Application of various types of recycled waste materials in concrete constructions

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Abstract. Studies have proved that the mechanical properties of concrete, suddenly is dropped off with employing waste materials as replacements. The effectiveness of fibre addition on the structural stability of concrete has been indicated in recent investigations. There are different waste aggregates and fibres as plastic, rubber tire, coconut, and other natural wastes, which have been evaluated throughout the last decades. The fibres incorporation has a substantial effect on the properties of concrete mix subjected to different loading scenarios. This paper has reviewed different types of wastes and the effect of typical fibres including Poly Ethylene Terephthalate (PET), rubber tire, and waste glass. Furthermore, plastic and waste rubber has been especially studied in this review. Although concretes containing PET fibre revealed a reduction in compressive strength at low fibre fractions, using PET is resulted to micro-cracking decrement and increasing flexibility and flexural strength. Finally, according to the reviews, the conventional waste fibres are well-suited to mitigated time-induced damages of concrete and waste fibres and aggregates could be a reliable replacement for concrete.

Keywords: recycled waste materials; rubber tire; waste plastic; waste rubber; Poly Ethylene Terephthalate

1. Recycled waste review

Report by (Okamura 1997) show that high-strength concrete with average density has the compressive strength above 41 Mpa. It was ascertained by (Mehta et al. 2017) that for concrete including two good quality lightweight aggregate and high cement content, it is possible to gain a compressive strength 40 to 50 Mpa. In this case, incorporation of basalt fibre could raise the splitting strength of high-strength concrete. Basalt fibre has become useful in concrete constructions due to its excellent mechanical properties and an environmentally friendly manufacturing process. There are three commercially types of basalt fibre filament, bundle dispersion and minobar fibres. However, when the content is raised to 5 kg/m³, basalt fibre could have an agglomeration phenomenon in concrete, which is led to a reduction in the split strength of high-strength concrete. following the results of this research, the optimum amount of basalt fibre was 3 kg/m³ (Boudaghpou et al. 2017). Furthermore, basalt fibre is proved to be efficient in concrete. At elevated temperatures, specimens with basalt fibre are performed properly at temperatures higher than 150°C. It is confirmed that basalt fibres enhance the concrete strength, ductility and energy absorption especially at elevated temperatures with the optimum 0.2% as fibre content (Ren et al. 2016). However, basalt fibres are vulnerable against harsh environments as chloride attacks and direct flame, also these fibres are most expensive in comparison to current synthetic fibres.

