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Effect of Utilization Waste Strapping Plastic Belts on Flexural Behaviour of Concrete

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ABSTRACT

Many researchers have investigated the solutions for the problem of solid waste in different ways. An example of that is reusing polyethylene terephthalate (PET) as reinforcement to concrete. Strapping plastic belts used to tie clay bricks while transportation in trucks are one of the common waste of construction that could be beneficial in enhancement of concrete flexural behaviour due to its high tensile strength. This paper is a trial to investigate the effect of utilizing waste strapping plastic belts on the flexural behavior of concrete. Concrete prisms (100*100*500mm) were reinforced with plastic belts as the main reinforcement for flexural strength. Five amounts of reinforcement were added to the concrete section in the tension zone (81, 67.5, 54, 40.5, 27 sqr mm). The reinforcement was included in concrete sections internally or externally using suitable glue. The behavior of the reinforced prisms was compared to plane concrete prisms (containing no reinforcement). Tests results showed an enhancement in flexural strength of concrete section while reinforcement ratio is increased externally. The addition of 81 mm^2 of plastic straps externally, increased the flexural strength by 21% compared to sections with 27 mm^2 reinforcement. The enhancement in flexural strength as internal reinforcement is added was limited. According to the flexural test of reinforced concrete prizms. Adding 81 mm^2 of plastic straps internally, reduced the flexural strength by 18% compared to sections with 54 mm^2 reinforcement due to the splitting of the cover as the area of the reinforcement increases. Increasing the number of belts in the section results in a sever reduction in the spacing between each two belts, leading to increase concrete cover tendency to split. For that, increasing the amount of plastic diversely affects connectivity for the internally reinforced sections.

1. INTRODUCTION

Plastic waste is considered one of the serious threats to the environment (land and water). Plastic materials are not biologically degradable in nature, and burning such waste is not a solution due to the dangerous chemical gases released into the air through the process. To rescue the environment against pollution, the best solution to consume plastic is the process of recycling. However, it is considered not economical to degrade plastics to make a new product; other recycling methods are needed.

In contemporary discourse, there has been a notable shift in emphasis toward trash reuse instead of disposal. This shift can be attributed to the limited availability of land for landfilling purposes and the concurrent rise in associated costs. Researchers are consistently inclined towards utilizing such compounds in the composition of concrete [1]. Concrete becomes more cost-effective, in addition to mitigating the issue of waste. Plastics are utilized in several applications as structural materials [2, 3]. Using recycled plastics in developing new materials is important for the plastic recycling industry and the construction sector. Before practical implementation, it is imperative to conduct testing on these novel materials. The extensive utilization of plastics has contributed to an increase in the volume of solid waste. Polyethylene accounts for most plastic trash, whereas polyethylene terephthalate (PET) ranks second in quantity. using plastic waste in on flexural behavior of concrete is a promising research field in the last decades. Many studies have investigated the use of plastic waste to improve the flexural behavior of concrete.

In 2022, Shereen Qasim incorporated waste rope fibers (WRF) into concrete. The researchers incorporated varying proportions of WRF into the concrete mixture, specifically 0%, 0.25%, 0.5%, and 1% by weight of the concrete. The researchers examined the impact of incorporating these fibers on the rheological and mechanical characteristics of concrete, as well as the structural performance of concrete elements. One of the most important finding of this study was that the addition of WRF resulted in an enhancement of the compressive and flexural strength of concrete by up to 22% and 4.3%, respectively. Also, they found that the breadth of cracks in reinforced concrete beams had a significant reduction, while the ductility index of beams based on WRF was measured to be between 3.07 and 3.24, in contrast to a value of 1.45 for beams without fibers [4].

