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Plastic Waste for the Enhancement of Concrete Properties - A review

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Abstract

Abstract. The consumption of different forms of plastics is interesting to the environmental protection subject. The increasing use of plastics in many areas of human daily life results in the accumulation of plastic waste in the environment. The introduction of plastic waste in concrete is a solution to preserve the environment and reduce the cost of concrete.

This paper presents an overview of some published research regarding the use of waste plastic in concrete. we present the work of many researchers on the valorization of plastic waste in concrete in different forms as a partial replacement of fine and coarse aggregate as well as fibers and their effects of waste plastic addition on the fresh, mechanical, and durability of concrete. The research work seems interesting, which shows the possibility of recycling plastic waste in concrete. However, it will be interesting to explore the combined uses of plastic as aggregate and fiber in concrete, which allows a possible recovery of additional quantities of plastic waste in concrete.

Keywords: *fiber in concrete, plastic waste, recycling, concrete properties, waste management.*

1. Introduction

Plastics have become an inseparable and integral part of our lives. The quantity of this material consumed annually has increased steadily. Its less density, user-friendly designs, manufacturing capabilities, long life, lightweight, and low costs are the factors that explain this phenomenal growth. Siddique et al (2008) have described that plastics have been used in packaging, automotive and industrial applications, medical distribution systems, other health applications, water desalination, soil conservation, flood prevention, food transport, and other uses. A large amount of plastic waste is produced each year.

We estimate that 8300 million metric tons (Mt) of virgin plastics have been produced to date. As of 2015, approximately 6300 Mt of plastic waste had been generated, around 9% of which had been recycled, 12% was incinerated, and 79% was accumulated in landfills or the natural environment. If current production and waste management trends continue, roughly 12,000 Mt of plastic waste will be in landfills or the natural environment by 2050 (Geyer et al., 2017).

Diverse usage and manufacturing of plastics in large quantities are considered the source of the environmental waste plastic problem, which the man focalized to reduce the impact of waste plastic (Singh et al., 2017). Recycling by using plastic waste in concrete in different forms is one of the solutions adopted by many searchers. Ismail and AL-Hashmi, (2008) used a plastic waste composed of about 80 % polyethylene and 20 % polystyrene with a variable length of 0.15- 12 mm and a width of 0.15 to 14 mm for different colors as a partial replacement of sand in the concrete. Rahmani et al., (2013), studied the use of plastic waste (Polyethylene terephthalate PET) as a partial substitute for fine aggregate with a maximum size of 7 mm. Usman et al (2015), used polyethylene bags in concrete to replace coarse aggregates. The workability, density, compressive and flexural strength, water permeability, static and dynamic modulus of elasticity, and abrasion resistance properties of concrete were investigated in the study of (Jain et.al, 2019) by adding different percentages (0, 0.5, 1, 2, 3 and 5%) of waste plastic bags by weight of concrete. Abu-Saleem et al., (2021), concluded that using plastic waste as a partial replacement for natural coarse aggregate up to 20% satisfies the concrete bloc design requirement and the strength loss is not detrimental. Up to 20% replacement of PET and PP showed an improved abrasion resistance compared to the control mix. PET exhibited an acceptable drying shrinkage compared to the control mix.

Rahim et al., (2013), examined the use of high-density polyethylene (HDPE) plastic waste as coarse aggregate in concrete with a size between 4.75 mm and 20 mm. Bhogayata and Arora, (2017), examined the fresh and hardened properties of concrete reinforced with metalized plastic waste (MPW) fibers (used for wafer packaging) of 5 mm, 10 mm and 20 mm with percentages from 0 to 2 by volume of the mixture.

In this paper, we study the different forms of use of plastic waste in concrete by different researchers around the world and their effect on concrete performance. Its objective is to reduce plastic waste in the environment so can be an asset to participate in sustainable development in reducing this waste.

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2. Valorization of plastic waste as aggregates

Due to the great problems of disposal of plastic waste, it has been used in concrete by many researchers as a partial replacement for fine or coarse aggregates.

