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# Behavior of Heavy Weight Concrete under Impact Effect

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**Abstract:** This study was carried out for designing concrete which has ability to resist the effects of nuclear explosions, this leads to discuss theses effects (blast, thermal, radiation and so on).
The present study has been carried out with a view to establish the basic engineering data and information about the technology of heavy weight concrete from local materials. It can be used as shielding materials because of its potential properties, radiation attenuation, mechanical characteristics, durability and economic structural use.
In this study, Ilmenite is used as coarse aggregate; serpentine is used as fine aggregate mixed with normal Portland cement and water. Also steel fibers were added with different percentages.

Different concrete mixes were designed, produced, cured, and tested for compressive, tensile, flexural, ultrasonic test and impact strength. Admixtures were employed to improve the mechanical properties. The results showed that the steel fiber Ilmenite-serpentine heavy weight concrete has good mechanical properties for construction of nuclear shelters.

Results show that Ilmenite-serpentine heavy weight concrete has good mechanical property compared with the ordinary concrete in most of tests specially the tensile and flexural strengths. It has been found that the ISFHWC can be produced with a maximum density of the order 3.35 t/m3.

Also, results show that Ilmenite-serpentine heavy weight concrete of suitable thickness will improve the impact strength more than the ordinary concrete with high values.

**Keywords:** Design, Ilimenite, serpentine, steel fiber, nuclear, impact, radiation.

## 1. Introduction:

The growth in the power and sophistication of explosives and firearms continued until World War I and defensive countermeasures merely increased the mass and strength of the structure in response to the more powerful attack. The conflict at that time was mainly confined to armed forces, who suffered twenty times more casualties than civilians. The next major shift in the balance of attack and defenses developed between 1918 and 1930 with the introduction of aerial warfare, widely used in World War II. The use of aero planes to deliver explosives was new, but the means of combating it was known. From front line experience now, however the general populace behind the front line could for the first time be directly involved in the conflict.

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This led to improvements in defenses by the development of public and private air-raid shelters, which could withstand a local explosion and in some cases, even a direct hit. Never the less, this did not prevent wholesale civilian carnage, in which civilians sustained as many casualties as the armed forces. The development of the atomic bomb and its 1st use on 6 August 1945at Hiroshima, when a 15 KT bomb known as thin Boy killed half the city's population, followed by a 20 KT bomb -Fat man- dropped three days later at Nagasaki, killing three quarters of its population, again radically. The following photo shows the great destination in Nagasaki as shown in fig (1).

**Fig. (1) The Damage in Nagasaki after the Nuclear Explosions**

Altered the nature of threat posed by the attacker, the increase in power afforded by the hydrogen Bomb was a quantum jump in men's continuing search for means to destroy each other, so that whole cities were vulnerable tracts of land downwind could be affected by a single bomb. Even, where military targets were selected, the whimsically named collateral damage (damage to civil centers of population by bombs aimed at other targets) would result in an effect little different from that if such purely civilian targets as cities were chosen[1].

This study illustrates the new type of highly hydrated heavy weight concrete, used as an effective nuclear shelter. Moreover the effect of adding fibers to such concrete will be discussed.

## 2. Expermintal work

The scope of the work deals with an experimental investigation to study the properties of heavy weight fiber concrete, with a specified type of aggregate, as influenced by some important parameters such as aggregates gradation, ratio between fine aggregates and coarse aggregates, cement content, w/c, plasticizing admixture and fiber content by concrete volume.

In this study, heavy weight concrete was perepared from naturally occurring ilmenite and serpentine ores as coarse and fine aggregates respectively. The ilmenite ore was choosen in order to increase the unit weight of the concrete in addition to its strenght under static and dynamic loads, while the serpentine ore was choosen since it contains chemically bound water in its composition (about 11.6%). Thus it increases the hydrogen content in the final concrete mixture [2].

