

EFFECT OF ADDING SISAL FIBER AND IRAQI BAUXITE ON SOME PROPERTIES OF CONCRETE ⁺

تأثير إضافة ألياف السيسال والبوكسايت العراقي على بعض خواص الخرسانة

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Abstract:

This investigation aim to study the effect of sisal fiber addition on the different properties of concrete, also to study the use of the Iraqi bauxite *for the first time in Iraq* as a pozzolanic material. Sisal fiber was used at three percentages of total mix volume (0.5%, 1.0% and 1.5%), Iraqi bauxite was used in three percentages (10%, 20% and 30%) as a partial replacement by weight of cement. This paper studied the effect of Sisal fiber and the Iraqi Bauxite on the mechanical properties which represented by the compressive strength, flexural strength, splitting strength, impact resistance for tiles, also the ultrasonic pulse velocity test which is one of the non-destructive testes, the pH level and water absorptions has been done.

The results from this study showing that the concrete reinforced with sisal fiber and using Iraqi bauxite exhibited improvement in flexural strength and splitting tensile strength while a small reduction in compressive strength was reported. The results showed also improvement in the impact resistance. Adding of sisal fiber made a reduction in the ultrasonic pulse velocity. The results showed that this kind of concrete reported a reduction in water absorption in comparative with reference concrete reinforced with fibers only. The use of bauxite as a partial replacement of cement reduced the alkalinity of concrete reinforced with fiber and that would improve its durability. From the results of this investigation, found that concrete reinforced with 1.0% of sisal fiber give the best results and using Iraqi Bauxite with 20% as a partial replacement by weight of cement enhanced the properties of reinforced concrete with sisal fiber.

Keywords: Bauxite concrete, Sisal fiber, composite concrete

المستخلص:

يهدف هذا البحث إلى دراسة تأثير إضافة ألياف السيسال على الخواص المختلفة للخرسانة وكذلك دراسة استخدام أطيان البوكسايت العراقي ولأول مرة في العراق كمادة بوزولانية. تم استخدام ألياف السيسال بثلاث نسب من الحجم الكلي للخرسانة (0,5%، 1,0% و 1,5%). استخدم البوكسايت العراقي كتعويض جزئي من وزن الاسمنت بثلاث نسب (10%، 20% و 30%). تم دراسة تأثير ألياف السيسال والبوكسايت العراقي على الخواص الميكانيكية للخرسانة والتي تتمثل بمقاومة الانضغاط، مقاومة الانثناء، مقاومة الانفلاق ومقاومة الصدم للبلاطات

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كذلك إجراء أحد الفحوص غير الإتلافية والمتمثل بفحص سرعة انتقال الموجات فوق الصوتية، وإضافة إلى ذلك تم دراسة امتصاص الماء والأس الهيدروجيني. تشير النتائج المستحصلة من الدراسة إلى حدوث تحسن واضح في مقاومة الإثناء ومقاومة الشد في الخرسانة المسلحة بألياف السيسال والحاوية على البوكسايت، وحدث انخفاض طفيف في مقاومة الانضغاط، كذلك تبين النتائج إلى إن إضافة الألياف واستخدام البوكسايت في الخلطات قد حسن من مقاومة الصدم. إضافة الألياف أدت إلى انخفاض سرعة الموجات فوق الصوتية، كذلك أظهرت النتائج ان هذا النوع من الخرسانة يعطي امتصاص اقل بالمقارنة مع الخرسانة المصدرية والمسلحة بالألياف فقط. أظهرت نتائج فحص الأس الهيدروجيني إن استخدام البوكسايت كتعويض جزئي عن وزن الاسمنت قلل من قاعدية الخرسانة المسلحة بالألياف وبالتالي تتحسن ديمومتها. وتبين النتائج في هذه الدراسة ان الخرسانة بنسبة حجميه ١٠,٠% من ألياف السيسال أعطت نتائج أفضل من باقي الخلطات، كذلك ان استخدام البوكسايت العراقي بنسبة ٢٠% كتعويض جزئي عن وزن الاسمنت في الخلطة قد عزز من خواص الخرسانة المسلحة بألياف السيسال.

Introduction

Concrete is the most versatile materials used in civil engineering structures. It is so simple and cheap, that is can so easily made by mixing aggregates, water and cement with simple equipment and poured or pumped into virtually any shape or section. The use of composite materials dates goes back to centuries ago, and it all started with natural vegetable fibers, which used for strengthening of brittle materials, for example, reeds embedded in asphalt were used in the walls of ancient Babylon as a mortar binder for brickwork, Raouf [1]. Straws, grass and reeds were used to reinforce mud bricks as early before (4000) years, for example in the Ziggurat Agar Quaff near Baghdad, Cook [2].

Cementitious materials in the form of concrete or mortar are attractive for use as constructural materials, but their deficiencies appear in their brittle characteristic, poor tensile and impact strength and in their susceptibility to moisture movements.

Many investigations have already been carried out on various mechanical properties and physical performance of concrete materials using natural fibers from coconut husk, sisal, hemp, sugar cane begasse, bamboo, jute, wood and other vegetable fibers. These investigations have shown encouraging commercial prospects of this new distinct group of materials for application in low cost housing construction, Aziz and Lee[3]

Materials:

Sisal Fiber

Vegetable sisal fibers that have been brought from Baghdad local markets and used in this research in the form of bundles with 1.5 meter long and they were cut into 30-millimeter length in order to be spread randomly in the concrete by using spreading method. Table (1) shows the properties of sisal fiber, fao.org [4]. The fibers were washed by tap water several times to remove dust from their surface.

