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Asst. Prof. Dr. Umut ÖZKAYA

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2 ND INTERNATIONAL CONFERENCE ON ENGINEERING AND APPLIED NATURAL SCIENCES

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15-18 Ekim 2022 tarihlerinde MEET üzerinden çevrimiçi olarak gerçekleştirilen 2 nd International Conference on Engineering and Applied Natural Sciences akademik teşvik kriterlerini sağlamaktadır. Toplam 587 adet bildirinin yer aldığı kongre dört gün boyunca çevrimiçi olarak gerçekleştirilmiştir.

Türkiye dışından toplam 24 farklı ülkeden katılım sağlanmış olup, 587 adet bildirinin 300 tanesi yabancı katılımcı tarafından sunulmuştur.

Kongremize ilginiz için teşekkür ederiz.
Saygılarımızla,

Asst. Prof. Dr. Umut Özkaya

Congress' Coordinator

Effects of expanded perlite on the thermal and mechanical performances of plaster mortar

Abdelaziz Meddah*, Samra Zaiter, Nadji Hadjab and Laid Baali

LMMS, Civil Engineering Department, University Mohamed Boudiaf of M'sila, M'sila, Algeria

*(abdelaziz.meddah@univ-msila.dz)

***Abstract* –** With the energy crisis in the world, selecting appropriate building materials can significantly improve energy efficiency. Basically, using lower thermal conductivity composites for non-structural elements of buildings such as parting walls and coating can effectively satisfy this strategy. In this paper, the mechanical and thermal efficiency of expanded perlite for plaster composites was analyzed. Expanded perlite particles (EPP) were incorporated into the gypsum mortar by partially replacing sand particles with different percentages varying from 0 to 60% of the total volume of sand. Mixes were tested for compressive strength, flexural strength, and thermal conductivity potential. The results showed that EPP incorporation lightens the composite, and decreases the thermal conductivity. In all, the use of perlite for gypsum mortar can significantly alternative insulating material hence contributing to the decrease in the energy used inside the buildings (i.e. cooling/heating systems).

Keywords – Plaster; expanded perlite; composite; strength; thermal conductivity

I. INTRODUCTION

Selecting appropriate insulating materials in construction is the best way to save energy in buildings. Gypsum-based composites are one of the materials that are frequently used to improve the insulation potential due to their thermal benefits and low costs as well [1]. Hence, there is more interest in the use of plaster composites in prefabricated panels and repair due to their good thermal properties and low environmental impacts, in comparison with concrete material. Indeed, plaster-based composites help in developing sustainable materials as gypsum required lower energy in manufacturing processes than cement which reduced CO_2 emissions and costs, thus making a relatively eco-friendly material. In addition, to the environmental impacts, there is a global trend to integrate alternative composites into construction applications for increasing energy efficiency.

In European Union (EU), buildings represent 40% of the total Union's energy consumption [2]. Accordingly, the EU planned long-term strategies to satisfy energy efficiency, while in Algeria authorities consider using materials with high insulation and low environmental impacts as the main way to reduce energy demand.

More recently, Algeria begin a new program for long-term energy security, considering the development of alternative materials and/or innovative techniques in building sectors as one of the main ways to satisfy such challenges [3]. To satisfy this approach many studies developed alternative plaster-based materials incorporating many kinds of waste additives including, polystyrene [4], rubber-derived wastes [1,5], while others made of fiber-reinforced composites [6–10].

Considering its good thermal benefits and lightweight as well, perlite can be used to produce lightweight composites for construction applications such as underfloor insulation, parting walls, and coating. In addition to its thermal insulation potential, perlite has high fire resistance, reduces noise transmission, and resists termites, mold, and insects [11].

Although arid zones like most parts of Algeria are characterized by a very hot climate in summer in which the temperature exceeds 50°C [12], using suitable materials can effectively therefore in improving thermal comfort inside residential buildings also reducing energy consumption. In this context, this paper aims to analyze the mechanical and thermal performances of plaster mortar containing EPP. The latter was incorporated by partial replacement by volume of sand with various concentrations varying from 0 to 60% (i.e. 10% rate). Composites were tested for physical properties (density, thermal conductivity) and mechanical characterization (compressive and tensile strengths).

