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Ceramic Covering of Prefabricated Reinforced Concrete Panels: Microstructural, Mechanical and Technical Aspects

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The precast components industry today aims to fully satisfy the designer's adaptation of the production to different requirements. The facing of precast components with ceramic is a very interesting solution under consideration and some little achievements have been accepted with pleasure by the market. For this application it is now necessary to go deeply into the scientific and productive knowledge. This work presents the actual results of research in progress into the microstructure of support and ceramic covering and mechanics properties. The research is constantly related to the real industrial aspects and the experience of which we speak refers to the operational control of production and time in the production of complete panels for and industrial building.

1. Introduction

In recent years the criteria for the production of prefabricated components have evolved towards a greater attention to the formal aspects, and, also, towards a greater disponibility to meet the express needs of the project. In other words production has moved further and further, from the concept of "mass production" to orientate itself towards personalized application and strongly infoluenced by the profile, of geometry, composition of materials and technological solutions in general.
Among the components of particular interest to this new philosophy are the sealing panels that, because of their nature as the skin of a building, have always constituted the principal element of the characterization of a building.
There are many practical solutions; some have become standard, others are in the initial stages of use, still others are at the stage of ever-stricter collaboration between designers and manufacturers.
The external covering of precast concrete slabs with ceramic material is one of the solutions most appreciated for its notable formal valence and the reliability of the strong covering material and its traditional presence in Italian Architecture.
The diffusion of this technique for finishing sealing panels has made necessary a better study of the production problems and the quality of the finished product. In particular the experience of which we speak refers to the controlling of the quality and time production of sealing panels for an industrial building.
Regarding the reliability and, above all, the durability of the entire operation, the microstructural compatibility between three constituent layers (slabs of reinforced concrete, binding paste and covering) has been analyzed considering the fact that while the first and third are the product of independent, but rigorously controlled production, the second is often the product of artisan formulation, even if in the field of industrial production, for the complete panel.
There is also the constant worry about the durability of the product, in terms of porosity, caused by the problem of frost susceptibility.
This work refers specifically to opaque external sealing panels positioned horizontally with length equal to the space between the mid-point of the load-bearing pillars of the building.
The panels are positioned on the external side of the structure and are joined to this in the following way: underneath by metal brackets installed in the pillars during their construction, above metal connecting plates and bolts.
The panels of 14 cm thickness are constituted of an external layer ceramic tiles 11.5x24.5x1.2 cm (space 12.5x25) with white binding paste (white cement, Carrara marble dust and retarding additive), a 4 cm thick layer of reinforced concrete, a 5 cm intermediate insulating and discontinuous layer of expansive polystyrene and a 4 cm external layer of reinforced concrete industrially floated. The cross section of the tile and the construction schema of the panels are reported in Figure 1 and 2 respectively.
Sealing with these panels in total gives a thermal insulation linked to the conduction coefficient equal to 1.20 kcak/hm^2 °C, calculated as the weighted average and considering the thermal bridges produced by the metal skeleton of the reinforced concrete.
The composition of the concrete is: powder (0-3 mm), sand (0-5), gravel (4-20 mm), white cement 525 and plasticizer.
The reinforcing consists of two electrowelded steel nets positioned above and below the expansive polystyrene and steel rods positioned between the insulation panels as shown in Figure 2.
The panel, utilized as a beam (with the dimension 674x176x14 cm) constrained at three points on the upper side and two on the lower side is very resistant to bending in the vertical plane. Regarding the bending caused by horizontal loads, considering the single reinforcing consisting of a double electrowelded steel net 25x25 ϕ5 a breaking strain of about 3400 N/m^2 relative to the single beam panel can be calculated. This resistance is sufficient

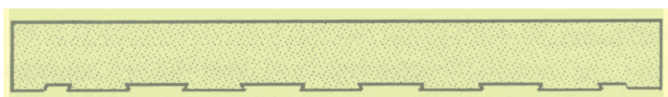

Figure 1. Cross section of the ceramic tile (11.5x24.5x1.2 cm).

