Using Of Recycled Rubber Tires And Steel Lathes Waste As Fibbers To Reinforcing Concrete

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Abstract

This research paper is accomplished to study the effect of using waste fibers in properties of concrete . Steel lathe waste fibers are added by percentages of (4, 6 and 8 %) from weight of concrete and a percentages of concrete coarse aggregate are replaced by rubber tires waste fibers in a ratios of (5, 10 and 15%) by volume . Besides to that, the combined fibers are used steel lathe waste fibers by adding (4, 6 and 8 %) with constant replacing of rubber tires waste fibers of (10 %). The results showed that adding of steel lathe waste fibers in plain concrete enhances its strength under compression about (15%) and tension about (20%), while rubber tires waste reduced both of compression about (80 %) and tension about (51%) strengths .Also the compression and tension strengths are reduced (88% and 30%) respectively with using combined fibers . The dry concrete density of lathe waste fibers concrete is (2345-2365kN/m^3) , the rubberized concrete density is (2130-2240kN/m^3) and for combined fibers concrete density (2025-2180 kN/m^3).

Key Words: Rubber Tires, Steel Lathe, Coarse Aggregate, Fibers, Industrial waste.

إعادة تدوير مطاط الإطارات المستهلكة ومخلفات خراطة الحديد كألياف تسليح للخرسانة

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الخلاصة

في هذا البحث تمت دراسة تأثير استعمال ألياف ألمخلفات على خواص الخرسانة.تم إضافة ألياف مخلفات خراطة الحديد بنسب مئوية (٤ ، ٦ ،٨ %) من وزن الخرسانة الكلي. كما تم تعويض نسب مئوية من الركام الخشن للخرسانة بألياف مخلفات مطاط الإطارات المستهلكة بنسب (٥ ،١٠ ،١٥ %) من حجم الخرسانة. بالإضافة إلى ذلك تم استخدام ألياف المخلفات بصورة مشتركة بإضافة ألياف مخلفات خراطة الحديد بنسب (٤ ،٦ ،٨ %) مع نسبة ثابتة لاستبدال ألياف مطاط الإطارات المستهلكة بنسبة (١٠%). بينت النتائج أن إضافة ألياف خراطة الحديد في الخرسانة الاعتيادية تعمل على تحسين مقاومة الخرسانة للانضغاط بنسبة (١٥ %) والشد بنسبة (٢٠ %)، بينما مخلفات مطاط الإطارات المستهلكة تقلل مقاومة الخرسانة للانضغاط بنسبة (٨٠%) والشد بنسبة (٥١ %). كما بينت النتائج أن إضافة الألياف بصورة مشتركة قد قللت مقاومة الانضغاط والشد بنسب (٨٨% ،٣٠%) على التعاقب. إن الكثافة الكلية الجافة للخرسانة قد

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تراوحت بقيم (٢٣٦٥ –٢٣٤٥ kN/m3) باستعمال مخلفات خراطة الحديد و(٢٢٤٠ –٢١٣٠ kN/m3) باستعمال مخلفات مطاط الإطارات المستهلكة و(٢١٨٠ –٢٠٢٥ kN/m3). باستعمال مخلفات خراطة الحديد ومطاط الإطارات المستهلكة بصورة مشتركة .

1. Introduction

Tires are bulky, and 75% of the space a tire occupies is void, so that the land filling of scrap tires has several difficulties(Garrick, 2005) :

- Whole tire landfilling requires a large amount of space.
- The void space provides potential sites for the harboring of rodents.
- Shredding the tire eliminates the above problems but requires high processing costs.

Because of the above difficulties and the resulting high costs, tire stockpiles have turned up across the country. These waste tires represent a significant environmental, human health, and aesthetic problem. Because of the shape and impermeability of tires, they may hold water for long periods providing sites for mosquito larvae development .

