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Performance of Concrete Incorporating Industrial and Agricultural Wastes

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ABSTRACT : Use *of industrial and agricultural waste products such as (sisal, flax, glass fiber and Carpet wastes fiber). materials in concrete is not only improves the strength of concrete but, also leads to the proper disposal of these materials, resulting in reducing impact of these materials on environment. Fiber admix can effectively improve the mechanical properties of concrete. Utilization of recycled fibers from post-consumer, industrial waste and agricultural waste offer some benefits such as waste reduction, resource conservation, also low-cost materials and reduced need for land filling. Concrete is a tension weak building material, which is often cracked not ridden in plastic and hardened states, drying shrinkage and so on, low tensile strength limited ductility and resistance to cracking. In order to improve attempt has been made to study the effect of these materials on ordinary Portland cement concrete. In the experimental work, glass fibers, sisal, flax and waste fiber in different percentage (0.5%, 1% and 2 %) has been added .The mechanical properties of concrete ware carried out (compressive strength test for 234 cubes, flexural strength test for 39 beams and indirect tensile strength test for 39 cylinders). The results showed improvement in mechanical and durability of concrete with glass fibers and waste fiber by a valuable degree.*

KEYWORDS: *Percentages added, concrete mixes, (sisal, flax, glass fiber and Carpet wastes fiber), Coarse Aggregate (CA), Fine Aggregate (FA), compressive strength test, flexural strength test, indirect tensile strength test.*

I. INTRODUCTION

Sisal and flax fiber is one of the most widely used natural fibers in yarns, ropes, twines, cords, rugs, carpets, mattresses, mats, and handcrafted articles [1] .Flax fiber is a natural fiber which has a look in the like jute fiber, but this fiber is used extremely in textile industries for its rough texture and has higher cellulose content and has better elasticity and strength. The chemical composition includes cellulose, lignin and hemicelluloses. Strength of this fiber is very high and this property makes it a chief geo-synthesizer fiber for it has smaller elongation coefficient [2]. This investigation aim to study the effect of sisal fiber addition on the different Properties of concrete, Sisal fiber was used at three percentages of total mix volume. (0.5%, 1.0% and 1.5%), found that concrete reinforced with1.0% of sisal fiber give the best results, 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 [3]. the addition of carpet fiber leads to enhance the splitting tensile strength, flexural strength and reducing the crack-size and a smoother mode of failure, unlike the brittle failure behavior of plain concrete [4]. Previous investigation glass fibers in different percentage 0 to 0.1% has been studies for the effect on mechanical properties of concrete by carrying compressive strength test, flexural strength test and splitting tensile strength test. The results have shown improvement in mechanical and durability properties with the addition of glass fibers [5].

II. EXPERIMENTAL WORK

To test the performance of concrete with addition of (sisal, flax, glass fiber and Carpet waste fibers) to concrete by ratio (0.5%, 1% and 2 %) concrete cubs were made the specific and materials tests were performance to choose the best one for concrete cubes [6] .

Materials

Cement: Ordinary Portland cement was used. Testing of cement was carried out according to Egyptian Standard Specification (ESS 4756-1, 2007) [7] .

FINE AGGREGATE: Natural sand composed of siliceous materials was used as Fine Aggregate (FA) in this study. Testing of sand was carried out according to the (ESS 1109, 2007). Specific Weight of used sand was 2.6 and bulk Density 1.78 t/m3 [8] .

COURSE AGGREGATE: Course Aggregate (CA) was used as gravel Aggregate in this study. Testing of gravel Aggregate was carried out according to the (ESS 1109, 2007). Specific Weight of used gravel was 2.64 and bulk Density 1.56 t/m3 [8].

MIXING WATER: Drinking water was used for mixing.

PLASTICIZER: In this study, In order to obtain same workability without increased water, plasticizer admix Sicament 163 was used. Sicament 163 is a plasticizer and flowing concrete Admix. (Complies with ASTM C 494 type f, B.S.5075 PART 3) .Table (1) show the Technical data.

