

## Recycling waste papers in green cement mortars

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### Abstract

This work investigates the utilization of waste papers (natural and industrial) i.e (citrus aurantium and papers A4) mortars containing specified contents 0.5%, 1%, 1.5% of waste papers were prepared and cured. Mechanical characteristics such as compressive and bending strengths, hardness and water absorption were determined for the mortars mixed with the waste papers and compared with those obtained from the pure mortars. Results showed that the addition of waste paper leads to increase the hardness to (69 - 68.5) shore D for (natural and industrial) wastes materials respectively comparing with pure specimen 66 shore D. The compressed strength of the mortar cement specimen cured for 28 days from 13 MPa to (17-18) MPa for (natural and industrial) wastes materials, respectively.

### Key words

Green cement mortar,  
waste papers,  
mechanical  
properties, hardness,  
compression.

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## إعادة تدوير النفايات الورقية لإنتاج مونة سمنتية خضراء

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### الخلاصة

يهدف البحث الى الاستفادة من النفايات الورقية (الطبيعية والصناعية) أي (أوراق الحمضيات كالنارنج والأوراق الصناعية A4) وإعادة تدويرها في إعداد مونة السمنت بإضافات محددة 0.5%، 1%، 1.5% من أوراق النفايات. وقد تم تحديد الخصائص الميكانيكية مثل قوة الانضغاط وقوة الانحناء والصلابة وامتصاص الماء لمونة السمنت الخضراء الممزوجة مع أوراق النفايات ومقارنة مع المونة السمنتية النقية بدون إضافات و أوضحت النتائج أن إضافة النفايات الورقية يؤدي إلى زيادة الصلابة إلى (68.5-69) شور D لمواد النفايات (الطبيعية والصناعية) على التوالي مقارنة مع العينة النقية 66 شور D. ان قوة الانضغاط لعينة الأسمنت المغمورة بالماء لمدة 28 يوم ازدادت من 13 ميكا باسكال إلى (17-18) ميكا باسكال لمواد النفايات الورقية (الطبيعية والصناعية) على التوالي.

### Introduction

The recycling of natural and industrial waste papers is an important process for the development of construction industry. Natural and industrial waste papers are new composite materials used as additives to Portland cement to reduce CO<sub>2</sub> emission and fabricate eco-friendly green mortar cement [1]. Lodhi Sing et al. showed that adding up to 10% by weight of waste paper in the cement concrete is allowed with benefits in cost of production and conserved

mechanical properties [2]. Nada Mahdi et al. showed that for the concrete mixes containing waste paper, the compressive strength of the concrete increased with the increase of the amount of waste paper. The waste paper addition causes a great increase in the compressive strength. This increase reached to (34.21 %) as compared with the reference specimens [3].

This research aims to investigate the physical and mechanical properties of the cement mortars mixed with

certain amount of waste papers. The specimen investigated in this study is a mixture of recycled papers (natural and industrial), sand, cement and water.

### Materials and methods

The waste papers consist of cellulose fibers and inorganic materials. No binder is, therefore, used in the cement mortar because cellulose fibers combine well with the cement paste [2]. The waste papers are collected from papers disposal machine shown in Fig.1. The papers are clipped to sheets having average dimensions of 7 mm×2 mm. The sheets thicknesses are 1 mm. The collected papers were soaked in water for 24 hours at room temperature so that the workability of the cement mortars is not affected during the mixing and later stages. The waste papers were removed from the soaking vessels prior to mixing process so that no excess water takes place in the mortar

formation. The waste papers were added by (0.5%, 1%, 1.5%) by volume of mortar. The properties of waste paper A4 is shown in Table 1.

The waste papers used were trees falling leaves (citrus aurantium paper) collected from garden. The papers pulp holds the moisture in its pores. The fibrous nature gives the leaves high energy absorbing ability and hence high compressive strength [4]. These papers are yellow in color with an average thickness of 0.1 mm. These leaves were processed by blade grinder for 10 minutes. Leaves were found to turn into small pieces 0.03 – 0.002 mm in size. The grinded leaves were then soaked in water for 24 hours before the excess of water was removed away. Fig.2 shows the grinded soaked leaves. The citrus aurantium leaves were added by 0.5%, 1%, 1.5% by volume of mortar.

