3D Documentation For Restoration Of Historic Buildings

The church of St. Michael the Archangel (1735) in the centre of Borgo di Terzo, near Bergamo, Italy, was showing cracks in the front elevation masonry, indicating serious building damage. Due to its irregular architecture, the church required a precise analysis of existing conditions as a basis for the renovation work.

Exact measurements are important, especially with structural intervention, forming the foundation for structural analysis using the finite element method (FEM). 3D laser scanning is superb for the accurate recording of existing conditions. Comprehensive spatial data that can be used for structural analysis with standard software solutions is quickly and easily available, also for CAD design of the restoration. Laser scanning provides records in which every individual point shows the same accuracy in the spatial coordinate system. Thus, it is possible to use the generated cloud of individual points (point cloud) for the investigation of a building component and to automatically record structural deformations of additional building components at the same time.

As a basis for the forthcoming structural improvements to the church in Borgo di Terzo, the engineering faculty of Bergamo University made use of a FARO laser scanner and was able to record the interior of the building in a single day. A graphical approach was chosen to filter and interpolate the scanning data for the detailed investigations that followed before the renovation. This enabled use of normal architectural procedures for the building analysis: for example, systematic investigation of crack patterns in the masonry to display the damage in the orthogonal projection or a comparison of the actual geometry of a vault deformed under its own weight with its ideal geometry.

In order to be able to use the church scan data with FEM, the point-cloud had to be converted from a continuous model to a numerical model. Subsequently, sections relevant to the damage investigation and orthogonal to each other could be selected. Here, element grids with a uniform spacing of 30 x 30 x 30cm proved to be a good compromise in representing significant parts of the building structure.

In the course of 3D documentation with the laser scanner, the cause of the observed damage became clear: The timber roof framework had settled as a result of earlier restoration. Both a tie anchor and upper spines resting on the vault were affected. This led to heavy deflection and severe damage to the underlying vault masonry. The current load distribution in the vault was evaluated and distribution following the planned restoration was checked, using FEM analysis. It showed that both the arched buttress supports and the corresponding anchors required renovation. In addition, the middle arch must be reinforced with a steel grid and lime mortar. The deformation of the vault under load also showed that a tie member of the vault spine had given way, suggesting replacement of this anchor. After these reinforcement measures were incorporated into the FEM model of existing conditions, a general improvement in the entire structural condition became apparent.