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Experimental Studies on M35 Fly ash Concrete Modified with Zeolite For Thermal Storage Application

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Abstract— *The purpose of this research is to find suitability of zeolite and fly ash with M35 grade concrete for thermal storage application in service industries. Cement is recognized as a major construction material throughout the world and in terms of its per capita consumption, it is the second most consumed material in the country. Nowadays the cost of cement used in concrete works is keep on increasing becomes unaffordable and cause damages to the Environment. The cement industry is responsible for 5% of overall CO2 emission, because production of one tone of Portland cement emits approximately one tone of CO2 into the atmosphere. Hence Portland cement usage demands an immediate suitable substitute in the construction field. The usage of supplementary materials such as fly ash, zeolite, silica fume, slag cement has been increased in the construction industry due to pozzolanic activities. In this investigation, the properties of concrete modified with zeolite and fly ash in M35 grade is determined. In the first sample cement is replaced by 5% zeolite and 15% fly ash, in the second sample Cement is replaced with 10% zeolite and 30% fly ash. The tests were carried out for assessing the Mechanical strength and Non-destructive properties of concrete for two samples in curing period of 3 days, 7 days and 28 days. Thermo gravimetric analysis (TGA) test also conducted to knew the Thermal Storage Capacity with a curing period of 28 days. Experiment results confirmed that concrete of M35 modified with zeolite 5% and fly ash 15% is suitable for thermal storage application in service industries.*

Keywords— *Thermal Heat, Fly ash, Zeolite, M_{35}, Concrete, Environment*

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I. INTRODUCTION

Fast worldwide economic development leads to a quickly increasing energy demand. However conventional fossil energy sources are limited and their use is related to emission of harm full gases which are responsible for climate change and environmental pollution so every structure has its own intended purpose to meet this modification in traditional cement concrete has become essential. The utilisation of natural mineral as an alternative in concrete may be one of the solution. This situation has led to the extensive research on concrete resulting in mineral admixture to be partly used as cement replacement to increase workability in most structural application. If some of raw material having similar composition can be replaced by weight of cement in concrete then cost could be reduced without affecting its quality. For this reason we had chosen use of zeolite minerals as partial replacement of cement due to its high content of silica (SiO2). A few studies have been carried out on the zeolite powder obtained directly from the industries to study pozzolanic activity and their suitability as binders, partially replacing cement. The objectives of this research were to make utilisation of zeolite powder as replacement for cement is incorporated in concrete in order to achieve increase in strength and a better bonding between aggregate and cement paste. The mix design used for making the concrete specimens was based on IS 10262-2009.

The building sector is the largest energy-consuming sector, accounting for over one-third of the final energy consumption in the world [1]. In the European Union, it is responsible for 40% of the total energy consumption [2] of which heating, cooling and hot water are responsible for approximately 70% [1]. Currently, around 75% of the primary energy supply for heating and cooling is based on fossil fuels [3]. In the pathway towards an energy sustainable, efficient,

environmentally friendly and low-carbon building sector, thermal energy storage (TES) offers a great range of opportunities and benefits to reduce energy consumption and Green House Gas emissions [1,4,5].

TES solutions can be based on sensible, latent or thermo chemical energy storage [6] and may be implemented in buildings through passive and active methods [7,8]. Passive methods improve the energy efficiency of a building by using materials with low thermal conductivity. Active method enhance the energy efficiency of a building by using materials with high thermal energy storage capacity. Recently investigation about the active methods one of the potential field of thermal energy storage in building industry.

II. CLASSIFICATION OF THERMAL ENERGY STORAGE MATERIALS

TES solutions for building applications can be based on sensible, latent or thermo chemical energy storage materials.

Sensible heat storage is the most widely used technique for building applications. It is simply based on increasing or decreasing the temperature of a high heat capacity storage medium, thus storing and releasing heat [9]. The average TES capacity of most materials employed is approximately 100 MJ/m3 [6], with water being the most practical available material having a storage capacity of 250 MJ/m3 for a temperature gradient of 60◦C [10].