Fiber reinforced concrete (FRC) is a composite material consisting of hydraulic cement, sand, coarse aggregate, water and fibers. In this composite material, short discrete fibers are randomly distributed throughout the concrete mass. The behavioral efficiency of this composite material is far superior to that of plain concrete and many other construction materials of equal cost. Due to this benefit, the use of FRC has steadily increased during the last two decades and its current field of application includes: airport and highway pavements, earthquake-resistant and explosive-resistant structures, mine and tunnel linings, bridge deck overlays, hydraulic structures, rock-slope stabilization. Extensive research work on FRC has established that addition of various types of fibers such as steel, glass, synthetic, and carbon, in plain concrete improves strength, toughness, ductility, post-cracking resistance, etc. Literature survey indicated that limited study has been conducted on FRC using industrial waste fibers. Furthermore, with increase in population and industrial activities, the quantity of waste fibers generated from various metals industries will increase manifold in the coming years. These industrial waste fibers can effectively be used for making high-strength low-cost FRC after exploring their suitability.

(Hwai et al., 1996) reported that the free shrinkage of the recycled tire fiber composites was found to be 34-55% higher than that of normal concrete, whereas the free shrinkage of steel fiber reinforced concrete SFRC (Vf = 1%) was 6% lower than that of normal concrete. The maximum crack widths in restrained ring specimens of such composites were two orders of magnitude smaller than crack widths in concrete.

(Kutzing,1997) showed that the shear capacity of concrete increased when steel fibers are added. The article deals with a test program which was still running at the University of Leipzig. The test equipment was introduced in detail and some first results were presented.

(Materschlager and Berbmeister, 1998) presented an experimental investigations to evaluate the influence of fibers made of steel, glass, carbon or hemp on the overall behavior of concrete. Different materials were selected such that concrete properties can be designed to satisfy specific requirements. Some of these demands were alkali resistance, corrosion resistance, insensitivity to magnetism and increased beam-column ductility to dissipate energy during seismic activities.

(Youjiang et al., 2000) showed that the use of recycle fibers from industrial or postconsumer waste offers additional advantages of waste reduction and resources conservation. These paper review some of the work on concrete reinforcement using recycled fibers, showed that the use of low-cost waste fiber for concrete reinforcement could lead to improved infrastructure with better durability and reliability. Potential applications could include buildings, pavements, columns,bridge decks and barriers, and for airport construction such as runways and taxiways.

(Rapoprt et al., 2001) explored the relationship between permeability and crack width in cracked steel fiber reinforced concrete SFRC. In addition, it inspected the influence of steel fiber reinforcement on concrete permeability. The cracks relax after induced cracking. The steel fibers decreased permeability of specimens with relaxed cracks larger than 100 microns.

(Segre et al., 2003)showed that the flexural strength of rubberized concrete was reduced with the addition of the rubber (3.6 ± 0.5 MPa for the specimens with rubber, 6.5 ± 0.8 MPa for the control). On the other hand, advantageous effects of the addition of the rubber were observed on the transport properties of mortar.

Experiments were conducted by (Garrick, 2005) to determine how the properties of concrete affected by the inclusion of waste tires. Waste tires were used in the form of chips and fibers. He noted a decline in the compressive strength of the concrete; however there was an increase in the toughness of the concrete. It was concluded that waste tire fibers were more suitable as additives than waste tire chips since they produced the highest toughness. He performed three-dimensional finite element analysis using ANSYS. Results obtained from this analysis were used to determine the critical fiber length. The models were able to predict a value of ultimate tensile strength that was very close to the experimental result obtained.

(Kuang and Baczkowski, 2006) presented reinforced concrete coupled shear-wall structures were used to provide the resistance of lateral loading caused by wind and earthquake. Coupling beams connect shear walls along the height of the building and were normally subjected to very high bending and shear stresses. Shear strength of conventional reinforced concrete beams depends mainly on the cross-sectional dimensions rather than on the amount of steel reinforcement and is therefore limited by architectural design .

(Skripkiunas et al., 2007) used the rubber additive as fine aggregate replacement in concrete mixtures by 3.2% of aggregates mass, their results showed that the rubber waste additives reduces both static and dynamic modulus of elasticity.

2. Objective

The overall objectives of this paper is to investigate the feasibility of incorporating rubber tire chips as a replacement for natural mineral aggregates in concrete with adding industrial steel lathe waste as fibers.The specific objectives of the paper are as follows:

1. To investigate the mechanical properties (compressive strength and tensile strength) of concrete.
2. To make use of waste tires rubber and waste steel lathe as fiber reinforcement of concrete (management of solid waste).
3. To check the behaviour of concrete in compressive and tensile strength with combine fibers of steel lathe waste and tires rubber.

