Experimental Study on Addition Palm Date Fibers as Reinforcement in Gypsum Mortar

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***Abstract*— Libya is considered one of the advanced Arab countries in the cultivation of palm trees, as it occupies the fifth place in the Arab world with about 8 million palm trees planted on an area estimated at about 70 thousand hectares. The present paper aims to characterize date-palm fiber-reinforced gypsum mortar, where different percentage of palm fibers was added by substitution of a variable percentage of gypsum weight. Physical properties of fibers have been measured as volumetric density, coefficient of absorption and water content. Moreover, it is known that the natural fibers include high content of hydroxyl groups (OH) which causes the hydrophilic behavior. Natural date palm fibers have used without treatment. For mortar cured up to 28 days, its composition which report W/G = 0.6. The mechanical behavior of hardened reinforced matrix of different lengths (1.3-19 cm) and kinds has been studied using compression test. Cubic specimens' compressive strength was (7x7x7 cm), are removed after 24 hours and then conserved in dry air at 28 days for mechanical testing.**

***Keywords*—Natural date palm fibers, Gypsum mortar, Physical properties of fibers, Compression test.**

I. INTRODUCTION

THE natural fibers have always played a central role in civilization development since they present optimal properties. The research literature has shown the advantages of using natural fibers in composite materials. As specific fibers that are selected and introduced into building materials can improve these properties and reduce the total cost of construction, or add them as a partial substitute for one of the components of concrete and thus can also support the use of sustainable materials. Natural fibers have many interesting properties as reinforcement by the composit**e**. They have the particularity of being low density, which gives relatively light composites with high specific characteristics. Natural fibers also offer significant cost advantages and associated processing advantages, compared to synthetic fibers. The amounts of cellulose and hemicelluloses in date palm are lower than in other natural fibers. As a result, the date palm has a significant amount of lignin compared to other natural fibers [1]. Usually a plant fiber is physically characterized by its diameter, density, water content and percentage of water absorption. It is characterized mechanically by its tensile strength at break and by the modulus of elasticity [2].

Mahdi et al., 2015 [3] appeared that the date palm leaf fiber (DPLF) showed high hydrophilic behavior and reached saturation (98.4%) within 24 hours. Natural Fibers have biodegradable characteristics; the alkali environment of the cement matrix leads to durability problems in the fibers. This will eventually cause reduction in fiber strength and toughness if these fibers were not treated to resist the effect of alkali attack. Moreover, weak bond interface between natural fibers and cement matrix reduces the influence of fibers to improve the performance of the new composite [4]. The cement industry is among the heavy and dangerous industries that many international environmental systems fear of their environmental and health hazards, especially when they are near residential areas. Therefore, concrete is not considered environmentally friendly because it is composed of natural materials with the chemical component of cement.

There are several ways to replace cement with natural materials, including (sawdust - palm fibers - and others). However, there are many complaints against this material, and they all relate to its mechanical properties and its affinity for water. Gypsum has a behavior defined as brittle elastic, that is to say that its failure occurs for relatively small deformations, and it also causes fairly extensive cracks. Gypsum is also hygroscopic, meaning it is susceptible to absorbing moisture, which is accompanied by expansion. Conversely, any departure of water induces a removal of the gypsum mass. Either phenomenon occurs depending on the relative humidity and temperature of the atmosphere, which vary greatly over the course of a year. These repetitive cycles of swelling and shrinkage induce very strong internal stresses in a partition, which causes spontaneous cracking. The main idea is to introduce a material in the form of fibers into a binder, called a matrix. It is then possible to obtain extremely resistant materials from a fiber and a fragile elastic matrix.

By incorporating plant fibers into it, a modification of this behavior is generally observed [5]. It is on this characteristic that the bibliographic collection on gypsum is most lacking, probably because the problems relating to setting are more sensitive on a cement; the setting time scales are in fact disproportionate, the setting time of the plaster being measured in tens of minutes, that of the cement in days.

The other three patents relate to the manufacture of gypsum matrix composites, but mention significant water uptake

problems for interior applications in damp rooms (kitchens, bathrooms).

