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Improving the mechanical behavior of pervious concrete using polypropylene and waste rope fibers

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ABSTRACT

Urbanization has led to the damage of infrastructure due to floods and water accumulation on roads and sidewalks. To address this problem, pervious concrete was designed to drain water smoothly. However, pervious concrete has certain drawbacks, such as brittleness and poor tensile strength. To overcome these shortcomings, it is reinforced with fiber. Polypropylene fibers are commonly used for this purpose. On the other hand, managing waste plastic is a major problem as it has a significant environmental impact and requires large areas for landfills. Waste rope fibers (WRF) are among these wastes. There have been very limited investigations on the use of WRF in pervious concrete. Therefore, this study aims to investigate the effect of polypropylene (PP) fibers and waste rope fibers (WRF) on the mechanical and structural properties of pervious concrete. PP and WRF fibers were added in proportions of 0.25%, 0.5%, and 0.75% by volume of concrete. A range of tests (compressive strength, tensile strength, density, permeability, load-deflection behavior, and ductility) were conducted to evaluate the resulting concrete. The results indicated that although the permeability was decreased by adding fibers, the fibers significantly improved the mechanical and structural properties of pervious concrete. The highest values for compressive strength, splitting tensile strength, and ultimate load were 83.4%, 72.4%, and 89.62% for PP fibers-based mixtures, while they were 49.9%, 41.9%, and 102.83% for mixtures made with WRF at an addition rate of 0.5% for both types of fibers. The results also demonstrated that the existence of fibers improved the ductility of the concrete, which means that WRF can be used successfully in producing eco-friendly pervious concrete with better performance than the control specimen.

1. Introduction

The rapid urbanization of recent decades has led to a corresponding increase in the number of roads, sidewalks, and parks. One of the primary troubles related to this is the accumulation of water on its upper surface.

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Nomenclature:

A	specimen area (mm^2)	k	permeability coefficient (mm/s)
D_I	ductility index	L	specimen length (mm)
D_u	ultimate deflection	t	discharge time (s)
Dy	deflection at yield	V	volume (mm3)
h	column height (mm)		

Many sidewalks in the city cover around 20-40% of the area, preventing rainwater from infiltrating the soil underneath [1], [2]. This leads to flooding in urban areas, causing damage to the infrastructure and becoming a serious problem for citizens who lose access to clean water. The standing water eventually turns into wastewater, which increases the risk of contamination [2]. Thus, it became important to develop suitable material to cover these problems. Depending on the idea of draining out the water to the underlying layers, previous concrete was studied to address the problem. Pervious concrete is an eco-friendly material that reduces heat island effects, enhances slip resistance, and sound absorption, and offers better permeability due to its porous structure [3]. It has become popular for use in permeable paving systems in urban areas [4]. Pervious concrete is designed with interconnected voids ranging from 2 to 8 mm to allow effective passage of water. Its high porosity results in a reduced mechanical strength [5]. The pore content in the pervious concrete ranges from 15 to 35% with a compressive strength within the range of 2.8 MPa to 28 MPa [6]. To achieve permeability, it is usual to use coarse aggregate with an open-grade structure and minimal or no fine aggregate [7], [8].

According to Li 2023 [9], the previous works have primarily focused on the compressive strength of pervious concrete and its correlation with permeability. However, in paving design, especially for permeable brick or slabs, it is equally important to consider tensile strength. Recently, researchers have been exploring new methods to enhance the performance of concrete, and adding fiber has emerged as an effective solution. Chavana et al. 2019 [10] used polypropylene fiber in pervious concrete with ratios of 0.2, 0.4, and 0.6% by the weight of cement. The study found that adding 0.6% fiber resulted in a 21.87% increase in compressive strength. Additionally, there was a 10.79% increase in flexural strength and a 35.78% increase in split tensile strength. However, the coefficient of permeability decreased with an increase in polypropylene fiber. Ozel et al. 2022 [11] conducted a study on the mechanical performance and permeability of pervious concrete with fibers. They used different aggregates such as pumice, limestone, and basalt, along with fibers like steel fibers and polypropylene at 0.5% by volume. Their laboratory investigation showed that pervious concrete specimens are suitable for structural applications. These specimens achieved compressive strength, flexural strength and split tensile strength of 8.8 MPa, 3.0 MPa, and 2.2 MPa, respectively. The fiber-reinforced mixtures had high deflection capacity, which is crucial for pavements exposed to fatigue stresses. The inclusion of steel fibers enhanced the resistance to abrasion, while polypropylene fibers improved permeability performance. Wu et al. 2023 [12] executed a study on the effect of polypropylene fiber content (ranging from 0 to 9 kg/m^3 in increments of 3 kg/m^3) on the pervious concrete performance. The results of the study showed that when the amount of fiber used was 6 kg/m^3, the axial compressive strength, cubic compressive strength, and bending tensile strength increased by 37.16%, 35.32%, and 13.04%, respectively, when compared to the fiber-free mixture. However, the coefficient of permeability and porosity decreased by 49.30% and 36.32%, respectively.

