The Effect of Adding Waste Plastic Fibers on some Engineering Properties of Roller Compacted Concrete

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(Received 27/11/2012; accepted 26/2/2013)

Abstract

This research includes producing compacted concrete by rolling method and the possibility for using in highway construction field with studying the influence of adding waste plastic fiber resulting from manual cutting for bottles used in the conservation gassy beverage on different characteristics of this type of concrete. For the purpose of selecting mix proportions appropriate for rolling compacted concrete (RCC). Approved design method for ACI-committee (5R-207 .1980) was selected for this research.

Destroying plastic waste by volumetric rates ranging between (0.5%) to (2%) was approved. Reference mix was produced for comparison. Tests were conducted on the models produced from rolling compacted concrete like compressive strength, flexural strength and split tensile strength. The analysis of the results showed that the use of plastic waste fibers (1%) has led to improve the properties of each of the compressive strength and flexural strength and split tensile strength compared with reference concrete. Compressive strength in 28 days with fiber ratio (1%) is higher than (52.15%) from compressive strength in 28 days of reference concrete. It can be also observed that each of the flexural strength and split tensile strength increases by (17.86, 25.61)%, respectively, from flexural strength and split tensile strength for the reference mix .

Key words: engineering properties, roller compacted concrete (RCC) , PET, Waste plastic

تاثير اضافة الياف الفضلات البلاستيكية على بعض الخواص الهندسية للخرسانة المحدولة بالرص

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الخلاصة

يتضمن هذا البحث انتاج الخرسانة المحدولة بالرص وإمكانية استخدامها في مجال انشاء الطرق مع دراسة تاثير اضافة الياف الفضلات البلاستيكية الناتجة عن التقطيع اليدوي للقناني المستخدمة في حفظ المشروبات الغازية على الخواص المختلفة لهذا النوع من الخرسانة لغرض اختيار نسب الخلط المناسبة للخرسانة المحدولة بالرص (RCC). تم اعتماد طريقة التصميم المعتمدة من قبل معهد الخرسانة الامريكي-اللجنة (5R-207 .1980). لقد تم اعتماد الياف الفضلات البلاستيكية بنسب حجمية تتراوح قيمتها بين (0.5%) الى (2%) . كما تم انتاج خرسانة مرجعية لغرض المقارنة. تم اجراء الفحوصات على النماذج المنتجة من الخرسانة المحدولة بالرص كفحوصات مقاومة الانضغاط, مقاومة الانثناء, مقاومة الشد بالانشطار. لقد أظهر تحليل النتائج ان استخدام الياف الفضلات البلاستيكية بنسبة (1%) قد ادى الى تحسين خواص كل من مقاومة الانضغاط ومقاومة الانثناء ومقاومة الشد بالانشطار مقارنةً بالخلطة المرجعية . مقاومة الانضغاط في 28 يوم عند استخدام نسبة الياف (1%) اعلى بمقدار (52.15 %) من مقاومة الانضغاط المرجعية كذلك يمكن ملاحظة بان كل من مقاومة الانثناء ومقاومة الشد بالانشطار تزداد بمقدار (17.86 ,25.61)% على التوالي من مقاومة الانثناء ومقاومة الشد بالانشطار عن الخلطة المرجعية.

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1. Introduction

Roller Compacted Concrete (RCC) is used all over the world for the dams construction. The use of RCC for pavements is of relatively new and growing interest. RCC pavement uses no forms, requires no conventional finishing, and needs no dowels or reinforcing steel, making it an economical choice since its first used in Canada in the 1970's [1]. Roller Compacted Concrete (RCC) is a zero-slump concrete consisting of dense-graded aggregate and sand, cementitionus materials and water. Because it contains a relative Small amount of water, it cannot be placed by the same methods used of conventional (slump) concrete [1].The low water-cement ratio (usually ranging from 0.30 to 0.40) provides very high strengths .Common design unconfined compressive strengths for pavements are in the range of (35 to 55 MPa) in 28 days[2].

The Engineers and Owners prefer RCC for the following reasons [1].

*High strength.
*Low maintenance costs.
*Easy preparation.
*Rapid construction for large projects.
* Environmental benefits.

RCC differs from the conventional concrete principally for its consistency requirement and effective consolidation .The RCC must be dry to pervert sinking of the vibratory roller equipment but wet enough to permit adequate distribution of the binder mortar throughout the material during the mixing and vibratory compaction operations. The concept of minimizing W/C ratio to obtain maximum strength does not hold the best compaction, which gives the best strength, and the best compaction occurs at the wettest mix that will support an operating vibratory roller. In other words, the consistency requirement plays a major part in the selection of materials and mix proportion .The objective of RCC proportioning to provide a compactable and stable mass that meets the strength, durability and permeability requirements for the application. There is generally 40% less and 30% less paste in RCC than in conventional concrete .This results in some differences in the properties of concrete[3].

