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EFFECT OF ADDING RECYCLED PLASTIC FIBERS TO CONCRETE ON THE STATIC PROPERTIES OF CONCRETE TILES

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ABSTRACT

This research paper is an attempt to reuse plastic waste fibre resulting from plastic sections industry as an additive to concrete matrix. The relationship between fibre volume fraction and mechanical properties of concrete and reinforced concrete tiles was investigated. Three volume fractions of fibre (0.5 % , 1 % and 1.5 % - by volume of concrete) were used through the experimental program. Tests' results proved a slight decrease in concrete compressive strength as plastic fibre was added compared with the reference mix. Flexural behaviour of concrete tiles was enhanced as adding fibres. Adding fibre to Concrete results in a negligible reduction in concrete density. Fibre with high volume fractions improved Splitting tensile strength compared to the reference mix.

1. Introduction

Polyvinyl Chloride (PVC) contributed to sustainable development especially in the last couple decades. For example, PVC has been used as windows and doors in buildings saving energy and weight. PVC is also used in production of pipes, furniture, electric cables, flooring and even clothes [1]. Therefore, an appropriate recycling strategy should be followed to protect the environment.

The procedure of recovering used materials from the waste stream and then incorporating those same materials into the industry is called recycling [2]

Currently, recycling is one of the most important environmental issues. The accumulation of recyclable plastic waste is a continuous problem for the environment. These plastic materials can be used in concrete mixtures as the world's demand for concrete production and consumption increases [3].

PVC waste has been widely recycled in different types of applications. However, PVC waste is considered a potential material in the construction industry due to its great physical characteristics including: lightweight, thermal and sound insulation, energy absorption, and elasticity [4].

Concrete is one of the most widely used building material because of its high compressive strength, long service life, and low cost. However, low tensile strength and low crack resistance of concrete are considered the two most important disadvantages. To overcome these weaknesses of concrete, some studies have been conducted on concrete reinforced

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by fibres. Investigations showed that adding fibres to concrete improves its performance [5].

As it is an interesting topic, numerous researchers discussed Fibre reinforced concrete in the last two decades. V. Malagavelli et. al. [6], investigated the impact of (High Density Polyethylene (HDPE)) recycled from cement bags waste on concrete, and they found that addition of 3.5% fibre in concrete increased its compressive and tensile strength considerably .

Z. Hasan A. et. al. [7] Evaluated producing a Sustainable Construction material through the use of Waste of Bottles in Concrete. To achieve this goal, they conducted an experimental work on recycling of glass and plastic wastes in concrete. They used different contents of each type of fibres (plastic fibre, pieces of bottle caps and glass) to achieve the optimum fibre content for each type of fibre. The optimum content of different types of fibres were emerged together as hybrid addition. They compared the results of these mixtures with a reference mixture containing no fibre. Tests results gave good indications about using these waste in concrete.

The effect of adding polyethylene (PET) lightweight aggregate to concrete on its compressive strength was studied by Choi et al. They concluded that concrete compressive strength decreases when increasing the quantity of the PET plastic aggregates [8].

PVC waste was added to concrete by O. I. Mahmood [9], PVC waste was used as a fine aggregate replacement. Different volumetric percentage of PVC waste were added (25%, 50%, and 75%). Due to the results, bending strength, tensile strength, and workability were improved, while concrete compressive strength decreased. Concrete behavior was also transformed from brittle failure in the case of normal concrete to ductile failure when PVC waste was used.

Batayneh et al. [10], replaced 20% of sand with plastic waste. They identified through their work a decrease in concrete compressive strength with an increase in plastic content. They found that replacing 20% of sand with plastic waste results in compressive strength reduction up to 70% compared to normal concrete.

In this work, the effect of adding plastic fibre type (PVC) resulting from the residues of PVC construction plants to concrete on its properties is studied. The relationship between the concrete properties and the fibre volume fraction was investigated. Some physical and mechanical properties of concrete mixtures, compressive strength, tensile strength, bending resistance of the slabs, and concrete density, were investigated..

2. Research Objective

This paper is an attempt to study the possibility of recycling (PVC) plastic waste resulting from the plastic forming plants residues. For this purpose, different plastic ratios were added to concrete, cubes and cylinders were casted and tests were conducted. A relationship was developed between plastic fibre ratio and concrete physical and mechanical characteristics. Reinforced concrete tiles for each mix were also casted and tested under static loading for its flexural strength. The effect of fibre volume fraction on flexural strength of reinforced concrete tiles was configured.

3. Materials and methods

3.1. Materials

3.1.1. Cement

An ordinary Portland cement correspondent to (ASTM C 150) [11]. was used in the experimental program

3.1.2. Fine Aggregate

The fine aggregate used in this investigation was correspondent to (ASTM C 33) [12].