Rai et al., (2012), studied the properties of concrete mixtures with plastic waste, which replaced fine aggregate with 5 %, 10 %, and 15 % by volume. They concluded that the compressive strength of concrete decreases as the rate of waste increases. This trend could be attributed to the reduction in adhesive strength between the plastic waste surface and cement paste, as well as the increased particle size of the plastic. Ramadevi and Manju, (2012), examined the possibility of using PET bottles as a partial replacement for fine aggregate in concrete. They found that the compressive strength increased up to 2 % of (PET) fibers and gradually decreased by 4 % and 6 % of substitutions as well as tensile strength.

Saikia and Brito, (2014), evaluated the effects of the sizes and shapes of PET aggregate on the fresh and hardened characteristics. Three types of plastic waste aggregates were used in this study. One in the form of (PA) pellets replacing the fine aggregate with 5 %, 10 %, and 15 %. The other two with shredded pieces, one replacing the fine aggregate PF with 5 %, 10 %, and 15 %, and the last substituting the coarse aggregate (PA) with the same percentages. They found that the differences in size and shape of (PET) aggregates affect the slump and the abrasion resistance of concrete mixes with PET types was better than that of reference concrete. Table 1 summarizes some recent work research, that waste plastic was used as aggregate in concrete.

Table 1. Summary of some research using plastic waste as aggregate in the concrete.

Type of plastic waste	Studied %	Size of particles Studied (mm)	Optimal %	The optimal size (mm)	Reference
80% polyethylene; 20% polystyrene	0-5-15- 20	Fine (0.15–12 length; 0.15-14 width)	10	Not indicated	(Ismail and AL-Hashmi, 2008)
Polyethylene Terephthalate PET	0-5-10-15	Fine (< 7)	10	< 7	(Rahmani et al. ,2013)
High-density Polyethylene HDPE	0-10-20-30	Coarse (4.75-20)	20	Not indicated	(Rahim et al., 2013)
Plastic pallet	0-5-10-15	Fine (NI)	5	Not indicated	(Rai et al., 2012)
PET bottle	0-5-10-15	Fine (< 4; < 2) Coarse (< 16)	10	Not indicated	(Saikia and Brito, 2014)
Recycled plastic Waste	0-7.5-15	Fine (1-4) Coarse (2-11.2)	7.5	Not indicated	(Silva et al., 2013)
PET bottle	0-5-10-15-20	Fine (< 4.75) Coarse (4.75-20)	5	Not indicated	(Saxena et al., 2018)

3. The effect of replacing aggregate with plastic waste on the mechanical properties of concrete.

3.1. Properties of fresh concrete

3.1.1. Workability

Ismail and AL-Hashmi, (2008), noticed that the slump values of concrete mixtures in plastic waste tended to decrease with the increase in the rate of these wastes. This reduction might be because some particles are angular and others have non-uniform shapes. The same result was found by Rai et al., (2012).

Rahmani et al., (2013), concluded that the slump value decreased with the percentage increase in the replacement of sand by PET in both water-cement ratios of 0.42 and 0.54.

The workability of the concrete decreased when the PET content was increased. This result could be related to PET particles being more specific surfaces compared to natural sand due to their mercenary form and there would be more friction between the particles. Unlike natural, plastic aggregates do not absorb water during mixing. Shubbar and Al-Shadeedi, (2017), examined the effect of the use of PET waste as a partial replacement of fine aggregate on the mechanical properties of concrete. The results indicated that as the waste content increases, the fluidity of the concrete improves, despite the decrease in the slump value. The spherical and smooth shape of the plastic aggregate is not only the reason for this behavior but it can also be related to water not absorbed by PET waste causing some abundant water in the mixture. Usman et al., (2015), found that the workability of the mixture decreased as the polyethylene waste rate increased. But the workability can be adjusted by varying the amount of water. Hama and Hilal, (2017), concluded that the slump flow diameters of mixtures produced with coarse plastic waste were less than that produced with fine plastic waste and mixed plastic waste. Figure. 1 illustrates the results of the effect of plastic waste on a concrete slump.