Table (1) Properties of Sisal Fiber

Density g/cm³	Tensile Strength 10⁶ N/m²	Modulus of elasticity Gpa	Elongation at failure %	Moisture absorption%
1.33	600-700	38	2-3	11

Bauxite

In this research, the Iraqi Bauxite has been used as a pozzolanic material. It was brought from the General Company for Refractory Industries. This pure Bauxite was burned in a special oven at a constant temperature degree (950°C) for two hours, Khalid [5] Chemical and physical properties of Bauxite are shown in Table (2) and Table (3) respectively.

Table (2) Chemical Analysis of Bauxite

Oxide	Bauxite %	Limit of ASTM C 618-89
Al ₂ O ₃	65.6	70(min)
SiO ₂	14.62	
FeO ₃	1.43	
Na ₂ O	0.17	1.5(max)
K ₂ O	0.53	
SO ₃	0.45	4(max)
Moisture Content	0.24	3(max)
L.O.I	1.29	10(max)

Table (3) Physical Properties of Bauxite

Physical Properties	Bauxite	Limit of ASTM C618-89
Fineness	18.6	34(max)
Specific Gravity	2.85	
S.A.I [P.A.I]	104	75(min)
Flow%	115	115(max)

Bauxite Deposit in Iraq

Bauxite deposit was discovered in north Wadi Hussainyat in the Western Desert of Iraq throughout the study of, Mustafa [6]. It is of karst type formed on the irregular surface of limestone. Flint clay, plastic clay (kaolin) is associated with bauxite.

Bauxite is of different chemical composition and the degree of Bauxitization is variable. The alumina content of bauxite deposit range from 42% up to 66% depending up on the contaminant minerals and the degree of Bauxitization.

The deposit is characterized by a core of high alumina content up to 67% Al₂O₃, surrounded by clay with lower alumina content (flint clay) and plastic clay. The major mineral of Bauxite is Bohemite (Al₂O₃.H₂O) with a minor Gibbsite mixed with kaolinite and Anatase, Khalid [5].

Cement

Ordinary Portland cement manufactured by Kubaiysa cement factory was used in all mixes throughout this investigation.

Fine Aggregate

The fine aggregate used was from Al-Ekadir region and tested to determine the grading and other physical properties. Results indicate that the fine aggregate grading and sulfate content were within the requirements of Iraqi specification (I.O.S) No.45 1984, zone (3).

Coarse Aggregate

Natural river irregular shape gravel used as coarse aggregate, maximum size 9.5mm was used for all mixes. The selection of this size was based on the consideration of getting acceptable workability and uniform dispersion of fibers in the composite, Hannant [7]. The grading of coarse aggregate used and it conforms to the Iraqi specification No.45 1980.

High-Range Water-Reducing Admixture (Superplasticizer)

A Superplasticizers type sulphonated melamine formaldehyde condensate, which is known commercially as MELMENT L10. This superplasticizers supplied by Baghdad Company, was used throughout this research as a HRWRE.

Pozzolanic Activity Index [P.A.I] of Bauxite

Reference and bauxite mortars were used for making Pozzolanic activity test specimens. Both mixes consist of (1) part of cement or cementitious materials (cement+bauxite), and (2.75) parts of sand by weight. Cement-Bauxite mortars contain 10, 20, 30 and 40% bauxite as a partial replacement by weight of cement.

Three 50mm cubes were molded from each type of mortar. After molding, the specimens were placed immediately in moist cabinet maintained at a temperature of $23\pm 2^{\circ}\text{C}$ and relative humidity of more than 95% for 20-24 hrs. then the cubes were demolded and placed in a container made of light-tinned sheet metal and having a capacity of three cubes. The container was sealed, airtight and stored at $38\pm 2^{\circ}\text{C}$ for 27 days. Before testing, the specimens were allowed to cool at $23\pm 2^{\circ}\text{C}$. The Pozzolanic activity index with Portland cement was determined according to ASTM C311-87a as follows:-

$\text{P.A.I} = \text{A}/\text{B} * 100$ Where: A: average compressive strength of test mix cubes.

B: average compressive strength of reference mix cubes.

Table (4): The results and details of the Pozzolanic activity index test

%HRWRA by weight of cement	%Bauxite by weight of cement	w/c to give flow 110±5mm	P.A.I
0	0	0.55	-
1.8	10	0.55	101.85
3	20	0.55	104
4	30	0.55	97.67
5.5	40	0.55	94.59

Experimental Program

The aim of this experimental work is to study the effect of fibers addition on the properties of plain concrete, also study the effect of pozzolana addition on the properties of fiber reinforced concrete. Table (5) shows the details of the mixes that used throughout this study. Many tests are required to be assessed in this experimental work such as: Compressive strength using 100mm cubes, flexural strength using (100*100*400)mm simply supported prisms, splitting tensile strength using (100*200)mm cylinders, impact resistance using (500*500*50)mm, ultrasonic pulse velocity; (U.P.V.) using (100*100*400)mm prisms, absorption by using 100mm cubes and PH-level.