3.1.3. Coarse aggregate

Rounded Coarse aggregate correspondent to (ASTM C 33) was used in this research paper [12].

3.1.4. Polyvinyl chloride (PVC) fibres

Polyvinyl chloride (PVC) fibres resulting from the laminating process of the manufacturing plants were added to concrete mixtures. The measurement of fibres was variable, the fibres added to all the mixtures were between (2 to 5 cm) in length. (5 mm) in width and (1 mm) in thickness.

3.1.5. Reinforcing steel

All photographs, schemas, graphs and diagrams are to be referred to as figures. Low-quality scans are not acceptable. Figures must be embedded into the text and not supplied separately. Every figure has a caption that includes the figure number and a brief description. This caption must be enough perceptible with out mention to the text.

3.2. Moulds and sampling

3.2.1. Cubes with dimensions (150 * 150 * 150) mm were used for the compressive strength test, as shown in Fig. 1. (a).

3.2.2. Cylinders: 150mm in diameter and 300 mm were used in height for splitting tensile strength test, as shown in Fig. 1. (a).

3.2.3. Wooden molds with dimensions (500 * 500 * 50) mm were used for tiles flexural strength testing, as shown in Fig. 1.

Fig. 1. Cubes and cylinder

3.3. Concrete mixes

Table 1. shows the proportions of Concrete mixtures for each cubic meter. Three volumetric ratios of fibres (0.5, 1 and 1.5%) were added to the same quantities of concrete mixture to produce three different matrices in addition to the reference mixture.

Table 1. Concrete mixtures and quantities of raw materials used

mix	Fibre ratio %	Plastic fibres (kg/m3)	Fine aggregate (kg / m3)	Course aggregate (kg /m3)	Water kg/m 3	Cement (kg/m3)
1	0	0	525	1400	175	
2	0.5	0.678	525	1400	175	
3	1	1.36	525	1400	175	
4	1.5	2.034	525	1400	175	

3.4. Casting and curing

Concrete samples were prepared and cured according to American Standards (ASTM C192) [13]. Figure 2. Shows the casting and curing condition.

Fig. 2. casting of some samples

3.5. Test procedure

The mechanical properties and physical characteristics were tested for all concrete mixtures. Test results were compared to the reference mixture to investigate the performance of concrete mixtures.

Table 2. Tests and samples

#	test	Number of samples	Age (days)
1	Compressive strength	3	7
2	Compressive strength	3	28
3	tensile strength	3	7
4	tensile strength	3	28
5	Flexural test	3	28
6	Density	3	28

3.5.1. Compressive Strength Test:

The tests were conducted according to British Standard (B.S 1881 Part 116: 2004) [14]. Six concrete cubes were tested for each mixture, three cubes were tested at seven days age, and the resent three were tested at 28 days age.

3.5.2. Siplitting tensile Strength Test:

Concrete splitting tensile strength was measured according to American Standard (ASTM C496-96) [15]. Three cylinders were tested at 7 days age, and the three cylinders were tested at 28 days age.

3.5.3. Density :

The density of all mixtures was tested (According to ASTM C642) [16], by measuring the weight of an oven-dried cubic sample with known dimensions.

3.5.4. Flexural Test of Tiles :

Three concrete tiles of each mixture were tested under static flexural loading. Each concrete tile was fixed on a manufactured steel structure simulating a simple supporting condition. The load was supplied on the centre of the tile with a loading rate of (1 kN/sec). The loading point was a steel disc with (50 mm diameter)

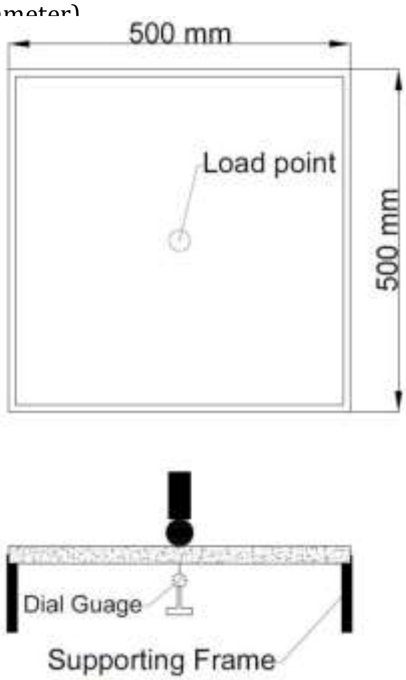

Fig. 3. deflection digital gage

4. Results and discussion

4.1. Compressive strength

Figure 4 shows the relationship between compressive strength and fibre volume fraction. It is noticed from the figure that a slight decrease in concrete compressive strength as fibre volume fraction increases. The decreases in compressive strength was due to the weak points produced in concrete matrix due to the addition of fibres.