3.Materials

The materials which are used in this experimental investigation are :-

1- Cement : ordinary Portland cement (OPC).Fineness = 235 m^2/kg, initial setting time=50minute , final setting time =8 hours , compressive strength(3 days) = 26 MN/m^2 .MgO=4 % , SO_3(C_3A less than 5%)= 2.5%, loss in burning =3%, non-dissolved materials=1.3%

2- Fine aggregate : locally available river sand having a specific gravity of 2.64, fineness modulus of 3.13, uniformity coefficient of 2.51,grading zone(2) and bulk density of 16.80 kN/m^3.

3- Coarse aggregate : gravel coarse aggregate of maximum size 25 mm and having a specific gravity of 2.69, uniformity coefficient of 1.4 and bulk density of 15.85 kN/m^3.

4- Water : water conforming to the requirements of water for concreting and curing .

5- Steel Lathe waste : waste steel fibers from industry zone which is cutted in uniformly pieces 2mm wide ,1mm thick and length of 50mm (straight or spiral as results in cut machines) ,as shown in Figure (1). Having a specific gravity of 5.85, Bulk density = 6750Kg/m^3.

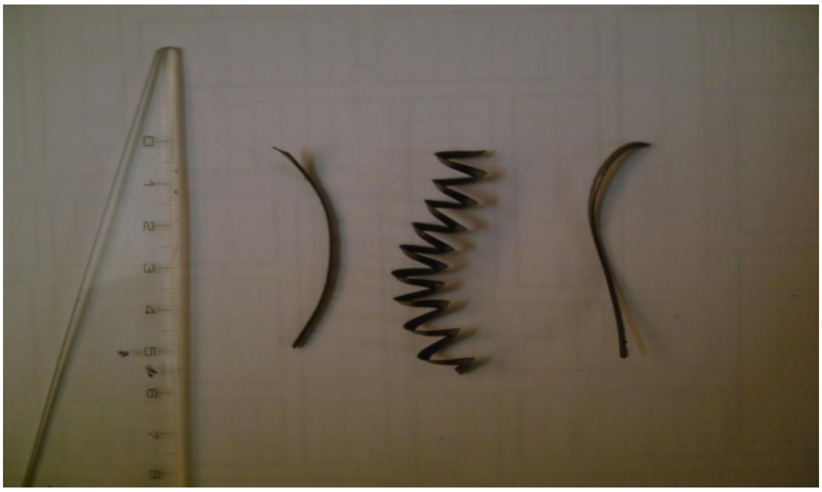

Figure 1. Types of steel Lathe waste used

6- Rubber Tires :- rubber tires waste are obtained by cutting of scrap tires to coarse aggregate sizes like a chips, as shown in Figure (2) and having a specific gravity of 1.138. The rubber of waste tires is nearly 100% of it passed through a 9.5 mm sieve, with the majority retaining on a 4.75 mm sieve. Having a specific gravity of 1.05, Bulk density = 650Kg/m^3.

Figure 2. Rubber tires waste used

4. Concrete Mixes

Concrete without rubber aggregate and steel lathe waste was used as the plain concrete. One mixture was designed with a targeted compressive strength of 21 MPa and the design was carried out according to BS 5328 and Design of Normal Concrete Mixes BS 1881-116:1983. The mixture proportions of the basic ingredients i.e. cement, water, coarse aggregate and fine aggregate, were the same for the plain concrete and steel lathe waste concrete, while the coarse aggregate of the plain mix was replaced by rubber aggregate. Table 1. shows the quantities of the constituents of the plain mix design, , for one cubic meter of concrete. For each group, three batches were made in which the steel lathe waste fibers is added in a ratios of 4, 6 and 8 % by weight from concrete weight. For each group, three batches were made in which the coarse aggregate was replaced by rubber tires aggregate at 5, 10 and 15 % by volume of 20 mm aggregate. Table 2. summarizes the steel lathe, tire rubber and Combine contents for concrete mixes.

