Effect of Date Palm Leaf Fiber on Mechanical Properties of Concrete

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Abstract

Searching of "green" or environmentally friendly materials in building industry involves the development of new materials, but might also lead to the reconsideration of traditional ones. The date palm is one of the common wastes abundantly available in the Middle East countries especially in Iraq. The present study aims to investigate the performance and effects of palm date leaf fiber on the mechanical properties of concrete, Leaf fiber (L) was used in three percentages 0.4, 0.8 and 1 % volume fraction with curing ages of 7, 28 , 90 and 120 days. A comparison was carried out for both untreated (UL) and 1% NaOH- treated palm date leaf fiber (TL). Results demonstrated major improvement in the compressive strength by 9.37% for UL1.0 and13.65% for TL0.8 and increase in flexural strength by 3.37% for UL1.0 and 7% for TL1.0. A decrease in splitting tensile strength was observed by 9.87% and 8.3 % for UL1.0 and TL1.0 respectively. A significant improvement in the impact resistance by 94.74% and 131.58% for UL0.4 and TL1.0 respectively, was observed at age 120 days curing.

Keyword: Leaf Fiber; Concrete; Mechanical Properties.

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1-Introduction

The concept of sustainability has enabled the utilization of industrial and agricultural waste in the construction industry to replace conventional construction materials, such as crushed granite aggregate, sand and cement. This has led to green and sustainable construction by reducing the cost of the production of construction materials and waste management [22]. The high cost of construction materials like cement and reinforcement bars, has led to increased cost of construction. This, coupled with the pollution associated with cement production, has required a search for an alternative binder which can be used in partial replacement of cement in concrete production. Further, disposal of agricultural waste materials such as rice husk, groundnut husk, corn cob and coconut shell have developed an environmental challenge, so the need to convert them into beneficial materials to minimize their negative outcome for the environment [11]. Date palm (Phoenix dactylifera L.) is mostly planted in hot and dry climate regions of Africa, the Middle East and Asia. Besides of food date production, large amounts of dates end up as waste. The global waste palm date production is nearly two million tons per year. Waste date has harder texture and more fibers than the commercial eatable class fruit. Nevertheless, it is a great source of sugar to produce refined sugar, concentrated juice, and confectionery pastes as well as fermentation products [19]. Iraq is the largest world producer of dates with more than 21 million date palm trees and an annual production of about 400,000 tons of the fruit [10]. In the Middle East, the amount of wastes is still increasing at an alarming rate due to the lack of waste management techniques as recycling or reuse. Management through recycling will usually add a burden on the behalf of the producer of the waste, which will eventually add to the cost of the product [9]. Some of these wastes are produced from date palm trees. The first use of fibers in reinforced concrete has been dated to 1870's. Since then, researchers around the world have been interested in improving the tensile properties of concrete by adding wood, iron and other wastes [15].

In addition to industrial fibers, natural organic and mineral fibers have been also investigated in reinforced concrete. Wood, sisal, jute, bamboo, coconut, asbestos and rock wool, are examples that have been used and investigated [23[4][18].

The use of fibers in the concrete became more and more a current practice in

rehabilitation of structures and the applications are more and more developed. That is due to the capacity of this new composite material (concretes reinforced by fiber) to limit and to control the cracks, to improve the flexural and tensile strengths as well as to improve the shock resistance [1] .

Addition of fibers can increase strength and also reduce plastic shrinkage and drying shrinkage by arresting the propagation of crack. The development of steel reinforcement has overcome the problem of poor tensile strength, but it doesn't completely solve the problem of micro cracks due to drying and plastic shrinkage owing to weathering conditions. Addition of steel reduced the micro cracks but over a long period, steel gets corroded due to various actions [21].

For health and economic reasons the researchers are actually oriented toward the reinforcement of concretes by vegetal fibers, notably for countries that possess these fibers in big quantity [1].

Ismail, 2006[12], describes the effect of the addition of various volume fractions (0-4%) of short natural fibers on the behavior of the composites. An experimental work has been carried out to study the mechanical properties of Roselle fiber - reinforced cement composites. The results show that the tensile strength of composite increases about 53%, while the compressive strength decreases as the fiber volume fraction is increased.