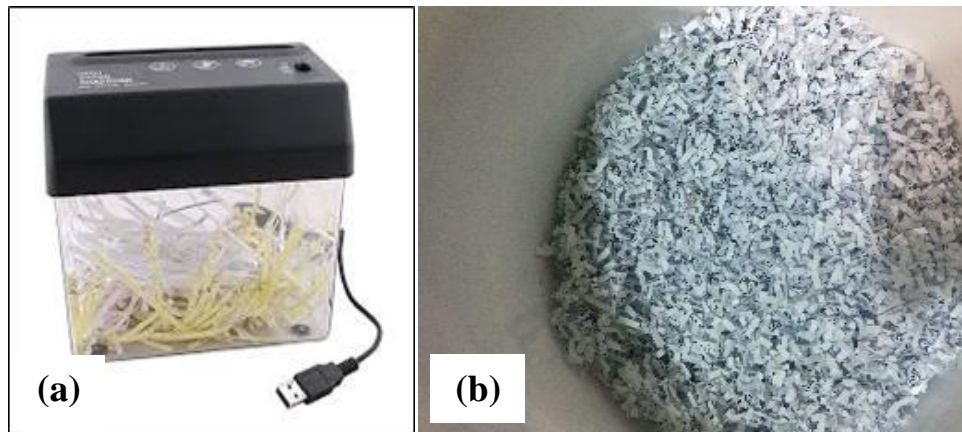


Fig. 1: (a) Power max CF 321 machine cross-cut (b) Industrial Waste papers A4.

Table 1: Properties of waste paper A4 [5-7].

Property of Waste paper A4	
Moisture content (%)	2.67
Gramm age (gm./m <sup>2</sup> )	80
Bulk density (kg/m <sup>3</sup> )=(Gramm age/thickness)	800
Aspect ratio	100
Specific gravity (SSD)	0.98
Absorption	198
Organic materials (%)	70
Inorganic material (%)	30



Fig. 2: Preparation natural papers (citrus aurantium).

The cement used is the ordinary Portland cement (OPC), produced by the United Cement Company, Tasluja Bazian in Sulaymaniyah, Iraq (Iq.s 5/1984 type I, 2011CEM I 42,5R / BS EN 197-1 / ASTM C150, Type -1). The sand grain size is less than 150µm and 600µm by using sieving. Ordinary water was used in the mortar preparation at 0.5 water to cement

ratio. Fig.3 shows the addition of waste paper to the dry cement-sand mixtures. The mortar pastes were prepared and placed inside cubic molds 5×5×5 cm<sup>3</sup>. The specimens were left for 28 days for curing before further measurements are made. Fig. 4 shows the mortar specimen after being removed from the molds. Table 2 shows the ratios of the mixing compounds.

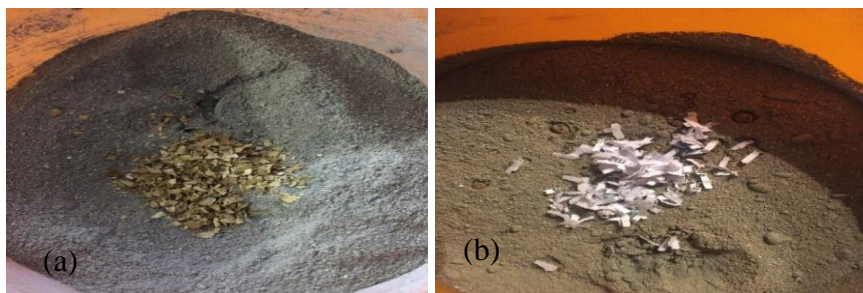


Fig. 3: Addition of waste papers to cement mortars. (a) Natural leaves (b) industrial waste paper.

