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# THE INFLUENCE OF CHOPPED COPPER FIBRE (CF) ON THE IMPROVEMENT OF PURE GYPSUM BY COMPRESSIVE STRENGTH

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This study investigates the efficacy, performance, and effect of chopped Copper Fibre (CF) on a Pure Gypsum (PG) mixture. The Copper Fibre (CF) is extracted from the waste of electrical wires that are considered as environmental waste. Three models of Copper Fibre (CF) with a diameter of 0.83 (mm) and lengths of 10 (mm), 20 (mm), and 30 (mm) (Aspect-Ratio  $L/d = 12, 24$  and  $36$  respectively), with Volume Fraction (V.f.) for Copper Fibre (CF) by two Water/Gypsum Ratios (W/G) worth (0.5 and 0.6) are created. The mixtures are divided into two groups of W/G ratios. Each group contains four samples, one reference without Copper Fibre (CF) and the other three with the addition of Copper Fibre (CF) individually with different lengths. The results show that adding Copper Fibre (CF) to the Pure Gypsum (PG) mixture increases the Compressive Strength. Further, the effect is to heighten the Compressive Strength of Pure Gypsum (PG) when the Aspect-Ratio is raised. In other words, when the (W/G) Ratio is reduced, the Compressive Strength increases in the presence or absence of Copper Fibre (CF). Moreover, the efficiency of the Copper Fibre (CF) develops further when the W/G ratio is decreased.

**Key words:** environmental waste, copper fibre (CF), pure gypsum (PG), (L/d) aspect-ratio, compressive strength, volume-fraction of CF (V.f.)

## INTRODUCTION

Gypsum substance (calcium sulphated hydrate,  $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ) is necessary for most building applications. It is popularly available as a binder, in boards and precast parts, indoor finishing work and walls for Acoustic Isolation [1-2]. Gypsum has multiple excellent features such as a readily formed process, volumetric stability, affordable cost, fire and thermic protection, engaging design, reduced density and simply made [2-3]. Gypsum is used as a support material in medicine and dentistry [4]. Concrete admixtures use gypsum to delay timing for setting in cement and ceramic casting [5]. According to various experimental research studies [6-17], the addition of substances such as fly ash, gum tree powder, silica fume, clay, polyvinyl chloride, cork, Portland, and minerals to a mixture may support the developmental properties of the gypsum matrix. This is true in terms of the physical and chemical aspects appearing in the actual effects of its hardening and fresh characteristics. Regarding the use of strengthening substances, a good deal of research demonstrates the relevance of including various fibres in gypsum mixtures [3, 18-23]. This is because the fibres increase the gypsum tensile strength and shape stability to support the mixture to reduce degradation and breakdown. Many researchers have studied the effect of even more substances such as steel fibre or chipped carbon fibres to reinforce a concrete mix, cement mortar, and

asphalt concrete admixtures [24-32]. The current work proposes to design Pure Gypsum (PG) of unique fibres that strengthen as a composite form by use of compact and ductile copper fibres haphazardly scattered in the gypsum. Copper fibres present high ductility [33] to improve problematic brittle material fractures to become ductile fractures and also block the tendency to pull-out from the gypsum. Therefore, this work adopts copper fibres as an additive to gypsum.

## RESEARCH OBJECTIVES

The objectives of this research are to:

- Test and study the potential of adding for the first time copper fibres extracted from environmental waste to pure gypsum as an environmental sustainable form.
- Study the effect of copper fibre on a pure gypsum mixture and discover if it has the ability to improve Compressive Strength.

## MATERIALS AND METHODS

### Pure Gypsum (PG)

Essentially Pure-Gypsum (PG) is used in this investigation as pure calcium sulphate hemihydrate-gypsum ( $\text{CaSO}_4 \cdot 1/2\text{H}_2\text{O}$ ), which is available locally.