Ali et al. [5], in 2022, incorporated PET fibers into concrete beams at two different volumetric percentages: 0.5% and 1%. The concrete was layered with PET fibers, and the impact of this on the flexural behavior of beams was assessed. For each mixture, they constructed reinforced concrete beams using three layers of PET fibers. They conducted a comparison between the beams that had the same percentage of PET fiber over the entire area. Aside from the load-deflection correlations, the flexural testing also involved determining the yield, initial cracking, and ultimate load characteristics. The evaluation also included an assessment of toughness, ductility, and failure modes. They found through test results that a significant improvement in the ultimate load when PET fiber concrete with a layered distribution was utilized. Additionally, they stated that concrete beams reinforced with stacked PET fibers displayed increased deflections before to failure.

Alani et al. [6] conducted a study in 2022 on the flexural and tensile properties of Fiber Reinforced Green Concrete, which was achieved by incorporating recycled waste plastic bottles (PET) fibers. The addition of Silica Fume and Ultra-fine palm oil fuel ash was explored at varying amounts. Fourteen concrete mixtures were formulated, using varying amounts of supplementary cementitious materials (SCMs) such as silica fume (SF) and unprocessed palm oil fuel ash (UPOFA), as partial replacements for ordinary Portland cement (OPC). The mixtures consisted of 25% to 50% UPOFA and 10% to 20% SF. 1% of the total mixture volume consisted of PET fibers. The test findings demonstrated that the rigid and fragile characteristics of concrete were altered by the inclusion of PET fibers. The use of PET fibers resulted in a significant enhancement in the ductility index, along with superior splitting tensile strength, compressive strength, flexural toughness, flexural strength, and flexural stiffness.

Conventional reinforcing was provided through near-surface mounted NSM (Near Surface Mounted) plastic strips in the tension zone of concrete members. Over the past two decades, there has been a global focus on the enhancement of reinforced concrete buildings through the use of the (NSM) by fiber-reinforced polymer (FRP) materials [7-10].

The implementation of NSM FRP strengthening technology is widely utilized for enhancing the resistance of reinforced concrete beams against flexural loads. Numerous experimental [11-19] and numerical [20-26] investigations have been conducted to examine the reinforcement of concrete beams by using bars or strips affixed close to the surface of the concrete member, specifically within the concrete cover at the beam soffit.

The findings from these tests indicate that despite the relatively strong connection between NSM FRP and concrete, the failure of NSM FRP flexural-strengthened RC beams is nevertheless prone to occur due to deboning at the ends. This is attributed to high normal and shear loads in the vicinity of the FRP ends.

In beams reinforced with NSM strengthening, failure due to end deboning can manifest in two primary modes: i) deboning of the FRP (Fiber Reinforced Polymer) end interface between the concrete and NSM FRP [16] and ii) separation of the FRP end from the concrete cover along the plane of the bottom longitudinal steel bars of the beam [11, 12, 18, 19]. The prevalence of FRP end concrete cover separation was observed to be more frequent than the interfacial deboning of FRP end. This can be attributed to the combined influence of two factors: i) the robust bond between concrete and NSM FRP and ii) the significant shear and normal stresses exerted by the bottom longitudinal steel bars (deformed steel bars) on the surrounding concrete [10].

This work is a trial to investigate the benefit of reusing Strapping Plastic Belts as a main reinforcement for concrete beams externally and internally. Also, it is to find the optimum quantity of belts to be added to concrete section in terms of flexural strength.

2. MATERIALS AND METHODS

In this work, concrete sections were reinforced using plastic straps. Tow procedures were followed in adding plastic strips to concrete sections. In the first procedure, plastic strips were attached externally to the bottom surface of the beams. In the second procedure, plastic straps were immersed in the section near the bottom surface of concrete beams. Five reinforcement ratios were tested in each procedure in addition to the plain concrete case details shown in Table 1.

Table 1. Chemical properties of cement

Model	Area Sqr mm	Model	Area sqr mm
A	81	D	40.5
B	67.5	E	27
C	54		

The concrete mixture was explicitly formulated to exhibit structural failure when subjected to a stress level of 30 MPa. The concrete components were combined in a mixture of cement, sand, and gravel with a percent of 1:1.5:3, with a (w/c) ratio of 0.45. The amalgamating constituents, specifically cement, sand, and gravel, continued until a desirable level of homogeneity was achieved.

