A REVIEW of WASTE MATERIALS on SELF-HEALING EFFICIENCY of ENGINEERING CEMENTATIONS COMPOSITES (ECC)

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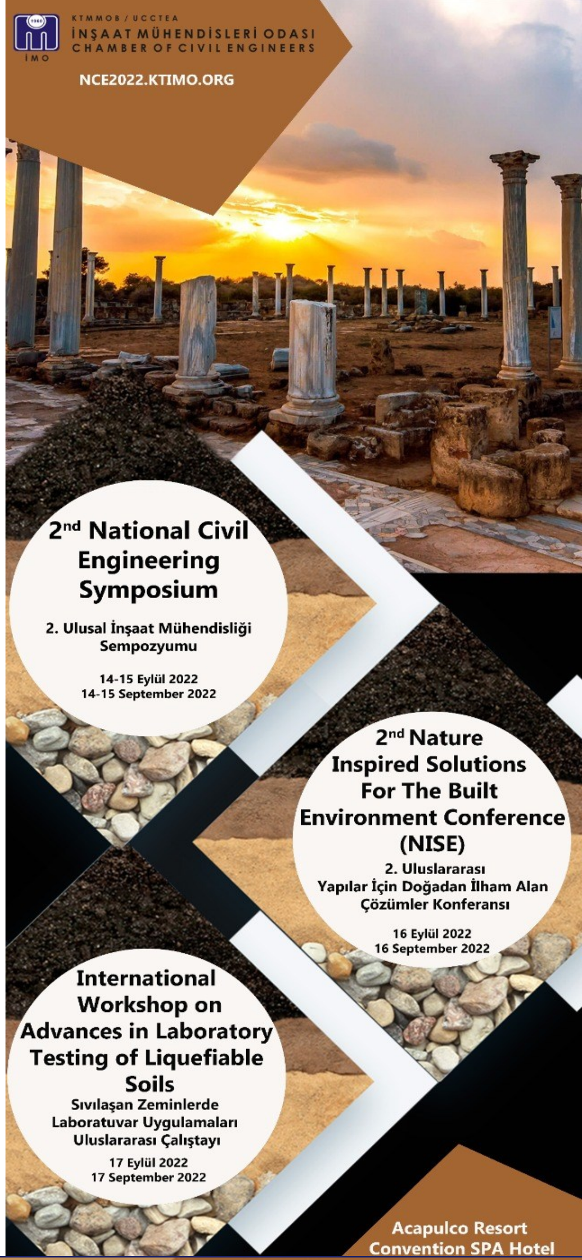
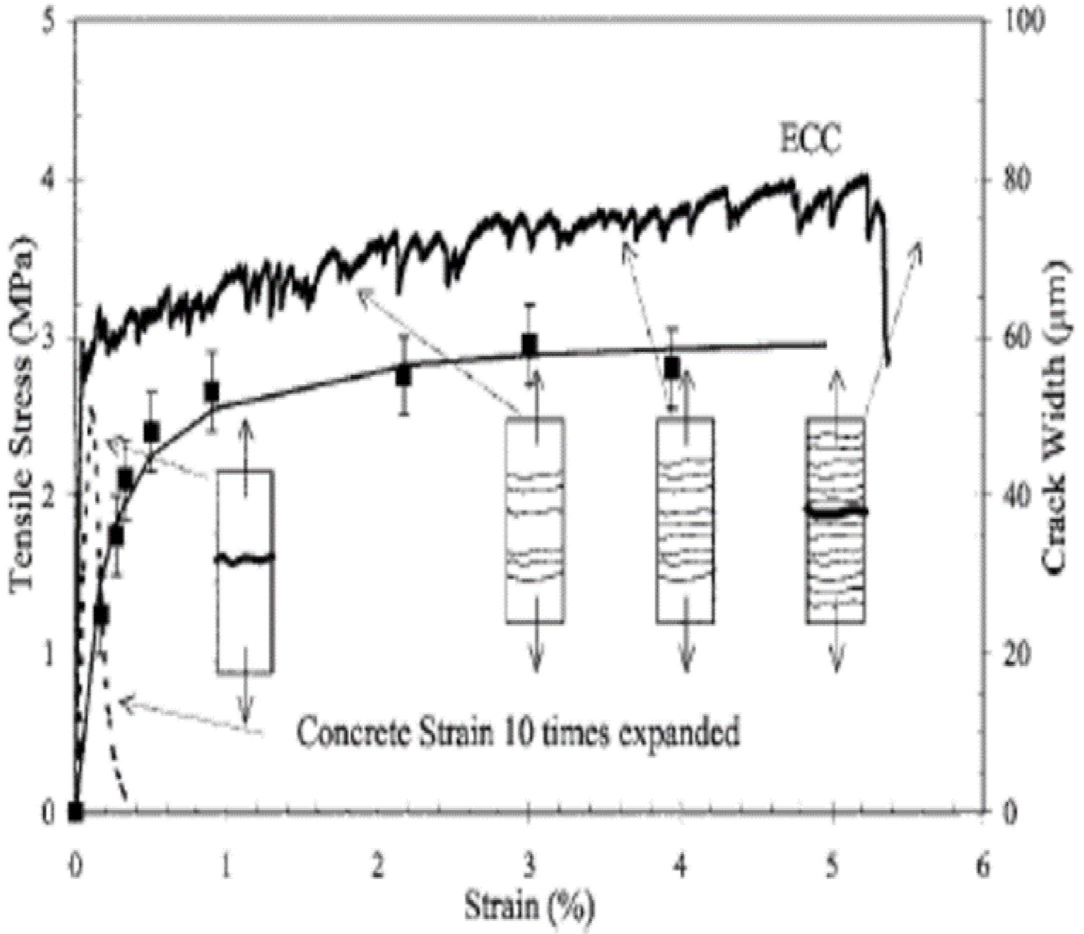


