Experimental and numerical analyses on ceramic elements obtained by 3D printing

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ABSTRACT

The international cultural and historical heritage is often subject to degradation and damage. The main causes contributing to these phenomena are the chemical and mechanical actions due to acid rain, environmental pollution, and earthquakes. Other causes are the cycles of freezing and thawing that induce the manifestation of internal stresses leading to the deterioration of the material and the collapse of structural parts [1].

In the field of architectural restoration this problem has been addressed by two main solutions. The first involves cleaning processes that leave the missing parts visible, the second consists of introducing reproductions of the missing parts, creating a clear distinction between pre-existing and new elements. In both cases the seismic behaviour of the structure is modified; in the second solution, the added elements do not contribute to the structural strength since they are made of plaster or stucco[1].

This work aims at presenting a preliminary study on the creation of replacements of missing elements within damaged heritage buildings. These elements do resemble the original ones whilst contributing to the overall structural resistance. Special 3D printers are used to print material parts based on a ceramic resin. Starting from an accurate architectural survey of the missing elements, which can also be done through historical photos, 3D graphic models are created in the. STL format that are the basis for the printing phase [2-3]. The stereolithographic type printers here used employ a resin that solidifies if exposed to a laser beam. The objects so created are completed with a heat treatment in a potter's kiln at 1200 °C and become totally compatible with mortar and other parts of the structures.

The work is structured in two distinct phases. In the first phase, specific cubic specimens are produced and subjected to uniaxial compression tests. These are carried out along two orthogonal directions; strain gages are used to identify the deformations and the Young's modulus in the different directions. Therefore, the experimental campaign provides useful information regarding the resin's engineering constants that are currently absent in the literature.

In the second phase, the experimental results are validated by numerical analyses [4]. Assuming an orthotropic behaviour of the material due to the overlapping of the printed layers, a homogenization procedure is conceived to derive constitutive laws that can be then used in finite element-based software for simulating the mechanical behaviour of the considered material.

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