University of Patras, Faculty of Civil Engineering

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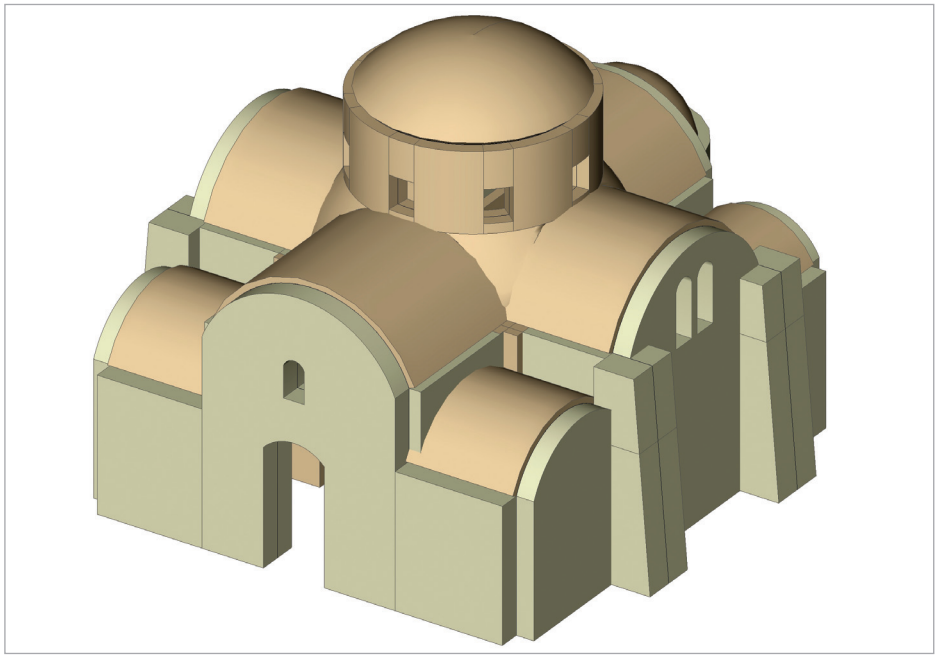
The Department of Civil Engineering of University of Patras was founded in 1972, consists of 35 fulltime faculty members and has an undergraduate student body of about 1.200 persons. It operates under the 5 years study program and offers the degree of Civil Engineering. It consists of three Divisions which cover the areas of Structural Engineering, Geotechnical Engineering and Hydraulic Engineering and Environmental Engineering, Transportation Engineering and Building Technology/City Planning.

The Department operates 8 Laboratories for teaching and research purposes. In addition, the Department has a Computer Centre with a large number of personal computers, which provides adequate computing facilities.

The Department is also responsible for graduate education leading to the degrees of Master of Civil Engineering and Doctor of Civil Engineering through a comprehensive graduate studies program involving graduate level courses.



Software: Scia Engineer

Monastery of Fragavilla - Amalias, Greece

Seismic analysis of a byzantine church using pressure only finite elements and its retrofitting by steel tendons

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Description of the structure

The byzantine church under consideration, which is called Monastery of Fragavilla, is located 2 km south-east from Amalias, in the Elis prefecture of western-Greece, one of the most seismic prone areas of Europe. It is built during the first half of the 12th century and because of its form the building is classified as a church of the type “enrolled cross with dome”.

The temple is formed by two orthogonal barrel vaults at the intersection of which is situated the cylindrical drum that supports the dome. The width of the stone masonry walls varies from 0.90 m to 0.70 m. The dome as well as the vaults are mainly made of solid bricks and have a thickness of 0.26 m.

Aim of the project

The aim of this project is to study the application of the pressure only elements on the seismic analysis of a masonry church with complex geometry and its retrofitting by steel tendons.

Pressure only elements

Pressure only elements were developed for the analysis of masonry walls, as this is a typical case of an element that can sustain only compression forces.

The calculation is based on an iterative process. In every finite element where tension is found, an orthotropy will be given in such a way that the stiffness in the direction of tension is lower, which causes that the force will find its way through the elements in the direction of pressure lines in which the element is given a higher stiffness. This iterative process continues until equilibrium is found, but never stiffness less than 5% will be given in a direction.

Seismic analysis

From the modal analysis we obtain the first two natural periods (T1 = T2 = 0.07 sec). The design spectral acceleration Sa(T) was calculated from the Greek Seismic Code equal to 0.41g. An equivalent static analysis for eight load combinations (G±Ex ±0.30Ey and G±0.3Ex ±Ey) was performed.

Steel tendons

A pair of steel tendons of 25 mm diameter was inserted into the masonry walls at the level of the springs of the secondary vaults. The steel tendons were simulated as 1D members that can sustain only axial forces.

Results

The non-linear analysis depicts that the developing tensile stresses at the critical parts of the church (vaults, drum and pendentives) are higher than the tensile strength of the masonry. After the insertion of the steel tendons, confinement of the structure was achieved and the developing tensile stresses at the critical parts of the church were slightly decreased.

The role of Scia Engineer

Scia Engineer proved to be a valuable partner for the simulation and analysis of the Monastery of Fragavilla.

Specifically:

- The general cross section module gave us the capability to simulate the complex geometry of the four masonry piers of the church
- The mesh generator was able to create with a great speed an excellent finite element mesh despite the complexity of the structure
- The 2D member components module of Scia Engineer made it possible to simulate the behaviour of the steel tendons inside the masonry walls
- Scia Engineer’s support team was always available when any problem occurred during this project

Monastery of Fragavilla

Amalias, Greece

Project information

Owner	Holy Metropolis of Eleia and Oleni
Construction Period	First half 12th century
Location	Amalias, Greece

Short project description

The byzantine Monastery of Fragavilla was built during the first half of the 12th century and is classified as a church of the type "enrolled cross with dome". The temple has survived almost undamaged over 900 years until the March 1993 Pyrgos (Greece) earthquake sequence, when it suffered severe damage to the extent that scaffolding had to be installed to prevent collapse. This project's aim is to study the application of pressure only elements on the seismic analysis of this masonry church with complex geometry and its retrofitting by steel tendons.