## 2.1 Scope of the Test Program

Concrete mixes with cement content 400 Kg/m$^3$ were investigated; four mixes were tested using various percentages of steel fiber contents. The consistency adopted for all mixes was the semi-dry concrete with a slump of 35-55 mm. The consistency of fresh concrete was determined by the slump test. The hardened concrete was tested for ultrasonic velocity, unit weight, compressive strength, indirect tensile strength, flexural strength and impact strength.

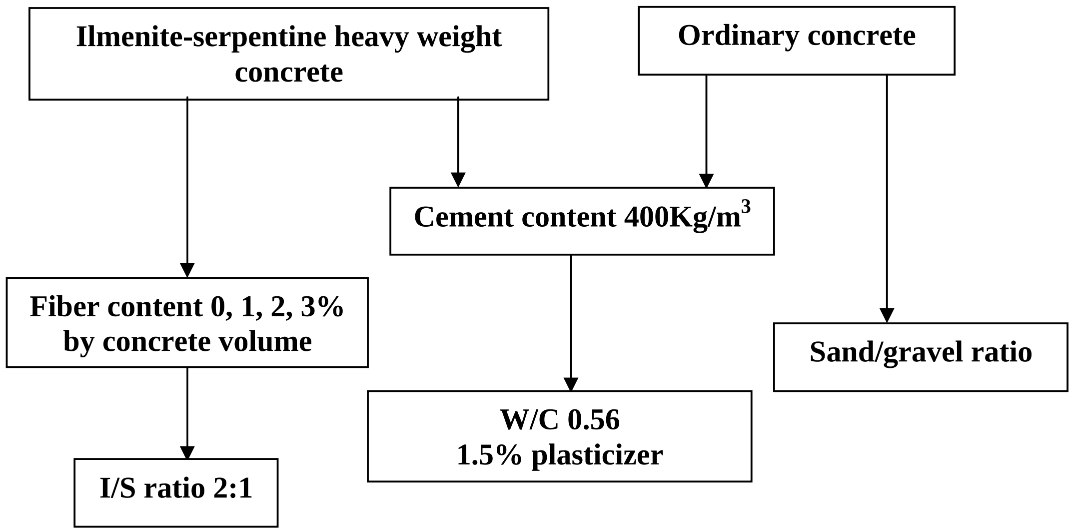



**Fig.(2) Scheme of Different Concrete Mixes of Ilmenite-Serpentine Heavy Weight Concrete and Ordinary Concrete.**

## 2.2 Mix Design

Concrete mixes were designed mainly by the empirical method based upon the absolute volume method recommended by the American Concrete Institute [3].

**Table (1) Ingredients of 1m3 of the Control Ordinary Concrete, Mix Number (1)**

| Material | Cement | Gravel | Sand | Water | Fiber | S.P. |
|---|---|---|---|---|---|---|
| Kg/m³ | 400 | 1328 | 664 | 224 | 0 | 6 |

**Table (2) Ingredients of 1m3 of I.S.F.H.W.C.**

| Material | Mix no. | Cement | Ilmenite | Serpentine | Water | Fiber | S.P. |
|---|---|---|---|---|---|---|---|
| Kg/m³ | 2 | 400 | 1947 | 541 | 224 | 0 | 6 |
| | 3 | 400 | 1947 | 541 | 224 | 78 | 6 |
| | 4 | 400 | 1947 | 541 | 224 | 156 | 6 |
| | 5 | 400 | 1947 | 541 | 224 | 234 | 6 |

## 2.3 Preparation of Specimens for Test

In this study, series of specimens were prepared and tested in the laboratories of the Civil Engineering Department, Military Technical College in Cairo.

The factors that can affect the strength of concrete can be classified into four categories: constituent materials, methods of preparation, curing procedures, and test conditions. We will here be concerned primarily with the effects of the concrete constituents such as fiber content and type of aggregates [5, 9].

The specimens used in the study take three shapes:

1-Standared cubes (15x15x15) cm

2-Standared cylinders (20x10) cm

3-Beams (70x10x10) cm

All samples were placed in the room temperature and were cured in water for 28 days, the curing water was changed every 7 days.

