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# Behavior of pumice hybrid-fiber reinforced concrete slabs under blast loading

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**ABSTRACT:** Nowadays, the explosion phenomenon has been considered by structural engineers due to the increase in terrorist attacks and unforeseen events. Therefore, the calculation of the final dynamic loads resulting from these loadings should be considered as a criterion in order to design structures and protect military buildings. In this investigation, the behavior of pumice hybrid-fiber reinforced concrete slabs under blast loading was assessed. To evaluate the performance of pumice hybrid-fiber reinforced concrete, contact explosion test on slabs with dimensions 100×100×10 cm3 was conducted. Six slabs, including one unreinforced concrete slab and five fiber-reinforced concrete slabs, were prepared. Also, C4 explosive material was used to investigate different failure modes of slabs. The results showed that the addition of various types of fibers improved the behavior of slabs. Also, it is concluded that the replacement of cement and steel fibers with pumice and polyolefin fibers, respectively, led to a slight increment in the number and extent of cracks; however, the costs were significantly decreased.

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## 1- Introduction

Nowadays, the explosion phenomenon has been considered by structural engineers due to the increase in terrorist attacks and unforeseen events. Therefore, the calculation of the final dynamic loads resulting from these loadings should be considered as a criterion in order to design structures and protect military buildings. The advantages of fiber-reinforced concrete under static loads, which are well known worldwide, have led to their introduction as a material resistant to dynamic loads such as impact and explosion [1-3]. In recent years, many researches have been conducted on the effect of blast load on fiber-reinforced concrete members [4-6]. However, experimental results showing the explosive behavior of fiber-reinforced concrete are limited. All of these researches highlight the need for practical action to reduce localized or global damage to concrete elements. The use of cheap materials such as polymeric fiber and pumice has been considered as an alternative to steel fiber and cement, respectively. In this study, firstly, steel fibers in the amount of 1, 1.5, 2 and 2.5% by volume were added to the mixing designs. Then, by performing mechanical tests on compression, tensile and flexural samples, the optimal percentage of steel fibers was selected. In the second phase of the research, 30%, 40% and 50% of the optimal steel fibers were replaced with polyolefin fibers, respectively, and mechanical tests were repeated on them to determine the optimal mixing scheme for hybrid fibers. In the final stage of the research, by selecting the optimal design obtained from the first and second stages of the research, the performance of concrete slabs reinforced with hybrid fibers and pumice under explosion was investigated. For this purpose, blast test was performed on contact slabs of 100 × 100 × 10 $cm^3$. The specimens consisted of 6 series of concrete slabs as one unreinforced slab and five slabs reinforced with fibers.

## 2- Methodology

In this study, $C_4$ explosive was used in experiments due to its low chemical sensitivity and low cost. Also, Type II cement and Khash pozzolan, which are in accordance with the criteria of ASTM C150 standard were applied. Moreover, coarse-grained has been used as a river with a specific gravity of 2.68 and fine-grained as a broken with a specific gravity of 2.64, water absorption of 1.6% and a soft modulus of 2.93. The largest coarse grain size is 19 mm. Two types of steel and polyolefin fibers were provided to investigate the differences in the behavior of fiber-reinforced concrete under blast load using different fibers with various volume percentages.

In order to achieve optimal designs containing single steel fibers and hybrid fibers (steel and polyolefin), compressive, tensile and flexural strength tests were performed on different

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**Fig. 1. The setup of blast loading test and arrangement of the support frame**

samples. A compressive strength test according to BS 1881 was performed as a load control on 10 × 10 × 10 $cm^3$ cubic specimens. Also, to determine the tensile properties of fiber-reinforced concrete, indirect tests of splitting tensile and three-point bending were used. A blast test was performed on contact slabs of 100 × 100 × 10 $cm^3$. The specimens consisted of 6 series of concrete slabs as one unreinforced slab and five slabs reinforced with fibers. The setup of the blast loading test and arrangement of the support frame is shown in Figure 1.

## 3- Results and Discussion

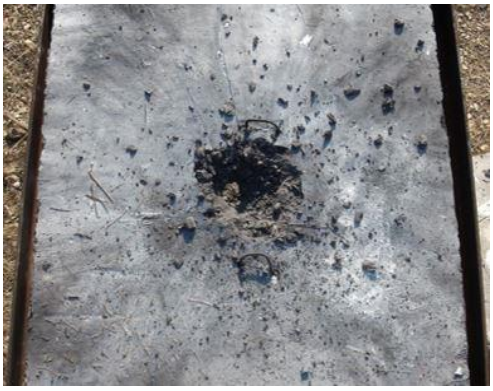
Generally, replacing part of steel fibers with polyolefin fibers reduces the mechanical properties of concrete. This is due to the lower tensile strength of polyolefin fibers compared to steel fibers. In fact, polyolefin fibers have less ability to reduce the growth and development of cracks when opened due to their low tensile strength. Among the hybrid fiber reinforced designs, the design with 40% replacement of steel fibers with polyolefin fibers has the best mechanical properties, and the strengths obtained from this design are very close to the strength values of the single-fiber design. Figure 2 shows the failure types of different samples.

The dimensions of the hole (diameter and depth of the hole) created in the slab due to the explosion are one of the parameters that can show a small amount of reinforcement effect. Due to the complete collapse of the unreinforced specimen, the relative percentage of degradation is shown in Figure 3 for each of the slabs. In fact, in each sample, the percentage of surface destruction (ratio of hole diameter to the dimension of the slab in contact with the explosive (100 cm)) and the percentage of deep destruction (ratio of hole depth to slab thickness (10 cm)) are expressed.

As can be seen in Figure 3, the presence of different types of fibers has significantly increased the strength of the concrete slab against the blast load. By replacing steel fibers

(a)

(b)



(c)

**Fig. 2. Failure types for various specimens: (a) WF specimen, (b) SPF-60-40/P0 Specimen, (c) SPF-60-40/P20 Specimen**

with polyolefin fibers and also moving part of the cement with pumice, although the amount of damage has increased slightly, it still retains its appearance and prevents sudden collapse.

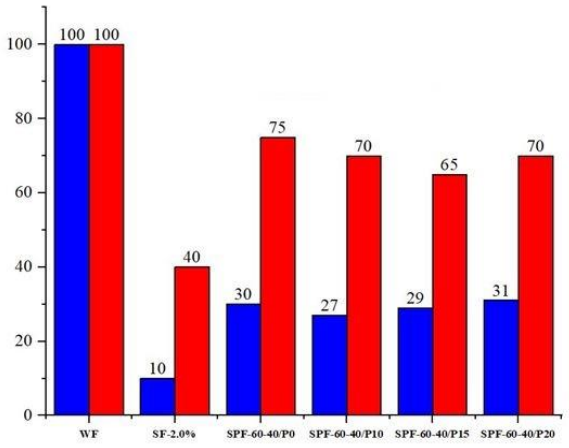



**Fig. 3. Percentage of surface and deep failure**

## 4- Conclusion

The following conclusions can be drawn:

(a) Replacing part of steel fibers with polyolefin fibers reduces the mechanical properties of concrete. This is due to the lower tensile strength of polyolefin fibers compared to steel fibers.

(b) Among the hybrid fiber reinforced designs, the design with 40% replacement of steel fibers with polyolefin fibers has the best mechanical properties

(c) The presence of different types of fibers has significantly increased the strength of the concrete slab against the blast load. By replacing steel fibers with polyolefin fibers and also moving part of the cement with pumice, although the amount of damage has increased slightly, it still retains its appearance and prevents sudden collapse.

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