Previous studies show the need to interpret and expand the results of gypsum compounds and highlight areas that have not yet been developed and covered, because the commercial production of date palm compounds is still in its infancy, and more efforts should be made to improve formulations and processing standards. Gallala et al., 2019 [6] thoroughly discusses date palm fibers, including fiber resources, the properties and treatments required to develop palm fiber-supported gypsum concrete. Gypsum concrete supported by date palm fibers was prepared with variable proportions of palm fibers with a ratio of W / G constant of 0.65, and then he made standard molds for testing. As the results, for the physical properties, increasing the percentage of fiber from 7 to 20% in gypsum concrete, it increased water absorption. This behavior is attributed to the fiber's porosity and its aqueous character which is mainly due to the presence of hemicelluloses.

In this paper, The performance of gypsum mortar reinforced with varying percentages of untreated date palm fibers is investigated to evaluate their feasibility for structural applications. This study based on the evaluation of physical and mechanical behaviour of different untreated fibers. This work concludes that is efficiency of using untreated natural fibers reinforced composite. However, In this research, the effectiveness of palm fibers in improving gypsum concrete resistance will be tested, in order to obtain environmentally friendly concrete and have no harm to humans, environment.

II. MATERIALS

A. Gypsum

The water-gypsum ratio (W/G) in the mixing process can vary from 0.6 to 0.8 or higher [7]. The gypsum (Ca(SO4)2H2O) used in this work is approved from Egypt (EL Etahad Gypsum, high quality plaster) It is mixed with water, using a water-gypsum plaster of 0.6 by mass. It has been found that this gypsum has a density of 1.2 g/cm3 and corresponding to a maximum compressive strength of 11 MPa.

B. Date palm fibers

The tree stem in the date palm is surrounded by the mesh made from single fiber. Labib, 2019 [8] explained that the fiber is used for the creation of different diameters from the natural crossed fibers woven mat. Based on the traditional practices, the annual removal of the mat from the trees takes place for the removal of the ropes. The date palm contains a fibrous structure, containing four types of fibers as explicated [9]: 1. Wood trunk fibers; 2. leaf fibers in the legs; 3. the leg fibers are at the level of the leg; 4.the superficial fibers around the trunk or at the krenaf. However, fibrous fibers between the krenaf and the trunk so called leaf. 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 [10]. A fruitful date palm known as Al Bakari. was brought from the eastern coast of Libya, in order to perform all laboratory tests on it. The preparation was made by first cutting the date palm tree with an electric saw into small pieces to facilitate the extraction of the fibers from it, see Fig. 1. Then the fibers were separated manually as indicated in Fig. 2 or by using sieve analysis to make sure it is free from any impurities and the fibers are assured to be loosen and prepared to be cut into required length for consistence in this study.

Fig. 1. Palm date tree after cutting with an electric saw.

Fig. 2. Palm date tree before (left) and after crumbling (right).

C. Type of fibers

Different types of date palm fibers could be obtained after extraction process as shown in Fig. 3. Since such fibers should be having the same geometrically approximately for use in the experimental program, it is reasonable to generalize the similar physical properties to the same type of fibers. All fibers have been dried at 50°C for 2 days (stability time of weight). Moreover, diameter's (D) 0.15 mm and length's (L) 11.4 cm of leaf root; D = 1mm, L = 1.3 cm of trunk fibers; D = 3.6 mm, L = 19 cm of leaf; and D = 8.6 mm, L = 2 cm.

Physical property has been studied using water content and coefficient of absorption test. Values have varied between (25-122%) and (43-348%) respectively, see Table I. Apparent density dry (less than 0.2 g/cm^3) and apparent density wet (0.25-0.4 g/cm^3) of trunk leaf, more detailed in [11]. In addition, mechanical property has effected by tensile test using SM100 Universal material testing machine capacity 100 kN (10 ton). The general properties of fibers are represented as the high tensile strength in the bundles made of long fiber. The difference in cross section and type of the fiber plays a major role on the deformation of the samples. Maximum tensile strength of 3 cm length's 3.54 MPa, Table II.

TABLE I. ABSORPTION COEFFICIENT AND WATER CONTENT OF DIFFERENT TYPES OF PALM FIBERS.