Table 1. Mix proportions of the plain mixes

Materials	Mix Proportions (kg/m^3) (W/C: 0.50)
Ordinary Portland Cement	320
Water	160
Fine aggregate (grade 2)	672
Coarse aggregate	1248

Table 2 . Summary of Steel Lathe, Tire rubber and Combine contents for concrete mixes

Type	Specimen Code	Percentage of Steel Lathe (**added**) (%)	Percentage of Tire rubber (**replacement**) (%)	Percentage of combine (Lathe **added**) + Rubber **replacement**) (%)
Plain Compressive	PC			
Plain Tension	PT			
Steel Lathe Compressive	LC	4		
	LC	6		
	LC	8		
Steel Lathe Tension	LT	4		
	LT	6		
	LT	8		
Rubber aggregate Compressive	RC		5	
	RC		10	
	RC		15	
Rubber aggregate Tension	RT		5	
	RT		10	
	RT		15	
Combine Compressive	CC			4+10
	CC			6+10
	CC			8+10
Combine Tension	CT			4+10
	CT			6+10
	CT			8+10

5. Test Programs

The following tests were carried out to establish the mechanical properties of concrete:

- Compressive strength, using cube (150mmx150mmx150mm) .

-Splitting tensile strength, using cylinder (150mm diameter ,by 300mm long)

-Dry concrete density (unit weight), using cylinder, in accordance with BS 1881-part 2 : 1983.

The first two properties were determined using British Standard BS testing equipment and procedures, as outlined below.

i.) Compressive strength: The compressive strength of concrete specimens was determined after 28 days of standard curing. A 2500KN capacity Avery-Denison compression testing machine was used for determining the maximum compressive loads carried by various cubes. The load was applied at a rate of 14 N/mm^2 per minute in accordance with the BS 1881-116:1983 .

ii.) Splitting tensile strength: The splitting tensile strengths of concrete specimens were determined after 14 days of standard curing. The tests were carried out by splitting the cylinders in the machine used for compressive testing in accordance with BS 1881-117:1983 . The testing machine is fitted with an extra bearing bar to distribute the load along the full length of the cylinder. Hardboard strips, 15 mm wide and 4 mm thick are inserted between the cylinder and the testing machine top and bottom bearing surfaces. From the maximum applied load at failure the splitting tensile strength is calculated as follows:

$$\sigma = 2F / \pi l d \qquad (1)$$

where σ = splitting tensile strength, N/mm^2, F = maximum applied load in N, l = length of cylinder in mm, d = diameter in mm.

Table 3. Summary of Steel Lathe, Tire rubber and Combine contents for concrete mixes

Type	Specimen Code/ percentage	No. of Specimens
Plain Compressive	PC	3
Plain Tensile	PT	3
Steel Lathe Compressive	LC(4%)	3
	LC(6%)	3
	LC(8%)	3
Steel Lathe Tensile	LT(4%)	3
	LT(6%)	3
	LT(8%)	3
Rubber aggregate Compressive	RC(5%)	3
	RC(10%)	3
	RC(15%)	3
Rubber aggregate Tensile	RT(5%)	3
	RT(10%)	3
	RT(15%)	3
Combine Compressive	CC(4%+10%)	3
	CC(6%+10%)	3
	CC(8%+10%)	3
Combine Tensile	CT(4%+10%)	3
	CT(6%+10%)	3
	CT(8%+10%)	3

6. Results and Discussion

From the Table 4 and Figure 3 it is clear that the addition of steel lathe waste fibers in plain concrete enhances its strength under compression. The increase in strength observed by adding steel lathe waste fibers by weight from concrete weight (4%, 6% and 8%) in the aforesaid compressive strength are 7%, 12% and 15%, respectively. This indicates that the strength of concrete increase slightly under compression . The compressive strength of concrete increases because of the steel lathe fibers work as a steel reinforcement.

Table 4. Summary of Compressive Strength of concrete mixes

Concrete Type	Specimen Number		
	1	2	3
	Compressive Strength(Mpa)		
Plain (PC)	20.48	22.07	21.46
Steel Lathe (LC) 4 %	22.50	23.70	22.34
Steel Lathe (LC) 6 %	22.95	24.72	24.26
Steel Lathe (LC) 8 %	24.72	25.83	23.35
Tire rubber aggregate (RC) 5 %	6.20	9.10	10.20
Tire rubber aggregate (RC) 10%	5.10	6.20	6.20
Tire rubber aggregate (RC) 15 %	4.50	4.00	4.00
Combine (CC) (4% + 10 %)	3.40	2.80	4.00
Combine (CC) (6% + 10 %)	4.53	4.53	2.83
Combine (CC) (8% + 10 %)	2.83	2.83	2.26