Introduction

Concern over sustainability in the construction industry is growing. Engineered Cementitious Composites (ECC) have the potential to reduce the carbon and energy impression of the built environment due to their crack resistance and self-healing properties.

Cracking is one of the major defects or damages in any stage of concrete structure. Cracks can be caused by loading, volumetric change due temperatures, creep, plastic settlement, shrinkage or deterioration mechanism such as alkali-silicate reaction and freezing/thawing cycles.



Typical tensile stress-strain curve and crack widths (ECC)

Cracking pattern of ECC under direct tensile loads

The crack width development during inelastic straining is also shown in figures multiple micro-cracks forming due to strain-hardening response. Even at ultimate load, the crack width remains on the order of 50 to 80 μm.

Typical water to cement ratio and fine aggregate to cement ratio are generally 0.5 or lower. The replacement of Portland cement by waste material can lower the cost and enhance the greenness of concrete, since the production of these two materials needs less energy and causes less CO_2 emission than Portland cement.

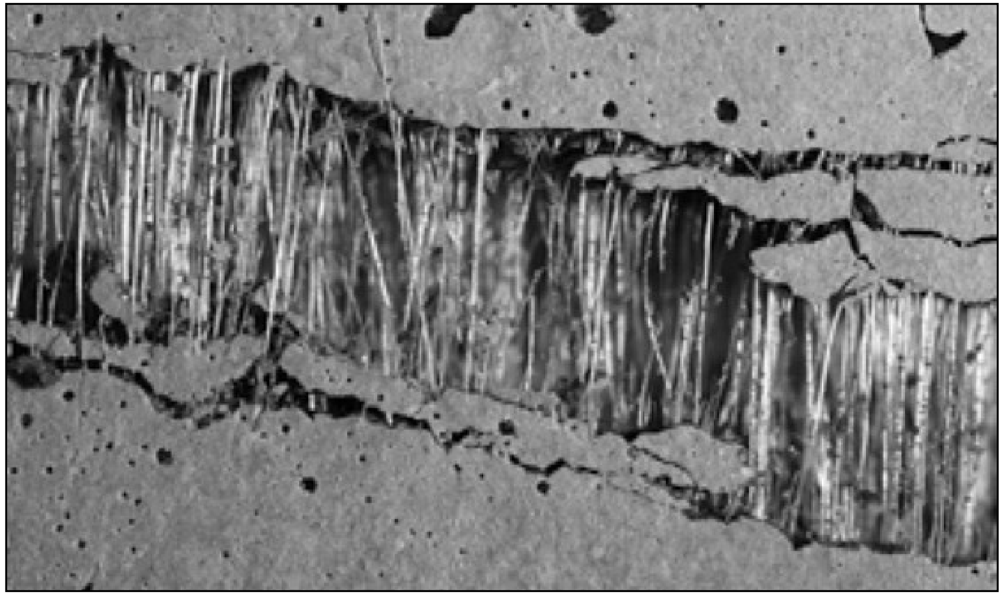
This study reviews some recent research work focusing on self-healing efficiency of ECC produced by high volume mineral admixtures such as Ground Granulated Blast Furnace Slag (GBFS) and Waste Marble Dust (MD).

GBFS is often used as a Supplementary Cementitious Material (SCM) in concrete. GBFS can be activated in the alkaline environment in concrete, contributing to the compressive strength in a long-term. The inclusion of GBFS changes the autogenous healing efficiency of concrete.

The effect of Waste MD as cement placement, as sand replacement, and filler was investigated, most of the researches showed positive results and benefits. Waste MD can be used as an additive material in production of cement and cost of cement production can be reduced by application.

Basis of ECC Mix Design

The mix design for ECC concrete is based on micro mechanics design basis. It captures the mechanical interactions among the fibers. Different ingredients of ECC work together to share applied load.



Mineral admixtures are also known as supplementary cementitious materials (SCM). These are the finely divided pozzolanic materials which are added in concrete to improve the quality of the concrete. Ground granulated blast furnace slag (GBFS), fly ash, metakaolin, silica fume (SF) and rice husk ash etc. are used as mineral admixture in the concrete.

These are industrial by product whose direct disposal to the environment cause hazardous impact. These are easily available and make the concrete cheaper and eco-friendly. These are added in the large quantities than any other type of admixtures. These admixtures improve the workability as well as finish-ability of fresh concrete, strength and durability properties of the hardened concrete.

Mix Design of ECC

ECC mix design proportions table gives a typical mix design of ECC with self-consolidating casting properties. All proportions are given with materials in the dry state.

Cement	Fly Ash	Sand	Water	HRWR*	Fiber(Vol%)
1	1.2	0.8	0.56	0.012	0.02

* HRWR: High Range Water Reducer

ECC mix design proportions by weight

Literature Review

Kan et al. studied the self-healing behavior of ECC materials, and found that the C-S-H gel (from continuous cement hydration and pozzolanic reaction) and $CaCO_3$ (from precipitation of $CaCO_3$) was the main self-healing product within the cracks.