Alawar et al., 2009[5] ,studied the effect of different treatment process on the data palm fiber (DPF). Raw DPF underwent different surface modification methods such as alkali treatment with concentrations 0.5%, 1%, 1.5%, 2.5% and 5%, and acid treatment with 0.3, 0.9 and 1.6 N. All treatments were performed at 100 ºC for 1 hr. The surface morphology, thermal

gravimetry analysis (TGA), Fourier transform infrared spectroscopy (FTIR), mechanical properties and chemical analysis, of treated DPF were investigated. Specimen treated with 1%NaOH showed optimum mechanical properties. Hydrochloric acid treatment

resulted in deterioration in mechanical properties. Ahmad and Noor, 2012[3], investigated the usage of palm oil fiber as discrete reinforcing fiber in concrete .Fiber reinforced concrete is able to increase its performance against tensile strength and toughness due to ability to absorb energy by reinforcing fibers. The results show that the mix design of palm oil fiber concrete added with and 0.50 and 10% pulverized fly ash (PFA) replacement gave the best compressive strength. It is shows that series with using palm oil, fibers reduces workability and compressive strength, but increases the tensile splitting strength. The present study aimed to investigate the effect of date palm leaf fiber on mechanical properties including compressive strength flexural strength splitting tensile strength impact resistance of concrete.

.2Materials and Mix Design

2.1 Materials

supplied by the Iraqi local market .

.1 Cement: Portland cement type I conforming to I.Q.S No. 5/1984 was used in all of types of concrete content mixes. The chemical and physical properties of the cement were analyzed in the building research directorate given in Tables 1and 2.

.2 Fine aggregate: Natural sand of zone (2) was used as fine aggregate in this study conforming to I.Q.S No.45/1980.The gradation of the used fine aggregate. Its physical and chemical properties were analyzed in the building research directorate Tables 3and 4.

.3 Coarse aggregate: Crushed river gravel of 19 mm maximum size was used as coarse aggregate. The properties of the coarse aggregate were determined and fulfilled according to Iraqi specification No.45/1984 and were conducted in the building research directorate, and its gradation is presented Table (5.(

.4 Mixing water: Ordinary tap water was used in this work for all concrete mixes and curing of specimens.

.5 High Range Water Reducing Admixture [super plasticizer] : High range water, reducing admixture (HRWR) super plasticizer, known commercially as (DEGASET AX 5011) was used. It decreases water/cement ratio to increase workability and mechanical properties of concrete complies with ASTM C 494 type F. The properties of this admixture (as claimed by the producer: YAPICHEM Company) are listed in Table (6.(

6. Date Palm Fiber (leaf): In order to study the possibility of using palm date fiber as reinforcement for concrete. The fiber was extracted from the surface of the trunk date palm tree (leaf). All fibers were washed with tap water for several times in order to remove part of soluble substances as well as residues and dust at fiber surface. Then manually dismantled into bundles of virgin fibers. The bundled fibers were dried at room temperature before being cut to the desired length 30 mm using a sharp blade then collected in polyethylene bags for later use (Fig 1).The fiber leaf (L) was added at three proportions (0.4%, 0.8% and 1%) as the volume fraction of the total mix. The physical; mechanical and chemical properties of the leaf fiber were carried out in advanced research materials center in the Ministry of Science and Technology Table (7)

Table (1): Chemical properties of cement

Compound composition	Abbreviation	Percent by weight	Limit of I.S No.5/1984
Lime	CaO	62.96	-
Silica	SiO_2	20.63	-
Alumina	Al_2O_3	6.96	-
Iron oxide	Fe_2O_3	1.62	-
Magnesia	MgO	2.50	≤ 2.85%
Sulfite	SO_3	2.54	≤ 5%
Loss on ignition	L.O.I	2.58	≤ 4%
Insoluble residue	I.R	0.98	≤ 1.5
Lime saturation factor	L.S.F	0.91	0.66-1.02
Main compounds % by weight			
Name of compounds	**Abbreviation**	**Percent by weight**	
Tri calcium silicate	C_3S	38.45	
Di calcium silicate	C_2S	30.38	
Tricalicium luminate	C_3A	15.85	
Tetra calcium alumino ferrite	C_4AF	4.92	
Free lime	-	1.14	

Table (2): Physical properties of cement

Physical properties	Limits of cement	Limits of I.S No. 5/1984
Fineness m^2/kg	388	≥ 230
Initial setting time (h:min)	2:00	≥ 00:45
Final setting time (h:min)	4:30	≤ 10:00
Compressive strength(Mpa) 3 days age 7 days age	 24 37	 ≥ 15 ≥ 23
Soundness	-	≤ 0.8