II. Materials

A. Plaster

Gypsum used in the present study is delivered by Taouab Factory in M'sila region, Algeria. It is composed of calcium sulfate dehydrate ($CaSO_4$, $2H_2O$). X-ray diffraction of this gypsum is shown in Fig. 1. This plaster is mainly composed of sulfur dioxide and calcium oxide. This plaster can be classified in Class I as per the classification of CNERIB (CNERIB 1993). The main properties of the plaster as given by the datasheet of the manufacturer are summarized in Table 1.

Table 1 Properties of gypsum

Setting times (min)		Apparent density (kg/l)	Particle size analysis	
Initial	Final		100µm	200µm
4-6	8-14	0.85-0.95	<20	<10

B. Sand

Very clean dune sand with a density of 2596 kg/m3 was used for all composites. The physical properties of the sand are shown in Table 2 while its grain size distribution is shown in Fig. 1.

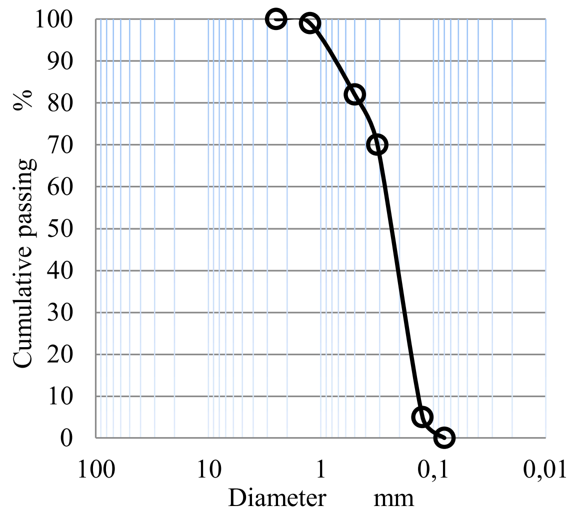

Fig. 1 Particle size distribution curve of rubber and sand.

Table 2 Physical properties of materials used

property	Apparent density (kg/m^3)	Specific density (kg/m3)	Porosity (%)	Sand Equivalent (%)
range	1428±14	2596±26	45±0.5	86±0.5

C. Perlite

Perlite with density of 60 kg/m3 is used in the study, it is delivered by Taouab Factory in M'sila region, Algeria. It is an inert material with white color obtained by calcination of volcanic siliceous rock at a temperature of 900 °C. It is composed mainly of silica (80%) and has an extra low density as well. In addition, EPP not only improves the thermal insulation, but also improves fire resistance rates, reduces noise transmission, and resists termites, mold, and insects. Also, EPP used is totally incombustible.

Fig. 2 Aspect of expanded perlite used

III. Procedures

The plaster mortar is formulated according to the recommendation of CNERIB [13]. Accordingly, the mix-design procedure consists in satisfying two criteria:

- Fix the water to plaster ratio (W/P) at 0.6.

- The plaster-to-sand ratio (P/S) is fixed at 0.5 (using a greater ratio negatively affected the strength).

Mechanical characterization is done using prismatic specimens of 40x40x160 mm^3 according to EN 13279-2 [14]. The molds are filled in three layers without vibration. All specimens were cured in laboratory conditions (24±2 °C and relative humidity of 45±2%). The arithmetic mean of three values is taken for all tests. To obtain a homogeneous distribution of fibers in the mix and reduce variability, oven-dried ingredients were mixed for 30 seconds, then, water is added progressively in parallel with good mixing for 30 seconds at high speed [1,4]. Seven concentrations were adopted to reinforce the composites, varying from 10 to 60% (with 10% interval) of the mass of sand particles.