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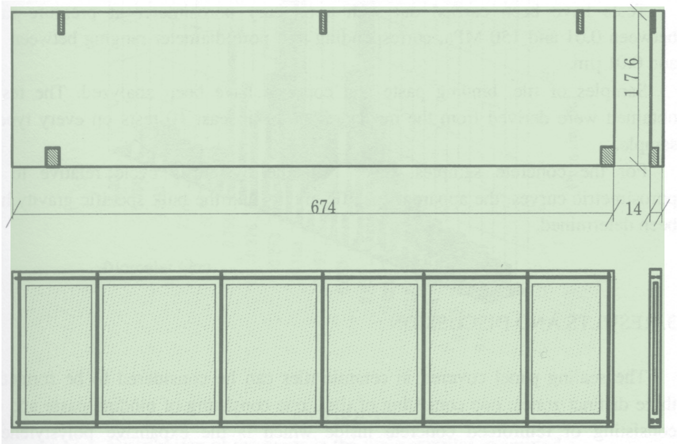

Figure 2. Scheme of the prefabricated reinforced concrete panel.

for the indicated application taking into account the usual loads of the project.
For eventual use as a real and proper sealing panel for civil construction strengthening the reinforcing has been considered, substituting it for example with a 20x20 ϕ7 with the same anchorage it would be possible to manufacture sealing panels of 330 cm height and increase the breaking strain to about 4500 N/m^2.

2. Experimental Procedure

Tests have been carried out with a mercury porosimeter at pressure range between 0.01 and 150 MPa, corresponding to a pore diameter ranging between 150 and 0.01 μm.
Samples of tile, binding paste and concrete have been analyzed. The results obtained were derived from the median value of at least 10 tests on every type of sample.
For the concrete samples, other than the hysteresis cycle relative to the porosimetric curves, the apparent specific gravity and the bulk specific gravity have been determined.

3. Results and Discussion

The sealing panel covered in ceramic tiles can be considered to be formed of three distinct zones: one consisting of tiles, one consisting of binding paste and one consisting of reinforced concrete inside which is the expansive polystyrene to reduced weight.
In this system we can locate two interfaces: one between tiles and binding paste and one between paste and concrete.
To evaluate the efficiency of the bond at the interfaces of the different zones, their microstructure was studied with a mercury porosimeter.
As has been noted the dimensions of the pores are of the same order of size as the particles around the pore. Therefore, by measuring the distribution of the porosity in the various zones it is possible to evaluate the microstructural compatibility at the interface in terms of the dimension of the particles and the pores.
The distribution of the pores in the three samples examined and expressed in percentage are given in Figure 3.
In Figure 3 all the samples presented analogous distribution of the porosity and demonstrated two intervals between 1.5 and 0.35 μm and between 0.15 and 0.04 μm respectively in which the porosity is overwhelmingly present.
This fact enabled us to predict that the interconnection between the binding paste and the concrete will be compatible and can verify diffusion, during setting, between the binding paste particles and those of the concrete guaranteeing, in that way, an optimum final anchorage.

On the bonding surface between tile and binding paste conditions exist for the diffusion of the binding paste particles to the inside of the pores of the tile, creating optirnal condition for perfect anchorage; this would also be guaranteed by the particular profile of the tile (see Fig. 1).
To evaluate the durability of the product especially in conditions of freezing and thawing, the hysteresis cycle relative to the porosimetric curves of the concrete (reported in Figure 4) has been studied. This analysis aids to determine the form of the pores.
In fact others studies [1, 2] have demonstrated that the distribution and the form of the pores influence the frost-resistance of the

