ZEOLITE ADDITION ON CONCRETE SUSTAINABILITY-A REVIEW

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ABSTRACT

One of the main reason of global warming is the emission of greenhouse gases. Out of these, Portland cement industry is responsible for 7% of global CO_2 emission. So in order to reduce CO_2 from cement industry, introduction of pozzalanic material as a replacement of cement is the main solution. Recently many studies were carried out on pozzalanic material as a partial replacement of cement. Some of them are flyash, GGBS, silica fume, Metakaolin etc. Recent research studies have given more focus on zeolite as a partial replacement for cement. Zeolite can be available naturally or can be synthesized artificially. Zeolite is an aluminosilicate minerals having infinite, open and three dimensional porous structure. Its structure has high influence on the strength development on concrete and a small proportion of zeolite on concrete provide higher strength. The use of zeolite in concrete decreased the global warming index compared to conventional concrete, which indicates the effectiveness of the consumption of zeolite in concrete to make concrete more environmentally friendly. The main aim of this paper, therefore, is to review the structure & properties of zeolite and the impact of zeolite addition on concrete for its mechanical properties, thermal properties, microscopic characteristics and its effect on sustainability.

Keyword: - *Zeolite, Mechanical properties, Thermal properties, Microscopic characteristics, sustainability*

1. INTRODUCTION

Concrete is one of the inevitable material in the construction industry. Various technologies and advancements are occurring from hundreds of years ago in the construction firm. Advancement is occurring in the case of concrete is entirely far better than other construction materials. Innovations in concrete is a new way to reduce the main raw materials or replacing it by other materials. Mainly cement industry alone responsible for 7% of the global CO_2 emission. So nowadays main advancement is occurring on the field of cement.

Various improvements in the development of a replaceable material by cement had nowadays successfully employed in construction firm also. Flyash, GGBS, Rice husk ash, Metakaolin etc are fall under this category. Flyash is the one, which had placed their place over construction firm efficiently due to its high pozzalanic activity.

Zeolites are available naturally or can be synthesized artificially. Zeolites are crystalline aluminosilicate with open 3D framework structures built of $(Al,Si)O_4$ tetrahedra and are classified according to SiO_2:Al_2O_3 ratio. The advantageous properties of zeolites are regular structure, large inner specific surface area (approx. 600–800 m^2/g), uniform size pores, and good thermal stability. Aluminosilicate framework topology is the sole criterion that enables to identify the structure of zeolites. In theory there may be many framework structures, although only 32 have been identified yet. The specific structure of zeolites make them beneficial in many applications. They are used to adsorb different substances from gas mixtures and solutions; they are used as molecular sieves because they let through only molecules of certain size; cation exchange properties of zeolites enable to replace cations with weak bonds by other cations on the surfaces of internal cavities and channels[1].

2. ZEOLITE ON CONCRETE

Zeolite had successfully replaced for cement and the impact on various mechanical and durability studies were analyzed. The material used in this study is the natural zeolite formed where volcanic rocks and ash layers react with alkaline ground water.

2.1. Microscopic characteristics

The mineral composition of zeolite was determined by using X ray diffraction method and the results showed that clinoptile is the major crystalline phase [2]. Rietveld method was used to analyze the mineralogical properties of zeolite and the results shown below [3].

Table -1: Mineralogical properties of zeolite

Mineral	Amount (% by mass)
Clinoptilolite	44.5
Cristobalite	9.2
Quartz	3.5
Illite + Mica	5.6
Feldspar (albite)	2.6
Amorphous phase	34.5

Mercury intrusion porosimetry was used for determining the pore size distribution of natural zeolite. The tests were performed for pressure ranging from 0.1 to 200 Mpa or pore radii from 10.0 to $3.8x10^{-3}$ µm. The mercury intruded volume at a given pressure gave the pore volume and the result indicate that porosity is 54.7%. graphical analysis of the porosity results reveals that almost 65% of the total pore volume of natural zeolite attributed to pores with diameter from 0.4 to 40µm[2]. By analyzing mercury intrusion porosimetry, a pore radius of 10nm to 100µm present on zeolite. The increase of pore volume was mainly due to fine pores of diameter below 0.1µm. Although incorporation of pozzolanic admixtures themselves into the binder system often causes refinement of the pore structure, in this particular case the most probable reason was the preservation of microcrystalline structure of zeolite in the hardened mixes. MIP specific pore volume of pure clinoptilolite is about 0.08 cm^3 g^1 and dominantly pores smaller than 0.1 lm are present. Thus, a presence of unreacted zeolite in the mix should be accompanied by an increase of pore volume just in the range below 0.1µm. The measured pore size distribution presents then an important indicator of the effectiveness of zeolite as a part of the blended binder [3].

