

Enhancing the Flexural Strength of Perlite/Gypsum Composite Panels and Their Sandwich Structures using Gypsum Layer

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ABSTRACT

In gypsum/perlite composite panels, due to incorporation of lightweight expanded perlite particles, the flexural properties are affected negatively. To address this issue, the flexural strength of gypsum/perlite composite panels and their sandwich structures with a gypsum surface layer was investigated in this work. The perlite contents of the composite were varied (40 g, 60 g and 80 g for each 390 g of gypsum) to manufacture the composites. A single gypsum layer was given on one side of the gypsum/perlite composite panels to improve the flexural strength. The sandwich structures with and without gypsum layer were fabricated by attaching formica sheet skins on both sides of the panels. Results show that the density reduced with more perlite content, making the panels lightweight and slightly increased due to addition of gypsum layer. Flexural testing revealed that pure gypsum panels had the maximum flexural strength while, with the increase of perlite in the matrix, the flexural strength decreased. Introducing the gypsum layer improved the flexural strength for these panels. Introducing formica sheet skins to the panels improved their flexural strength significantly. However, the best result was obtained for the sandwich panels using the gypsum layer in the gypsum/perlite composite core. The findings of this work show the method of improving the flexural strength of gypsum/perlite composite panels without losing the lightweight properties significantly.

Keywords: Gypsum, Perlite, Reinforcement Layer, Sandwich Structure, Flexural Properties.



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1. Introduction

Gypsum and perlite possess distinct properties that is specifically attractive for building applications. Gypsum is renowned for its fire resistance, excellent binding capabilities, and thermal insulation properties [1]. Meanwhile, perlite exhibits remarkable attributes such as low density, low thermal conductivity, inertness, and high porosity [2, 3]. The combination of these materials holds the promise of creating a versatile, eco-friendly building material that can be effectively utilized in building wallboard applications. Incorporation of perlite in the gypsum results in a lightweight building board but the flexural properties decrease to some extent [4]. This paper addresses the method for improving the flexural properties of perlite-incorporated gypsum/perlite composite panels without losing the lightweight properties significantly.

Improvement of mechanical properties of gypsum with the incorporation of various fillers is an ongoing. Utilization of various fillers, e.g., jute fiber [5], vermiculite [6, 7], expanded perlite [1, 4, 8, 9], seagrass [10], expanded clay [1, 6], glass microsphere [11], etc. in gypsum leads to improvement in mechanical and thermal properties. Some lightweight fillers contribute to the improvement in thermal conductivity and density with a loss in mechanical properties.

Recently, Karua and Arifuzzaman [4, 8, 9] revealed that the incorporation of perlite decreases the flexural strength of gypsum but the gypsum board showed improvement in terms of density and compressive strength. They have also showed that sandwiching the gypsum/perlite composites with brown paper enhances the flexural strength significantly. When expanded perlite is used as filler in gypsum the decrease in flexural strength of the resulting board is attributed to the particles cellular structure. So, the hypothesis of this work is

that if a gypsum layer is added in the tension side of the gypsum/perlite boards the flexural strength would improve because of the continuous gypsum matrix that would add additional strength to the composite panels. The reason for this is that when the gypsum/perlite boards are subjected to the bending load the failure occurs at the tension side of the sample. For the same reason, if the boards are sandwiched between the stiff skins the bending strength would further be enhanced.

Therefore, in this work, gypsum/perlite composite panels with and without additional gypsum layer were manufactured for various perlite contents to investigate the effect of gypsum layer on the flexural strength. Also, formica sheet (a paper based thin sheet used in furniture industries) was used to fabricate sandwich structure utilizing gypsum/perlite composite with and without gypsum layer to investigate the effect of gypsum layer as well as sandwiching on the flexural strength of the sandwich structures.

2. Materials and Method

Natural gypsum, a naturally occurring form of calcium sulfate, is most commonly found as dehydrate ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) and anhydrite (CaSO_4). Gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) was purchased from Shahenoor Chemicals, Dhaka in powdered form. Lightweight expanded perlite of particles of size 2-3 mm was purchased for King Caster Perlite, China and used as filler in the gypsum. Formica sheet was purchased from local store to manufacture sandwich using gypsum/perlite composite as core. Epoxy resin (Lapox) with hardener was purchased from GlarosBD, Dhaka and the manufacturer recommended epoxy to hardener ratio is 2:1. Citric acid was collected from local stores and used with distilled water to delay the curing of the

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gypsum so that the mixing can be done properly before the curing starts.