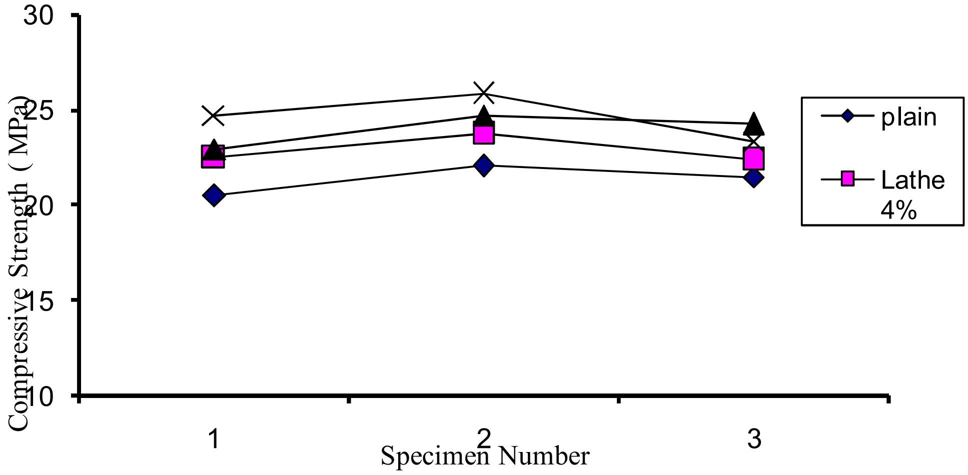

Figure 3. Specimen Number(Steel Lathe) Vs Compressive Strength

Figure 4 and Table 4 show that the compressive strength decreased with increasing percent of replacement of rubber tires waste. The compressive strength of concrete decreases due to weak bonding between waste rubber aggregate particles and cement . The decrease in strength was observed by replacement of coarse aggregate by tire rubber wastes (5%, 10% and 15%) in the aforesaid compressive strength are 60%, 73% and 80%, respectively.

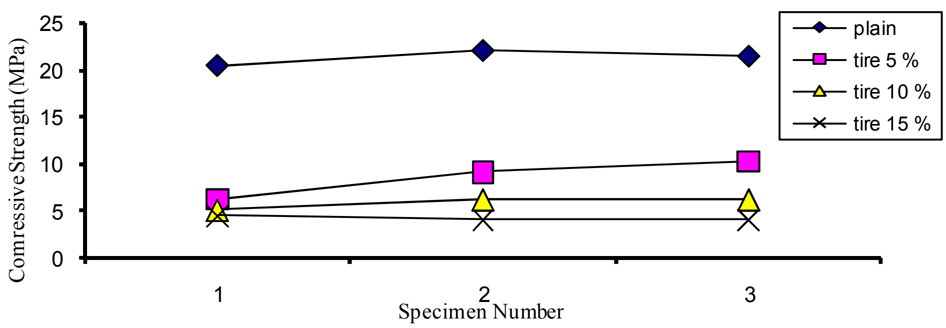

Figure 4. Specimen Number(Rubber Tires) Vs Compressive Strength

Figure 5 and Table 4 show that the compressive strength decreased with increasing the addition of steel lathe waste fibers and replacement percentage of rubber tires waste in plain which has constant value (10%). The decrease in strength was observed by adding waste fibers (4%, 6% and 8%) with replacement of rubber tires waste in the aforesaid compressive strength are 84%, 81% and 88%, respectively. This attributed to the increasing of the fibers amount (rubber and lathe) and that leads to decrease the bonding among the concrete compositions .

