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The assessment of using fiber produced from plastic broom bristles on the impact property of normal-weight concrete slabs

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ABSTRACT

Plastic has emerged in many modern industries, and petroleum is an essential source for the manufacture of many materials of importance in our contemporary life, such as plastic bags, paints, brooms used for cleaning, and others. This study showed that it is possible to use these plastic products in other ways to reduce the plastic pollution that invades the world, and one of these ways is the possibility of adding plastic to concrete to improve some of its properties. In this work, the bristles of plastic brooms are used in the form of fibers to improve the properties of concrete, and the results showed a significant improvement in the resistance to compression, flexural, and impact resistance of concrete, in addition to a slight decrease in the density. The fibers were added in different proportions (0.6, 1.0, and 1.4) as a percentage of the concrete volume, and the duration of the test ranged between (7 and 28) days for the tests of compression, flexion, and density, while the impact resistance tested at the age of 90 days.

1. Introduction

Concrete is one of the most important materials used in building construction, as it is the most widely used resource after water. Concrete provides a healthy and safe environment for the world's population [1]. In addition, it has exceptional strength and mechanical properties if its production conditions are considered well. Currently, the world's annual cement production is 4.4 billion tons, and by 2050, this product is expected to increase to more than 5.5 billion tons [2]. That is why reducing the depletion of natural resources and improving the environment are globally important [3]. The construction industry consumes up to half of the consumption of raw materials and industrial waste, 40% of global energy consumption [4], and between 40 and 50% of greenhouse gas [5].

In addition, this industry is considered one of the most important negative influences on the environment in terms of the deterioration of the ecosystem in general and the pollution of soil, water, and air [6]. There are many applications for fiber-reinforced concrete. For example, fiberglass is widely used in precast panels, sewer pipes, plaster, and concrete blocks. In addition, Steel fibers are used in roofs, sidewalks, pipes, airport runways, explosion-proof buildings, and tunnel lining, while synthetic fibers are used in dams, well fills, and slope stabilization. Conventional synthetic fiber materials improve the performance of concrete, but they cannot be reused due to their high cost. In addition, they generate waste and have a negative impact on the environment because they are not biodegradable. Whereas natural fibers are cheap and inexpensive, and because they are renewable, they represent a sustainable source of fiber for FRC [7-8]. When recycled fibers are used in the concrete industry, it contributes to reducing its environmental impact and the disposal of waste in landfills. Previous studies by several researchers have shown that many types of recycled fibers can be used to produce reinforced concrete at a lower cost than non-recycled fibers. Fibers [9-13]. Based on the foregoing, it is possible to successfully recycle and reuse some materials in the concrete industry as alternative materials to produce reinforcing fibers.

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2. Experimental setup

2.1. Materials preparation

Cement

Ordinary Portland cement (O.P.C) Adjusted to European Standard No. EN 197-1:2011 [14] and IQ. Standards No. 1984-5 [15] were utilized in this study.

Fine Aggregates

A fine aggregate of good properties was utilized in all mixes, ranging in size from 150 microns to 4.75 mm. The grade was adjusted to IQ. Standards No. 1984-45 [16].

Coarse Aggregate

A natural aggregate with a maximum size of 10 mm was utilized in all tested mixes. The grade-adjusted No. 1984-45 [16]

Plastic Fiber (PF)

The resulting plastic fiber was produced from the cutting broom bristles manual. The features res of this fiber are illustrated in Table 1. and Fig. 1. Show plastic fiber.

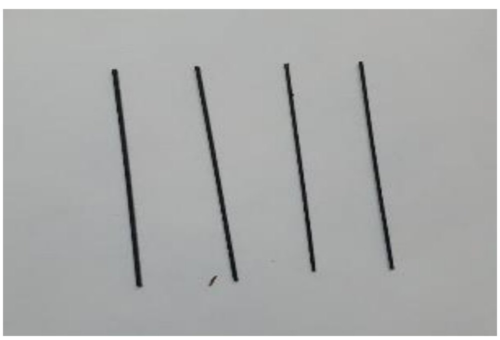

Figure 1. Plastic fiber

Table 1. Properties of plastic fiber.