2.36 mm	1 mm	0.6 mm	0.3 mm	Leaf mixed with trunk	Leaf	Sheath leaf	Trunk leaf	Root leaf	Type of fibers
122	28	21	35	40	39	18	30	25	W (%)
43	152	348	178	195	137	132	209	143	C (%)

TABLE II. MECHANICAL PROPERTIES OF NATURAL DATE PALM FIBERS.

Type of fibers	D	L	F	ε	A	σ	E
	cm	cm	N	mm/mm	mm²	MPa	MPa
Fibers of root	0.6	3	100	0.066	28.27	3.54	54.00

Fig. 3. Fibers extracted from palm tree.

D. Water

In this research, ordinary tap water was used for all the mixes to prepare fresh concrete.

III. SPECIMENS PREPARATION

A. Mortar of reference

The design mix proportion of mortar grade 15 was used in this study. A mortar has been prepared as indicated in Table III. The dimension of reference matrix (Ref G) is 7x7x7 cm, test specimens are removed after 24 hours and then conserved in dry air for 28 days at T = 30- 35 °C for mechanical testing.

B. Date palm fibers reinforced mortar

Date palm fiber was added in the gypsum mortar by the subtraction of gypsum weight of (0 – 70) % as indicated in Table IV.

- *Calculation of fiber and matrix mass in composites*

According to [12] we have law of mixtures as following:

$$\rho_c = \rho_f + \rho_m \quad (1)$$

$$\varphi_f(\%) = \frac{m_f}{m_f + m_m} \quad (2)$$

$$m_f = m_m\,[\varphi_f\,(1 - \varphi_f) \quad (3)$$

Where:
m_f *and* m_m: are respectivly the weight of fiber and matrix (water with gypsum).
φ_f: is the used mass fracion.

The mixing process is carried out by mixing the dry gypsum first with choosing short fiber at low speed during two minutes in electrically mixer. Mixing water is added with increasing the speed during one minute. But when the choosing fiber is longue so mixing the dry gypsum first with low speed during two minutes then mixing water is added with increasing the speed during one minute, but the longue fiber was added manually for 30 sec. As a result, using the electrically mixer lead to the longue fiber wrapped around the paddle, and mortar is deposited in the mixing bowl after adding water. It is important to note that when the longue fibers are introduced into mortar as, so, it is difficult to obtain homogeneous samples as well as these fibers require large molds, and vice versa.

- *Curing test specimens*

The sample for 24 h then it is taken out from mold and cured in dry air for 28 days; temperature was between 30-35°C. Cubes specimens (7x7x7 cm) were affected. The dimension of the mold depends on % of fibers that has been introduced. For this reason, we selected the diameter of fibers which coincide with dimension of mold. So Fig. 4 is shown an example of two samples after casting. Homogenization specimens surface depending on the percentage and diameter of fibers, see Fig. 5.

TABLE III. MIX PROPORTION OF GYPSUM MORTAR.

W (g)	G (g)	W/G
600	1000	0.6

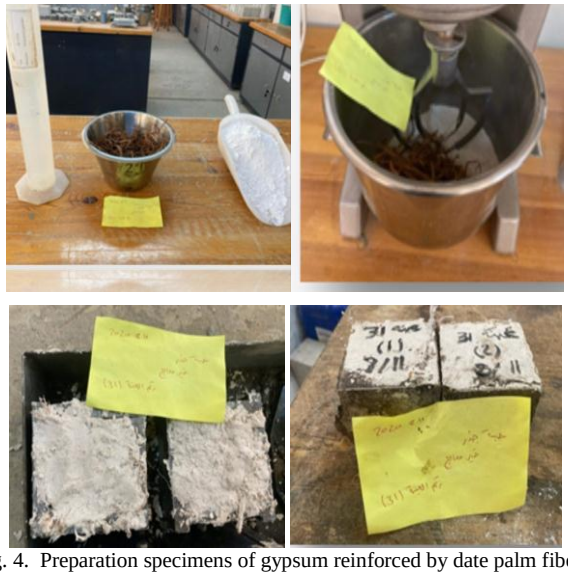

Fig. 4. Preparation specimens of gypsum reinforced by date palm fibers.