3.1.2. Density

Rai et al., (2012), found that the fresh density decreased by 5 %, 8.7 %, and 10.71 % for 5 %, 10 %, and 15 % of replacement respectively. This trend could be attributed to the density of plastic waste being less than that of sand by 70 %, resulting in a reduction in the fresh density. These results were consistent with those (Ismail and AL-Hashmi, 2008).

The substitution of fine aggregate with PET waste had a measurable effect on fresh density with a downward trend resulting from the addition of plastic waste to the mixture.

The results indicated that at a PET replacement level of 1 %, 2 %, 4 % and 8 %, there was a decrease of 0.5 %, 2,8 %, 7.3 % and 9 % in the fresh density. This was due to the lighter specific gravity of the plastic aggregate, which was 13.75 % lower than the fine aggregate used (Shubbar and Al-Shadeedi, 2017). Saikia and Brito, (2014), showed that there was a reduction in the density of fresh concrete when the plastic aggregate content increased because the density of plastic aggregate particles is very low compared to natural aggregate. Silva et al., (2013), found that the wet density of concrete with plastic aggregates was significantly lower than that of control concrete, due to the lower density of plastic aggregate (PA). The loss of density was greater when progressively bigger and flakier PA was incorporated. Figure. 1 summarizes the results of the effect of plastic waste on the fresh density of concrete.

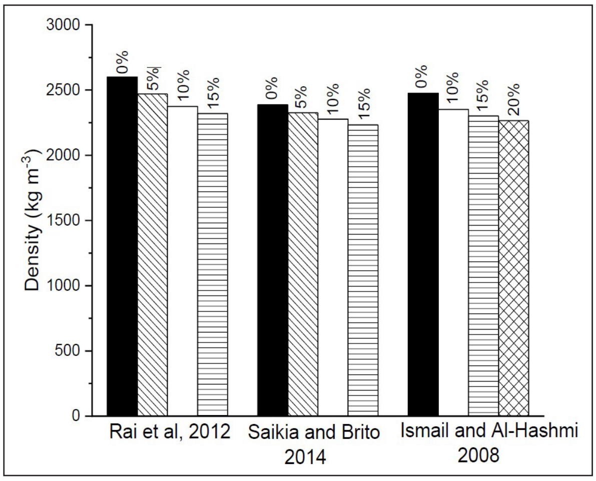

Figure 1. The effect of plastic waste on the fresh density of concrete.

3.2. Properties of hardened concrete

3.2.1. Compressive Strength

Ismail and AL-Hashmi, (2008), concluded that the compressive strength decreased with increasing plastic content for all plastic concrete mixtures at all curing ages. This could be attributed to the reduction in the adhesion strength between the plastic surface used and the cement paste. These results were consistent with those (Rai et al, 2012).

Rahmani et al., (2013), found that the replacement of 5 % of sand by PET gave the optimum strength for both mixtures and with an increase in the PET content, the resistance decreased. The results indicated that as sample sizes increase, the compressive strength decrease. Shubban and Al-Shadeedi, (2017), observed a slight increase in the compressive strength in the percentage of 1 % by 3.7 % and 1.6 % during the 7 and 28 days of hardening. But an obvious increase was observed by adding 2 % of PET waste approximated by 15 % and 13 %, respectively at 7 and 28 days. Followed by a drop to about 25 % for 8 % of replacement at both curing periods. The compressive strength of the cube increased with increasing PET waste et it gives a maximum value of 2 % PET.

Mustafa et al., (2019), found that the compressive strength of the plastic concrete decreased with the increase in plastic content. As the sand was replaced by plastic waste, the average compressive stress was reduced by 24 % with 20 % of volume replacement.

Rahim et al., (2013), concluded that the compressive strength of concrete containing aggregate (HDPE) is less retained compared to the control samples. However, the resistance decreased significantly when the proportion of HDPE was greater than 20 %. The decrease in strength might be attributed to the lower bond between the cement paste and PHD aggregate and the lower strength of the plastic.