Table (3): Gradation of fine aggregate

Sieve size (mm)	Percentage passing %	Limit of I.Q.S No.45/1984, zone(2)
10 mm	100	100
4.75 mm	90	90-100
2.36 mm	74.5	75-90
1.18 mm	63	55-90
0.6 mm	44.4	35-55
0.3 mm	14.8	8-30
0.15 mm	3	0-10

Table (4): Physical and chemical properties of fine aggregate

Properties	Values	Limits of I.Q.S No.45-1980
Sulfite % (SO_3)	0.047%	≤ 0.5%
Fineness modulus	3.1	-
Absorption %	1.5	-
Density (kg/m^3)	1600	-
Specific gravity (s.g)	2.67	-

Table (5): Gradation of coarse aggregate

Sieve size(mm)	Percentage passing %	Limit of Iraqi specification NO. (45/1984)
20 mm	100	100
10 mm	37	30-60
5 mm	2.8	0-10
Sulfite content	0.07	0.001≤
Chloride content	0.017	-

Table (6): Properties of HRWR

Chemical content	Polycarboxylate based
Color, appearance	Brown liquid
pH	4-8
Density	1.06±0.02 g/cm^3
Chlorine content (%)	< 0.1(EN 480-10)
Alkaline content (%)	10 (EN480-12) <

Table (7): Properties of leaf fiber

Properties	Leaf
Density(kg/m^3)¤	612
Water absorption after 24h in water %	82%- 67%
Ultimate tensile strength Mpa ≈	(25-127)
Aspect ratio	(130.4-26.8)
Dimensions mm≈	(0.23-1.12) diameter
Moisture wt%*	5
Volatile matter wt%*	78.1
Fixed carbon wt%*	5.2
Ash wt%*	11.7

¤ This test carried in IBN SINA center

≈This test carried out in advanced research materials center in ministry of science and technology.

*Sait et al , 2012[17]

Fig. 1: Palm date leaf fiber

2.2Alkalized Treatment of Leaf Fiber

In order to improve the fiber surface and modify the strength of the fiber–matrix interface, alkali treatment was used to remove hemicelluloses and lignin to produce a rough surface topography, the procedure of alkalization included:

- The clean fiber with 30mm length was soaked in 1% concentration NaOH solution at 100C° for 1 h then washed thoroughly with water to remove the excess of NaOH sticking to the leaf and leaf stem fibers [5 .[
- Fiber was immersed in tap water until saturation state before mixing with concrete mixing for 24hr at room temperature.
- Then the fiber was air dried for 15 min. to obtain fiber saturated surface dry condition and then added to the concrete mixture.
- The leaf was used treated and untreated in the concrete mix.

evaluate the addition of date palm fiber in different percentages.

2.3Mix Design

All the experiments were conducted at room temperature from December 2013 to October 2014, in the laboratory of concrete in the building research directorate.

2.3.1Concrete Mixing

Mixture proportioning for each reference concrete mixtures consisted of 750kg/m3 sand, 1035 kg/m3 gravel, 400 kg/m3 cement and a W/C ratio of 0.406 and 1.2% HRWR and it was designed to achieve compressive strengths of 50 Mpa at 28 days. For fiber - containing concrete , the fibers were air dried at room temperature to obtain saturated surface dry condition and then added to the dry constituents mix at volume fraction of 0.4 , 0.8 and 1% for a period ranging from 1 to 3 min depending on the amount of fiber while the rotary mixer was running for 1.5 min. followed by adding 30% of mix water ranging between 0.384 to 0.416,with 1.2% admixture and finally adding the remaining water gradually, over mixing was avoided because the fiber will be damaged and loss strength, such procedure results in a good dispersion of fiber and prevent balling problems.

The slump was kept within the range 90±10 mm. They were chosen to evaluate the addition of date palm fiber in different percentages.

