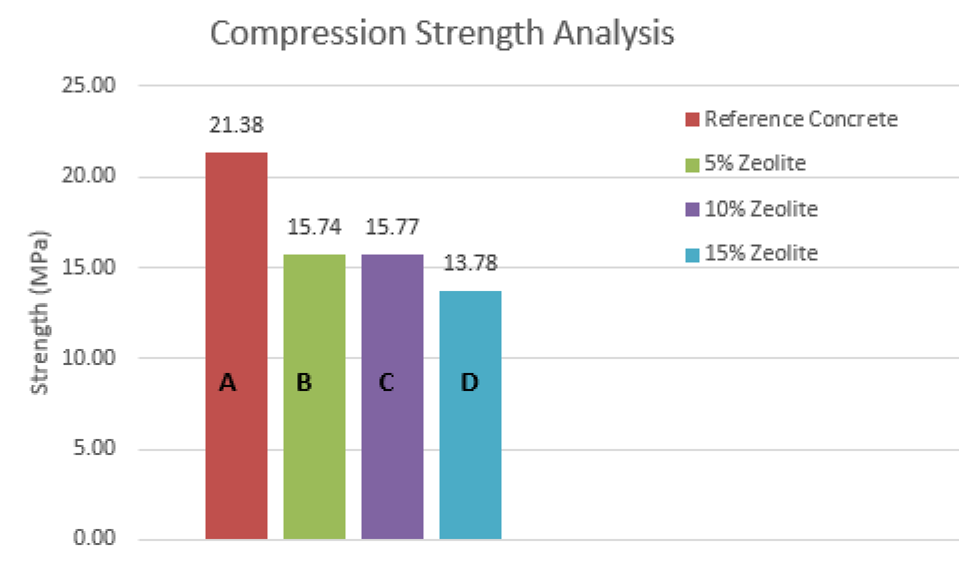

Figure 6: Compression average strength

CONCUSLION

The following conclusions are drawn out from this research:

- The binding material effect the compressive strength of the mortar as well as of the concrete. The higher the binder strength, the more will be the strength of the material (mortar and concrete).
- The percentage reduction in strength between 5%to 10% addition of Sodium Zeolite has almost same effect on the compressive strength of the mortar that is reduced by 26% as that of the reference cement mortar which reveals that the binding strength of Sodium Zeolite is less than that of the cement.
- Upon 15% addition of Sodium Zeolite in place of cement to mortar by weight, the compressive strength of the mortar was reduced by almost 35%. This reveals that increasing the percentage of Sodium Zeolite in place of cement in the mortar the strength will go on to be reduced.
- In all the cases the mortar strength wass above the minimum requirement of the ASTM standards for mortar in non-load bearing walls, hence the zeolite containing mortar can be used in walls have no load bearing function.

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