Waste rubber is known for its noteworthy sustainability indicators, such as embodied energy, material input factor known as an ecological rucksack, and carbon footprint. The reported values could justify the necessity of reusing rubber instead of its disposal. Such justification is the main reason for the current recycling rate of 300 million pounds of used rubber to crumb rubber annually. Because of the elasticity, lightweight, energy absorption, and heat-insulating, it has been taken as a promising material in constructions (Ghosh et al. 2015). Considering the non-biodegradability of waste rubber tires in nature, burning down the wastes is the cheapest decomposing solution, but resulting air pollution including greenhouse gases that signify the waste rubber tires’ re-application. According to Grubeša (2018), previous permeable and no-fines concrete has carried similar literal components like the standard concrete, but with more porosity and void content (11%-35%) and the water permeability coefficient of 2–6 mm/s. Waste plastic bottles are one of the undegradable materials which have been turned into the pressing environmental issues not only because of the increasing disposal of waste plastic, but also because of the limited space that is remained for deposits. Besides, due to the MEP of PET bottles, employing PET fibres has been investigated on the MEP of concrete where PET strips shows a promising effect on the corrosion resistivity and crack propagation coverage of concrete (Foti 2013). Reinforced plastic concrete has shown lower mechanical performance compared to normal concrete. Furthermore, recycled plastic fibres were added to concrete mixture, then water absorption and ductility of concrete were increased (de Brito et al. 2018). In a study, different tests have been conducted on PET fibre reinforced concrete to obtain the MEP of fibrous concrete in the presence of waste PET fibres. The results have indicated that these
kinds of fibres could decrease the compressive strength and increased the shrinkage while are able to enhance the ductility and ultimate strength of concrete (Kim et al. 2010). Waste plastic fibres (WPF) are used to stabilize the soil together with rice husk ash (RHA) and lime, where the reported observations have proved the proficiency of WPF. Using WPF along with RHA/lime mixture as the stabilizer has enhanced the shear strength and improved the soil strength (Muntohar et al. 2012). One of the recycled plastic production is glass fibre reinforced plastic (GRP) which has employed in concrete as recycled powder, also GRP shows an appealing effect on the MEP of concrete where the experimental tests have proved that using GRP could assist the compressive and flexural strength of the elder age concrete due to the polymeric compounds of GRP (Asokan et al. 2009). Another study has performed GRP recycled fibres along with adding superplasticiser into the concrete mixture where MEP were improved as compressive strength, split tensile strength, shrinkage, water absorption and density (Asokan et al. 2010, Safa et al. 2019, Shariati et al. 2020d). When the recycled woven plastic sack waste (RWS) fibres and recycled PET fibres have been used in eco-efficient concrete, some appealing results have been reported. However, the recycled aggregate concrete (RAC) is proved to be susceptible against the chloride and other chemical attacks, also the presence of RWS and PET fibres have addressed this issue and enhanced the alkali resistance of concrete. On the other hand, employing PET fibres has enhanced the MEP of RAC concrete better than that of RWS fibres; also the incorporating of silica fume (SF) with PET fibres covers the compressive strength loss (Bui et al. 2018). Furthermore, using different PET fibre content and aspect ratios have been investigated in different studies. Results are reported when different conclusions indicate different results about the effect of PET fibre aspect ratios and fibre contents on the hardened and fresh properties of concrete (de Oliveira et al. 2011, Pacheco-Torgal et al. 2012, Nibudey et al. 2013, Razavian et al. 2020). In a study, recycled waste plastic bags (RWPB) have been used to determine the effect of RWPB on the fresh and hardened MEP of self-consolidating concrete, showing the positive effect of RWPB fibres on the fresh properties as slump and tensile strength of Self Compacting Concrete (SCC); however, workability of SCC has been decreased by adding fibres (Ghernouti et al. 2015). Waste or recycled plastic could be used in a variety of purposes such as asphalt stabilizer, or concrete additive where the recycled plastic has been added to the eco-efficient concrete and increased the performance of concrete, also as stabilizer. Recycled plastic is employed in asphalt and impressive outcomes are derived as the efficiency of waste plastic on pavement strength (Sarang 2019). In a study, waste plastic bags are turned into fibres and cast into the concrete where the results have shown the improvement of MEP of concrete by employing recycled polythene fibres (Kandasamy et al. 2011). It has been reported that employing Poly-ethylen Terephthalate (PET) bottle granules could lead to a lightweight concrete due to the low unit weight of PET aggregates, also combining PET aggregates with normal sand along with using slag as cement replacement has been proved to be a reliable mix design. Although using PET aggregates was responsible for decreasing the compressive strength of lightweight concrete, the lower weight concrete produced with PET made it more attractive for the lower weight purposes (Akcaozoglu et al. 2010). In another study, the performance of asphalt has been investigated along with using PET aggregates, where the sustainable behavior