.3Results and Discussion

3.1Compressive Strength

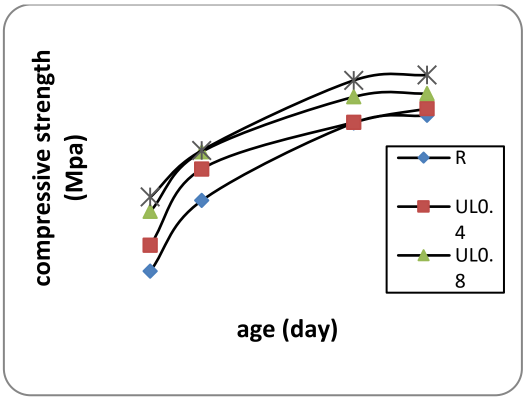
The effect of different content of untreated leaf fiber (UL) on the compressive strength of concrete at different periods is shown in Fig 2a. It is clear that the compressive strength improved by using leaf fiber for all percentages, this type of fiber has better mechanical properties and their aspect ratio is larger and it adjusts well with concrete matrix; there are no voids in the concrete matrix which means less entrapped air and lower porosity; better compaction and also can last longer in the alkali medium. The compressive strength values of UL concrete mixes were higher than the compressive strength of plain concrete .It increased with time when fiber volume fraction Vf increased. Throughout the test, as the fiber content increases, the crack visibility was less, indicating good bonding can be developed with the addition of fiber.

Fiber in concrete can play an important role in concrete by providing good fiber-matrix bonding, and being able to interrupt the distribution of compressive stress that results in multi cracking in concrete. Similar observation was reported by [16.[

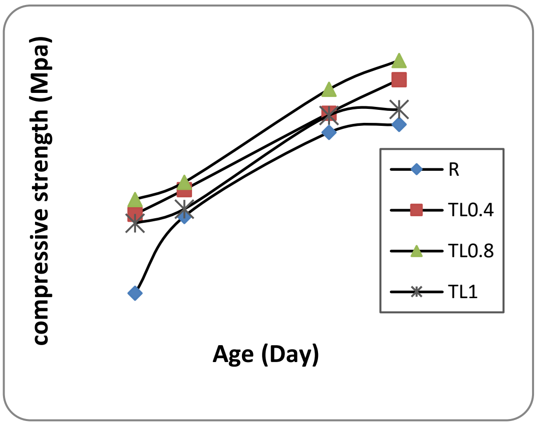
Table (8) shows that the maximum increase in compressive strength was 9.37% for UL1.0 while the minimum increase was 1.59% for UL0.4 compared with plain concrete tested at age 120 days. The uniform dispersion of this type of fiber in the matrix without curling and balling helps the compressive strength to increase.

For treated leaf fiber concrete, the compressive strength was improved at all ages and continued to increase with curing time, and it increased as the fiber volume fraction increased up to 0.8 (by volume) then it decrease as the volume fraction reached 1% volume fraction as compared with the compressive strength of plain concrete, Fig.2a.

In addition, Table (8) shows the ratios of compressive strength of treated and untreated leaf fiber. The results show that the maximum increase in compressive strength is about 13.65% and 9.52% for TL0.8 and TL0.4 respectively, compared with plain concrete at age 120 days.



(a) Untreated leaf fiber



(b) Treated leaf fiber

Fig.2: Effect of various content of leaf fiber on compressive strength as compared with plain concrete

Table (8): Rate of increase and decrease in compressive strength of leaf fiber concrete with and without treatment

Concrete mix	Increment ratio,%			
	Curing ages (day)			
	7	28	90	120
UL0.4	9.43	9.1	0.16	1.59
UL0.8	21.59	14.03	6.14	5.08
UL1.0	27.79	14.43	10.02	9.37

TL0.4	26.3	7.11	4.2	9.52
TL0.8	31.27	9.1	9.37	13.65
TL1.0	23.33	1.98	3.72	3.17

3.2Flexural Strength

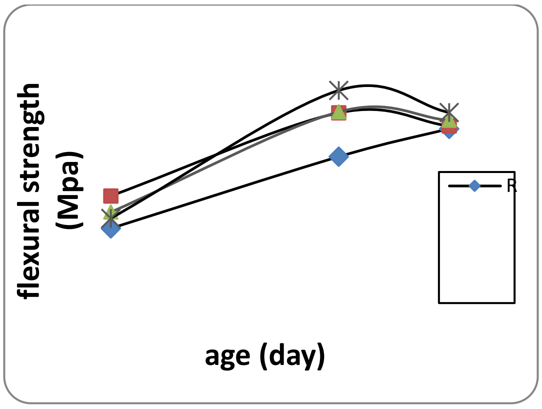
The flexural strength results for specimens of plain concrete and fiber reinforced concrete with and without treatment stored in water and tested at various ages (28, 90, 120) days ,are shown in Fig. 3. The flexural strength of leaf fiber concrete had significantly increased until the curing age 90 days as compared with plain concrete. As given in Fig.3a, this observation agrees with the results obtained by Al-Noaimy 2001 [8]. The flexural strength of leaf fiber reinforced concrete increased as fiber content increased up to 1% vf. The resistance to the bending of concrete of plant fibers of palm increases with the increasing of the fiber percentage [1]

