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Use of pozzolanic mortars for the thermal comfort of buildings

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ABSTRACT

The main objective of this study is to provide more data on the use of natural pozzolan located in the region of Beni-Saf west of Algeria as a substitute for cement mortars made with different percentages of pozzolan. We also analysed the effectiveness of the addition of natural pozzolan on the thermal properties of the mortar. To do this, the measuring instruments were installed in order to quantify the overall interior environment and particularly the thermal environment. Since the thermal environment is characterized by physical quantities; the air temperature, the wall temperature and the air humidity, this allows assessing the level of the energy consumption and thermal behaviour of the envelope of the structure to verify the conformity of housing for thermal comfort requirements. The building's energy efficiency improvement approach must be thought globally, which not only focus both on the frame (building materials), but also on the equipment and component systems. In order for the process to be completed, it should also incorporate the use of renewable energies. The regulation is handled by robots that are more or less complex according to the requirements of the initial specifications and the type of individual housing construction, collective or tertiary. These controllers can process the measurement information (temperature, humidity ..) and status (on / off ...) of heating, cooling and lighting to adjust, optimize, secure and counting consumed energy. To improve thermal comfort in a building and save energy, it is necessary to implement special performance materials, providing good thermal insulation.

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1. Introduction

What is a smart building? To define its intelligent building. "It must meet at least 3 criteria: the comfort of the occupants. Then it must be environmentally friendly. Lastly, it must be financially and economically at the market price, do not make buildings too smart and too expensive that can not find investors or buyers. To get a smart building must have less energy expenditure.The performance of the energy efficiency of intelligent buildings must be thought globally: both on the building (building materials) and on the equipment and systems that make them up. For the approach to be complete, it will also have to integrate the use of renewable energies. The potential to reduce energy consumption induced by the new equipment in our profession is still largely unknown and underestimated. The technical solutions already exist and are complementary to the procedures on the building envelope. The control is managed by automatons that are more or less complex according to the requirements of the initial specifications and according to the type of building individual, collective or tertiary housing. These PLCs can be used to process temperature, humidity, and status information (on / off ...) of heating, air conditioning and lighting equipment in order to adjust, optimize, the energy consumed.

2. Materials Used

Ceramic samples of (1-x)$CaCu_3Ti_4O_{12}$ - x(0.3ZnO-0.7TeO_2), (x=0, 0.01, 0.03 and 0.05) were prepared separately through three different steps using solid-state synthesis method. Firstly, high purity chemicals (99.99%) of $CaCO_3$, CuO, and TiO_2 powders were mixed according to the stoichiometric ratio and ground repeatedly using an agate mortar and pestle to achieve good homogeneity for CCTO synthesis. The mixed powders were then calcined at 1000°C for 12 h followed by grinding for 2h. Then the calcined powder was pressed into pellet and sintered at 1100°C for 24 h. Secondly, the binary tellurite glass, 0.3ZnO-0.7TeO_2 was prepared by mixing high purity chemicals (99.99%) of ZnO and TeO_2 powders. The powder mixture was then placed in a ceramic crucible and heated in a melting furnace at 800 °C for 1 h. The melt was then transferred to a quenching furnace and annealed at 350 °C in a stainless steel mold for 4 h. Finally, appropriate amount of the synthesized powder of $CaCu_3Ti_4O_{12}$ and ZnO-TeO_2 glass were mixed and reground to form a uniform dispersion of composite. The mixture were pressed into pellets and sintered at 1050°C for 4h. Phase analysis of the samples was conducted on the sintered powders using Philip X'pert Pro Model PW3040 Diffractometer. The lattice parameter values of all the samples were calculated using Least-Square method from the XRD data. Carl Zeiss FESEM (scanning electron microscope) was used to determine the morphologies of the samples. The dielectric properties were measured using a HIOKI 3531-Z Bridge between 10^2 Hz to 10^6 Hz at different temperatures.

2.1 Cement

The cement used in all the tests is a cement CPA-CEM I 42,5N from the Zahana cement plant, with a data sheet N ° FR-0026LAB Version2 according to the Algerian Standard NA442.

2.2. The Natural Pozzolana

The natural pozzolana used is of volcanic origin extracted from the Bouhamidi deposit located south of Béni-Saf. The deposit is represented by a mountain of conical form called El-Kalcoul located at the absolute coast of 236 m. This pozzolana is essentially composed of slag and pumice stones, stratified, varying in color from red to black [4, 9]. The natural pozzolan used in all the tests is in the form of a powder, resulting from crushing the pozzolanic slag, steamed for 24 hours at a temperature of 50 ° C. in order to remove their moisture, then ground until the powder Result can pass through a sieve of 80 µm mesh. [6], [5]. The Blaine specific surface area of the natural pozzolana is: SSB = 4330 cm^2 / g. The absolute density of natural pozzolan is 2.45 g / cm^3.