Water cement ratios for different conditions are given in Table (3). The table contains the ratios for both ISFHWC with and without plasticizer, in addition to ordinary concrete.
All concrete mixes have nearly the same slump values, which can be classified as a semi plastic consistency.

**Table (3) Variation of Water-Cement Ratio for Different Concrete Mixes**

**Mixes with Plasticizer for All Mixes**

| | O.C. | I.S.C. | | | |
|---|---|---|---|---|---|
| Cement content Kg/m$^3$ | 400 | 400 | 400 | 400 | 400 |
| % of serpentine | 33 | 33 | 33 | 33 | 33 |
| W/C ratio | 0.65 | 0.65 | 0.65 | 0.65 | 0.65 |
| Fiber content,%vol. | 0 | 0 | 1 | 2 | 3 |

### 2.4 Impact Strength Test

The energy consumed by the specimen until failure was consider as a measure of its impact resistance.

This energy achieved by the falling weight method as shown in figure (3) is given according to the following relation

$$E = \text{Mass (kg)} \times \text{Height (m)} \times g\ (\text{m/sec}^2)$$

where, the height is equal to the summation of heights to failure.

## 3. Results

### 3.1 Bulk Density

Table (4) shows that bulk density is influenced by different parameters. Since the bulk density of concrete is the property of main concern, it is important to study the parameters which have the influence on the bulk density. In this study the ISFHWC was produced using Ilimenite as coarse aggregate and serpentine as fine aggregate with bulk density ranges between 3 and 3.47 ton per cubic meter. This value is 25%-48% higher than that of O.C.

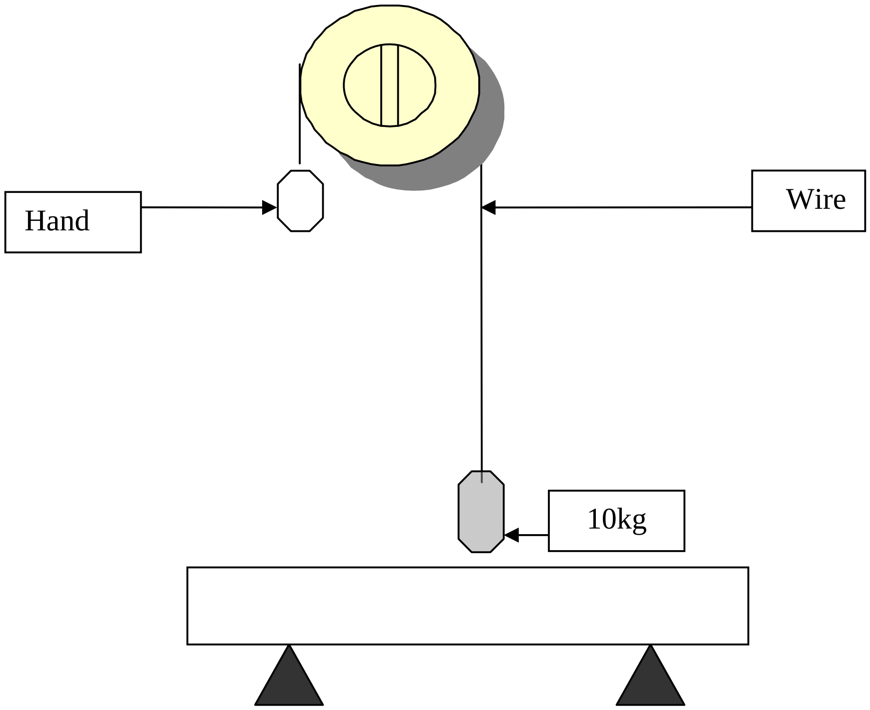



**Fig.(3) The Falling Weight Method**

**Table (4) Bulk density kg/m3**

| | | I.S.C. | | | |
|---|---|---|---|---|---|
| Fiber content % by volume of concrete | O.C | 0 | 1 | 2 | 3 |
| Compressive strength kg/cm$^2$ | 333 | 342 | 354 | 412 | 408 |
| Bulk density kg/m$^3$ | 2194 | 3215 | 3321 | 3359 | 3286 |