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### Chopped Copper Fibre (CF)

Waste electrical wiring is considered an environmental waste, which is the material used in this study. After electrical work is performed for buildings, the wires are gathered from the waste materials. The standard properties that apply to copper wire are "BS. EN. 50525-2-31" and "IEC. 60227-3", with 9810 Kg/m<sup>3</sup> density, 70 MPa Yield Strength, 220 MPa Ultimate Strength [34]. The Single Core Stranded wires used in this work have a total diameter of 4 mm, and after stripping the rubber outer insulation, they produce seven wires with a combined diameter of 3.2 mm. To create a suitable model for the fibre-forming electrical conductors, the seven-wires were modelled as a single wire with a diameter of 0.83 mm. Then the copper wires are divided into three groups with different lengths, so that the length of each group is one of 10 mm, 20 mm, or 30 mm individually. The Aspect-Ratio (L/D) will be (12, 24, and 36 consecutively) as shown in Figure 1. The Aspect Ratio may be defined as the ratio between the length and diameter of the copper wire.

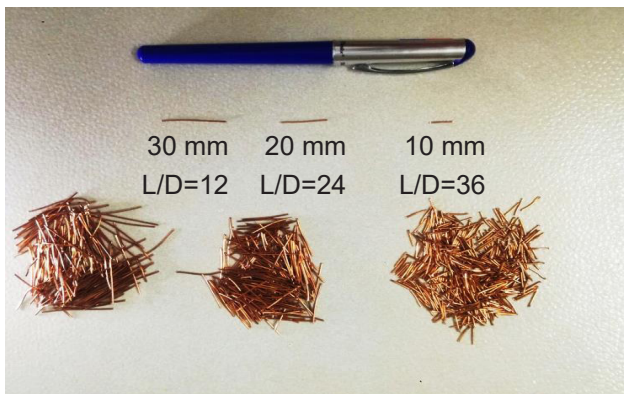


Figure 1: Copper Fibre (CF)

### The mixing water

The pure gypsum mixture utilises tap water to perform this work.

### Pure Gypsum Mixes

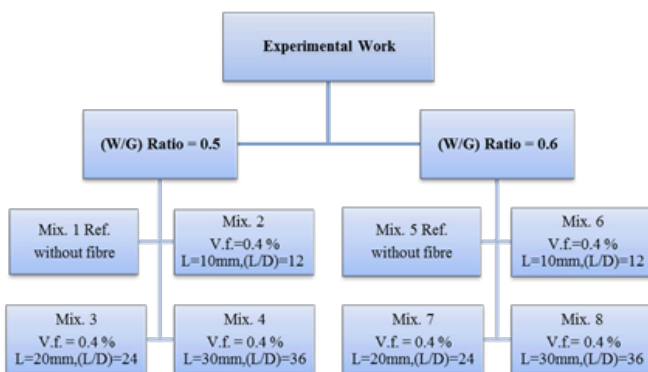


Figure 2: Experimental Work Plan

The experimental plan contains eight mixtures separated into two sets with the (W/G) ratio fixed at (0.5 and 0.6). Each set comprises of four mixtures containing one reference mixture without copper fibre and three mixtures containing three individual models of copper fibres (V.f. = 0.4). The 0.83 mm diameter copper fibre model employs 10 mm, 20 mm, and 30 mm individual lengths of each model (with an Aspect ratio equal to 12, 24, and 36 consecutively), as detailed in Figure 2 and Table 1.

Table 1: Details of mixes

Mixture No.	Volume Fraction, (Copper Fibre) (V.f.) %	Length of Copper Fibre (L) mm	Diameter of Copper Fibre (D) mm	Aspect Ratio (L/D)	(W/G) Ratio
1.	0.0	None	None	None	0.5
2.	0.4	10	0.83	12	0.5
3.	0.4	20	0.83	24	0.5
4.	0.4	30	0.83	36	0.5
5.	0.0	None	None	None	0.6
6.	0.4	10	0.83	12	0.6
7.	0.4	20	0.83	24	0.6
8.	0.4	30	0.83	36	0.6

### Mixing procedure

The mixing process starts with the weight of Copper Fibre (CF) equivalent to the Volume Fraction (V.f.) of 0.4 %, then mixed with the amount of Pure Gypsum (PG) required for mixing (dry mixing) until the Copper Fibre (CF) is homogeneous with the Pure Gypsum. After that, water is added according to the W/G ratio (0.5 or 0.6). The mixture is mixed and placed in cubic moulds of (50 × 50 × 50) mm. After completing the hardening phase, the Pure Gypsum (PG) mixture is removed from the moulds and exposed for 30 hours to a heat source with a temperature of 45 °C. The reference mixtures use the same previous steps but without Copper Fibre (CF).

