Effect of Using Chopped Sisal Fiber (CSF) on Enhancing Properties of Pure Gypsum with Various Water Content

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Abstract. The current study investigates the influence of employing one of the natural fibres (Sisal Fibre (SF)) on pure gypsum characteristics (specifically compressive strength and density). The four pure gypsum mixtures used in the study plan are split into two groups based on the (water / pure gypsum) ratios (0.55 & 0.65). Based on the volume fraction (Vf) of chopped sisal fiber (CSF), each group was split into two groups: 0.0 and 0.4 percent. For every mixture, three cubic (50 x 50 x 50 mm) samples were made. For both (W/PG) ratios, it was discovered that adding CSF to pure gypsum mixtures increased compressive strength; the proportion of this increase increased as the (W/PG) ratio increased. Additionally, the compressive strength decreases for all (Vf) of CSF when the (W / PG) ratio is increased, and this percentage of degradation decreases when CSF is present. However, it was also shown that adding CSF to pure gypsum mixtures results in a modest loss in density for both W/PG ratios, with the proportion of this drop decreasing as the W / PG ratio increases. Additionally, the density deteriorates for all (Vf) of CSF when the (W / PG) ratio is increased, and this percentage of degradation is marginally reduced when CSF is present.

1 Introduction

The mineral gypsum, which is sometimes referred to as calcium sulfate hydrate ($CaSO_4.2H_2O$), is highly sought after and is frequently utilized in the construction of a wide range of kinds of buildings. Gypsum has been utilized widely in a wide range of applications, such as acting as a construction binder, serving as an interior ornamental

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material, being used in precast building units, and being used to isolate noise in walls [1]. The volumetric uniformity of gypsums, their low density, their resistance to heat and/or fire, their ease of construction , their low cost, and their attractive shape are only some of the distinguishing traits that they exhibit [2]. According to the findings of a number of studies [3-6], the utilization of a variety of materials (including fly ash, ordinary portland cement, and silica-fume) has the potential to enhance the physical and chemical properties of the gypsum matrix, which may, in turn, result in favorable impacts on the characteristics of both the hardened and fresh forms.

As part of the use of reinforcing materials, a number of tests have been conducted to illustrate the relevance of in-cluding a broad variety of fibers into gypsum mixes [7-15]. These experiments have been carried out in order to highlight the value of this inclusion. It is a well-established fact that fibers may be utilized in an efficient manner in order to bring about enhancements in the tensile strength, dimensional stability, and strength of gypsum. Furthermore, it is able to prevent its structure from being harmed or collapsing, which is a significant advantage.

As a result of their excellent characteristics, natural fibers, such as sisal fiber, are currently regarded to be an appropriate material for reinforcing. These characteristics include the fact that they are recyclable, have a high strength-to-weight ratio, and are inexpensive. When compared to standard materials, compound materials have a number of advantages, the most significant of which is that they have greater stiffness, specified strength, and fatigue characteristics.

Increasing the compressive strength of gypsum by means of the production of a gypsum composite that is reinforced with short sisal fibers that are randomly spread throughout it is the objective of the current study that makes use of sisal fiber. The sisal fibers were selected due to their high strength, low weight, resistance to corrosion, cheap cost, less health dangers, and the fact that they were sourced from renewable resources.

2 Study Objectives

This investigation aims to improve the compressive strength and density of purified gypsum, which are two of its most significant attributes. To investigate the impact of these parameters on the compressive strength and density of gypsum, a parametric study was conducted on the volume fraction (Vf) of chopped sisal fiber (CSF) (0.0 %, 0.4%) and the water / gypsum ratios (0.55, 0.65).

3 Experimental Work

3.1 Constituent Materials

3.1.1 Pure gypsum

In this particular investigation, Iraqi pure gypsum is utilized. Calcium sulfate hemihydrate gypsum, which may be represented by the formula $CaSO4.1/2H2O$, was the material that has been utilized in this study. The majority of the gypsum combinations were mixed with tap water, which was employed for the mixing process.

3.1.2 Sisal fibers

Fibers made of sisal are obtained by extracting them from the leaf of a plant known as Agave sisalana. At the present day, the plant is mostly farmed in the countries of Indonesia, India, Haiti, East Africa, and Brazil. Its traditional homeland is Mexico.