Latent heat storage consists of storing or releasing heat in the storage medium when it undergoes a phase change (from one physical state to another) [9,11]. Compared to sensible heat storage, phase change materials (PCM) can store a larger amount of heat in a much shorter temperature range around the phase change temperature. According to Tatsidjodoung et al. [6], the typical latent heat storage capacity of most materials usable for this end is in the range 300–500 MJ/m3.

Thermochemical heat storage relies on the use of a source of heat to induce a reversible chemical reaction and/or sorption process [12,13]. The potential benefits of these storage systems is their rather high energy density (approximately 1000 MJ/m3[6]), negligible heat loss, and long-term heat availability [14].

III. ZEOLITE

Zeolite is a natural or synthetic hydrated aluminosilicate mineral of alkali and alkaline earth metal with an open three-dimensional crystal structure Shown in fig.1. Zeolite concrete is much less frequent subject of investigation as compared with fly ash, silica fume or ground granulated blast furnace slag

The most significant effects of using zeolite as cement in concrete are reduction in expansion due to alkali-silica reaction, resistance to acid and sulfate attacks and pozzolanic consumption of calcium hydroxide component of Portland cement hydration in the paste.

The performance of natural zeolite in mortar/concrete has been compared with performance of other pozzolanic materials [15,16]. Poon et al. determined that the degree of reaction of natural zeolite in a paste with a higher percentage of replacement is lower than in a paste with a lower percentage of replacement [16]. Pancar [17] determined that using zeolite in concrete mixture reduces alkali-silika expansion. Chan and Ji noticed that pozzolanic reactivity of natural zeolite is between pulverized fuel ash and silica fume [18]. Kılınçarslan determined that using zeolite as Portland cement decreases the thermal conductivity of concrete [19]

A smooth utilization of thermal solar energy for climate control in buildings requires short- and/or long term thermal adsorption storage or energy transformation methods. Naturalzeolites are well known for different applications in agriculture, purification of water, drying of air and technical gasses. Some attempts have been made in the past to utilize those minerals for thermal adsorption storage [20]. Beginning in ancient times in Italy up to present, zeolitic tuffs played an important role as construction materials or cementing agent [21].

Because of the relative inexpensive and broad availability of natural zeolites (cf. for example in Greece or in Serbia and many other countries [21]) many researches proved its use in buildings for energetic reasons.

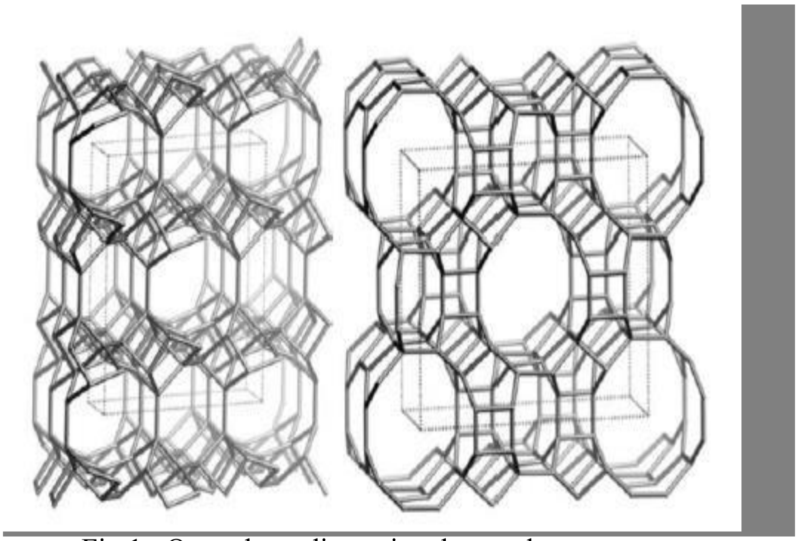

Fig 1 : Open three-dimensional crystal structure

IV. RESULT AND DISCUSSION

Compressive strength test

To determine the compression strength test, two cubes (150x150x150)(mm) were casted for each mix and the samples were tested after 3, 7 and 28 days of curing.

