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Enhancing Mechanical Properties of No-Fines Concrete Using Waste Plastic Fibres

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Abstract: Tensile strength might be considered as Achilles heel of concrete, especially when it comes to No-Fines Light-Weight Concrete (NFLWC) where there are inherent weaknesses in its mechanical properties. Many techniques are available to improve these properties, among them and one of the best techniques is introducing fibres in the concrete mass. In this study, the effect of incorporating waste-plastic fibres (an environmentally non-friendly material usually causing pollution) on the mechanical properties of NFLWC was investigated experimentally. Two main variables were considered, namely, the fibres volume fraction which was taken in the range of 0.0-1.5% and the fibres aspect ratio (8.16 and 24). It has been shown that the addition of waste-plastic fibres to the no-fines light-weight concrete mix succeeded in increasing both its compressive and tensile strength. The density of the trialled NFLWC mixes is also discussed.

Key words: Light-weight concrete, fibre reinforced concrete, waste plastic, mechanical properties, compressive, trialled

INTRODUCTION

It has been found that the addition of small closely spaced and uniformly distributed fibres to concrete would act as crack arrestors and substantially improve the tensile strength, cracking resistance, impact strength, wear and tear and fatigue resistance. Even, the ductility of concrete is improved by the addition of fibres. Such a composite material is called Fibre Reinforced Concrete (FRC). The fibre reinforced concrete is an attractive material and has several applications in the field of civil engineering. Many types of fibres can be used in the production of FRC like steel, carbon, glass, nylon, polypropylene, polyester. Even the plastic fibres can be used in the production of FRC. The plastic is progressively becoming a real problem for the environmentalists. The plastic is not biodegradable material, soil cannot decay it and water cannot dissolve or disintegrate it (Ghernouti *et al*., 2015). However, heat and fire can burn it but with the production of many toxic gases. Sustainable and safe methods of plastic destruction are not yet invented.

One of the most brilliant solutions for the waste plastic problem is using it (in the form of fibres) in concrete mass. This is an economical, sustainable and environmental-friendly solution which can both enhance the mechanical properties of concrete and dispose the waste plastic safely at the same time. Polyethylene Terephthalate (PET) is the most commonly used thermoplastic polyester. PET is used predominantly in the form of bottles for storing carbonated and non carbonated drinks. It is a transparent polymer that has good mechanical properties and good dimensional stability under variable load. Semi crystalline thermoplastic polyester, durable, low gas permeability, chemically and thermally stable, easily processed and handled, wear and tear resistant and non biodegradable are the common characteristics of PET (Anonymous, 2009). Based on its versatility, it is also used in textiles, films, utility ware, sportswear, etc. Food processing industries prefer PET as it is hygienic, strong and lightweight. This shows that it has a wide range of applications. PET belongs to the thermoplastics with excellent physical properties. It constitutes around 18% of the total polymers produced worldwide and over 60% of its production is used for synthetic fibres and bottles. Which consume about 30% of the global PET demand (Chavan and Rao, 2016).

Light-weight concrete usually suffers from low compressive and tensile strengths and using waste plastic fibres with this type of concrete have an extra advantage of improving its mechanical properties. No-fines concrete is considered as one of the main types of light-weight concrete. It is produced using the cement-water-coarse aggregate mixture without incorporating fine aggregate

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(sand) in the mix to increase the void ratio and decrease the density of the produced concrete as much as possible. The density of the light-weight concrete depends mainly on the sieve analysis of the used aggregate among other parameters (Neville, 1981).

In this experimental investigation, an attempt was made to incorporate the waste-plastic fibres in the NFLWC mix and study its effect in enhancing the mechanical properties of concrete.

Literature review: Al-Hadithi (2008) studied the effect of adding small percentages of waste plastic fibre (waste of plastic beverage bottles) on some of the mechanical properties of concrete. In his study, the volume fraction of waste-plastic fibres was 0.1 and 0.2% by volume. The obtained results proved that adding plastic fibres led to improvements in compressive and flexural strengths. The results also showed an increasing in densities of fibre concrete samples with respect to the reference mix.