One of the major problems of the environment is plastic waste because it takes a long time to decompose [13]. This makes it challenging for governments and scientists to manage. However, reusing plastics in other industries or converting them into valuable materials can help solve this problem. The construction sector is a promising area for the reuse of plastic waste. For instance, the characteristics and behavior of pervious concrete with expanded polystyrene (EPS) aggregate in addition to polyethylene terephthalate (PET) as waste plastic fiber, was investigated in 2020 by Ali et al.[14]. The findings indicated that the pervious concrete density and compressive strength were reduced by incorporating EPS and PET fibers. However, the addition of PET fibers led to increase the flexural strength up to 1%. In addition, concrete porosity and the coefficient of water permeability increased by adding PET fibers. In 2020 the impact of adding steel fibers (STF) and waste plastic fibers (WPF) by (1 and 2)% was explored by Toghroli et al. [15] on recycled aggregate pervious concrete. Results showed that there was a significant improvement in compressive and flexural strength when 2% of STF were added, by 65% and 79% respectively compared with non-reinforced concrete. However, reinforced mixtures with WPF did not perform as well as those with STF.

Recycling is a recent technique, where the waste materials are used to provide new products in order to control the detrimental effect of environmental pollution and provide a substitute for new fresh natural sources[16]. Previous studies have shown that recycled fibers can be used in the concrete industry to contribute to reducing the environmental impact and the disposal of waste in landfills[17]. Rope fiber waste is one of plastic waste types that has been studied previously, which comes from cutting nylon ropes into small pieces. Previous research has examined the influence of waste rope fibers (WRF) on different properties of concrete or mortar in concrete technology [18], [19]. Abdulridha et al. 2022[18] studied the influence of using different percentages of WRF (by concrete weight) which were (0%, 0.25%, 0.5%, and 1%) on concrete properties. It concluded that the maximum increase in compressive and flexural strengths due to adding WRF were 22% and 4.3%, respectively. Also, the findings indicated that WRF addition by 0.5 was the optimum ratio to enhance the mechanical strength and the ductility of the beams. Abeer et al. 2023[20] examined the influence of using two different fiber types which are Steel Waste Fiber (SWF) and Rope Waste Fiber (RWF) on the mechanical properties of concrete with recycled aggregate. It is concluded that adding 1% fiber (steel and plastic together) led to improved compressive strength. Most previous studies have focused on the use of steel, polypropylene, plastic waste, and PET fibers to enhance the performance of pervious concrete. However, according to the author's knowledge, no research has been conducted on the potential benefits of using fibers from rope waste to improve the properties of pervious concrete. Therefore, this is the authors' contribution to the field. Moreover, few investigations have addressed the effect of polypropylene (PP) fibers with rope waste fibers on the mechanical properties and structural performance of pervious concrete. Therefore, this study aims to explore how the permeability, compressive and tensile strengths, density, load-deflection, and ductility behavior of pervious concrete are affected by the amount and type of plastic fibers (PP and WRF).

2. Materials and methods

Portland limestone cement was used for the preparation of all mixes. Its chemical composition and physical characteristics were conformed with

EN 197-1 [21]. These properties can be shown in Tables 1 and 2, respectively. Crushed gravel with grading of 5-19 mm conformed to Iraqi specification No.45 [22] was utilized as a coarse aggregate.

Two types of fibers were used in this study; polypropylene (PP) and waste rope fibers (WRF) as shown in Fig. 1. The properties of polypropylene fibers are displayed in Table 3. The WRF fibers were secured by cutting nylon rope fibers into small pieces (0.38 × 15 mm) [23].

Table 1. Chemical composition of cement

Oxide Composition	Content (%)	Limit of BS EN 197-1
Lime (CaO)	62.79	----
Silica (SiO_2)	20.58	----
Alumina (Al_2O_3)	05.60	----
Magnesia (MgO)	02.79	----
Iron Oxide (Fe_2O_3)	03.28	----
Sulfate (SO_3)	02.35	≤ 3.5
Insoluble Residue (I.R)	01.00	----
Loss on Ignition (L.O.I.)	01.94	----
Chloride content	00.02	≤ 0.1 %

Table 2. Physical Characteristics of Cement

Physical Properties	Test result	Limit of BS EN 197-1
Setting time (hr: min.):		
Initial	122	≥ 60 min.
Final	3:13	----
Specific Surface Area, m^2/kg	314	----
Compressive Strength (MPa) at:		
2 days	21.0	>10.0
28 days	45.8	≥42.5

Seven concrete mixtures were made for this study. One control (reference) mixture was cast without fibers, while fibers were added to the other six mixes. Two types of fibers were utilized: PP and WRF. Each type of fiber was employed in three volumetric ratios (0.25, 0.5 and 0.75) %.