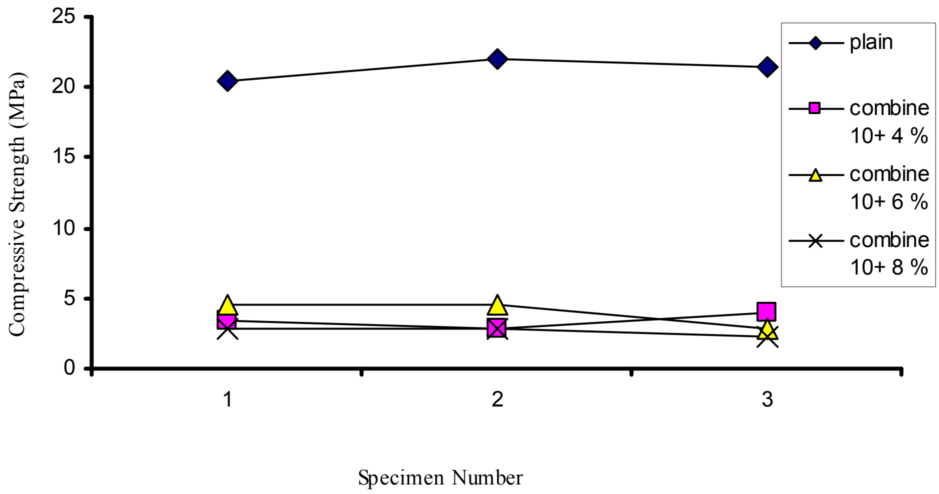

Figure 5. Specimen number(steel lathe + rubber tires) vs compressive strength

The tensile strength of concrete increased in splitting tensile strength when the percentage of lathe increased. Table 5 and Figure 6 show the splitting tensile strength that are recorded during the test and with respect to the difference in percentage of added lathe. The increase in tensile strength was observed by adding waste fibers (4%, 6% and 8%) in the aforesaid tensile strength are 42%, 10% and 20%, respectively. The added fibers, leads to that the lathe waste fibers work as a steel reinforcement, thus the tensile strength of concrete increases .

Table 5. Summary of Tensile Strength of concrete mixes

Concrete Type	Specimen Number		
	1	2	3
	Tensile Strength(Kpa)		
Plain (PC)	2210	1600	1870
Steel Lathe (LC) 4 %	2830	2545	2690
Steel Lathe (LC) 6 %	1985	2050	2265
Steel Lathe (LC) 8 %	2265	2265	2265
Tire rubber aggregate (RC) 5 %	1600	1065	1330
Tire rubber aggregate (RC) 10%	800	935	1200
Tire rubber aggregate (RC) 15 %	800	1065	935
Combine (CC) (4% + 10 %)	1130	1130	1130
Combine (CC) (6% + 10 %)	1700	1130	1130
Combine (CC) (8% + 10 %)	1560	1410	990

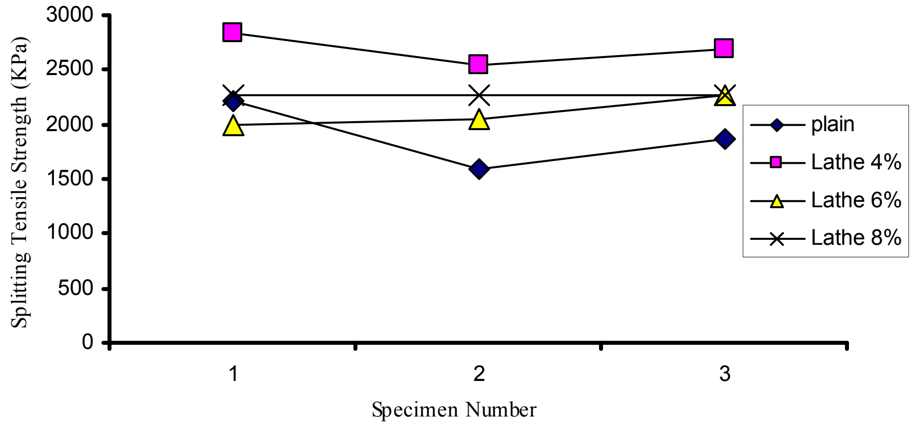

Figure 6. Specimen Number(Steel Lathe) Vs Tensile Strength

Figure 7 and Table 5 show that the splitting tensile strengths decreased with slight increasing percent of replacement of rubber tires waste, because of the bonding between aggregate particles and cement decrease. The decrease in tensile strength was also observed by replacement of coarse aggregate (5%, 10% and 15%) in the aforesaid tensile strength are 30%, 48% and 51%, respectively.