## 3-2 Properties of hardened ISFHWC

### 1. Ultrasound Testing OF ISFHWC

Since the pulse velocity depends only on the elastic properties of the material, so the ultrasound test is very convenient technique for evaluating concrete quality. In this test we determined the pulse velocity through a known thickness of ISFHWC. Figure (4) shows that the ultrasound velocity increases with increasing fiber content up to 2% while at higher percentages the ultrasound velocity decreases, this behavior can be attributed to the cracks or honey comb formation inside the concrete samples when the fiber content exceeds 2%.

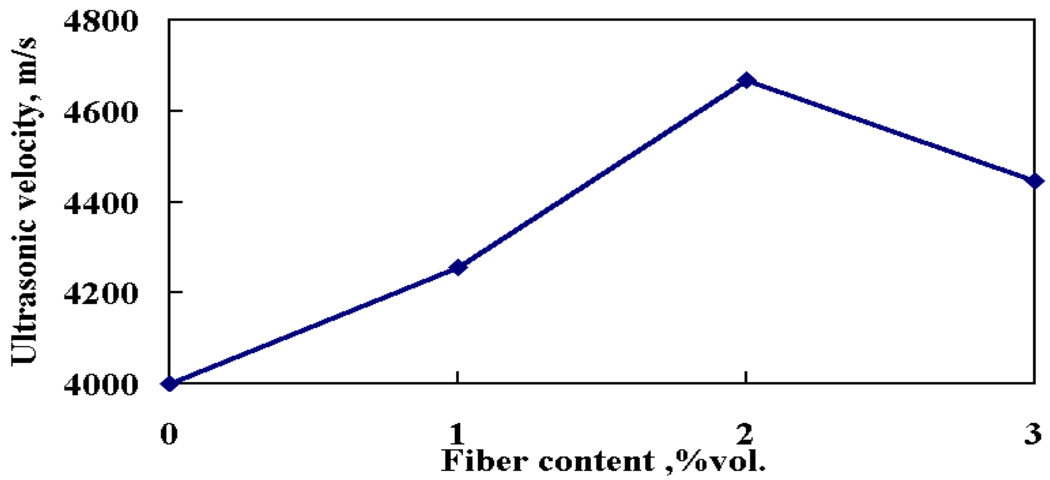



**Fig. (4) Ultrasonic velocity values of I.S.C. with different percentages of steel fiber**

## 2. Compressive Strength

In many codes the compressive strength is named a concrete rank because of its importance; the compressive strength test was carried out on samples containing steel fiber (Harks) with percentages 0, 1, 2, 3% by concrete volume. Such results are illustrated in figure (5).

The specimens were tested at 7 and 28 days age for all mixes with and without fibers. From the curves, the following conclusions can be found:

Compressive strength increases as concrete age increases. Generally ISFHWC behaves in a manner similar to that of ordinary concrete.

It is clear that increasing fiber content, the compressive strength increases up to 2% vol., this increasing may be attributed to the hindering effect of the fibers to the production and propagation of the cracks.

The above phenomena occurred up to 2% fiber content, while at higher percentages the compressive strength went to decrease. This may be attributed to the production of voids which make weak points which leads to decreasing the compressive strength.