"Table 1" - properties of plasticizer

Technical data	type
base material	polymer
appearance	brown liquid
density	1.2 kg /1at25□ C
chloride content	nil
air entrainment	practically nil
compatibility	all type of Portland cement

III. FIBER MATERIALS

SISAL AND FLAX : The utilization of sisal and flax fiber which are light weight and high tensile bearing capacity, addition to that its low cost as compared to other substitutes, This experimental study demonstrates the properties of concrete containing Percentages added from fiber as shown in Figures (1) and (2). Sisal and flax which are agricultural fibers and brought from a local environment were used. In Textile Consolidation Fund (Tcf) (Alexandria), they had these necessary tests: First, moisture content the instrument is illustrated in figure (3) and table (2), Second, fibre bundle strength is measured by Pressley tester that is figured in (4) and table (3). As a result of these two tests, it is Concluded that Flax humidity is less than sisal humidity, this resulted in adding fibers as 10 mm bristles randomly in concrete and Flax cutting force is higher than sisal cutting force.

"Fig. 1" sisal

" Fig. 2" flax

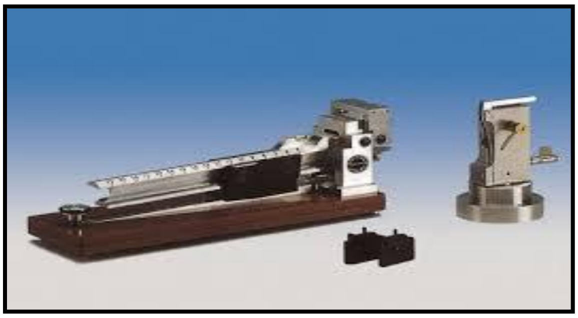
"Fig. 3" (Libeccio) semiautomatic regains cabinet code 245B.

"Table 2" - Humidity contain for sisal and flax fibers

Test	Standard specifications	Sample		Note
		Flax	Sisal	
moisture content%	ASTM-D 2495	7.1	7.8	Temperature 20°C Relative humidity 65%

"Table 3" - Breaking strength and elongation for sisal and flax fibers.

Test	Standard specifications	Sample		Note
		Flax	Sisal	
Fiber bundle strength "Pressely index 1/8 inch " (g / tex.)	ASTM-D 1445	52.3	41.1	Temperature 20°C Relative humidity 65%
Elongation%	ASTM-D 1445	1.7	3.1	



"Fig. 4" Pressley Tester - code 231 A

Carpet wastes fiber: Carpet wastes used in a local environment and a sample was taken to be tested in laboratory of textile materials, Faculty of engineering, Mansoura University. Carpet elements are analyzed accurately and scientifically as shown in table (4 and 5) and make use of carpet wastes to improve concrete features. We chopped carpet to have bristles used in concrete; their length is 10 mm to be easily used as shown in Figure (5).

"Fig. 5" carpet wastes

"Table 4" - The density of materials used in the components of carpet

Components of carpet layers	Density (t/m^3)
- Polypropylene	0.92
- Canvas	1.5
- Polyester	1.38

"Table 5 " - Components of carpet

Configure carpet	Components of carpet layers	
Natural fibers	Canvas	Cotton
Synthetic fibers	Polypropylene	Polyester

GLASS FIBER: These fibers are more used in the technology of Concrete industry as shown in Figure (6). It in a production of the company of modern building chemicals, the product has a brochure show its specifications as shown in table (6). They are used to improve concrete industry. The mix features such as compressive strength and tensile will be better, so the concrete used will be improved.

"Fig. 6"glass fiber

"Table 6" - Properties of fiber glass

Matrix materials	Thermal properties	Mechanical properties
Type: pure polypropylene Density: 0.91 gm / cm^3 Color : white	Melting point 160° C Ignition temperature > 320 ° C	Tensile strength 370 N/ mm^2 Modulus of elasticity 3750 N/mm^2 elongation at break 11%

CONCRETE MIXES: Mixes were made with different cement contents (300,350, and 400 kg/m^3) and water ratio (0.525, 0.525and0.425). 39 (3groups mixes were made, with plasticizer dosage ranges between 0.6 % to 2.5% of cement content to achieve the required level of workability defined by a slump value of 10± 2cm. fibers added such as (fiber glass, carpet wastes, sisal and flax) amounting (0%, 0.5%, 1% and 2% by volume of concrete volume) to the mix. the ratio of fine to coarse aggregate was about (1:1.5), this experimental study demonstrates the properties of concrete containing Percentages added from fiber. Composition of designed
Mixes have been shown in Table (7). All the concrete mixes were mixed at many institutions such as: laboratory of Properties of Laboratory materials - Faculty of Engineering- Assiut University, textile consolidation fund- Alexandria and also laboratory of properties of Laboratory materials - Faculty of Engineering- Mansoura University.