Mixing Procedure:

All mixes were batched in a rotary mixer of 0.1m. At first the dry constituent cement, sand and aggregate are initially mixed for one minute then the required amount of water is added and the whole mix constituents are mixed for another minute. The fibers are then added for a period ranging from (1 to 3) minutes depending on the amount of fiber. The required dosage of super plasticizer added in steps, then the whole constituents mixed for proper time until a uniform dispersion of fibers is achieved.

Mix Design

The reference concrete mix as designed according to the British method B.S. 1881. All mixes were designed to have a 28-day cubic compressive strength of 40MPa. After many trails one mix proportion was used in this study (1:1.16:2.01) (cement: sand: gravel) by weight. Cement content was 513 kg/m³ and w/c ratio was 0.4. The HRWR was used to maintain specific slump for all mixes.

Table (5): The details of mixes used throughout this investigation:

Mix	Fiber (%)	Bauxite (%)	HRWR (%)	Slump(mm)
R	-	-	0	75
0.5F	0.5	-	0.43	73
1.0F	1.0	-	0.74	73
1.5F	1.5	-	1.1	72
1.0F+10B	1.0	10	2.9	73
1.0F+20B	1.0	20	3.4	72
1.0F+30B	1.0	30	4.0	74

Results and Discussions

Compressive Strength Test

Results represented in figure (1), indicate that there is a small reduction in the compressive strength due to the inclusion of sisal fiber Table (6). The strength reduction is caused probably by the increasing amount of entrapped air voids due to the presence of fiber. The increase in air content could be attributed to the difficulty in compaction fiber reinforced concrete. Small reduction in compressive strength of natural fiber reinforced concrete is also reported by, Akers and Gerneke [8, 9, 10, and 11]. From results we can notice that the compressive strength is found to reduce as fiber volume fraction increased, Aziz and Lee [3]. The reduction in the compressive strength of this type of mixes can be attributed to:-

1. Lower cement content, with adversely effect the compressive strength, Chern and Chan [12].
2. Low Pozzolanic activity of bauxite at early ages.
3. Difficulties in mixing and compaction at high level of replacement that lead to insufficient distribution of fibers in the matrix and increase the voids content.

Figure (2) shows that the fiber reinforced bauxite concrete exhibited a slight increase in compressive strength up to 90-days of curing, this behavior may be attributed to the Pozzolanic reactivity of bauxite, which is react with calcium hydroxide producing additional gel and reduce the amount of voids in the matrix. It is noticed that compressive strength increased with age with 23% for reinforced concrete with 1.0% fiber and 10% Iraqi bauxite and 21%, 19% for concrete reinforced with 20% and 30% bauxite respectively, and the rate of development of strength become less with progress of age, Al-Noaimy [13].

Table (6): The compressive strength results of fiber reinforced concrete with and without

Mix	Compressive Strength (MPa)		
	Curing Periods (Day)		
	7	28	90
R	26.95	38.87	47.51
0.5F	25.6	35.31	45
1.0F	25.21	36.82	46.11
1.5F	24.62	34.42	44.51
1.0F+10B	26	35.72	46.21
1.0F+20B	26.35	36.87	46.58
1.0F+30B	25.87	36	44.48

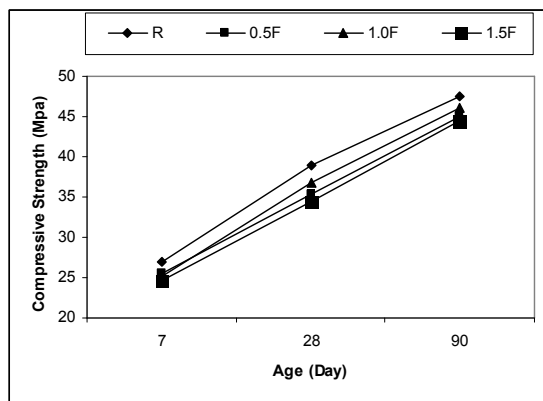


Figure (1): The effect of various content of sisal fibers on the compressive strength of plain concrete.

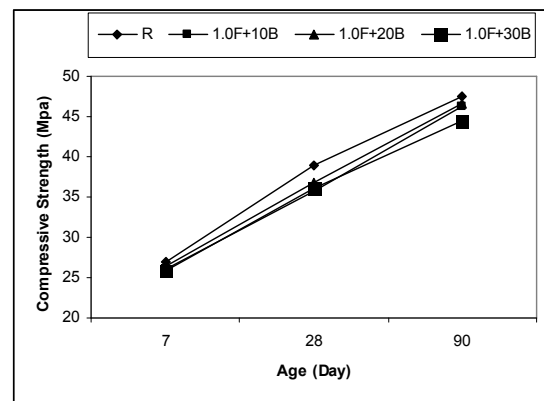


Figure (2): The effect of various content bauxite by weight on the compressive strength of concrete reinforced with 1.0% sisal fiber by volume.

