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# Experimental Assessment of Flaxseed Gel on Mechanical and Physical Properties of Mortar

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**ABSTRACT**

*Based on all previous researches on using natural biomaterials to develop physical and mechanical properties of mortar, the extracted gel from the flaxseed as bio-admixture is examined and tested as a sustainable chemical admixture in the production of cement mortar, as well as determining its influence on some mechanical and physical properties such as compression strength, flexural strength, workability and water absorption) of mortar. Flaxseed gel was added to mortar mixes with the percentage of 5%, 10% and 15% as a partial replacement by weight of mixing water. FTIR spectroscopy for flaxseed has been performed to identify organic/inorganic components. The effect of flaxseed gel in the mortar structure was evaluated, and the results showed a good enhancement in the properties of mortar caused by using variable percentages of gel replacement in the mixture in which, the compressive strength of cement mortar exhibited a significant increase to 56.3% by replacing 15% of mortar cement with flaxseed gel, while the higher increase in flexural strength reached 25.6% was achieved by replacing 5% of mortar cement with gel. There is a slight increase in the water absorption of mortar mixture containing 15% of flaxseed gel which reached 5.7% compared to 4.3 % achieved by the reference mixture.*

**Keywords**: Cement, Biomaterials, Compression strength, flexural strength, water absorption, Carboxyl group

## 1. INTRODUCTION

The mortar technology, like any other engineering and science technology field, undergoes further specialization through the formation of biological or synthetic additives in order to improve its performance [1]. Therefore, natural, eco-friendly materials still have high demand since they are recyclable and can also be used in the construction industry as a construction material. Nowaday different types of sustainable cement-based composites are produced by using novel materials technologies [2]. The traditional mortar consists of cement, sand and water. In addition to that, several other additives are added to improve the different properties of cement products. Usage of polymeric admixtures can improve the durability and mechanical properties of concrete or mortar. However, the majority of the synthetic polymers have harmful environmental effects, and usage of different synthetic admixtures in concrete have been proven to contribute in an immense way in the emission of toxic wastes into the environment. Therefore, various types of bio-polymer admixtures are considered as low-cost alternatives to synthetic admixtures. Izaguirre et al. [3] observed the beneficial effects of potato starch, a bio-degradable natural polymer on the properties of hardened lime. Karandikar et al. [4] investigated the effect of different types of natural bio-polymeric extracts on various fresh and hardened state properties of cement mortar and concrete. Results were also compared with a commercially available chemical admixture and they have been observed to have similar or even better performances with the natural bio-polymeric materials compared to the chemical admixtures. Flaxseed is a naturally occurring inexpensive source of

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biopolymer. Linseed or flaxseed is scientifically known as "Linum usitatissimum", a leafy plant belonging to the linen family.

Its seeds are brown, oily and become sticky when wet. Flaxseed contains a lot of health-beneficial ingredients, also contains the most important components like omega-3, fatty acids, albumin, lignan compounds and the dissolved and insoluble fiber in water. Flaxseed is a naturally occurring inexpensive source of biopolymer. Linseed or flaxseed is scientifically known as "Linum usitatissimum", a leafy plant belonging to the linen family. Its seeds are brown, oily and become sticky when wet. Flaxseed contains a lot of health-beneficial ingredients, also contains the most important components like omega-3, fatty acids, albumin, lignan compounds and the dissolved and insoluble fiber in water. Flaxseed has several applications in pharmaceutical and natural health products. Flaxseed has many biologically active components, where most clinical studies of flaxseed have an emphasis on extracts including lignin and a-linolenic acid. Elements like polysaccharides, alkaloids, cyclic peptides, and cadmium can be extracted from flaxseed [5]. Flaxseed oil is considered as one of the most common organic materials which are used as additives to improve the properties of mortar in the first civilizations. Considerable works have been done to understand the chemical and rheological behavior of flaxseed oil and its effects on the properties of concrete or mortar. Cristiana et al. [6] studied the effect of linseed oil on some properties of cement mortar, which has different characteristics than a lime-based mortar. The effect of linseed and whale oil on hydrated lime mortar was tested by Holmes et al. [7]. The researchers detected a decline in capillary absorption of mortars with linseed oil addition compared to original mortars. A few experiments have been done on the usage of extracting the gel from flaxseed in the preparation of cement-based composite materials. By considering the importance of natural bio-admixtures as low-cost, sustainable chemical admixture in the production of eco-efficient concrete, in this investigation, flaxseed gel is considered as a natural and eco-friendly alternative to synthetic additive for mortars. The influence of flaxseed gel (as a partial replacement of water) was investigated on fresh and hardened properties of cement composites to determine the proper percentage of flaxseed gel replacement that gives the optimum properties of mortar.