of the proposed mixture has proved the PET eligibility as an aggregate replacement (Ahmadinia et al. 2011). Employing waste plastic trays (WPT) and recycled gypsum while incorporated together to enhance the soil stability has been studied, where the results have shown the effect of WPTs strips on soil strength. According to the reported observations, the size of strips was a responsible factor in soil compressive and shear strength (Ahmed et al. 2011). The effect of PET on the thermal behavior of concrete has been explored, where PET aggregates are employing along with using fly ash (FA) and Nano silica (NS) as cement replacements. Concerning the results of using PET has enhanced the porosity and concrete stability at elevated temperatures, also PET corporation has not affected the compressive and flexural strength severely (Alfahdawi et al. 2019). PET flakes are used as fine aggregates and employed in concrete instead of normal fine aggregates, also the experimental tests have been performed on concrete specimens, and the observations have indicated that using these fine aggregates could be advantageous compared to the natural aggregates either in MEP or porosity indexes (Rahmani et al. 2013). PET fibres were added to self-consolidating concrete, in which the fibre content has been changed from 0.2% to 2% because the fibre presence slump flow were decreased, and compressive strength was enhanced (Al-Hadithi et al. 2016). In another study, the effect of using PET fibres on the mechanical features of concrete has been investigated. The investigation has presented a reliable evidence of PTE fibres role on the mechanical improvement of concrete; also the reports have illustrated that employing PTE fibres could enhance the flexural strength of concrete and control the shrinkage (Al-Tulaian et al. 2016). Different aspects of recycled waste plastic usage have been reviewed in a review study, in which the authors have mentioned the critical role of PET and other types of waste plastic utilization on the environment saving. The effect of plastic fibres has been reviewed, showing the decisive role of PET fibres on the permeability and crack propagation of concrete, however, performing of these fibres harms the compressive and shear strength of concrete (Siddique et al. 2008). In another review study, employing virgin plastic aggregates has been proved to be ineffective for performance improvement, also it is mentioned that if plastic aggregated is processed with cementitious natural materials as Fly Ash (FA), Silica Fume (SF), it could be useful to enhance the compressive and flexural strength (Sharma et al. 2016). On the contrary, a study has presented the positive effects of waste PET fibres on the compressive strength, split tensile strength, modulus of elasticity of concrete and porosity of concrete compared to normal concrete (Irwann et al. 2013). Performing PET fibres on the ductility and permeability of concrete was promising. Also, compressive strength was not influenced...
severely by addition of fibres (Foti 2011). The porosity of concrete was enhanced by using waste PET fibres in concrete mixture, in which the waster to cement ratio was also responsible for attaining the recommended porosity of concrete (Frigione 2010). Previous studies focusing on the use of waste glass in cement mortars and standard concrete mixes have shown that using glass cullet as fine aggregates is an effective solution to produce cement-based construction products (Tan et al. 2013, Du et al. 2014, Lu et al. 2017a, Lu et al. 2017b, Liu et al. 2018). Though the replacement of river sand by glass cullet may reduce the compressive strength (Park et al. 2004, Topcu et al. 2004), the inclusion of glass cullet could impressively advance the durability of mortar or concrete against sulfate attack (Wang 2009) and acid corrosion (Khan et al. 2011). Thus, drying shrinkage and chloride ion penetrability of glass concrete are declined when the glass aggregate content is raised (Kou et al. 2009). One concern of recycling waste glass into cement mortars and concrete is the potential expansion because of the alkali-silica-reaction (ASR) of glass particles. To mitigate the ASR effect, the replacement of a portion of cement by supplementary cementitious materials (e.g., silica fume, fly ash, metakaolin, glass powder) could be influential method. It was shown that ASR in porous concrete blocks which is prepared with glass cullet as aggregates couldn’t be a problem since the presence of large pores could accommodate the expansive ASR gel (Yang et al. 2018). Moreover, following the studies on waste glass cullet (WGC) in concrete and mortars, replacing fine aggregates by WGC has potentially produced a sustainable PC. Also, the water permeability of PC could be developed because of the smooth surface of glass particles and negligible water absorption. Hong Kong and China are facing with dwindling natural aggregates resources (particularly for natural river sand) and severe environmental problems because of the over-exploitation of natural aggregates in last decades for construction development. Besides, great amount of construction wastes and municipal solid wastes make high pressure on landfills in Hong Kong, adding that available landfills could be full by 2020 (EPD, 2013). Since crushed WGC could be relatively applied to replace river sand, and RCA could be a source of coarse aggregates, the recycle of these two recycled materials would be cooperatively promising into PC for stormwater management. Waste tire rubber (Gesoğlu et al. 2014a) are evaluated as porous concrete components. Despite the reduction of concrete strength by use of these waste materials, some other properties as density and permeability can be advanced.

