International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 05 | May 2020 www.irjet.net p-ISSN: 2395-0072

A Review on Application of zeolite as a partial replacement of cement in a rigid pavement

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Abstract - *Concrete is mostly used construction material in the world (about 10 billion tons of concrete used per year in world). This also increases the amount of CO2 produced during Cement production. This proposal will try to reduce the amount of CO2 from the environment by adding the zeolite in Concrete Production. This will not only reduces the amount of CO2 but also does not hamper the characteristics properties of Concrete.*

In this proposal, addition of Zeolite blended concrete is used in rigid pavement to test the various properties of rigid pavement for heavy traffic load.

Key Words: Zeolite, Rigid Pavement, CO2, Concrete, SCM etc.

1.INTRODUCTION

It has been found that plenty of quantity of carbon dioxide (CO2) gets emitted from various construction activities. This emission need to be reduced. With this as a main motive, need of designing a concrete (which is main constituent of construction) by taking Zeolite as a must. This partial replacement of zeolite for cement will therefore absorb the CO2. Zeolite is usually manufactured in factories. This kind of material has characteristics to absorb CO2 with incredible strength. Because of this nature, zeolite can be substituted in place of cement. This type of material is easily available in market. As the material comparatively little costly even the replacement is made only up to certain extent so that this will be affordable due to its additional benefits. Considering all these problems and properties of this material, a CO2 absorbing concrete need to be manufactured. Instead of disposing such materials, utilization in various types of concrete such as "CO2 absorbing concrete" can eventually reduce the environment pollution and also help to establish

2. Literature Review

1. MeysamNajimi et.al.(2012) "An experimental study on durability properties of concrete containing zeolite as a highly reactive natural pozzolan" Construction and Building Materials 35 (2012) 1023–1033, Elsevier

In this Study, the application of natural zeolite as a supplementary cementitious material has been carried out. To this aim, some mechanical and durability properties of concrete made with 15% and 30% of natural zeolite are studied in comparison with concrete without natural zeolite replacement. The performance of natural zeolite in cement and concrete composites has been also compared with that of other Pozzolanic materials and found that the Pozzolanic activity of natural zeolite is higher than fly ash and lower than silica fume. Also compared the effectiveness of zeolite in enhancing the performance of concrete in comparison with silica fume and pulverized fuel ash (PFA). They concluded that zeolite is more effective than PFA in improving the compressive strength and decreasing the initial surface absorption and chloride diffusion but it is less beneficial than silica fume.

The results revealed considerable effectiveness of natural zeolite application on water penetration, chloride ion penetration, corrosion rate and drying shrinkage of concrete; however, satisfactory performance was not observed in acid environment. Altogether, from the practical point of view, the incorporation of 15% natural zeolite was found as an appropriate option for improving strength and durability properties of concrete.

2. M. Sedlmajer et.al.(2015) "Possibilities of Utilization Zeolite in Concrete" World Academy of Science, Engineering and Technology International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering Vol:9, No:5, 2015

The paper presents the properties of concrete containing natural zeolite as an active admixture in the concrete which partly substitutes Portland cement. The properties conferred here bring data about the main mechanical properties and frost resistance of concrete containing zeolite. The properties of concretes with the admixture of zeolite are matched with a reference concrete with zero content of zeolite. The properties of the individual concretes are observed for 360 days. The effort to reduce the amount of Portland cement used in concrete production is brings both economical as well as ecological benefits. The concept of the composition of the individual concrete mixes was based on a gradual increase in the substitution of. Portland cement with natural zeolite. The observed properties of concretes with admixture of zeolite are compared with the reference concrete where only Portland cement is used. The concrete was designed as an aerated one with Portland cement (CEM I 42.5 R), three fractions of aggregate with maximum grain size 16 mm, aeration (SIKA LPS super-plasticizing admixture (SIKA Viscocrete 1035). The dosage of zeolite, which contained 45 % clinoptilolite and 35 % of amorphous phase, ranged from 7.5 % to 30 % of the mass of the cement.

