Integration of durability parameters of cultural heritage building stones using by integrated geomatic methodologies

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The “Porte de Mars”, is one of the most emblematic ancient monuments of the city of Rheims. This three-bay roman arch rises at the northern end of former *Durocortorum,* capital of *Gallia Belgica* province. Its construction dates from the mid 2nd to early 3rd c. AD. It was then integrated into the Late Roman rampart of the city. Encased, from 1162 to 1856, in the medieval city wall and then in the castle of the city's archbishops, it was completely cleared and restored during the 19th century. During this period, it was barely saved from being dismantled after the ruin of the archbishops' castle and its complete dismantling by the town's population. It is considered the largest "arch" of the Roman Empire north of Roma. It is 32.35 m long, 6.45 m wide and 12 m high today. Since its rediscovery and until today, the “Porte de Mars” is located in the centre of Rheims, at the crossroads of major traffic axis.

A photogrammetric survey was carried out using a total of 370 high-resolution photos. For this, a camera with a 20.3 Megapixel sensor was used, taking care to work with a single focal length. The upper part of the monument was treated in a second step thanks to the presence of an aerial lift. Part of the photos were taken by fixing the camera on a pole and using a tablet as a means of preview, georeferencing and remote control. After a quality control; the photographs were processed with the Agisoft Metashape software which allows to carry out all the operations of the photogrammetry calculation chain (Structure fFrom Motion - SfM method). This method allows the reconstruction of 3D objects from 2D data. The technique is based on an algorithm that automatically matches points in a set of photos. These points are then treated as remarkable points and repositioned in space in the manner of the perception of volumes by biological eyes. The spatial coordinates of the points are on the one hand calculated by the software and on the other hand provided by the georeferencing data of the images. The distances between 125 key points on the monument are measured with a laser range distance meter (Leica Disto D2) in order to scale the model to its final dimensions. The software allows the extraction of orthophotographs from the 3D mesh according to the chosen orientations.

The modelled datas and orthophotos are injected into a geographic information system (GIS) implemented under QGis 3.4 because of the interoperability of the formats considered. Its data is then used as the basis for plan and volume plots on the one hand and an attribute database on the other. These data are both qualitative (nature of the stone, petrography, assumed origin, restoration phase, etc.) and quantitative (chemical composition, mineralogy, porosity, capilarity, etc.). The methodology will also make it possible to discretize continuous information such as thermal data at the stone scale.
This non-destructive approach to the monument built from an integrated geomatics chain of operations allows the cross-referencing of data of various origins (geological, environmental, archaeological...). Interoperability of the database is essential so that this tool can represent a transversal interest and be used in the framework of building conservation. This approach allows the construction of thematic maps of the monument, such as material maps, stone compatibility maps or prospective parameter maps such as the durability of materials. In addition, the use of photogrammetry has considerably lightened the process of acquisition and calculation of the model, making the construction of the information system much easier.

Keywords: Photogrammetry, GIS, 3D model