The maximum strength obtained with 10 % replacement of bottle caps increased by 9.72 % and 5.97 % at 7 and 28 days compared to the reference concrete. (Saxena et al., (2018), concluded that the incorporation of PET plastic waste as coarse aggregate in concrete results in a decrease in compressive strength due to a poor bond between the plastic waste and the mortar paste. Figure. 2 shows the results of the compressive strength of concrete with the percentage of waste plastic replacement.

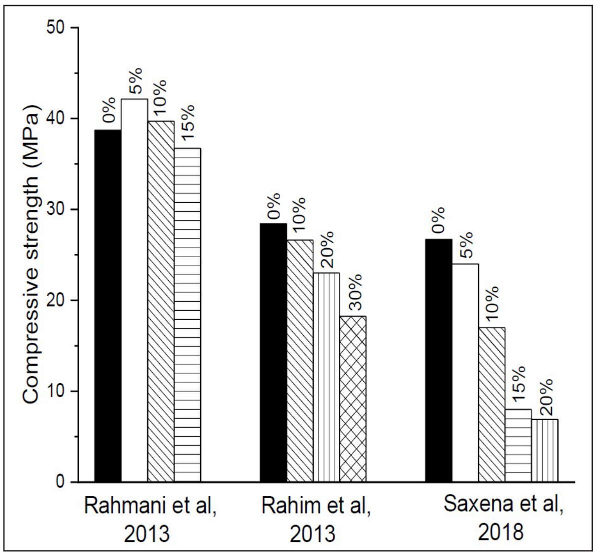

Figure 2. Compressive strength with % of waste plastic replacement at 28 days.

3.2.2. Tensile Strength

For the tensile strength, (Rahmani et al. 2013), showed a decrease in the tensile strength with increasing PET up to 15 % for the two water-cement ratios of 0.42 and 0.54. Shubbar and Al-Shadeedi, (2017), observed an increase in tensile strength by splitting with the increase in substitution of fine aggregate with PET bottles waste up to 2 % at 7 and 28 days of curing. After that, there was a decrease to obtain a minimum value of 8 % replacement. The decrease in strength could be due to the aggregate density and adhesive strength between the aggregate and the cement. Albano et al., (2009), studied the replacement of sand by PET with a grain size of 0.26 and 1.14 cm in concrete with the variation in the water-cement ratio (0.50 and 0.60).

They found that for a water-cement ratio of 0.50, there was a decrease in the tensile strength by splitting compared to the reference concrete regardless of the size of the PET added. However, when the amount of recycled PET was 20 %, the decrease was more significant because of the high porosity of the concrete may have with this amount of PET. When the water-cement ratio is equal to 0.60, the trends observed remain the same. Again, the tensile strength values decreased compared to the control mixture, but in higher amounts.

They showed that the tensile strength increased when the fine aggregate was partially replaced by 6 % of plastic. However, replacing more than 6 % decreased resistance.

3.2.3. Flexural strength

For flexural strength, (Ismail and AL-Hashmi, 2008), found that the flexural strength of plastic concrete mixes decreased with increasing plastic rates. These results were consistent with (Rai et al., 2012). Ramadevi and Manju, (2012), concluded that the flexural strength of the specimens with the replacement of the fine aggregate with PET bottle fibers gradually increased with the increase in the percentage substitution.

Shyam and Drishya, (2018), studied the replacement of fine aggregate by high-density polyethylene powder (HDPE) at percentages of 5 %, 10 %, 15 %, and 20 %. They concluded that the optimal value was obtained with a 5 % replacement of the fine aggregate by HDPE powder. The flexural strength increased to 46.34 % for 5 % of replacement and was significantly higher than that of the control samples and all other percentages of substitution. Rahmani et al, (2013), concluded that the maximum value of flexural strength is found at 10 % replacement of coarse aggregates by plastic waste.

3.2.4. Water absorption and durability

Albano et al., (2009) found that for a water-cement ratio of 0.50, the absorption percentage for mixtures with 10 % was lower than those with 20 % because to lower porosity. Also, the mixtures with PET of large particle size have higher values of water absorption. For a water-cement ratio of 0.60, trends in particle content and size were similar to those obtained for a water-cement ratio equal to 0.50. Moreover, it can be seen that for the higher water-cement ratio, the less the surface area covered by the aggregate was reduced, so reducing the amount of paste, voids, or pores in the concrete also increased the water absorption.