The scanning electron microscopy tests of zeolite gave the structure of zeolite. They are plate shaped and overlapping. The test results by using laser granulator showed a particle size of 11.82µm [1]. The morphology of clinoptilolite analyzed by SEM and it occurs in form of thin plates in the range of 10-30µm, sometimes of distinct hexagonal shapes [2]. The tests for concrete density reveals that the highest density 2404kg/m^3 was in the concrete with 10% zeolite additive and the lowest density 2380kg/m^3 was in the batch containing no zeolite amount. This revealed that density increased with zeolite content [1]. The bulk density of the analyzed concretes decreased with the increasing amount of natural zeolites. The open porosity increased in the corresponding way [6]. With the increasing amount of zeolite the bulk density decreased by up to 9% and a reverse trend could be seen for the open porosity [3].

2.2. Mechanical properties

The compressive strength test results on zeolite blended concrete showed that in specimens containing 10% of zeolite additive the compressive strength increases up to 13.3% and up to 15.0% after 28 days of curing [1]. The use of natural zeolite decreased the workability of the concrete mixture. The higher water demand of concrete mixture with zeolite is caused by the porous microstructure of the natural zeolite. Investigation on mechanical properties of concrete with zeolite additive showed a reduction of strength until 90 days of hardening, but after 180 days compressive strength of concrete containing zeolite exceeds the strength of concrete without zeolite [2]. Both compressive and bending strength after 28 days decreased with increasing zeolite content in the mix but the strength values of CZ 10 and CZ 20 with 10, resp. 20% natural zeolite in the blended binder could still be considered as acceptable. In addition, within the time period of 28–360 days the compressive strength of mixes containing zeolite increased faster than the reference mix, as a result of the pozzolanic activity of zeolite [3]. In the mixtures containing 20% zeolite, the compressive strength reduction was observed to be about 17% compared with reference concrete at age of 3 days. The decreasing trends are about 6%, 5% and 7% at ages of 7 days, 28 days and 90 days respectively [4]. The compressive strength of studied concretes decreased with the increasing amount of natural zeolites used as the replacement of Portland cement. The 7- days strengths were similar for the reference concrete and 10% zeolite blended concrete. For higher amounts of natural zeolites in the mix the compressive strength was significantly lower which was an expected outcome, taking into account the pozzolanic properties of zeolites. The values of compressive strength after 28 days showed that up to the 20% replacement level the concretes still maintained their high performance characteristics [6].Concrete mixtures with replacement level up to 10% with zeolite (Z10) produced blended concrete with a similar strength compared to reference concrete at 28 days with a use of Portland cement [7]. A linear relation has been found between zeolite rate and compressive strength [8]. The compressive strength values are reduced substantially, by approximately 2 to 44 % by about 8 to around 40 % from zeolite substitution 7.5% to 30%. The values for the static modulus of elasticity also decrease compared to the reference concrete [9]. Compressive strength of concrete blocks made by zeolite substitution with cement and sand with 20% Replacement (10% sand + 10% cement) resulted similar compressive strength that of reference concrete [10]. Zeolite in concrete affects the compressive strength of the concrete. In contrast with control mix, ZE10 increased the compressive strength. ZE20 did not modify the compressive strength significantly and ZE30 reduced compressive strength [11]

2.3. Thermal properties

Thermal conductivity in dry state decreased with increasing zeolite dosage which was a consequence of increase in porosity. Thus, the addition of zeolite improved the thermal insulating properties of concretes. The differences were substantial; thermal conductivity of the material with 60% replacement level was 20% lower than for reference concrete [3]. The thermal properties of hardened high-performance concrete containing natural zeolite were studied. Natural zeolite was used as a supplementary cementitious material, its amount varying from 0 to 60 mass % of the cement binder. The measurements were performed by the differential scanning calorimetry (DSC) and thermo-gravimetry (TG) in the temperature range from 25 to 1000^0C with a rate 5^0C min^{-1} in an argon atmosphere. Thermal properties showed changes in the mineral composition of the studied materials at high temperatures. The temperature and enthalpy of the liberation of physically bond water and C–S–H, ettringite dehydration, portlandite decomposition, the α to β transformation of quartz, and the calcite decomposition were distinguished and described [5]. The thermal conductivity decreases with the increasing zeolite rate in the concrete. A nonlinear relation has been found between thermal conductivity and unite weight. As the thermal conductivity is an important parameter in concrete production, due to low thermal conductivity, zeolite can be used to obtain isolation in the structure [8].