Pervious concrete is defined as concrete with almost zero slump and smaller coarse aggregates. This type of concrete as an open-graded material has significant permeability due to the interconnected pores, ranging from 2 to 8 mm. In order to obtain a great amount of stormwater into the ground, the pervious concrete has been considered in recharging groundwater (Toghroli et al. 2017, Toghroli et al. 2018, Li et al. 2019, Shariati et al. 2019a). Concrete has outstanding compressive strength due to its dense and robust texture, which does not experience the local or distortional buckling or other accidental deformations along with low flexural and torsional strength, and this made concrete as a useful material for axial structural elements (Nosrati et al. 2018, Shariati et al. 2019b, Trung et al. 2019, Shariati et al. 2020).

Waste recycled materials also can be employed in high strength concrete (HSC), where the high mechanical properties are necessary for HSC structural performance. Some waste materials can be used as lightweight concrete additives along with aggregates to decrease the weight of the mixture. The management of waste materials should be considered as a fundamental issue for appropriate usage in construction applications (Shariati 2008, Hamidian et al. 2011, Shariati et al. 2011, Mohammadhassani et al. 2014a, Mohammadhassani et al. 2014b, Heydari et al. 2018, Ismail et al. 2018, Ziaei-Nia et al. 2018, Sajedi et al. 2019, Toghroli et al. 2020).

The seismic performance of waste recycled concrete is an important issue for researchers. Hence some dynamic response tests can be helpful to categorize the best exist waste materials according to their seismic performance (Daie et al. 2011, Jalali et al. 2012, Khorami et al. 2017, Luo et al. 2019, Shariati et al. 2020a, Shariati et al. 2020b, Shariati et al. 2020c).

Concrete plays a key role in steel-concrete composite structures. The quality of concrete depends on its ingredients, such as aggregates (coarse and fine), cement (cementitious materials), and supplementary additives (natural polymers, synthetic fibres, and recycled materials). Employing waste materials that have already been an appealing topic for researchers could take some adverse effects on either mechanical properties or hardened properties of concrete. In concrete-filled tubes (CFTs), concrete should be as strong as possible to resist the fraction force at the surface of steel and concrete. In this regard, the use of waste materials can be effective (Arabnejad Khanouki et al. 2010, Arabnejad Khanouki et al. 2011, Sinaei et al. 2011, Arabnejad Khanouki et al. 2016, Xie et al. 2019, Naghipour et al. 2020, Shariati et al. 2020c, Shariati et al. 2020f).

2. Concrete behaviors

2.1 Compressive strength

2.1.1 Rubber tire

Rubber tires have been used by 3 various particle-size as very fine, very fine and coarse including fine crumb rubber, crumb rubber (CR), tire chips (TC) replaced for cement and coarse aggregates. The concrete derived from rubber tire is named “rubberized concrete”. Waste rubber tire, tire chip and CR are depicted in Figs. 1(a), 1(b) and 1(c) (Ghosh et al. 2015). Grinding and converting of tire rubber have been regarded as the most preferred method in tire recycling. CR concrete or asphalt pavement mixes have been sized (0.0075 mm-4.75 mm) used in athletic tracks’ outer surface, games, or its combinations such as asphalts (Thomas et al. 2016, Aoudia et al. 2017, Safa et al. 2020, Shariati et al. 2020b). (Gesoğlu et al. 2014b) has declared that waste rubbers have been implemented in 3 diverse particle-size
such as very fine, fine, and coarse, subsequently, tire chips in a gravity of 1.02 are applied as coarse rubber aggregate, while 2 types of CR with nominal particle size (4 & 1 mm) are applied as fine aggregates in a 0.83 and 0.48 gravity.

The modification of PC properties by CR has indicated that rubber adding has slightly decreased the strength and permeability, while significantly enhanced the ductility and freeze-thaw resistances (Liu et al. 2018), accordingly, the compressive-strength has been decreased by the raising of rubber incorporation range. Though the rubber addition has reduced the compressive strength of PC, the requirements of non-structural use have been met yet. (Khaloo et al. 2008) has observed more ductile behavior for rubberized concrete compared to the plain concrete specimen in compression testing. Another study conducted by Al-fadhl et al. (2017) has mentioned that the replacement of mineral aggregate by tire rubber particle in concrete has excessively reduced the final strength and tangential modulus of elasticity (Gesoğlu et al. 2014b). Mehmet et al. (2014) has investigated PC properties including waste tires proving that by using tire chips and CR, the compressive strength of porous concrete is 6.45 MPa, whereas the compressive strength of PC is 3 to 30 MPa. However, CR has probably been used for the partially replacement of natural fine aggregate up to 7.5% with no adequate decline in its desired strength. High-strength rubber concrete has also been gained by magnesium oxychloride cement providing favorable bonding properties to rubber and essentially improving the rubber concrete performing. Furthermore, adhesion between rubber particles and other constituents substances have been surpassed by pre-treating the rubber aggregate with magnesium oxychloride (Siddique et al. 2004). (Son et al. 2011) has investigated the strength of PC by use of waste rubber tire indicating that the compressive capacity of 24 MPa concrete has been decreased to 8 and 32% by 0.5 and 1% rubber particle addition to concrete mix. Likewise, 0.5 and 1% rubber particle usage in the 28 MPa concrete mix has produced a 14% and 18% decline in the compressive capacity of the column specimen.