2-Materials Used

Cement

Ordinary Portland cement (northern cement) ,manufactured by eastern province Co. a product of Saudi Arabic is used throughout this work .The chemical and physical properties of such cement are presented in Table (1) and (2), respectively, the test results show that the cement conforms to the provision of Iraqi specification[4].

Table (1) chemical properties of cement

Oxide	%by weigh	Limit of Iraqi specification No.5/1984
Ca0	62.6	-
SiO_2	22	-
Al_2O_3	5.2	-
Fe_2O_3	3.1	-
MgO	2.4	≤ 5
SO_3	2.4	≤ 2.5
Loss on ignition	1.8	≤ 4
Insoluble residue	1.2	≤ 1.5

Table (2) physical properties of cement

Physical properties	Test result	Limit of Iraqi specification No.5/1984
Setting time		
Initial setting ,hr :min	2:25	≥ 45 minutes
Final setting ,hr :min	3:25	≤ 10 hours
Compressive strength		
3-days	25.23 N/mm2	≥ 15N/mm2
7-days	27.35 N/mm2	≥ 23 N/mm2

Aggregate

Natural uncrushed gravel with maximum size of 1″ (25.4mm) is brought from AL-Anbar west region (Al-jaraishy). Natural sand of maximum size (4.75mm) is brought from AL-Anbar west region with grading conforming to Iraqi specification (No.(45)-1999), and lying in zone (2),is used as a fine aggregate in this work .These types of aggregates are combined together ,and in order to satisfy the requirement of the combined aggregate grading. The final combined grading test results conform the ACI committee 325-10R 1991[5]. recommendation for combined grading of RCC as shown in table (3).

Table (3) Grading of combined aggregates for RRC

Sieve size	Percent passing	Limits according to ACI-325-10R % passing
1″(25mm)	100	100
3/4″(19mm)	92	90-100
1/2″(12.5mm)	82	70-90
3/8″(9.5mm)	72.2	60-85
No.4(4.75mm)	55	40-70
No.16(1.18mm)	36	20-40
No.100(150μm)	14.5	5-20
No.200(75μm)	5	2-8

SO_3 content in sand (0.23%) (Specification requirement < 0.5%)
SO_3 content in gravel (0.08) (specification requirement < 0.1%)

Waste Plastic Fibers

This type of plastic fiber used is conforming to(ASTM –A 820, 2002).The geometrical characteristics of plastic fibers throughout the experimental work are illustrated in Table (4) and resulting from cutting by hand.

Table (4) Characteristics of plastic fibres

Type of fibre	Length(mm)	Width(mm)	Thickness(mm)	Specific gravity
Plastic fibres	30	4	0.30	1.12

Water

Al-Ramadi ordinary drinking water was used in all mixes and curing.

Mixes

In order to select the mixture proportion for RCC, the design method recommended by ACI committee 207-5R, 1980[6],is adopted .The weights of the materials per cubic meter of RCC are:

Name	Weight(Kg/m^3)
Ordinary cement	202-355
Water	114-160
Aggregate	2020-2090

Therefore it is decided to use the mix which contends 329 Kg/m^3 cement and water/cement ratio 0.4 as fixed mix proportions , at the same time the aggregate content is 2060 Kg/m^3 where the gravel is 927kg/m^3 and the sand is 1133kg/m^3 by using maximum size aggregate of 25mm ACI committee -207-5R 1980[6].

Mixing

The mixing was carried out in the laboratory by hand using trowel and big pan The interior surface of the pan was cleaned before placing the materials and the coarse aggregate washed first and dried then the raw materials , coarse and fine aggregate ,cement and admixtures (plastic fibers) are added , and they are mixed dry manually for about three minutes before the required water added to the mix .Finally constituents are mixed wet for about five minutes until a homogeneous material was obtained .Then the mix is placed in testing moulds and RCC container.

Mix Proportions

Table (5) shows the mix proportions of materials used in this work (Kg/m3).