''**Table 7** '' - Concrete mixes

Mix No	Designation	C (Kg/m^3)	W (litter/m^3)	SP %of Cement content	FA (Kg/m^3)	CA (Kg/m^3)	F (4 types) % by volume
Control(1)	M1(300)	300	158	1	798	1197	0
G1	M 2:5(300)*	300	158	1.5	793	1189	0.5
	M 6:9(300)*	300	158	2	788	1181	1
	M10:13(300)*	300	158	2.5	777	1165	2
Control (2)	M14(350)	350	184	0.8	779	1168	0
G2	M15:18(350)*	350	184	1.3	773	1160	0.5
	M19:22(350)*	350	184	1.8	768	1152	1
	M23:26(350)*	350	184	2.5	767	1136	2
Control (3)	M27(400)	400	170	0.6	828	1242	0
G3	M28:31(400)*	400	170	1.1	823	1234	0.5
	M32:35(400)*	400	170	1.5	817	1226	1
	M36:39(400)*	400	170	2.5	807	1210	2

*Four mixes means fiber glass, carpet wastes, sisal and flax respectively.

PROPERTIES OF USED FIBERS: Fibers such as (glass fibers, carpet wastes, sisal and flax) were used in the concrete in the form of bristles, their distribution was random, they represent a rate of the concrete mix and they were added according to each fiber density. Table (8) shows the used fibers density. Test was done after 28 days of Cubes. Weight of cubes after 28 days shows that all of them are higher than 2t /m^3, this look like ordinary concrete. Which are used ordinary aggregate, which the light concrete is less than 2 t/m^3. (Fiber glass, sisal, flax and waste fiber) have been brought from local markets, and they were cut into 10 millimeter length in order to be spread randomly in the concrete by using spreading method.

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''**Table 8**'' - Materials density

Materials	Density(t/m^3)
Fiber Glass	2.54
flax	1.50
sisal	1.32
carpet Waste	1.30

IV. CONCRETE TESTS

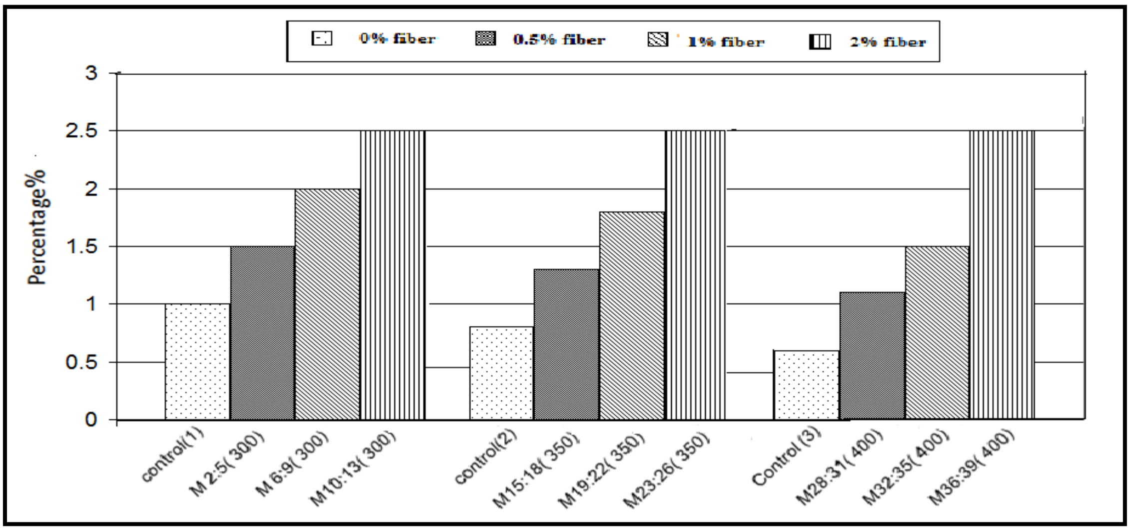
All the concrete mixes were carried out at Laboratory of properties of materials - Faculty of Engineering-Assiut University, Textile consolidation fund- Alexandria and Laboratory of Properties of materials - Faculty of Engineering - Mansoura University. It is through these labs available, it was material processing, and work samples, and then processed, the samples are as follows:

The slump test was conducted on fresh concrete to determine the slump value. For each concrete mix, six 150×150×150 mm cubes were casted to determine the compressive strength at 7 and 28 days.
Three 150mm × 300mm cylinders were casted for the determination of the average indirect tensile strength at 28 days. Three prisms of dimensions 100 × 100 × 500 mm were casted for the determination of flexural strength at 28 days. All casted specimens were covered by plastic sheets and water saturated burlap and left in the laboratory for 24 hour.