According to the data shown in Table (1) [16] ¸ it does not appear that the elastic modulus and tensile strength of the fiber are dependent on the gage length. When it comes to tensile strength¸ the range is between 347 to 577 MPa¸ while the elastic modulus may be anywhere from 9 to 19 GPa. This covariance might be understood by three primary components¸ as was noted in the introduction: (i) measurements of the region; (ii) features of the plant; and (iii) test settings and circumstances. The following is a condensed list of the test parameters that have the potential to influence the results: strain rate¸ gage length¸ accuracy of the instruments¸ compliance of the machines¸ and kind of grips. In terms of the features of the plant ¸ the mechanical response of the sisal fiber is determined by its age¸ the source of the plant¸ the kind of processing (the mechanism that is used to separate the fibers)¸ and the microstructure of the fiber [16]. Also, the physical properties of sisal fibres include a density range of 1400~1450 kg/m3, and fibre diameter range of 100~300 µm [17]. When conducting this study¸ a chopped sisal fiber with a length of 25 millimeters was utilized¸ as seen in Fig. 1.

Table 1. Tensile test Outline [strain rate varied from (0.15 to 0.16) per second; displacement (0.1) mm per minute]. [16]

Gage length (mm)	Elastic modulus (GPa)	Tensile strength (MPa)	Area (mm^2)	Strain to failure(%)
10	10.7 ± 4.0	391 ± 89	0.046 ± 0.008	5.2 ± 2.5
20	10.4 ± 3.0	392 ± 105	0.050 ± 0.020	3.8 ± 1.1
30	14.8 ± 6.2	385 ± 99	0.040 ± 0.004	2.8 ± 0.6

Fig. 1. Chopped Sisal fibers.

3.1.3 Mixing water

In the current investigation¸ the water that was utilized for all of the Pure Gypsum (PG) combinations¸ both with and without CSF¸ was regular potable water.

3.2 Pure gypsum mixes

This research involved the preparation of four different gypsum mixes. On the basis of their gypsum ratios (0.55 and 0.65) ¸ mixtures were divided into two sets. Each of these sets was then further divided into two subsets based on the volume fraction (Vf) of chopped sisal fibers (CSF) that they contained (0.0% and 0.4%). Figures (2) illustrate the experimental program.

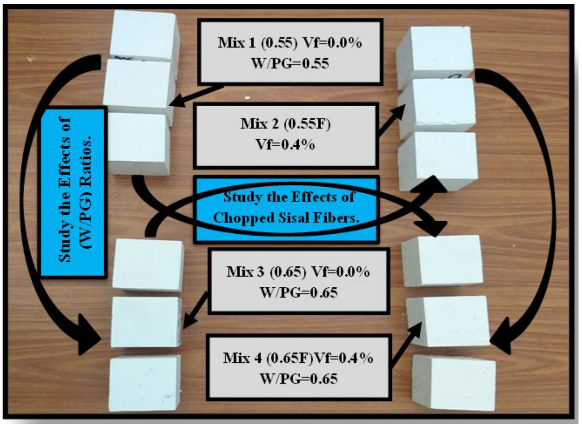

Fig. 2. Plan of research method

3.3 Mixing procedure

Initially, CSF is procured from the local market in our country as a bundle of fibers, measuring approximately 75 cm in length. It is subsequently chopped using specialized scissors to a length of 25 mm, weighed, and combined with the measured amount of Pure Gypsum. The mixture is then thoroughly dry-blended until the CSF is evenly distributed throughout the dry components. Subsequently, water is incorporated in accordance with the W/G ratio of either 0.55 or 0.65. The mixture is combined and placed into cubic molds measuring 50 × 50 × 50 mm. Upon completion of the hardening phase, the Pure Gypsum (PG) mixture is extracted from the molds. The reference mixtures follow the same previous steps, excluding CSF. All samples were subjected to direct sunshine for roughly one week at a temperature of around 35°C to guarantee full desiccation.

3.4 Plan of testing

The preparation of the test plan for the current investigation includes carrying out the expected tests that will demonstrate the impact that the incorporation of CSF has on the compressive strength of Pure Gypsum (PG) mixes. This will be performed through the utilization of the testing machines and instruments that are housed inside the "Constructional Materials Lab" that is located within the Faculty of Engineering at "Mustensiriyah University."

3.4.1 Compression strength

The cubic samples, which measured 5 centimeters by 5 centimeters by 5 centimeters, were put through a series of tests in this study at the age of seven days in order to ascertain their compressive strength. Within the scope of this investigation, the compressive test was carried out in accordance with the recommendations provided in ASTM C472-99 [18].