Splitting Tensile Strength Test

From the test results presented in table (7), it is noticed that the splitting tensile strength of plain concrete, improved by the addition of sisal fiber. The results of this test increased up to 1.0% by volume then decreased as fiber volume fraction increased, but still higher than plain concrete. This can be attributed to the segregation problems as a result of insufficient compaction of the higher fiber volume mixes. It is shown that if segregation of fibers is avoided, then the increasing volume percentage of fiber more or less linearly increases the strength of the composite, ACI Committee [14]. We can notice that the splitting tensile strength of sisal fiber reinforced bauxite concrete increased with the addition of bauxite and that can be clear to the 20% of adding percentage. This is due to the effect of the bauxite addition, it is reduced the alkalinity of the matrix, that affected adversely on fiber components. The visual observation was that all specimens reinforced with fiber remained together in one piece, though broken unlike plain concrete, which exhibited total disintegration.

Figure (3) showing that the splitting tensile strength increased with age and the rate of development in strength become less with progression of age. The visual observation was that all specimens reinforced with fibers remained together in one piece, though broken unlike the plain concrete, which exhibited total disintegration

Table (7): The effect of various content of bauxite by weight on the splitting tensile strength of concrete reinforced with 1.0% sisal fiber by volume

Mix	Splitting Tensile (MPa)		
	Curing Periods (Day)		
	7	28	90
R	1.73	2.42	2.97
0.5F	2.17	2.69	3.2
1.0F	2.54	3.21	3.56
1.5F	2.36	2.95	3.32
1.0F+10B	2.16	2.76	3.30
1.0F+20B	2.34	3.00	3.59
1.0F+30B	1.99	2.37	2.75

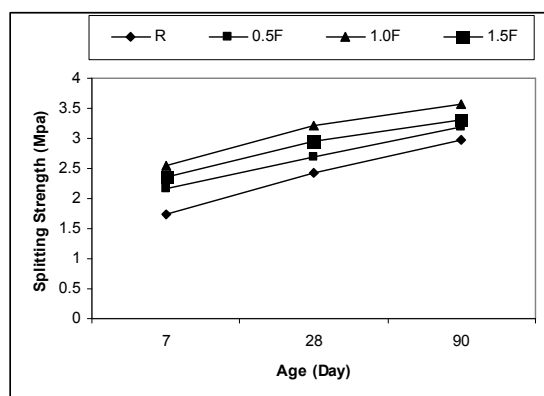


Figure (r): The effect of various content of sisal fiber by volume on splitting tensile strength

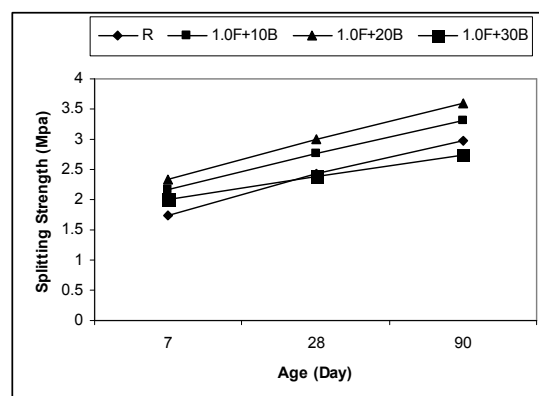


Figure (z): The effect of various content of bauxite by weight on the splitting tensile strength of concrete reinforced with 1.0% sisal fiber by volume.

Flexural Strength

From the test results presented in Figure (5), it is noticed that the flexural strength of plain concrete improved by the addition of sisal fibers. The results at Table (8) showing that the flexural strength at age 28 day has been increased with (8%, 13.6% and 9.1%) for concrete reinforced with sisal fiber with the three percentage respectively and the strength increased with (15.3%, 16% and 5.2%) at the age of 90day. The same finding was observed by Nilsson[15], who conclude that the addition of sisal fiber to the plain concrete, increase the flexural strength up to (20-25) %, Swift & Smith[16] also showed the same results. The flexural strength increased up to 1% of fiber by volume, then decreased as fiber volume fraction is increased. This can be attributed to the curling and bundling of fibers during mixing which limit the effectiveness of the entire length in transmitting stresses and similar observation reported by Ramirez [17]. He claimed that the inclusion of fiber in the matrix improved the flexural strength, reaching maximum value at 2.0% (by volume) of fiber and fiber content above this value produced a drop of strength due to unworkable and segregated mixes.

It is noticed that the flexural strength of sisal fiber reinforced bauxite concrete increased with the addition of bauxite, it is increased up to 20%(level of replacement by weight of cement) then significantly decreased at high level. This is in agreement with the conclusion by Soroshian and Won [18], this behavior is due to the high pozzolanic reactivity of bauxite,

which is chemically react with calcium hydroxide, producing additional gel, the possible reaction is lead to decrease the densification of hydration products around the fibers which reduced their embrittlement and help the composite to be more ductile.

