Recycling of disposal Polypropylene Blister Tablets and Strapping ties as fiber reinforcement for Pervious concrete

Ahmed M Ahmed1,*, Ahmed H Hussein1, and Mohammed T Hammood2

1 University of Samarra, College of Engineering, Iraq.
2 Tikrit University, College of Engineering, Iraq
*Corresponding Author: ahmed_m@uosamara.edu.iq

Abstract. Pervious concrete (PC) was introduced as a solution for the runoff from rainfall. To insure high porosity, pervious concrete should contain limited quantities of fine aggregate, which adversely effects concrete mechanical properties. As an attempt to improve PC mechanical properties, fibers were added to concrete matrix. As PC is allows water to pass through it, metal fibers are uncourageous to be added to it. Plastic fibers were selected as an alternative to metal fibers to be added to PC. Concrete physical and mechanical properties were studied for mixtures containing different quantities of fibers. Tests results showed a slight improvement in concrete compressive strength (0.48% to 1.44%) as fibers were added. The addition of fibers improved splitting tensile strength by (6.36% to 27.67%). As adding fibers, concrete flexural strength increased by (11.37% to 24.17%) compared to the reference mixtures. of PC. Concrete physical properties (Density, Porosity and permeability) were also investigated. The addition of fibers to concrete has a slight effect on (density, porosity and permeability).

1. Introduction
The permeability of most materials used in construction is low [1]. Due to the use of these materials, the hydrological cycle in the cities is radically changed, as rainwater no more infiltrating to the soil and lead to run-off. Responding to that, researchers are searching for new materials with high permeability characteristics without altering their mechanical properties. In that sense, Pervious Concrete (PC) is among these materials [2].
Pervious concrete pavements (PCP) are structures permeable enough to serve storm water management and bear pedestrian/traffic loads, depending on the application. In this pavement system, a pervious concrete layer is placed on a highly voided stone bed as the base layer, to insure a rapid percolation of runoff through the pavement system instead of allowing it to run on the surface [3, 4].
Pervious concrete (PC) has acquired renewed interest in the past decade due to its positive environmental impacts. Widespread researches employing different strategies has been carried out to improve the overall performance of PC. Lots of literatures have been published. As high performance pervious concrete (HPPC) advanced, extensive application of this material has been made possible. [5]
However, this type of pavement cannot be used for heavy traffic due to a high amount of voids and consequently low strength of pervious concrete. [6]
Several research efforts focused on improving the mechanical and durability properties of PC by using various supplementary materials, fibre reinforcement can be used. Fiber reinforcement should be selected carefully depending on its interaction with a given pervious concrete mix. To avoid corrosion,
Metallic reinforcement should not be used for pervious concrete. Instead of metallic fibers, fibers made of carbon, glass, synthetic or natural materials may be added to pervious concrete [7-13]. Saeid Hesami et al (2014) [6], studied the effect of adding different weight percentages of rice husk ash as a cement replacement in concrete mixtures on the mechanical properties. They also added 0.2% volume fraction of glass and 0.5% volume fraction of steel and 0.3% volume fraction of polyphenylene sulfide (PPS) fibers to improve the mechanical properties of the pervious concrete. Different water to cement (w/c) ratios were used in their study. They investigated concrete physical and mechanical properties including permeability, porosity, compressive strength, flexural strength, and tensile strength. Due to the results, concrete mechanical properties were improved as fibers and rice husk ash were added. [6]

Also, the effect of adding volume fractions of cured carbon fibre composite to pervious concrete on its abrasion resistance was studied by Rangelov et al. [14]. They noticed that mixtures containing cured carbon fibre composite have better performance than the control mixture. Fiber reinforcement enhances the strength of the matrix and delays the generation of the cracks. However, the bonding mechanism between fiber and concrete matrix is controversial in literature and needs better explanation. Due to surface smoothness and inert chemical nature of commercially available fibers, researchers studied several treatment techniques to improve the fiber-matrix bonding properties. The use of fibers in pervious concrete is even more challenging due to high porosity and insufficient fiber-matrix bonding interface [15].

