MECHANICAL PROPERTIES OF FIBER WASTE TIRE CONCRETE

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الخــلاصـــــة:

درس العديد من الباحثين استخدام مفروم الاطارات المطاطية المستهلكة كمادة داخلة فـــي انتـــاج انـــواع خاصة من الخرسانة كبديل عن جزء من الركام الخشن او الناعم او كليهما. وفي هـــذا البحـــث تـــم اضـــافة الاطارات المطاطية المستهلكة الى الخرسانة على شكل الياف بابعاد 1×1×3 سم كجزء مـــستبدل مـــن حجـــم الركام الخشن. تم اختيار خلطتين حاويتين على الالياف اضافة الى الخلطة المصدرية، بنسب استبدال 20% و 30% ، وتم اجراء الفحوصات التالية : مقاومة الانضغاط، مقاومة شد الانفلاق و مقاومة الانثناء . من خـــلال دراسة نتائج الفحوصات تبين ان اضافة الياف الاطارات المطاطية المستهلكة يؤثر بشكل سلبي علـــى اغلـــب خواص الخرسانة، على سبيل المثال كانت نسبة النقصان في مقاومة الانضغاط نسبة الى الخرسانة المرجعيـــة بعمر 28 يوم هي 20% و 27.3% للخرسانة المستبدلة ب 20%و 30% الياف اطارات مطاطيـــة مـــستهلكة كنسبة حجمية من الركام الخشن على التوالي.ولكن استخدام هذه الالياف اعطى مؤشراً جيـــداً علـــى امكانيـــة الاستفادة من خرسانة الياف الاطارات المطاطية المستهلكة كمادة انشائية جديدة يمكن استخدامها في تطبيقـــات كثيرة.

ABSTRACT:

Many of researchers study the uses of chopped worn-out tires as a replacement material to production special types of concrete. In presented work, the worn-out tires were used as fibers which have dimensions of 1×1×3 cm. The fibers used as a partial replacement from volume of coarse aggregate. Two mixes of fiber worn-out tires (F.W.T.) concrete in addition to reference mix were selected, using Partial Replacement Ratio (PRR) of 20% and 30%. The tests which were used in this study were: compressive strength, splitting tensile strength and flexural strength. It was found that incorporating of F.W.T. in concrete effected negatively on most properties of concrete, for example the percentage decreases in compressive strength relative to reference mix at 28 day were 20% and 27.3% for concrete with 20% and 30% F.W.T. by volume of coarse aggregate respectively. However, it gave good indicator to be utilized as a new construction material in many applications.

1. INTRODUCTION:

As a result of wide progress that was achieved in the transport and the wide use of vehicles, this gave birth to various problems one of them is the environmental pollution. The Combustion of large quantities of worn-out (waste) tires got accumulated , thus facing very serious problems of safe disposal , either by the wide land , which was needed to store or by the incineration of the large quantities[1] . For example in 1990, over 240 million scrap tires were discarded in the United States [2] and in Iraq, it is estimated two million tires are thrown into the environment per year [1]. As the substance is little affected by water and biological factors and maintains its stability in nature for a relatively long time , some countries have adopted the method of burning worn-out tires underground as a mean of getting rid of them to avoid further pollution of the environment which way result from burning the material . Hence to avoid the hazardous effect of chemical gases resulting from the burning process such as sulfur dioxide and the distribution of fine carbon particles in the air. Many researches have endeavored to make use of enormous quantity of waste rubber tires and decrease environmental pollution resulting from them. Generally speaking, this material was mixed with asphalt to produce road-paving mixtures that provide higher flexibility and better shock-absorbance material in addition to its reducing noise resulting from the movement of vehicles and their friction with the ground [3]. On the other hand , some countries use a small part of worn-out tires to manufacture shock protection layers for platforms subjected to sea waves and ship movement. The idea of using a material of chopped worn-out tires in construction material industry emerged as it enjoys several favorable characteristics such as high resistance to weather conditions, temperature and humidity, low water absorption and light weight in comparison with other materials that are usually used. It is also characterized by its high-insulation capacity. The use of chopped worn-out tires has several economic benefits such as [4]:

1. Reducing environmental pollution and preventing the accumulation of worn-out tires without having in burn them.
2. Manufacturing a high insulating light weight concrete [this can not be locally manufactured for lack of natural and manufactured light weight aggregate].
3. Lightweight masonry of this type of concrete has a positive economic effect on total cost of the construction, it reduces the dead weight loading, giving smaller supporting sections and foundations as well as saving in transport and construction costs.