2.1.2 Waste plastic

Waste management is one of the most important eco-efficient management focused on decreasing the growing amount of wastes like plastic, where plastics have directly deteriorated human well-being and health safety. In this case, waste plastic (Figs. 2(a)-2(c)) is used to be recycled in a variety of applications, and one of the byproducts of recycled waste plastics is introduced in the construction and building industry as aggregates and fibres. This paper has presented a review of waste plastic applications on construction industry, especially the concrete technology where these additives have been performed, and the experimental observations have been reported throughout the strong papers.

As discussed in introduction, WPFs have been employed to reinforce the concrete against the subjected loadings, also the presented results and observations have either proved the efficiency of WPF and introduced them as reliable reinforcements or denied their proficiency and rejected their applications. This uncertainty was not only limited to the WPF reinforced concrete, but also was against employing Waste Plastic Aggregates (WPA) both as coarse and fine aggregates in concrete, in which according to the reported data using these aggregates have both advantages and disadvantages on compressive strength. However, all studies are anonymous about using either processed recycled waste plastic aggregates or cement replacements incorporating WPFs while the results have shown that performing these approaches could address the compressive strength loss and compensate the possible deficiencies of waste plastic byproducts. Fig. 3 illustrated the compressive strength outcomes of fibrous concrete with different fibre content, where both recycled PET and propylene fibres have been used into the mixtures. According to Fig. 3, it is evident that the inclusion of PET fibres has decreased the compressive strength compared to normal concrete while
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Fig. 3 Compressive strength values corresponded to different fibre content (Kim et al. 2010)

this strength losing is not very critical (Kim et al. 2010). In Fig. 4, compressive strength has been investigated according to the waste plastic fibre length, where the represented results have shown that fibre length and compressive strength work against each other (Ghernouti et al. 2015). Fig. 5 represents the variation of compressive strength due to the WPB content, also the presented results have proved that by raise of more WPB, more compressive strength is decreased.

2.1.3 Waste glass

The compressive strengths of PCs that incorporate RCA and WGC are illustrated in Fig. 6 a. Accordingly, the compressive strengths of PCs including RCA or WGC were steadily reduced by the raise of WGC or RCA content. Considering WGC, the replacement of natural fine aggregates by WGC has led to a weaker bond between the cement paste and aggregate because of the inherent smooth surface of glass. This could be the reason of strength losing in WGC-based PCs. Similar case has been occurred in applying WGC in concrete (Kou and Poon 2009, Ali and Al-Tersawy 2012, Tan and Du 2013b). Fig. 6(b) shows the compressive strength of 50G50R when compared to100G and 100R. The compressive strength of 50G50R was 22 MPa, lower than the compressive strength of 100G, but higher than the one of 100R. Thus, adding WGC as fine aggregates to PCs could enhance the compressive strength when it is compared to that of PCs prepared with only coarse RCA. It might be due to the presence of WGC that could fill the inter-granular voids between coarse aggregates (Lucchin et al.), then this interlocking has been contributed to compressive strength.

2.2 Flexural strength

2.2.1 Waste rubber

The flexural strength values from 2.16 to 0.40 MPa have

Fig. 5 Compressive strength variation in the order of WPB content (Jain et al. 2019)

Fig. 4 Different SCC compressive strength corresponded to different fibre length (Ghernouti et al. 2015)