Saikia and Brito, (2014) concluded that the abrasion resistance of concrete mixes containing various types of PET aggregate was better than that of the control concrete. The abrasion resistance of concrete with the incorporation of various types and contents of PET-aggregates can be related to its compressive strength.

Nikbin et al., (2016) studied the feasibility of using waste polyethylene terephthalate (PET) particles to replace aggregates for acid erosion of normal and durable lightweight structural concrete. They concluded that the ultrasonic wave velocity decreased in the specimens containing more percentages of PET particles. It might be due to the higher capacity of concrete containing PET particles to resist the internal pressure caused by the expansion of cement paste and retain more integrity during the reaction to sulfuric acid, which could be related to its more porosity as accommodation for reaction products and the flexibility of PET particles.

Saxena et al., (2018) found that the addition of PET plastic waste improves the ductile behavior of the concrete and the energy absorption capacity of the plastic concrete increase with the waste plastic aggregate content in the concrete. Silva et al., (2013) concluded that the water absorption increased when replacing natural aggregates with plastic aggregates. Concrete with plastic aggregates showed higher carbonation depths and chloride migration coefficients than control concrete.

4. The effect of the use of plastic waste in the form of fibers on the concrete

4.1. Valorization of plastic waste as fiber in concrete

Concrete is characterized by several facts such as low tensile strength, low ductility, heavyweight, and low energy absorption. These disadvantages have led civil engineers to use conventional reinforcement to increase tensile strength and ductility. The notion of using fibers as reinforcement is not new.

Pesic et al., (2016) studied the mechanical properties of concrete reinforced with recycled high-density polyethylene extruded plastic fibers (PHDE). Two fiber diameters of 0.25 (AR = 92) mm and 0.40 mm (AR = 75) with three-volume fractions of 0.40 %, 0.75 % and 1.25 % were used in this study. They concluded that the introduction of PHDE fiber does not influence the modulus of elasticity and the compressive strength of concrete.

Marthong and Sarma, (2015) examined the influence of different PET fiber geometries on the physical and mechanical properties of concrete. The test results showed that the geometry of the fiber has a marginal effect on the workability of concrete. However, it plays an important role in achieving good compressive and tensile strength of concrete. Table 2 summarizes some recent work research, that waste plastic was used as fiber in concrete.

Table 2. Summary of some research on the use of plastic waste as a fiber in concrete.

Type of plastic fiber	Studied %	Size of fiber studied (mm)	Optimal %	The optimal size (mm)	Reference
PET bottle	0-0.6-0.8-1-1.2	AR= 30-50-70	1	50	(Singh et al., 2017)
Metalized plastic Waste	0-0.5-1-2	AR= 5-10-20	1	20	(Bhogoyata and Arora ., 2017)
High-density Polyethylene	0-0.4-0.75-1.25	Θ = 0.25;0.40 1.25	1.25	Not indicated	(Pesic et al., 2016)
PET bottle	0-0.5-1-1.5	AR= 1.33-1.67-2	0.5	1.33	(Shamskia et al., 2012)
PET water bottle	0-0.5-1	AR= 0.5-1-1.5	0.5	Not indicated	(Taherkhani et al., 2014)
Polyethylene LDPE	0-0.25-0.5-0.75-1-1.25	AR= 10	0.5	Not indicated	(Mohammad- hosseini et al., 2018)