4 Experimental Results

4.1 Strength of compression

4.1.1 Impact of Incorporating Chopped Sisal Fiber (CSF) on the Compressive Strength of Pure Gypsum with Varying Water-to-Pure Gypsum Ratios (W/PG) Proportions

Table 2 and Figure 3 illustrate the effects of 0.4 percent CSF on the strength of compression of pure gypsum at two (W / PG) ratios of 0.55 and 0.65. The ratios being considered were 0.55 and 0.65. The compressive strength increases with an increase in the proportion of chopped sisal fiber compared to the mixes (Mix 1 and Mix 3 references), and this behavior is constant across both water-to-pure gypsum ratios in the combination. Mix 1 and Mix 3 act as references. This activity might be attributed to chopped sisal fiber (CSF)'s improved tensile strength¸ which enables it to limit the development of initial cracks and slow the advancement of cracks that occur as a result of increasing load. Another piece of evidence supporting this hypothesis is that the samples with chopped sisal fibre did not fail catastrophically. This contrasts with other samples¸ which include limitless amounts of chopped sisal fiber and are labelled as reference samples. This is seen in Figure 4.

Furthermore¸ as seen in Figure 3 and Table 2, the augmentation rates in compressive strength when CSF is mixed with a 0.4 percent content increase as the (W / PG) ratio climbs from 0.55 to 0.65. This happens when the ratio varies between 0.55 and 0.65, compared to the mixes (Mix 1 and Mix 3 references).

Table 2. Influence of CSF composition (Vf) on the pure gypsum's compressive strength across varying (W / PG) ratios.

Name of Mix	Symbol of Mix	Chopped Sisal Fiber (Vf) %	(Water / Pure Gypsum) ratio	strength of compression (MPa)	Increasing Percentage %
Mix. 1	55O	0.0	0.55	11.07	----------
Mix. 2	55F	0.4	0.55	12.45	12.5
Mix. 3	65O	0.0	0.65	9.62	----------
Mix. 4	65F	0.4	0.65	11.78	22.5

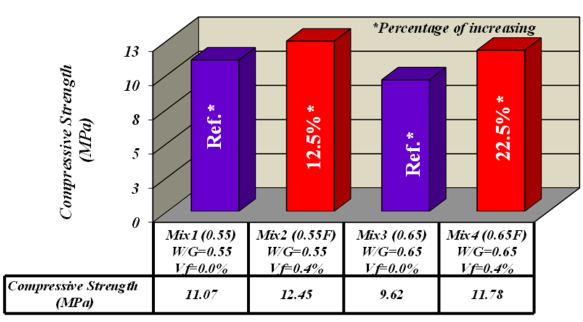

Fig. 3. Influence of CSF composition (Vf) on the Pure Gypsum's Compressive Strength across varying (W/PG) ratios.

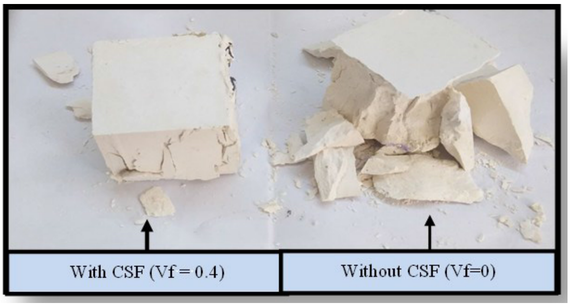

Fig. 4. Failure sample form with and without sisal fiber chopped.

4.1.2 The effect of water / pure Gypsum ratios on compression strength of gypsum with and without containing chopped sisal fiber

Table (3) and Figure (5) illustrate the impact of augmenting the water / pure gypsum ratio from 0.55 to 0.65 on the compressive strength of pure gypsum, including two distinct volume fractions of CSF (0.0 and 0.4 percent). The compressive strength of pure gypsum exhibited these values. Relative to the mixes (Mix 1 and Mix 2 references), the compressive strength diminishes when the water-to-pure gypsum ratio increases. The effect is similar for both concentrations of CSF. The findings suggest that this is observable. As the volume of water increases beyond that of the reaction water, evaporation induces the formation of voids, subsequently leading to an augmented number of holes in the hardened samples. This mindset may be explained by the occurrence of this phenomena. This renders the Pure Gypsum inner structural composition more pliable, thereby diminishing the efficacy of the combination [19].