Table (8): The Flexural strength results of fiber reinforced concrete with and without bauxite

Mix	Flexural Strength (MPa)		
	Curing Periods (Day)		
	7	28	90
R	2.69	4.21	4.94
0.5F	3.15	4.56	5.83
1.0F	3.36	4.87	5.88
1.5F	3.00	4.63	5.21
1.0F+10B	3.98	4.51	5.73
1.0F+20B	4.21	4.97	5.89
1.0F+30B	3.1	4.12	4.61

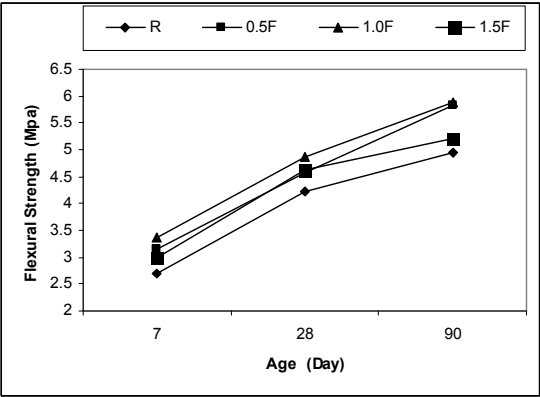


Figure (5): The effect of various content of sisal fiber by volume on the flexural strength.

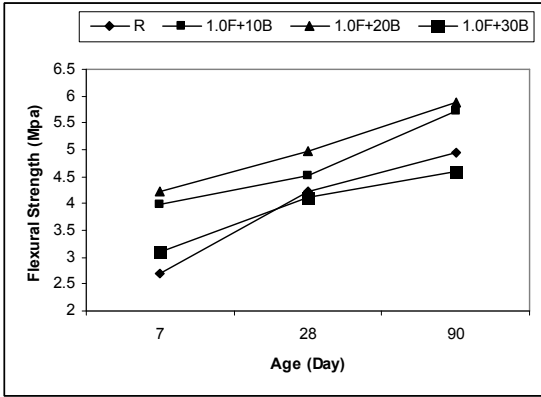


Figure (6): The effect of various content of bauxite by weight on the flexural strength of concrete reinforced with 1.0% sisal fiber by volume.

Impact Resistance

The impact resistance of fiber reinforced concrete can be measured by a test method that is simple and easy to carry out. It is has been developed by ACI committee 544, which recommends the use of repeated impact “drop weight test to estimate this important property”. In this study a simple repeated drop-weight impact testing apparatus is developed in which the impact resistance of the precast slabs can be evaluated in terms of the number of blows required to cause failure, the apparatus consist mainly of three parts which are described as follows:

1. The main supported frame: A steel frame strong enough to be held rigidly during impact load, the columns of the base were fixed in concrete to insure the stability of the frame during test. The specimens (500*500*50) mm were placed in position in the testing frame using a continuous square steel angle to provide simply supported boundary conditions in all four sides of the specimen.
2. Drop weight guide system: A tube of circular section with an inside diameter of 105mm, is held vertically above the center of the slab using four arms fixed to the

steel frame so as to allow vertical movement only. This tube is used to drop the falling mass from a control height of 2.5m with accurate guideness.

3. Striker: falling ball with a mass of 4Kg and diameter of 94mm was used as a striker which repeatedly dropped throughout the guide system on to the slab until failure.

The results of the impact resistance test for sisal fiber reinforced concrete with and without bauxite cured in tap water at 28-day, are presented in Table (9).

From the test results, it is noticed that the impact resistance of plain concrete slabs, improved by the addition of sisal fibers, and the impact resistance increased as the fiber content increased. Figure (7)

From the test results presented in Table (9) and figure (7) and figure (8), it is noticed that the impact resistance of fiber reinforced bauxite concrete slabs is higher than the impact resistance of fiber reinforced concrete slabs without bauxite, this behavior can be refer to the combined action of the fiber and the bauxite which will increase the chemical reaction and produce additional gel. It is clear that the impact resistance of concrete slabs containing 20% bauxite by weight reinforced with different fraction of fiber is higher than the impact resistance of fiber reinforced concrete slabs containing 10% bauxite by weight. This can be attributed to the pozzolanic reactivity of bauxite which is chemically react with calcium hydroxide producing additional gel lead to decrease the densification of hydration products around the fiber, which reduced the embrittlement of them and help the composite to be more ductile, thus increase the energy absorption, Jorillo and Shimizu [19] stated that there is precipitation of cement hydration in the lumen of fiber to few micrometer thickness, which gradually thicken and fill the lumen and pores of the fibers, thus cause fiber embrittlement, also the alkalinity of 10% bauxite concrete is higher than concrete containing 20% bauxite by weight of cement, which caused fiber deterioration and that lead to minimize the ability of the composite to absorb energy. The important visual observation is that the mode of failure in all fiber reinforced concrete slabs with and without bauxite was fiber pull-out and slab remains together in one piece though broken, whilst plain concrete slabs exhibited total disintegration and shattering. This concurs with the conclusion made by Ramaswamy and Krishnamoorthy[20].