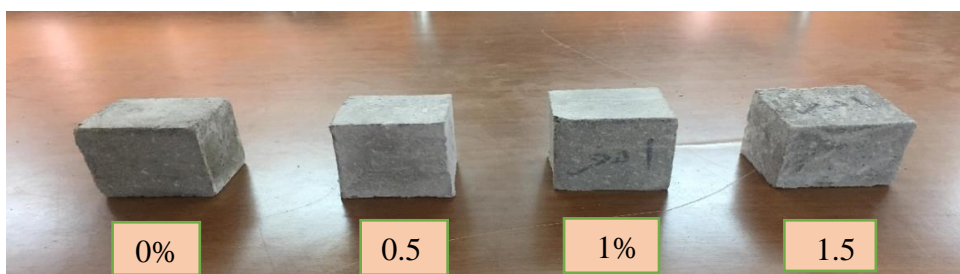


Fig. 4: Compression test specimens.

Table 2: The composition of the cubic specimens.

Specimen	Industrial and natural waste paper content %*	Waste paper weight / specimen (g)**	Cement weight (g)	Sand weight (g)	Water weight (g)
1	0%	0	87	263	52
2	0.5%	1.75	87	263	52
3	1%	3.5	87	263	52
4	1.5%	5	87	263	52

\* Weight percentage of Industrial and natural waste paper with respect to mold volume.

\*\* Weight of Industrial and natural waste paper.

The mortar pastes were prepared and placed inside cuboidal molds having dimensions of  $(16 \times 4.5 \times 4) \text{ cm}^3$ . The specimens were left for curing for 28 days before further measurements

were made. Fig. 5 shows the mortar specimen after being removed from the molds. Table 3 shows the ratios of the mixed compounds.

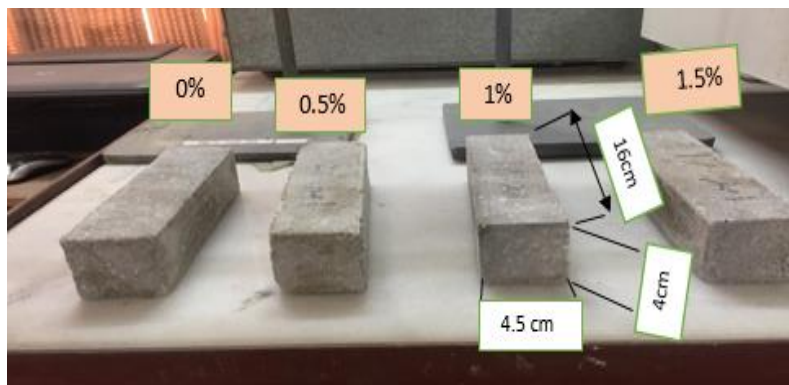


Fig. 5: Bending test specimens.

Table 3: The composition of the cuboidal specimens.

Specimen	Industrial and natural waste paper content %*	Waste paper weight / specimen (g)**	Cement weight (g)	Sand weight (g)	Water weight (g)
1	0%	0	201	604	120
2	0.5%	4	201	604	120
3	1%	8	201	604	120
4	1.5%	12	201	604	120