2.3 Sand

It is the sea sand of Terga corrected with 40% Sea Sand, 60% Sand of Career. The sand is initially prepared to be classified according to French standards NF P 15-403, its particle size curve satisfies the reference spindle. This sand is a granular skeleton that has the most impact on the qualities of concrete and mortar [9]. The mixing water used for the preparation of the mortars is the drinking water of the tap, its chemical composition is illustrated [6].

3. Methodology and Discussions

The preparation of the mortar was carried out according to the following steps: Standard ASTM C 305-99 [9]. Mixtures of the mortar were made from portland cement CEM I 42.5N and three combinations of binders obtained following the partial replacement by weight of the cement with different levels of natural pozzolana (10%, 20% and 30%). For each binder, mixtures of the mortar were made according to ASTM C1012 [4]. The mortars are intended for the manufacture of test specimens of dimensions 50x50x50 mm^3.

In order to evaluate the thermal properties of the mortars and to highlight the influence of the substitution of the cement by the natural pozzolana of Beni-Saf.

To measure the thermal conductivity of the mortars we used an "Isomet 2104" type apparatus (figure 1). It is a portable measuring instrument for direct measurement of the coefficient of thermal conductivity, specific volumetric capacity and temperature using the exchange of syringes and surface probes, according to ISO8302 [9].

Fig. 1. Conductivimètre

3.1 Thermal Insulation of Buildings

To improve the thermal comfort in a building and to save energy, it is necessary to use materials that perform particularly well, providing good thermal insulation. Indeed, good thermal insulation results in the choice of air conditioning equipment less powerful and therefore more economical. In most cases, insulation is obtained by the use of specific materials which, in addition to good resistance to heat transmission, must have other qualities which depend on the implementation requirements such as

- Lightness and non hygroscopicity in order to preserve its insulating qualities over time,
- Good mechanical strength,

• Good resistance to operating temperatures,
• No detrimental effects on the materials in contact with the insulation.

For example, if there is a need for additional insulation, opt for the use of insulation to cover the construction both internally and externally, but in this case it would be necessary to treat the bridges with care. Another solution consists in using materials which, because of their insulating properties, are self-sufficient and do not require the use of additional insulation.

3.2 Thermal Insulation

Thermal insulators differ from each other in many parameters. Below is an overview of the main characteristics by insulation type [8] and [6].

3.2.1 Mineral glass wool (MW)

Mineral glass wool comes in different shapes (mattresses or panels). The products are made from a mixture of molten raw materials (for rock wool it is essentially diabase and limestone, for glass wool mainly sand and glass debris) until obtaining Fibers of woolly consistency.

3.2.2 Expanded polystyrene (EPS)

A distinction is made between non-fire-resistant modified expanded polystyrene and fire-resistant modified expanded polystyrene. The density and, therefore, the specific properties of thermal insulation are adapted during manufacture. Indeed, the thermal conductivity for example is related to the density. The density is a function of the size of the beads, their rate of introduction and the steam flow rate.

3.2.3 Cellular glass (CG)

Cellular glass insulations are in the form of panels with edges or pieces cut from the panels. The density or specific thermal insulation properties are adapted during manufacture. The product is obtained by pure fusion and additives, then passed through a stretcher, vitrified and ground.

3.2.4 Extruded polystyrene (XPS)

The extruded polystyrene is in the form of panels with straight edges, grooves and tongues or with stop. The specific properties of thermal insulation are adapted during manufacturing. The product is obtained by mixing polystyrene granulates and additives (expanding agents in particular) until a paste is obtained which is introduced into an extruder to produce the desired thickness. The product owes its insulating properties specific to the type of expanding agent used as well as to the rate of rise in temperature and the speed of intrusion. The addition of the expanding agent causes an expansive air / expander migration which stabilizes with time.

3.2.5 Polyurethan (PUR) and polyisocyanurate (PIR)

The products are in the form of panels with straight edges, possibly provided with grooves and tongues. The panels consist of a rigid foam core made of PUR / PIR and are fitted with a facing on both sides. The facings partly control the insulating properties. The rigid PUR / PIR foam results from an exothermic chemical reaction of polyisocyanurates and polyol under the effect of expansive agents.

3.2.6 Wood wool

Wood wool panels are made from wood fibers, the binder being wood lignin. This natural material has a thermal conductivity coefficient identical to the other insulation wools, a rigid structure with grooved assembly guaranteeing a very long life.

3.2.7 Phenol (PF)

This product is in the form of panels with straight edges, possibly provided with grooves and tongues. The panels consist of a phenolic foam core and are fitted with a facing on both sides which partially conditions the insulating properties. The product has its insulating properties specific to the type of expanding agent and the formulation adopted.