### Testing programme

All tests are performed at the College of Engineering using the tools and a series of test machines of the MUSTANSIRIYAH UNIVERSITY laboratories known as the "Structural Materials Laboratory".

### Compression strength

The samples are tested with a cubic size of 50 mm conducted for 36 hours to investigate the compressive strength using the standard ASTM: C472-99 applied to the tests [35].

**RESULTS AND DISCUSSION**

**The effect of the Aspect Ratio of differing lengths for Copper Fibre (CF) on Pure Gypsum (PG) through testing Compressive Strength with varying W/G ratio.**

Figure 3 and Table 2 show the effect of the Aspect Ratio of differing lengths for Copper Fibre (CF) on Pure Gypsum (PG) through testing Compressive Strength with varying W/G ratios (0.5 and 0.6). The test result presents a cumulative increase in the value of Compressive Strength in pure gypsum (PG) mixtures containing copper fibres. This increase is perhaps because of the presence of CF (Copper Fibres). This increase means the Copper Fibres work to delay the appearance of cracks and to reduce the speed of their growth. In addition, the result shows the effectiveness of the Copper Fibre (CF) increases with an increase in the Aspect Ratio, which arises from the increase of the length of the Copper Fibre (CF) for both W/G ratios (0.5 and 0.6). Perhaps this behaviour is developed by increasing the length of the Copper Fibre length, so the possibility of the Copper Fibre (CF) pulling out is reduced.

Table 2: Effect of Aspect-Ratio (differing lengths) of Copper Fibre (CF) on the Compressive Strength for Pure Gypsum (PG) with varying (W/G) ratio

Mixture No.	W/G (ratios)	Volume Fraction of Copper Fibre (V <sub>f</sub> ) %	Length of Copper Fibre (L) mm	Aspect-Ratio (L/D)	Compressive Strength (MPa)	Increasing Percentage (%)
1.	0.5	0.0	Non	Non	12.03	-----
2.	0.5	0.4	10	12	15.90	32.2
3.	0.5	0.4	20	24	18.22	51.5
4.	0.5	0.4	30	36	22.26	85.1
5.	0.6	0.0	Non	Non	8.97	-----
6.	0.6	0.4	10	12	9.11	1.6
7.	0.6	0.4	20	14	10.01	11.6
8.	0.6	0.4	30	36	11.86	32.3

**Water Gypsum ratio effect on Compressive Strength of Pure Gypsum (PG) by varying Aspect Ratios.**

Figure 4 and Table 3 show the influence of changing the Water Gypsum ratios on the Compressive Strength of the Pure Gypsum (PG) with the variable Aspect Ratios (variable length) of the Copper Fibre (CF).

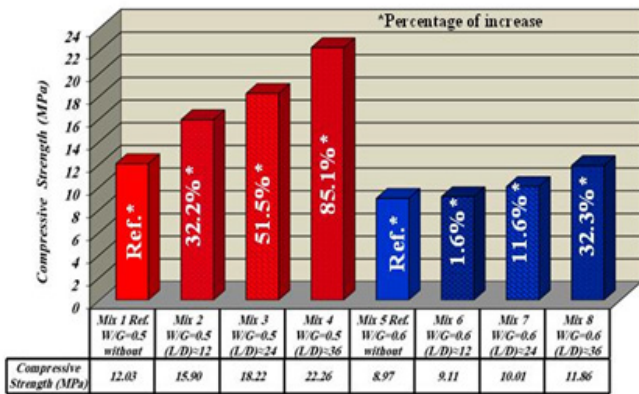


Figure 3. Effect of Aspect-Ratio (differing lengths) of Copper Fibre (CF) on the Compressive Strength for Pure Gypsum (PG) with varying (W/G) ratio