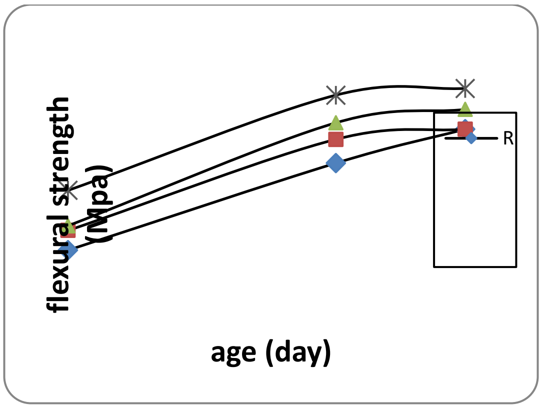
At 120 days curing age, there are slight decreases in the flexural strength of the untreated leaf fiber concrete, but it's still higher or equal to the flexural strength of plain concrete due to the large fiber aspect ratio used. Increasing the aspect ratio of the fiber linearly increased the flexural strength of the concrete [13]

The maximum increase in flexural strength was 3.37% for UL1.0 at age 120 days in comparison with plain concrete, Table (9).

For treated palm leaf fiber, the flexural strength increased linearly with age and it is increased as the fiber content increased. Fig.3b.

The maximum increase in flexural strength was 7% for TL1.0 compared with plain concrete at curing age 120 days. This is due to the increase in the tensile strength of the fibers when immersed in NaOH solution, the fiber tensile strength is one of the most parameters that influencing the flexural strength of composite [3]. The flexural strength of 1% Vf treated leaf fibers concrete was better than the untreated leaf fibers at 120 days as compared with plain concrete, This result was in agreement with the results given by [8][5] . The lower lignin content of treated leaf fiber gave rise to an increase of hydrophilic character of the fibers, as a consequence, the wet ability of the fiber surface will be increased, and this will provided stronger adhesion between the fiber and the matrix [14].





(a) Untreated leaf fiber (b) Treated leaf fiber

Fig. 3: Effect of various content of leaf fiber on flexural strength as compared with plain concrete

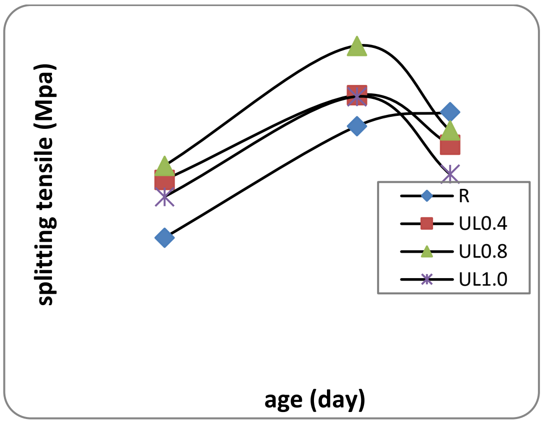
Table (9): Rate of increase and decrease in flexural strength of leaf fiber concrete with and without treatment

Concrete mix	**The Increment ratio, %**		
	Curing ages (day)		
	28	**90**	**120**
UL0.4	8.5	9.67	0.85
UL0.8	4.25	17	1.74
UL1.0	2.64	14.6	3.37
TL0.4	4.25	4.32	0
TL0.8	5.28	7.32	3.37
TL1.0	12.9	12.35	7