IV. Results and Discussions

A. *Effect of fiber addition on density*

In the Fig.2, the relationship between density and EPP contents is illustrated. By considering the difference in unit weight between perlite particles and sand, the density of the composite regularly decreased with increasing EPP contents.

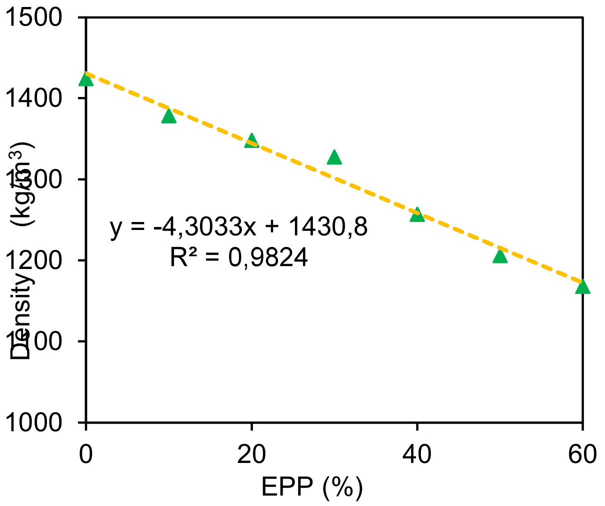

Fig. 3 Effect of EPP addition on the density

B. *Effect of fiber addition on compressive strength*

The variation of compressive strength with respect to the fiber content of the composite is illustrated in Fig. 4. By increasing EPP content, the unconfined compressive strength of the composite decreased. It changed from 12.34 to 8.21 MPa when 60% of perlite are added to the control mix.

Although the decrease in composite strength caused by EPP addition, all mixes exhibited very acceptable strengths considering that plaster composites are designed for non-structural applications that does not require high values.

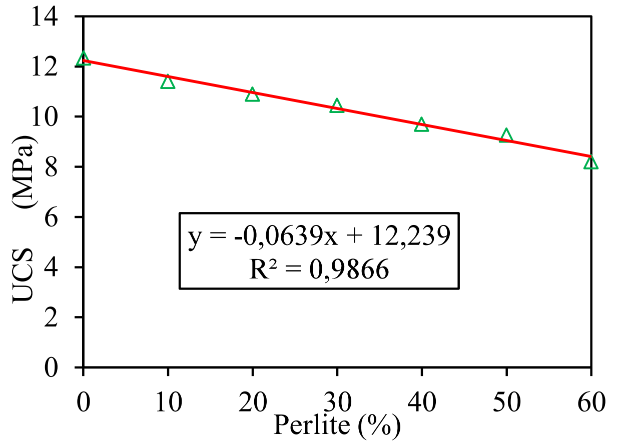

Fig. 4 Effect of EPP on the unconfined compressive strength

C. *Effect of fiber addition on flexural strength*

The impact of EPP on the flexural strength for various cure periods is shown in Fig. 5. A regular decrease in the flexural strength is observed with increasing EPP contents.

The 28 strength decreased from 5. to 3 MPa. In a similar way to compressive strength, the lower density and rigidity of EPP a responsible for strength losses. Despite strength losses, when comparing these findings with literature, it is observed that the flexural strength of the composite produced in this study is greater. In the study of Laoubi et al., the flexural strength of gypsum composite contained polystyrene with 60% of replacement.