The effect of the Copper Fibre (CF) (for all Aspect Ratios or lengths) is active in improving the Compressive Strength of the Pure Gypsum (PG), which increases very significantly when the W/G decreases. The most likely explanation is that a decrease in the Water Gypsum ratio drives an improvement in cohesion and adhesion between the Pure Gypsum (PG) and the Copper Fibre (CF), which leads to a scaling down and reduction of the hypothesis of pulling the Copper Fibre (CF) from the Pure Gypsum (PG).

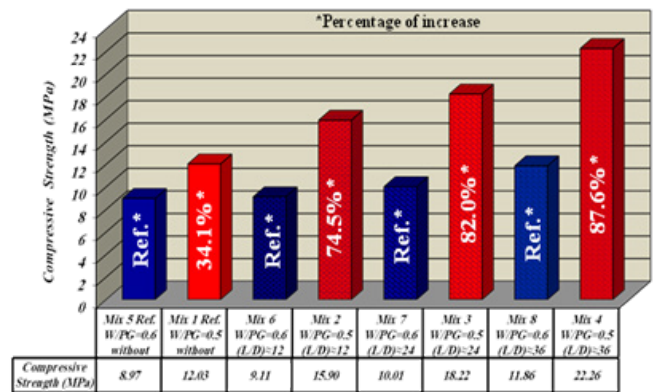


Figure 4. Effect of Water Gypsum ratio on Pure Gypsum (PG) Compressive Strength values with the variable Aspect Ratios (variable length) of the Copper Fibre (CF)

The decrease in the Water Gypsum ratio may help to increase the Compressive Strength value. This increase in behaviour applies in the presence or absence of the Copper Fibre (CF) in the mixture. This increase occurs in mixtures that contain Copper Fibre (CF), which increases when the Aspect ratio is increased by increasing the length of the copper fibre.

Table 3: Effect of Water Gypsum ratio on Pure Gypsum (PG) Compressive Strength values with the variable Aspect Ratios (variable length) of the Copper Fibre (CF)

Mixture No.	W/G (ratios)	Volume Fraction of Copper Fibre (V.f.) %	Length of Copper Fibre (L) mm	Aspect-Ratio (L/D)	Compressive Strength (MPa)	Increasing Percentage (%)
5.	0.6	0.0	Non	Non	8.97	-----
1.	0.5	0.0	Non	Non	12.03	34.1
6.	0.6	0.4	10	12	9.11	-----
2.	0.5	0.4	10	12	15.90	74.5
7.	0.6	0.4	20	24	10.01	-----
3.	0.5	0.4	20	24	18.22	82.0
8.	0.6	0.4	30	36	18.86	-----
4.	0.5	0.4	30	36	22.26	87.6

### CONCLUSION

1. The addition of Copper Fibre (CF) to Pure Gypsum (PG) increases the compressive strength, and it rises even more when the Aspect Ratio (increase the length of copper fibre) is increased.
2. Copper Fibre (CF) works to enhance the Compressive Strength of the Pure Gypsum (PG) by increasing the Compressive Strength when the W/G ratios are reduced for all Aspect Ratio values (12, 24, and 36).
3. By decreasing the Water Gypsum ratio, the Compressive Strength increases with or without Copper Fibre (CF) in the mixtures.
4. The effect of reducing the Water Gypsum ratio on the Compressive Strength of gypsum in mixtures containing Copper Fibre (CF) (V.f. = 0.4) is already increased (at item 3 above) but rises even more when the Aspect Ratio increases (the length increases).

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#### **Nomenclature**

(W/G) Water/Gypsum Ratios  
L/d Aspect-Ratio

#### **Abbreviations**

CF Copper Fibre  
PG Pure Gypsum  
V.f. Volume Fraction

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