Geophysical Research Abstracts
Vol. 14, EGU2012-1791, 2012
EGU General Assembly 2012

Stone decay assessment of the Madrid′s Royal Palace (Spain) by means of ultrasound and magnetometric prospection

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The architrave of the entablature of the 4 façades of the Palace was built in a limestone known as Colmenar stone (biomicrite), a traditional material used for construction in Madrid. This stone shows such petrophysical properties that make it resistant to decay processes. Despite its high quality, the ashlars of the architrave have undergone fissuring processes resulting on fragments fall, some of them being blocks weighing more than 300 Kg, with the consequent risk for visitors and passers-by.

Fissures were caused by the presence of metallic elements (iron-based) used to tie ashlars. These elements, which could have performed properly in absence of water, underwent oxidation processes due to the water entrance, exerting significant pressures inside the stone that derive into fractures with their planes being almost parallel to the façade surface.

Once verified that the presence of these metallic elements, and their oxidation, was the cause of the ashlars fissuring, an inspection of the building façades architrave was performed by using two portable and non destructive techniques: magnetometry for detecting iron elements, and ultrasound velocity prospection for detecting non visible stone fissures behind the surface. This survey will allow defining the guidelines for a restoration intervention.

The inspection of the architrave consisted of analysing around 1100 ashlars (circa 600 meters long were surveyed), during a lapse of time of one year, in 4 survey campaigns, one for each façade, with the aid of a mobile and self-operating that allows to reach up to 40 m high.

Results from the magnetometry prospection made possible to locate metallic elements (flat bars and cramps), and sometimes the flat bars overlapping. Such bars are usually located at 3-5 cm deep from the surface, just below the freeze and in a case cut in the architrave limestone. In the areas of flat bars overlapping, a depth from the surface into the façade of 8-10 cm was measured. Such bars were several meters long, tieing several ashlars, from 55 to 65 mm wide, and 15-20 mm thick. In vaulted areas of the frieze, iron beams were detected, of around 9 cm thick, as well as iron angle bars behind the mentioned iron beams, vertically arranged and going through the architrave.

The ultrasound propagation velocity survey in all the architrave ashlars was carried out by means of the indirect or surface mode, using a measuring net of 15 cm side and 20 to 30 readings in each element. Results obtained allowed detecting fissures inside the ashlars non visible at the stone surface. Main fissures were located in areas of cramp-stone coupling. Therefore, this technique was sucessful in locating architrave ashlars with risk of fall, and thus it made possible to plan the structural intervention to consolidate these elements by micro reinforcement with stainless materials (e.g. glass fiber).