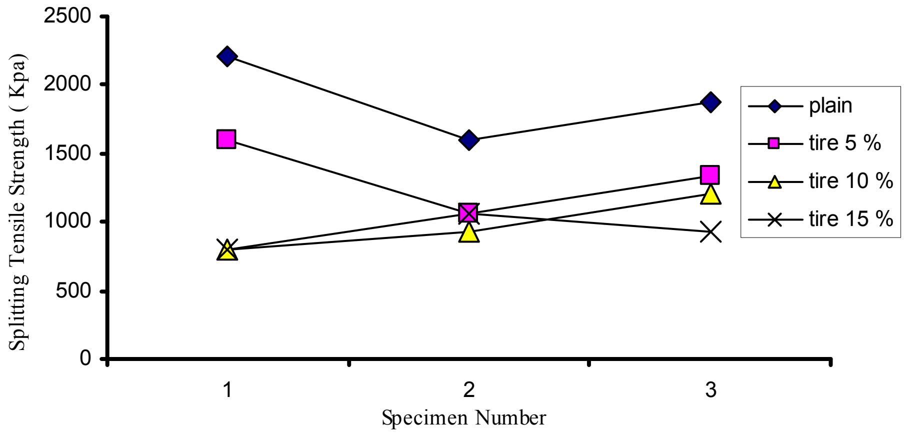

Figure 7. Specimen Number(Rubber aggregate) Vs Tensile Strength

Figure 8 and Table 5 show how tensile strength decreased with increasing the addition of steel lathe waste fibers and replacement percentage of rubber tires waste was taken (10%). The decrease in tensile strength was observed by adding waste fibers (4%, 6% and 8%) with replacement of rubber tires waste in the aforesaid tensile strength are 40%, 30% and 30%, respectively. The decreases in the bonding among the concrete compositions ,as a result of increasing of the fibers amount (rubber and lathe) .

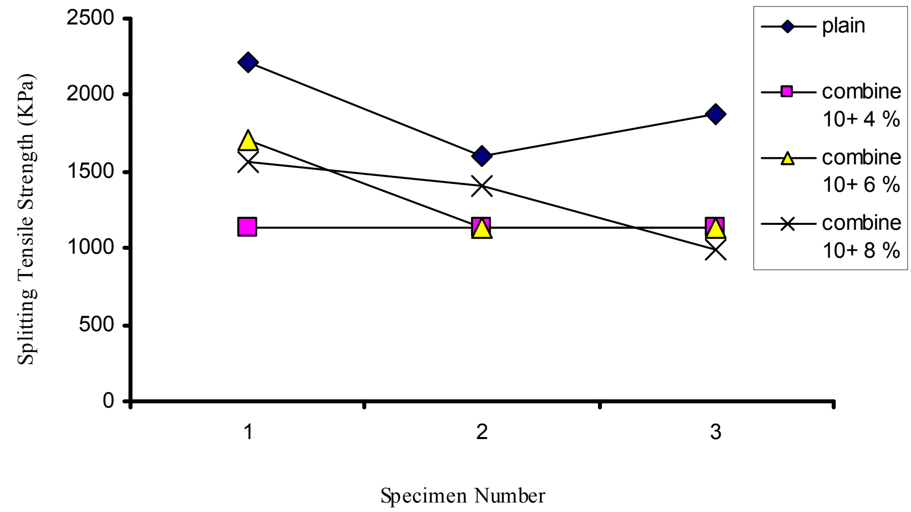

Figure 8. Specimen number(steel lathe + rubber aggregate) vs tensile strength

Dry concrete density (at 28 day age) decreases when the addition of lathe waste fibers and waste tires rubber increases as shown in Table 6 and Figure 9 show that the average for three values of dry concrete density specimen . In the case of steel lathe waste adding, the decreasing in concrete density is about (2%), this due to the increasing in voids between concrete composites in this concrete type . With this slight reduction, the concrete is considered to be normal weight concrete. While with replacement of waste tires rubber , the dry concrete density will reduce below 2300 kg/m^3. With respect to this density the concrete is considered to be light weight concrete. Also the dry concrete density of the combine fibers is reducing about 12 % from the normal concrete and represent light weight concrete too .

Generally the dry concrete density decreases with increasing of waste tires rubber percentage replacement; Since the waste tires rubber has lower specific gravity than coarse aggregate .