Type of Fiber	Length (mm)	Diameter (mm)	Aspect ratio (l/d)	Specific Gravity (gm/cm^3)
PF	30	0.8	37.5	1.169

2.2. Normal-weight concrete (NWC) Mix Component

Four mixes were made of Normal-Weight Concrete (NWC) with the same mixing proportions, one mix, with zero percent of fiber was represented as a reference mix, and three different ratios of (PF) percentage were added to these mixes (0.6, 1.0, and 1.4%) as volumetric ratios. The process of mixing conformed to the standards of ASTM C I92 [17]. Table 2. Represented mix proportioning for Normal-Weight Concrete (NWC) for this work.

Table 2. Weights of Normal-Weight Concrete Components.

Mix	Cement (kg/ m^3)	Fine Agg. (kg/m^3)	Coarse Agg. (kg/m^3)	w/c (L)	PF (Kg/m^3)
R1	418.1	685.5	1099.3	183.9	0
M1	393.0	644.5	1033.6	172.9	7.01
M2	384.6	630.7	1011.5	169.2	9.35
M3	376.3	617.1	989.7	165.6	11.69

Where:

R1: Normal-weight concrete without fiber

M1: Normal-weight concrete with 0.6% carbon fiber

M2: Normal-weight concrete with 1.0% carbon fiber

M3: Normal-weight concrete with 1.4% carbon fiber.

2.3. Curing

The curing of specimens was conforming to the procedure of ASTM C 192 [17].

3. Experimental lab work

3.1. Density investigation

The density determines the homogeneity of concrete texture, which affects its properties and behaviour. The dry density can be calculated as the mean of weighing the samples after drying and dividing by their volume. This test was performed according to ASTM C 642 [18] at the ages of 7 and 28 days.

3.2. Compressive Strength

Compressive strength is a characteristic that expresses the degree of quality of concrete, and compressive strength is also considered the most important characteristic of hardened concrete, as most of the other properties of concrete are affected by the change in compressive strength. The purpose of determining compressive strength is to control the quality of concrete production and determine the optimum compressive strength in the structural design, which is taken as a percentage of its maximum compressive strength. The procedure that followed in this work was adjusted to BS 1881 – 119 [19]. Fig. 2 shows the tested cubes.

3.3. Flexural Strength

Flexural Strength is the resistance of concrete to indirect tensile tension (the result of bending). It expresses the fracture parameters, and the purpose of finding the bending resistance is to specify the fracture parameters in the bending of concrete, which represents 12-25% of the compressive strength value. Flexural strength is computed according to ASTM C 293 [20]. Fig.3.

Figure 2. Tested cubes

Figure 3. Tested prisms

3.4. Impact test for slabs

Concrete slabs are sometimes subjected to high dynamic impact loading conditions due to direct exposure to projectiles, falling loads, fragments of explosions, or missiles. These loads may cause significant damage to lives and property. By using the repeated falling method of Steel ball weight (1300) gm to find Low-Velocity impact tests, this method counted the number of times a falling ball with a velocity of 6.928 m/s from a height of 0.8 m fell freely onto a concrete slab with dimensions (400×400×50) mm. The slabs were tested at the age of (90) days. The number of blows that caused the first crack and final failure was recorded. Fig. 4. Show the tested slabs of Normal Weight Concrete (NWC).

4. Results and discussions

4.1. Density Test

The results showed that the density decreased slightly with increasing the volume ratio of (PF). The replacement of concrete components with plastic fibers as volume reducing the density due to the density of plastic being much less than concrete components causes this. Table 3 lists the density of tested specimens for all mixes and Fig. 5. Showed the changes in the density of Normal Weight Concrete (NWC).

Figure 4. Tested slabs

Table 3. The density of the NWC specimens.

Mix	Density at 7 days	Density at 28 days	Development at 28 days
R1	2380	2388	-
M1	2368	2357	-1.298%
M2	2363	2342	-1.926%
M3	2345	2328	-2.512%

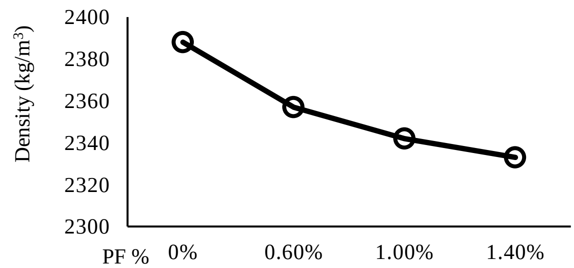

Figure 5. The density at (28) days.

4.2. Compressive Strength Test

Test results in Table (4) showed that compressive resistance improved by 11.88% for the largest fiber added to the mix compared to the reference mix without fiber. This increase can be attributed to the fact that the presence of fiber has improved the cohesion of concrete texture, as well as the fact that concrete is less porous, more solid, and stronger due to the continuous hydration of concrete with age. Fig. 6 shows the compressive strength of cubes at (28) days.

