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Original Research

THE BEHAVIOR OF CONCRETE CONTAINING POLYPROPYLENE FIBERS AND STEEL MESH ON THE IMPACT RESISTANCE

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Abstract: Annually, engineers face many sustainability problems due to thousands of tons of concrete being manufactured for buildings and structures. So, alternatives to some construction materials are used. In this research, cement composites reinforced with steel mesh and cement composites reinforced with polypropylene fibers (PPFs) were used. For this purpose, 36 concrete slabs were poured with dimensions of 40 x 40 x 4 cm containing steel mesh, and PPF with dimensions (10 x 10, 15x15, 20x20, 25x25, and 40x40) cm in the center of the slab. The impact resistance of both types of concrete was examined, in addition to noting the initial cracking of the samples and examining the energy absorption at the initial cracking and the final failure of both types, through the results, it was found that the use of steel mesh 40x40 cm is the best in terms of its resistance to repeated impact loads as well as its energy absorption.

Keywords: *Energy Absorption; Impact Load; Normal Concrete; Polypropylene Fibers; Steel Mesh.*

1. Introduction

Steel mesh is an assured enhanced material that produces enough crevice via ducting capability at the material scale, which may increase post-cracking impedance to exterior loads, abstract crevice expansibility, and promulgation and therefore defers members fracture [1].

Many of the defects of ordinary concrete can be passed by utilizing polypropylene fiber (PPF) reinforcement. PPFs can enhance the ductility of concrete by improving properties such as impact resistance and flexural toughness [2-4]. Polypropylene fiber reinforcement has more impact resistance than most other commercially available fibers with higher dosing rates [5].

Impact forces particularly hit the structure or a section of it fortuitously, whilst, on a few other occasions, the structure was previously planned for such kinds of loads like in the matter of airport runways, because of airplane tires which impact the concrete airport runways face permanently [6-9]. Moreover, the dropping of building materials from high floors and loftiness, the crash of cars by the columnar constructional components in car parking stations, or the bomb impact of libelers in struggle regions are typical instances of unwitting impacts [10, 11]. There are a few tests usually to evaluate the impact resistance that are utilized to calculate the impact energy absorption capacity of various kinds of materials inclusive of concrete.

Structural members such as slabs or beams can be measured by impact testing utilizing a non-manual weighing impact tester.

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The Charpy pendulum test is considered the best typical impact test. This exam is characterized by less complicated and minimal costly comparison to the other tests and was also embraced by numerous former authors [12, 13] to investigate the function of steel fibers in improving concrete impact strength.

Few ersatz materials to normal concrete that have been excessively researched and virtually proceeded in many building plans around the world in the last few years are fiber-reinforced cementitious composites and ferrocement (with thicknesses of 10-25 mm). Whereas the first utilizes metallic or non-metallic fibers as reinforcement in hydraulic cement mortar while, the second utilizes steel mesh [14- 16].

In ferrocement, there are warnings since the restriction of 10-25 mm thickness in augmentation the number of mesh layers, since aloft volume fraction of steel mesh in mortar mixture might fragment the tensile stratum and that leads to breakdown [17]; and on the same side, uses volume percentage of fibers (discontinuous type non-metallic or metallic fibers) beyond 2.5% in fiber reinforced cementitious composite leads to difficulties in mixing or casting of the fibrous mortar is expert [18, 16] regardless, randomly oriented discontinuous fibers into a cementitious matrix [19, 20].

Impact strength is regarding the capability of concrete to supply safety in utilization and to warranty its behavior after the impact [21]. The engineers and investigators shall improve powerful and tougher cementitious composites [22] with ductile properties [23] without easily collapsing and fracturing because of absorbing high levels of impact energy. So, it's important to improve public safety [24-26]. Impact loading of constructional members contains convoluted procedures where both material and structural variables can affect their behavior [27]. So, to assess the impact energy absorption of composite materials, many scientific ways were used such as instrumented pendulum impact test, dropping weight single or repeated impact test, projectile impact test, weighted pendulum type impact test, explosion-impact test, constant strain rate test, and split Hopkinson bar test [25, 27, 28].