## 2. EXPERIMENTAL WORK

### 2.1 Materials Used

1. Cement: Ordinary Portland cement which is commercially known as Tasluja Bazian, supplied from United Cements company in Sulaymaniyah was used in this study. The physical properties and chemical composition of the cement used are conformed to ASTM C150-04 [8].
2. Sand: Natural sand from the Al-Ekadir region in Iraq which is complying with the ASTM C33-03 [9], is used in the research. The sand used was within the zone 2 with a sulfate content of 0.12% and specific gravity of 2.65.
3. Flaxseed gel: Flaxseed gel is prepared by boiling the flaxseed seeds in water with proportion of 1:100 (flaxseed: water) for about 15 minutes. After that, seeds are filtered from the gel and then added to the cement mortar by a weight fraction of 5, 10 and 15% as a partial replacement of mixing water.

### 2.2 Flaxseed Characterization

A fully FTIR spectrum of flaxseed powder was taken using Shimadzu FTIR8400s, as shown in Figure 1. The analysis of flaxseed in the infrared spectrum revealed broadband at 3290-3309 $cm^{-1}$. This bundle is due to the presence of a carboxyl group which is a part of Amino acid (or / and) asymmetrical and asymmetric stretch bundles belonging to NH2 Aniline groups. So, carboxyl groups can make the mixture hydrophilic [13]. The sharp peak that appeared at 3010 $cm^{-1}$ may be attributed to the presence of an aromatic compound (benzene ring) to the presence of aromatic (C−H). In an aromatic compound, the electrons that travel in a rapid manner between the binary and monocular forms are not concentrated. That means the resonance process, in which the bilateral bonds move around the hexagonal ring. In general, the total momentum of the aromatic bonds included in the aromatic phenomenon is stronger than the total momentum of the links when viewed as a union between mono and bilateral bonds. This, in turn, may improve the mechanical properties of the compound. The appearance of bundles at 2953.13 $cm^{-1}$ and 2924.18 $cm^{-1}$ belongs to the Aliphatic group (C−H). Alkane (C−H) bonds are appropriately found everywhere and therefore generally less useful in structure determining. Also, a sharp absorption peak appears at 1743 $cm^{-1}$, indicating the presence of a carbonyl group (ketone, ester, aldehyde, etc.). The stretching absorption of the carbonyl group has a strong IR absorption, so it is very useful in structure determination. The importance of the carbonyl group comes from determining the number of carbonyl groups and estimating the types of stretch (if peaks do not overlap). Moreover, outgoing vibration at 1651-1645 $cm^{-1}$ attributed to the (C═N) bond, also (C−N) bond looked at 1377 $cm^{-1}$. The symmetrical and asymmetric aromatic alkene (C═C) bond as well appeared at 1543-1533 $cm^{-1}$. A carbon-carbon double bond formation desired in artificial chemistry furthermore, water or partially aqueous solvents has significant applications as the four valance electrons give strength to the subsequent long chains and ring structure. The appearance of clear peck at 1456 $cm^{-1}$ is due to (C−H) bending (in methyl functional group). This functional group is resistant to very strong bases/acids, which is one of biomaterials properties. It also seems that there is a group of halogens that often appear in an area ranging from 700-600 $cm^{-1}$ and these halogens may be Br or Cl. The absorption intensities in the FTIR spectrum could be stronger or weaker than expected because of dipole moment dependence.