Venu and Rao (2010) investigated concrete slabs using two different fibres namely poly ethylene terephthalate (i.e., mineral water bottles) and high density poly propylene (i.e., disposable glasses). The experimental work consisted of nine samples of slabs. It has been observed that the ultimate load carrying capacity increased considerably by using these two types of fibres. In addition, it has been observed that the compressive strength of cubes was gradually increasing by using both types of fibres with different volume fractions up to 1% and then gradually decreasing afterward. The maximum reported compressive strength of cubes was 36.0 and 36.4 N/mm^2 by using HDPP and PET fibres, respectively.

Kandasamy and Murugesan (2011) studied the influence of addition of polythene fibres (domestic waste plastics) at a dosage of 0.5% by weight of cement. The properties studied included compressive strength and flexural strength. They concluded that addition of 0.5% of polythene (domestic waste polythene bags) fibre to concrete would increase the cube compressive strength of concrete at 28 days by 5.1%. It also increases the cylinder compressive strength of concrete at 28 days by 3.84% and the splitting tensile strength by 1.63%.

Al-Hadithi *et al*. (2013) investigated the effect of addition of waste plastic fibres on the strength and behaviour of concrete slabs under low velocity impact. In their study, they showed that the incorporation of domestic waste plastic fibres improved the mechanical properties and the impact resistance for the tested slabs. It was reported that the compressive strength and flexural strength of concrete is increased by 3.2 and 26.0%, respectively at an age of 90 days. In addition, their study showed that the impact strength of concrete slabs with waste plastic fibres was 340% higher than normal concrete without fibres. This significant increase was achieved by adding 1.5% volume fraction of waste plastic fibres to the reference concrete mix.

Nibudey *et al*. (2013) reported that fibres made from waste PET bottles were appropriate for concrete reinforcement. The experimental compressive strength of PET Fibre Reinforced Concrete (PFRC) was found to increase by 7.35% compared to normal concrete for M20 grade of aspect ratio 50 for 1% fibre volume fraction thereafter the strength decreased at higher percentage volumes of fraction as they noted a 27% fall in compressive strength for 3% fibre volume fraction for the same grade and aspect ratio. The rise in compressive strength for M30 grade concrete is very little and the fall in strength on increasing the fibre volume fraction was low.

Prahallada and Prakash (2013) studied the effect of adding waste plastic fibres with different aspect ratios (0, 30, 50, 70 and 110) on the mechanical properties of concrete. In their study, they showed that the waste plastic fibre reinforced concrete show an increasing trend in the compressive, tensile and flexural strengths from zero aspect ratio to 50 aspect ratio. After an aspect ratio of 50, the strength goes on decreasing. Therefore, the higher strength can be achieved for the aspect ratio of 50 and the percentage increase in the compressive strength, the tensile strength and the flexural strengths were 11, 13 and 10%, respectively. They had the same conclusion for impact strength and reported a percentage increase of impact strength for first crack and for final failure of 50 and 110%, respectively.

Baldenebro-Lopez *et al*. (2014) investigated the strength of concrete beams reinforced using both short discrete and continuous waste plastic fibre arrangements. The mechanical behaviour of reinforced concrete samples were evaluated and compared by bending tests. The results showed a better performance of the continuous PET fibre reinforcement than that of the short, discontinuous one. The continuous PET samples presented a higher increase in the concrete properties represented by a 150% increase in the maximum load capacity in bending.

Many researches dealt with the effect of adding waste plastics as aggregate or fibres for normal and lightweight mortars and different kinds of concrete like Roller Compacted Concrete (RCC), Self-Compacting Concrete (SCC) and high performance concrete (Al-Hadithi and Alani, 2015; Al-Hadithi, 2013; Pandya and Purohit, 2013; Hannawi *et al*., 2012; Verdolotti *et al*., 2014; Saikia and de Brito, 2012; Batayneh *et al*., 2007; Hannawi *et al*., 2010; Mesbah and Buyle-Bodin, 1999; Remadnia *et al*., 2009; Sikalidis *et al*., 2002; Safi *et al*., 2013; Marzouk *et al*., 2007; Al-Hadithi and Hilal, 2016) but to the knowledge of the researcher, no study deal with such effects on no-fines concrete. The present study investigates the effect of adding WPFs on the mechanical properties and density of no-fines concrete as a starting point to study its effect on the structural performance of such concrete.