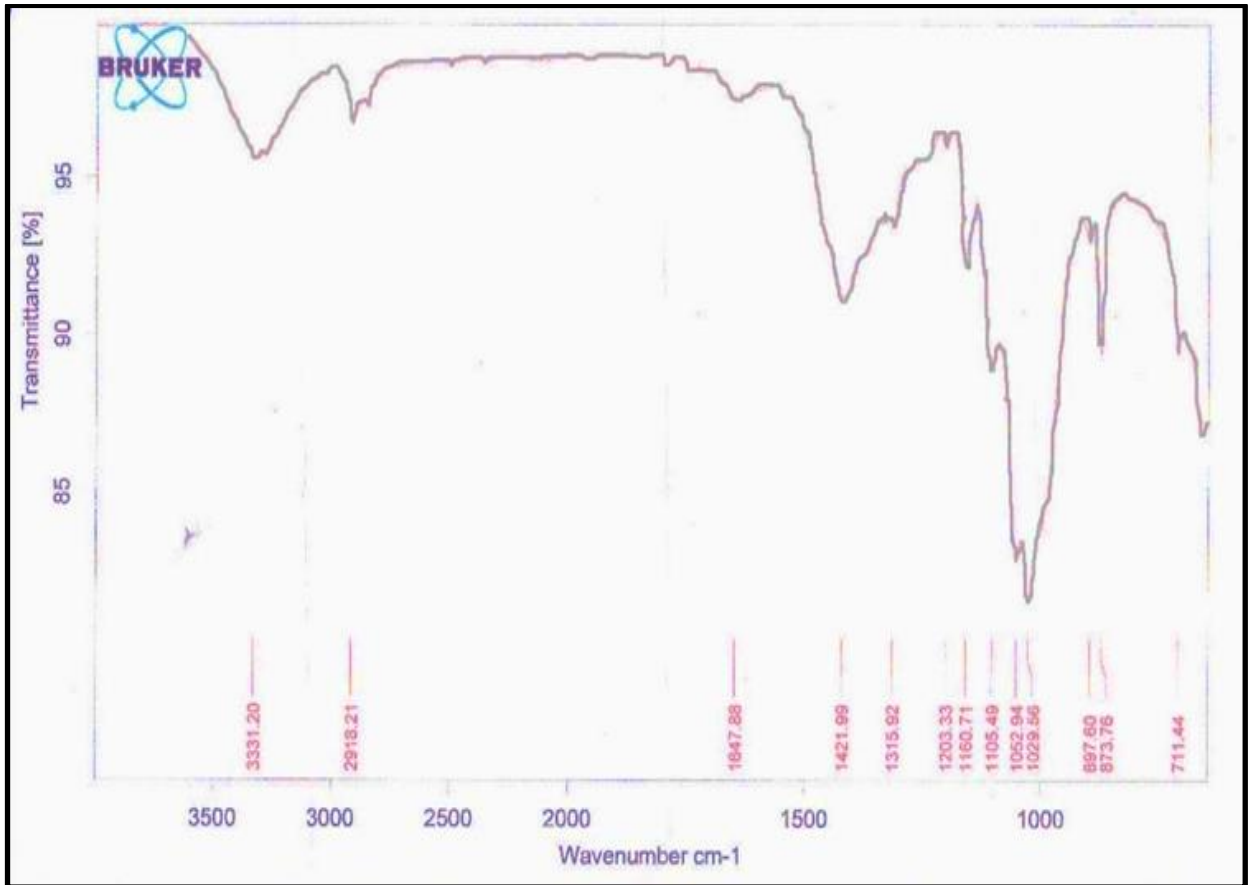
\* Weight percentage of Industrial and natural waste paper with respect to mold volume.

\*\* Weight of Industrial and natural waste paper.