Furthermore, Figure (5) and Table (3) illustrate that the reductions in strength of compression when the water-to-pure gypsum ratio increases are increased upon the incorporation of chopped sisal fiber into the material.

Table 3. Effects of Water / Pure Gypsum Ratios on compression strength of Gypsum with different CSF Volume Fractions (Vf)

Name of Mix	Symbol of Mix	Chopped Sisal Fiber (Vf) %	(Water / Pure Gypsum) ratio	strength of compression (MPa)	Percentage of decrease %
Mix 1	55O	0.0	0.55	11.07	----------
Mix 3	65O	0.0	0.65	9.62	13.1
Mix 2	55F	0.4	0.55	12.45	----------
Mix 4	65F	0.4	0.65	11.78	5.4

4.2 Density of Pure Gypsum

4.2.1 Effect of CSF on Pure Gypsum Density at Different (W/PG) Ratios.

Figure (6) and Table (4) illustrate the effect of incorporating chopped sisal fiber at a concentration of 0.4% on the density of pure gypsum, evaluated at two different Water / Pure Gypsum ratios (0.55 and 0.65). The findings indicate that an increase in the percentage of chopped sisal fiber in the mixture correlates with a decrease in density when compared to the reference samples (Mix 1 and Mix 3). This behavior pattern is similarly noted for two distinct ratios of Water to Pure Gypsum. One potential explanation for this behavior is that the chopped sisal fiber contributes to the formation of a greater number of air voids .

Furthermore, as illustrated in Figure (6) and Table (4), the observed rates of density loss upon the addition of CSF at a concentration of (0.4 percent) diminish with increasing (W / PG) ratios when compared to the mixes (Mix 1 & Mix 3 references). This behaviour may be attributed to the contribution of CSF to an increased voids ratio (enhanced porosity), mitigated by the augmented workability of the combination (i.e., elevated W/GP ratio).

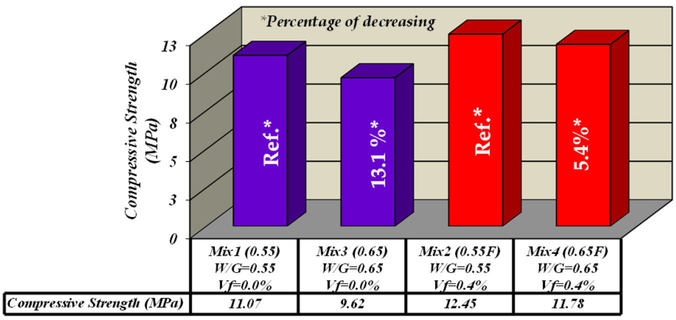

Fig. 5. Effects of Water/ Pure Gypsum Ratios on strength of compression of Gypsum with Different CSF Volume Fractions (Vf).

Table 4. Influence of CSF on the Density of Pure Gypsum at Various (W/PG) Ratios.

Name of Mix	Symbol of Mix	Chopped Sisal Fiber (Vf) %	(Water/ Pure Gypsum) ratio	Density (Kg/m^3)	Percentage of decrease %
Mix 1	55O	0.0	0.55	1285	----------
Mix 2	55F	0.4	0.55	1276	0.7%
Mix 3	65O	0.0	0.65	1195	----------
Mix 4	65F	0.4	0.65	1191	0.34%

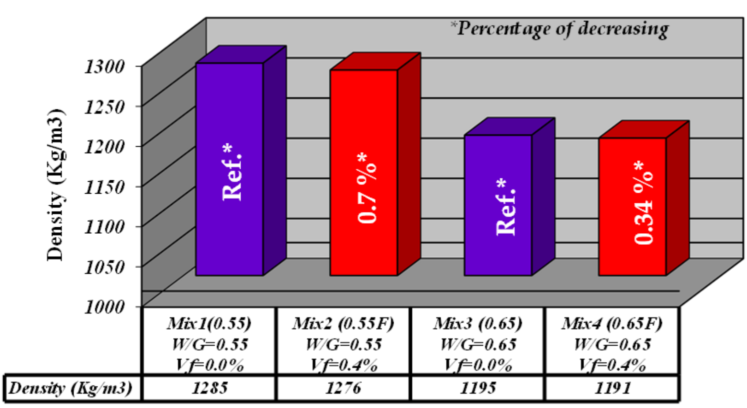

Fig. 6. Impact of CSF on the Density of Pure Gypsum at Various (W/PG) Ratios.

