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EXPERIMENTAL INVESTIGATION AND NON-LOCAL MODELLING OF THE THERMOMECHANICAL BEHAVIOUR OF REFRACTORY CONCRETE

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This paper describes an experimental characterisation and a non-local finite element analysis on the influence of the testing temperature on the mechanical properties and cracking propagation in refractory cement bricks. Therefore, isothermal four-point bending and uniaxial compression tests have been carried out at different testing temperatures (25, 500, 800, and 1000 °C) to determine the stress-strain response for each independent testing temperature. Based on this response, material constants are identified using the inverse estimation method. Then, they are introduced in a non-local finite element model using CAST3M software. The experimental results indicate that with an increase in the testing temperature, the thermomechanical behaviour of the refractory concrete shows a critical temperature of 800 °C, for which the compression and tensile strengths are the largest. Their values are respectively around 28 and 9 MPa. The present numerical simulation results indicate two types of crack propagation; continuous crack failures when the temperature varies between 25 and 800 °C and multi-identified cracks producing a localised damage zone at 1000 °C. Notably, the sample tested at 1000 °C requires a deflection of 0.2 mm to achieve 0.3 (30 % damaged). In contrast, the damage variable achieves 1.0 (100 % in damage) for the sample tested at 25 °C with the same imposed displacement (0.2 mm). Finally, the enhanced non-local damage model produces a realistic simulation of the experimental failure mechanisms, proving the validity of the implementation method.

INTRODUCTION

Refractory concretes are the simplest to implement among monolithic refractories. They are generally composed of a mixture of refractory cement and aggregates in addition to small amounts of some other elements like silica fume to improve other chemical and physical properties [1–6]. For the last 20 years, refractory concrete has improved to be relatively easier to use than shaped materials. Moreover, it is commonly used in various installations where severe coupled thermal stresses and mechanical loadings are applied: cement furnaces, electric arc furnaces and blast furnaces [7, 8].

Many researchers have studied the mechanical properties of refractory concretes at room temperature through tension, bending, and compression tests. Schmitt et al. determined Young's modulus and the tensile properties of two industrial refractories using uniaxial tension and three-point bending tests. They concluded that the Young's modulus derived from both tests is nearly the same [9]. Additionally, Simonin et al. conducted four-bending tests on aluminous refractory concretes fired at different temperatures ranging from 200 to 1600 °C. Strain gauges were set on the tensile and compressive surfaces to measure the relative difference in the elastic modulus. They concluded that the relative difference is minimal for the samples fired at 450 °C or below. Above this temperature, the difference in the modulus sharply increases [10]. Also, Kakroudi et al. investigated the mechanical properties of two refractory castables fired at different temperatures ranging from 110 to 1100 °C using tensile tests. They found that the damage behaviour is typically associated with the firing temperature in both castables [2]. High temperatures are described as one of the most critical physical deterioration procedures that affect the quality and sturdiness of concrete structures [11]. However, very few researchers have focused on identifying and understanding the thermo-mechanical behaviour of refractory concretes.