2. REVIEW OF LITERATURE:

To reduce the problem of waste material dumping, it is imperative that waste materials should be utilized in an environmentally safe manner either as raw materials for other products or for some other beneficial purposes. While such large quantities of waste materials get accumulated facing very serious problems of safe disposal, the building material industry is one the adage of diversification and it could be possible with the help of the industry to sensibly but to use such waste products into very useful, interesting and cost effective items. The idea of “No waste" that is accepted and followed in the developed countries can be transferred to our situation [5].

According to these ideas most of scientists, engineers and technologists look out for using different types of natural or industrial waste material as alternative for some ingredients of concrete. There are few researches about using chopped worn-out tires (Ch. W T.) in concrete especially in Iraq. A research team in the Iraqi Building Researches Center investigated the use of chopped worn-out tires in the production of high thermal insulation concrete [6]. The beneficial effect depends on the difference in density between the fine aggregate used in conventional concrete (about 2.65 gm/cm^3) and the rubber of chopped worn-out tires (about 0.95 gm/cm^3). In that research, partial replacement for conventional fine aggregate by chopped worn-out tires was done for producing insulator sheets used on roofs of buildings and house as an alternative to the conventional clay layer or some lightweight materials such as polystyrene have many disadvantages.

It was stated that the increment replacement in various proportion of fine aggregate by chopped worn-out tires in concrete led to [6]:

1- A decrease in compressive strength and modulus of elasticity of concrete.

2- An increase in thermal insulation of concrete.

3- A decrease in concrete density.

Al-Sakini J.S.[7] investigated some properties of Ch. W.T. concrete, the experimental program included using three percentage of Ch.W.T. by volume of concrete mortar (25,30, and 35%). It was found that the inclusion of Ch.W.T. in concrete affects the properties of the matrix significantly in its fresh and hardened states. The results of this research were compatible with previous research in general. Also he tested two types of brick masonry walls which were built up by using two types of Ch.W.T. brick concrete masonry units. He concluded that the Ch.W.T. concrete masonry units offer satisfactory or even better alternative units for wall construction as compared with the traditional brick masonry units.

Najim K.B. [8] Study the effect of Ch.W.T. as partial replacement of volume of aggregate (sand and gravel of equal proportion) on the modulus of elasticity and impact resistance of this type of concrete. Three mixes of Ch.W.T. concrete in addition to the reference mixes were selected . Partial Replacement Ration (PRR) of 30%, 40%, and 50% were used. The tests which were used in this study were; compressive strength, modulus of elasticity (static and dynamic), and impact resistance (low velocity). It was found that incorporating Ch.W.T. in concrete decreases the compressive strength, modulus of elasticity and impact resistance.

Gregory [2] study how the properties of concrete were affected by the inclusion of waste tires. In this investigation the waste tires were used in the form of chips and fibers. The fibers were further divided into batches with different length to determine the effect of length has on the properties of concrete. The results were indicated that the compressive strength was decreases, but the toughness of the concrete was increases. It was concluded that waste fibers were more suitable as additives than waste tire chips since they produced the highest toughness.

3. EXPERIMENTAL WORK:

3.1 Materials:

3.1.1 Cement:

Ordinary Portland cement was used throughout this work. The physical test result of the used cement is shown in Table (1). It conforms to the Iraqi Specification No.5 / 1984.

3.1.2 Fine Aggregate:

The natural sand was used in presented work. It's grading which was with in the limits of the Iraqi specification No. 45/ 1984. The specific gravity, absorption and sulfate content were (2.6), (0.199%) & (0.032%) respectively.

3.1.3 Coarse Aggregate:

Natural gravel was used in presented work. The maximum coarse aggregate size was chosen to be 20mm. The grading of this aggregate confirmed to the Iraqi specification No. 45/1984. The specific gravity & absorption were (2.7) & (0.09%) respectively. It had negligible sulfate content & fine materials.