4.2. Properties of fresh concrete

(Pelisser et al., (2012) showed that a greater loss of slump occurred as the fiber content increased. The concrete reinforced by PET fiber still has good workability and was easily compacted without excessive vibration. Bhogayata and Arora, (2017) found that the workability of the concrete was affected by the two test parameters, namely the fraction and type of MPW fibers. Concrete containing fibers of type A (5 mm) showed a reduction in the slump of 5 %, 8 %, 12 %, and 16 % to vary the fraction from 0.5 % to 2 %. Concrete with fibers of type B (10 mm) and type C (20 mm) reduced the slump relatively more than the first type. They concluded that a higher dosage of MPW fibers increases the viscosity of the matrix and decreases the consistency of the fresh mixture at a higher volume fraction. Marthong and Sarma, (2015) concluded that for the water-cement ratio of 0.50, the workability of concrete was slightly decreased with the inclusion of 0.5 % PET fibers. However, the geometry of the fiber had a small significant effect on the workability of the concrete. Shamskia, (2012) examined the influence of PET fiber on the fresh and hardened properties of the concrete. The results showed that by increasing the percentage of fibers, the workability decreased significantly. Thus, to produce a feasible mixture, a superplasticizer was used.

Singh et al., (2017) used various types of PET fiber in concrete to improve its performance at percentages of 0.8 %, 1 %, and 1.2 % by weight of cement. They concluded that the workability of the concrete mix decreases with the incorporation of PET fibers for all aspect ratios. Concretes containing straight PET fibers had higher workability than concretes containing folded PET fibers.

4.3. Properties of hardened concrete

Marthong and Sarma, (2015) found that the addition of 0.5 % PET fiber in the concrete improves the compressive strength of the samples and varied with the fiber geometry. On the other hand, many researchers found that the compressive strength was not affected by plastic fibers (Pesic et al., 2016; Bhogoyata and Arora, 2017).

Borg et al., (2016) studied the performance of concrete reinforced by fibers produced from plastic waste, and polyethylene terephthalate (PET). Different types of shredded, straight, and deformed recycled PET fibers, as well as different lengths of 30 mm and 50 mm, were evaluated for a percentage of addition ranging from 0.5 % to 1 % in the concrete. They concluded that the addition of recycled PET fibers leads to a reduction in compressive strength of 0.5 % to 8.5 % compared to the control mixture.

Taherkhani, (2014) studied the use of PET waste as fiber in concrete with different lengths of 1, 2, and 3 cm at percentages from 0.5 to 1 % by volume of the mixture. They concluded that the compressive strength at 7 and 28 days decreased with increasing length and fiber content, with the lowest resistance for the mixture containing 1 % PET of 3 cm. This reduction was attributed to a lack of adequate bonding between the fibers and the cement paste, and more potential for crack development.

Kumar and Daule, (2017) concluded that the compressive strength increases with the increase in fiber content and the maximum value at the percentage of 1.5 %. (Mohammad hosseini et al., 2018) concluded that the incorporation of metallized plastic waste (MPW) in percentages of 0.25 %, 0.5 %, 0.75 %, 1 % and 1.25 % decrease the strength by 6 %, 7 %, 11 %, 18 % and 21 %, respectively. This decrease could be attributed to the existence of air voids in the matrix that are increased by the addition of fibers in the concrete. Figure. 3 presents the results of compressive strength as a percentage of waste plastic fibers.

For the tensile strength, (Marthong and Sarma, 2015) demonstrated that the inclusion of 0.5 % PET fiber enhances the resistance. On the other hand, (Taherkhani, 2014) concluded that the tensile strength of the mixture reinforced by fibers was lower than that of the reference mixture. The resistance increased with increasing fiber length, while at higher levels it decreased with the increase of the fiber length. (Pelisser et al., 2012) found that the tensile strength increases with increasing fiber content, despite the effect diminished at 150 days. Singh et al., (2017), concluded that the resistance of mixtures with PET fibers increases up to 1 % for all aspect ratios and concrete with crimped fibers had a high value than concrete with straight fibers. Khalid et al., (2018) investigated the effect of incorporating waste PET bottles as fibers on the performance of concrete. They concluded that the tensile strength increased by 16.9 %, 26.3 % and 13.3 % at 0.5 %, 1 % and 1.5 % of fiber content respectively, in RPET-5 type (60 mm diameter and 5 mm thickness).

