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Full Length Research Paper

Laboratory study of ductile Cementitious panels under impact loads

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Ductility is one of the factors effective on study of impact loads resistant elements including explosion. One of the weaknesses of concrete elements is their low ductility against intensive loads and the engineers use fibrous concretes in order to reinforce these elements. In order to make fibrous concretes, different fibers such as steel, carbon, glass and polymer fibers. One of the superpower polymer fibers which are used in concrete elements is PVA fibers. Concrete made from these fibers has high ductility. In this article, behavior of the cementitious composites under impact loads is studied and assessed and the obtained results are presented.

Keywords: Engineered Cementitious Composites, Strain Hardness, Impact Loads, Permeation

INTRODUCTION

Today, concrete structures have been widely used. However, it has some weak points such as its low tensile strength in spite of desirable specifications of the concrete. Use of fibers in concrete matrix leads to increase of its tensile strength to desirable extent. One of the types of fibrous concretes which have been raised recently is engineered cementitious composites (ECC) from PVA fibers with volume of 2%. These fibers have high tensile strength and elasticity module. One of the applications of cementitious composites is construction of explosion resistant structures of which ductility is increased desirably in addition to enough strength. In material used for such structures, transformation, resistance against applied impacts and effect of strain rate are important in addition to high capacity to absorb energy. In ECC concretes, speed of cracks expansion is reduced due to fine double cracks and strain hardness phenomenon is found in them during loading like the metals leading to increase of bearing capacity and toleration of plastic transformations without failure in the specimen.

In order to study and assess the incurred damages and modes of failure in ECC under impact loads, Dr. Maalej et al performed some tests in Singapore University. They studied the incurred damages in terms of depth and diameter of permeation and cracking conditions and the obtained results indicate high impact strength of ECC in comparison to RC.

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Specifications and description of test

In order to compare behavior of ECC and RC, some examples of ECC with thicknesses of 50, 75 and 100 mm were made of which specifications are given in table 1. In this study, effects of panel thickness on behavior of ECC are assessed while behavior of ECC and RC is compared.

Nominal compression strength of the RC-made specimen was considered to be 40MPa and concrete cover was considered to be 15 and 10 mm in two sides of the specimen with thickness of 100 and 75 mm. an example of ECC and layout of the reinforcements is shown in figure 1.

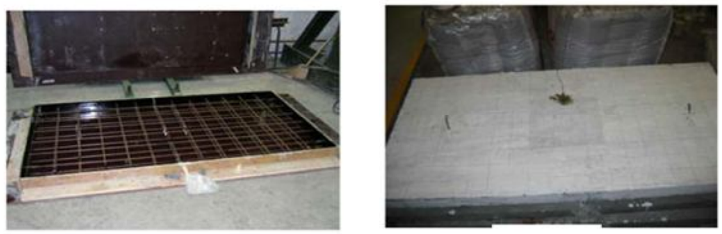
Specifications of impact test are given in table 2 and impact test device and weight throwing are shown in figures 2 and 3.

Test weight applies impact in the middle of the specimen due to its weight and as free fall. In each one of the specimens, their strength continues under different impacts to cause perforation and record the results.

In order to make RC and ECC, we pour them in the die and finish them after vibration of its surface for reaching

Table 1. Specifications of tested panels (4)

Row	Type of panel	Dimensions of panel	Size and distances of reinforcement	Consumed reinforcement ratio
1	RC100	1000×2000×100	Φ8mm@150mm c/c	0.6%
2	ECC100	1000×2000×100	Φ8mm@150mm c/c	0.6%
3	ECC75	1000×2000×75	Φ8mm@150mm c/c	0.8%



A B

Figure 1. ECC example, A-Panel reinforcement, B-Pre test Specimen

Table 2. Specifications of Impact Test

Mass of weight	Weight tip diameter	Fall height
45 kg	96 mm	4 m

Figure 2. Impact test device with fixed connection frame under simple support condition