3.1.4 Fibers Worn-Out Tires:

Tires from light vehicles, such as cars were used. The tires were cut by hand. They were cut into strips of (1×1×3) cm Fig (1).

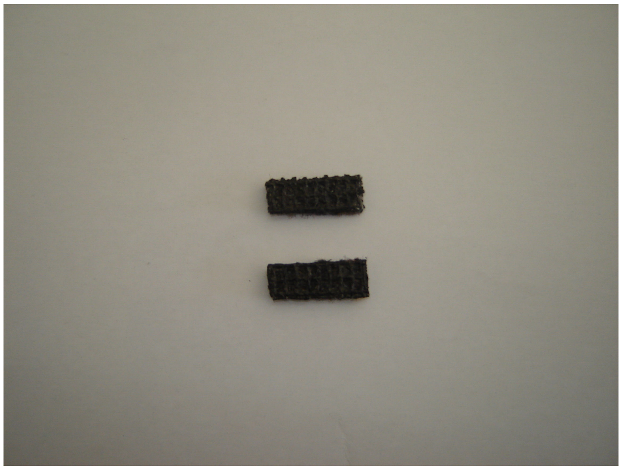


Fig. (1): Illustrated the Fibers Worn-Out Tires.

3.1.5 Water:

Ordinary tap water was used for all concrete mixes and curing.

Table (1): physical properties of cement.

Physical properties	Test result	limit of Iraqi specification
Fineness using Blane air permeability apparatus (m3/kg)	311	> 230
Soundness	0.4%	< 0.8%
Setting time using vecot's Instruments Initial (min) Final(hr)	113 3	> 45 < 10
Compressive strength for cement paste cube at 3 days (mpa) 7 days (Mpa)	21.9 31.4	>15 > 23

3.2 Experimental program:

The experimental program is planned to investigate the effect of addition F.W.T. as a partial replacement of gravel on mechanical properties of F.W.T concrete. Table (2), shows the details of reference and F.W.T concrete mixes used throughout this work.

Table (2): Details of the experimental program.

Mix. Des.	Cement content. Kg/m^3	w/c ratio	Mix. properties by weight	F.W.T proportion % by volume	Compressive strength (MPa)at 28 day
C_o	400	0.5	1:2.17:3.25	0	30
C_{20}	400	0.5	1:2.17:3.25	20	24
C_{30}	400	0.5	1:2.17:3.25	30	21.8

3.3 Mixing Procedure:

A mechanical mixer of (0.1) m^3 capacity was used. The interior surface of the mixer was cleaned and moistened before placing the materials. The raw materials such that gravel, sand, cement and F.W.T were first mixed dry for about one minute then water, was added to the mixer. After that mixing continued for about three minutes until the concrete becomes homogenous in consistency.

3.4 Casting Compactions and Curing:

The molds were lightly coated with mineral oil before use, according to ASTM-C192-88, concrete casting was carried out in different layers each layer of 50 mm. Each layer was compacted by using a vibrating table for (15-30) second until no air bubbles emerged from the surface of the concrete, and the concrete is level off smoothly to the top of the molds. Then the specimens were kept covered with polyethylene sheet in the laboratory for about (24±2) hrs. After that the specimens remolded carefully, marked and immersed in water until the age of test. The specimens were tested at age of 7 and 28 days.

3.5 Testing of Hardened Concrete:

3.5.1 Compressive Strength Test:

The Compressive strength was determined according to B.S.1881. Part 4, 1970. The average of compressive strength of three cubes was recorded for each testing age (7 and 28 days).

3.5.2 Splitting tensile Strength Test:

100×200 mm concrete cylinders were prepared according to the ASTM 192-88. The average of splitting tensile strength of three cylinders was recorded for each testing age (7 and 28 days). The Splitting tensile Strength was calculated as follows:

$$Ft = 2P / \pi dL$$

Were:

Ft = Splitting tensile strength (MPa). , P = Maximum applied load, (N).

L = Length, (mm). , d = Diameter, (mm).