Figure 1. Polypropylene (on left) and waste rope (on right) fibers

Table 3. Properties of polypropylene fibers according to the manufacturer

Property	Specifications
Tensile strength	320-400 MPa
Diameter	38 µm
Length	13 mm
Young modulus	3.5 - 3.9 GPa
Density	910 kg/m^3
Elongation at break	12%-14%

The compositions for the pervious concrete mixture were comprised of cement (370 kg/m^3) with gravel/cement and water/cement ratios of 4:1 and 0.3 respectively. The details for all mixtures are explained in table 4.

A planetary mixer was utilized to blend the mix raw materials according to the subsequent procedures (which are chosen after several trials by trial and error method):

- The dry components were introduced into the mixer and blended for 0.5 minutes.
- Subsequently, the mixing water was introduced to the dry components and agitated for one minute.
- Regarding fibers, while the mixer was running for 2.5 minutes, fibers were introduced during the first 0.5 minutes of this time frame and mixing continued until the end of the above period.

Once the mixing process was completed, the prepared mix was put into molds and compacted using an electric vibrator. Following a period of approximately 24 hours, the molds were extracted, and the samples were submerged in a water tank until the age of examination. Three types of specimens were cast for each blend: one slab (700×700×70) mm³ for observing mechanical behavior (load-deflection behavior and ductility), six cubes (150×150×150) mm³ for compressive strength testing at 7 and 28 days, and three cylinders (100×200) mm² for splitting tensile strength and permeability tests. There are new techniques that use optical method to test brittle materials [23-24]. ASTM C496 and BS EN 12390-3 specifications were adopted for the splitting tensile strength and compressive strength tests [25]. Linear variable differential transformers (LVDTs) were used for calculating the deflections at each mid-span of the slabs as in Fig. 2.

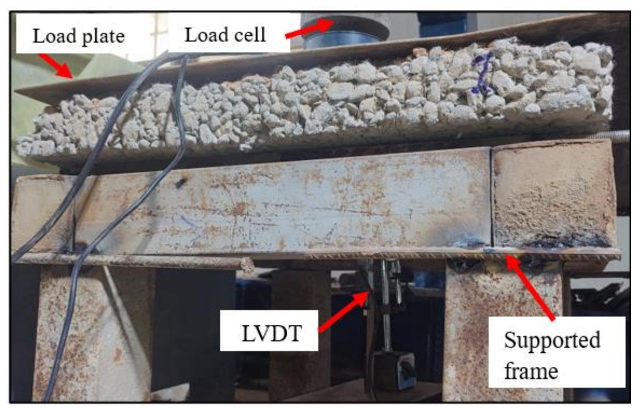

Figure 2. Previous concrete slabs under load

The permeability test of the previous concrete was performed using the following equation [26]:

$$k = \frac{V \cdot L}{h.A.t} \quad (1)$$

Where V is the volume in mm^3, L is the specimen length in mm, h is the column height in millimeters (885 mm), A is the specimen area in mm^2, and t is the discharge time in seconds and k is the permeability coefficient (mm/s). The device that is used for the permeability test is shown in figure 3, which is used to measure the water volume instead of height. The test was carried out according to the ACI 522R-10 [27] depending on the falling head concept.

Figure 3. Permeability device

Table 4. Mix proportion details (kg/m^3)

Mix designation	Cement	Coarse aggregate	Fiber content, %		Water/cement
			PP	WRF	
Control	370	1480	0	0	0.3
0.25PP	370	1480	0.25	0	0.3
0.50PP	370	1480	0.50	0	0.3
0.75PP	370	1480	0.75	0	0.3
0.25WRF	370	1480	0	0.25	0.3
0.50WRF	370	1480	0	0.50	0.3
0.75WRF	370	1480	0	0.75	0.3

3. Results and discussion

3.1. Compressive strength

The compressive strength test findings are presented in Fig. 4. It was observed that, at 7 days of age, the addition of fibers enhanced the compressive strength of the previous concrete. The degree of improvement in strength varied depending on the type of fibers used. The highest improvement rates were achieved using 0.5% fibers for both PP and WRF, with rates of 144.2% and 165.9%, respectively. On the other hand, the lowest improvement in compressive strength compared to all other mixtures was recorded in the 0.75% WRF mixture, which was higher than the control sample by 2.6%. This improvement in compressive strength can be ascribed to the fact that the addition of fibers strengthens the fiber matrix bond by bridging the cracks and distributing internal stress over a larger area [15], [28] [29].