PLAIN : IS (100% CEMENT)
SAMPLE : 1 IS (80%CEMENT+15% FLY ASH+5% ZEOLITE)
SAMPLE : 2 IS (60%CEMENT+30% FLY ASH+10% ZEOLITE)

TABLE: 1 COMPRESSIVE STRENGTH TEST AT 3,7,28 DAYS

Sample	Load (KN)			Compression strength in N/mm^2			Average Strength in N/mm2		
	Day 3	Day 7	Day 28	Day 3	Day 7	Day 28	Day 3	Day 7	Day 28
Plain - 1	720	909.7	1012.5	31	40	45			
Plain - 2	642.2	806.7	967.5	28	36	43	29.5	38	44
Sample-1(1)	536	669.5	855	23	29	38			
Sample-1(2)	536.8	680.4	900	23	30	40	23	29.5	39
Sample-2(1)	314.1	514	742.5	14	23	33			
Sample-2(2)	349.3	455.8	675	15	20	30	14.5	21.5	31.5

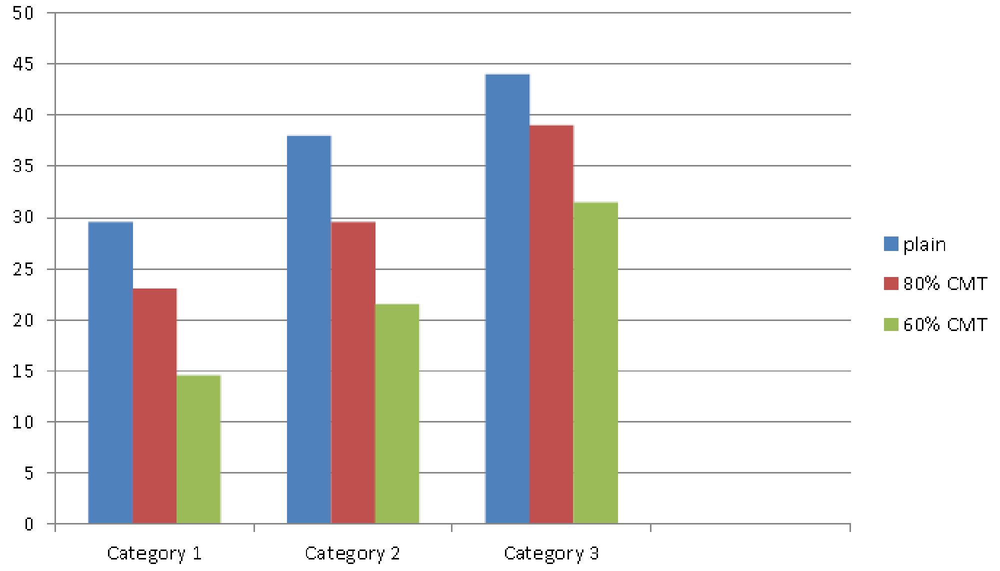

Fig 2 : Compressive Test Results

Split Tensile strength test

To determine the Split tensile strength test, (100mmx150mm) were casted for each mix and the samples were tested after 3, 7 and 28 days of curing.

The split tensile strength test results are the 3, 7 and 28 days are given below the tables

HERE PLAIN : IS (100% CEMENT)

SAMPLE : 1 IS (80%CEMENT+15% FLY ASH+5% ZEOLITE)

SAMPLE : 2 IS (60%CEMENT+30% FLY ASH+10% ZEOLITE)

TABLE: 2 SPLIT TENSILE STRENGTH TEST AT 3,7,28 DAYS

Sample	Load (KN)			Split Tensile strength in N/mm^2		
	Day 3	Day 7	Day 28	Day 3	Day 7	Day 28
Plain - 1	181.8	226.4	308.9	2.6	3.3	4.4
Sample-1	120.9	177.2	257.2	1.7	2.6	3.7
Sample-2	97.2	108.7	207.8	1.4	1.6	3.0