The deflection under the centre point of the tile was also measured using a digital gage device with (0.001 mm) accuracy. Test procedure is shown in Fig. 3

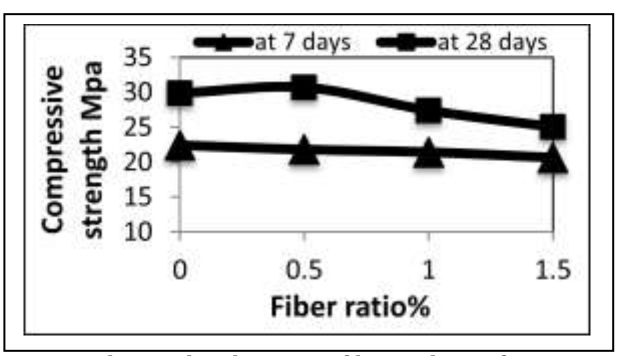

Fig. 4. relationship between fibre volume fractions with compressive strength

4.2. Splitting Tensile Strength:

Concrete tensile strength tests' results for all mixtures are shown in Fig. 5. Concrete tensile strength was slightly improved when adding fibre. When adding fibre by (1.5%) volume fraction, concrete tensile strength increased by (9.5%) and (13.6%) at the 7 and 28 days age respectively, compared to reference mixture. This increase happened due to the behaviour of fibres connecting concrete components together.

As shown in fig. 6. The reference mixture failed by completely sudden splitting into two parts, while there is no sudden separation in the concrete containing fibres. Concrete resistance continues even after cracks development. Concrete undergoes higher elastic deformation before failure.

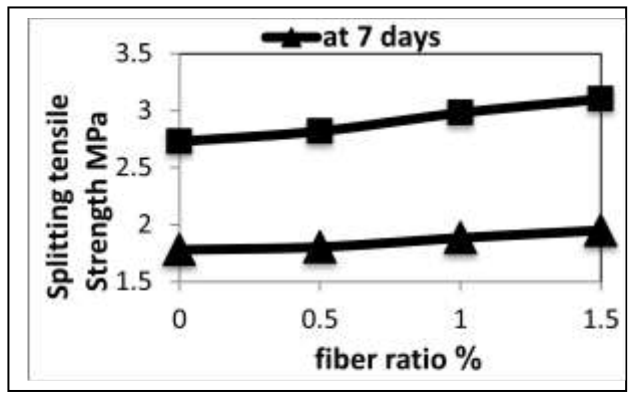

Fig. 5. relationship between fibre volume fraction Strength and Splitting Tensile

Fibre reinforced specimen *Reference specimen*

Fig. 6. tensile failure of fibre reinforced concrete and reference concrete

4.3. Density

The results showed that the added volume fractions of fibres have no significant effect on concrete density, while it's expected that, concrete density will be decreased when adding higher volume fractions due to the low density of plastic compared to the density of other concrete components. Figure 7 shows the reduction in concrete density as plastic fibre was added.

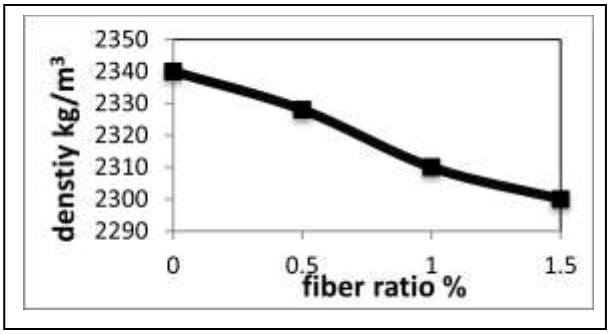

Fig. 7. relationship between fibre ratio and concrete density

4.4. Tile flexural strength under static load

4.4.1. Maximum load

The effect of adding PVC fibre to concrete, on the load that concrete tiles can carry until failure is illustrated in Fig. 8. and 9. The load that concrete tiles can carry until failure was improved as fibre volume fraction increased. Adding PVC fibre to concrete also increased the load that concrete tiles can carry until the first crack is occurred. When adding 1.5% of PVC fibres to concrete, the first crack load and the failure load were increased by 53.38% and 14.72%, respectively. This increase can be attributed to the increase of concrete tensile strength when adding fibres. Fibres connect concrete constituents together and prevent cracks spread. Figure 10. represents that the highest deflection was achieved by the tiles containing 1.5% volume fraction of fibres. Samples containing (0.5% fibre) achieved the best flexural behaviour. Adding fibres prevent cracks expansion, due to the interconnection of the concrete mixture. Also, the capillary cracks are discontinued by fibres.