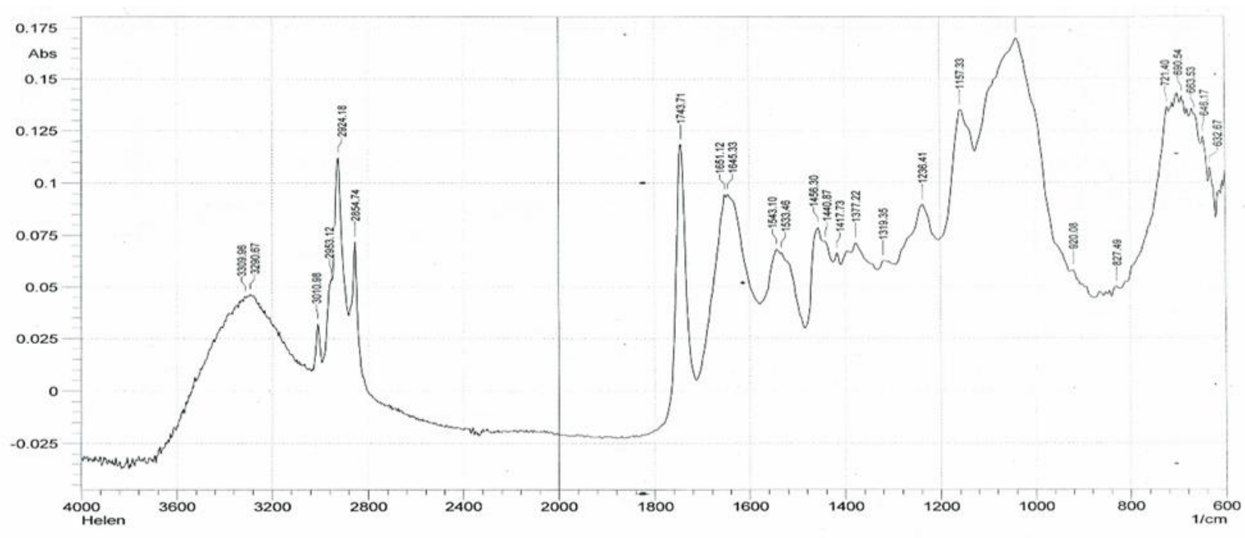


**Figure 1.** FTIR for flaxseed

## 2.3 Mix Proportion

In the experimental work of this research, the first step was producing mortar mix (as a control mix) having the proportions of 1:3 by weight of cement: sand, with a cement content of 250 kg/$m^3$ and water: cement ratio of 0.48. Then, three different mixes are prepared from the control mix by a partial replacement of water with flaxseed gel. The percentages of replacement are 5%, 10%, and 15% by weight of mixing water with keeping the flow values of mortar mixes in the range of 100±5 % flow. The details of the mortar mixes are shown in Table 1.

**Table1.** Mix proportion

| Mix symbol | Cement (kg/m3) | Sand (Kg/m3) | Water (Kg/m$^3$) | Flaxseed gel (kg/m3) | w/c ratio (%) |
|---|---|---|---|---|---|
| F0 | 250 | 750 | 120 | 0.0 | 0.480 |
| F5 | 250 | 750 | 114 | 6.0 | 0.456 |
| F10 | 250 | 750 | 108 | 12.0 | 0.432 |
| F15 | 250 | 750 | 102 | 18.0 | 0.408 |

## 2.4 Test Methods

### *2.4.1 Workability Test (Flow Test)*

The workability of mortar mixes was determined using the flow test, according to ASTM C1437-03 [11]. The flow test was carried out by measuring the spread diameter of fresh mortar and expressed as a percentage of the original base diameter (100 mm).

### *2.4.2 Compressive Strength*

A compressive strength test was carried out for all the samples after 28 days of curing. This test was determined according to ASTM: C109M – 07 [12] with 50 x 50 x 50 mm sample dimensions. The samples were examined to failure utilizing a loading rate of 200KN/min using the compressive digital machine (ELE-Auto test). The result of each mix was obtained by using the average of three specimens.

### *2.4.3 Modulus of Rupture (Flexural Strength)*

Modulus of rupture was determined by using samples having the dimensions of 4 x 4 x 16 cm which were tested according to ASTM C293-04 [13], at the age of 28 days. In the code of design, the flexural strength is normally expressed as the modulus of rupture (fr). According to the standard, the modulus of rupture can be determined by using three-point loading test. All the prisms were tested by using a test machine of 10 KN flexural/tensile testing machine of ELE International Company.

### *2.4.4 Water Absorption*

This test was performed according to ASTM C642 [14], using 100 mm cubes at age of 28 days. The average of three specimens was taken for each value of water absorption.