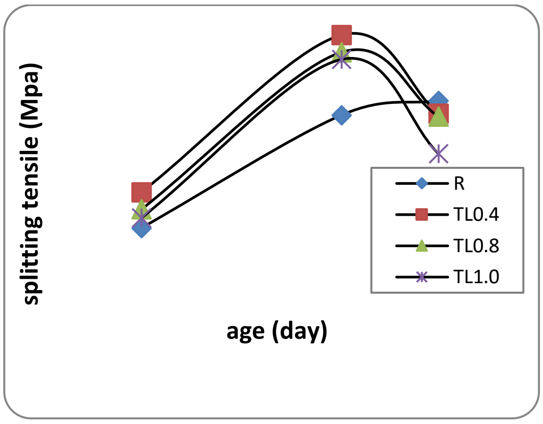
3.3Splitting Tensile Strength

It is noticed from the test results presented in Fig.4 that the splitting tensile strength of leaf fiber (treated and untreated) concrete increased significantly at the age of 90 days but as it reached 120 days decreased. Both treated and untreated leaf fiber concrete gives almost the same behavior. The splitting tensile strength of treated and untreated leaf fiber concrete increased extremely at the age of 90 days, and then decreased at the age of 120 days. This is due to preservation of leaf fiber mechanical and physical properties with time passing so that leaf fibers are highly susceptible to volume changes due to the variations in fiber moisture content. Fiber volumetric changes that accompany variations in fiber moisture content can drastically affect the bond strength between the fibers and cement matrix.,Table(10) shows that the maximum decrease in splitting tensile strength was 9.87% and 8.3 % for UL1.0 and TL1.0 respectively compared with plain concrete at 120 days curing. And the minimum decrease was 2.91 % and 2.02% for UL0.8 and TL0.4 respectively.

From the visual observation, it can be seen that all specimens reinforced with leaf fibers remained attached together without breaking into two pieces as compared to what happened with the plain concrete and leaf stem concrete specimens which were broken to the half



(a) Untreated leaf fiber



(b) Treated leaf fiber

Fig.4: Effect of various content of leaf fiber on splitting tensile as compared with plain concrete

Table (10): Rate of increase and decrease in splitting tensile strength for leaf fibers concrete with and without treatment

Concrete mix	The increment ratio, %		
	Curing ages (day)		
	28	90	120
UL0.4	11.48	5.05	-5.16

UL0.8	14.29	13.07	-2.91
UL1.0	8.12	4.82	-9.87
TL0.4	7	12.84	-2.02
TL0.8	3.64	10.1	-2.47
TL1.0	1.96	8.94	-8.3

3.4Impact Resistance

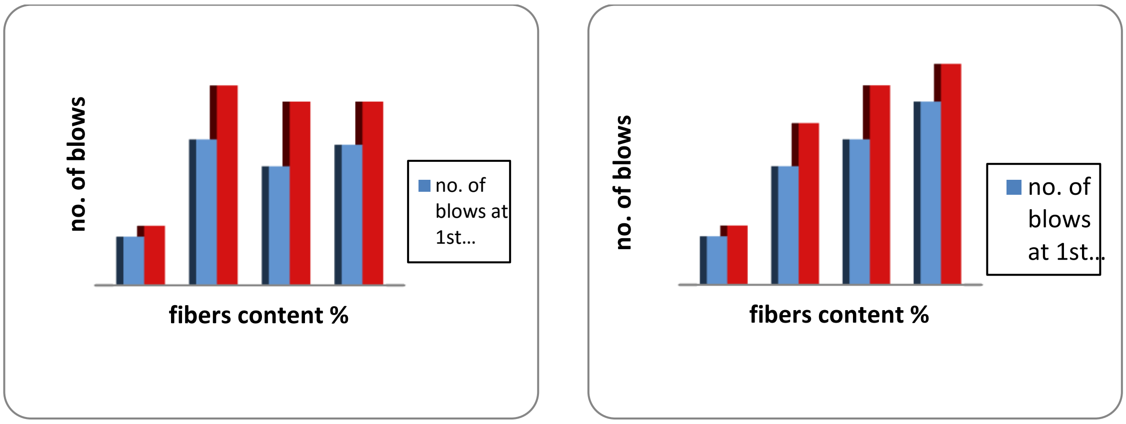
Test results presented in Fig 5a, indicated that the impact resistance of plain concrete enhanced by the inclusion of untreated leaf fiber, and the impact resistance increased as the fiber content is increased up to 0.4 % and never decreased as the fiber content increased .

The impact resistance of concrete significantly increased by the addition of treated leaf fiber at the first crack and at failure in comparison with plain concrete. The impact resistance increased as the fiber content increased up to 1.0%, Fig.5b .

The treated leaf fiber-concrete gave better results for the impact resistance characteristic than the untreated leaf fiber-concrete at 1.0 % of the fiber content at the first crack because they had better mechanical properties and better tolerance in the alkali medium as a result of the alkalization treatment.