Tabatabaei et al. [29] have examined the impact performance of long CFRCs (carbon fiber reinforced concretes) by dropping weight impact tests utilizing impact testing instruments. The authors dropped a 23 kg steel rod with70 mm diameter from a specified height onto the simply supported condition on all four sides of a panel in mid-span, registered the falling weight by apparent watching the first crack, and marked the final fracture basis on the subsidence weight desired to enough open the crack and the panel was a failure. After the first crack, the energy for failure has improved for long carbon fiber reinforced concrete panels in comparison to the traditional samples; long carbon fiber reinforced concrete panels have shown an increase in impact resistance than ordinary panels.

1.1 Research Significance

A few researches have been conducted on the effect of the dimension of mesh on the dynamic properties of normal concrete during the last decays. So, 36 normal concrete slabs (400x400x40) mm have been cast with dimensions (10x10, 15x15, 20x20, 25x25, and 40x40) cm steel mesh and PPF reinforcement were put in the center of slabs in addition to plain concrete (without mesh or PPF). Impact resistance (Number of blows), First cracks observation, and first and final energy absorbed have been calculated during this experiment.

2. Experimental Work

2.1 Materials

36 slabs of normal concrete with dimensions (400x400x40) mm to examine the impact test on these slabs which were divided into two groups, the first group contains galvanized steel soldering mesh (with a grid spacing of 12.5 x 12.5 mm and a diameter of 0.70 mm) the specification of a steel mesh was (470 Mpa, 225 Mpa, and 12.9%) (TS, YS, and Elongation) respectively, the volume fraction of steel mesh will take as 1%, the position of mesh was in the center of the slab in 5 dimensions (10x10, 15x15, 20x20, 25x25, and 40x40) cm in addition to reference slab (without mesh). The second group contains PPFs (with diameter 0.032mm, length 12mm, and tensile properties 600-700MPa) the volume fraction of PPF was 1%.

Ordinary Portland Cement OPC (type 42.5) was utilized in this experimental investigation from the local cement factory (Mass). The cement that had been utilized with a specific surface area of 368 m^2/kg, while its specific gravity equaled 3.15. Natural coarse aggregates were brought from the Al-Ekhadir area in Iraq. It was crushed gravel and had a maximum particle size of 12.5 mm, while the fine aggregate was brought from the Al-Ekhadir area with a fineness modulus of 2.46 and a specific gravity of 2.65. The sieve analysis of the used gravel and sand is depicted in Fig. 1.

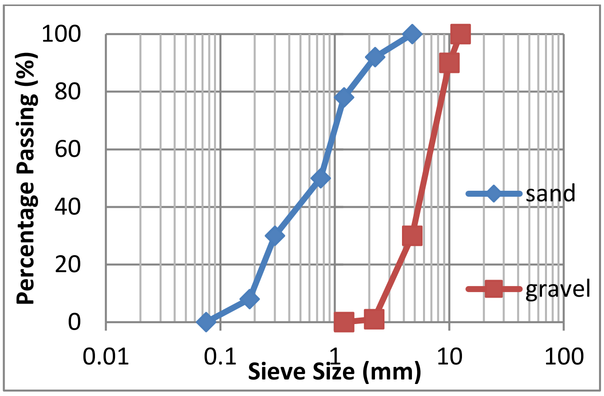

Figure 1. Particle grading for sand and gravel

2.2 Mix Design & Samples Preparation

A 36 normal concrete slab with mix design 1:2:4 (cement: sand: gravel) as shown in Table 1; to produce nominal concrete (M15) was cast by weight, which was prepared after several experiments were conducted by the authors and depended on the intermediate amounts utilized in past articles [29, 30-32; 14-16; 33; and 19-20).

Fig. 2 clarifies the mold of the impact strength. All tests were done at 28 days. 3 slabs for each (type and dimension of mesh and fiber) in addition to the reference slab according to Table 2.

Table 1. Details of mix design

Cement Kg/m³	300
Sand Kg/m³	600
Gravel Kg/m³	1200
Water Kg/m³	105
Fibers Kg/m³	21

Figure 2. Molds of concrete and position of mesh and

During molding, half of the mold was filled with concrete, and after the compaction process, the fibers or mesh were installed, then the other half of the mold was filled with concrete. Then the molds were covered with nylon sheets for 24 hours, after that the molds were opened and the concrete slabs were immersion in tap water for curing until the test age.