IV. RESULTS AND DISCUSSION

FRESH CONCRETE PROPERTIES

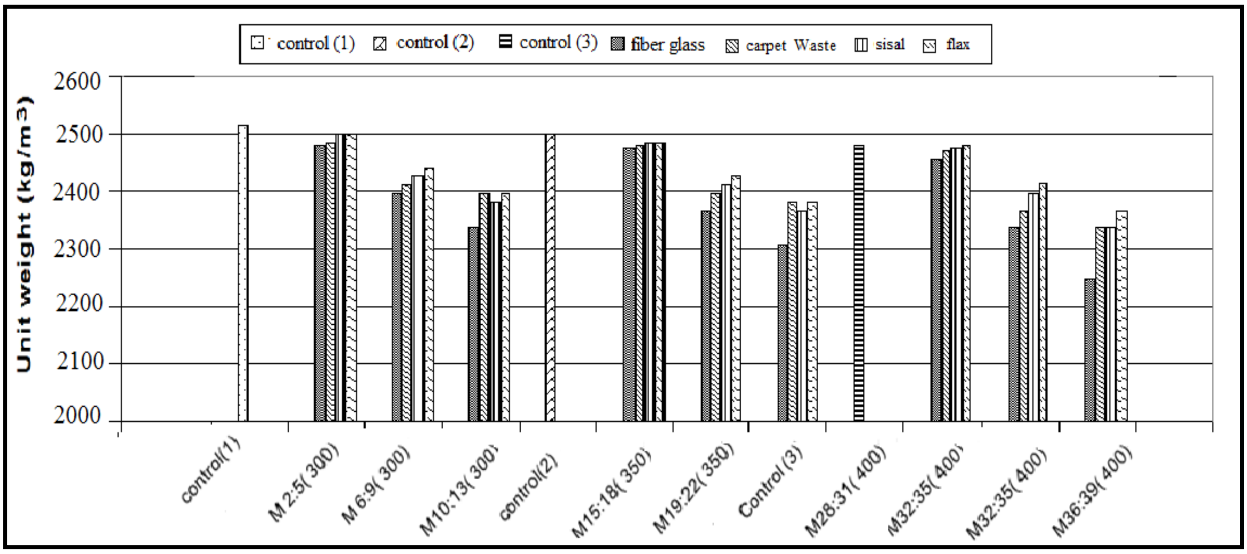
SLUMP TEST: The dosage of super plasticizer added to different concrete mixes to maintain a constant slump of 10± 2 cm was ranged between 0.6 % and 2.5 % of cement content, it can be noticed that the dosage of plasticizer should be increased significantly by increasing the percentage of fibers. In general, the fiber needed more water mix than the normal concrete [9] .



"Fig. 7" Plasticizer dosage for concrete mixes

Hardened concrete properties

Unit weight: The unit weight of various concrete mixes at the age of 28 days is shown in Figure (8). It was found that the unit weight of concrete mixes ranged from 2248 to 2514 kg/m^3, which are in the range of normal aggregate concrete (i.e., 2500 kg/m^3) and lightweight concrete less than (2000 kg/m^3) [10].



"Fig. 8" Unite weight

According to figure (8), the weight of cubes used in the replacement aggregate by fibers in concrete, that can be concluded through the following elements: The more cement content, the less weight unit of cubes without fibers, The more glass fibers in the mix, the less weight unit of cube. Concerning to glass fibers, when cement content increases in the mix, the weight unit will decrease. Glass fibers have the least weight unit of cubes, because of the less of water cement ratio. Flax fibers have the highest weight unit of cubes, because of increased of water cement ratio. Flax fibers have the highest weight for cubes, sisal is the second, wastes are the third and glass is the last one[11].