The use of zeolite in concrete as a partial cement substitute appears to be appropriate. Zeolite as a silicate material is

entirely compatible with other concrete components. Due to use of zeolite, need for a greater content of water in the mixture which is required which is visible in the composition of the concretes. Composition of concrete with the original water content is kept, by a change or a greater amount of the plasticizing agent, very good properties can be attained even at higher content of zeolite while decreasing the need of Portland cement. Worse mechanical properties with a higher portion of zeolite are believed to be due to the greater content of water in the mixtures. Another possible option could be to adapt the granulometry of the zeolite being used, especially as far as very fine grades are concerned. This step could lead to the reduction of the amount of water necessary in the concrete production. When substituting cement with zeolite by up to 22%, after change in stress and a corresponding change in flexural relative strain.

3. Cenk Karakurt et. al. (2017) "Effect of blended cements produced with natural zeolite and industrial by-products on alkali-silica reaction and sulfate resistance of concrete "Construction and Building Materials 25, 1789–1795, Elsevier

In this study, influence of blended cements produced with different types of pozzolanas on alkali-silica reaction (ASR) and sulphate resistance of concrete was examined. For this reason, natural zeolite (clinoptilolite), fly ash (FA), and ground granulated blast furnace slag (GBFS) are used in various types of blended cement manufacturing. Zeolite, FA, and GBFS reduce the ASR gel formation in the microstructure of the composite. In this study, the influence of blended cements produced with different types of pozzolans on ASR and sulfate resistance of concrete was investigated. For this reason, natural zeolite (clinoptilolite) and two different types of industrial by-products (FA and GBFS) were used in blended cement production. The length changes and mechanical properties of the mortar specimens with different types of blended cements were determined and analyzed to obtain a durable cement composition against ASR and sulfate attack.

The early-age strength development of GBFS-blended cement shows better performance than Z- and FA-blended cements. However, 180-day long-term compressive strength of all the produced blended cements is found to be higher than the reference CEM I 42.5 cement by up to 30% replacement ratio. According to the expansion results, the ASR performances of blended cements are better than ordinary Portland cement. Zeolite, FA, and GBFS reduce the ASR gel formation in the microstructure of the composite. GBFS showed best performance against ASR tests. Sulfate resistance of concrete is related to ettringite, gypsum,and thaumasite formation in the composite. As observed from the test results, Z-, FA-, and GBFS-blended cements protect the composite material against sulfate attack. Ettringite formation in the blended cement specimens are reduced than the reference ordinary Portland cements. The strength and UPV loss of CEM I 42.5 reference specimen against sulfate attack at the end of the 26 weeks curing period were found as 132% and 164% respectively. However, no significant strength loss was determined for blended cements.

4. T. Subramani et. Al. (2016) "Experimental Study on Absorption of CO2 by M30 Concrete As a Partial Replacement of Cement By 25% of Zeolite" International Journal of Application or Innovation in Engineering & Management (IJAIEM) Volume 5, Issue 5, May 2016 ISSN 2319 – 4847

An experimental investigation was carried out to evaluate the mechanical and durability properties of concrete mixtures containing natural zeolite (NZ) in binary blended system up to 25% replacements. In order to serious climate change, deep reduction in CO2 emission will be required in coming decades.CO2 absorption is one of the key technology to control the global warming. Global warming is caused by sharply increased greenhouse gases emission by human activities. In building industry, CO2 emission mainly come from cement production. Capturing of CO2 from point source, from ambient air and reducing atmospheric CO2 concentration by using Zeolite powder and Zeolite sand. Concrete with Zeolite as a supplement material can absorb large quantity of CO2.Introducing Zeolite material into the concrete absorbs CO2 from the atmosphere hence it will be eco-friendly. Absorb CO2 and reduces the air pollution, Keep environment clean and full of oxygen. Zeolite, a type of natural Pozzolanic material, is abundantly deposited in China and is easy to quarry. It is widely used in producing blended cement and concrete structural elements. The direct partial replacement of cement by zeolite resulted in the decrease of compressive strength, especially the early strength and tensile splitting strength. Silica fume was incorporated to enhance the strength performance of zeolite. It was found that the ternary blended cement (zeolite plus silica fume and cement) concrete performed better than the binary blended cement (zeolite and cement) concrete. Study of effect of zeolite on the strength of concrete made in this study by Choosing M30 Grade of Concrete and Replacement of Cement With 25% of zeolite and Also Project Conducted Compressive Test, Split Tensile Test and Acid Attack Test.