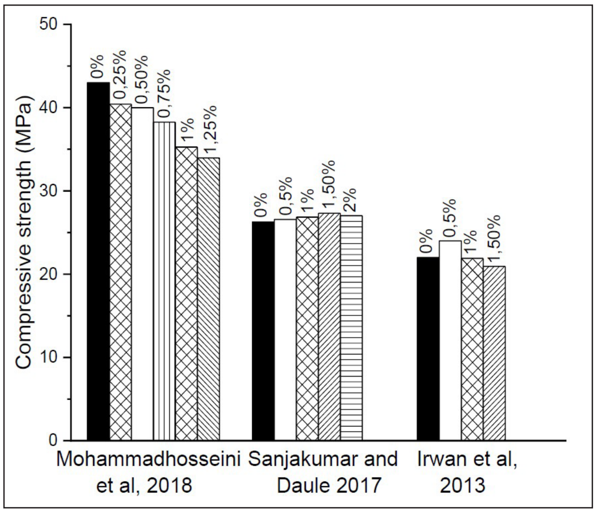

Figure 3. Compressive strength with different waste plastic fibers at 28 days.

Bui et al., (2018) concluded that recycled PET bottle waste (RPET) and recycled woven plastic sack waste (RWS) improve the tensile strength of recycled aggregate concrete (RAC). The tensile strength of RAC reinforced with RPET fibers increased from 11.8 to 20.3 %, while RWS fibers only improved strength by 9 to 16.6 %. Figure. 4 shows the results of the effect of plastic waste fibers on the tensile strength of concrete.

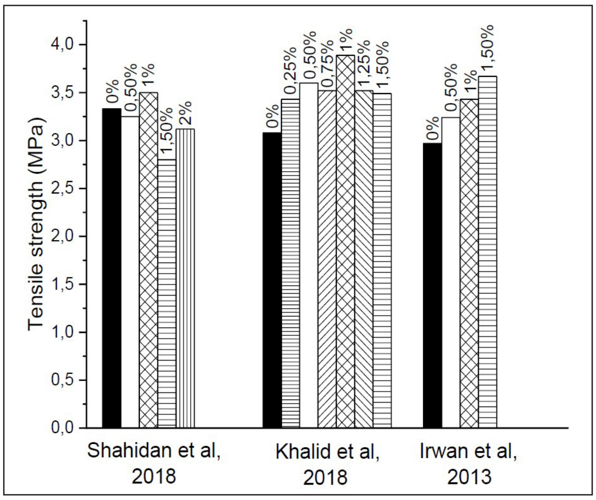

Figure 4. Effect of plastic waste fibers on the tensile strength of concrete.

For the flexural strength, (Taher Khani., 2014) concluded that the flexural strength of the mixtures increases with increasing fiber length. He also found that the strength of the blends decreases with the increase in fiber content. This was attributed to staying more water in the mix with a higher fiber rate, which leads to weak concrete. In addition, the smooth surface of the fibers causes a reduction in the bond between the fiber and the cement paste.

Mohammad hosseini et al., (2018) observed an increase in flexural strength in concrete mixes containing metalized plastic waste compared to control concrete at 7, 28, and 90 days of curing. In contrast, the researchers found that the flexural strength was not directly affected by the inclusion of PET fiber in concrete, (Bhogoyata and Arora, 2017).

4.4. Durability

Taherkhani, (2014) found that the mixture containing PET fiber was more abrasion resistant than the control mix. Abrasion resistance increased with increasing fiber lengths. On the other hand, mixtures containing short fiber had a lower modulus of elasticity than the control mixture. Marthong, (2015) found that the PET fibers increase both the ductility and energy absorption of axially compressed concrete samples. The results showed that the inclusion of PET fibers in concrete has improved the crack resistance of conventional concrete. The presence of MPW fibers has extended the ductility of the cement paste against brittle failure and reduced the spread of microcracks in the cured mass. Besides, MPW fiber improved the deformation capacity at higher loads subjected to axial compression, (Bhogoyata and Arora, 2017). Pesic et al., (2016) found that the HDPE fibers reduced the water permeability of concrete by a significant magnitude of 17- 42 % when the depth of water penetration was measured. This proved that HDPE will be more sustainable in the exploitation than ordinary concrete.