4.2.2 Impact of Elevated (W/GP) Ratios on Pure Gypsum Plaster Density with and without Chopped Carbon Fibre

Figure (7) and Table (5) present an analysis of the impact that raising the Water / Pure Gypsum ratio (W/PG) from 0.55 to 0.65 has on the density of pure gypsum. The analysis is performed for two different volume fractions of chopped sisal fiber (Vf = 0.0 and 0.4 percent). In light of the findings¸ it can be deduced that an increase in the ratio of water to PG results in a reduction in density as compared to the mixing benchmarks represented by Mix 1 and Mix 2. Both degrees of chopped sisal fiber content exhibit this pattern in a consistent manner. This behavior may be linked to the same explanation that was stated in the first paragraph of section (3.2.1).

Furthermore¸ the inclusion of chopped sisal fiber is shown to result in a reduction in the fraction of density degradation¸ as seen in both Table (5) and Figure (7). This tendency may be linked to the role of chopped sisal fiber¸ which is to increase the surface area and Its ability to absorb excess water ¸ this function helps to reduce the negative consequences that are associated with an elevated water-to- pure gypsum ratio.

Table 5. Effects of Water/ Pure Gypsum Ratios on Pure Gypsum Density with Different CSF Volume Fractions (Vf)

Name of Mix	Symbol of Mix	Chopped Sisal Fiber (Vf) %	(Water / Pure Gypsum) ratio	Density (Kg/m^3)	Decreasing Percentage %
Mix 1	55O	0.0	0.55	1285	----------
Mix 3	65O	0.0	0.65	1195	7.0%
Mix 2	55F	0.4	0.55	1276	----------
Mix 4	65F	0.4	0.65	1191	6.67%

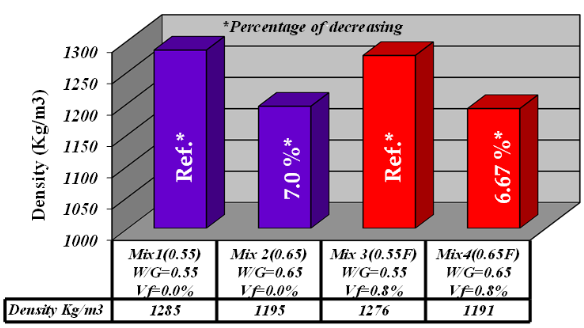

Fig. 7. Effects of (W/PG) Ratios on Pure Gypsum Density with Different CSF Volume Fractions (Vf)

5 Conclusions

The following is a synopsis of the most important findings that might be drawn from the research that is currently being conducted:

1. The use of chopped sisal fiber results in an increase in compressive strength (Volume Fraction content (Vf=0.4%) when contrasted with reference mixtures (i.e., Mix1 and Mix3) that do not contain chopped sisal fiber. This effect is consistent across two (W/PG) ratios (0.55 to 0.65).
2. In comparison to the mixes (Mix 1 & Mix 2 references), the percentage improvement in compressive strength when CSF is added with contents (0.4 percent), was enhanced by increasing the (W/GP) ratio (from 0.55 to 0.65).

3. The compressive strength diminishes in comparison to the references mixtures when the (W/PG) ratio is increased from 0.55 to 0.65. This behaviour is consistent for the two CSF content levels (Vf=0.0 and 0.4 percent).
4. The percentages of decreased compressive strength when the (W/PG) ratio is increased from 0.55 to 0.65,are reduced in the presence of CSF.
5. The density decreases in comparison to the reference mixtures (i.e., Mix 1 and Mix 3) when CSF is employed (Volume Fraction content Vf=0.4 percent), and this behaviour is consistent across two (W/PG) ratios.
6. In comparison to the reference mixtures (Mix 1 & Mix 2), the percentage of decreased density when CSF is introduced at a content of (0.4 percent), decreases as the (W/PG) ratio increases from 0.55 to 0.65.
7. The density decreases as the (W/PG) ratio increases from 0.55 to 0.65 in comparison to the reference composites. This behaviour is consistent with the two chopped sisal fiber content (Vf=0.0 and 0.4percent).
8. As the (W/PG) ratio rises from (0.55 to 0.65), the reductions in density percentages diminish when chopped sisal fiber is incorporated.

Acknowledgements, Authors wish to acknowledge Mustansiriyah University / Baghdad / Iraq. [www.uomustansiriyah.edu.iq].

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