MATERIALS AND METHODS

Experimental programme

Cement: Sulphate resistant Portland cement is used throughout this research. The chemical and physical properties of this cement are presented in Table 1 and 2, respectively. The test results show that the cement conforms to the Iraqi specifications provision of (Anonymous, 1984a, b).

Coarse aggregate: Natural washed uncrushed gravel with maximum size 10 mm was used. It was brought from Al-Nibaey Region in Iraq. Sieve analysis indicated that the aggregate conformed to the Iraqi standards (IQS/45) (Anonymous, 2009a, b) as can be seen in Table 3.

Waste-plastic fibres: Because of the rapid growth in population in the recent years there is an increase in the waste plastic products. The major composition of these waste plastic bottles is Polyethylene Terephthalate (PET). PET exists as an amorphous (transparent) and as a semi crystalline (opaque and white) thermoplastic material. Generally, it has good resistance to mineral oils, solvents and acids but not to bases. The semi-crystalline PET has good strength, ductility, stiffness and hardness while the amorphous type has better ductility but less stiffness and hardness (Anonymous, 2002). The common examples of PET are fibres, barrier films, soft drink bottles (amorphous PET), etc. (Mark , 1999). The type of plastic fibre used in this study conforms to ASTM-A820 (Anonymous, 1996).

The waste plastic considered in this study is the beverage bottles waste plastics having an average thickness of 0.3 mm. The waste plastic bottle is sliced into small uniformed pieces with different lengths resulting in different aspect ratios. This process was done using a paper shredding machine. The geometrical properties of the waste-plastic fibres used in this work are illustrated in Table 4. Figure 1 shows a picture for the stages used in producing the waste plastic fibres in this study.

Test variables and mix proportions: An attempt was made to study the effect of different volume fractions and aspect ratios of waste-plastic fibres on the mechanical properties of NFLWC. Table 5 shows the test variables, the number of mixes and the mix proportions adopted in this experimental programme. Each of these mixes was tested 3 times which is at an age of 7, 14 and 28 days. It is worth mentioning that the effect of fibre volume fraction was investigated for the mixes with waste-plastic fibres

Table 1: Chemical properties of the used cement

Oxide composition	Content (%)	Limits of Iraqi specifications No. 5/1984
CaO	63.60	-
SiO_2	20.17	<21%
Al_2O_3	5.23	<8%
Fe_2O_3	3.10	<6%
SO_3	2.41	<2.8%
MgO	2.25	<5.0%
Loss of Ignition (LOI)	1.39	<4.0%
Insoluble Residue (IR)	0.38	<1.5%
K_2O	0.62	
Na_2O	0.12	
FCaO	1.23	
Saturation factor	0.94	0.66-1.02
Main compounds (Bogue's equation)		
C_3S	64.34	-
C_2S	10.19	-
C_3A	4.41	-
C_4AF	13.85	-

Table 2: Physical properties of the used cement

Physical properties	Test result	Limits of Iraqi specifications No. 5/1984
Specific surface area (Blaine/cm^2/g)	3456	>2300
Initial setting (h: min)	2:45	≥0:45
Final setting (h: min)	3:50	≤10:00
Compressive strength		
3 days (N/mm^2)	36	≥15
7 days (N/mm^2)	46	≥23

Table 3: Sieve analysis of coarse aggregate

Sieve size (mm)	Percent passing	Limits of Iraqi specifications No. 45:1984
12.5	100.000	100
9.5	86.000	85-100
4.75	5.500	0-25
2.36	1.000	0-5
1.18	0.000	0
Specific gravity	2.650	-
Absorption	0.52%	-
Sulphate content	0.09%	≤0.1%

