Fabrication of Gypsum Panels with Low-Cost Alternative Materials

José de la Torre1, Luis Tapia2, Ernesto de la Torre2 and Sebastián Gámez2

1. Modular Q, Quito 170102, Ecuador
2. Department of Extractive Metallurgy, Escuela Politécnica Nacional, Ladrón de Guevara E11-253, Quito, Ecuador

Abstract: During decades, gypsum has been employed as construction material for its versatility and particle size. In the present work, the possibility of developing gypsum panels with the incorporation of pumice and polypropylene as alternative materials has been investigated. Pumice as well as polypropylene allows obtaining lighter panels than those on the market and with a lower production cost. Each one of these materials was characterized separately. In the case of gypsum and pumice, their granulometry, pH and humidity were determined, whereas polypropylene was characterized by a traction-deformation essay. Then, panels composition (gypsum and pumice concentration), particle size, water temperature and the way polypropylene was added, was assessed. Panels with a 70% of gypsum, with a particle size of 198 µm and with polypropylene added in a laminar fashion, presented a compressive strength of 350 kPa, which accords to the norm ASTM 1396 and with market requirements. Finally, it was proposed a block diagram of the process for the fabrication of 100 kg/day of formulated panels.

Key words: Panels, gypsum, pumice, polypropylene.

1. Introduction

In the home building industry, drywalls have demonstrated to be the most preferable solution worldwide. Between the main advantages of these panels, there is their low fabrication cost which is according to their materials and production volumes. One of these materials is gypsum which has been employed as construction material since XVII century. During that time, gypsum was used as ornamental element for building decoration. At the end of XIX century, gypsum was incorporated to civil architecture as construction material and as interior decoration element due to the production of laminated plasterboard which soon became indispensable for its low cost, easy installation, lightness and versatility [1]. In order to employ gypsum in all the mentioned applications, it is necessary that it has an ultra-fine particle size moreover when it is used as additive in cementation [2]. In the south of Ecuador, near the Valley of Malacatos and in the zone of Bramaderos, Loja Province, it is located the largest source of gypsum of the country. These stockpiles are capable to cover all the existing demand from cement and construction industry [3]. Similarly, in the Provinces of Santa Elena and Guayas, there are stockpiles whose exploitation provides sufficient quantities of gypsum for handicrafts and other minor applications. Other material necessary for gypsum panels fabrication is pumice. In Ecuador there is one of the ten largest pumice reservations of the world. For instance, the porous material founded in the mines of Cotopaxi Province is used for the fabrication of lightened blocks and handicraft of low economical yield. Nevertheless, because of pumice characteristics, it should be employed in a greater number of applications like concrete and panels construction. In that way, it could be solved effectively the house building problem of the country [4].

In order to obtain a lighter panel, it is necessary to increase the porosity of the material. However, other alternative to elaborate lighter plates, consists in adding
polypropylene fibers which are available on the market with low prices. This polymer has the suitable mechanical features to increase panels flexural strength which diminish significantly the risk of plate break [5]. This effect is important to consider especially when subjection ways are analyzed within construction industry.

In this work, it has been proposed a new formulation and procedure for the elaboration of gypsum-pumice-polypropylene panels. Pumice as well as polypropylene is considered as alternative materials in gypsum panels composition. In addition, one of the main purposes of this research is to improve gypsum panels features from those on the market which are 100% imported.

2. Materials and Methods

2.1 Materials

For the fabrication of the essay panels in the experimentation stage, it was employed the following raw materials: gypsum, pumice and commercial polypropylene.

2.2 Methodology

The study for panels fabrication can be divided in four stages: (1) Physical, chemical and mineralogical characterization of the raw materials, (2) Evaluation of pumice addition into panels, (3) Evaluation of the different ways that polypropylene can be added and (4) Determination of panels compressive strength.

2.3 Physical, Chemical and Mineralogical Characterization of the Raw Materials

For gypsum and pumice characterization it was determined: apparent density, real density [6] pH, humidity, granulometry [7].

Raw materials were first submitted to acid disintegration in a microwave to determine their chemical composition by atomic absorption spectroscopy on a Perkin Elmer S. Analyst 300 equipment. Mineralogical analysis was determined by X-ray diffraction using a Bruker D8 Advance equipment and the program EVA/TOPAS. Finally, polypropylene fibers were characterized through a traction-deformation essay according to the norm ASTM D882 [8].

2.4 Pumice Influence over Panels Composition

Panels were elaborated with gypsum, pumice and water mixtures on a 1:1 proportion, varying pumice concentration from 0%, 10%, 20%, 30%, 40% and 50%. Immediately, pumice particle size varied from 710, 600, 500, 425 and 355 µm. Water temperature of the mixture was assessed as well (10, 20, 30 and 50 °C).

2.5 Polypropylene Influence over Panels Composition

Once gypsum and pumice proportions were established on panels compositions; polypropylene fibers were added in tow manners: (1) laminar way and (2) in form of fragments with a particle size of 5 cm.