Even a small amount of added PHDE fibers showed a significant reduction in the cracking of concrete. The reduction of crack widths by more than 50 % was achieved with a volume of 0.40- 1.25 % of HDPE fibers. The mixture of 0.5 % PET fiber in the concrete showed no signs of a porous structure. Since a predicted range of UPV values (3.5 km/s to 4.5 km/s) has been obtained (Marthong and Sarma, 2015). Krishnammorthy et al., (2017) studied the durability of concrete with PET fibers. Three volume fraction 0.5 %, 1 % and 1.5 % used with three aspect ratios 0.15- 0.30 and 0.45. They concluded that the mixture with PET fiber with a volume fraction of 1 % and an aspect ratio of 0.45 gives better results in acid and chloride attacks. Kim et al., (2010) examined the properties of concrete with the incorporation of recycled PET fibers. They found that cracking due to drying shrinkage was delayed in samples of reinforced concrete with PET fibers compared to unreinforced samples.

After the concrete samples have been immersed in the magnesium chloride solution for 30, 60, and 90 days, (Vijaya et al., 2018) observed that the percentage reduction in weight loss decreased as the percentage of fiber content increased and the chloride penetration was reduced with an increasing percentage of fiber content.

Bui et al., (2018) found that the recycled woven plastic sack waste (RWS) and recycled PET bottles waste fiber (RPET) enhanced the shear strength of recycled aggregate concrete (RAC) by about 2–4 % and 7–15 %, respectively. Both RWS and RPET fibers improved the post-cracking behavior and ductility capacity of RAC. Kim et al., (2010) concluded that the concrete mixes with recycled PET fibers had relative ductility indices about 7 to 10 times higher than fiber-free mixes. Beyond a volume fraction of about 0.5 %, the ductility index and energy capacity decreased as the volume fraction of the fibers increased. Hosseini and Tahir, (2018) examined the durability performance of concrete containing metalized plastic fibers (MPW). They found that the penetration depth in the OPC mix with 0.5 % MPW fibers was 14.8 mm, 24 % less than the 19.5 mm obtained in the control mix.

Bhogayata and Arora, (2018) concluded that the acid and sulphate resistance, corrosion resistance, and resistance to oxygen permeability of conventional concrete were improved due to the presence of short MPW fibers. The type A fibers (5 mm long and 1 mm wide) filled the pore spaces around the aggregate-hydrated cement paste transition zone due to better adhesion of the constituents and helped to reduce voids within the hardened mass.

5. Conclusions

The results of the various researchers indicated:

- The addition of plastic as a substitute for aggregate increases tensile and flexural strengths compared to the reference concrete.
- Water absorption decreases in mixtures containing plastic as an aggregate because plastic waste has a lower water absorption capacity than the natural aggregate, an important positive parameter to produce durable concrete.
- The abrasion resistance of concrete mixes containing various types of PET aggregate is better than that of the control concrete due to the incorporation of fiber.

- The addition of PET plastic waste improves the ductile behavior of the concrete and the energy absorption capacity of the plastic concrete increase with the waste plastic aggregate content in the concrete.
- The incorporation of plastic aggregate in concrete show higher carbonation depths and chloride migration coefficients than control concrete, explained by the law of porosity of concrete.
- The chloride penetration was reduced with an increasing percentage of fiber content in the concrete, due to the impervious plastic particles which block the passage of the chloride ion.
- The plastic waste fiber enhanced the shear strength, post-cracking behavior, and ductility capacity of recycled aggregate concrete, due to the reinforcing role of fiber.

Abbreviations and definitions

LDPE : Low- Density Polyethylene
PS : Polystyrene
PET : Polyethylene Terephthalate
HDPE : High-density polyethylene
MPW : Metallized Plastic Waste
PET : Polyethylene Terephthalate
PC : Plastique aggregate
PHD : Polyethylene High-Density
UPV : Ultrasonic Pulse Velocity
RWS : plastic sack waste
RPET : Recycled Polyethylene Terephthalate
RAC : Recycled Aggregate Concrete
OPC : Ordinary Portland Cement
AR : Aspect Ratio

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