This finding is in agreement with the previous observation reported by [20.[

Table (11) shows that the maximum increase in the impact resistance at the first crack of the untreated leaf fiber-concrete was 94.74 and 89.47% for UL0.4 and ULS1.0 respectively as compared with plain concrete slabs. Table (11) also shows that the increase in the impact resistance at the first crack of the treated leaf fiber-concrete was 94.74% and 131.58% for TL0.8 and TL1.0 respectively as compared with plain concrete slabs



(a) Untreated leaf fiber (b) Treated leaf

Fig.5: Effect of various content of leaf fiber (UL) on impact resistance as compared with plain concrete

Table (11): Rate of increase in impact resistance of leaf fiber-concrete with and without treatment

Concrete mix	The increment ratio, %	
	120 day curing period	
	No. of blows of first crack	No. of blows of failure
UL0.4	94.74	123.81
UL0.8	68.42	109.52
UL1.0	89.47	109.52
TL0.4	68.42	90.48
TL0.8	94.74	123.81
TL1.0	131.58	142.86

4. Conclusion

1. Using of leaf fiber with concrete has a significant improvement in compressive strength. The best fiber content was 0.8% and 1% of treated and untreated leaf fiber respectively.
2. The use of leaf fiber in concrete improved the flexural tensile strength, especially at age 90 days more than 120 days and the

best fiber content was 1% for treated and untreated leaf fiber, TL is better than UL at age 120 days.

3. The splitting tensile strength improved significantly by the addition of leaf fiber at age 90 day and decreased at age 120 day for treated and untreated leaf fibers.
4. The impact resistance, improved significantly by the addition of leaf fiber, and the treated fiber gave better results than the untreated.

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تأثير الياف النخيل على الخواص الميكانيكية للكونكريت

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سهير كاظم االحبوبي
مركـز بحـوث البنـاء / وزارة الاسـكان والاعمـار- العراق
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الخلاصة

احدى التحديات الكثيرة التي يواجهه العالم النامي هو مسألة إدارة النفايات. في الآونة الأخيرة، بذلت الكثير من الجهود لإعادة تدوير النفايات المختلفة في الخرسانة المستدامة.تعتبر مخلفات النخيل في الدول المنتجة لمحصول التمور عبئاً كبيراً على المزارع ، مما شكل تلوث بيئي ظاهر من أثر تراكم مخلفات أشجار النخيل من الجريد والسعف والجذوع البالية مما دعت الحاجة إلى إيجاد بدائل لإنشاء مشاريع تحويلية لتلك المخلفات .

يهتم البحث الحالي بدراسة تاثير اضافة الياف جريد النخيل وبنسبة حجمية (0.4و 0.8 و 1) ٪المعالج بـ1% هيدروكسيد الصوديوم والغير معالج على الخواص الميكانيكة للخرسانة ، كل النماذج تم فحصها لفترات معالجه 7، 28، 90 و 120 يوما.

اظهرت نتائج البحث ان الياف الجريد تحسن وبشكل كبير مقاومة الانضغاط للخرسانة حيث بلغ اعلى معدل زيادة 9.37٪ و13.65٪ عند استخدام 1% من الياف الجريد الغير معالجة و0.8% من المعالج على التوالي وازدادت مقاومة الانحناء بنسبة 3.37٪ وبنسبة 7٪ عند استخدام 1.0% من الياف الجريد الغير معالج والمعالج على التوالي، كما سببت الياف الجريد انخفاض في مقاومة الشد الانشطاري بنسب 9.87٪ و 8.3٪ عند استخدام 1.0% من الياف الجريد الغير معالج والمعالج على التوالي كما تحسنت وبشكل كبير مقاومة الصدمة حيث بلغت 94.74٪ و 131.58٪ لUL0.4 وTL1.0 عند استخدام 0.4% من الياف الجريد الغير معالج و1.0% من المعالجة على التوالي بعمر 120 يوما.كما تم التوصل الى ان اختبار قياس سرعة النبضات تراوحت مابين (4.94-4.69) كم / ثانية لخرسانة الياف الجريد (المعالجة والغير المعالجة) بعمر 120 يوما والتي كانت ضمن مجموعة الممتازة لاختبارقياس سرعة النبضات للكونكريت .

الكلمات الرئيسية : الياف الجريد ; كونكريت ; الخواص الميكانيكية