2. Materials and Methods

2.1. Cement

Ordinary Portland cement (OPC. Type I) was used in this investigation confirming to (ASTM C 150) [16].

2.2. Gravel

Two types of gravel were used in this experimental work, both of them was rounded single sized gravel. The first type of gravel passed through (9.5 mm) sieve and retained on (4.75 mm) sieve. The second type of gravel passed through 12 and retained on 9.5 mm sieve.

2.3. Fibers

PVC strapping ties were cut to pieces (3 cm in length, 2 mm in width and 1 mm in thickness) as shown in fig.1. Two volumetric ratios of this fibers were added to concrete (0.5 %) and (1 %) by total volume of concrete.
PVC Blister tablets were cut to pieces (3 cm in length, 2 mm in width and 1 mm in thickness) as shown in fig.2. Two volumetric ratios of this fibers were added to concrete (0.5 %) and (1 %) by total volume of concrete.

A. Before cut

B. After cut

Figure 1. Strapping ties.
A. Before cut  
B. After cut  

**Figure 2.** Blister tablets.

### 2.4. Water

Portable water was added to the dry mixture.

### 3. Mix proportion

To reach the best consistency and achieve an appropriate porosity for the matrix, trial batches were done. Figure (3) and table (1) shows the details of trial mixes and its results.

**Figure 3.** Trial Cubes.

### Table 1. Trial mixes.

| Cube | Cement (kg / m³) | Gravel (kg / m³) | Sand (kg / m³) | W/C ratio | Superplasticizer (%) |
|------|------------------|------------------|----------------|-----------|----------------------|
| A    | 1400             | 425              | 0.25           |           |                      |
| B    | 425              | 1400             | 400            | 0.35      | 1                    |
| C    | 425              | 1400             | 400            | 0.4       | 0                    |
| D    | 425              | 1600             | 400            | 0.3       | 0                    |
| E    | 425              | 1700             | 200            | 0.3       | 0                    |

The best proportioning discovered through trial mixes (F) was followed in the experiential work. Table 2. describes the selected symbols for each of the mixtures and table 3. Contains the proportions of each of the investigated mixtures.
Table 2. Mixtures symbolling

| symbol  | Description                                                                 |
|---------|-----------------------------------------------------------------------------|
| R1      | is the refers to the reference mixture, casted using (9 - 4.75 mm) aggregate. |
| R2      | is the refers to the reference mixture, casted using (12.5 – 9 mm) aggregate |
| M1F-0.5%| is the matrix casted using (9 - 4.75 mm) aggregate and reinforced with (0.5% Strapping ties fibers). |
| M1F-1%  | is the matrix casted using (9 - 4.75 mm) and reinforced with (1% Strapping ties fibers). |
| M2F-0.5%| is the matrix casted using (12.5 – 9 mm) and reinforced with (0.5% Strapping ties fibers). |
| M2F-1%  | is the matrix casted using (12.5 – 9 mm) and reinforced with (1% Strapping ties fibers). |
| B1F-0.5%| is the matrix casted using (9 - 4.75 mm) aggregate and reinforced with (0.5% Blister tablets fibers). |
| B1F-1%  | is the matrix casted using (9 - 4.75 mm) aggregate and reinforced with (1% Blister tablets fibers). |
| B2F-0.5%| is the matrix casted using (12.5 – 9 mm) aggregate and reinforced with (0.5% Blister tablets fibers). |
| B2F-1%  | is the matrix casted using (12.5 – 9 mm) aggregate and reinforced with (1% Blister tablets fibers). |