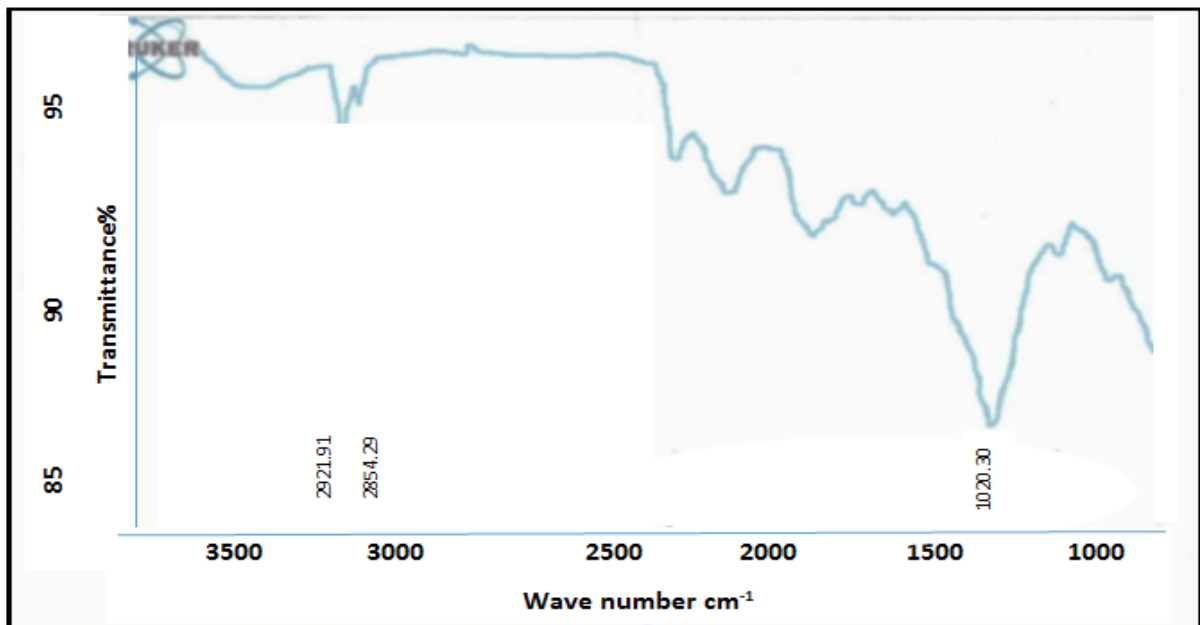
### Results and discussion

Fig. 6 shows the FTIR spectrum of the waste papers. The wavelength  $14021.99 \text{ cm}^{-1}$  (medium bond of (C-O)), refers to the molecule carboxyl while the wavelength  $105.294 \text{ cm}^{-1}$  and  $1029.56 \text{ cm}^{-1}$  refer to the strong peak of Amines (C-N) groups. Fig.7 is the

FTIR spectrum of the citrus aurantium leaves. The two wavelengths  $2921.91 \text{ cm}^{-1}$  and  $2854.29 \text{ cm}^{-1}$  are attributed to the weak bonds of the alkane (C-H) group while the wavelength  $1020.93 \text{ cm}^{-1}$  are due to the strong peak of amines (C-N) group.



**Fig. 6: FTIR spectrum of the industrial waste paper.**



**Fig. 7: FTIR spectrum of citrus aurantium leaves.**

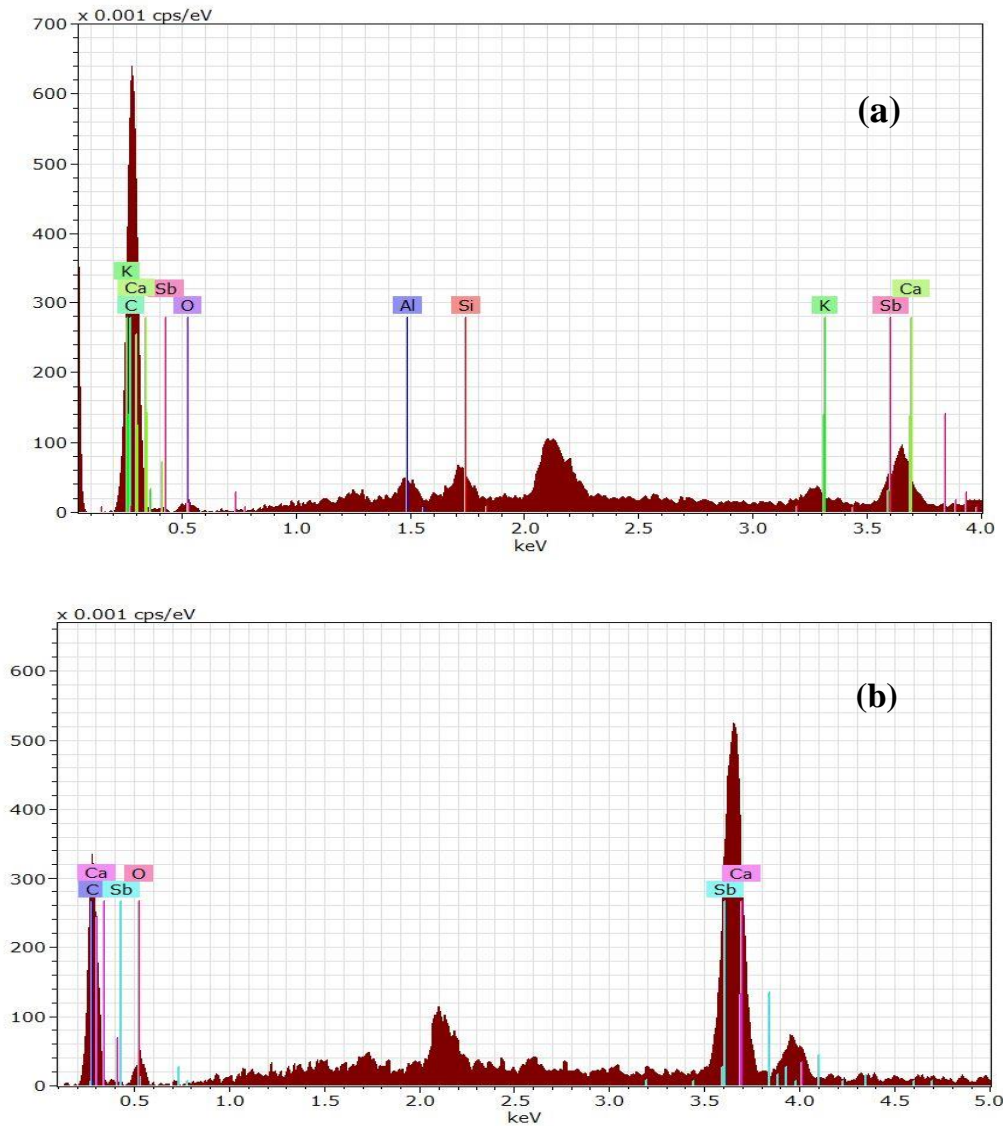
The mortar specimens were examined by energy dispersive spectrometry (EDS); the results of which are shown in Fig. 8 (a and b).