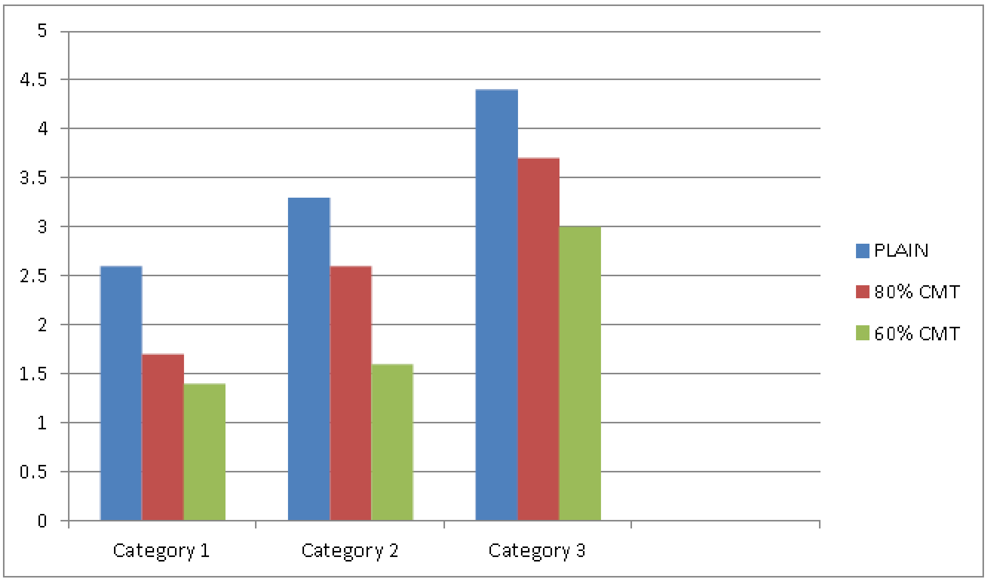

Fig 3 : Split Tensile Test Result

Flexural strength test

To determine the flexural strength test, (500x100x100)(mm) were casted for each mix and the samples were tested after 3, 7 and 28 days of curing.

The flexural test results are the 3, 7 and 28 days are given below the tables

HERE PLAIN : IS (100% CEMENT)

SAMPLE : 1 IS (80%CEMENT+15% FLY ASH+5% ZEOLITE)

SAMPLE : 2 IS (60%CEMENT+30% FLY ASH+10% ZEOLITE)

TABLE 3 : FLEXURAL STRENGTH TEST AT 3,7,28 DAYS

Sample	Load (KN)			Flexural strength in N/mm^2		
	Day 3	Day 7	Day 28	Day 3	Day 7	Day 28
Plain - 1	19140	26491	27397	3.34	4.95	5.03
Sample-1	16613	19908	24208	2.99	3.62	4.36
Sample-2	10566	11604	16051	1.89	2.11	2.95

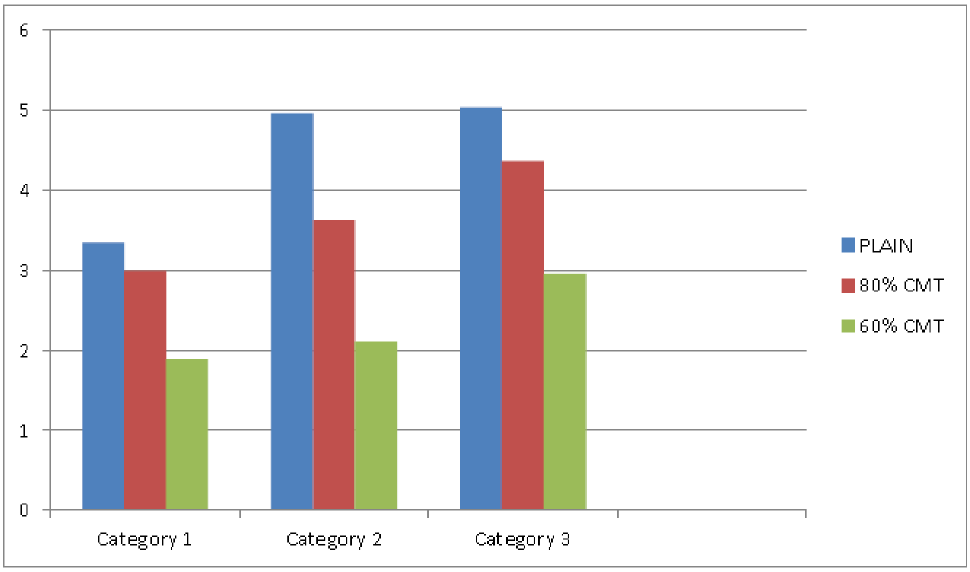

Fig 4: Flexural strength test

REBOUND HAMMER RESULTS

To determine the Rebound hammer strength test, two cubes (150x150x150) (mm) were casted for each mix and the samples were tested after 3, 7 and 28 days of curing.