Furthermore, At the age of 28 days, some mixtures showed improvement with fiber, but others had a negative effect. For instance, when PP fibers were added at the lowest rate of 0.25%, the compressive strength was reduced by 18.5%. The weak bond among the aggregate, cement, and fibers caused decreased compressive strength [30][due to low PP fiber and cement content and high voids. However, at higher percentages (0.5% and 0.75%), the compressive strength significantly increased. The improvements in strength compared to the control sample were 83.4% and 28.4% for fiber ratios of 0.5% and 0.75%, respectively.

In contrast, the WRF exhibited a rise in compressive strength when added in ratios of 0.5% and 0.25% (by 30.4% and 49.9%, respectively). However, when added at a ratio of 0.75%, the compressive strength declined by 32.9% in comparison to the reference specimen. The presence of fibers in concrete in high proportions can lead to the occurrence of defects (voids) at the interface with plastic surfaces, resulting in weak areas and the propagation of cracks. This is accompanied by the high content of voids in previous concrete which also reduces its compressive strength. Similar findings were recorded in the literature [18], [31], [32].

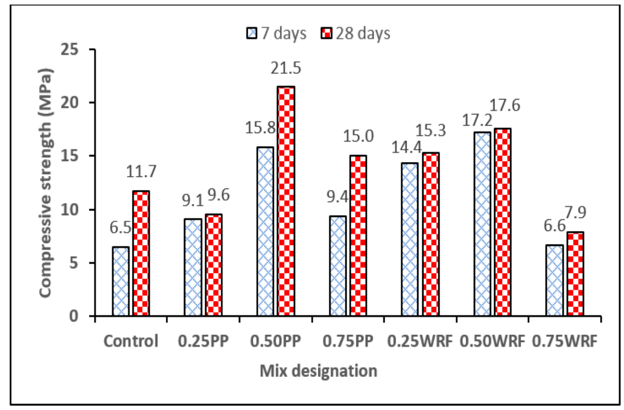

Figure 4. Compressive strength results of pervious concrete mixtures at 7 and 28 days

3.2. Splitting tensile strength

The results of the tensile strength test are displayed in Fig 5. Generally, the results indicated that the splitting tensile strength followed a path similar to the compressive strength (at 28 days); the tensile strength decreased at the low addition of PP fibers (0.25%) and the high addition of WRF fibers (0.75%). At the same time, it improved for the other addition percentages. The mixtures containing 0.25% PP fibers had a 19.2% decrease in tensile strength compared to the reference mixture. However, higher percentages of additions (0.5 and 0.75%) resulted in a significant increase in tensile strength, with a 72.4% and 47.5% boost, respectively. On the other hand, mixtures containing WRF showed a 2.7 and 41.9% increase in tensile strength at 0.25 and 0.5% addition rates compared to the control sample. The improvement in the tensile strength of concrete can be attributed to the incorporation of PP WRF fibers. They possess a significant function in the even distribution of internal stresses, the prevention of crack formation, and the reinforcement of cracks as they propagate [33]. However, the high fiber rate (0.75%) of WRF displayed a slight decline in tensile strength by 2.9%.

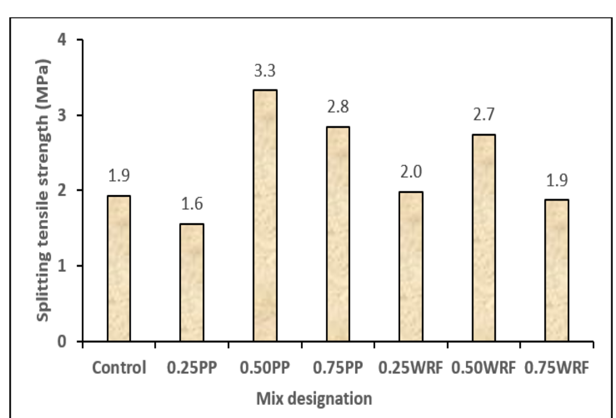

Figure 5. Splitting tensile strength results of previous concrete mixtures at 28 days.