Table 4: Geometrical properties of waste-plastic fibres

Factors	Length (mm)	Width (mm)	Thickness (mm)	Specific gravity	Aspect ratio
F-24	30	4	0.3	1.12	24
F-16	20	4	0.3	1.12	16
F-08	10	4	0.3	1.12	8

Table 5: Test variables

Reference	Fibre aspect ratio	Fibre volume fraction (%)	Mix proportion: Cement	Gravel	w/c ratio
M0.0-0.0	-	0.0	1.0	4.0	0.45
M24-0.5	24	0.5	1.0	4.0	0.45
M24-1.0	24	1.0	1.0	4.0	0.45
M24-1.5	24	1.5	1.0	4.0	0.45
M16-1.0	16	1.0	1.0	4.0	0.45
M08-1.0	8	1.0	1.0	4.0	0.45

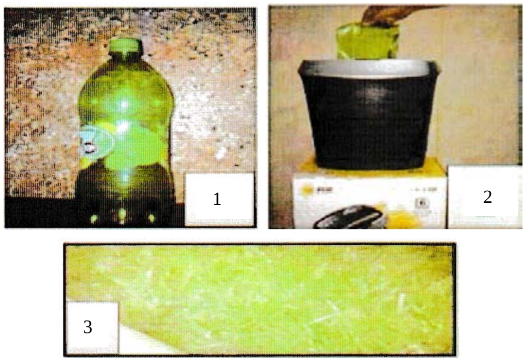

Fig. 1: Producing the waste-plastic fibres stages

having an aspect ratio of 24. Then the optimum fibre content was used to study the effect of fibre aspect ratio. Mixing and casting procedures: manual mixing was used in this research. After preparing and weighing all mix components, the cement was added to the gravel gradually using a clean pan until a homogenous dry mixture is reached, then the plastic fibres were spreaded with the mix gradually. The water was added afterward and an attempt was made to make sure the plastic fibres were evenly distributed all over the mix. After lubricating the moulds, the concrete was poured in three layers each layer was compacted using a steel rod with at least 35 strokes evenly distributed all over the surface area of the sample. The surface of each sample was then evenly finished and then left for at least 24 h before de-moulding. Each sample was then marked and cured in a water tank until 24 h before the testing date.

Test specimens and instrumentations: From each mix shown in Table 5, nine 100×100×100 mm cubes and nine 100×100×400 mm prisms were cast. Each 3 specimens represent the average of one test at an age of 7, 14 and 28 days. The cubes were used to test the compressive strength according to the British Standards BS 1881 Part116: 1983 using a BESMAK machine with a capacity of 1900 N. Flexural test was carried out using three points loading according to ASTM C78-02 with an ELE machine having a capacity of 50 kN. Maximum tensile strength in flexural (modulus of rupture) was calculated by using the following Eq. 1:

$$f_r = 1.5\frac{PL}{bd^2}$$

Where:

f_r = Modulus of rupture (flexural strength) (MPa)
P = Maximum load indicated by the testing machine (kN)
b = Width of specimen (mm)
d = Depth of specimen (mm)

It is worth mentioning that each cube was weighed before the test to calculate the density as will be seen later in the discussion of the test results. Figure 2 shows photos for the test machines and some specimens under test.