3.5.3 Flexural Strength Test:

(100×100×500) mm concrete prisms were prepared according to ASTM C192-88. The test was carried out using two point load according to ASTM C78-84 . The average modulus of rupture of two prisms was obtained for each testing age (7 and 28 days) .The ultimate tensile strength in flexural (modulus of rupture) was calculated by using the following formula:

$$fr = PL/ bd$$

Were:

fr = modulus of rupture , (MPa) .

P = Maximum applied load indicated by testing machine, (N).

b = Average width of specimen, (mm). , d = Average depth of specimen, (mm).

4. RESULTS AND DISCUSSION:

4.1 Compressive Strength:

The compressive strength was determined at age of (7, 28) days for moist cured concrete specimens .The results of compressive strength are summarized in Table (3).

Fig (2) And Table (3), shows that the compressive strength for concrete decreases with addition of F.W.T in general, however, this reduction in compressive strength was depended on the partial replacement ratio (PRR) of aggregate.

The reduction in compressive strength was depended on the effect of F.W.T on the micro structure of concrete matrices and the transition zone between the aggregate and the cement past [4]. Hence, in general, the addition of F.W.T reduces the compressive strength; this reduction can be explained by the following:

1. The F.W.T particles are weak materials and compressible with flexibility, hence the compressive strength of concrete will be reduced because it is affect by the strength of the components.
2. The F.W.T concrete required higher w/c ratio to achieve the suitable workability. This property results in the lower strength.
3. The number of voids increases in the mixes containing F.W.T, which would affect the compressive strength negatively.

From Table (3), it can be seen that the percentage decreases in compressive strength values at 7 days were 14.7% and 46.8% for concrete with 20% and 30% F.W.T PRR by volume of course aggregate respectively. At 28 day the percentage decreases in compressive strength values were 20% and 27.3% for concrete with 20% and 30% F.W.T PRR by volume of coarse aggregate respectively.

Table (3): Average Compressive strength of F.W.T concrete.

Mix. Desg.	Cement content kg / m^3	F.W.T content (%) by volume	w/c ratio	Mix proportion by weight	Compressive strength (MPa)	
					7 day	28 day
C_o	400	0	0.5	1:2.17:3.25	23.7	30
C_{20}	400	20	0.5	1:2.17:3.25	20.2	24
C_{30}	400	30	0.5	1:2.17:3.25	12.6	21.8

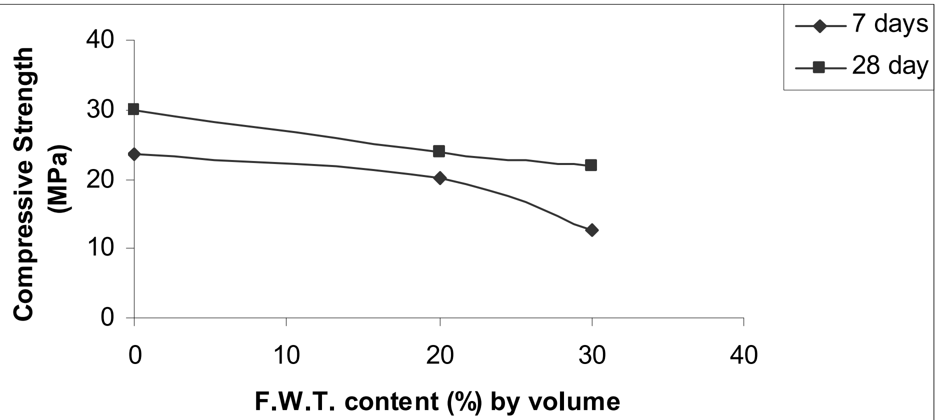


Fig (2): Relationship between F.W.T. content and compressive strength

4.2 Splitting Tensile Strength:

The Splitting tensile strength was determined at age of (7, 28) days for most cured concrete specimens. The result of Splitting tensile strength are summarized in Table (4).

Fig (3) And Table (4), shows that the Splitting tensile strength of concrete decreases with addition of F.W.T in general. The reduction in Splitting tensile strength was depended on the effect of F.W.T on the microstructure of concrete matrices and the transition zone between the aggregate and the cement past. From Table (4) , it can be seen that the percentage decreases in Splitting tensile strength at 7 days were 11.6% and 54.2% for concrete with 20% and 30% F.W.T PRR by volume of coarse aggregate respectively . At 28 days the percentage decreases in Splitting tensile strength were 18.2% and 41.9% for concrete with 20 and 30% F.W.T PRR by volume of coarse aggregate respectively .