Fig. 5. Specimens of gypsum reinforced by date palm fibers after 24h.

TABLE IV. TYPES AND PERCENTAGE OF FIBERS OF COMPRESSION SPECIMENS.

Types of fibers	%. of fibres	No. of specimens	size of specimens (cm)
Ref G	0	4	7x7x7
Leaf mixed with trunk	0.3	2	7x7x7
Sleath krenaf	0.8	2	7x7x7
Leaf of root	0.4-2.5	6	7x7x7
Trunk fibers	1.5-6	3	7x7x7
Fibers remaining on sieve 0.6 mm	1	6	7x7x7
Fibers remaining on sieve 1mm	2-70	2	7x7x7
Fibers remaining on sieve 2.36 mm	3.5	2	7x7x7

IV. THE EXPERIMENTAL RESULTS AND DISCUSSION

A. *Physical properties*

- *Apparent volumetric weight*

Mean apparent volumetric dry weight at 28 days is 1.2 g/cm3 of Ref G. Fig. 6 shown the results of the gypsum mortar reinforced by leaf of root with different percent (0.4-2.5%), their volumetric weight is between 1.1- 1.34 g/cm^3.

- *Effect the percentage of fibers on apparent volumetric weight*

Fig. 7 appeared that increasing the percentage of fibers do not improve the results of apparent volumetric dry weight.

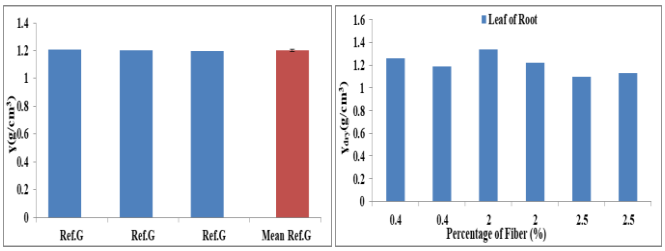

Fig. 6. Volumetric density of ref (left), root fibers (right).

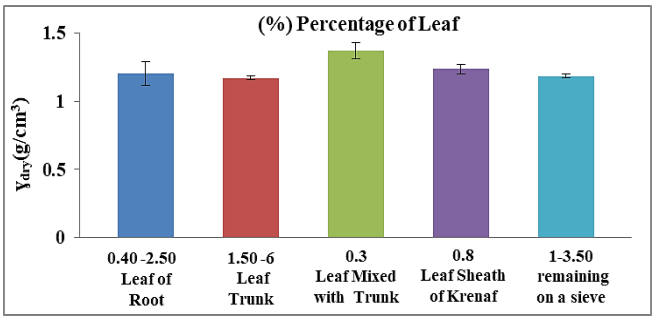

Fig. 7. Influence the percentage of fibers on volumetric density.

- *Effect type of fibers on apparent volumetric weight*

No major influence of fiber kinds on apparent volumetric dry weight, we concluded that means values approach to 1.2 g/cm^3. Thus even the percentage and type of fibers the gypsum mortar reinforced with date palm fibers usually has lightweight, Fig. 8.

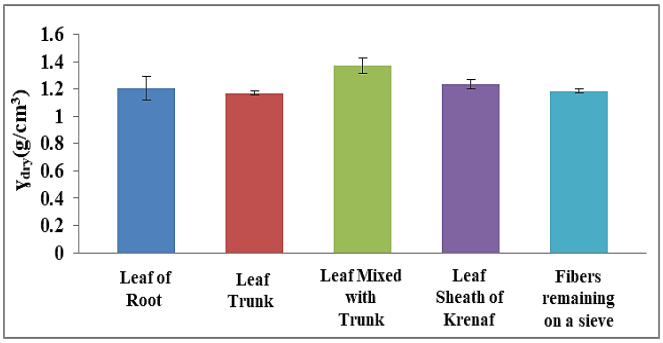

Fig. 8. Influence the type of fibers on volumetric density.

B. *Mechanical properties*

Mechanical testing of hardened mortar samples after 28 days of curing tests was performed cubical samples as explained in Table III; they were subjected to compressive loading based on ASTM C109/C109M where the maximum load and stress at failure were recorded. It is noticed that the high strength values in some cases due to the difficulty in controlling the dimensions and quantity of the fibers during casting process.