Table 2. Details of mixes

Mix ID	Dimension of Mesh(cm x cm)	Weight of Sample (kg)
C1	No Mesh (Reference sample)	21.800
C2	10x10	21.835
C3	15x15	21.870
C4	20x20	21.910
C5	25x25	21.950
C6	40x40	22.015
G1	No PPF	21.800
G2	10x10	21.480
G3	15x15	21.500
G4	20x20	21.509
G5	25x25	21.554
G6	40x40	21.618

Fig.3 illustrates the impact test device which was a steel frame with a rigid base simply supported by a pipe 1 m height and a steel ball of 1 kg weight. The method of the test demands computing the number of repeated impacts which leads to causing the first visible surface crack and the number of impacts to fall the sample.

Figure 3. Impact strength test device

3. Results and Discussions

3.1 Impact test

The dynamic performance of concrete undergoes impact is a complex test, and depends on variables such as the maximum size of coarse aggregate, amount of coarse aggregate, type of fiber, and the amount of fiber, in addition to the length of the fiber. So, in this investigation, two types of fiber were utilized with different dimensions to find out their effect on the impact test of concrete.

Figs. 4 and 5, showed the number of blows at 1st and final failure of concrete with steel fiber. From the above Figures, it can be noticed that as the dimensions of the mesh increase the No. of blows increases. For example, for C1 it can withstand 3 blows and after that, the 1st crack begins to initiate, while C2, C3, C4, C5, and C6 (5, 8, 9, 12, and 15) blows respectively. This means, there is an increase ranging between (40 for C2 to 80 for C6) %, the same trend was repeated for the final failure of concrete.

For instance, the increment ranged between (71.4 - 79.4) %, this performance was expected when using fiber or mesh because; the integration of a small amount of fibers or mesh in concrete is demanded as the fibers or meshes were capable of bridging cracks and holding concrete together as shown in Fig. 6.

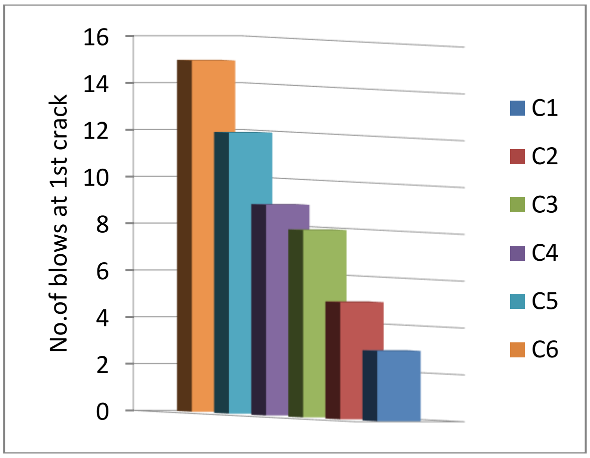

Figure 4. No. of blows at 1st crack of concrete for different dimensions of steel mesh

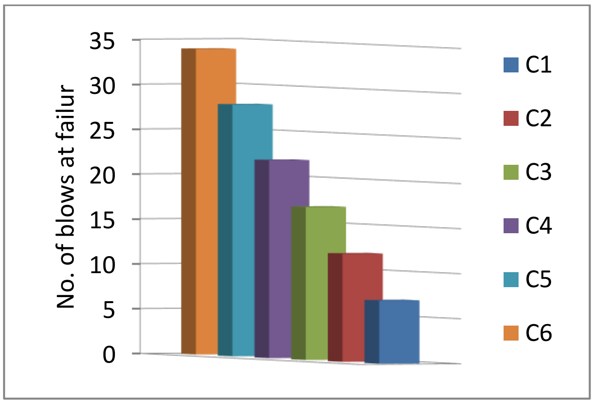

Figure 5. No. of blows at failure of concrete for different dimensions of steel mesh

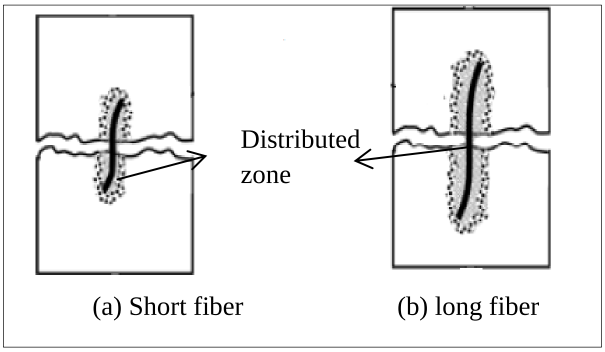

Figure 6. Effect of fiber length

However, when using PPFs the same performance of a steel mesh but with less increment as shown in Figs. 7 and 8. However, the PPF lengths where the same length as the steel meshes. For example, in G6 mixes it can withstand 12 blows to initiate the 1st crack while; it can withstand 28 blows to failure compared to C6 which can withstand (15, and 32) blows for 1st and final failure respectively. These results are compatible with the results of reference [34] who said that since the PPF has a lower dynamic modulus of elasticity than steel mesh, these results are considered accurate.