Table (9): The effect of various content of sisal fibers by volume on the impact resistance

Mix	Dimension (cm)	No. of Blows
R	50*50*5	9
1.0F	50*50*5	28
1.5F	50*50*5	32
1.0F+10B	50*50*5	30
1.0F+20B	50*50*5	33
1.5F+10B	50*50*5	36
1.5F+20B	50*50*5	39

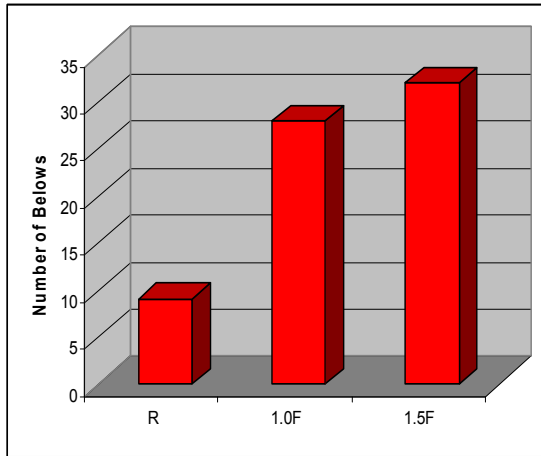


Figure (V): The effect of various content of sisal fibers by volume on the impact resistance

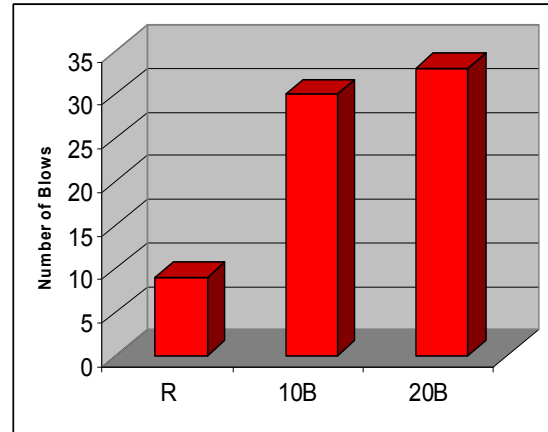


Figure (A): The effect of various content of sisal fibers by volume on the impact resistance

Ultrasonic Pulse Velocity (U.P.V.)

The addition of sisal fiber to the concrete mixes, cause a reduction in the ultrasonic pulse velocity. This attributed to the lower density of concrete, which caused probably by increasing amount of entrapped air voids due to the incorporation of fibers into mix, also due to the insufficient compaction of concrete mixes. It is noticed that the reduction in the ultrasonic pulse velocity increased with the increase of fiber content and the same finding was observed by Al Rubiy[21].

From Figure (9) and Figure (10) it is noticed that there is a reduction in the ultrasonic pulse velocity of fiber reinforced bauxite concrete and this can be attributed to:-

1. Lower density of the concrete due to difficulties in mixing and compaction at high level of replacement, which lead to insufficient distribution of fibers in the matrix and increase the void content.
2. Low pozzolanic activity of Bauxite at early ages.

After that, the fiber reinforced bauxite concrete exhibited a slight increase in ultrasonic pulse velocity was detected up to 90-days of curing. This is attributed to the pozzolanic reactivity of bauxite which is reacting with calcium hydroxide producing additional gel and reduces the amount of voids in the matrix. In all mixes, adding sisal fiber and bauxite will reduce the workability; HRWRA was used to ensure that the mixes have the same workability and slump.

Table (10): The effect of various content of sisal fibers by volume on the impact resistance

Mix	Ultrasonic Puls Velocity (Km/sec)		
	Curing Periods (Day)		
	7	28	90
R	4.48	4.73	4.76
0.5F	4.43	4.48	4.55
1.0F	4.38	4.47	4.54
1.5F	4.20	4.34	4.55
1.0F+10B	4.21	4.28	4.63
1.0F+20B	4.28	4.31	4.70
1.0F+30B	3.90	4.28	4.68

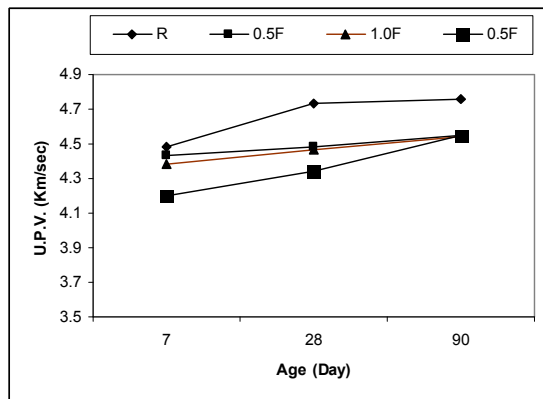


Figure (9): The effect of various content of sisal fiber on the ultrasonic pulse velocity of plain concrete

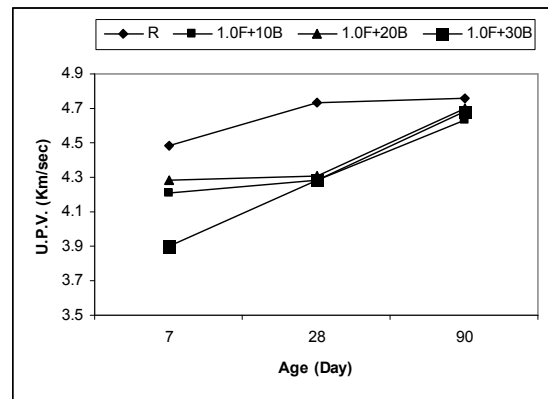


Figure (10): The effect of various content of bauxite by weight on the ultrasonic pulse velocity of concrete reinforced with 1.0% sisal fibers by volume

Water Absorption

This test was determined according to the B.S.1881: part 122/1989 by using 100mm cubes. The cubes were oven dried at $(105 \pm 5)^\circ\text{C}$ for (72 ± 2) hours, then they were placed in a suitable air tight cabinet for $(24 \pm 1/2)$ hours before testing, they weighted and immediately immersed in tap water for $(30 \pm 1/2)$ minute, then they removed and dried with a cloth as rapidly as possible so that the free water is removed from the surface. The specimens weighted again, the water absorption is determined by weight change after immersion. The test was conducted at 90 days.