After achieving adequate homogeneity, water was introduced to the dry mixture, and the mixing process was then prolonged. The investigation of concrete consistency was conducted by employing the slump test as per the guidelines specified in ASTM C143-01 [27]. Three concrete specimens, each measuring 150 mm in size, were tested to ascertain the compressive strength of the concrete. The assessment of concrete tensile strength encompassed the examination of three cylindrical specimens, each measuring 300 mm in height and 150 mm in diameter.

In order to assess the flexural strength of each reinforcement scenario, three prisms measuring 10 cm by 10 cm by 50 cm were fabricated, subjected to a curing process, and then tested. The prism testing was conducted per the ASTM C 78 [28] standard, which involved implementing a four-point loading condition approach.

The assessment of concrete compressive strength adhered to the guidelines outlined in BS 1881 Part 116: 2004 [29]. The concrete tensile strength was evaluated according to the ASTM C496-96 standard [30]. The modulus of rupture was determined for each instance of reinforcement details of specimens and molds shown in Table 2.

Table 2. Detail of specimens and molds

Test	Dimensions of Mold (cm)	Cases	Total No. of Specimens
Compressive Strength	15*15*15	1	3
Tensile Strength	15*30	1	3
Flexural Strength	10*10*50	8	24

3. COMPONENT CHARACTERISTICS

3.1 Cement

The experimental program in this study uses a locally manufactured Ordinary Portland cement (OPC) known as Tasluja. Tables 3 and 4 present this cement's chemical and physical test results.

The cement underwent testing in accordance with the (Iraqi Standard Specifications) IOS No. 5/1984 [31].

Table 3. Chemical composition of cement

SiO_2	Al_2O_3	SO_3	Loss on Ignition	Insoluble Material	Lim Saturation Factor
13.5	4.5	1.2	0.94	1.06	0.8

Table 4. Cement physical characteristics

Specific Surface Area m^2 / kg	Setting Time		Compressive Strength MPa		Expansion by Autoclave Method
	Initial Setting	Final Setting	3 days	7 days	
250	1: 30	3: 40	21.5	31.3	0.39

3.2 Aggregate

The fine aggregate utilized in concrete consists of graded fine aggregate sourced from Samarra city, with a particle size that passes through a 4.75 mm filter. The testing of fine aggregate adheres to the specification outlined in IOS No. 45/1984 [19]. Also, Table 5 presents the grading of the fine aggregate.

Concrete uses non-crushed graded natural gravel from Samarra, Iraq. 9.5 mm was the highest aggregate size. The coarse aggregate testing specification is IOS No. 45/1984 [32]. Test results revealed coarse aggregate by Iraqi standards. The results of aggregate grading are in Table 6.

Graded fine aggregate from Samarra city (passing 4.75 mm filter) is utilized in concrete. The fine aggregate testing specification is IOS No. 45/1984 [19]. The result of fine aggregate grading is shown in Table 5.

Table 5. Fine aggregate test of grading (Cumulative Passing)

Sieve Size	9.5	4.75	1.18	300	150
%	100	90.39	66.84	15.86	6.03

Table 6. Grading of coarse aggregate (Cumulative Passing)

Sieve Size	9.5	4.75	2.36	1.18	600	300	150
%	100	91.32	83.6	67.74	20.4	2.47	0

3.3 Plastic strapping ties

Plastic strapping ties shown in Figure 1 were used as the main reinforcement for concrete prisms. The tensile stress of ties was tested and achieved 223.8 MPa on average, as shown in Table 7. Figure 2 shows the strapping ties under test.