Tables 4 and 5 show the compositions of these two specimens as estimated from the EDS spectra. The two EDS spectra showed peaks that are related



to carbon, oxygen and calcium constituents in the investigated specimens. These elements give the

green mortar its desirable hardness and bonding with the cement mortar.



**Fig. 8:** EDS spectra (a) the citrus aurantium leaves (b) the industrial waste paper.

**Table 4:** The chemical composition of the natural leaves (citrus aurantium).

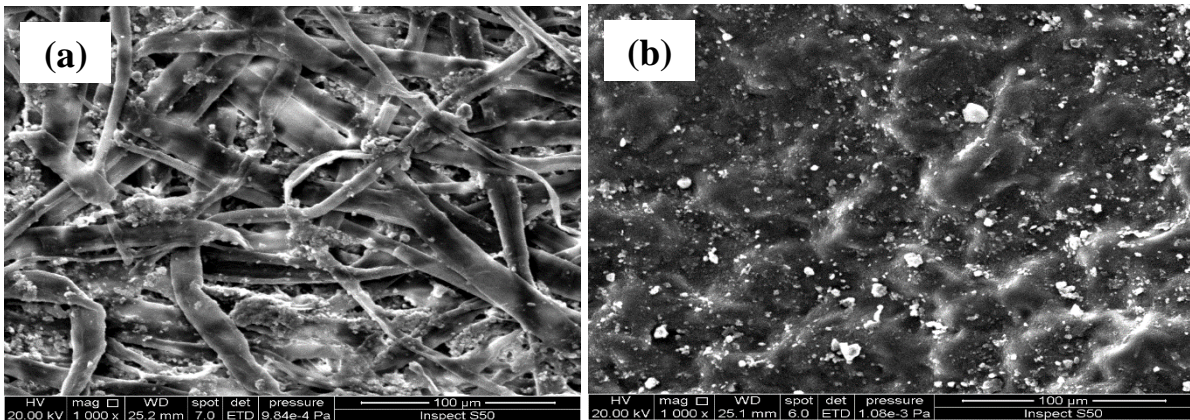
Element	Weight percentage (%)	Normalized weight (%)
C	34.58	82.32
O	3.00	7.14
Sb	2.20	5.25
Ca	1.20	2.84
Si	0.39	0.93
P	0.34	0.80
Al	0.28	0.68
Total weight	42.01	100%

**Table 5: The chemical composition of the industrial papers.**

Element	Weight percentage (%)	Normalized weight (%)
C	18.91	40.67
Sb	14.21	30.59
Ca	8.50	18.30
O	4.84	10.42
Total weight	46.46	100%

The morphologies of the waste paper and natural citrus aurantium leaves are measured using scanning electron microscope (SEM) and shown in Fig. 9 (a and b). Fig. 9 (a) shows in clearly the industrial waste paper

sheets randomly oriented over the mortar matrix. The cement-sand mixture is observed between these micro-sheets. Fig.9 (b) shows the broken leaves randomly distributed in the cement-sand medium.