The water absorption test results for all types of composites with and without bauxite are given in Table (11) and plotted in Figures (11) and (12).

It is noticed that the water absorption of sisal fiber reinforced concrete is higher than the absorption of plan concrete. We can see that the water absorption increased with 5.9% for concrete reinforced with 0.5% sisal fiber and 16%, 23.8% for the mixes reinforced with 1.0% and 1.5% respectively with sisal fiber. Similar observation was made by, Al-Noaimy [13], also it is noticed that the water absorption increased as fiber volume fraction is increased. This is in agreement with Soroshian and Won[18], they found that the increase in fiber content from 4% to 8% (mass fraction) lead to an increase in the water absorption of the composite.

From results presented in Table (11) it is noticed that there is a reduction in the water absorption of the composite due to the addition of the bauxite to the mixes. The reduction was 19.8% in water absorption for concrete reinforced with 10% bauxite as a partial replacement by weight of cement and 21.4%, 18.52% for 20% and 30% as a partial replacement by weight of cement respectively, Soroshian and Won [18] stated that partial replacement of cement with pozzolana (15% silica fume or 30% fly ash), produce composites with lower water absorption compared to those without pozzolana.

It is obvious from Figure (12), the water absorption of fiber reinforced bauxite is lower than the absorption of plain concrete and fiber reinforced concrete, this is due to increase of mix density of the fiber reinforced bauxite, Coutts [22] stated that overall density of the composite reflects the changing properties of the constituents (fiber and matrix), however the density decrease the water absorption increase.

Table (11): The water absorption results

Mix	Absorption (%)
R	2.24
0.5F	2.38
1.0F	2.67
1.5F	2.94
1.0F+10B	1.87
1.0F+20B	1.84
1.0F+30B	1.89

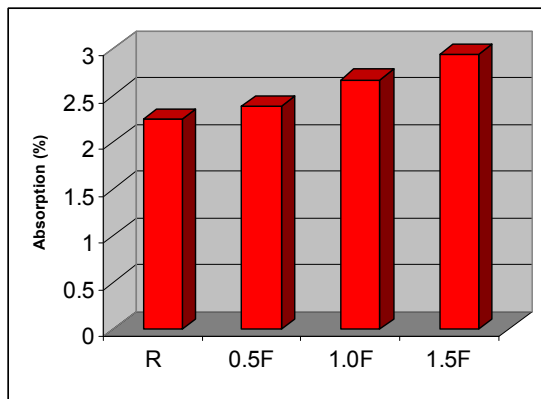


Figure (11): The effect of various content of sisal fiber by volume on water absorption

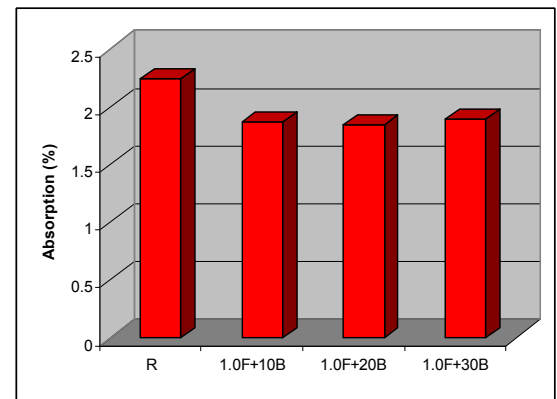


Figure (12): The effect of various content of bauxite by weight on water absorption of concrete reinforced with 1.0% of sisal fiber

pH-Level Test

The results presented at table (12) indicate that the incorporation of bauxite at various percentages of replacement (10,20 and 30) % by weight of cement, reduce the concentration of OH⁻ ions and caused a significant reduction in pH values. The reduction in pH-values increased, as the partial replacement with bauxite by weight of cement is increase. The same finding was observed by [13], who concludes that replacing about 30% of the Portland cement with pozzolana, reduces the pH-value of the pore water.

The presence of bauxite in fiber reinforced concrete positively effect on the durability of the composite. Similar observation was reported by Gram [23], on the durability studies of sisal fiber in cement matrices (concrete, mortar and cement), he found that the alkalinity of the matrix is reduced by replacing part of the ordinary Portland cement with silica fume, flay ash or completely by high alumina cement. From Figure (13) and (14), it is noticed that the pH-value decrease with age, this can be attributed to the continuity of pozzolanic reaction which lead to decrease OH content. The same finding was observed by Hooten [24], who found that the pH-value of 28-day decreased by about 6.14% compared with 28-day.