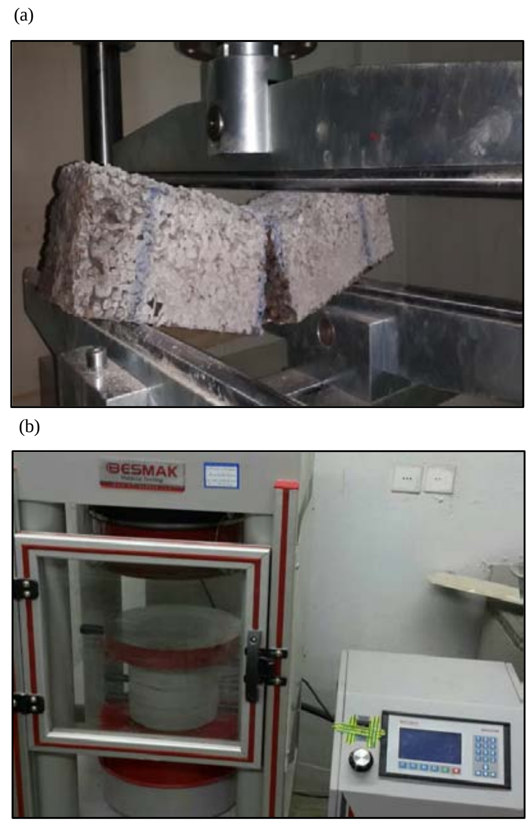

Fig. 2: Test machine and proto samples under test: a) Flexural test and b) Compression testing machine

RESULTS AND DISCUSSION

Compressive strength: Table 6 shows the results of the compressive strength tests for different fibre volume fractions and different aspect ratios at different testing ages. Figure 3a and b show the behaviour of these test results for different waste-plastic fibres volume fractions (0.0, 0.5, 1.0 and 1.5%) and different aspect ratios, namely 24, 16 and 8, respectively. It is observed from Table 6 and Fig. 3a that all specimens exhibit an increase in compressive strength with the progress of age at continuously diminishing rate. This increase in compressive strength is due to the continuity of cement hydration process which forms a new hydration product within the concrete matrix.

The optimum fibre content was determined from the mixes with waste-plastic fibre having an aspect ratio of 24 by increasing the fibre volume fraction from 0.0-1.5% as can be seen in Table 6. The optimum fibre content will

Table 6: Test results for the compressive cubes

References	Fibre aspect ratio	Fibre volume fraction (%)	Average compressive strength (MPa) 7 days	14 days	28 days
M0.0-0.0	-	0.0	13.5	17.2	19.3
M24-0.5	24	0.5	17.1	20.4	21.5
M24-1.0	24	1.0	17.8	21.9	23.1
M24-1.5	24	1.5	17.2	21.1	22.2
M16-1.0	16	1.0	16.8	21.8	23.1
M08-1.0	8	1.0	17.3	21.5	22.7

Table 7: Test results for the flexural prisms

Reference	Fibre aspect ratio	Fibre volume fraction (%)	Average compressive strength (MPa) 7 days	14 days	28 days
M0.0-0.0	-	0.0	3.61	3.70	3.74
M24-0.5	24	0.5	3.53	3.62	3.67
M24-1.0	24	1.0	3.74	3.87	3.98
M24-1.5	24	1.5	3.76	3.88	3.95
M16-1.0	16	1.0	3.65	3.83	3.74
M08-1.0	8	1.0	3.50	3.61	3.73

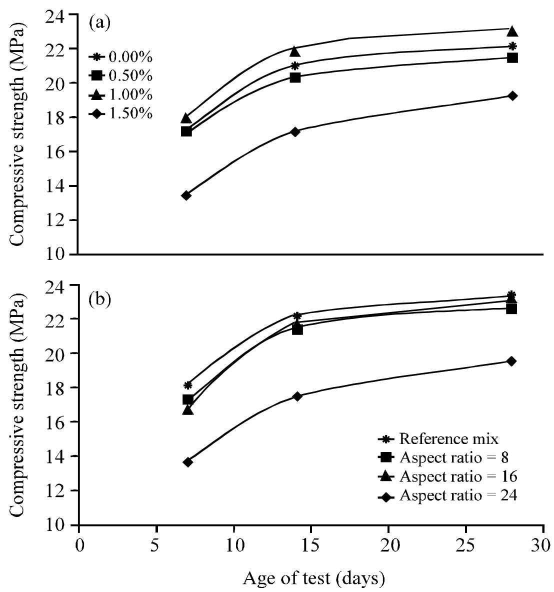

Fig. 3: Compressive strength tests for different fibre volume fractions and aspect ratios at different testing ages: a) Effect of fibre volume fraction for an aspect ratio = 24 and b) Effect of aspect ratio with the optimum fibre volume fraction of 1.0%

then be used again to study the effect of different aspect ratios (i.e., 16 and 8). The improvement of the compressive strength results is due to the ability of the fibres to elongate the crack path and the reason of compressive strength decreasing after (1.0%) might be due to the forming of segregate on mix. This led to form stiff bond around these bulks. Therefore, the existence of waste plastic fibres increased the porous inside the mix structure and allows the absorption of water inside the porous also (Al-Obaidi, 2013).