2.1 Sample manufacturing

A mold with a 300 mm × 300 mm × 10 mm inner dimension was made using particle board to manufacture the gypsum/perlite composite panels. The mix proportion of the composites is given in Table 1.

Table 1 Mix proportion of gypsum/perlite composites with and without an additional gypsum layer.

ID	Gypsum, g	Water, g	Perlite, g	Citric acid, % of water
PG			0	
GPC_40-P			40	
GPC_60-P			60	
GPC_80-P	390	300	80	0.025
GPCL_40-P			40	
GPCL_60-P			60	
GPCL_80-P			80	

The citric acid was mixed with the required amount of water to retard the reaction for proper mixing of the gypsum and perlite with water. For pure gypsum sample (PG), the gypsum was mixed with the water for about 2 minutes and placed in the mold. The curing process for all samples was 2 hours at room temperature followed by drying in the oven at 80° until the weight loss became zero. For expanded perlite filled gypsum/perlite composites, the expanded perlite particles were added to the mixture of water and gypsum and mixed for another 3 minutes and the slurry was poured into the mold for curing. For samples with additional gypsum layer, firstly, 250 g gypsum was mixed with water and poured in the mold and partially cured for 1 hour then the mixture of gypsum/perlite/water was placed on top of the gypsum layer for manufacturing gypsum/perlite composites with a pure gypsum layer. For sandwich fabrication, the formica sheet was attached on both sides of all composite panels in Table 1 using epoxy resin as adhesive. Some photographs of the cross section of pure gypsum, gypsum/perlite composites, and gypsum/perlite composites with additional gypsum layer and their sandwiches are shown in Fig. 1.

2.1 Flexural test method

The width of the flexural test specimens was 30 mm. Three point bending test was conducted in the Universal Testing Machine (Shimadzu AGX 300kNV) at a crosshead speed of 5 mm/min according to ASTM D 393. The diameters of the loading and support rollers were 10 mm and 35 mm respectively. The flexural strength and modulus were determined for all composites panels.

3. Results and Discussion

The densities of pure gypsum (PG), PG core-based sandwich (PGS), gypsum/perlite composites (GPC), GPC core-based sandwich (GPCS), gypsum/perlite composites with additional gypsum layer (GPCL), GPCL core-based sandwich (GPCLS) are given in Fig. 2. The PG showed the maximum density because of the high density of gypsum. It is seen that the densities of the GPCs, GPCLs, GPCs, and GPCLSs decreased with the increase in perlite content in the composite. The reason for the drop in density is the incorporation of lightweight cellular expanded perlite particles in gypsum. The densities of the sandwich structures

i.e., PGS, GPCS, and GPCLS are greater than the respective densities of the PG, GPC, and GPCL because of attaching formica sheet skins.

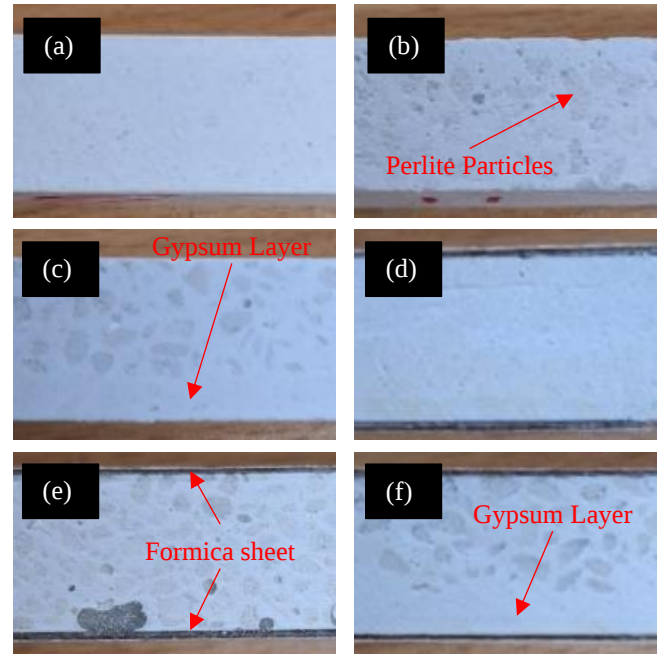


Fig.1 Cross section of the fabricated samples: (a) Pure gypsum (PG), (b) Gypsum/perlite composites (GPC), (c) Gypsum/perlite composites with additional gypsum layer (GPCL), (d) Sandwich with PG (PGS), (e) Sandwich with Gypsum/perlite composites (PGCS), and (f) Sandwich with Gypsum/perlite composites with additional gypsum layer (GPCLS)