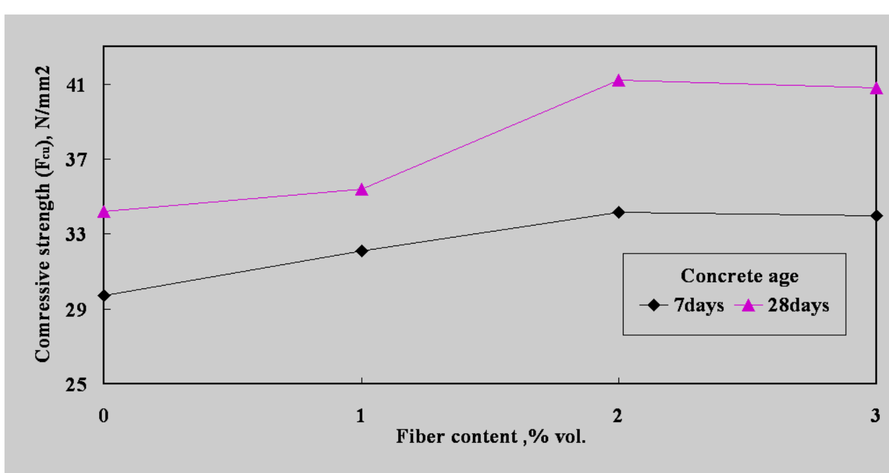



**Fig. (5) Compressive strength of I.S.C with different percentages of steel fibers**

### 3. Tensile Strength

Tensile strength is not as important as the compressive strength for concrete; there is a relationship between compressive strength and tensile strength. General important remarks can be summarized as follows:

1- The tensile strength increased as fiber content increased up to 2%.
2- The tensile strength of I.S.F.H.W.C. is 1.48 times than that of O.C.
3- The maximum tensile strength of I.S.F.H.W.C. reached 22.2 $Kg/cm^2$ at fiber content 2%.

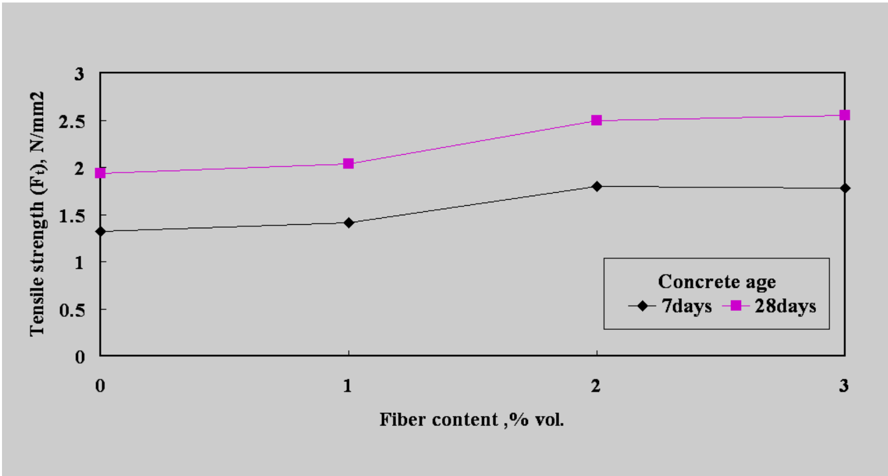



**Fig. (6) Tensile strength of I.S.C with different percentages of steel fibers**

### 4. Flexural Strength

Results of flexural strenght test show that introducing fiber into I.S.C causes improvement of the flexural strength nearly 10%. The increasing of fiber content leads to increasing of flexural strength up to 3%, this may be due to the presence of fiber,which in turn cauases a big surface faces the bending . Such results were displayed in fig (7).