- *Mortar of reference*

The mean maximum strength of mortar of reference at 28 days is equal to 11 MPa as shown in Fig. 9.

- *Effect the percentage of fibers on maximum compression load*

Fig. 10 shown the maximum applied load on cubical specimens contain the remaining fibers on different sieves. Average values is equal to 25 kN for remaining fibers on sieves of 1mm then is equal to 54 kN of Ref G. and with increasing the diameter of sieve the maximum compression load attain 30 kN but remaining lower than Ref G values. It is clear that the resistance of reference, Ref G (0% fibers) diminished with added the palm date fibers (22- 30 kN) with different percentages and varied diameter. For leaf of root their strength is no significant compared to preceding figure and varied the percentage of fibers from 0.4 to 2.5 does not have major influence on maximum compression load as shown in Fig. 11. It observed that the specimen with 2% given a resistance equal to 131 kN due to internal strength of root fiber or the percentage of fiber in this mould was higher.

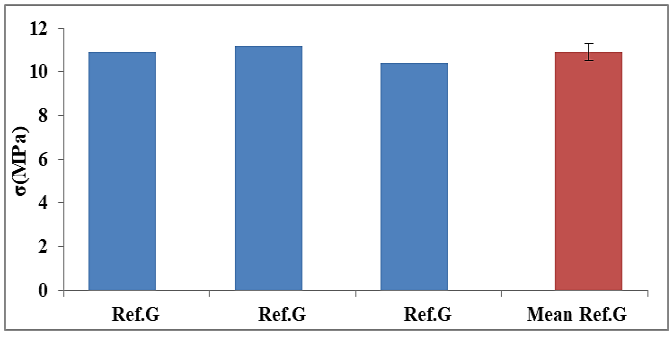

Fig. 9. Maximum compressive strength of Ref G.

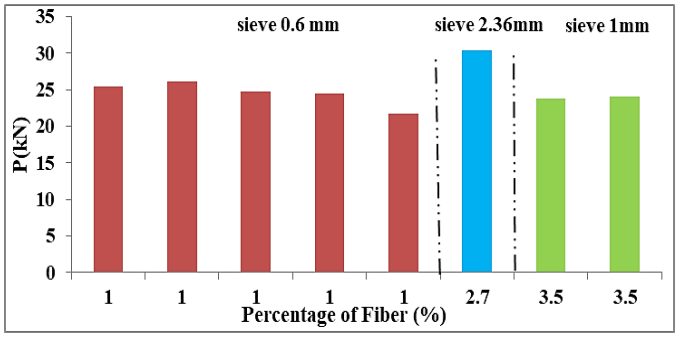

Fig. 10. Max. compression load values of remaining fibers on different sieve diameters.

Mean values of all used fibers and varied percentage of fibers compared to Ref G is showed in Fig. 12. Consequently, introduced the date palm fibers reduced maximum compression load compared to Ref G. Anf found a valued higher than Ref G due to the reason explained above with take into account the coefficient of variability.

- *Effect the percentage of fibers on maximum compressive strength*

Compression test results appeared that as diameter of fiber increases as maximum compressive strength decreasing with the percentage of fibers, see Fig. 13. It is clear that the maximum compressive strength is approached for all kinds of fibers with the diverse percentages of fibers but lower the Ref G value as shown in Fig. 14, 15.

However, the water absorption of the developed composite increased with the increase in date palm fibers content. As explained in Table I, the coefficient of absorption and water content very high for some types of date palm fibers this conduit to increasing fin porosity especially at interface level.

Moreover, the effects of fiber size, content and porosity on the stiffness of date palm fibers -gypsum composite. The addition of date palm fibers resulted in an increase in the stress–strain and stiffness of date palm fibers gypsum composites and prevented the brittle fracture which can be attributed to the high strength rupture parameter of date palm fibers. Thus, date palm fibers are applicable as a reinforcement for gypsum material in order to develop composite materials for several applications in building constructions [13].

