Experimental and numerical thermomechanical characterization of refractory masonries

Summary

The manufacturing process of several materials adopted in industry, in civil construction and in our daily life has processes performed at high temperatures, such as melting and heat treatments. Thus, these production processes require products that resist to high temperatures, maintaining their physical and chemical properties in service. Refractory ceramics, due to their properties, have been used for this purpose, having crucial importance in high temperature processes. Refractory linings (composed of refractory ceramics) are used in industrial vessels to produce steel, iron, cement, non-ferrous metals, glass, metallic alloys, in melting process, in petrochemical industry, in incinerators, in mineral processing, in power plants and many other applications. The service temperature of these vessels is around 1650°C for the steel ladles and 1450 °C for the cement kilns, however, some processes may reach 2000°C.

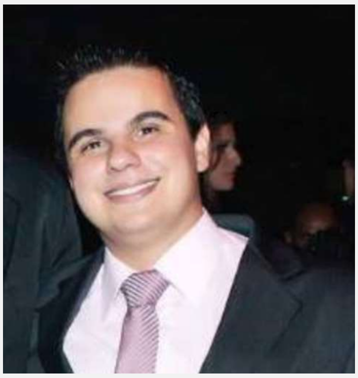
The focus of this study is to fully characterize the thermomechanical behaviour of dry stacked refractory masonry under diversified situations. Therefore, a large experimental campaign was performed covering the behaviour of the brick, the behaviour of the joints and the behaviour of the masonry panels. The refractory bricks are injected into the moulds, pressed and then fired during their production processes. Consequently, the ceramics present an anisotropic behaviour. Therefore, the material was characterized using specimens extracted from different types of bricks and from different directions in the same bricks. It was observed that the bricks present a higher compressive strength in the direction of the pressing. The compressive strength of the material was characterized both at room and elevated temperature (600 °C, 800°C and 1000 °C). The dry joints formed between the stacked bricks play an important role on the thermomechanical behaviour of the masonry panel. The presence of joints reduces the stiffness of the masonry, therefore, the compressive stresses developed in the linings during the heating of the vessels are reduced. The bricks' shape imperfections were found to have the largest influence on the dry joints behaviour, therefore, a statistical analysis of the distribution of the bricks' shape imperfections was carried out. Several studies were carried out on the normal behaviour of the joints: classical joint closure test; bed joint closing action in a masonry wallet measured with a DIC; effects of brick's height imperfections on its loadbearing capacity; effects of bricks height imperfections on the wall's behaviour at ambient and high temperatures and a comparison between the bed and head joints behaviour. To characterize the joints tangential behaviour at high temperatures a novel device was developed and successfully used.

Aiming to assess the behaviour of the masonry panels a large experimental campaign was developed. The main purpose was to fully characterize the masonry walls at different temperatures and different loading conditions. Several aspects that may influence the behaviour of these walls have been tested, namely the loadbearing capacity, the behaviour under cyclic loading and the restrained thermal elongation. Masonry panels were tested under uniaxial and biaxial loading conditions at ambient and elevated temperatures. The experimental results allowed to identify the effects of the stress concentrations caused by bricks height imperfections in the mechanical behaviour of the bricks and in the loadbearing capacity of the specimens, the evolution of the wall's stiffness with the load application, the developed crack patterns and the mechanical behaviour of the specimens at ambient and high temperatures. The effects of the viscoplastic strains developed due to creep and relaxation were also investigated.

Finally, numerical models were also developed to simulate the behaviour of the walls under different testing conditions and a good agreement with the experimental results was obtained. The concrete damaged plasticity model, using a micro-modelling approach, proved to be suitable for representing the behaviour of these walls at ambient and intermediate temperatures. For temperatures above 1000 °C, creep effects starts to raise and the Norton-Bailey creep law was successfully used to represented the material behaviour.

Keywords

Refractory, masonry walls, ambient and high temperature testing, thermomechanical modelling, dry-stacked masonry.



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