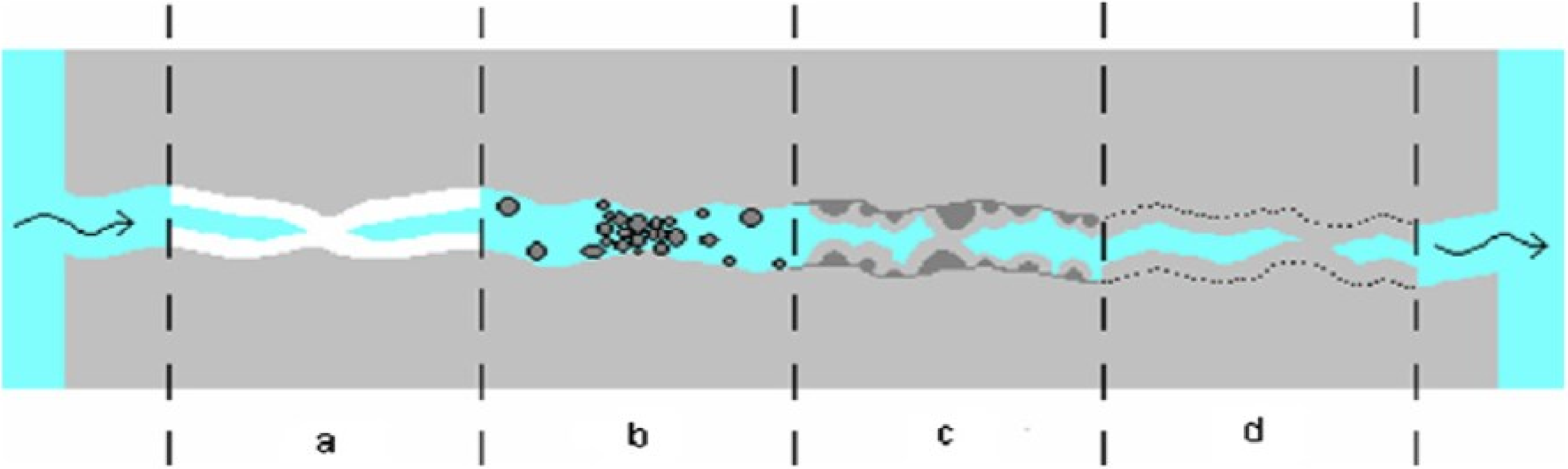
Sahmaran et al. investigated the effect of type of mineral admixtures (Class-F fly ash, Class-C fly ash, and slag) on the self-healing. They roughly observed that ECC with Class-F fly ash, ECC with Class-C fly ash, and ECC with slag can heal the cracks with the width of 30 µm, 50 µm, and slightly above 100 µm, respectively.

Ashish et al. explored the feasibility of replacing sand and cement with waste marble powder, an industrial by product, and found that replacing 10% of sand and 10% of cement with marble powder was optimal. Therefore, it is a viable concrete admixture. It was despicted that the incorporation of waste marble powder enhanced the performance of concrete due to filling effect.

Mechanism of ECC

The following mechanisms for healing have been cited by previous research: hydration of unreacted cement, swelling of Calcium-silicate-hydrate gels (C–S–H), precipitation of Calcium Carbonate ($CaCO_3$) crystals, closing of cracks by impurities within the water, and the closing of cracks by concrete particles from spalling on the crack faces continuous hydration of unhydrated cement particles, and pozzolanic reaction of supplemental cementitious materials.

Possible Mechanisms for Self-healing in Cementitious Materials



a. Formation of calcium carbonate or calcium hydroxide.

b. Blocking cracks by impurities in the water and loose concrete particles resulting from crack spalling.

c. Further hydration of the unreacted cement or cementitious materials.

d. Expansion of the hydrated cementitious matrix in the crack flanks (swelling of C-S-H)

Factors Affecting the Efficiency of Self-healing Process

- Size of the Crack
- Age of Concrete & Its Crack
- Tempereature, Pressure & Healing Time
- Presence of Water & Air
- Dosage, Size & Dispersion of Capsules
- Healing agent and Its Viscosity
- Concrete Materials Composition
- Expansive agents & mineral admixtures
- Ca2+ Ions Concentration
- Healing Mechanism

Conclusion

- Compared with the standard mixing sequence by adjusting mixing sequence increases the tensile strain capacity and ultimate tensile strength of ECC and improves the fiber distribution.
- It has a self healing property that is it can heal itself by using CO_2 and rain water.
- ECC incorporates high volumes of industrial wastes including ground granulated blast furnace slag (GBFS), and waste marble dust (MD).

- The benefit of filler material by marble dust usage in ECC can be said as improve workability with reduced cement content.

- The self-healing of cracks in concrete is beneficial for low maintenance cost and long service life of infrastructures.

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Thank you