Table (5) Mix proportions of Materials

Fiber%	Cement(kg)	Aggregate(kg)	Water(kg)	Plastic Fibers(kg)
Ref.	329.78	2061.125	131.912	0
0.5%	328.13	2050.82	131.252	5.5
1%	324.48	2040.5	130.592	11
1.5%	324.83	2030.21	129.93	16.5
2%	323.18	2019.9	129.27	22

Preparation of Specimens

The specimens of RCC are prepared by using Cylindrical steel moulds of size (150×300mm), cubes of size (100mm^3) and prisms of size (100 ×100×500 mm).For most testing which is carried out throughout this work. Before casting, the moulds are cleaned, rigidly tightened, and lightly oiled to prevent concrete sticking to them. After mixing, the materials are placed by filling these cylinders, cubes and prisms in three layers and compaction by place the vibrating hammer with tamping plate on to the concrete as shown in Fig (1) and then start the vibrating hammer and allow the concrete to consolidate under the tamping plate. Observer the concrete in the annular space between the edge of the tamping plate and in the inside wall of the mould as the concrete consolidates, mortar should fill in the annular space between the outer edge of the tamping plate and the inside mould wall. Observing the mortar until it forms a ring round the total perimeter of the tamping plate, when the mortar ring forms complete the tamping plate, stop the vibrating hammer according to (ASTM C-1435[7].

Fig (1): Vibrating Compaction Hammer with tamping plate

Experimental Tests

Compressive Strength

Compressive strength measures the quality and uniformity of concrete. The compressive strength is determined by using cylinder specimens according to ASTM C-39 2003[8]. All the cylinder specimens are tested under compression using the (ELE) testing machine, with capacity of 2000 kN and loading rate of 3 N/mm2/min, the average compressive strength of three cylinder specimens is recorded.

Splitting Tensile Strength

The splitting tensile strength is carried out according to ASTM C-496 2002[9]. Cylinders of (150 X 300) are used as the same (ELE) machine was used too and the average splitting strength of three specimens was recorded.

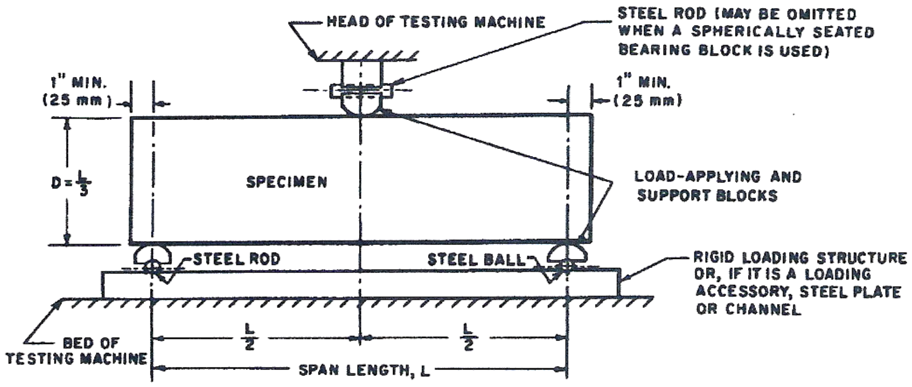
Flexural Strength (modulus of rupture)

The flexural tests are carried out using an average universal testing machine which had a capacity load of 50 KN.The flexural strength of the (100 X100 X500 mm) specimens are determine by applying center point loading of sample beam according to ASTM C-293 2003[10].The following equation (1) is used to determine the flexural strength property.

$$R = \frac{3P\,L}{2b\,d^2} \tag{1}$$

Where:

R = modulus of rupture, psi, or MPa,
P = maximum applied load indicated by the testing machine, lbf, or N,
L = span length, in., or mm,
b = average width of specimen, at the fracture, in., or mm, and
d = average depth of specimen, at the fracture, in., or m



Fig(2):Diagrammatic View of a Suitable Apparatus for Flexure Test of Concrete by Center-Point Loading Method.

Analysis and Discussion of Results

Compressive strength

1-Compressive strength of RCC mixes without plastic fibers

The effect of age on compressive strength of RCC mixes without plastic fibers is shown in figure (3). This figure shows the development of cubic strengths with age up to 28 days for RCC. The results show that the early age is marginally affected as the result of applied vibration during moulding the test cube. The compressive strength of samples of RCC increases with increasing age, the rate of increasing is high up to 28 days, where this increase is because of development of hydration operation with age.