3.3. Density

In Fig. 6, the results of the density test are displayed. The findings indicated that when PP fibers were added to the mixtures at a rate of 0.25%, the density dropped by 4.4% compared to the reference one. However, the ratios of 0.5% and 0.75% showed an increase in density by 10% and 5.5%, respectively. Regarding WRF-based mixtures, it was discovered that up to 0.5% addition did not have a significant impact on density, with the amount of increase not exceeding 1.9%. However, the mixture that contained 0.75% showed a decrease in density by 5.9%. Based on the information presented, it can be inferred that the density outcomes for all concrete blends adhered to the pattern of compressive strength, either increasing or decreasing. This is because density and compressive strength have a direct correlation [34].

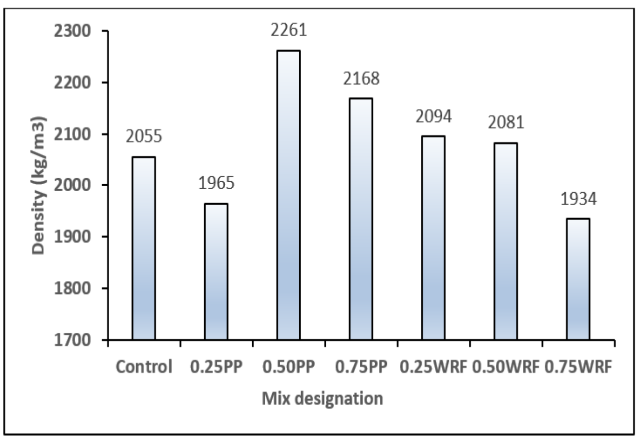

Figure 6. Density outcomes of pervious concrete mixtures at 28 days

3.4. Permeability

Permeability is a crucial characteristic of pervious concrete designed to facilitate percolation runoff. Therefore, it must meet specific permeability requirements [15]. According to the literature, the permeability coefficient's minimum value is 1.3 mm/s [15], [35]. The results of the water permeability test are shown in figure 7. It was found that adding a small amount of fibers (0.25%) enhanced the permeability of the pervious concrete for both types of fibers. The improvement rate was 57.1.9% for PP fibers and 18.9% for WRF. However, increasing the fiber content resulted in a decrease in permeability. The decrease rate ranged from 57.9% to 42.5% for PP fibers and 12.2% to 32.6% for WRF fibers, with fiber contents of 0.5% and 0.75%, respectively. These findings are consistent with the existing literature [36]. It is believed that the reason for reducing the permeability of the high percentage addition of fibers is that the fibers hinder or slow down the flow of water through the pervious concrete, which results in a longer time needed for water drainage. However, further and in-depth studies are necessary to substantiate this belief.

Furthermore, out of all the permeable concrete mixes tested, only the control, 0.25PP, 0.25WRF, and 0.50WRF exceeded the minimum permeability coefficient of 1.3 mm/s. The other mixes had low values. The 0.50PP mixture had the lowest water permeability coefficient of 0.74 mm/s, but it also had the highest compressive strength. This suggests that the PP fibers tightened the concrete matrix and reduced the voids, resulting in higher strength and lower permeability.

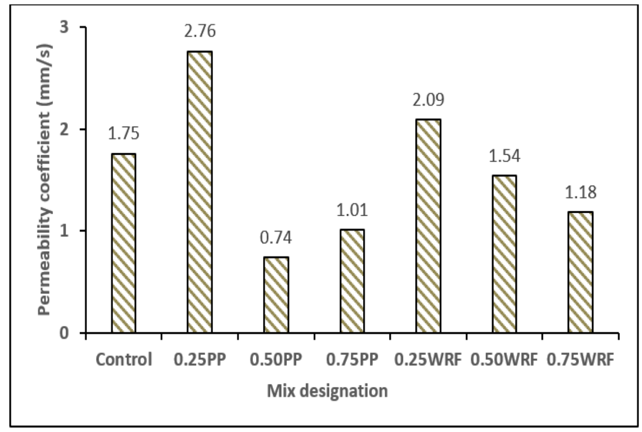

Figure 7. Permeability coefficient results of pervious concrete mixtures at 28 days

3.5. Load–deflection behavior

Figure 8 presents the load-deflection behavior for all concrete specimens. The results indicated that the reference slab model (control) failed at a deflection of 10 mm much less than all models containing rope waste fibers. This gives an initial impression of the ability of rope waste fibers to improve the ultimate deflection condition of the concrete models adopted in the current work. The ultimate increase in percentages of occurred deflections (figure 9) compared with the specimen with no fibers were (87.02, 50.90, and 52.36 %) for specimens (0.25WRF, 0.50WRF, 0.75WRF), respectively. Where in percentages of WRF (0.5 and 0.75%) the increasing percentages were so close, indicating that increasing the percentage of rope fibers from 0.50% to 0.75% has a slight effect on the deflection. The results declared adding (0.25% WRF) could greatly enhance the ability of the pervious slab specimen to deflect, as the fibers of the ropes increase the binding of the sample particles and delay the occurrence of the failure process. Where increasing the amount of waste rope fibers requires a larger amount of binder for it to be an effective material capable of completing the bonding process and delaying failure.