Table (4): Average splitting tensile strength of F.W.T concrete.

Mix. Desg.	Cement content kg / m3	F.W.T content (%) by volume	w/c ratio	Mix proportion by weight	Splitting tensile strength (MPa)	
					7 day	28 day
C_o	400	0	0.5	1:2.17:3.25	2.4	3.46
C_{20}	400	20	0.5	1:2.17:3.25	2.12	2.83
C_{30}	400	30	0.5	1:2.17:3.25	1.10	2.01

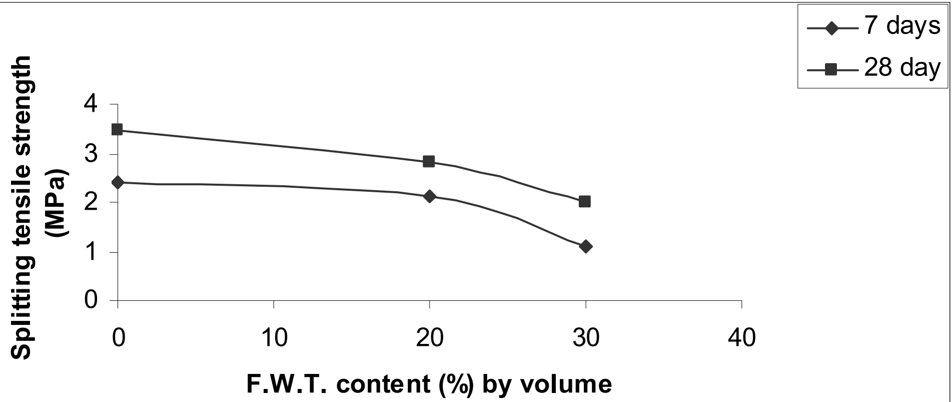


Fig (3): Relationship between F.W.T. content and splitting tensile strength

4.3 Flexural Strength:

The Flexural Strength was determined at age of (7, 28) days for moist cured concrete specimens. The results of Flexural Strength are summarized in Table (5).

Fig (4) And Table (5) , shows that the Flexural Strength for concrete decreases with addition of F.W.T in general , The reduction in Flexural Strength was depended on the effect of F.W.T on the strength was depended on the effect of F.W.T on the micro structure of concrete matrices and the transition zone between the aggregate and the cement past . From Table (5), it can be seen that the percentage decreases in flexural strength at 7 days were 28.2% and 46.1% for concrete with 20% and 30% F.W.T PRR by volume of coarse aggregate respectively .

At 28 days the percentage decreases in flexural strength were 25% and 39.5% for concrete with 20% and 30% F.W.T PRR by volume of coarse aggregate respectively.

Table (5): Average Flexural Strength of F.W.T concrete.

Mix. Desg.	Cement content kg / m3	F.W.T content (%) by volume	w/c ratio	Mix proportion by weight	Flexural strength (MPa)	
					7 day	28 day
C_o	400	0	0.5	1:2.17:3.25	3.9	4.8
C_{20}	400	20	0.5	1:2.17:3.25	2.8	3.6
C_{30}	400	30	0.5	1:2.17:3.25	2.1	2.9