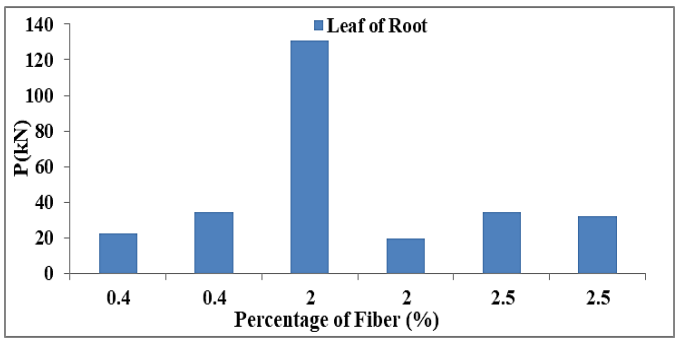

Fig. 11. Max. compression load values of fibers of root.

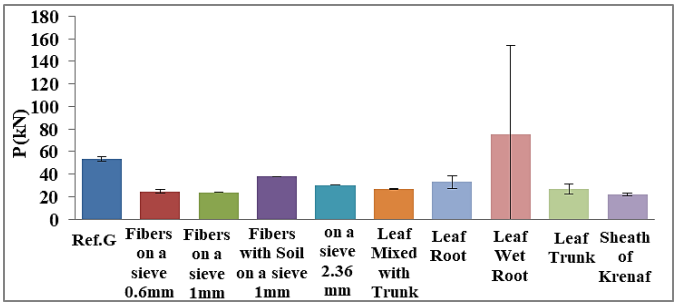

Fig. 12. Mean max. compression load values of different fibers.

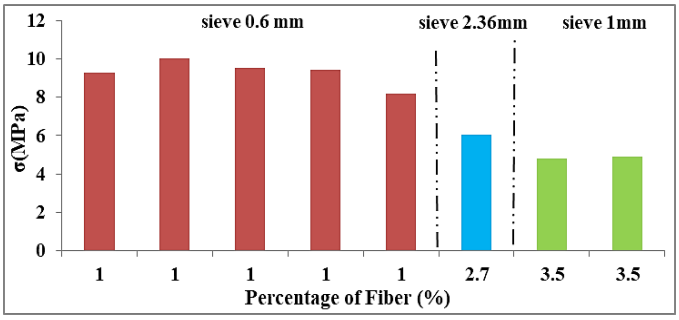

Fig. 13. Max. compression resistance of *re*maining fibers on different sieve diameters.

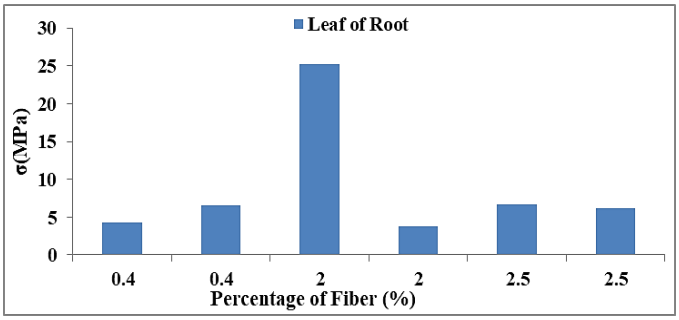

Fig. 14. Max. compression resistance of fibers of root.

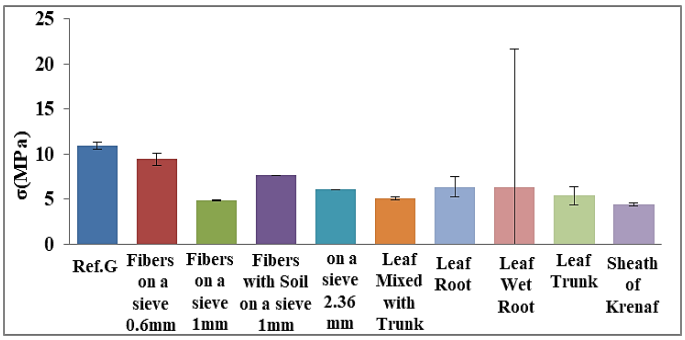

Fig. 15. Mean max compression resistance of different fibers.

