A Study of the Load Stages by the Displacement of Mortars Composed of Ornamental Stone Residues by the Method of Squeeze Flow

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Abstract The objective of this work is the study of mortars of multiple use incorporated by 'ornamental stones' residues (OSR), from the municipality of Cachoeiro de Itapemirim/ES. The materials used were: Portland cement type CP II, CP III and CP V, washed sand of the region and water. The sand of the mortars was replaced by percentages of 10, 30 and 60% of stone residue. Thus, using the squeeze flow method, the main stages of the load were evaluated by the displacement of the different compositions tested, the influence of the cement, and the influence of the velocities proposed by the method cited.

Keywords Mortar · Ornamental stone residues · Load

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Introduction

Brazil has large reserves of marble and granite that, when they are extracted, are transformed into products that compete with floors and ceramic tiles. Among the producing states, Espírito Santo is responsible for about 80% of the national production of ornamental stones [1].

In the city of Cachoeiro de Itapemirim, in the southern region of Espírito Santo, the production of ornamental stones accounts for about 90% of the Capixaba production, making this sector the main economic activity in the region, supplying not only the national market, but also other countries such as the United States [1, 2].

For the use of ornamental stones in civil construction, it is necessary to unfold them to obtain blocks and slabs, which are polished to result in finished products for the market. This process is responsible for the residues in the form of mud, which in Cachoeiro de Itapemirim, is of the order of 400 tons/month. This sludge, when dried, becomes a non-biodegradable solid waste classified as Class III waste, which is most often disposed of inappropriately, causing damage to the environment and human health [1, 3, 4].

Ornamental stones residues (OSR), such as granites and marbles whose predominant minerals are calcites and dolomites, can be incorporated into mortars used in civil construction, solving a problem faced by many industries in this mineral sector. In this way, studying and evaluating the waste is justified because, besides the possibility of minimizing the environmental impact generated by the adequate disposal, the residue of ornamental stones has great potential as a raw material [5, 6].

The main objective of this work is to study the replacement of sand by ornamental stones residues from the municipality of Cachoeiro de Itapemirim in the State of Espírito Santo in the production of mortars used in construction and to evaluate the level of workability of each composition using the method by squeeze flow.

Materials and Methods

The material developed in this study consists of three mortars, one composed of Portland cement type CP II with 35% pozzolana, CP III with 70% pozzolana and another one by type CP V, both of which were added sand and stone residue collected in the city of Cachoeiro de Itapemirim/ES. The mortars were tested with three different compositions, with the consequent substitution of percentage of the sand by stone residue in the percentages of 10, 30 and 60%.

In order to analyze the range of consistencies of the mortars in the fluid state, a rheological analysis was used by the squeeze flow method, which determines the spreading of mortar after the actuation of a compression force [7].

The results emitted by the squeeze flow test are differentiated in three stages, namely, linear elastic behavior, plastic behavior or viscous flow and stress hardening phase. These three stages are evaluated in exponential curves, expressed in the form of force versus displacement [8, 9].

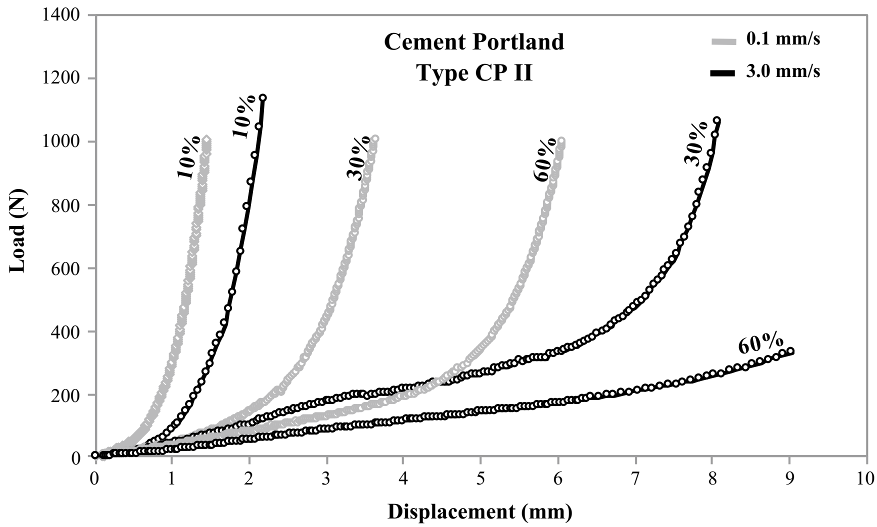

Fig. 1 Result of squeeze flow for CP II (Portland cement type II)

Results and Discussion

With the results emitted by the curves generated by the technique of squeeze flow, it is possible to describe the level of consistency of the material studied. Three levels of consistency are described, the first with the high consistency range being the occurrence of the extension of the plastic deformation stage at very low loads, with the transition to the stress curing phase occurring only at larger displacements.