Fig. 6 The compressive strength of PCs prepared with WGC and RCA (Lu et al. 2019)
indicated the highest strength value for control concrete (Fig. 7). Addition of rubber to PC has negatively influenced the flexural strength as in ordinary concrete providing a systematic decline by the rubber content’s increment. When the rubber is substituted by natural aggregates, weak bonds between the cement paste and rubber particles have been formed compared to the stronger bonds between aggregates and cement paste. Therefore, based on the research, the rubber size is highly effectual on the flexural strength than the rubber content. PC with fine CR has provided the least flexural strength (Gesoğlu et al. 2014a). (Aliabdo et al. 2018) has defined the influence of recycled rubber aggregate’s substitute ratio on PC flexural strength. Any growing of substitute ratio of recycled aggregates has decreased the flexural strength of PC. The flexural strength reduction ratio because of the recycled aggregate usage at 50%, 100% replacement level is 18.8% and 41.2%, therefore, on using 9.5 mm aggregate size, the flexural strength decreasing ratio is 34% and 54% to the 19 mm aggregate size usage, which is a behavior similar to splitting tensile strength (Fig. 8). Negative effect of the recycled aggregate’s usage might be subjected to the weak features of transition zone toward the recycled aggregates. Also, the transition zone has highly affected the concrete tensile strength.

2.2.2 Waste plastic

Dynamic and monotonic flexural tests have been performed on the recycled PET fibres reinforced concrete, and the results have shown that PET fibres played as bridge role and connected the different cracked textures inside the mixture and limited the crack propagation in concrete (Kim et al. 2010). The more PET fibre content is increased, the more crack propagation is restricted. The split tensile strength of fibrous concrete using PET fibres has been studied, and the results have proved that the best performance of PET inclusion is when the 0.25% PET fibres is incorporated with 5% SF (Bui et al. 2018). Generally, using PET fibres harms the split tensile strength of concrete while the other additives could cover this deficiency but not as possible as it must be (Fig. 8).

The effect of fibre aspect rate and fibre content on the split tensile strength of concrete has ben investigated, and Fig. 9 demonstrates that more aspect ratio has enhanced the split tensile strength when the fibre content plays more involved role. When the fibre content is raised from 0 to 1.0 %, split tensile strength is correspondingly increased when more content has decreased the tensile strength as shown in Fig. 8 (Nibudey et al. 2013).

2.2.3 Waste glass

Indirect tensile strength and flexural strength are performed on control and RGS (recycled glass sand) concrete at 28 days. As a result, there was no significant difference in flexural and tensile strength for glass sand addition compared to control concrete (Fig. 10). Strength results have tended to be increased with glass sand amount increment. The angular size of glass sand could be attributed to a better interlocking between glass sand and cement. Whereas, a strength decrement has been occurred for flexural=40 RGS and tensile strength=60 RGS. A tensile strength concrete reduction with more RGS replacement (60%) is align with the compressive strength reduction at 60% replacement level. Percentage of indirect tensile strength to compressive strength was between 8% and 11% (Tamanna et al. 2020).

2.3 Permeability and porosity

Permeability is a capability possessed by rocks to pass fluid or fluid through interlocking pores or cavities. The permeability values of porous concrete are gained from 0.14
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Fig. 10 Flexural and tensile strength of RGS concrete (Tamanna et al. 2020)

Fig. 11 The permeability coefficient of RMPC versus rubber content

to 1.22 cm/sec. The value of permeability could be delineated by testing through the use of principle of high energy down (Falling Head Meter) (Limantara et al. 2018).

2.3.1 Waste rubber

According to (Güneyisi et al. 2016), substituting natural aggregate with recycled aggregate has resulted permeability coefficient raising, however, the mechanical properties of such concretes have been negatively affected up to a certain degree. (Liu et al. 2018) has shown the varieties of the permeability coefficient of PC vs rubber content (Fig. 11), thereafter, the addition of rubber has decreased the absorption for control mixture of 2.89%, so in a mixture with 10%, CR is 3.15% and in a mixture of 20%, CR is 3.32%. The same pattern has been gained in the series with water cement ranges of 0.45 and 0.50. (Gesoğlu et al. 2014b) has observed that the permeability of PC has fallen down into 0.25-0.61 cm/s, recommending the pervious concrete limitations. (Aliabdö et al. 2018) has also indicated the effects of rubber fibers content on PC permeability (Fig. 11). According to outcome, raising rubber fibers content has increased the PC permeability occurred because of the PC density reduction in the result of using rubber fibers as coarse aggregates. Comparing to control mix, an increase in PC permeability is 5.5% and 10.3% for 1.5% and 3% rubber fiber. (Gesoğlu et al. 2014b) has investigated the mechanical characteristics and permeability, then three rubber types have been applied in producing the rubberized plain PC mixtures gained by some replacement of rubber aggregate. Furthermore, using rubber has significantly aggravated the mechanical characteristics and PC permeability, but in various degrees based on the applied rubber’s type and rate.

