FABRICATION OF GYPSUM MATRIX COMPOSITE PANELS

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ABSTRACT

One of the most common problems of using gypsum panels is their low strength, as well as their low toughness in comparison with those of ordinary walls, and also their low impact resistance especially at the time of earthquakes, which confines their usage in buildings. In the past decades, thin fibers of different dimensions have been used to decrease the brittleness of ceramic materials. The positive effect of short fibers in a great variety of composite systems with polymer, metal or ceramic matrices have been proved [1]. There are different types of fibers used to reinforce ceramic materials, such as plastic fibers and fiberglass, which are produced in different shapes and sizes. In the current study, short polymer fibers have been used to reinforce gypsum panels. Triple point bending test has been used to determine the effect of the addition of polymer fibers on the mechanical properties of the resulting composites.

1. INTRODUCTION

The usage of gypsum panels is confined due to their low strength and toughness in comparison with those of ordinary building material, and also their low impact resistance especially at the time of earthquakes. There are different ways to strengthen gypsum panels, but it should be noted that these methods must not increase the costs of production processes or result in high weight of the product. In the past few decades, thin fibers of different dimensions with a homogenous and irregular distribution in the matrix have been used to decrease the brittleness of ceramic materials and to produce isotropic conditions. Such usage of fibers has an ancient history. It is now decades that materials reinforced with short discontinuous fibers are being studied. The positive influence of short fibers in a great variety of composite systems with different matrix materials including polymers, metals or ceramics have been proved [1].

Different types of fibers are used to reinforce ceramic materials, such as plastic fibers and fiberglass. These fibers are produced in different shapes and sizes. Gypsum-matrix composites are now being extensively used in building applications. That is because of their low density, low cost and simple fabricating processes. In most countries, wood filings are used to reinforce gypsum [2]. Olivares et al. have proven the effective interaction between cork grains and the gypsum matrix in cork-gypsum composites. Such composites have lower density than unreinforced gypsum, but fiberglass should be added to the composite in order to obtain better mechanical properties [3]. Li et al. have investigated the positive effect of adding cotton stalk fibers to gypsum, which results in better mechanical properties [2]. Rio Merino et al. have also used cork granules to lower the density of gypsum panels and improve their mechanical properties [4].

Taking the results of previous researches into consideration, polymer fibers of 12 mm length and with volume percentage of 2.5 have been chosen in this research to strengthen gypsum panels.

2. EXPERIMENTS

To fabricate the panels with dimensions of $66.6 \times 50 \times 7$ cm, building gypsum was used as the matrix material, while two different types of reinforcing fibers were used to

reinforce the panels: polypropylene (PP) and Kevlar fibers. The characteristics of these fibers are given in Table 1.
Three types of samples were prepared for the triple point bending test:
(a) Unreinforced gypsum panels: No fibers were used in these panels. To fabricate these simple panels, water and gypsum were mixed together with equal proportions before being introduced into the panel mold.
(b) Gypsum composite panels reinforced with Kevlar fibers: these panels were fabricated by adding 2.5 volume percentage of Kevlar fibers to simple panels. The distribution of fibers in the panel was absolutely irregular and without any specific order.
(c) Gypsum composite panels reinforced with PP fibers: these panels were produced the same way as the previous composite panels. Polypropylene short fibers were used in these panels instead of Kevlar fibers.

Table 1: Properties of Kevlar and PP fibers.

Fiber	Diameter	Density (gr/cm^3)	Modulus Of Elasticity (GPa)	Tensile Strength (GPa)
Kevlar	0.5 mm	1.44	131	2.8
PP	35 μ	0.95	1.3	1.7

The samples then underwent the triple point bending test. According to the standard, to perform the test, three panels of each type would be needed. Before the test, panels were heated in an oven under the temperature of 40 ± 2 to become absolutely dry, and to make sure their weight would be constant and would not change due to water evaporation.
To determine the bending resistance of the panels, they were laid horizontally upon the two bars shown schematically in Figure 1. The distance between each bar and the edge of the panel was 50mm. The load was applied slowly and gradually to the panel by a 20mm wide bar placed across the panel and in the middle of it. Loading rate was about $2\,kg.s^{-1}$. The load causing the piece to fail is called *bending failure load*.