4.3. Flexural strength test

Fig. 7 shows that the flexural strength increased with the increase in the percentage of plastic fibers (PF), and the highest percentage of fibers recorded an increase of (23.8 %). This is because the plastic fibers (PF) create bridges that connect the two ends of the microscopic cracks in the concrete fabric and prevent them from growing and spreading when the concrete is under the influence of tensile force. Table 5 presents the results of the flexion tests at (7 and 28) days of age.

Table 4. Compressive strength results for cubes.

Mix	Compressive Strength (MPa) at 7 days	Compressive Strength (MPa) at 28 days	Development at (28) days
R1	32.0	34.5	-
M1	32.8	35.2	02.03 %
M2	33.9	37.4	08.41 %
M3	34.4	38.6	11.88 %

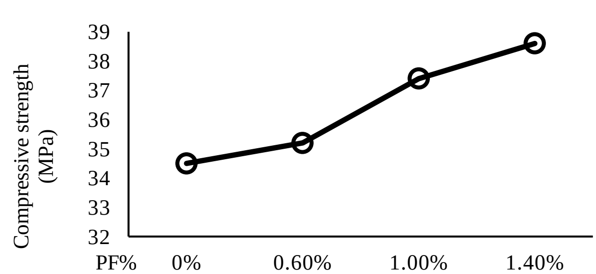

Figure 6. The compressive strength at (28) days.

Table 5. Flexural results for prisms

Mix	Flexural (MPa) at 7 days	Flexural (MPa) at 28 days	Development at 28 days
R1	2.6	4.2	-
M1	3.1	4.6	9.5 %
M2	3.7	5.1	21.4 %
M3	3.9	5.2	23.8 %

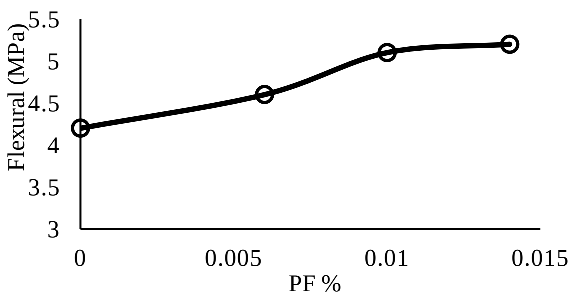

Figure 7. Flexural at age (28) days.

4.4. Impact Test

Observation of impact resistance results showed a significant improvement in the number of blows with an increase (PF) over the Reference mix. This increase may have resulted from the improvement of the shock energy absorption of the concrete and the increase in its hardness, as the fibers have prevented cracks from developing because of repeated loads. The maximum increase in hit resistance was (121.4%). Fig. 8 shows the improvement in the number of blows in concrete slabs by increasing the percentage of fibers; the details are in Table 6 and Fig. 8.

Table 6. No. of blows for NWC slabs.

Mix	No. of blows (First Crack) at 90 days	No. of blows (Failure) at 90 days	Development of No. of blows (Failure) at 90 days
R1	3	14	-
M1	4	19	035.7 %
M2	4	23	064.3 %
M3	7	31	121.4 %

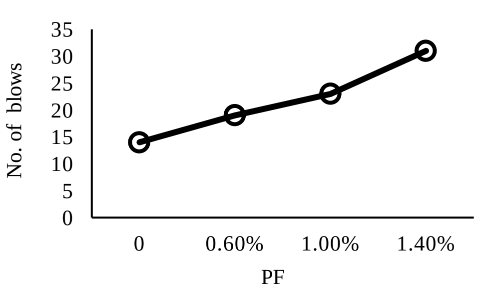

Figure 8. No. of blows at the age (of 90) days.

5. Conclusions

The experimental work in this study shows the following conclusions-

- The addition of plastic fibers in different proportions significantly reduced the density of concrete by increasing these proportions.
- Increasing the percentage of fibres increases the compressive strength of concrete compared to the reference mix.
- An improvement in the flexural resistance of concrete by increasing the proportion of fibers added to concrete.
- The addition of plastic fibers has improved concrete hardness, energy absorption, and increased ductility by increasing the proportion of fibers.

Authors' contribution

All authors contributed equally to the preparation of this article.

Declaration of competing interest

The authors declare no conflicts of interest.

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