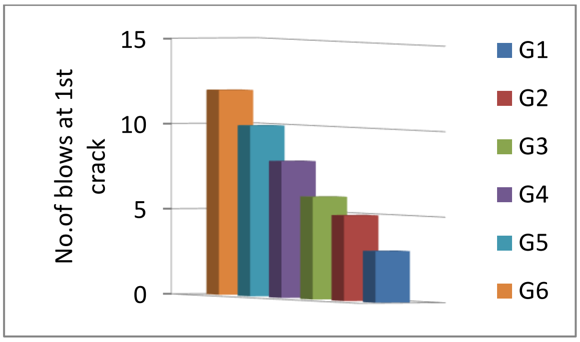

Figure 7. No. of blows at 1st of concrete for different dimensions of PPFs

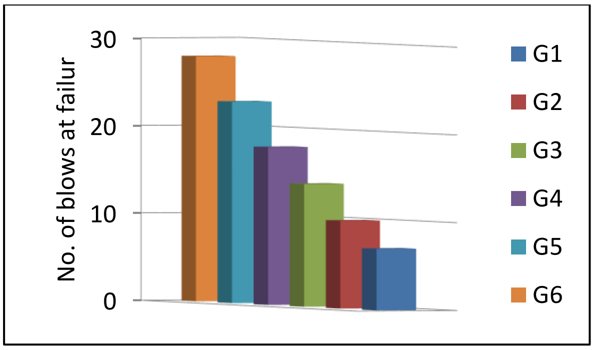

Figure 8. No. of blows at failure of concrete for different dimensions of PPFs

3.2 Absorption Energy

Energy absorption indicates the procedure of receding the input energy from external loading by plastic distortion or break. The calculation for finding the energy absorption capacity of the concrete sample at the initial, and final crack:

$$E = m.g.h.n \quad (1)$$

Where E= energy absorption, joule m=mass of the projectile, kg H= Height of drop, m

n= numbers of blows.

From Table 3 it can be concluded that when using steel mesh, the absorption was much greater than when using PPF at initial crack and final failure. For example, the rate of increase when using C6 was greater than (20, 17.6) % when using G6 at the initial cracking and final fracture, respectively. But compared to reference concrete the rate of increase when using C6 was (80, 79.4) % at the initial crack and final smash respectively while, when utilizing G6 the increase rate was (75, 75) % at the initial crack and final fracture respectively.

Table 3. Energy Absorption for steel mesh and polypropylene fiber

Concrete ID	initial crack (joule)	Final failure (joule)
C1	29.43	68.6
C2	49.05	117.6
C3	78.48	166.6
C4	88.29	215.6
C5	117.72	274.4
C6	147.15	333.2
G1	29.43	68.6
G2	49.05	98.1
G3	58.86	137.34
G4	78.48	176.58
G5	98.1	225.63
G6	117.72	274.68

3.3 Failure Pattern

From Figs. 9 and 10, it can be noticed that when using plain concrete the slabs were divided into 5 or more parts but, when using mesh or fiber indeed it fails but it remains as one piece, and as the dimension of mush or fiber the crack failure increased until it reached the hole slab as it can be seen when using C5 and G5 (i.e. when the dimension of fiber increased indeed it fails but it the cracks became as a tree in the whole slabs and as the length of fiber increased these cracks increased but, the slab remain as one unit; unlike the reference concrete, which was divided into 5 or more sections, as shown in Figs.9 and 10. This attitude may be due to the length of the fibers and the overlap between the cement mortar and the fibers.