From Table 6 and 7 and Fig. 3a which is illustrating the results for the mixes having plastic fibres with an aspect ratio of 24 and different fibre volume fractions, it can be seen that all the mixes including the reference one (M0.0-0.0) behaved typically in the same manner where the compressive strength kept increasing with time, however, the rate of increase was different depending on the fibre volume fraction. From Fig. 3, it is obvious that the compressive strength kept increasing with increasing the fibre volume fraction up to 1.0% and then dropped again with fibre volume fraction of 1.5%. This means that the optimum fibre content in this study isfound to be 1.0%. The increase in the compressive strength for the mix with fibre volume fraction of 1.0% (M24-1.0) over the reference one (M0.0-0.0) was 31.9, 27.3 and 19.7% for testing ages of 7, 14 and 28 days, respectively. This means that the fibre gives much higher rise to the compressive strength at early ages. This observation could be very helpful for time critical projects like precast structures for instance.

However, form Fig. 3a it can be seen that the rate of increase in the compressive strength with aging of concrete was higher for concrete without waste-plastic fibres (reference mix). For the mix with 1.0% fibre volume fraction (M24-1.0), the compressive strength increased 23% from 7-14 days and only 5.5% from 14-28 days in comparison to an increase of 27.4% from 7-14 days and 12.0% from 14-28 days for the reference mix without fibres (M0.0-0.0). This could be justified by the abovementioned comment where the fibres gave a much higher increase in the compressive strength to the concrete at early ages and then slowed down, however, to a higher compressive strength than that of the reference mix at the same age.

Figure 3b shows the effect of fibre aspect ratio on the compressive strength at different tasting ages (7, 14 and 28 days). The curves follow the same trend as previous ones, however with a more compact pattern. This means that the effect of increasing the aspect ratio is similar to the effect of increasing the fibre volume fraction but to a relatively lower extent. From Table 6, it can be seen that increasing the aspect ratio of the plastic fibre for the same volume fraction (1.0%), from 8-24 increased the ultimate compressive strength at an age of 28 days by 19.7%. It is very interesting to note that this ratio is identical to the ratio of increase in the compressive strength when adding plastic fibres with volume fraction equals to 1.0% to the reference mix. The variation in the compressive strength when changing the plastic fibres aspect ratio from 8-16 and 24 was insignificant as can be seen from Fig. 3b.

The effect of fibre aspect ratio on the gain of strength with aging of concrete (from 7-14 and 28 days) is again almost identical to the effect of increasing the fibre volume fraction from 0.0-1.5%.

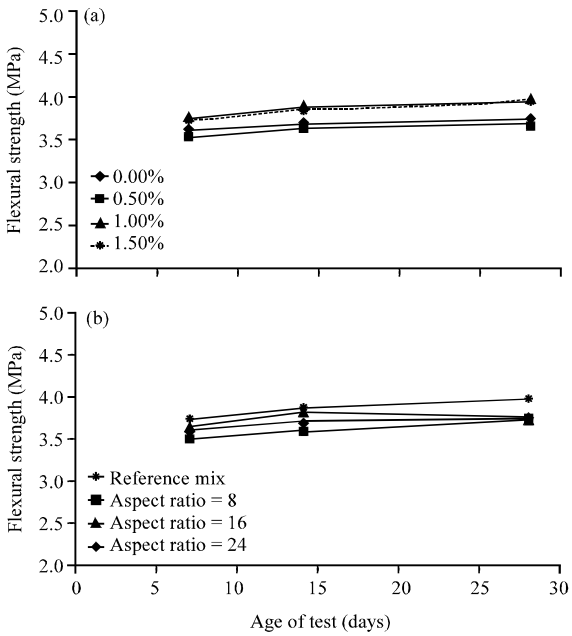

Fig. 4: Flexural strength tests for different fibre volume fractions and aspect ratios at different testing ages: a) Effect of fibre volume fraction for an aspect ratio = 24 ands b) Effect of aspect ratio with the optimum fibre volume fraction of 1.0%