Table 7. Tensile strength of strapping ties

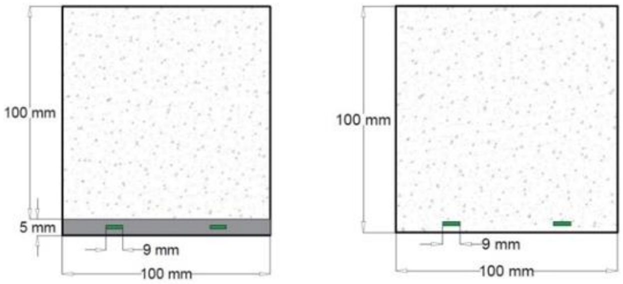
Sample 18 * 1.5 mm	1	2	3	Average
Tensile Force kN	5.97	6.12	6.04	6.043
Tensile Strength MPa	221	226.6	223.7	223.8

Figure 1. Strapping ties

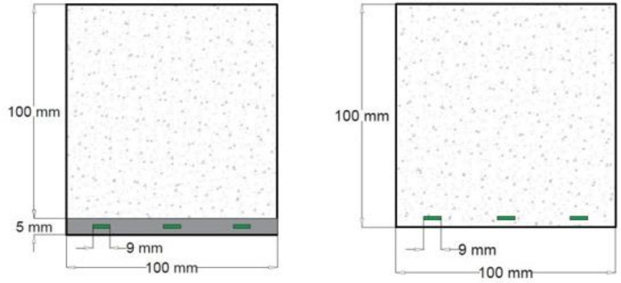
Figure 2. Strapping ties under tensile strength test

3.4 Sika dur

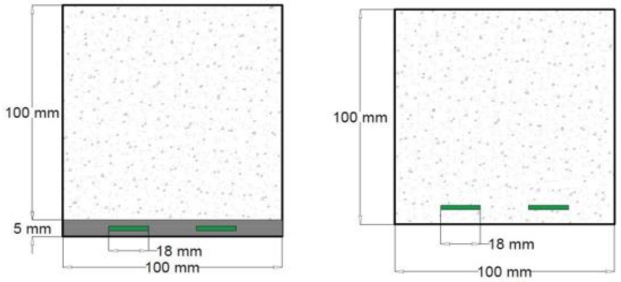
Sikadur-31 CF was used to connect plastic straps to concrete beams. Plastic strips were attached externally to the bottom surface of the beams, as shown in Figure 3.



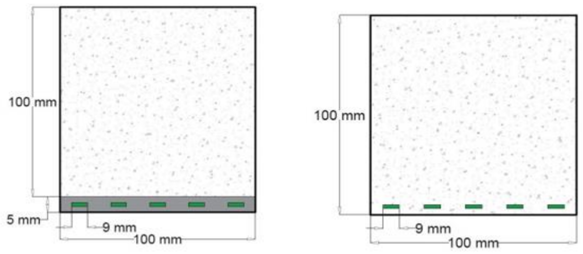
A) Sample A area of reinforcement 27 mm^2



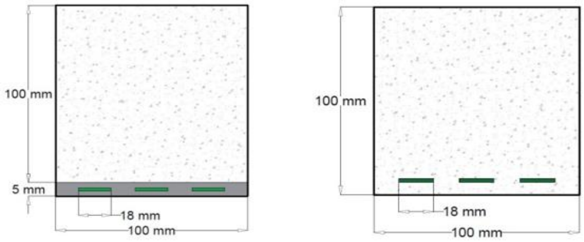
B) Sample B area of reinforcement 40.5 mm^2



C) Sample C area of reinforcement 54 mm^2



D) Sample D area of reinforcement 67.5 mm^2



E) Sample E area of reinforcement 81 mm^2

Figure 3. Sections of concrete beams

4. RESULTS AND DISCUSSION

4.1 Concrete compressive strength

The compressive strength of concrete used in casting was 28 MPa. At the same time, concrete achieved 3.04 MPa in tension.