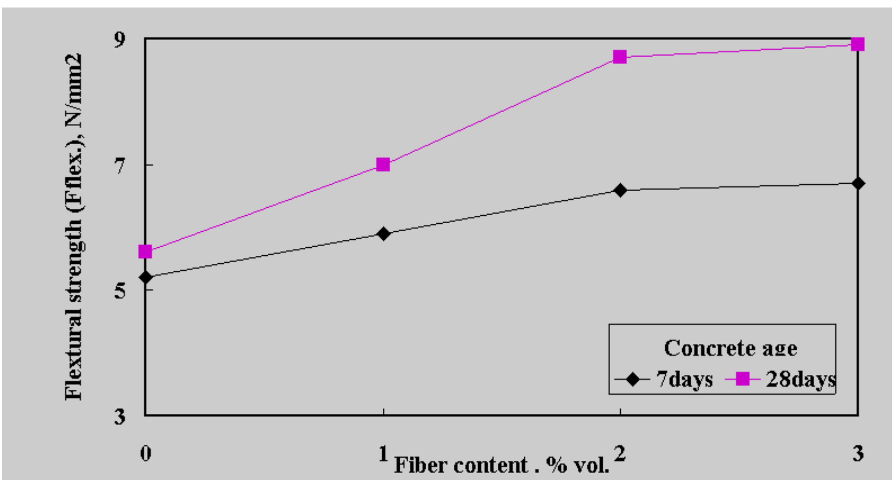



**Fig. (7) Flexural strength of I.S.C with different percentages of steel fibers**

### 5. Impact Strength

Impact strength test was carried out on beams of dimensions 70*10*10 cm using a10kg steel ball felled from a specific height (50 cm), the readings recorded the begining of the cracks of concrete samples and also when full damage appears.
The impact strength was evaluated from the following equation:

$$I.S = W \times F$$

where: W is the total weight of the steel ball

F is the total distance until failure

The results show that both the impact strength values at first crack and failure crack in I.S.F.H.W.C.are much bigger than that of O.C., since it is 4.1 times in case of first crack while it is 1.69 times in case of failure crack as shown in figure(8). Also, increasing the steel fiber contents will lead to the increase of impact strength up to 3%.as shown in fig. (9) .