Fig. 16. Specimens of root fibers (left) and remaining fibers on different sieve diameters after failure (right).

Fig. 16 exhibited the mortar reinforced with date palm fibers after compression test. The failure and deformation is brittle and resistance of specimens depends on the quantity of fibers in the cubic.

It can be noted also that the addition of fibres interrputs the mineral skeleton of the gypsum mortar, creating voids inside the matrix and increasing its porosity, by giving it a minimal strength. These observations are in agreement with the results of previous research on different fibres mortar studied.

- *Effect type of fibers on maximum compression load*

An example on influence the type of fiber exhibited in Fig. 17. Trunk fibers were weak kinds of palm tree as confirmed in [9]. The results shown maximum compression load and compressive strength is lower the Ref G.

- *Effect type of fibers on maximum compressive strength*

From previous figures, we demonstrated the type of fibers do not have main effect on compression behavior than diameter of fibers. Fig 18 appeared that the trunk fibers given approximated one-half the strength of reference mortar.

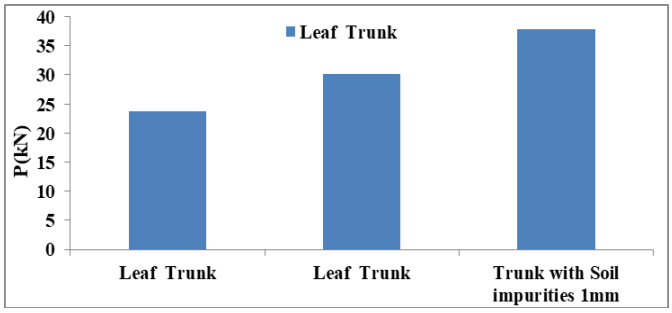

Fig. 17. Max. compression load values of trunk fibers.

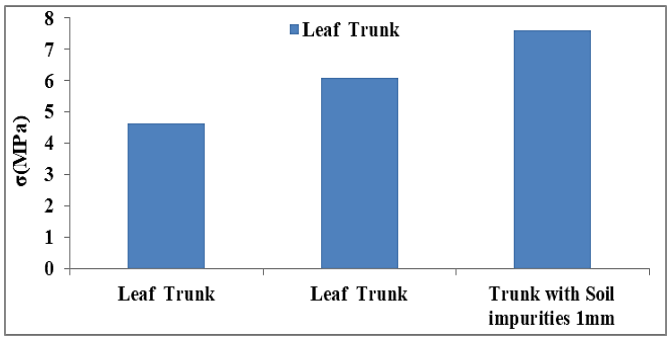

Fig. 18. Max. compression resistance of of trunk fibers.

V. CONCLUSION

This study has investigated the properties of palm leaf fibers. Characterization of date palm fibers used as composites reinforcement appeared that efficacy using these fibers with low percentage. The maximum strength of untreated fibers is influenced by the percentage and palm fiber structure. As untreated fibers is depending principally on fibers structure. The maximum strength is influenced by diameter of fibers; from where fine fibers lead to improve the strength than thick fibers take into account coefficient of variation. So, small diameter and untreated fibers lead to obtain more homogenize composite. The larger diameter induces greater the ability of concrete to withstand the applied load and the bonding between the fiber and concrete depends on the type of fiber. In addition introduced the date palm fibers into gypsum concrete is very weak and has no effectiveness in concrete compared to reference mortar. This is due to chemical reaction between the fibers and gypsum mortar. Furthermore, an idea to use mixed fibers did not show any efficacy in increasing compressive strength. It is also concluded that the conserved medium has a major role in resisting concrete.

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VI. RECOMMENDATIONS

1. For more support previous results, it is suggested to use microstructure analysis.
2. It is recommended to complete the physical and mechanical test by make chemical test to understand the reaction at interface between fibers and gypsum matrix.

3. It is recommended to varied tests results using different date palm tree kinds and percentages of fibers from 0 to 100% of same sort of fibers.
4. It is recommended in the future to use pretreatment date palm fibers in gypsum matrix and studied their effect on mechanical performance.
5. Investigation on date palm fibers reinforced gypsum concrete under different curing conditions.