Table 3. Mixtures symbolling

| symbol   | Cement kg / m³ | Gravel kg / m³ | Fibers kg / m³ | Water kg / m³ |
|----------|----------------|----------------|----------------|---------------|
| R1       | 425            | 1700           | 0              | 127.5         |
| R2       | 425            | 1700           | 0              | 127.5         |
| M1F-0.5% | 425            | 1700           | 7.5            | 127.5         |
| M1F-1%   | 425            | 1700           | 15             | 127.5         |
| M2F-0.5% | 425            | 1700           | 7.5            | 127.5         |
| M2F-1%   | 425            | 1700           | 15             | 127.5         |
| B1F-0.5% | 425            | 1700           | 7.5            | 127.5         |
| B1F-1%   | 425            | 1700           | 15             | 127.5         |
| B2F-0.5% | 425            | 1700           | 7.5            | 127.5         |
| B2F-1%   | 425            | 1700           | 15             | 127.5         |

4. Mix procedure
The proportioned ingredients were mixed and batched using a mechanical drum mixer of 125 liter in volume. The specimens were molded and compacted according to (ASTM C 192) [17]. The specimens were immersed in water 24 hours after casting and until tested at 28 days age.
Figure 4. Pervious concrete specimens.

5. Tests.
The investigated properties were (compressive strength, Splitting tensile strength, flexural strength, Porosity, Density and permeability).

5.1. Concrete Compressive Strength Test
Concrete compressive strength was tested according to (BS 1881, Part 116) [18]. For compressive strength test, three (15 cm) cubes of concrete were casted for each mix. Concrete specimens were immersed in water (24 HRs) after they were casted, and stayed in water until testing it at 28 days age.

5.2. Splitting Tensile Strength Test
According to (ASTM C 496) [19], three cylinders (15 cm in diameter and 30 cm in height) were casted for each mix for the Splitting Tensile strength test. Concrete specimens were cured for 28 days before tested.

5.3. Flexural Strength Test
Concrete flexural strength was tested through casting three (10*10*50 cm) prisms for each of the five mixtures. Curing started (24 Hrs) after casting and continued until testing at 28 days age. The test was conducted according to (ASTM C 78) [20].

5.4. Density
Three cylinders were casted for density measurement of each mixture. Concrete density was measured according to (ASTM C 1754) [21], as listed in the procedure below:

- Determine the dimensions of the test specimen (Diameter and Length).
- Dry the specimen.
- Determine the constant dry mass of the specimen A
- Determine the submerged mass, B.

Density = (K*A)/(D^2*L)  
(1)

Where:
A = dry mass of the specimen, g [lb],
D = average diameter of the specimen, mm [in.],
L = average length of the specimen, mm [in.], and
K = 1 273 240 in SI units or 2 200 in [inch-pound] units

5.5. Porosity
Concrete porosity was also tested through measuring the volume of water could be held by voids of a specimen with respect to the gross volume of the specimen its self. Porosity test was conducted according to (ASTM C1754) [21].
5.6. Permeability
To measure concrete permeability, two test procedures could be followed (Constant head permeability test) and (Falling head permeability test) according to previous studies, Constant head permeability test is preferred to investigate the permeability of pervious concrete [22]. Three cylinders were casted to measure concrete permeability. Each cylinder was installed in the test instrument described in figure (6). The coefficient of permeability was calculated for each specimen.

6. Test results
6.1. Total Void in aggregate based on Angularity number
The single sized gravel allows the creation of continuous voids which is the base concept of pervious concrete. Total void percent and aggregate angularity number are shown in table 4. Table 4 shows the angularity number for two sizes of aggregate used in this study. The percentage of voids present in the aggregate increases as the angularity number increases. It is observed that the size of aggregate has pronounced effect on the voids.

| Gravel       | Total void percent | Aggregate angularity number |
|--------------|--------------------|----------------------------|
| Grading 1    | 37.5%              | 4                          |
| Grading 2    | 39.5%              | 6                          |
6.2. Compressive Strength
Table 5 shows the compressive with various mixture proportions. The specimens with all the two selected size of aggregate followed the same trend. It is observed that compressive strength is slightly effected as the mixture proportions changed.

