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Energy Efficient and CO2 Absorbing Concrete Material

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***Abstract*—** Concrete greater consumption in construction due to its high strength releases greenhouse gas emissions both directly and indirectly. In order to reduce the effects of global warming, this research work objective is to construct concrete that can absorb carbon dioxide without affecting strength and life span of concrete structures. Therefore to absorb CO_2, Zeolite is added to cement which would help CO_2 absorption from environment and hence decrease the overall CO_2 content. Moreover concrete has heavy weight and has higher thermal conductivity. Efforts are made in order to make concrete lighter and energy efficient. Introducing foam material in form of polystyrene beads can decrease its density as well as make it energy efficient as its insulation properties will be enhanced. The blocks will be tested for Tension, Compression, and Thermal Insulation as well for CO_2 absorption. Addition of zeolite for absorption of CO_2 and EPS beads for Insulation properties is an innovative approach and helps in a cleaner and healthier environment.

***Keywords*—** Concrete, Zeolite, Eps beads, Compressive Strength, Insulation.

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 CO_2 occurs during process called calcination that occurs through chemical process in which $CaCO_3$ is converted into CaO and CO_2, however indirect emission is due to the burning of fuels to heat the kiln [2]. To reduce the atmospheric imbalance as well as global warming, we need to design blocks that can absorb CO_2[3]. Zeolite is a material, which absorb CO_2 after adding it to cement due to its sieve like structure and catalytic behaviour. This will help cement absorbing specific amount of CO_2 and thus it can minimize the amount of CO_2 in atmosphere [4,5]. Moreover Zeolite replaced in place of cement will help reduce CO_2 in process of calcination.The second major problem is greater 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 will have less impact on them [6].Emissions of CO_2 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 [7,8]. Probably the most common material used is zeolite. This decreases the consumption of cement in concrete which in turn reduces the CO_2 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 CO_2 absorption in the later stages due to its sieve like structure [9]. 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 [10,11].

II. Experimental

A. Materials

Materials used in this study are Type 1 Portland cement, river sand, ¾ inch coarse aggregates and water. ASTM C33 was used to determine gradation of fine and coarse aggregates. Expanded polystyrene beads (EPS) of size 3 to 5mm were used with density of 18 kg/m^3. Zeolite with chemical formula of $NaAlSi_2O_6.H_2O$ was used and had a density of 1.04 g/mL at 25ºc. . Mix design ratio of 1:2:4 was used with targeted strength of 2500psi.

B. Test methods

Twenty four cylinders (radius=3inch, height=12inch), 12 rectangular specimen (25×100×100mm) and 6 rectangular specimens (50×100×100mm) were prepared of normal concrete and samples substituted with EPS beads and zeolite. EPS substitution was 15% in place of coarse aggregates and sand while zeolite was also substituted as 15% in place of cement and sand. The final specimens had both EPS beads and zeolite replacement for 30%. All specimens were compacted with a compacting rod and cured for 28 days in water. Cylinders were tested for compression and splitting tensile strength and rectangular samples were tested for thermal conductivity and CO_2 absorption test. Thermal conductivity was calculated by “Thermal conductivity of building material apparatus” by Guarded Heat Flow Meter Technique [12]. After calculation of heat flux and temperature difference across the specimens, Fourier’s law was used to determine their thermal conductivities. CO_2 absorption was confirmed by weight analysis of rectangular specimens using weigh machine. ASTM C39 was used for compressive strength, ASTM C496 was used for splitting tensile strength and ASTM C518 was used for thermal conductivity measurement [13].

III. RESULTS AND DISCUSSION

A. *Dry Density*

Dry density of concrete depends on the amount and density of added aggregates along with air content and water to cement ratio. Zeolite has its physical properties close to that of cement and sand therefore it doesn’t affect the density of concrete too much. EPS beads are very lighter than coarse aggregates and sand hence there is a greater decrease in density upon addition of EPS beads. The results are shown in fig.1 with concrete types on X-axis and their densities in Kg/m^3 on Y axis.

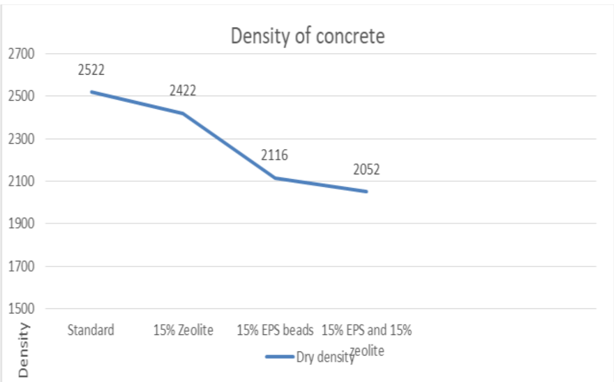

Figure 1 Dry Density of Concrete

B. *Compressive strength*

All the samples were tested in Universal Testing machine for compressive strength. The testing was done according to ASTM C39 standards. The following results were obtained in table I.

TABLE I. COMPRESSIVE STRENGTH RESULTS

Type of sample	Compressive Strength	Percentage change
Control	2751	0%
15% Eps Beads	2176	-20.1%
15% zeolite	2384	-13.1%
15% Eps Beads + 15% zeolite	2005	-27.01%

The results show that the strength of control samples is quite high and we achieved our targeted strength, but with the addition of 15% EPS beads the strength was reduced almost by 20.1%. Zeolite addition of 15% reduces strength by 13.1%. In our final samples containing both EPS beads and zeolite the strength is reduced by almost 27%. The strength achieved for our final samples is acceptable for concrete structures [14].