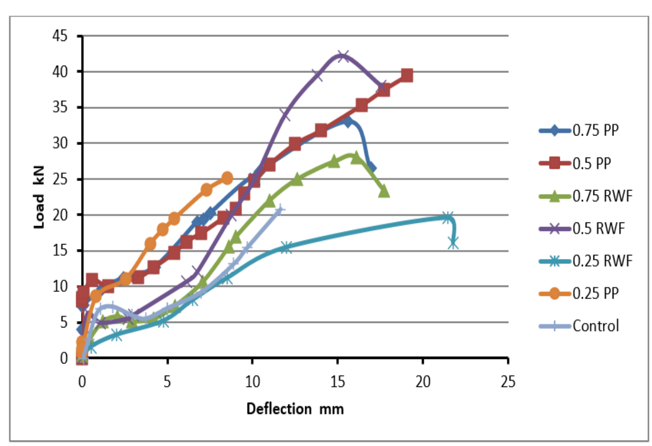

Figure 8. Load – deflection results of the specimens with and without fibers

It is known that pervious concrete in general has an insufficient amount of binder material that is capable of binding the concrete matrix as the ratio of rope fibers increases. The ultimate increase in percentages of occurred deflections compared with the specimen with no fibers were (63.97, and 45.57 %) for specimens (0.50 % polypropylene, 0.75 % polypropylene) respectively. So, adding 0.50% polypropylene fibers enhances the capability of the pervious slab specimen for more deflection. While the specimen of (0.25 polypropylene) has a decrease in deflection with a percentage of 26.66%. Therefore, the effect of fibers added to pervious concrete may be restricted or related by several factors, such as the random distribution of fibers within the concrete matrix [37].

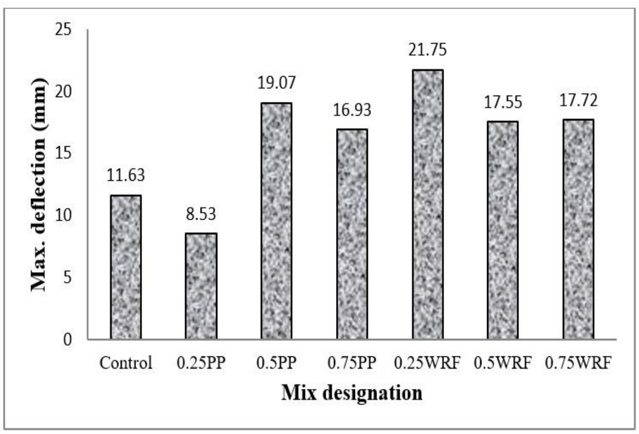

Figure 9. Maximum deflection diagram of the control, PP and WRF specimens

In general fiber-reinforced pervious slab specimens accomplished a high ability to deflect which is compatible with previous conclusions [11].

On the other hand, adding fibers also affects the load capacity of the pervious concrete specimen, see figure 10. Adding (0.50WRF and 0.75WRF %) increases the maximum load capacity with percentages of (102.83% and 34.91%). Also adding (0.25, 0.50, and 0.75 %) polypropylene fibers increases the load capacity of specimens by about (21.23, 89.62, and 58.96 %). It could be noted the ratio of 0.50WRF added showed the largest increase in load capacity by about double the capacity of pervious concrete specimens free from fibers. Likewise, the adding ratio of 0.50% polypropylene fibers showed slightly less than double the load capacity of specimens free from fibers. Enhancing the load capacity of concrete slab specimens containing fibers as presented in the current study agreed with numerous previous studies [37], [38], [39], [40], [41].

Therefore, the effect of fibers added to pervious concrete may be restricted or related by several factors, such as the random distribution of fibers within the concrete matrix. Due to the nature of pervious concrete which has little amounts of fine particles and rather large pores, using fibers to enhance its strength nowadays represents a challenge for the interested researchers.