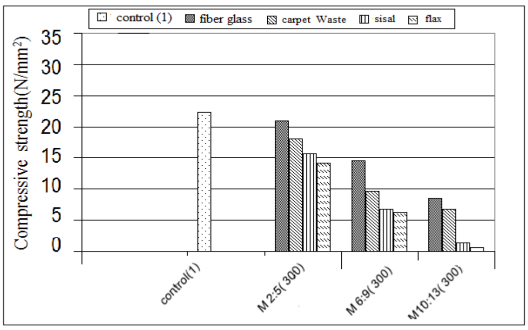
Compressive strength: The Compressive test results of concrete mixes were presented in Tables (9and10). The Compressive strength after 28 days of mixes groups were shown in Figures (From 9 to 14). Samples were poured and tested during the period from 7and 28 days. The results were as follows:

"Table 9" - Compressive strength after 7 days (N/mm^2)

Mix No COMPRESSIVE STRENGTH N/mm^2	Designation	fiber glass	waste fiber	sisal fiber	flax fiber
Control (1)	M1(M-0%-300)	22.3			
G1	M 2:5(M-0.5%-300)	20.98	18.05	15.71	14.16
	M 6:9 (M-1%-300)	14.57	9.65	6.72	6.24
	M 10:13(M-2%-300)	8.49	6.73	1.32	0.67
Control (2)	M14(M-0%-350)	24.4			
G2	M 15:18(M-0.5%-350)	25.81	27.26	24.83	23.05
	M 19:22(M-1%-350)	24.58	20.27	18.15	15.83
	M23:26(M-2%-350)	22.93	15.78	2.09	1.51
Control (3)	M27(M-0%-400)	27.1			
G3	M28:31(M-0.5%-400)	35.19	36.11	34.93	31.99
	M32:35(M-1%-400)	34.63	31.47	27.19	25.13
	M 36:39(M-2%-400)	33.27	27.12	3.13	3.40

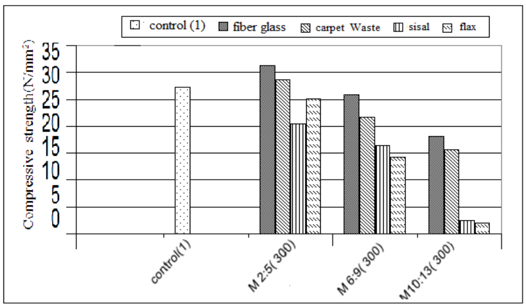
"Table 10" - Compressive strength after 28 days (N/mm^2)

Mix No Compressive Strength N/mm^2	Designation	fiber glass	waste fiber	sisal fiber	Flax fiber
Control (1)	M1(M-0%-300)	27.3			
G1	M 2:5(M-0.5%-300)	31.26	28.71	20.43	25.15
	M 6:9 (M-1%-300)	25.80	21.63	16.34	14.23
	M 10:13(M-2%-300)	18.14	15.61	2.46	1.96
Control (2)	M14(M-0%-350)	31.8			
G2	M15:18(M-0.5%-350)	37.88	38.87	37.13	35.61
	M19:22(M-1%-350)	36.27	31.79	29.29	27.47
	M 23:26(M-2%-350)	35.34	26.81	3.77	2.26
Control (3)	M 27(M-0%-400)	37.9			
G3	M 28:31(M-0.5%-400)	47.52	46.14	46.61	42.58
	M 32:35(M-1%-400)	45.77	39.57	36.38	34.28
	M 36:39(M-2%-400)	42.96	37.29	4.03	3.65



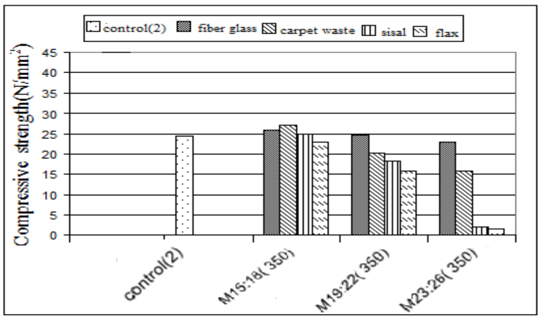
"FIG. 9" Compressive Strength after 7 days

And Cement Content 300 (G1)