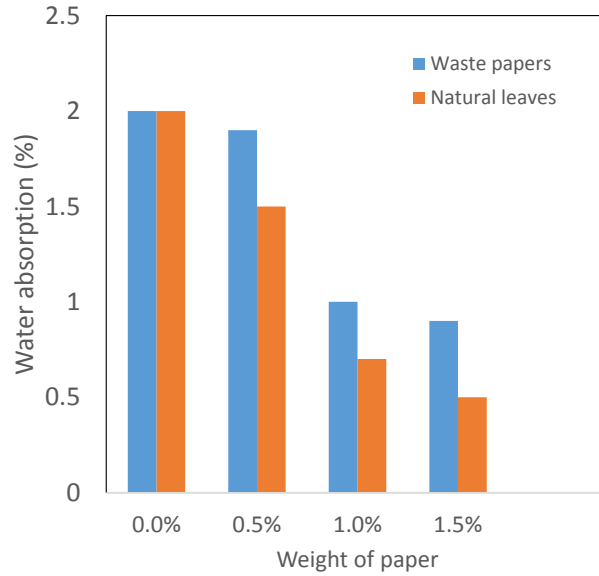


**Fig. 9: Scanning electron micrographs of mortars reinforced with (a) waste paper (b) natural leaves.**

Fig.10, the water absorption test, shows that increasing the waste papers contents of the specimen results into a decrease of the water absorption property. The decrease of water absorption is higher in the specimen containing natural leaves than in those containing the waste papers. This behavior is found reproducible in all

reinforced mortars investigated in this work. This behavior is attributed to the fact that the fragments of the natural leaves might have filled the micro-cracks and the pores of the mortar matrix leading to decrease in voids being otherwise occupied with water. As shown in Eq. (1).

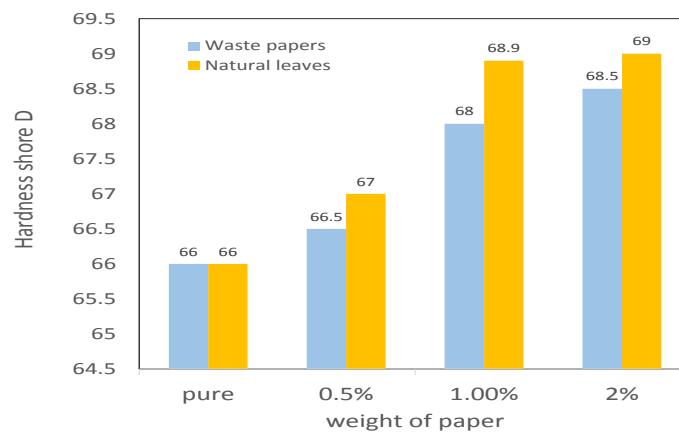
$$\text{Water Absorption} = \left( \frac{(\text{Wet Weight} - \text{Dry Weight})}{\text{Dry Weight}} \right) * 100 \quad (1)$$



**Fig. 10: Water absorption test of the reinforced mortars.**

The hardness for both the reinforced specimens are shown in Fig.11. Results show that increasing the content of the reinforcing material leads to an increase of the specimen hardness regardless the type of the reinforcing material (i.e. waste paper or natural leaves). However, the hardness of the specimen containing

natural leaves is higher than that containing waste paper. This is attributed to the fact that natural fibers are known to have higher specific strength than the waste papers which transfers to the cement mortar specimens reinforced with these materials. Our results are in agreement with the results Aseel [8].