3.6. Ductility

The ductility of a reinforced concrete slab could be defined as its ability to resist additional load and deflection capacity in the inelastic domain [18], [42]. In general, this property could be tracked when using fibers with concrete where logically the fibers may enhance in some manner the ductility [43]. The ductility can be measured in terms of the curvature or terms of the deflection, whereas the second one is more applicable, so it is dependent on the present work. To evaluate the ductility of a member two important parameters to be specified precisely. The first one is the ultimate deflection stated before the final failure (Du), while the second one is the deflection at yield (Dy). Most studies prefer determining ductility index (DI)in a dimensionless form as shown below:

$$D_I = \frac{D_u}{D_y} \quad (2)$$

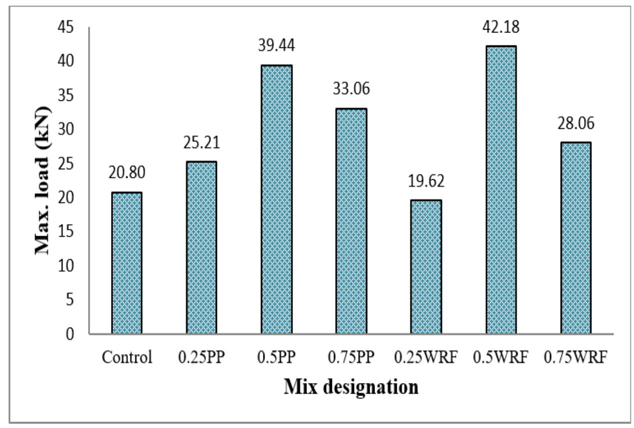

Figure 10. Maximum load diagram of the control, PP and WRF specimens

The ultimate deflection could be stated easily during the test of the specimen. The deflection of the specimen at the yield stage is rather complicated or cannot be specified directly from the load versus deflection diagram. To some extent, a practical specification of Dy among numerous methods is to determine it depending on the equivalent elastoplastic scheme as shown in figures 11 and 12, where Dy is specified as the secant stiffness at 75% of maximum load. This technique was adopted for specifying Dy because it takes into account reducing the stiffness by cracking [44]. Generally, the pervious concrete type has low ductility because of the small volume of the paste matrix, whereas in the present study, it was (1.13) for the free fiber specimen. Adding fibers (polypropylene or waste rope) introduces some improvement in this characteristic. The maximum percentage of ductility increasing was 31.04% when adding 0.25% WRF, and it was 15.68% when adding 0.25% PP, track table 5. This indication is compatible with previous works that clarified the enhancement of the ductility of structural elements incorporating fibers such as polypropylene, waste rope fibers, and steel fibers [18], [45], [46], [47], [48], [49]. At higher percentages of added fibers, the DI_u is slightly improved, it may be due to little fine material available to cover these fibers and provide a chance for the added fibers for restriction action.

3.7. Modes of failure and crack pattern

During the testing of slabs under static loading, it observed that the cracks are formed in star shape for all specimens. Where, the first cracks formed in the center part of the bottom surface and then the cracks be wider and propagated toward the edges at higher loading stages. Finally, the slab failed.

In general, the using of fibers was limited the growth for the cracks and decreased their width. But, at final stage for the slabs with 0.25% of fiber (PP or WRF) were failed in concrete crushing (as the reference slab) which is the unwanted brittle failure.

