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Problems in the use of the Salamanca sandstone in historic monuments

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In 1988, the downtown area of Salamanca, in western Spain, was declared a world heritage site in order to preserve its striking monuments. Among these are the two cathedrals (S. XII and S. VI), the Plaza Mayor (1755), Casa de Las Conchas (S. XV), University (1533), San Esteban church (S. XVI) and Santo Tomás de Canterbury church (1175). All of them are build with the Villamayor arkosic sandstone (Tertiary), which overlies the Salamanca sandstones, a Cretaceous–Tertiary lithic wacke.

The Villamayor sandstone (Middle Eocene) is rather a soft rock when wet, and easily carved by sculptors, but also easily adversely affected by the weather. It thus is very common that in the lower part of the façade, the Salamanca sandstone (an Upper Cretaceous – Paleocene rock) has been used as ashlar material instead of the Villamayor sandstone, to avoid the differential erosion between the lower (first 40 cm) and the upper ashlars that had been encountered in some historical buildings. Even though this solution has worked in some cases, in others the damage, although certainly less widespread than if the ashlar had been made of the arkosic sandstone, is still important.

The aim of this work is to study the mechanical and physical properties of both rocks (density, porosity, absorption and uniaxial compression strength or UCS), as well as their petrographic features, in order to understand their different behaviors. We were able to characterize the properties of both building stones, which is a first step in the determination of restoration mechanisms most appropriate for each one. This type of work is very helpful to identify the specific source of many of the stones used in the historical buildings.

On the basis of the thin sections studied, the Salamanca sandstone is a wacke with heterometric subrounded and subangular clasts. These clasts are set in a silica cement and a smectite matrix, especially in the coarser horizons. The origin and precipitation of the silica cement are related to the formation of intrasedimentary paleosoils. Quartz is the main component in the sandy and silt fraction, and kaolinite is the main component for the clay fraction. There are also feldspars, micas (muscovite), and illite. The ferric oxide content attains 10-15% in some places, giving to these rocks a characteristic violet hue.

The Villamayor sandstone (the Cabrerizos Sandstone lithofacies of fluvial origin) has been classified as an arkosic-feldspathic sandstone, with quartz (40-70%), feldspars (10-30%), micas and a clay-rich matrix. Tourmaline is locally present. Petrographic studies show the homometric and subrounded grains embedded in the clay matrix, constituting a b-fabric with no grain-to-grain contacts. Both feldspars are very weathered. Regarding the physical and mechanical tests, the Villamayor sandstone presents higher values of porosity and absorption, and its UCS value is 25 Mpa, on average, decreasing by close to 90% under water-saturated conditions (σ_c^{sat} 3 MPa). For the Salamanca sandstones, the UCS value is somewhat higher under dry conditions (σ_c^{dry} 32 MPa), but the main differences exist in its behaviour under water-saturated conditions, with values down 44% of the reference value (σ_c^{sat}18 MPa).

Owing to the presence of the silica cement, the Salamanca sandstone has a higher UCS, even under water-saturated conditions. Nevertheless, the distribution of the silica and ferric oxide minerals, and thus the degree of cementation, are very irregular. Because of that, it is probable that samples of the building stone were taken from different quarry sites and do not behave in the same way.

The Villamayor sandstone, with a lower UCS and with a very high susceptibility to weakening by water, is commonly used as ashlar material in some façade. It has been adopted in some important buildings, but the bottom of the structures should lie on more resistant rocks in order to avoid erosion. The use of the Salamanca sandstone is appropriate to preserve the lower part of the buildings from capillary absorption. Nevertheless, the irregular distribution of the silica cement makes this lithology inappropriate for that use in some instances. A careful petrographic study of the rock should be required before selecting which quarries will provide blocks of good-quality Salamanca sandstone for the lower part of the historical buildings, where a replacement is needed.