Other levels show the low consistency range, the absence of the plastic deformation stage, and the average consistency, the variation of the load level as the plastic deformation occurs. It is also important to note that in mortars with a medium consistency range, the material tends to flow and then stop, and this stop causes higher loads and, when they return to flow, the load tends to decrease [10].

Figures 1, 2 and 3 show the results obtained in the mortars composed of Portland cement type CP II, type CP III, and type CP V in the different substitutions (10, 30 and 60% of rock residue), compressed at speeds of 0.1 and 3.0 mm/s.

Influence of Cement Type

Analyzing the curves of Portland cement mortars type CP II, CP III and CP V, mixtures with 10% of stone residue tested at a speed of 0.1 and 3.0 mm/s similar results were obtained. It is noteworthy that the 10% curve of CP V tested at 3.0 mm/s speed showed a variation in the phase transition range. However, analyzing the percent-

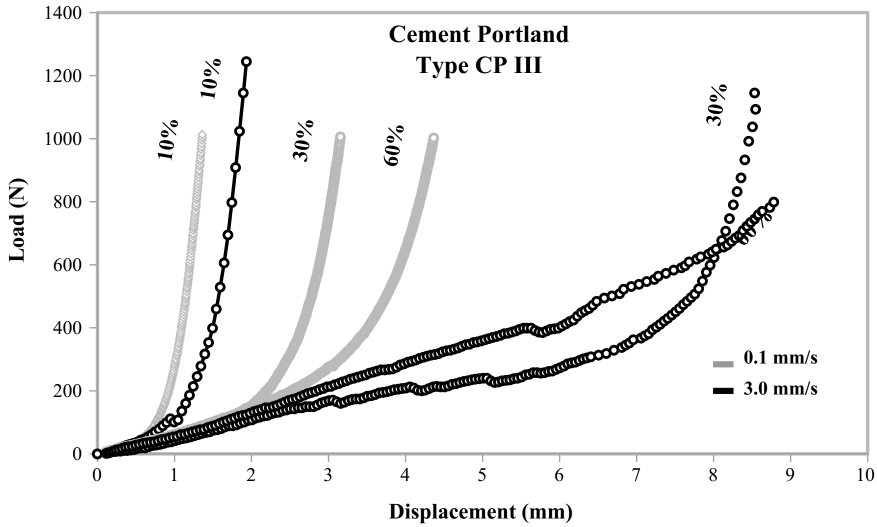

Fig. 2 Result of squeeze flow for CP III (Portland cement type III)

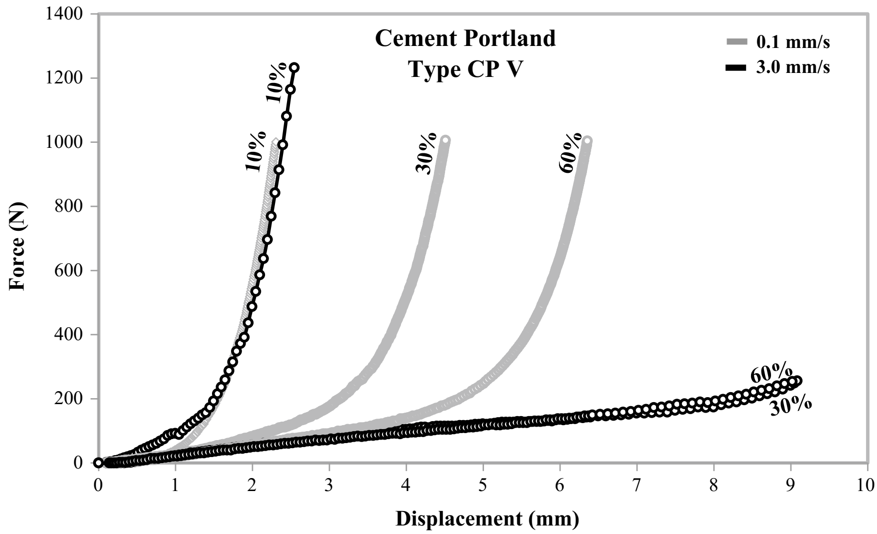

Fig. 3 Result of squeeze flow for CP V (Portland cement type V)

ages of 30% in CP II and CP III cements, a similarity is observed in the curves for both types of cement, tested at both speeds. Otherwise, the curve generated by the squeeze flow with the cement in the type CP V obtained a result different from those mentioned above, presenting only the stage of viscous flow.