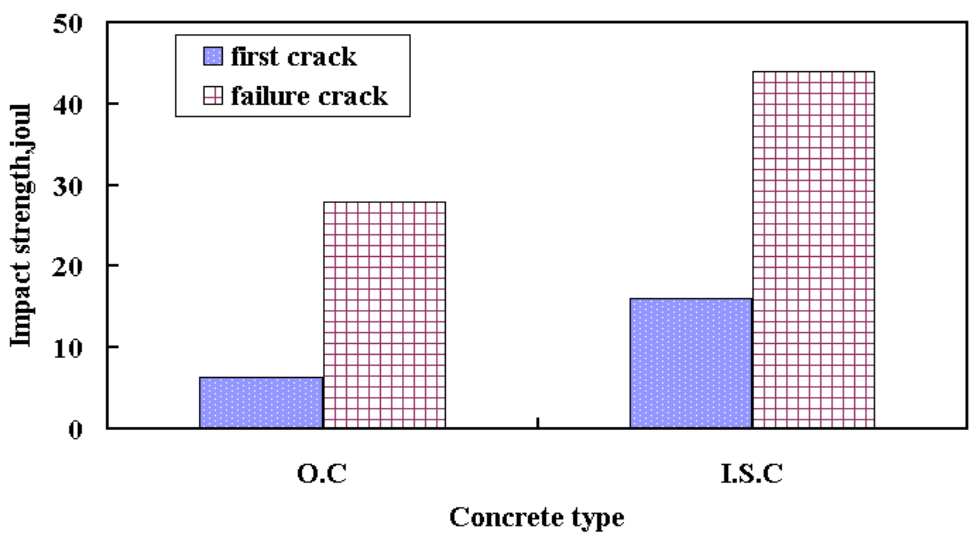


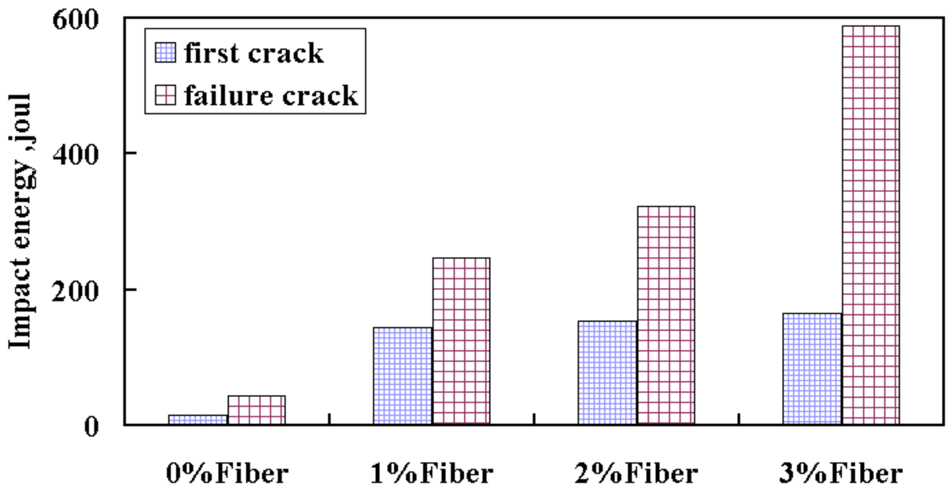

**Fig (8) Impact strength of O.C. and I.S.C**

## 4. Conclusions

The following general conclusions could be derived from the experimental results previously obtained.

- The ilmenite and serpentine ores in addition to steel fibers can be selected for the production of heavy weight concrete used for design of nuclear shelters.
- The ilmenite and serpentine ores and steel fibers can be used to produce a concrete of 3359 kg/m3 unit weight, and 410 Kg/cm2 compressive strength.
- The addition of steel fibers to I.S.C. can lead to an increase of 100% the tensile strength compared to that of O.C.
- The I.S.F.H.W.C. can be used to design all bending members because of its high flexural strength.
- The failure of the new concrete has no fragments, which ensures a high degree of protection for anything inside the structures.
- The new type of concrete shield has attenuation coefficients greater than the ordinary concrete (for different gamma ray energies).

- The half reduction values of I.S.F.H.W.C.can are reduced by nearly 50% less than that of O.C.
- The structure elements of the shelter can be designed by nearly half dimensions when using I.S.F.H.W.C instead of O.C.
- The I.S.F.H.W.C. can increase the impact strength nearly 13.3 times more than that of O.C.



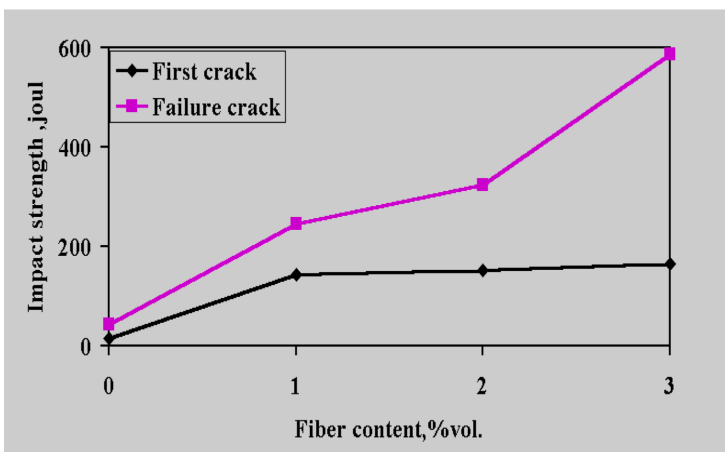




**Fig (9) Impact strength of I.S.F.H.W.C with different percentages of steel fibers**

## 5. Recommendations

The following recommendations for future work can be displayed as follows:

- Using other types and shapes of steel fibers in I.S.H.W.C.
- Applying blast tests on I.S.F.H.W.C. for ensuring its resistance for blast loads using different amounts of explosive materials.
- Taking the other effects of nuclear explosion into consideration in the future testing programs.

- A theoretical model must be designed to adopt the design rules and equations applied in case of O.C. design and perform the necessary corrections.
- Effect of I.S.F.H.W.C. on the reinforcement.
- Construction of concrete elements (beams, columns, slabs) and testing them under different cases of loading (static and dynamic loads).
- Construct a prototype (model) for an actual structure and test it.

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