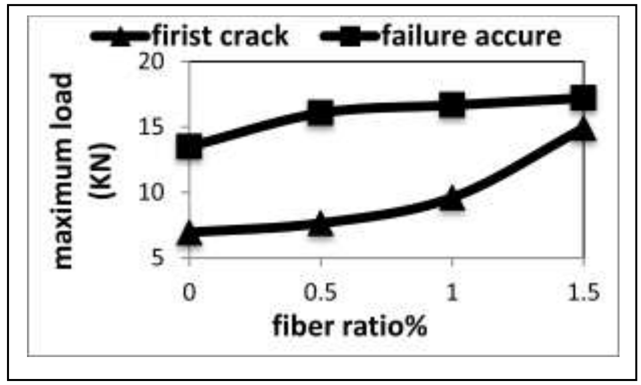

Fig. 8. relationship between fibre ratio and max. load

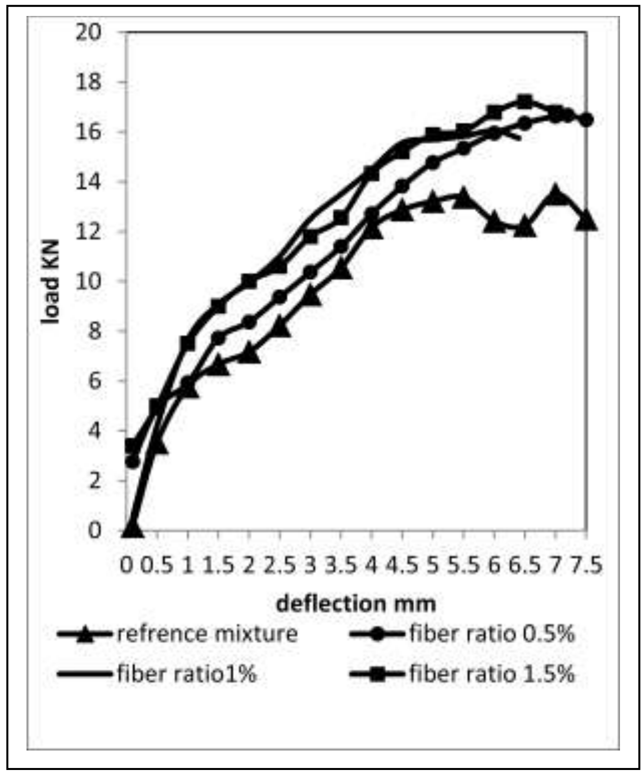

Fig. 9. Load – Deflection curves

4.4.2. The stages of failure

As shown in fig. 10. and fig. 11. , the form of failure in the reinforced concrete tiles starts with tensile fracture at the bottom of the tile due to bending, followed by concrete crushing at the compression zone. At the initial stages of loading the initial cracks begin to grow in the centre of the bottom of the tile, and gradually the cracks begin to extend randomly towards the edges while loading is continued. Cracking happens due to exceeding the concrete allowable tensile stresses. As concrete is weak in resisting tensile stresses, fibres contribute to reduce the number of cracks and stop its extension. Unlike the reference tiles, the fibre-reinforced tiles are not shredded into pieces due to the presence of fibres which worked as connectors between concrete constituents.

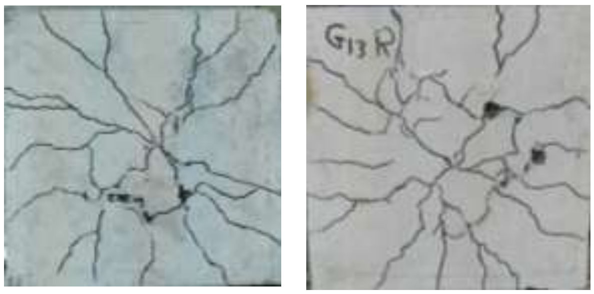

Fig. 10. Crack Patterns (with fibre)

Fig. 11. Crack Patterns (reference mix)

4.5. CONCLUSIONS

This work included casting and testing different concrete mixtures with varying ratios of PVC fibres, and comparing the properties of these mixtures with the properties of normal concrete (free of fibres). Tests' results proved many points including :

1. Addition of plastic fibres to concrete adversely affects concrete compressive strength, due to the weak points produced in concrete matrix when adding fibres.
2. Plastic fibres addition leads to an enhancement in concrete tensile strength up to failure.
3. Concrete density is slightly affected when adding fibres.
4. Flexural strength of concrete tiles was improved for both of the failure load and the first crack load, and the increase was proportional parallelism with the increase of fibres volume fraction.
5. Fiber-reinforced concrete tiles preserve their form after failure due to the connectivity rule that fibres play.

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