Figure 3.A) Test weight, B-End part of the weight

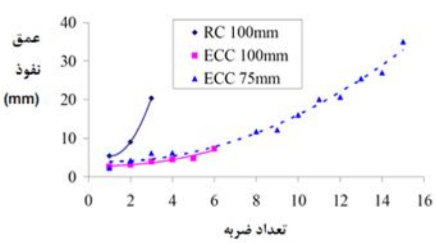


Figure 4. Depth of permeation in terms of impacts number

the desired thickness. For each one of the mixtures, cubic specimens of 100 mm are made. In order to decrease effects of shrinkage, processing is done within 7 days and plastic coatings are used in order to prevent

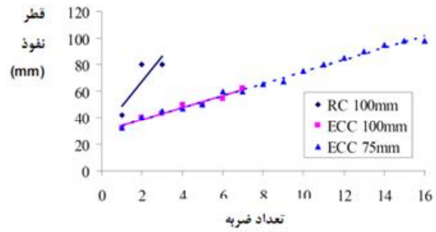


Figure 5. Diameter of permeation in terms of impacts number

Figure 6. Damage incurred on impact side of the RC100 panel: A) after the first impact, B) after the second impact, C) after the third impact

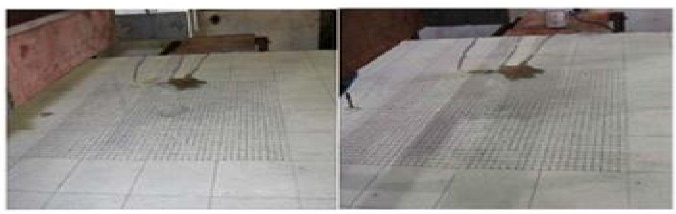


Figure 7. Damage incurred on impact side of ECC100 panel, A) after the first impact, B) after the 10th impact

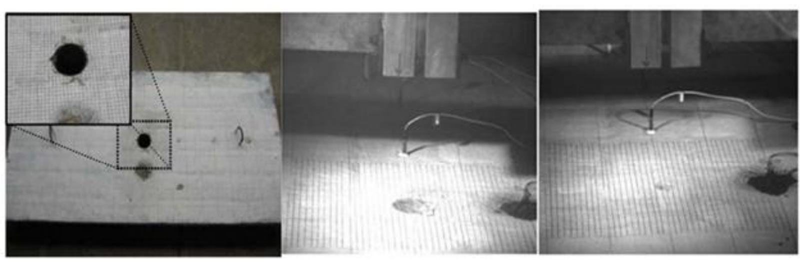


Figure 8. Damage incurred on impact side of ECC75 panel, A) after the first impact, B) after the 10th impact, C) after the 17th impact

Figure 9. debris after A) the second impact on RC100 panel, B) the 17th impact on ECC75

surface evaporation and do suitable processing. In order to measure the incurred damages, 10-mm grids have been specified in the middle of the specimens. 28-day average strengths of the cubic specimens are 55 MPa and 40MPa for ECC and RC.

RESULTS STUDY AND ANALYSIS

After each one of the impact tests, rate of the damage incurred in terms of diameter and average depth of permeation , expansion of crack and crust , scabbing and debris have been studied. The first two parameters have been obtained from the specimens after each test and other parameters have been obtained from results and finding of digital and video cameras. Results are shown in figures 8 and 9. Damage incurred on impact side of RC panel in the first three impacts is shown in figure 10.

Depth and size of permeation in ECC panels after 10 impacts are shown in figures 11 and 12 for ECC100 and ECC75.

Cracking behavior in ECC panel has improved considerably in comparison to RC panel. As result of impact on ECC panel, there are fine cracks of which width is low increasing its strength. Rate of debris after the second impact on RC panel and the 17th impact on ECC75 panel is shown in figure 13 A and B. after application of the tenth impact on the ECC100 and ECC75 except for impact zone , there was no considerable damage and there were only fine cracks therein.

CONCLUSION

Results obtained from test indicate that ECC panels have better resistance against impact loads than RC panels have and they are rarely damaged. Some results are as follows:

- Depth and size of permeation in impact zone in ECC are lower than those of RC.
- Cracking behavior of ECC panels is better than that of RC and the material used for absorbing energy has higher strength.
- Resistance against impact loads in ECC panels is higher than that of RC panels and their capacity to absorb energy against different impact loads is higher.

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