Flexural strength Table 7 shows the results of the flexural strength tests for different fibre volume fractions and different aspect ratios at different testing ages. Figure 4a and b) show the behaviour of these test results for different waste-plastic fibres volume fractions (0.0, 0.5, 1.0 and 1.5%) and different aspect ratios, namely 24, 16 and 8, respectively. The results exhibited a continuous increase in flexural strength for all type of WPFs concrete with increasing curing age. This increase in flexural strength is due to the continuity of cement hydration process which forms a new hydration product within the concrete matrix, as mentioned previously.

From Table 7 and Fig 4a which is illustrating the results for the mixes having waste plastic fibres with an aspect ratio of 24 and different fibre volume fractions, flexural strength increased with the increase in fibres volume. This increase in flexural strength can be attributed to the fact that the:

- Waste plastic fibres arrest cracks progression
- The addition of waste plastic fibres contributed to strengthen the interior tensile stresses (Al-Obaidi, 2013)

These results confirm similar predictions made by Rebeiz *et al.* (993) and Al-Rawi (2011). It can be seen that

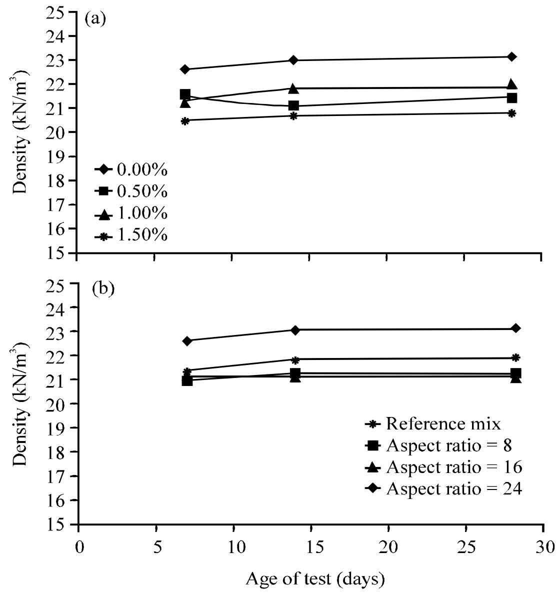

Fig. 5: Density of concrete cubes for different fibre volume fractions and aspect ratios at different testing ages: a) Effect of fibre volume fraction for an aspect ratio = 24 and b) Effect of aspect ratio with the optimum fibre volume fraction of 1.0%

all the mixes including the reference one (M0.0-0.0) behaved typically in the same pattern, where the flexural strength kept increasing almost linearly with time, however, the rate of increase was typically low. From the figure, it can be seen that the flexural strength increased with increasing the fibre volume fraction up to 1.0%. The increase in the flexural strength for the mix with fibre volume fraction of 1.0% (M24-1.0) over the reference one (M0.0-0.0) was 3.6, 4.6 and 6.4% for testing ages of 7, 14 and 28 days, respectively. This means that the fibres give higher rise to the flexural strength at older ages. This observation is absolutely the opposite of the conclusion drawn from the compressive strength tests, however, to a much less extent.

Figure 3b shows the effect of fibre aspect ratio on the flexural strength at different tasting ages (7, 14 and 28 days). The curves follow the same trend similar to the case of increasing the fibre volume fraction. This support the earlier conclusion that the effect of increasing the aspect ratio is similar to the effect of increasing the fibre volume fraction but to a relatively lower extent. The mixes having fibres with an aspect ratio of 24 behaved the best and recorded the highest flexural strength as can be seen from Fig. 3b. From Table 7, it can be seen that increasing the aspect ratio of the plastic fibre for the same volume fraction (1.0%), from 8-24 increased the ultimate compressive strength at an age of 28 days by 6.7%.