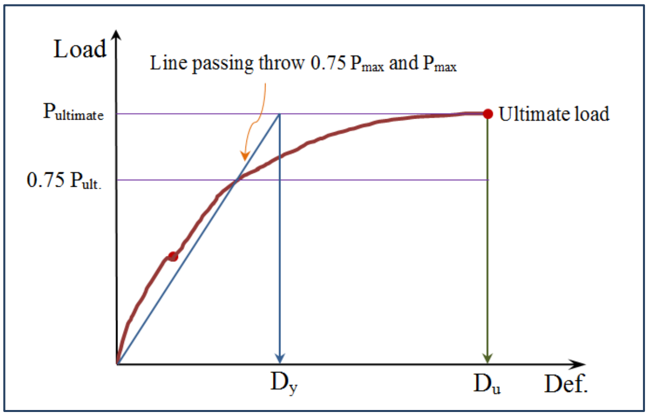

Figure 11. Parameters necessary to determine DI_u

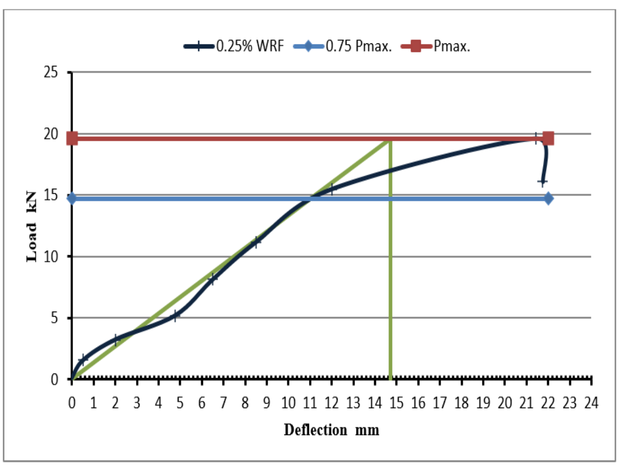

Figure 12. Scheme of specifying DI_u of 0.25 % WRF specimen

Figure 13. Crack pattern at failure of 0.5 % PP specimen

Figure 14. Crack pattern at failure of 0.5 % WRF specimen

Figure 15. Crack pattern at failure of 0.75 % PP specimen

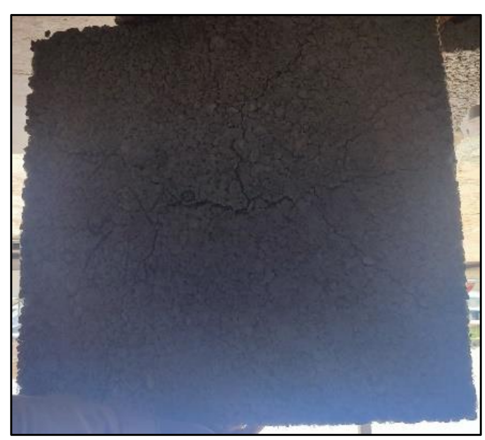

Figure 16. Crack pattern at failure of 0.75 % WRF specimen

On the other hand, the increase of fiber ratio from 0.25% to 0.5 and 0.75 % led to a change in the failure mode from crushing to flexure mode and that must be attributed to the ability of fiber to arrest and disperse the developing of micro-cracks in the sample under the applied load. Figures 13-16 show the crack pattern of slabs with (0.5 and 0,75) % after failure. Therefore, it can be said that using fiber ensures the desirable ductile flexural behavior which is compatible with flexural failure control.

Table 5. Ductility indexes of previous concrete slab specimens

Specimen	Dy	Du	DI_u = Du/ Dy	% DI_u Increase from Control
Control	10.30	11.63	1.13	00.00
0.25% WRF	14.70	21.75	1.48	31.04
0.50% WRF	15.00	17.55	1.17	03.62
0.75% WRF	15.40	17.72	1.15	01.91
0.25% PP	07.22	08.53	1.18	04.63
0.50% PP	14.60	19.07	1.31	15.68
0.75% PP	13.00	16.93	1.30	15.34

4. Conclusions

Based on the findings from the experimental examination, the following conclusions were reached:

1. The addition of PP and WRF fibers enhanced the compressive strength of the previous concrete at early ages (7 days). This improvement was sustained even after 28 days, except for the 0.25PP and 0.75WRF blends, which decreased the strength by 18.5 and 32.9%, respectively. The mixture containing 0.5% fiber yielded the highest compressive strength, with an increase of 83.4% and 49.9% compared to the control concrete for the 0.50PP and 0.50WRF mixtures, respectively.
2. At 28 days, the impact of fibers on splitting tensile strength followed the same trend as compressive strength for all percentage additions. Among the mixtures, 0.50PP and 0.50WRF showed the greatest improvement in tensile strength, with an increase of 72.4% and 41.9%, respectively, compared to fiber-free concrete.
3. The addition of PP and WRF fibers to previous concrete had a negative impact on its permeability when added at 0.5% and 0.75% proportions. However, the addition of these fibers at a lower proportion (0.25%) improved the permeability. The 0.50PP mixture had the highest reduction in permeability, while 0.25PP had the highest improvement. However, the mixtures containing 0.25PP, 0.25WRF, and 0.50WRF were found to meet the minimum permeability requirements mentioned in the literature for permeable concrete.
4. Regarding density, the addition of fibers has a similar impact as compressive strength and splitting tensile testing, particularly with PP fibers. The density increased at 0.5% and 0.75% additions for PP fibers and at 0.25% and 0.5% for WRF fibers. The most significant increase in density (10%) was observed with a 0.50PP mixture, while the smallest decrease in density (5.9%) was seen with a 0.75WRF mixture.
5. The addition of PP and WRF fibers could greatly enhance the ability of the pervious slab specimen to deflect with maximum enhancement percentages of 87.02 and 63.97% for 0.25WRF and 0.50PP mixtures, respectively.
6. Using of fibers increases the ultimate load capacity of pervious concrete. The maximum improvement was recorded at 0.50% addition for both types of fibers. The increment values were 102.83% for 0.50% WRF and 89.62% for 0.50% PP.
7. Adding fibers (polypropylene or waste rope) to the pervious concrete slab specimen improves its ductility. The maximum percentage of ductility increasing was 31.04% when adding 0.25% WRF, and 15.68% when adding 0.5% PP.

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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Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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