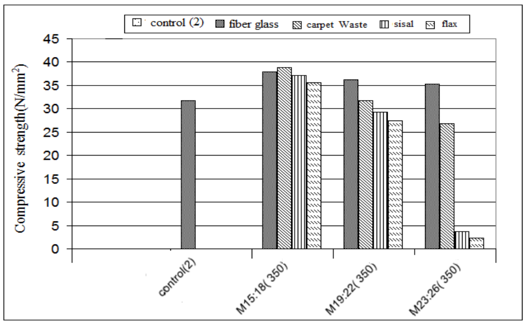


"FIG. 10" Compressive Strength after 28 days

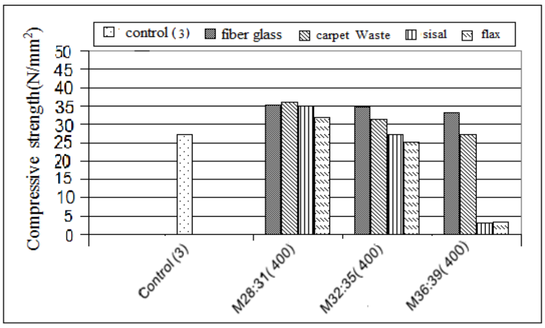
And Cement Content 300 (G1)



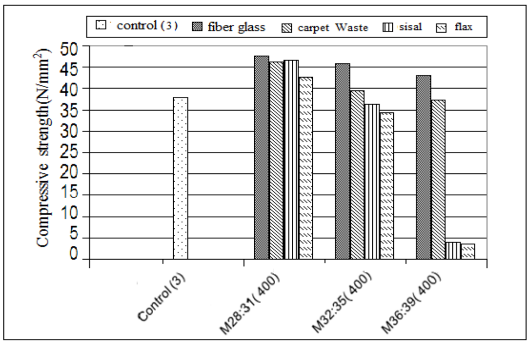
"FIG. 11" Compressive Strength after 7 days And Cement Content 350 (G2)



"FIG. 12" Compressive Strength after 28 days And Cement Content 350 (G2)



"FIG. 13 " Compressive Strength after 7 days And Cement Content 400 (G3)



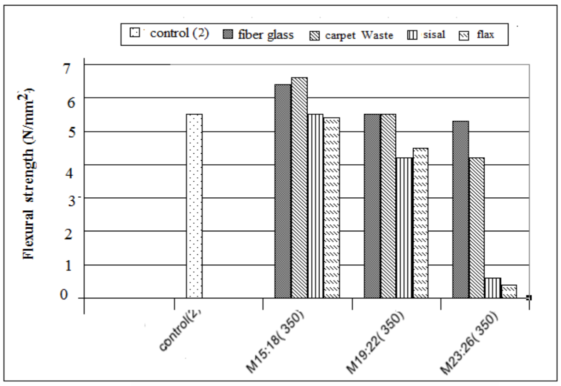
"FIG. 14" Compressive Strength after 28 days And Cement Content 400 (G3)

From obtained results can be concocted four points: first, when cement content increases, strength increases. Glass fibers have the highest compressive strength, textile fibers is the second, sisal is the third and flax is the last one. Second, Flax fibers have the least compressive strength because they don't interact with concrete mix and effect on strength negatively. Third, Sisal fibers strength is more than flax fibers because sisal fibers have strength and hardness, so they have more homogeneity than linen fibers. Fourth, Compressive strength of concrete without fibers is higher than that has fibers because of fibers increase air bubbles and voids [12,13].

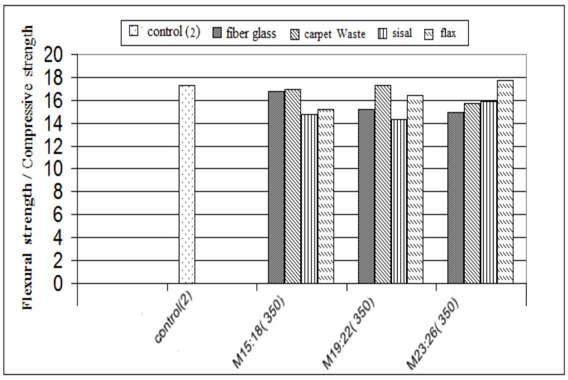
Flexural strength: The Flexural test results of concrete mixes were presented in Table (11). The Flexural strength after 28 days of mixes groups were shown in Figure (15). According to the test that was done after 28 days of curing samples, some results are concluded: first, When we add 0.5% fibers and cement content 350 kg\ m^3, concrete that contains carpet wastes have the highest flexural strength (6.6 N/mm^2), fiber glass fibers are the second (6.4 N/mm^2), sisal fibers are the third (5.5 N/mm^2), and flax fibers have the least flexural strength (5.4 N/mm2). Second, when we add 1% fibers and cement content 350 kg\ m3, concrete that contains glass fibers and waste fiber has the highest flexural strength (5.5 N/mm^2), flax fibers are the second (4.5 N/mm^2), and sisal fibers are the third (4.2 N/mm^2). Third, When we add 2% fibers and cement content 350 kg\ m3, concrete that contains glass fibers have the highest flexural strength (5.3 N/mm^2), wastes fibers are the second(4.2 N/mm^2), sisal fibers are the third (0.6 N/mm^2),and flax fibers have the least flexural strength (0.4 N/mm^2).