2.4. Sustainability

Concrete with Zeolite as a supplement material can absorb large quantity of CO_2. Incorporating zeolite powder into the concrete absorbs CO_2 from the atmosphere hence it will be eco-friendly. Absorb $CO_2$and reduces the air pollution, Keep environment clean and full of oxygen. CO_2 absorbed by concrete blocks equal to 0.63 mole of $CO_{2.}$ The zeolite concrete block of size 10x10x10 cm has ability to absorb around 1 mole of CO_2 in 50 days. The $CO_{2.}$ absorption property does not lose its strength and durability. Hence it can be used at any place without any doubt [10]. According to the life span values, using zeolite in concrete improves durability, causing it to require less demolitions and renovations in a 15-year period. Then, by considering the reduction coefficient and also the number of required demolitions and renovations in a 15-year period, the total GHG emissions of concrete during its service life were calculated. The results showed that the use of zeolite in concrete decreased the global warming index compared to conventional concrete, which indicates the effectiveness of the consumption of zeolite in concrete to make concrete more environmentally friendly. These reductions for 10%, 20%, and 30% replacement of zeolite in mixes amounted to 60.3%, 69.7%, and 64.3% global warming index reductions, respectively. In addition, the results confirmed that a 20 % replacement of cement by zeolite reduced the global warming index more than any other replacement level [11].

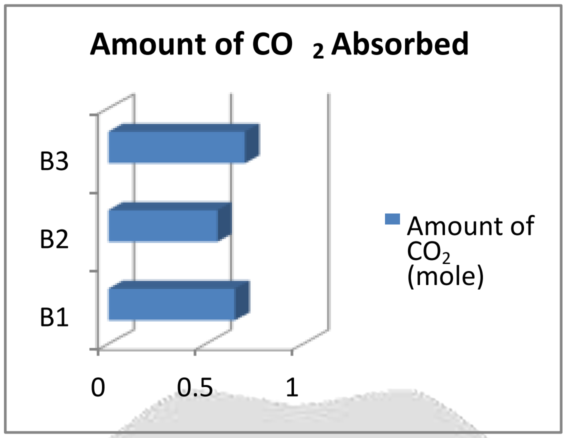

Fig – 1. Amount of CO_2 absorbed

3. CONCLUSIONS

Natural zeolite is an aluminosilicate mineral formed where volcanic rocks and ash layers react with alkaline ground water. Natural zeolite have porous structure with a porosity of 54.7%. A pore radius of 10nm to 100µm present on zeolite. The increase of pore volume was mainly due to fine pores present in zeolites. Zeolites can be used to manufacture concretes of high mechanical strength up to 10% zeolite content [1]. Mechanical properties of concrete with zeolite additive showed a reduction of strength until 90 days of hardening, but after 180 days compressive strength of concrete containing zeolite exceeds the strength of concrete without zeolite. Thermal conductivity in dry state decreased with increasing zeolite dosage which was a consequence of increase in porosity. A nonlinear relation has been found between thermal conductivity and unite weight. The zeolite as a supplement material in concrete can absorb a large quantity of CO_2. The zeolite concrete block of size 10x10x10 cm has ability to absorb around 1 mole of CO_2 in 50 days. The use of zeolite in concrete decreased the global warming index compared to conventional concrete, which indicates the effectiveness of the consumption of zeolite in concrete to make concrete more environmentally friendly. These reductions for 10%, 20%, and 30% replacement of zeolite in mixes amounted to 60.3%, 69.7%, and 64.3% global warming index reductions, respectively. Totally zeolite is an environment friendly material with good mechanical characteristics and thermal properties. The studies showed that it reduces global warming index to a certain level.

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