Addition of zeolite up to 25% improves the strength properties of concrete. It becomes evident that cement based matrices zeolite with thus bringing new trends in composite materials. But to make this a reality, some conditions may have to be met. Channelization of waste CO2 for curing of concrete in precast plants for its stable sequestration is a way of reducing pollution.

5. R. Madandoust1 et.al.(2013) "Concrete made with zeolite and metakaolin: a comparison on the strength and durability properties" ASIAN JOURNAL OF CIVIL ENGINEERING (BHRC) VOL. 14, NO. 4 (2013) PAGES 533-543

An experimental investigation was carried out to evaluate the mechanical and durability properties of concrete mixtures containing natural zeolite (NZ) and metakaolin

(MK) in binary blended system up to 20% replacements. Concrete mixtures were evaluated for compressive strength, penetration of water under pressure and water absorption in 30 minutes and 24 hours at various ages up to 90 days. Water to binder ratio and total cementitious materials content were kept constant for all mixtures as 0.4 and 400 kg/m3 respectively. The results showed that despite the observed decrease of compressive strength of proposed composites, they gained enough strength at the later ages similar to that of normal concrete. Moreover, the results confirmed the beneficial effects of zeolite and metakaolin on the durability indexes of concrete which lead a green and environment friendly concrete. Natural Zeolite is a popular type of natural pozzolan which has been widely utilized in constructions since ancient times. Zeolite group of minerals currently include more than forty naturally occurring species, and is the largest group of silicate minerals. Clinoptilolite, heulandite, analcime, chabazite, and mordenite are the most common types of natural zeolite minerals on the earth. It is known that they show considerable Pozzolanic activity despite their distinct crystalline structure. Pozzolanic activity of natural zeolites has been principally attributed to dissolution of zeolitic crystals of three dimensional framework structures under the attack of hydroxyl ions available in hydrating cementitious system.
Zeolite contained concrete led to a decrease on compressive strength at all curing ages, however, its strength reduction is not impressive. Concrete mixtures with replacement level up to 20% with metakaolin or zeolite (M20 and Z20) produced blended concrete with a similar strength compared to reference concrete at 90 days while they use lower pollutant Portland cement. Utilizing 20% of MK increased the WA-30 while it was decreased up to 24% after 28 days and 90 days of curing respectively. The results of water penetration and water absorption confirmed the beneficial effects of zeolite and metakaolin on the durability indexes of concrete by replacement volume up to 20 %.

6. Farnoosh Jokar, Mohammad Khorram, Gholamreza Karimi, Nader Hataf (2019) Experimental investigation of mechanical properties of crumbed rubber concrete containing natural zeolite- Construction and Building Materials 20, 651-658 Elsevier
Crumbled Rubber Concrete improves mechanical properties of C.R.C by addition of natural Zeolite as partial replacement of cement. To improve cement-rubber bond, the surface treatment of rubber particle is carried out with 1M aqueous solution of NaOH. Crumbled rubber with size 1-6mm, 5, 10, 15% is replaced the C.A having maximum size 9mm. For reduction of the cement quantity and enhancing the concrete properties, replacement of 5, 10, 15% of cement with Zeolite. Following tests are examined such as-
1) Compressive strength
2) Brazilian tensile strength
3) Flexural strength
4) Specific weight
5) Modulus of elasticity of samples.
For M-30 concrete the design is carried out.
When we add all percentage of Crumbled rubber then mechanical properties reduced as compared to ordinary concrete. Only the concrete comprising 5% replaced crumbled rubber, flexural strength was enhanced as compared to other replaced percentages. The w/c ratio= 0.48 is constant all over. Addition of zeolite improves the compressive strength and flexural strength associated to samples containing 5% rubber, 15% zeolite and 5% rubber, 10% zeolite respectively.