Table (12): The pH-Level results

Mix	pH-Level	
	Age (Day)	
	7	90
R	12.25	12.10
1.0F+10B	11.92	11.73
1.0F+20B	11.87	11.68
1.0F+30B	11.80	11.65

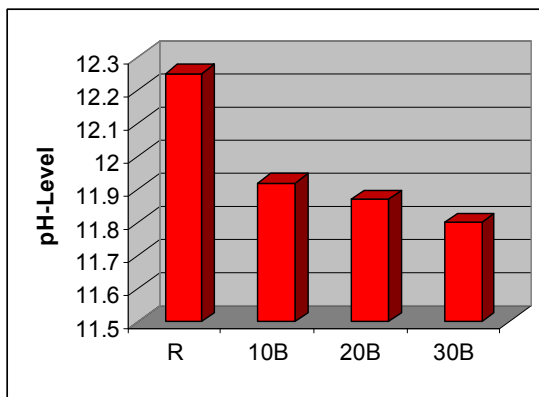


Figure (13): The pH-Level of plain concrete and fiber reinforced concrete containing 1% Sisal fiber by total mix volume and various content of bauxite by weight at 90-days

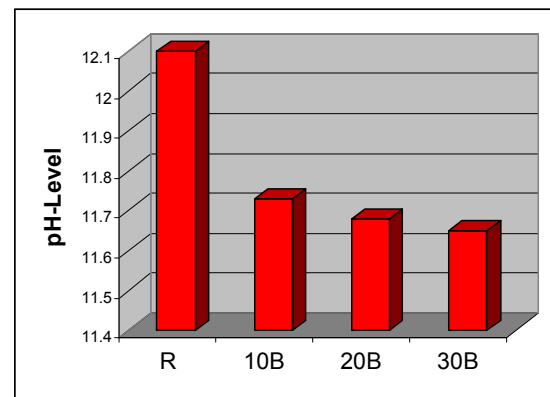


Figure (14): The pH-Level of plain concrete and fiber reinforced concrete containing 1% Sisal fiber by total mix volume and various content of bauxite by weight of cement at 7-days

Conclusions

From a careful examination of the experimental results of this study, the following conclusions can be drawn:

1. The addition of sisal fiber and using bauxite as a partial replacement by weight of cement reduced the workability of the concrete mixes, and to control on this reduction in workability, superplasticizer was used in different dosages.
2. The addition of sisal fiber reduced the compressive strength of plain concrete. The reduction at 28 day was (10%, 5.7% and 13%) for concrete reinforced with fiber (0.5%, 1.0% and 1.5%) respectively and at age of 90 day, the reduction was (6%, 3% and 6.74%) for concrete reinforced with fiber (0.5%, 1.0% and 1.5%) respectively.
3. The compressive strength of fiber reinforced concrete, increased due to the incorporation of 10% and 20% of bauxite as a partial replacement by weight of cement but it is still lower than plain concrete.

4. The addition of sisal fiber improved the flexural strength and splitting tensile strength of plain concrete. The increase in flexural strength at age of 28 day represented by (7.7%, 13.6% and 9.1%) for concrete reinforced with sisal fiber with (0.5%, 1.0% and 1.5%) respectively and at age of 90 day the improvement in flexural strength represented by (15.3%, 16% and 5.2%) for the same percentage of fiber respectively.
5. The flexural strength and splitting tensile strength of fiber reinforced concrete, increased due to the incorporation of 10% and 20% as a partial replacement by weight of cement compared with plain concrete.
6. The impact resistance of precast concrete slabs improved by the addition of sisal fibers and increased with the increase of fiber content. The improvement can be represented by 68% for concrete mix reinforced with 1.0% fiber and 72% for concrete mix reinforced with 1.5% fiber.
7. The impact resistance of precast concrete slabs improved due to the addition of sisal fiber and various level of replacement of bauxite, after a soaking period of 28-day in water. This increase can be represented by (70% and 73%) for mixes reinforced with 1.0% sisal fiber and containing 10% and 20% bauxite respectively. Increase of impact resistance for mixes reinforced with 1.5% sisal fiber was (75% and 77%) for mixes containing 10% and 20% bauxite respectively.
8. The ultrasonic pulse velocity reduced due to the addition of sisal fiber. The reduction in velocity increased with the increase of fiber content. The reduction at age of 28 day was (5.6%, 5.82% and 9%) for concrete reinforced with (0.5%, 1.0% and 1.5%) Sisal fiber respectively and at age of 90 day the reduction was (4.6%, 4.8% and 4.6%) respectively.
9. Incorporation of bauxite as a partial replacement by weight of cement increased the velocity of the ultrasonic pulse velocity but it is still lower than the plain concrete. This increase in velocity of ultrasonic waves from the percentage between the age of 28 and 90 day. Percentage of increase was (7.6%, 8.3% and 8.55%) for concrete containing bauxite clay with (10%, 20% and 30%) as a partial replacement by of cement, with this reduction the concrete can be classified between excellent and good type.
10. The water absorption was increased due to the addition of sisal fiber. For mixes contain (0.5%, 1.0% and 1.5%) sisal fiber by volume of total mix the increase in water absorption was (5.9%, 16.1% and 23.8%) respectively.
11. Using bauxite as a partial replacement by weight of cement shows a significant reduction in water absorption of fiber reinforced concrete as compared with plain concrete. The decrease in water absorption for Concrete containing bauxite clay with (10%, 20% and 30%) as a partial replacement by weight of cement was (19.8%, 21.74% and 15.52%) respectively.
12. The incorporation of bauxite as a partial replacement by weight of cement reduced the pH-level of plain concrete. The reduction at age of 90 day was (3.15%, 3.6% and 3.9%) for mixes containing bauxite as partial replacement by weight of cement (10%, 20% and 30%) respectively.

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