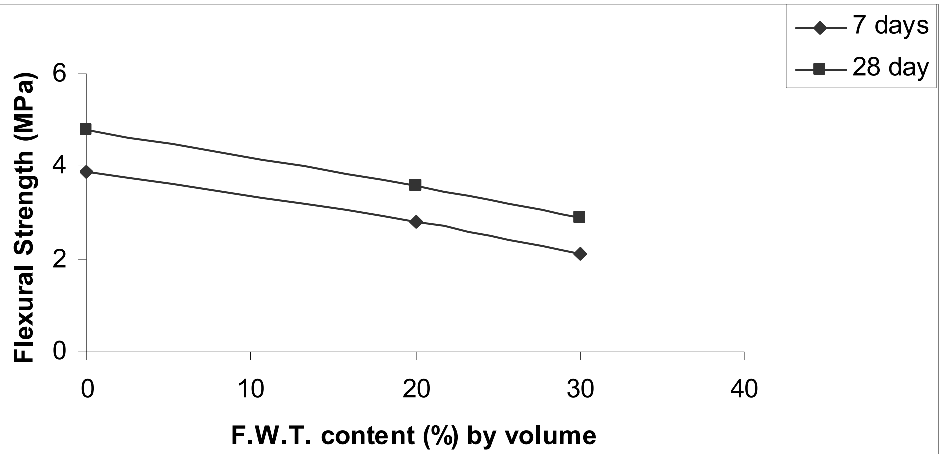


Fig.(4): Relationship between F.W.T. content and Flexural Strength

4.4 Relationship between Compressive Strength and Splitting Tensile Strength:

Relationship between Compressive Strength and Splitting Tensile Strength for various type of concrete with curing age was illustrated in Fig. (5), from this figure, it can be seen that, when compressive strength increased the splitting tensile strength also increased, but at different rate. The splitting tensile/compressive strength ratio depend to large extent on the curing ages, fiber worn-out tire content and general level of strength of the concrete.

From Table (6), and Fig. (6), the splitting tensile/compressive strength ratio was increased with age for all mixes. This behavior is strangely liked with a significant decrease in porosity of matrix and the transition zone with increase of curing ages, which leads to general improvement for both the compressive and splitting tensile strength of concrete.

Concrete which is containing 20% worn-out tier fibers (C20) exhibited increase in splitting tensile/compressive strength ratio comparative with reference concrete (Co). This behavior is mainly attributed to the direct effect of F.W.T. on splitting characteristics of concrete more than effect on compressive characteristics of concrete.

From Table (6), it can be seen that the addition of 30% F.W.T. to concrete as PRR by volume of coarse aggregate leads to degrease in splitting tensile/compressive strength. This attributed to, the increase of air voids in concrete due to an increase in w/c, which is required to maintain a given workability, when the compressive and splitting tensile strength is very sensitive to the presence of these voids. As well as the F.W.T. are weak material and compressible with flexibility [9].

Table (6): Average splitting tensile / compressive strength ratio.

Mix. Desg.	Splitting tensile / compressive strength ratio	
	7 days	28 day
C_o	10.1	11.5
C_{20}	10.5	11.8
C_{30}	8.7	9.2

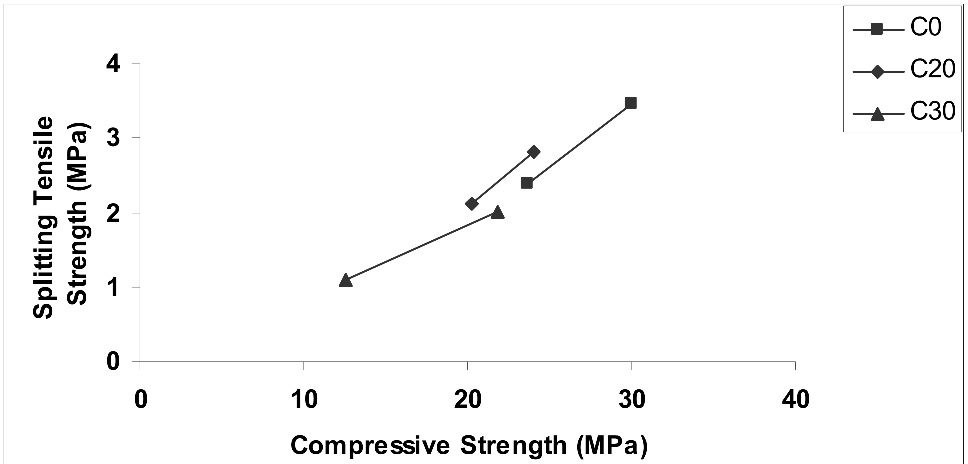
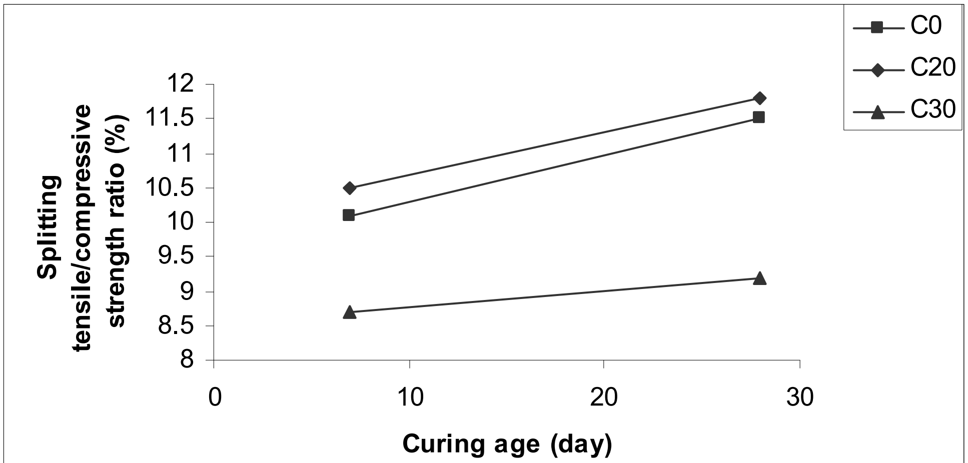