7. Eva VEJMELKOVÁ et. Al (2013), Application of Natural Zeolite as Supplementary Cementitious Material in Concrete Production - Central Europe towards Sustainable Building

Basic physical characteristics, compressive strength, bending strength, thermal conductivity, volumetric heat capacity, and thermal diffusivity of several concrete mixes containing natural zeolite as partial replacement of Portland cement are studied and compared with reference concrete. Experimental results reveal a good potential of natural zeolite as environmental friendly material in concrete production but its dosage is to be considered carefully due to the worsening of mechanical properties for higher zeolite amounts.

8. Kianoosh Samimi et. Al (2017), Influence of pumice and zeolite on compressive strength, transport properties and resistance to chloride penetration of high strength self-compacting concretes - Construction and Building Materials 151, 292–311 Elsevier

This study focus on the effect of two different natural pozzolan (pumice and zeolite) on compressive strength, transport properties and resistance to chloride penetration both in immersion and tidal conditions when used in high strength self-compacting concrete (HSSCC). Taking into account all the results, the partial substitution of OPC by 15% of pumice or 10% of zeolite is affordable for all aspects including economic and environmental issues.

9. Giedrius Girskas, Gintautas Skripkiunas (2017), The effect of synthetic zeolite on hardened cement paste microstructure and freeze-thaw durability of concrete - Construction and Building Materials 142, 117–127 Elsevier.

The test results shows that replacement of cement with 10% of synthetic zeolite reduces water absorption of hardened cement paste 23.8%; the addition of air entraining admixture does not vary the rate of water absorption.

With the addition of zeolite in concrete with and without air entraining admixture escalate the volume of closed pores from 1.6% to 2.1% and from 4.1% to 7.6% respectively.

10. Qing Wang, Jun Zhang, J.C.M. Ho (2020), Zeolite to improve strength shrinkage performance of high-strength engineered cementitious composite Construction and Building Materials 234, 1-9 Elsevier

Engineered cementitious composite (ECC) is high performance material gives high strength at the same time it gives multiple crack formation under tension. ECC is act as a binding mortar or repairing material for concrete cracks in existing structure. But one drawback of ECC is high shrinkage due to extra tensile stress that affects its durability. To decrease the shrinkage without sacrificing the strength we use zeolite. Following are different test conducted, replacement of zeolite by 15%, 20%, 30%.
1. Shrinkage.
2. Internal relative humidity.
3. Compressive strength.
The test result indicates that the 28 days autogenous shrinkage of ECC decrease reduction was 55% for 30% natural zeolite replacement. From shrinkage to strength ratio it with the zeolite replacement ratio. Using zeolite the maximum 28 days autogenous shrinkage shows that ECC with 30% zeolite yields the lower shrinkage per compressive strength .Zeolite replacement ratio>30% is used for future shrinkage reduction study.

3. Objectives:

Following are the objectives of study.
1. Characterization of materials present in concrete.
2. To prepare mix design for M25 grade concrete.
3. To study the Workability properties of fresh concrete with zeolite.
4. To study the mechanical properties of hardened concrete with zeolite.
5. To compare economically the rigid pavement with and without zeolite.
6. To provide green environment through rigid pavement with zeolite.

4. CONCLUSIONS

Zeolite is natural available Mineral that can be used in Concrete as a Supplementary Cementitious Material without any adverse impact on the physical, Chemical or Mineralogical property of concrete or any of its constituents. Various previous literatures suggest that Zeolite can be replaced by some fixed amount of Cement. This replacement proved to be Economical and doesn't have negative impact on concrete. The replacement of zeolite should be done within permissible limits only. Most literatures suggested that 10% of Cement can be replaced by Zeolite as an optimum mixture.

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