Table 8: Density of the cubes in the experimental programme

Reference	Fibre aspect ratio	Fibre volume fraction (%)	Average density (kN/m^3) 7 days	14 days	28 days
M0.0-0.0	-	0.0	22.6	23.0	23.14
M24-0.5	24	0.5	21.5	21.1	21.50
M24-1.0	24	1.0	21.3	21.8	21.90
M24-1.5	24	1.5	20.5	20.7	20.80
M16-1.0	16	1.0	21.2	21.1	21.10
M08-1.0	8	1.0	21.0	21.2	21.20

Density of concrete: Each specimen was dried at ambient temperature for 24 h before the test. Then it was weighed using a digital scale with an accuracy of 1.0 g. The dimensions of the specimen were measured and the density of the specimen was calculated accordingly. This was done for all the specimens at each testing age (7, 14 and 28 days), Table 8 shows the density for the tested cubes.

Figure 5a and b shows the behaviour of the test results for different waste-plastic fibres volume fractions and aspect ratios. From Fig. 4a and Table 8, it can be noticed that adding the plastic fibres reduces the density and these results confirm similar predictions made by Al-Obaidi (2013) and Daud *et al*. (2012, 2013). The reason of decreasing the density is the low density of waste plastic fibres.

It can be seen that incorporating 1.5% volume fraction of waste-plastic fibres succeeded in reducing the density of no-fines concrete by 10.1% at the age of 28 days. In addition, Fig. 4b shows that the less the plastic fibre aspect ratio the more the reduction in the density of concrete. The highest reduction resulted from plastic fibres having an aspect ratio of 8 and 16. Nevertheless, from analyzing the numbers in Table 8, it can be stated that the effect of fibre aspect ratio on the density of concrete is insignificant.

CONCLUSION

In this experimental study, waste-plastic fibres have been added to no-fines concrete both to enhance its mechanical properties and to find an environmental friendly and an economical method for the disposal of waste-plastic which has become an increasing problem to the environment recently. The volume fraction of the waste-plastic fibres was studied as one of the main variables in this study within the range of 0.0-1.5% of the total volume of concrete mass. It has been found that a volume fraction of 1.0% of the concrete represents the optimum ratio that gave the best enhancement in the mechanical properties of concrete. Adding waste-plastic fibres having an aspect ratio of 24 with a volume fraction of 1.0% succeeded in increasing the compressive strength of concrete by 31.9, 27.3 and 19.7% for testing ages of 7, 14 and 28 days, respectively in comparison to the reference mix. This is an interesting result because it means the fibre gave much higher rise to the compressive strength at early ages. This observation could be very helpful for time critical projects like precast structures for instance.

The tensile strength was also increased by using waste-plastic fibres but to a lower extent. It has been found that using waste-plastic fibres having an aspect ratio of 24 with a volume fraction of 1.0% succeeded in increasing the flexural strength of concrete by 3.6, 4.6 and 6.4% for testing ages of 7, 14 and 28 days, respectively in comparison to the reference mix.

The effect of waste-plastic fibres on the density of no-fines concrete was also studied. It has been found that incorporating 1.5% volume fraction of waste-plastic fibres succeeded in reducing the density of no-fines concrete by 10.1% at an age of 28 days.

The optimum fibre content of 1.0% was used again to study the effect of fibre aspect ratio by changing it from the default of 24-16 and 8. No significant effect was found for changing the aspect ratio on the compressive strength within the limits of this work; however, this was not the case with respect to the flexural strength. It has been observed that the higher the aspect ratio, the higher the strength was. Using an aspect ratio of 24 (1.0% volume fraction) gave an increase to the compressive strength by only 1.7% in comparison to an increase of 6.3% in the flexural strength over the mix having plastic fibres with an aspect ratio of 8.

All the above-mentioned advantages of using waste-plastic fibres with no-fines concrete makes it an attractive solution both for enhancing the concrete properties and disposing waste-plastic material economically.

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