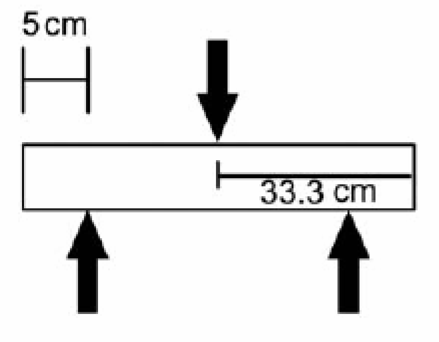


Figure 1: Schematic plan of triple point bending test setup.

3. EXPERIMENTAL RESULTS

Unreinforced gypsum panel was tested first. As expected before, the panel was broken into two pieces at the time of failure due to its ceramic nature. Figure 2 illustrates the load-displacement diagram of these panels.

The load-displacement diagrams for gypsum composite panels reinforced with Kevlar and PP fibers are shown in Figure 3 and Figure 4, respectively. At the time of failure, the two pieces were not completely separated from each other in these panels, and were held together by the fibers.

Some properties of the tested panels are briefly shown in Table 2.

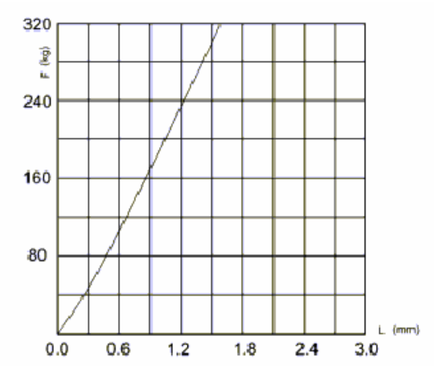


Figure 2: Load-displacement diagram of the unreinforced gypsum panels.

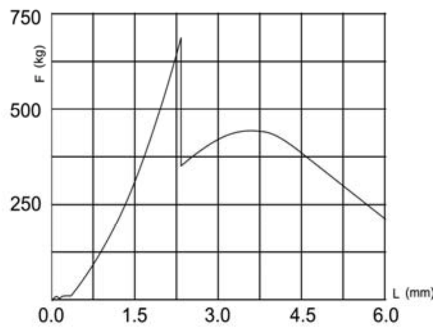


Figure 3: Load-displacement diagram for the gypsum composite panel reinforced with Kevlar fibers.

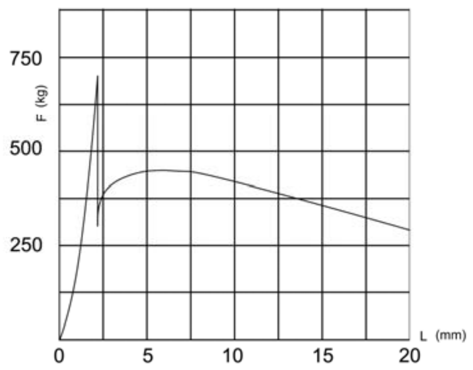


Figure 4: Load-displacement diagram for the gypsum composite panel reinforced with PP fibers.

Table 2: Properties of unreinforced and composite gypsum panels resulted from bending test.

Type of Panel	Maximum Load (kg)	Tolerated Load After Matrix Failure (kg)	Total Absorbed Energy (J)	Fiber Consumption (g)
Unreinforced Panel	320.0	0	2.43	0
Composite Panel With PP Fibers	708.0	280	110.10	530
Composite Panel With Kevlar Fibers	690.0	350	19.95	840

4. DISCUSSION

The fracture mechanism in the unreinforced panel is absolutely brittle; that is, the panel is divided into two separate pieces immediately after the occurrence of fracture. These panels show no resistance against the applied load.

In gypsum composite panels, as can be seen in corresponding diagrams, the amount of load drops after the initial fracture, but increases again, as loading continues, until it reaches a maximum. After that, it begins to approach zero with a specific slope, where final fracture occurs and the panel breaks into two pieces. The ultimate strength of the composite panel with Kevlar fibers is more than twice the ultimate strength of the composite panel reinforced with PP fibers.

The increase in the ultimate strength happens because the gypsum matrix has been reinforced with polymer fibers. The material forming the matrix, i.e. gypsum, is brittle. In the presence of the fibers, a noticeable part of the applied stress is transferred to them; hence the ultimate strength rises. In this case, the site of crack initiation is either the matrix or the matrix-fiber boundary.

After the maximum point, the matrix fails and crack grows inside it. In such a situation, what holds the two separate pieces of the panels together are the polymer fibers which act as small bridges between the two pieces (see Figure 5). The mechanical bond between the polymer and gypsum prevents full separation of the two panel pieces.