"Table 11 "- Flexural strength (N/mm^2)

Mix No Flexural strength (N/mm^2)	Designation	fiber glass	waste fiber	sisal fiber	flax fiber
Control (2)	M14(M-0%-350)	5.5			
G2	M15:18(M-0.5%-350)	6.4	6.6	5.5	5.4
	M19:22(M-1%-350)	5.5	5.5	4.2	4.5
	M 23:26(M-2%-350)	5.3	4.2	0.6	0.4



" Fig. 15 " Flexural strength (G2)



" Fig. 16" Flexural strength / Compressive Strength (G2)

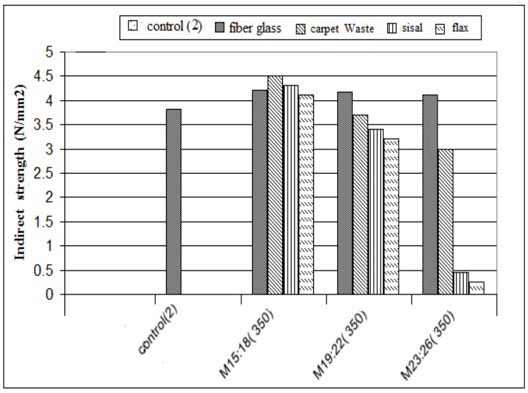
From Obtained results can be concocted points as following: First, when compressive strength increases, flexure strength of concrete components with fibers increases. Second, Flexure strength of glass fibers is the highest; this means that adding fibers to the mix affects flexure strength more. Third, Fibers that don't absorb water have more flexure strength than fibers that absorb water. Fourth, Sisal fibers are the first and carpet wastes are the second as they similarly don't absorb water and harmonize with the concrete flexure more than the other fibers. Fifth, Linen and sisal fibers absorb water more than others because of their nature and ability to absorb. This enables them to keep water more than others, so their humidity is higher than other. When we poured and untied cubes, they took a long time to be dry, this result confirms what's above mentioned.

Analyzing Flexural Test Results : It's clear that on analyzing flexural test, percentages ranges between(14:17)% of compressive strength, this matches the rule that value of flexural test / value of compressive test = (12:20)% of compressive strength as shown in figure (16), this matches the results of the research concerning reference [18] and shows that the results are acceptable and follow prescriptions [14,15].

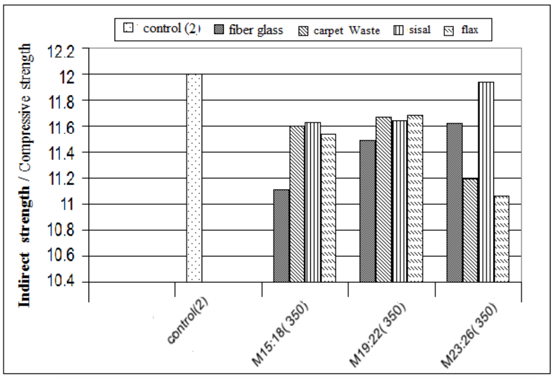
Indirect tensile strength: The tensile test results of concrete mixes were presented in Table (12). The Tensile strength at 28 days of mixes groups were shown in Figure (17). We poured samples and tested them after 28 days, and then we had the following results: The percentage of added fibers have an influence with cement content 350 such as: if we add 0.5% fibers and cement content 350kg/m3, tensile strength of concrete with glass fibers will be the highest (4.21N/mm^2), concrete with wastes fibers will be the second (4.51N/mm^2), the third will be concrete with sisal fibers (4.32N/mm^2) and concrete with flax fibers will be the least (4.11N/mm^2), on anther hand if we add 1% fibers and cement content 350kg/m3, tensile strength of concrete with glass fibers will be the highest (4.17N/mm^2), concrete with wastes fibers will be the second (3.71N/mm^2), the third will be concrete with sisal fibers (3.41N/mm^2) and concrete with flax fibers will be the least (3.21N/mm^2), even if we add 2% fibers and cement content 350kg/m^3, tensile strength of concrete with glass fibers will be the highest (4.11N/mm^2), concrete with wastes fibers will be the second (3.00N/mm^2), the third will be concrete with sisal fibers (0.45N/mm^2) and concrete with flax fibers will be the least (0.25N/mm^2).