The Rebound hammer strength test results are the 3, 7 and 28 days are given below the tables

HERE	PLAIN	:	IS (100% CEMENT)
	SAMPLE	:	1 IS (80%CEMENT+15% FLY ASH+5% ZEOLITE)
	SAMPLE	:	2 IS (60%CEMENT+30% FLY ASH+10% ZEOLITE)

TABLE 4 : REBOUND HAMMER STRENGTH TEST AT 3,7,28 DAYS

Sample	3 Days in N/mm^2	7 Days in N/mm^2	28 Days in N/mm^2
Plain – 1	31.5	34.5	40.5
Plain – 2	34.3	35.5	42.1
Sample - 1 (1)	33.1	30.5	37.3
Sample - 1 (2)	33.1	34	38.1
Sample - 2 (1)	22.6	27.3	32.6
Sample - 2 (2)	23.5	27.3	32.6

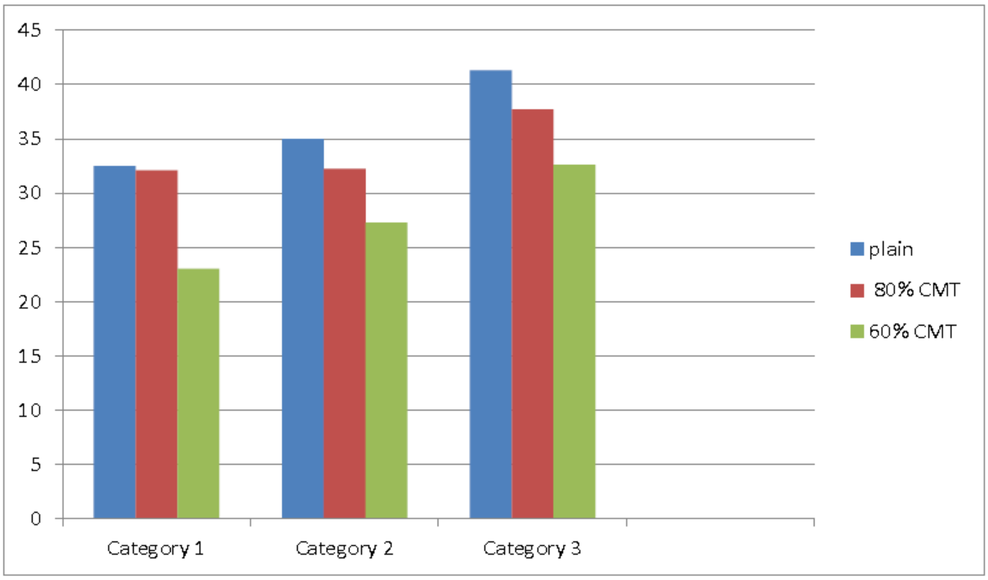

Fig 5 : Rebound Hammer Strength Test

DURABILITY STUDIES

THERMOGRAVIMETRIC ANALYSIS PROCEDURE

Three samples were analysed by thermogravimetric analysis .The samples were taken in a ceramic crucible and heated from room temperature to 950°C in thermoanalyser at a heating rate of 10 0C min-1 using air as a medium under static condition. Alumina powder was used as the reference material.TG were done simultaneously. The samples were dried at 105 0C in oven and cooled at room temperature before performing TG analysis.

Table 5 Thermogravimetric analysis test result

Sample	Temperature Range	Peak Temperature	Wt loss %	$Ca(OH)_2$	$CaCo_3$
0% Zeolite	290 – 800	950	74	36	68
5% Zeolite	290 – 800	950	62	24	72
10% Zeolite	290 – 800	950	46	15	77

V. CONCLUSION

The results obtained from the compressive strength, split tensile strength, flexural strength test after a curing period of 3, 7 and 28 days shows that concrete containing zeolite and fly ash exhibits lower strength than the normal concrete. But gaining M35 strength for 5% zeolite and 15% fly ash and 80% cement. Then 5% zeolite and 15% fly ash and 80% cement can be used for thermal storage application

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