Influence of Speed

It is observed that the curves presented only two stages: plastic deformation and tension hardening. The mortars, in the different compositions, started in stage 2 with small loads. The displacement increased gradually, as the load slowly increased, and in the transition to stage 3 in some compositions, occurred in a short space of displacement, while in others, the transition took place over a long space of displacement.

Mortars composed of 10, 30 and 60% CP II cement at the rate of 0.1 mm/s showed different phase transition. The mortar composed of 10% of stone residue showed the phase transition at the mark of 0.5 mm of displacement, reaching a maximum displacement of 1.20 mm. As the percentages were increased to 30 and 60%, the phase transition doubled, achieving a maximum displacement of 60% of 6.0 mm. It should be pointed out that the curves reached a maximum force of 1 kN, thus, the behavior of the mortars tested in the different stone residue compositions were influenced by the velocity of displacement (0.1 mm/s), showing sensitivity to segregation.

When the compositions were observed at a speed of 3.0 mm/s, the composite mortar of 10% presented a similar result to the mortar of 10% tested at a speed of 0.1 mm/s. The mortar composed of 30% of stone residue obtained the transition of phases in 5.80 mm and a maximum displacement of 7.80 mm. On the other hand, the 60% mortar behaved plastically until the maximum displacement of 9.0 mm [10].

Analyzing the mortar composed of cement type CP III, at a velocity of 0.1 mm/s, it is observed that the composition of 10% behaved plastically up to 0.80 mm displacement, that of 30% up to 1.80 mm and 60% to 2.60 mm. Therefore, the maximum displacement of the three compositions was totally different from one another.

When tested at a velocity of 3.0 mm/s, the obtained curves were significantly different. The composite mortar with 10% behaved plastically for a short range of displacement, having its maximum displacement of only 1.80 mm. The mortar with 30% of stone residue had the transition of stages in the mark of 6.50 mm and a maximum displacement of 8.50 mm. The composite mortar with 60% obtained an expressive result, as it behaved plastically up to the maximum displacement mark of 9.0 mm [10].

Analyzing the behavior at both speeds, it was verified that the mortars tested at a speed of 0.1 mm/s reach the maximum displacement with the load of 1 KN, being in the range of 1.0–4.50 mm. Otherwise, when tested at a speed of 3.0 mm/s, the loads, to increase the maximum displacement, vary from composition to composition, having a mean load range of 1 KN and, consequently, a displacement greater than that at the speed of 0.1 mm/s, varying in the range of 1.80–9.0 mm [8].

Mortars composed of CP V cement of 10%, 30% and 60% at a velocity of 0.1 mm/s, obtained phase transition at the mark of 1.0 mm, 2.90 mm, and 4.30, respectively. A maximum displacement of 6.30 mm in the mortar composed by 60%. It was also concluded that all mortars reached a maximum force of 1 kN. At the speed of 3.0 mm/s, the mortar composed of 10%, obtained a similar result to the mortar composed of 10% at a velocity of 0.1 mm/s, in contrast, the mortar composed by 30 and 60% obtained similar results only at the speed of 3.0 mm/s, behaving plastically until the maximum displacement of 9.0 mm [9].

Conclusions

With the results found the following can be concluded:

- Different compositions of OSR incorporated mortars have a high level of consistency due to the large displacement obtained in the squeeze flow test.
- The velocity of 3.0 mm/s obtained more expressive results, being close to a mortar for plastering, in addition, this mortar needs better moldability.
- The influence of Portland cements in the different compositions of mortars tested is a difficult task to discuss, since it is necessary to know the physical characteristics of their particles, such as granulometry and specific mass.
- When analyzing the mortars in the fluid state, the mortar resistance is modified over time, especially by the hydration of the cement, considering a variable rheological behavior.

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