"Table 12" - Indirect tensile strength (N/mm^2)

Mix No Indirect tensile strength (N/mm^2)	Designation	fiber glass	waste fiber	sisal fiber	flax fiber
Control (2)	M14(M-0%-350)	3.82			
G2	M15:18(M-0.5%-350)	4.21	4.51	4.32	4.11
	M19:22(M-1%-350)	4.17	3.71	3.41	3.21
	M 23:26(M-2%-350)	4.11	3.00	0.45	0.25



"Fig. 17" Indirect tensile strength (G2)



"Fig. 18" Indirect tensile strength / Compressive Strength (G2)

There are some points concluded from the previous results such as: First, when we add fibers in tensile test, we see that indirect tensile strength of concrete with fibers is less than the indirect tensile strength of sample without fibers, Second, Tensile strength of concrete with glass fibers is the highest, Tensile strength of concrete with wastes fibers is the next, Tensile strength of concrete with flax fibers is the third and Tensile strength of concrete with sisal fibers is the least. Third, Tensile strength of glass fibers is the highest. Fourth, Tensile strength of concrete with flax fibers is the highest; this matches the tests done by Alexandria Fund for Supporting Textiles and which proved that flax fibers have the highest tensile strength and cutting force. Fifth, Sisal fibers have the least tensile strength and cutting force, this matches the tests done by Alexandria Fund for Supporting Textiles. Sixth, Sisal fibers have the least tensile strength and glass fibers have the highest tensile strength. Seventh, Cutting force of wastes fibers is more than sisal cutting force, Eighth, Tensile strength of wastes is higher than sisal tensile strength. Ninth, Flax fibers are one of the best agricultural fibers, so linen factories in Almahala depend on flax only, they process and sort bristles, determine each fiber quality and export it abroad to make bags for keeping food as flax doesn't interact with food. Tenth, Glass fibers are the best fibers used in concrete, characteristics of poured concrete and tests show this clearly[16].

Analyzing test results of Indirect Tensile Strength : On analyzing test results, found that most samples are between (11:12) % of compression, Tensile Strength for fiber represents 85% of indirect tensile strength, direct tensile strength ranges from (7:14) %, representing, with the average 10% from compressive strength, indirect tensile strength is 15% more than direct tensile strength, this equals (8.05:16.1) %, with the average 12% from compressive strength as shown in figure (18), this matches reference [17,18] and shows that results are acceptable and follow prescriptions.

V. CONCLUSIONS

For protecting environment and good utilizing of wastes and improve concrete properties. A destructive test were carried on concrete specimen mixed with these waste (sisal, flax, glass fiber and Carpet wastes fiber) with variant ratios, the results of tests can be brief in the following points:

[1] Concrete mixes with glass fibers need more water mix and plasticizers.
[2] Concrete mixes with fibers need a long time curing and take much time as fibers added to concrete mixes absorb water a lot .
[3] Compressive strength increased for all mixes containing 0.5 % fibers where as degradation begins for mixes contains more than 1% fiber.
[4] Adding glass fibers to concrete mixes increase compressive strength by about (10 to 90%) than sisal, Flax and wastes fibers.
[5] Mixes contains Flax fibers are the heaviest, followed by waste carpet, Followed by sisal and finally flax.
[6] Adding wastes carpet and glass fibers to the concrete mixes increase flexure strength by about (16%, 20%) respectively for adding 0.5% fiber, secondly: adding 1% fiber was as same as control mix, and finally: flexural strength was reduced by about (4%, 24%) for adding 2% fiber.
[7] Adding 0.5% fibers to concrete increases indirect tensile strength by abut (8%-18%)
[8] Concrete containing glass and waste carpet fibers exhibited good mechanical properties than sisal and flax fibers as they are solid and don't absorb water .
[9] It is recommended that, adding 0.5% of fibers is the best ratio. Adding more, decrease the results of mechanical properties
[10] It is recommended that, the priority for fibers to be added to concrete were glass, carpet waste, sisal and flax respectively.

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