2.6 Panels Compressive Strength

Panels of sections 2.2.2 and 2.2.3 were assessed trough compression essays performed in the essay universal machine Tinius Olsen H25KS with test tubes elaborated according to the norm NTE INEN 1 688 [9].

3. Results and Discussion

3.1 Physical, Chemical and Mineralogical Characterization of the Raw Materials Results

Gypsum and pumice properties are presented in Table 1. It can be noticed that real density of gypsum and pumice are very similar. In the case of apparent density, which is more important for the calculation of the volume that occupies the raw material, pumice is less dense than gypsum due to its high porosity. Gypsum particle size is far smaller than pumice, which is advantageous since gypsum shows a greater adherence and plasticity in the mixture during panels preparation.

Gypsum and pumice pH is neutral, which allows ensuring that pH mixture will be over the minimum
Fabrication of Gypsum Panels with Low-Cost Alternative Materials

Table 1  Physical properties.

| Parameter                  | Gypsum          | Pumice          |
|----------------------------|-----------------|-----------------|
| Real density (g/cm³)       | 2.6 ± 0.1       | 2.3 ± 0.1       |
| Apparent density (g/cm³)   | 1.2 ± 0.3       | 0.9 ± 0.2       |
| d₈₀ (µm)                   | 198             | 355             |
| pH                        | 6.7 ± 0.2       | 7.1 ± 0.2       |
| Humidity (%)               | 8.5 ± 0.2       | 4.1 ± 0.2       |

value (pH > 6). That value is a requirement for the elaboration of panels.

Humidity percentage corresponds to the free water quantity which can be removed from gypsum and pumice. In the case of gypsum, humidity content is higher than in the case of pumice.

For polypropylene, a traction-deformation essay was performed. The mentioned test indicated that the polymer supports a load of 18 ± 3.9 MPa before it breaks. This parameter indicates that the addition of polypropylene fibers may increase panels compressive strength.

Gypsum and pumice chemical characterization can be appreciated in Table 2 and the mineralogical analysis of gypsum performed by DRX is presented in Table 3.

In the case of gypsum, the component with the highest is calcium. The presence of minerals like Gypsum (55%), Basanite (42%) and Anhydrite (2%) in the mineralogical composition confirms the high value of calcium obtained in the chemical analysis.

As far as pumice is concerned, its majoritarian component is silicon. Since this material is a volcanic amorphous glass with a low grade of crystallinity, it was not possible to quantify it by DRX.

In both cases, it can be noticed the presence of iron (< 0.7%), which can be attributed to the presence of oxides traces like limonite or hematite. Due to the presence of clays like kaolinite, it can be noticed small amounts of sodium, potassium, aluminum and magnesium.

3.2 Pumice Influence over Panels Composition Results

In order to stablish the influence of pumice over panels composition, various essays were performed according to the methodology.

Table 2  Chemical analysis.

| Element   | Gypsum | Pumice |
|-----------|--------|--------|
| Aluminum (%) | 0.8    | 6.3    |
| Silicon (%) | 0.9    | 28.7   |
| Calcium (%) | 28.5   | 26     |
| Sodium (%)  | 0.8    | 0.4    |
| Potassium (%) | 0.3    | 1.8    |
| Magnesium (%) | 0.7    | 0.6    |
| Iron (%)    | 0.4    | 0.6    |

Table 3  Cast mineralogical analysis.

| Compound | Formula       | (%) |
|----------|---------------|-----|
| Anhydrite | CaSO₄        | 3   |
| Basanite | CaSO₄×0.5H₂O | 42  |
| Gypsum   | CaSO₄×2H₂O   | 55  |

Fig. 1  Compressive strength in function of panel composition.

In addition, panels consistency was determined through a mechanical stress essay. To stablish what panel composition was the best one, compressive strength tests were performed and the results obtained are presented in Fig. 1.

According to the norm ASTM 1396 [10], the compressive strength that a panel must present is 116 N in order to be effective. In the essays performed, the panel that approximates to the norm is the one with a 70% of gypsum in its composition (compressive strength of 118 N).

Once the panel composition (gypsum-pumice) was stablished, various tests were performed varying other parameters like pumice particle size. New panels were
Fabrication of Gypsum Panels with Low-Cost Alternative Materials

fabricated with different pumice particle size and all of them were submitted to compressive strength tests. The results obtained are shown in Fig. 2.

According to the value mentioned in the norm previously, it can be noticed that the panel elaborated with pumice of 355 µm is the one which approximates to the mentioned value in the norm. This panel presents a compressive strength of 119.6 N. In addition, pumice with this granulometry, shows a better adherence to gypsum, which allows having a manageable panel for further essays.

It is important to mention that the natural pumice d80 is 355 µm, that is why thus raw material does not need any further size reduction process.

Water temperature employed for panels preparation was varied with the purpose to reduce set time. In Fig. 3, panels compressive strengths at different water temperatures are presented.

As it can be seen in Fig. 3, the best compressive strength value is obtained when the water temperature is 30 °C. Nevertheless, when water at 20 °C (ambient temperature) is used in the mixture, a compressive strength value corresponds to the norm. Therefore, an additional heating of water must be considered when panels with high compressive strength are required.