## 3. Results and Discussion

### 3.1 Compressive Strength

Compressive strength test results for mortar mixes F5, F10 and F15 with three different concentrations of flaxseed gel (5%, 10%, and 15%), respectively, in addition of controlling mix (F0) without flaxseed gel, after 28 days of water curing, is shown in Figure 2. It is obvious that higher compressive strength values were found in flaxseed gel/mortar mixtures compared with the control mixture. Also, the compressive strength of mixtures increases with increasing the amount of flaxseed gel and the higher the percentage of flaxseed gel, the greater value of compressive strength. The increase in flaxseed gel replacement from 0% to 5%, 10% and 15% causes increase in compressive strength reach to about 50%, 47.6% and 56.3%, respectively. The significant improvement was when using 5% replacement instead of 0%, while using 15% replacement show little improvement compared with 5% replacement. This is due to the presence of gel in the mortar structure which causes a reduction in water/cement ratio and enhancement in the bonding strength of the mixture by filling the interfaces between the basic components, so it shows high resistance to compressibility [15]. Also due to increasing the hydration products as the result of the consumption of $Ca^{2+}$ ions by bio-material and therefore increases the compressive strength [4].

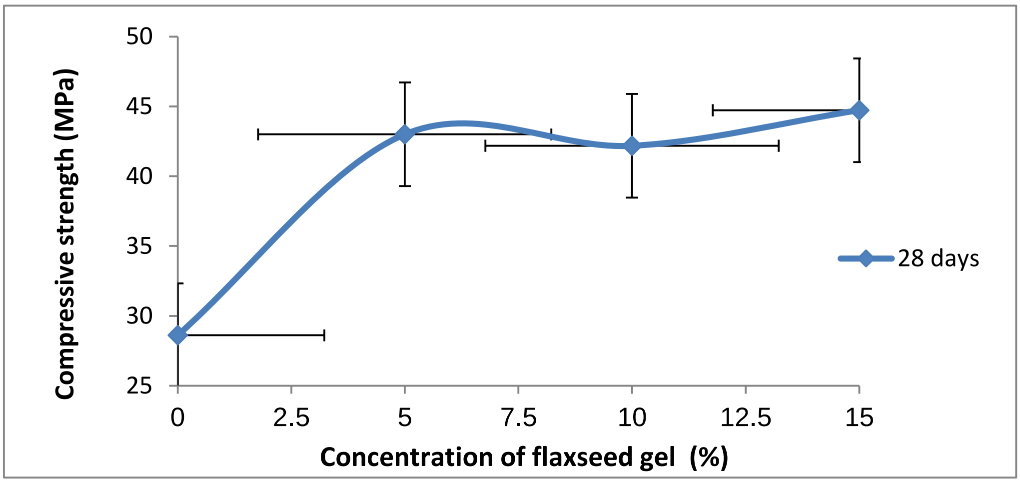


**Figure 2.** The effect of flaxseed gel concentration on the compressive strength of cement mortar

### 3.2 Flexural Strength

Figure 3 displays the flexural strength values of mortar mixes containing four different concentrations of flaxseed gel (0%, 5%, 10%, and 15%), as a partial replacement of mixing water, a curing age of 28 days. The results show an increase in the values of flexural strength which are 3.52, 4.42, 4.2, 4.35 MPa, respectively. The increase in flexural strength was 25.6%, 19.3% and 23.6% for mortar mixes F5, F10 and F15, respectively compared with the control mix (F0). This improvement in flexural strength is due to the high rate of improvement in the structure of mortar and increasing in the hydration of cement particles when using flaxseed gel (especially at 5% replacement) and achieving minimum voids and absorption capacity, which lead to control water permeability within sample structure. Generally, the hydration process can give strength besides achieving a certain level of durability [16]. Structurally, carboxyl groups in the flaxseed gel provide a hydrophilic medium in the mortar mixture. In other words, the decrease in the porosity led an increase of strength.