Table 6. Summary of Dry Concrete Density of concrete mixes

Concrete Type	Dry Concrete Density (kg/m^3)		
Plain (PC)		2410	
Steel Lathe (LC) 4 %		2365	
Steel Lathe (LC) 6 %		2345	
Steel Lathe (LC) 8 %		2345	
Tire rubber aggregate (RC) 5 %		2240	
Tire rubber aggregate (RC) 10%		2215	
Tire rubber aggregate (RC) 15 %		2130	
Combine (CC) (4% + 10 %)		2180	
Combine (CC) (6% + 10 %)		2150	
Combine (CC) (8% + 10 %)		2025	

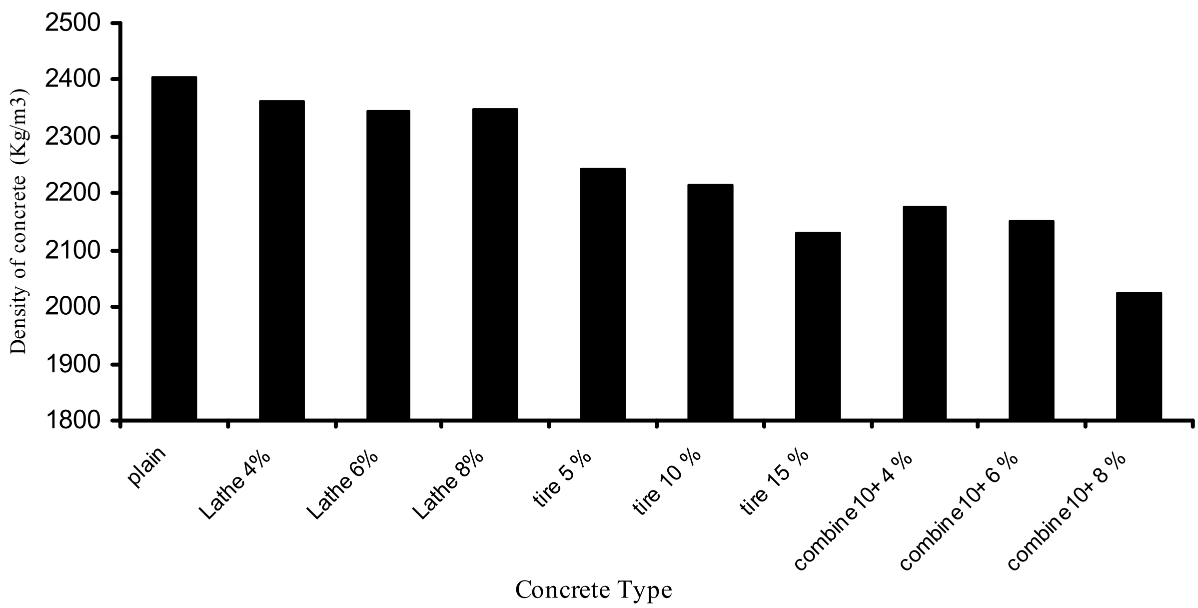

Figure 9. Concrete type vs dry concrete density

7. Conclusions

-Compressive strength increases by addition steel lathe waste about 15 % .The compressive strength decreases by replacement rubber tires waste about 80 % , and decreases with combined rubber tires and steel lathe about 88 % .

- Splitting tensile strength is rising about 20 % with adding the steel lathe waste, while this strength is reducing about 51 % when replacement coarse aggregate by rubber tires waste and it is reducing about 30 % when adding lathe and replacement coarse aggregate by rubber . So, the steel lathe waste give additional tensile strength to the concrete.
- Dry concrete density remain in normal weight concrete limits when adding the steel lathe waste, while it will be light weight concrete when replacing coarse aggregate by rubber tires waste and combine fibers concrete .
- Above points can give us a conclusion that the use steel lathe waste is better than use rubber tires waste , and can use it in structural constructions . The rubberized concrete can use in non-structural constructions like curbs and roads.
- By this method, the solid waste that generated from waste tires and steel lathes waste may be managed effectively .

8. Recommendations

- Another percent of adding steel lathe waste and replacement coarse aggregate by rubber tires waste is recommended as a future studies.
- Polymers , carbon and steel fibers may be used with replacement percentage of coarse aggregate by rubber tires waste may be done as a future researches and to study the mechanical properties of concrete .

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