4.2 Modulus of rupture

Table 8 shows flexural strength for PVC strapping tie-reinforced and control prisms. The best ratios of internally and externally reinforced prisms achieved modulus of rupture 5.355 and 7.3035 MPa, respectively, compared to the reference mix (4.26 MPa) the result of modulus of rupture shown in Figure 4.

Prisms reinforced internally by plastic straps failed by splitting the cover and the reinforcement, as shown in Figures 5 and 6. While the externally reinforced prisms failed by concrete crushing in the tension zone. That is due to the high ductility of the reinforcement compared to the ductility of concrete.

Table 8. Flexural strength of prisms

Area (Sqr. mm)	27	40.5	54	67.5	81
Inter. Reinf. kN (MPa)	10.32 (4.66)	11.6 (5.22)	11.9 (5.35)	10.83 (4.87)	9.81 (4.41)
Exter. Reinf. kN (MPa)	12.6 (5.76)	13.24 (5.95)	13.9 (6.25)	15.08 (6.78)	16.23 (7.30)

Figure 4. Splitting of cover due to high quantity of reinforcement

Figure 5. Failure pattern

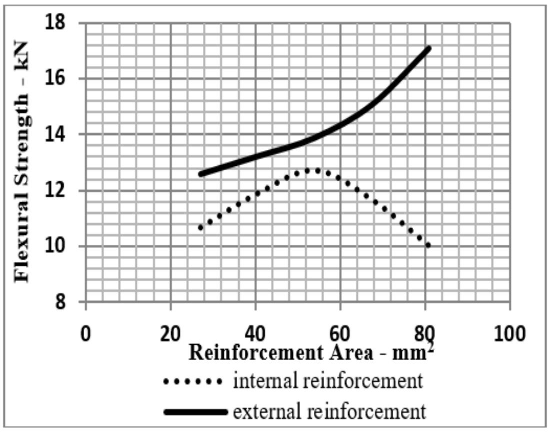


Figure 6. Flexural strength for different reinforcement

4.3 Toughness

The incorporation of ties in concrete mixtures resulted in elevated levels of toughness, indicating an enhanced capacity for energy absorption in the concrete. This may be quantified by calculating the area beneath the load-deflection curve for the concrete model as shown in Figure 7.

The energy absorption capacity of concrete was shown to improve by 44% and 124% when plastic straps were added internally and externally, respectively, compared to the reference mixture.

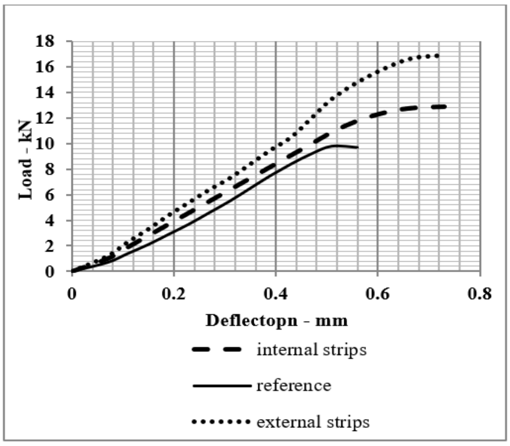


Figure 7. Illustrates the load-deflection relationship of the sample

5. CONCLUSIONS

The recycling of plastic straps in concrete is a solution for addressing the environmental concern. Additionally, this practice contributes to the production of more efficient concrete sections.

From the load-deflection curves, absorption capacity, or toughness, of concrete sections reinforced by plastic straps, is greater than that of plain concrete.

Concrete flexural strength was increased when adding plastic straps externally. The addition of 81 mm^2 of plastic straps increased the flexural strength by 21% compared to sections with 27 mm^2 reinforcement.

When reinforcing concrete sections internally, the flexural strength is increased only to a limited area. The increase in the quantity of reinforcement byond 54 mm^2 resulted in reduction of flexural strength. Adding 81 mm^2 of plastic straps internally, reduced the flexural strength by 18% compared to sections with 54 mm^2 reinforcement.

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