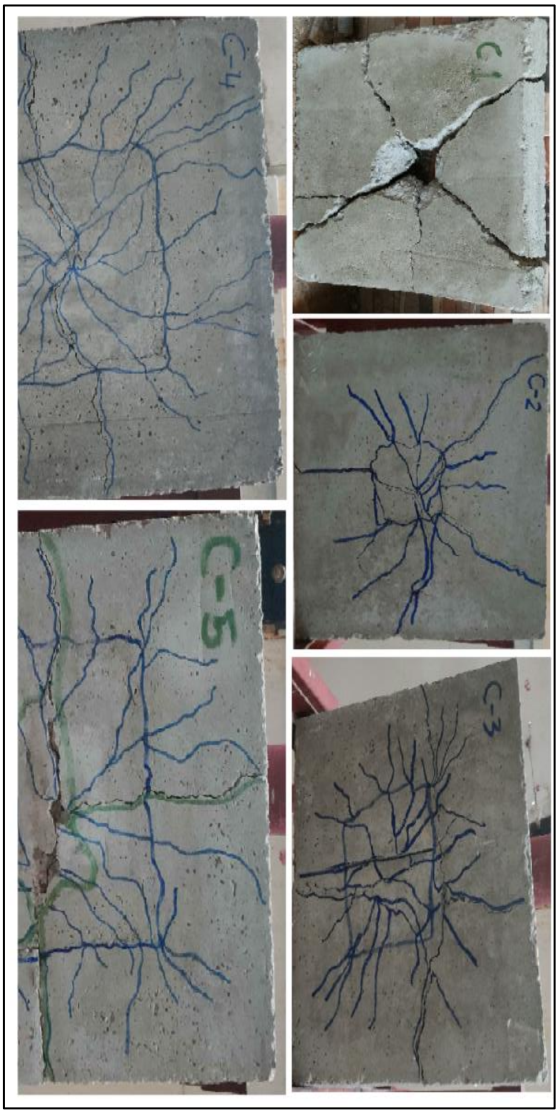

Figure 9. Cracking pattern for reference and steel mesh reinforcement

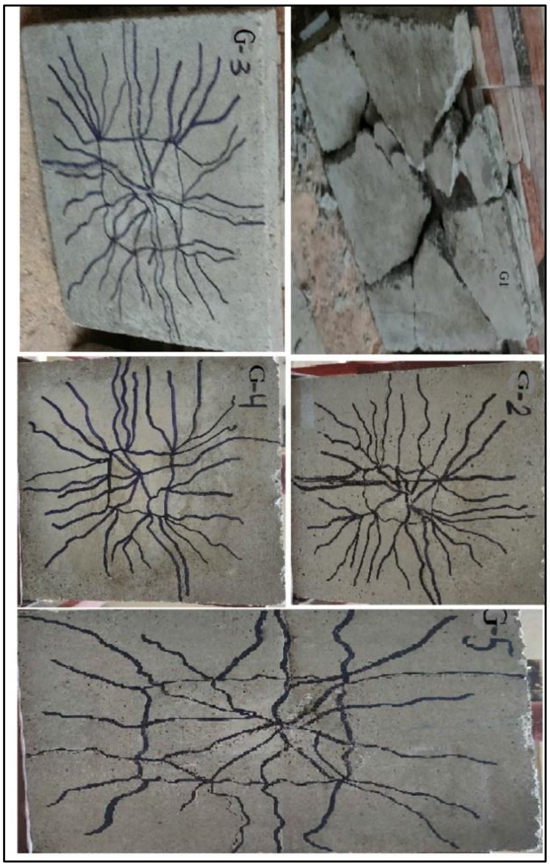

Figure10. Cracking pattern for reference and PPF reinforcement

4. Conclusions

Many conclusions were drawn from the experimental investigation, such as:

The utilization of steel or fiber improves the 1st crack, impact resistance, and both initial and final absorption of concrete. As the dimension of mesh and fiber increased the 1st crack, impact resistance and both initial and final absorption of concrete increased. For the same dimension of mesh when, using steel mesh the rate of increments was much higher than when using polypropylene fiber for 1st crack, impact resistance, and both initial and final absorption of concrete. Plain concrete was divided into more than 5 pieces at final failure while the same concrete but with steel mesh or polypropylene fiber still as 1 unit. As the dimensions of steel mesh or polypropylene fiber increased the number of cracks increased at the final fracture.

In terms of sustainability, the use of fibers itself is a type of sustainability since it is considered a waste material. In addition, the use of fibers leads to extending the life of concrete and thus reducing the use of slabs, which leads to a decrease in the use of sand, gravel, and cement.

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Conflict of Interest

There is no conflict of interest between the authors.

Author Contribution Statement

Ammar Muttar and Sana Taha proposed the research problem. Ammar Muttar and Osamah Mohammed performed the laboratory work. Osamah Mohammed writes the final version of the manuscript. All authors read the manuscript and approved it.

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