2-Effect of volume fraction of plastic fibers on the compressive strength of RCC

Figure (4) shows the results of tests of reference mixture and adding plastic fibers to the mixture of reference RCC. This figure shows the relationship between compressive strength and plastic fibers. The compressive strength increases from plastic fibers ratio of (0%) up to ultimate compressive strength at plastic fibers of (1%) because this fibers work on reducing of cracks development then the strength decreases as plastic fibers ratio increases at any curing age. The reduction in compressive strength beyond the optimum (plastic fibers) of (1%) may be due to decrease in workability factor, this leads to resistance in that the compaction process and not to obtain fully compacted mixture. The ultimate compressive strength at (7,14 and 28) days is higher by (41.2, 48.5 and 52.153%) respectively than the compressive strength at plastic fibers ratio of (0%).

Flexural Strength

The effect of volume fraction of plastic fibers on the Flexural Strength (ultimate flexural Strength) of RCC specimens at (7, 14 and 28) days is shown in figure (5). It can be noticed that the flexural Strength increases with the increase of plastic fibers .The ultimate flexural Strength at 28 days is higher by (17.86%) than the flexural Strength at (plastic fiber) ratio of (0%) .The flexural strength increases because the plastic fiber work bridging among materials during applied load.

Splitting Tensile strength

Figure (6) shows the effect of volume fraction of plastic fibers on splitting tensile strength of RCC specimens in (7, 14, and 28) days . In general, it can be seen that the splitting tensile strength is improved by the addition of plastic fibers, the average of increasing at 28 days is higher by (25.61%) than the splitting tensile strength at (plastic fibers) ratio of (0%) .The reason increasing the splitting tensile strength is because of plastic fiber which works interlocking with materials, and the other reason is plastic fibers may prevent cracking in specimen.

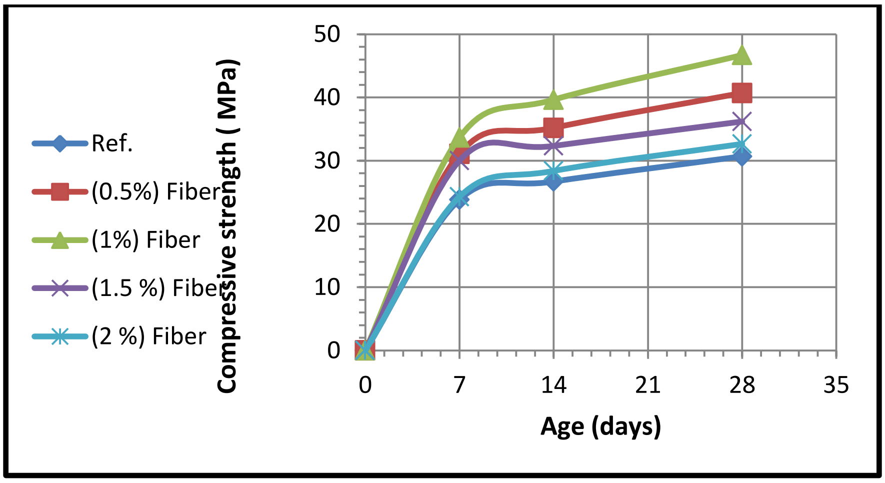


Fig (3): Relationship between compressive strength of RCC mixes with age.

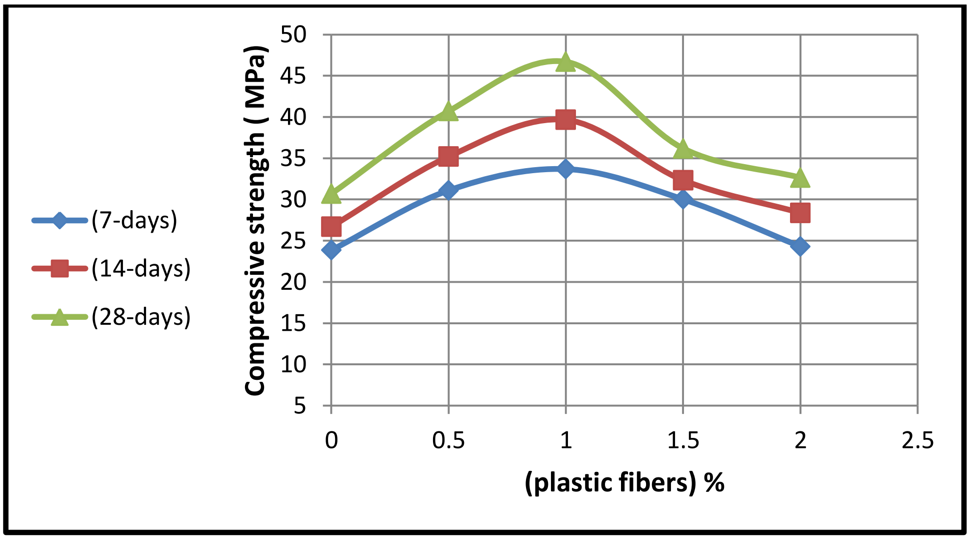


Fig (4): Relationship between compressive strength of RCC mixes with percentage of plastic fibers.