C. *Splitting Tensile Strength*

All the samples were tested in Universal Testing machine for split tensile strength. The testing was done according to ASTM C496 standards. The following results were obtained in table II.

TABLE II. SPLITTING TENSILE STRENGTH RESULTS

Type of sample	Split Tensile Strength	Percentage change
Control	1079	0%
15% Eps Beads	774	-28.1%
15% zeolite	861	-20.2%
15% Eps Beads + 15% zeolite	712	-34.01%

The results show that the strength of control samples is quite high and we achieved our targeted strength, but with the addition of 15% EPS beads the strength was reduced almost by 28.1%. Zeolite addition of 15% reduces strength by 20.2%. In our final samples containing both EPS beads and zeolite the strength is reduced by almost 34%. The strength achieved for our final samples is acceptable for building concrete structures.

D. *Thermal Conductivity*

Results of thermal conductivity are shown in table III. The aim was to check thermal conductivity value “k” of simple concrete and concrete having zeolite and EPS beads substitutions [15]. Results show that with addition of EPS beads the thermal conductivity decreases considerably. This can be attributed to the lower thermal conductivity and density of EPS beads as compared to coarse aggregates and natural sand. After the addition of 15% EPS beads, thermal conductivity decreases by almost 62.1%. Zeolite doesn’t affect the thermal conductivity too much due to the similarity of its properties with sand and cement. Addition of 15% zeolite decreases the thermal conductivity by 8%.Hence, thermal conductivity in final samples is reduced by a total of 70% which is considerably quite high.

TABLE III. THERMAL CONDUCTIVITY RESULTS

Type of sample	Thermal Conductivity	Percentage change
Control	1.38	0%
15% Eps Beads	0.52	-62.1%
15% zeolite	1.27	-8.03%

15% Eps Beads + 15% zeolite	0.42	-70.01%

E. Test on Zeolite Block (CO_2 absorption test)

The aim was to check CO2 absorption by zeolite concrete blocks. The apparatus required was weighing balance, moulds of size 10×10×5 cm. The table IV as shown below.

TABLE IV. WEIGHT ANALYSIS TO CONFIRM CO2 ABSORBTION

	Block B1	Block B2	Block B3	Average of block B1, B2 and B3.	Block B4(Normal concrete block)
Weight of Block on 10th day(gm)	1226	1232	1227	1228	1269
Weight of Block on 14th day(gm)	1233	1240	1231	1234	1264
Weight of Block on 21st day(gm)	1249	1248	1239	1245	1261
Weight of Block on 28th day(gm)	1260	1256	1248	1254	1261

Calculations: Increase in weight of Zeolite block while weight of Normal block remained almost same.

Amount of CO2 absorbed by block: Final Weight – Initial weight/Molecular weight of CO2

Taking the average value of zeolite blocks B1, B2 and B3: 1254-1228/44=0.59 mole CO2 absorbed. Hence a block with 15% substitution of zeolite can absorb about 0.59 mole of CO2 in 28 days.

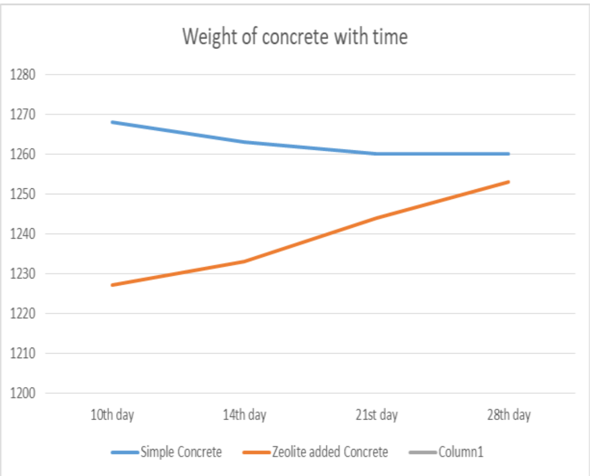

Figure 2 Weight of normal and Zeolite added concrete block with time

CONCUSLION

The following conclusions are drawn out from this research:

1. The dry density of concrete decreases with addition of EPS beads as replacement of Coarse aggregates and sand, which means it can be used as light weight concrete.

2. The compressive strength decreases with incorporation of both EPS beads and Zeolite, but the decrease with EPS beads is high due to very low density of EPS beads. Compressive strength decreases by 21% with incorporation of 15% EPS beads. Addition of 15% zeolite decreases compressive strength by 13%.

3. The splitting tensile strength also decreases with EPS beads and Zeolite addition. Splitting tensile strength decreases by 28% with incorporation of 15% EPS beads and 20% with addition of 15% zeolite.

4. Zeolite helps us in carbon capture in the later stages and substituting it in place of cement also helps to decrease CO2 release in the production stages during calcination hence decreasing the overall carbon signature. Zeolite can be substituted in place cement and sand.

5. The thermal conductivity of concrete decreases with addition of EPS beads, which means it can provide better insulation in building compared to normal concrete. After the addition of 15% EPS beads, thermal conductivity decrease by 62%. Eps beads can be substituted in place of coarse aggregates and sand. The decrease in thermal conductivity in case of zeolite is less as it has its physical properties close to that of sand.

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