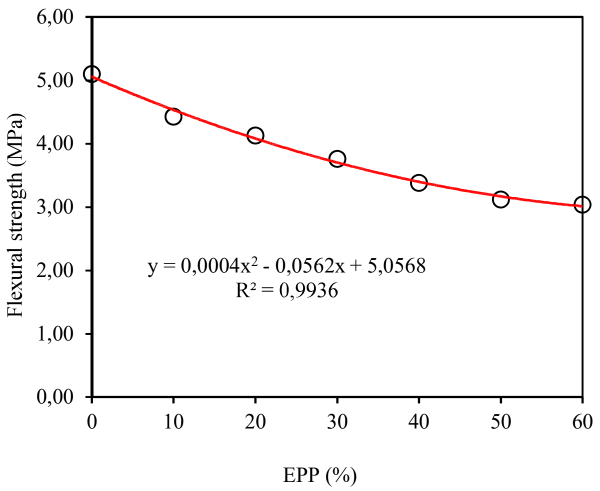

Fig. 5 Effect of perlite addition on the flexural strength

D. *Effect of fiber addition on thermal conductivity*

For evaluating the efficiency of the composites formulated, the thermal conductivity measured for each EPP content and the obtained results are shown in Fig. 6. It can see that EPP addition decreases the thermal conductivity. The decrease in thermal conductivity of composites can explain by the fact that EPP has lower thermal conductivity than dune sand substituted.

These findings were confirmed by analyzing the relationship between thermal conductivity and density of the composite, as seen in Fig. 7. Indeed, a good correlation was obtained between thermal conductivity and density traduced by the high correlation coefficient (R^2=0.97).

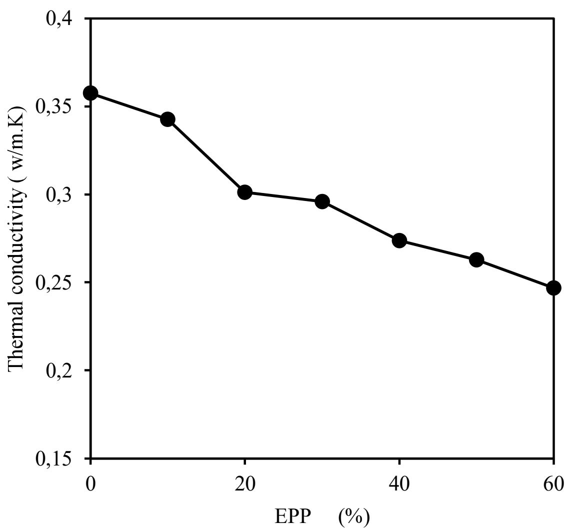

Fig. 6 Effect of EPP on thermal conductivity of the composite

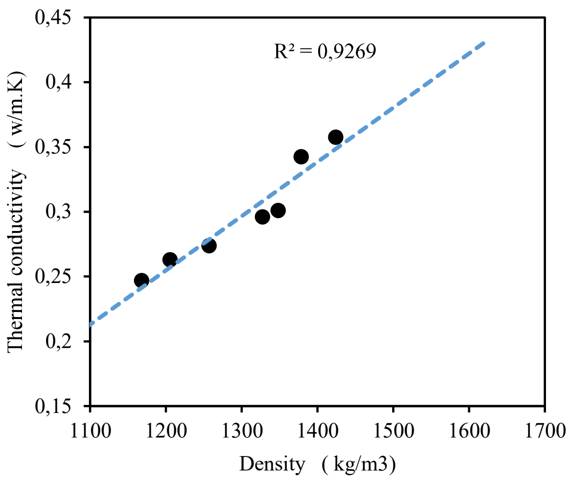

Fig. 7 Relationship between thermal conductivity and EPP concentrations in the composite

V. CONCLUSIONS

The main goal of this research is to assess the mechanical and thermal characterization of plaster mortar incorporating perlite particles. The main conclusions that can be drawn from the study are:

1. Incorporating perlite into plaster mortar decreases the density due to the relative difference in density between fibers and sand particles substituted, also the voids generated by fibers.
2. By incorporating perlite, the strength decreases (compressive and flexural) strengths of the composite. Despite that strength losses, the composite proposed can be used for parting walls, coating, and repair as these applications do not require great strength.
3. The addition of perlite to plaster composite improved its thermal insulating potential. Thus, is an attractive finding as it helps to save energy in buildings.

Based on our findings, perlite fibers can be used effectively to reinforce plaster composites for many applications (precast plaster panels, parting walls, coating, repair, etc.), due to their potential in improving thermal insulation.

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