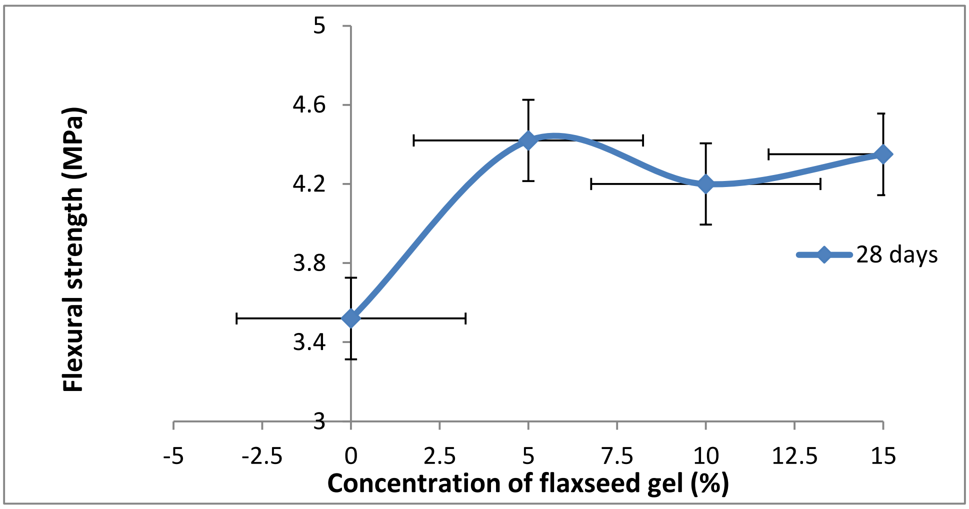


**Figure 3.** The effect of flaxseed gel concentration on the flexural strength of cement mortar

### 3.3 Water Absorption

The water absorption test for all samples was done after 28 days and the results are illustrated in Figure 4. The values of water adsorption were 4.3, 4.6, 5.1 and 5.7 % for mixes of F0, F5, F10 and F15 respectively. It is obvious from the figure that mixes containing flaxseed gel show little increase in water absorption with increasing the flaxseed gel ratio compared with the control mix (F0), and the maximum water absorption observed at 15% flaxseed gel replacement. This is attributed to the fact that bio-based flaxseed extract has the ability to absorb water despite its presence in the cement structure. The recorded values of the concrete absorbance of the samples are within acceptable limits and the experimental values are within the ranges of those of the good one [17]. The increase in the water absorption with the increase in the concentration of flaxseed gel is also due to the carboxyl group as mentioned in the FTIR analysis. So, 5% gel replacement can be considered as the best one.

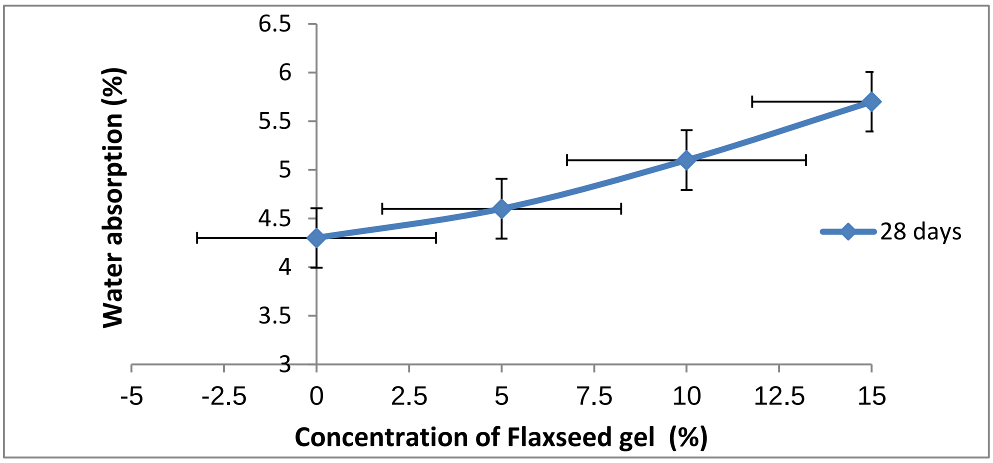


**Figure 4.** The effect of flaxseed gel concentration on the water absorption of cement mortar

### 4. Conclusion

After 28 days of curing, the main results of this study can be summarized as follows:

1. Flaxseed gel can rearrange the structure of the mortar mixture, which improves its mechanical properties. The best concentration of flaxseed gel as a replacement for mixing water in cement mortar is 5% which gave the proper and better properties to mortar mixes.
2. The compressive strength increases in value from 28.61 to 44.73 MPa as the percentage of flaxseed gel increases from 0% to 15% as a replacement for mixing water.
3. Significant improvement in compressive strength is when using 5% replacement instead of 0% while using 15% replacement show little improvement compared with 5% replacement.
4. Using flaxseed gel as a replacement for mixing water causes improvement in flexural strength of mortar, especially at 5% replacement.
5. The water absorption test for all samples illustrated little increase as the flaxseed gel ratio increase and the maximum value at 15% flaxseed gel which is 5.7% compared with 4.3% of the mix without flaxseed gel.

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