| Mix      | R1  | R2  | M1F-0.5% | M1F-1% | M2F-0.5% | M2F-1% | B1F-0.5% | B1F-1% | B2F-0.5% | B2F-1% |
|----------|-----|-----|----------|--------|----------|--------|----------|--------|----------|--------|
| Concrete compressive strength | 11.1 | 10.4 | 11.2 | 11.15 | 10.45 | 10.48 | 11.25 | 11.26 | 10.45 | 10.47 |
| Difference compared with R1 and R2 | 0 | 0 | +0.9 | +0.45 | +0.48 | +0.77 | +1.35 | +1.44 | +0.48 | +0.67 |

6.3. Splitting tensile strength
The splitting tensile test results are shown in table 4. The tests results indicate that the splitting tensile strength was increased by (6.36 % to 27.67 %) as fibers were added.

| Mix      | R1  | R2  | M1F-0.5% | M1F-1% | M2F-0.5% | M2F-1% | B1F-0.5% | B1F-1% | B2F-0.5% | B2F-1% |
|----------|-----|-----|----------|--------|----------|--------|----------|--------|----------|--------|
| Concrete compressive strength | 2.53 | 2.05 | 2.83 | 3.21 | 2.32 | 2.52 | 2.71 | 2.23 | 2.25 | 2.48 |
| Difference compared with R1 and R2 | 0 | 0 | +11.9 | +26.9 | +13.2 | +22.9 | +6.36 | +27.67 | +9.76 | +20.97 |

6.4. Flexural strength
The flexural strength of pervious concrete was increased by (11.37 % to 24.17 %) when adding fibers as shown in table 7.

| Mix      | R1  | R2  | M1F-0.5% | M1F-1% | M2F-0.5% | M2F-1% | B1F-0.5% | B1F-1% | B2F-0.5% | B2F-1% |
|----------|-----|-----|----------|--------|----------|--------|----------|--------|----------|--------|
| Concrete compressive strength | 2.11 | 1.82 | 2.4 | 2.62 | 2.15 | 2.25 | 2.35 | 2.61 | 2.08 | 2.19 |
| Difference compared with R1 and R2 | 0 | 0 | +13.75 | +24.17 | +18.13 | +23.63 | +11.37 | +23.7 | +14.29 | +20.33 |

6.5. Permeability, porosity and density
The permeability of PC is increased as the size of gravel increased. This is due to the increase in volume of voids presented in aggregate. The increase of PC density is a logical result of the increase of porosity as the aggregate size increased. Density, Porosity and permeability is slightly effected by fiber type an volume fraction. The results of density, porosity and permeability are presented in table 8.
Table 8. Permeability, porosity and density

| Mix     | R1  | R2  | M1F-0.5% | M1F-1% | M2F-0.5% | M2F-1% | B1F-0.5% | B1F-1% | B2F-0.5% | B2F-1% |
|---------|-----|-----|----------|--------|----------|--------|----------|--------|----------|--------|
| Density kg/m³ | 2125 | 2100 | 2128     | 2130   | 2102     | 2104   | 2127     | 2129   | 2102     | 2103   |
| Porosity %    | 19.51 | 20.84 | 19.33    | 20.53  | 20.90    | 19.58  | 19.81    | 21.12  | 21.18    |
| Permeability (cm/s) | 0.907 | 1.094 | 0.905    | 0.904  | 1.093    | 1.09   | 0.906    | 0.904  | 1.092    | 1.091  |

7. Conclusion

- According to the permeability of Pervious concrete, it presents an efficient solution for most of runoff cases.
- PC permeability increases as the size of aggregate increases.
- The use of (superplasticizers) in pervious concrete results in mix segregation.
- The mixture proportion for pervious should be carefully selected to insure uniform distribution of matrix components.
- Plastic fiber has slight effect on PC compressive strength.
- The addition of recycled plastic fibers to PC increase its tensile strength by (6.36% to 27.67%).
- The addition of recycled plastic fibers to PC increase its flexural strength by (11.37% to 24.17%).

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