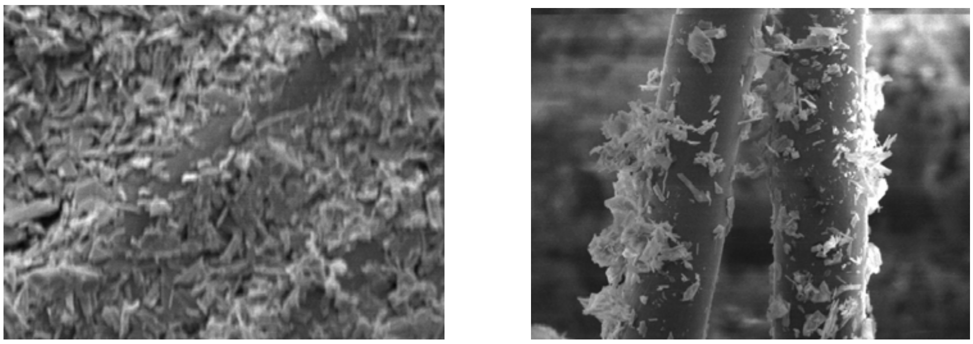
Figure 5: Polymer fibers act as small bridges between the two pieces of the broken panel.

The area under the load-displacement of composite panels is much higher than that of the unreinforced panel, which indicates their higher toughness. The fibers are *pulled out* of the matrix under the applied force. This energy consuming process results in high toughness.

A closer look at the load-displacement diagrams of Kevlar and PP reinforced composites indicates that, after the crack initiation, the strength of the Kevlar-reinforced composite panel is more than that of the composite panel reinforced with PP fibers. After crack initiation, the load is tolerated only by the fibers and the friction force between fibers and the matrix. Although PP fibers have a higher interface area with the matrix, they show lower resistance against the applied load while the friction force only bears the load. This shows that the bond between gypsum and Kevlar fibers is stronger than the bond between gypsum and PP fibers. The reasons for this observation are:

- Smooth surface of PP fibers lowers the friction between them and gypsum.
- Kevlar has polar molecules, which have a high affinity to form bonds with polar molecules of gypsum.

Microscopic analysis approves this observation (see Figure 6).



(a) (b)

Figure 6: Polymer fibers in the gypsum matrix: (a) Kevlar fibers and (b) PP fibers.

A comparison between Figure 3 and Figure 4 shows that he absorbed energy by Kevlar composite panels and PP composite panels are also different. The toughness of the composite panel with PP fibers is more than that of the composite panel with Kevlar fibers. It can be a result of a better distribution of PP fibers in the gypsum matrix, which in turn, is because of the higher number of the PP reinforcing fibers in comparison to Kevlar fibers. Better distribution leads to a higher number of fibers which can prevent crack growth and separation of the two pieces of the panel. In this case, separation of a PP fiber has less influence on the panel strength than a Kevlar fiber; thus the descending slope of the diagram decreases and the area under the diagram increases.

5. CONCLUSIONS

1. Using polymer fibers (polypropylene and Kevlar fibers) distributed homogenously in gypsum panels, increases the bending strength and also the toughness of these panels.
2. Although PP fibers have less adhesion to the matrix, panels fabricated using these fibers were tougher due to small diameter and better distribution of PP fibers.
3. Composite panels reinforced with PP and Kevlar fibers demonstrate a high strength, almost twice that of unreinforced panels.
4. High strength, high toughness, flexibility, resistance against crack growth, and elastic behavior after being unloaded are important characteristics of gypsum composite panels, which can play an important role in safety at the time of earthquakes.

REFERENCES

1- Toutanji H. A., “Evaluation of the Tensile Strength of Cement – Based Advanced Composite Wrapped Specimens”, *Composite science and Technology*, 1999; 59: 2261-2268.

2- Li G., Yu Y., Zhao Z., Li G., Li C., “Properties study of cotton stalk fiber/gypsum composite”, *Cement and Concrete Research*, 2003; 43-46.

3- Hernandez Olivares F, Bollati M.R, del Rio M, Parga-Landa B., “Development of cork-gypsum composites for building applications”, *Construction and Building Materials*, 1999; pp. 179-186.

4- Rio Merino M., Santa Cruz Astorqui J., Hernandez Olivares F., “New prefabricated elements of lightened plaster used for partitions and extrados”, *Construction and Building Materials*, 2005; pp. 487-492.