Comparing the density of GPCs with GPCLs, it is seen that the density of GPCLs is higher because of the gypsum layer. It is also seen that the density of the GPCLs is still lower than the density of PG. The addition of 80 g perlite in gypsum caused a 32.69 % and 30.77 % reduction in the density of GPC (80-P) and GPCS (80-P) respectively compared to PG and PGS. The density of GPCL (80-P) and its sandwich GPCLS (80-P) showed 17.31 % and 19.66 % decrease compared to respectively PG and PGS. The observation indicates that the incorporation of perlite particle contributes to decreasing the density of both gypsum/perlite composites with and without additional gypsum layer and their sandwich structures.

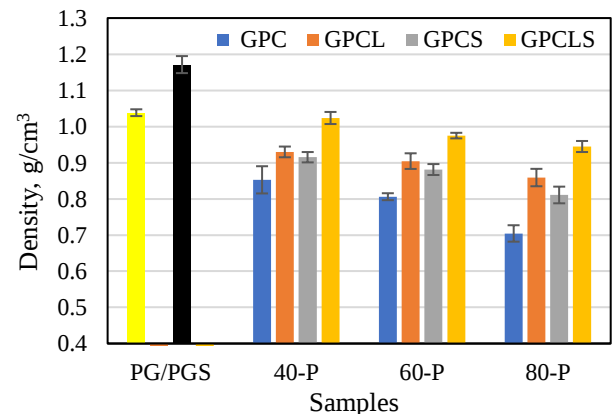


Fig.2 Density of gypsum/perlite composite panels and their sandwich structures.

The flexural strengths of PG, GPCs, and GPCLs are given in Fig. 3. The flexural strength decreased with the

incorporation of perlite in gypsum. For both GPC and GPCL, the flexural strength decreased with increasing perlite content. However, the flexural strength of GPCLs is greater than GPCs for all perlite content indicating the effectiveness of adding additional gypsum layer. For 40-P, 60-P, and 80-P, the flexural strengths of GPCLs are respectively 13.83 %, 20 %, and 20 % greater than respective GPCs. The flexural strength of GPC (40-P) is 26.39 % lower than PG but the flexural strength of GPCL (40-P) is only 16.20 % lower than PG.

The flexural strengths of the sandwiches made of PG, GPC, and GPCS are given in Fig. 4. The flexural strength of GPCS, GPCLS also decreased with increasing perlite content as expected since the failure was initiated at the core. However, the flexural strengths GPCLSs are significantly greater than GPCSs due to addition of gypsum layer.

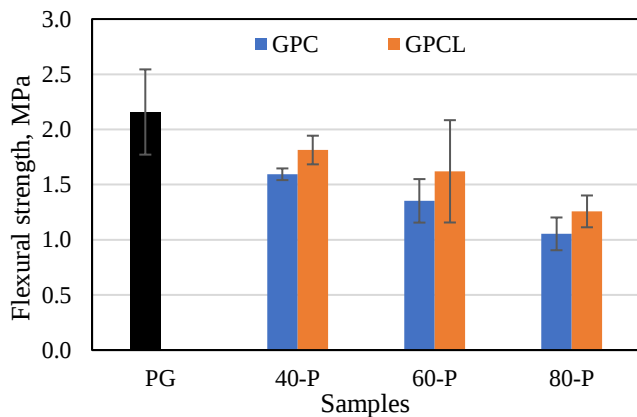


Fig.3 Flexural strength of gypsum/perlite composites for various perlite content with and without additional gypsum layer.

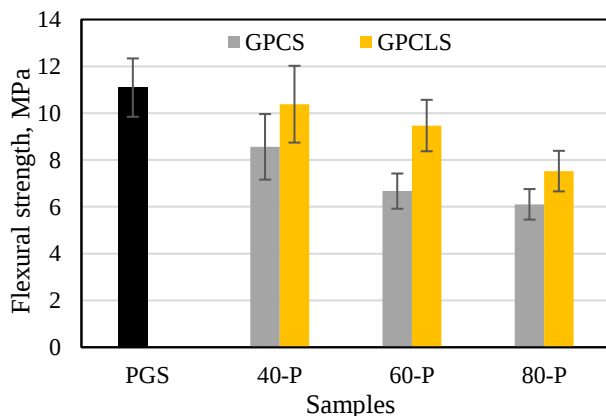


Fig.4 Flexural strength of sandwich structures made of gypsum/perlite composite cores with and without additional gypsum layer.