Fig.(5):Relastionship between compressive and splitting tensile strength



Fig(6):Relationship between splitting tensile/compressive ratio strength and curing age

4.5 Relationship between Compressive Strength and Modulus of Rupture:

Relationship between Compressive Strength and modulus of rupture was illustrated in Fig. (7), from this figure, it can be seen that, when compressive strength increased modulus of rupture also increased, but at different rate.

The following empirical formula can be derived to produce the modulus of rupture (fr) for concrete type Cx :

$$fr = o.23\ fcu - 1.92 \qquad R = 0.99$$

Where: fcu =28-day compressive strength of 100mm concrete cub, MPa

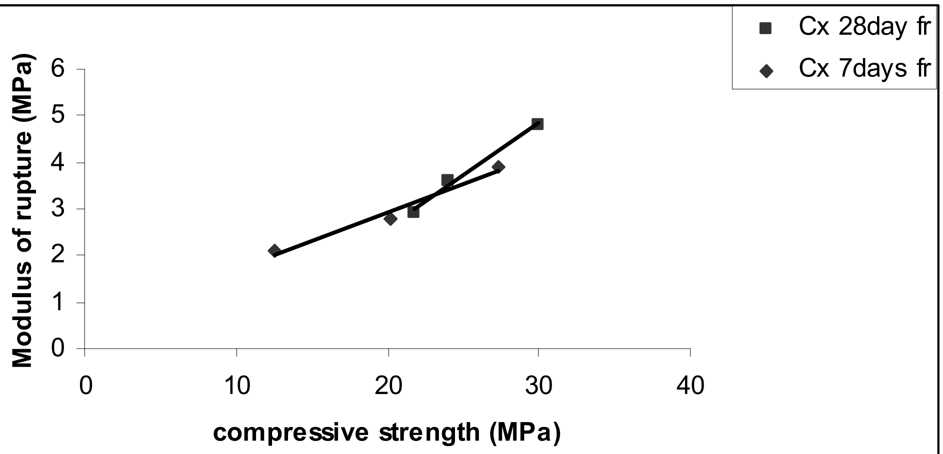


Fig.(7): Relationship between comperssive srength and modulus of rupture

5-CONCLUSIONS:

Depending on the results of this investigation, the following conclusions can be drawn.

1. The compressive strength, splitting tensile strength, and flexural strength increase with age of test.
2. The compressive strength decreases significantly with increases of F.W.T content in concrete.
3. The Splitting tensile strength and Flexural strength decreases with increases of F.W.T content.
4. The splitting tensile/compressive strength ratio increase with increase of F.W.T. content up to 20% PRR by volume of coarse aggregate, but with 30% PRR this ratio was decreases.
5. Modulus of rupture increase with increases of compressive strength.

6. Symbols and Abbreviations:

- F.W.T = Fiber Worn-Out Tire.
- PRR = Partial Replacement Ratio.
- Ch.W.T. = Chopped Worn-Out Tire.

- Co = Reference concrete.
- Cx = Concrete with (x)% PRR by volume of coarse aggregate.

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