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An Experimental Study on Mechanical Properties and Durability of Concrete with Recycled Aggregate Concrete and Zeolite

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1. Introduction

Concrete as a building materials is now being widely used worldwide. However, concrete industry is notorious for its adverse effects on the environment. Construction waste from demolition of dilapidated buildings produces major part of waste materials in the world. For example, more than 300 million tons of construction waste is generated annually only in the United States. Concrete is one of the building materials that can be recycled by paying small fortunes. This material might be able to have the best quality and closest properties to raw materials by the least interference. In this regard, extensive measures have been taken in European countries. Various studies have shown that aggregates from concrete crushing have more water absorption, less bulk modulus, lower specific gravity, more corrosion, more shrinkage and creep, less compressive, tensile and flexural strength, lower modulus of elasticity and similar frost resistance in comparison with natural aggregates.

In China more than 200 million tons of cement are produced annually and up to 20% of this amount can be replaced by natural zeolite. Currently, the highest consumption of zeolite in China is in the cement industry. Moreover, according to the Ruski Research Institute, the largest future market for zeolite will be its use as pozzolans instead of part or all of Portland cement used in concrete which is reported to have desirable properties in improving the mechanical properties of concrete.

The aim of this study was to investigate the effect of simultaneous use of zeolite and recycled aggregates as a percentage replacement of required aggregates on the mechanical properties and durability of concrete.

Mechanical properties have been studied by conducting compressive strength and tensile strength tests. Moreover, to evaluate durability aspects, rapid chloride penetration tests were conducted.

According to previous studies, the optimum replacing percentage of cement weight by zeolite in concrete is 10% and for concretes which are made by recycled aggregate up to 30% of cement weight can be replaced by natural zeolite to acquire the minimum reduction in strength and durability compared to ordinary concrete. In this study, the simultaneous effect of replacing a proportion of cement weight with zeolite and replacing a part of natural aggregates by recycled aggregates with for preparing of eco-friendly concrete with desirable mechanical and durability properties were been investigated.

2. Experimental program

For this laboratory research study, fourteen mixing schemes with different replacing percentages of recycled aggregate and zeolite were used. The crushed coarse aggregate which was used in this experiment had a maximum dimension of 19 mm and a density of 2700 kg/m^3. Moreover, the density of fine aggregate was fine aggregate with 2467 kg/m^3. The recycled fine and coarse aggregates were obtained from waste concrete and were broken manually. The superplasticizer (superplasticizer) used in this study was poly-carboxylate-based, used to reach intended workability. The water used in these experiments was tap water. The cement used in this research is ordinary Portland cement type 2 according to ASTM C150-11 standard.

2.1. Compressive strength. Compressive strength test was done according to ASTM C39-11 after 7, 28, and 56 days of moist curing. In the specimens with recycled aggregate the major trend was reduction in compressive strength by increasing the percentage of recycled aggregate. Existence of cement mortar on recycled aggregate and deteriorated mechanical features in recycled aggregate were the main reasons of reduction in compressive strength.

In NZ-incorporated mixtures, the major trend was a significant increase in compressive strength after longer periods of moist curing. Interestingly, pozzolanic reaction of NZ could compensate the strength loss which was caused by replacing natural aggregate with recycled aggregate.

2.2. Tensile strength. In this research, tensile strength test was carried out according to ASTM C496-11 after 7, 28, 56 days of moist curing, The results show that when up to 40% of coarse aggregate was replaced by recycled aggregate, when up to 15% of fine aggregate was replaced by recycled aggregate, and when up to 6% of coarse and fine aggregate was replaced by recycled aggregate, incorporating NZ in mixture design resulted in higher compressive strength than the reference mixture after 28 days of moist curing.

2.3. Electrical resistivity. Electrical resistivity test was conducted on cylindrical specimens having 10 cm diameter and 20 cm height after 7, 28, and 56 days of moist curing according to AASHTO T358-15. The outcomes show that electrical resistivity reduces when the percentage of recycled aggregate in the mixture increases. To be more accurate, replacing up to 25% of coarse aggregate by recycle aggregate and replacing up to 30% of fine aggregate by recycled aggregate caused 22% reduction in compressive strength. However, replacing 10% of cement weight with NZ increased these figures by 64% and 106% after 28 days of moist curing.

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2.4. Rapid chloride migration test. Rapid chloride migration tests was carried out according to AASHTO TP 64-03 and NT-Build 492 after 56 days of moist curing. As the percentage of recycled aggregate increases, rapid chloride migration index increases as well. However, the specimens containing coarse recycled aggregate showed better results in comparison to the specimens containing only fine recycled aggregate and the mixtures containing a mixture of coarse and fine aggregate. Increase in electrical resistivity is accompanied by reduction in rapid chloride migration index and this point shows that the results of these sections are compatible.

3. Conclusion

The study investigated the effect of natural zeolite and recycled aggregate on mechanical and durability properties of concrete. To evaluate mechanical properties, compressive and tensile strength were done and to evaluate durability aspects, rapid chloride migration test and electrical resistivity test were carried out.

- Incorporation of NZ in mixture design of the specimens without recycled aggregate caused 30% increase in compressive and tensile strength in addition to 80% increase in electrical resistivity after 28 days of moist curing. Additionally, NZ could reduce rapid chloride migration index by 80%.
- Using recycled aggregate caused a decline in compressive strength. To be more accurate, replacing fine aggregate by recycled aggregate, replacing coarse aggregate by recycled aggregate, and replacing a mixture of fine and coarse aggregate by recycled aggregate caused 38%, 15%, and 18% reduction in compressive strength in comparison to the reference mixture, respectively.
- Replacing 15% and 30% of fine and coarse aggregate separately caused 15% increase tensile strength after 28 days of moist curing. Simultaneous use of fine and coarse aggregate reduced tensile strength by 6%.
- Replacing 15% of total aggregate weight with recycled aggregate and replacing 10% of cement weight with NZ is recommended as the optimum replacing percentage to reach sustainable construction in construction industry.