2.3.2 Waste plastic

WPF and recycled waste aggregates have been employed in concrete mixture, and the reported results have shown that the inclusion of PET and other types of waste plastic materials in concrete improved the permeability and increased the porosity of concrete where the exhibited pore structures worked in favor of these characteristics (Akçaözoğlu et al. 2010, Frigione 2010). Addition of WPB into the concrete proportion has increased the permeability. According to Fig. 12, the higher WPB content is, the higher water penetration specimen(s) is, in which the created WPB improves the pore structure and increases the concrete void content (Jain et al. 2019). Fig. 13 demonstrates the active role of PET fibre inclusion on the improvement of permeability, however, the optimized fibre percentage has been proposed as 1.0 % (de Oliveira and Castro-Gomes 2011).

2.3.3 Waste glass

The effect of Waste Glass Cullet (WGC) and Recycled Concrete Aggregate (RCA) replacement on the permeability
of PCs is shown (Fig. 14). Obviously, the PCs prepared with coarse aggregates has more water permeability than the PCs prepared with fine aggregates, which is described by a denser matrix of PCs prepared with fine aggregates. For the PCs with RCA, water permeability is stayed relatively constant by increasing replacement level of RCA. It could be because of the similar gradation and features of coarse NA and RCA. When fine NA has been replaced by up to 50% WGC, the permeable coefficient of PCs has not been affected. In contrast, the permeability has been essentially improved to 0.3 mm/s when 100% NA is replaced by WGC. It is believed that the non-absorbing nature of glass particles benefits the water to permeate through concrete. Also, the permeability requirement of JIS A 5371 specification for pervious concrete is 0.1420 mm/s. Thus, the PCs proportioned with 100% WGC as fine aggregates is feasible in terms of permeability and compressive strength.

3. Conclusions

This study has reviewed three types of recycled waste materials which have been reproduce by either demolition or deconstruction process. Waste plastic fibre, waste plate aggregate, waste rubber tire, waste glass has been reviewed in this study beside plastic usage in concrete and the effect of employing WP on the fresh and hardened characteristics of concrete. The primary purpose of this study is to study the potential performing of Waste Plastic Fibre (WPA) in pervious concrete. In this case, the precursor experimental studies about WPF and WPA utilization in the construction and building applications have been reviewed, also to have a better understanding different synthetic fibres have been mentioned and reviewed in introduction. However, according to the discussed studies, there is not a reliable study investigating the pervious concrete with the inclusion of either WPF or WPA. For the sake of the brevity what has mentioned above have been pointed in the following:

• Concerning the discussed studies about the compressive strength, employing PET fibres and WPA would decrease the compressive strength. However, using concrete additive powder as SF and FA are able to cover this deficiency, while the incorporation of PET and SF leads to a sustainable concrete.
• Though using WPF has a negative influence on compressive strength, performing WPFs has improved the flexural strength and increased the ductility of specimen(s). The more elongated PET fibre is contained, the more flexural capacity is gained. Employing PET fibres and WPA has decreased the split tensile strength of concrete, even with the increment of fibre content, this tensile strength loss would be increased. Using PET fibres have actively restricted the crack propagation through the load-deflection experimental test, in which WPF played a reinforcing role and enclosed the connection between interior parts. Furthermore, with the increase of fibre length, the crack propagation was restrained more. However, the inclusion of WPF and WPA increases the void content, the porosity of specimen(s) is improved, also the permeability has been increased in the case of WPF inclusion.
• The pozzolanic impact of waste glass in concrete is highly visible at the later age of 28 days. The optimal percentage of waste glass which provides the highest values of flexural strengths and compressive is 20%. Flexural and indirect tensile strengths values have been delineated to decline the proportion toward an increase in W.G.

According to the pervious concrete characteristics as required compressive strength, flexural strength and the recommended porosity and permeability, using WPF and WPA could be a logical decision not only with respect to the discussed properties of WPF reinforced concrete but also to achieve an eco-efficient and green concrete which could help to decrease the increasing amount of waste plastic.

References


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