3.2.8 Expanded perlite (EPB)

The manufacturing process involves placing on a conveyor belt a mixture of expanded perlite water, glass fibers, cellulose and a bituminous binder. The mixture is compressed to the desired thickness. Materials such as glass aggregates, hemp, and terracotta are used in the manufacture of specific bricks that are used in the composition of particularly insulating elements.

3.2.9 Poured

These are mortars based on different levels of pozzolana (10%, 20%, 30%) using a layer of internal and external wall covering in buildings. Pyrolusites, which are projections derived from volcanic eruptions, are referred to as pozzolana. Natural pozzolan mortars have a density between 1100 and 1500 kg / m3 [9]. Their mechanical and physical properties make it possible to use them either as insulating mortars.

4. Thermal Resistance

Iillustrates the variation of the thermal conductivity as a function of the different types of insulators. We note with type of insulation 7 that when the content of pozzolana increases the thermal conductivity decreases.

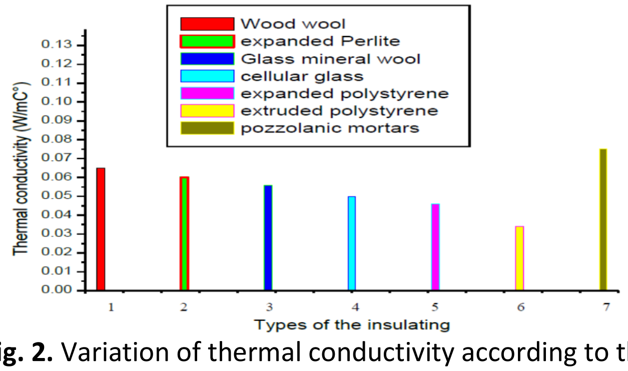

Fig. 2. Variation of thermal conductivity according to the different types of insulation [7]

Figure 3 below shows that the resistance increases when the thermal conductivity is low with a constant thickness d. Pozzolanic mortars have low thermal conductivity.

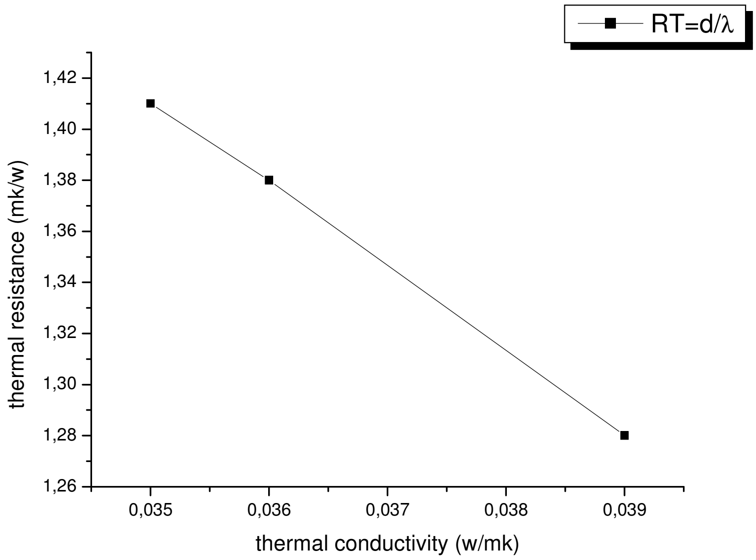

Fig. 3. Variation of thermal resistance as a function of thermal conductivity

5. Conclusion

The main conclusion from the current study can be summarized as follow
- The quality of the building envelope determines the energy consumption, but also the comfort
- When selecting the insulation material, consideration must be given to different criteria - thermal performance - environment - health - freshness
- Use of systems and / or insulation with technical approval (ATG, ETA, ...) and preferably an eco-label
- Conscientious and thoughtful choice of construction method
- Pay attention to the application of the basic rule
- Indeed, pozzolana, being a natural product, that pozzolanic mortars can be recommended as thermal insulation materials because the thermal conductivity is low when the pozzolan content increases.

The major interest which has been the origin of study of this article is:
- Thickness of walls - The filling of the framework reduces the thickness, taking into account the sections of the wood and traditional method of construction and therefore known, the choice of insulation determines the thickness.
- Thermal mass Light construction, use the thermal mass of the floor, pay particular attention to solar gains and heavy construction, pay attention to the accessibility of the thermal mass.
- Environment Wood is a natural product and therefore has a lower impact on the environment and the choice of insulation (thickness and conductivity) largely determines the impact on the environment.
- Higher material cost, but more prefabrication possible, lower foundation costs due to lightness and traditional building materials, pay attention to the standard dimension.

• Air-tightness requires more attention, but intermediate evaluation is easier, the plaster layer acts as airtight, details are usually simpler.

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