For 40-P, 60-P, and 80-P, the flexural strength GPCLSs are respectively 21.26 %, 41.98 %, and 23.24 % greater than respective GPCSs. The flexural strength of GPCS (40-P) is 22.81 % lower than PGS but the flexural strength of GPCLS (40-P) is only 6.40 % lower than PGS. The observation is again indicating the effectiveness of adding additional gypsum layer in GPC. It is also seen that the flexural strength of gypsum composites can be increased significantly by sandwiching them using stiff skins. By sandwiching, the flexural strength of PG is increased by 5.13 times. The

minimum flexural strength of sandwich (GPCS for 80-P) is found to be 2.83 times greater than that for PG.

The specific flexural strength is the measure of flexural strength per unit density of the specimen. The specific flexural strengths of PG, GPC, and GPCL are given in Fig. 5. It is seen that the specific flexural strength also decreased with increasing perlite content in gypsum composites for both GPC and GPCL.

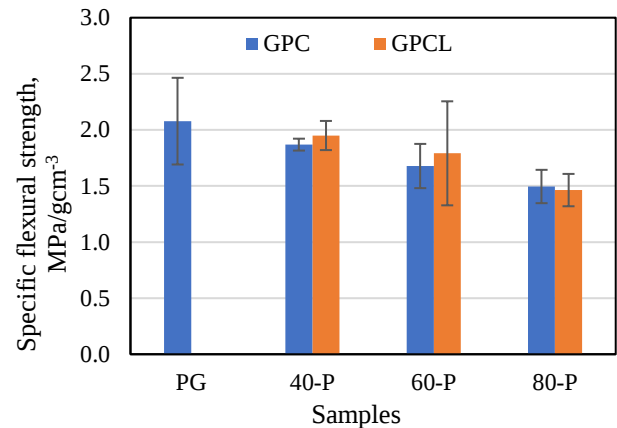


Fig.5 Specific flexural strength of gypsum/perlite composites for various perlite content with and without additional gypsum layer.

However, the specific flexural strengths of GPCLs are greater than GPCs suggesting improvement due to the addition of gypsum layer. At 40-P, the specific flexural strengths of GPC and GPCL are only 10 % and 6.25 % lower than PG which is insignificant indicating the effectiveness of perlite filling in gypsum.

The specific flexural strength of PGS, GPCSs, and GPCLSs are given in Fig. 6. Again, the specific flexural strength decreased with increasing perlite content for both GPCSs and GPCLSs. The specific flexural strengths of GPCLSs are significantly greater than corresponding GPCSs indicating the improvement due to addition of gypsum layer. It is interesting to see that the specific flexural strengths of GPCS (40-P), GPCLS (40-P), and GPCLS (60-P) are well comparable with PGS.

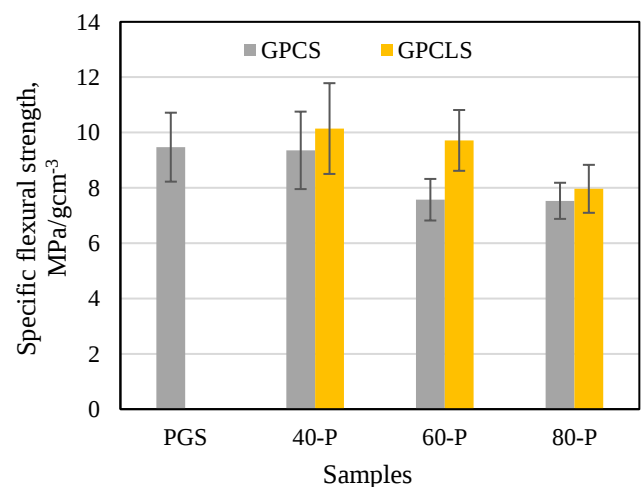


Fig.6 Specific flexural strength of sandwich structures made of gypsum/perlite composite cores with and without additional gypsum layer.

4. Conclusions

In this work, an effort was given to enhance the flexural strength of the gypsum/perlite composite using an additional layer of pure gypsum and sandwiching the composites using formica sheet as skins. The findings are summarized below.

- The addition of gypsum layer improved the flexural strength of gypsum/perlite composites but still it is lower than the pure gypsum.
- Sandwiching the gypsum/perlite composites using formica sheet as skin significantly enhanced the flexural strength of the composites.
- The specific flexural strengths of some gypsum/perlite composite core-based sandwiches are comparable with the pure gypsum core-based sandwiches.

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