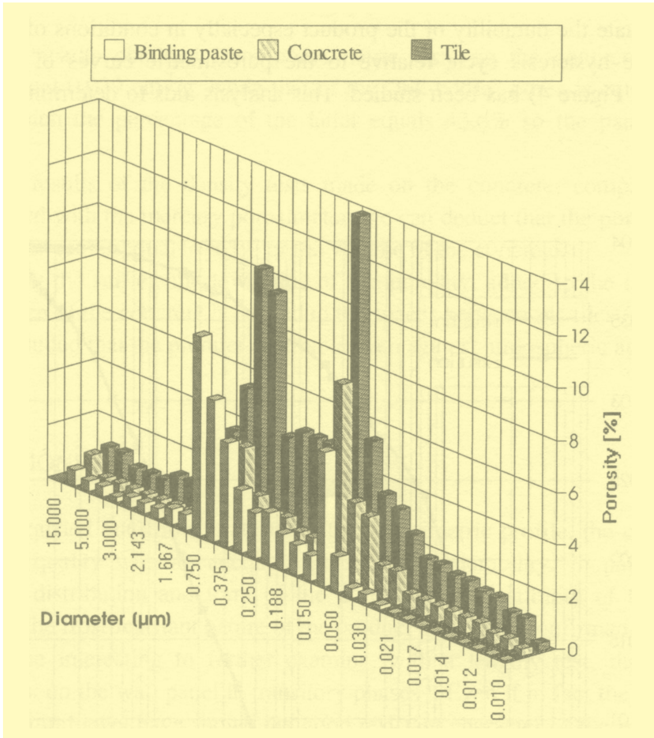

Figure 3. Distribution of the pores in the three samples examined.

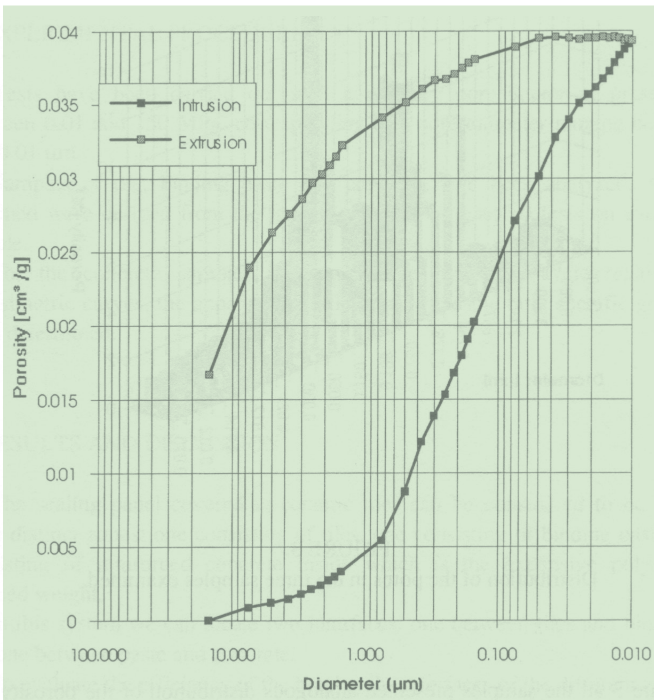

Figure 4. Intrusion-extrusion hysteresis of the porosimetric test relative to the concrete sample.

material. In particular the presence of "ink-bottle" pores or the connection of pores of diverse diameter can cause degradation of the material under conditions of freezing and thawing.
It has been demonstrated1 that if the volume of the "ink-bottle" pores is less than 50% of the total porosity, independent of the value of this, the material will be frost-resistant.
From the results obtained from porosimetric tests on the concrete, the total porosity is equal 0.039 cm^3/g, while that of the "ink-bottle" pores is equal to 0.017 cm^3/g for which the percentage of the latter equals 43.6% so the panel is frost-resistant.
From the results of the density tests made on the concrete, compared to the results obtained with the mercury porosimeter, we can deduct that the porosity of the concrete is open and is equal to 9.3% of the volume of the concrete.
Considering the sufficiently low value of this porosity, added to the fact that the exposed surface of the concrete is limited to the spaces between the tiles (1 cm apart) it can be concluded that the product is durable even against atmospheric agents.

4. Conclusions

The tests carried out affirm that, under the porosimetric profile, the components present good quality with an adequate guarantee of durability. In particular, by analyzing the distribution and form of the pores, the compatibility of the various materials and the frost-resistant nature of the product have been confirmed.
It would be interesting to further examine, with a lengthy test, the effect of dynamic stress, on the wall panel in transitory phases [3]. Even if in fact the analysis at the microstructural level have shown the good resistant character of the product it is evident that attention must be given to avoiding microfissuring phenomena extremely dangerous to its durability.

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