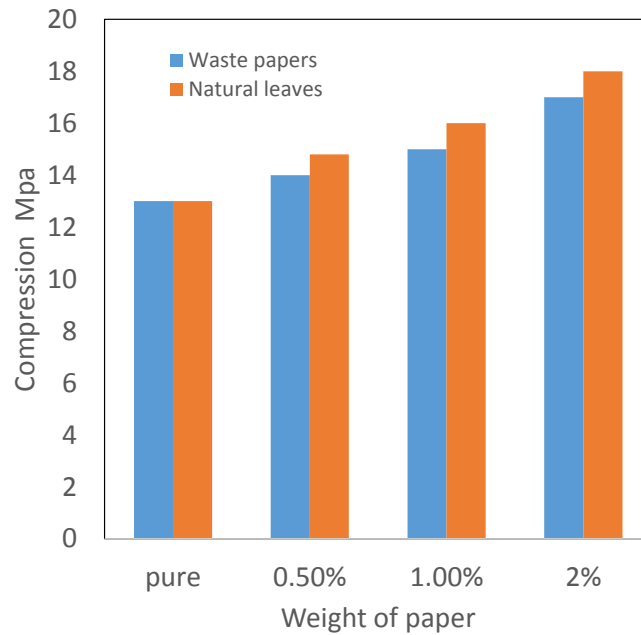


**Fig. 11: Hardness of the reinforced cement mortars.**

The compression test for both the reinforced specimens is shown in Fig.12. Results show that increasing the content of the reinforcing material leads to an increase of the specimen compression regardless the type of the reinforcing material (i.e. waste paper or natural leaves). However, the compression strength of the specimen

containing natural leaves is higher than that containing waste paper. This is attributed to the fact that natural fibers are known to have higher specific strength than the waste papers which transfers to the cement mortar specimens reinforced with these materials. Our results are agreement with the results of this source [8].

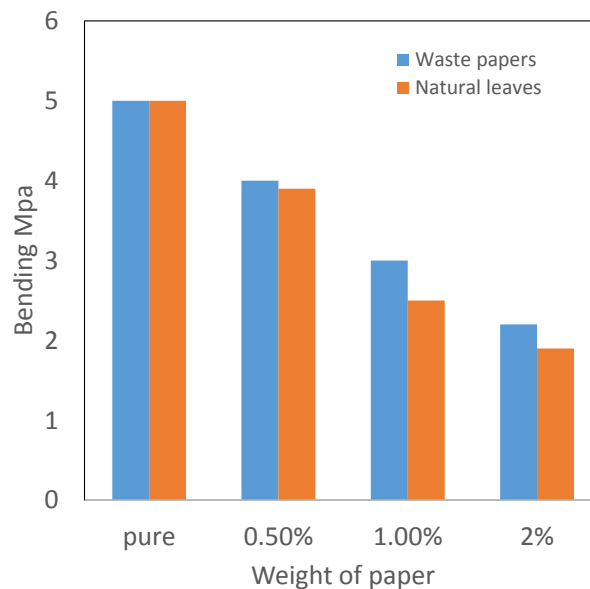




**Fig. 12: Compression test of the reinforced mortars.**

Fig.13 shows the bending test of the reinforced specimens compared with the pure ones. It is found that bending strength decreases with the increase of reinforcement with the waste papers as

well as with the natural leaves. In addition the bending strength of the mortar specimen reinforced with natural.



**Fig. 13: Bending test of the reinforced.**

Fiber exhibits higher values than those exhibited by the specimens reinforced with waste papers. This may be attributed to the increase of the specimen hardness. Our results are agreement with this source [8].

### Conclusions

1. Waste papers and natural leaves of citrus aurantium were effectively used in the reinforcement of cement mortars.

2. Increasing waste papers and natural leaves contents of the mortars leads to decrease of water absorption. Water absorption is lower in case of reinforcement with natural leaves fragments.

3. The specimen hardness increases generally with the increase of waste papers or natural leaves. Addition of natural leaves results into higher hardness than waste papers.

4. Compressive strength increases with the increase of reinforcing materials. The natural leaves resulted into higher compressive strength than waste papers.

5. Cement mortar specimen exhibit higher bending resistance with the increase of waste papers and natural leaves in accordance with the increase of specimens' hardness.

6. Green mortar Cement can be used to hold together bricks, stones or other hard scape components in construction structures.

7. The percentage of the waste paper (natural and industrial) component in the mortar cement mixture is not sufficiently large so that the building unit is exposed to fire hazards because the material base is a green ceramic cement.

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