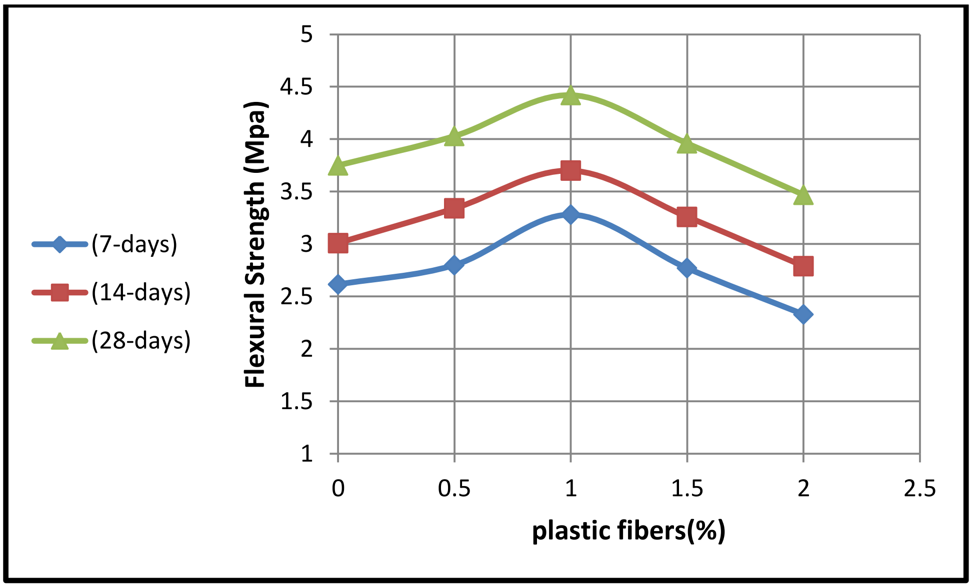


Fig (5): Relationship between flexural strength of RCC mixes with percentage of plastic fibers.

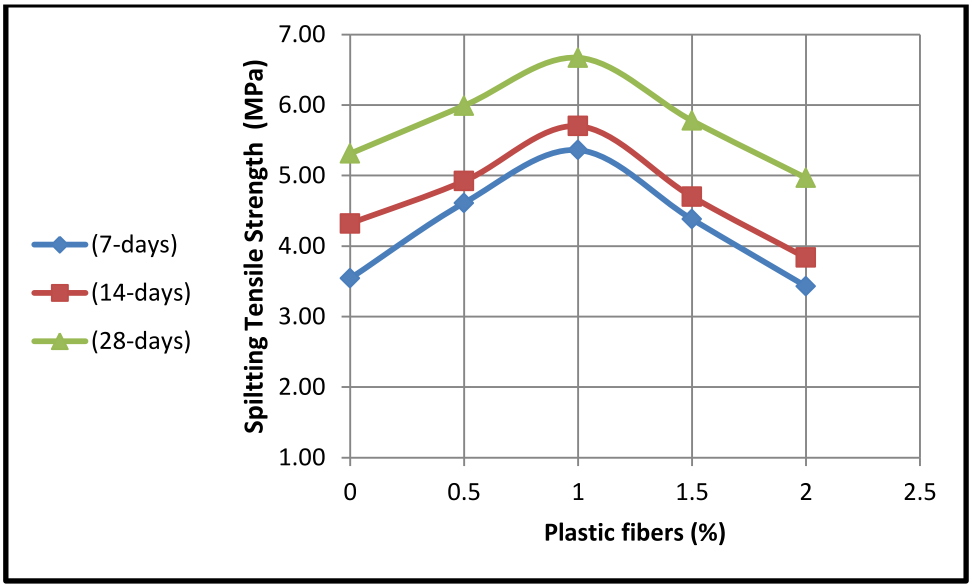


Fig (6): Relationship between splitting tensile strength strength of RCC mixes with percentage of plastic fibers.

Recommendations for future work:

1- Possible the use of RCC as replace in pavement.

2- More research is required to study the effect of using other admixtures like fly ash, fumed silica, and synthetic fibers.

3- Reducing cement content for economical side.

4- Studying the effect of internal stresses product external loads by microscope technicality.

5- Studying possibility of achievement experimental project.

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