3.3 Polypropylene Influence over Panels Composition Results

To assess polypropylene addition influence into panels, compressive strength essays were performed with test tubes which contained PP (polypropylene) in their composition. Panels were elaborated with PP added in a laminar way or in form of fragments.

At the end of the tests, the panel fabricated with polypropylene added in a laminar way presented the highest compressive strength. In Table 4 the compressive strength values for both way of polypropylene addition are presented.

3.4 Panels Compressive Strength Results

To evaluate panels compressive strength the procedure indicated in Section 2.2.4 was followed. In Figs. 4 and 5 compressive strength results in function of panels composition and particle size respectively are presented. In the case of Fig. 4, panels with 70% and 80% of gypsum in their composition present similar compressive strength values. This result indicates that any of the mentioned panels can be selected for further applications. However, as it was determined in Fig. 1, the most suitable panel composition is the one with 70% of gypsum and 30% of pumice.

- **Fig. 2** Compressive strength in function of particle size.

- **Fig. 3** Panels compressive strength in function of water temperature.

| Table 4 | Panels compressive strength with polypropylene |
|---------|-----------------------------------------------|
| Compressive strength (kPa) | Laminar way | Fragments form |
| 350.75 | 301.47 |
Fig. 4  Test tubes compressive strength in function of their composition.

Fig. 5  Test tubes compressive strength in function of pumice particle size.

The results presented in Fig. 5 indicate evidently that with smaller pumice particles size panels present higher compressive strength values. Especially panels elaborated with pumice of 425 and 355 µm exhibit the best results. Nevertheless, pumice with a d$_{50}$ of 355 µm is considered the most appropriate material since that granulometry is the particle size of natural pumice.

3.5 Conceptual Process Diagram of Gypsum-Pumice-Polypropylene Panels Fabrication

According to the results obtained, panels with 70% of gypsum, 30% of pumice, gypsum particle size 198 µm, pumice particle size 355 µm, water temperature of 20 ºC and polypropylene added in a laminar way, present the market established requirements. With the mentioned features, In Fig. 6 a block diagram is proposed for the fabrication of gypsum-pumice-polypropylene panels.

4. Conclusions

With 33% of solids concentration, a gold recovery of 80.6% was obtained in cyanidation at 24 h and, in ammoniacal thiosulfate leaching, gold recovery was of 80.9% in just one hour. Evidently ammoniacal thiosulfate leaching is faster than cyanidation but its speed depends on an adequate equilibrium of the
leaching reagents.

Ion flotation was the best technique for gold recovery from ammoniacal thiosulfate solution since it delivered a gold recovery of 84%, the highest of all proved processes. So ion flotation would be the next step after leaching process in order to extract gold from polysulphide ores.

The presence of sodium sulphite avoids the formation of gold sulfide in the electrolysis process. However, it reduced the gold recovery on cathode surface.

Gold recovery on cathode surface from ammoniacal thiosulfate solution was of 28% whereas a gold recovery of 29% was obtained from ionic flotation concentrate at a voltage of 0.4 V. Therefore, organic reagents present in ionic flotation concentrate did not impede the normal development of electrolysis tests and it can be used after ion flotation to extract gold from froth.

A higher applied voltage is fundamental to ensure a high gold-thiosulfate reduction. That is why at a voltage of 0.4 V a gold recovery of 63% was obtained on cathode surface meanwhile, with a voltage of 1.5 V, a gold recovery of 82% was achieved in 3 h of electrolysis.

References
[1] Merino, M. D. 2004. “Aplicaciones del yeso y la escayola en la edificación. Nuevas aplicaciones.” Informes de la Construcción 56 (493): 53.
[2] Deniz, V. 2011. “Investigation of the Breakage Parameters of Gypsum as Dependent on Interstitial Filling in a Laboratory Ball Mill.” Granular Matter 13 (4): 447.
[3] Calvo, B., Gajardo, A., Maya, M., Proaño, G., and Jarrín, J. 2000. Rocas y Minerales Industriales de Iberoamérica. Madrid: Instituto Tecnológico Geominero de España.
[4] Paladines, A. 2005. Los Recursos No Renovables del Ecuador. Quito: Editorial Universitaria.
[5] García Santos, A. 2009. “Escayola reforzada con fibras de polipropileno y aligerada.” materiales de Construcción 59 (293): 105-24.
[6] Instituto Ecuatoriano de Normalización. 2010. Normas Técnicas Ecuatorianas NTE INEN 0856:2010 Determinación de la densidad, densidad relativa, y absorción del árido fino.
[7] ASTM C136/C136M-05. 2014. Método de ensayo normalizado para la determinación granulométrica de agregados finos y gruesos. Obtained from http://www.astm.org.
[8] ASTM D882. 2010. Método de ensayo de tracción y deformación. Obtained from http://www.astm.org.
[9] Instituto Ecuatoriano de Normalización. 2010. Normas Técnicas Ecuatorianas NTE INEN 1 688 Preparación de probetas para ensayo.
[10] ASTM 1396. 2010. Método de ensayo de resistencia a la compresión. Obtained from http://www.astm.org.