“ PROHITECH ”

Title: PROHITECH – Earthquake Protection of Historical Buildings by reversible mixed technologies

Fund: European Commission – Sixth Framework Programme

Partners: University of Naples Federico II – Engineering (Italy), University of Liège (Belgium), University "Sts. Cyril and Methodius" of Skopje (FYROM), National Technical University of Athens (Greece), University of Naples Federico II – Architecture (Italy), Instituto superior tecnico of Lisbon (Portugal), The “ Politehnica University of Timisoara (Romania), Technical University of Civil Engineering – Bucharest (Romania), University of Ljubljana (Slovenia), Bogazici university (Turkey), TECHNİON – HAIFA (ISRAEL), Engineering centre for Archaeology and Environment (ECAE) – Faculty of Engineering – Cairo university (Egypt), NATIONAL SCIENTIFIC AND TECHNICAL RESEARCH CENTRE (MOROCCO), SECOND UNIVERSITY OF NAPLES (Italy), Ecole Polytechnique d'Architeture et d'urbanisme (E.P.A.U) Algiers (Algeria)

Coordinator: Professor I. Vayas (NTU Athens)

Research group: A. Marinelli, M.E. Dasiou, M. Papageorgiou, K. Papantonopoulos, S.K. Kourkoulis, I. Psycharis

Duration: 01/10/2004 - 30/09/2007

Budget: 2.400.000 €

Summary

The project tackles the very important subject of the seismic protection of historical and monumental buildings, namely of constructions dating back from the ancient age up to the mid of the 20th century. Its main objective is to develop sustainable methodologies for the use of reversible mixed technologies in the seismic protection of existing constructions, with particular emphasis to buildings of historical and artistic interest. Reversible mixed technologies exploit the peculiarities of innovative materials and special devices, allowing ease of removal if necessary. The endpoint of the research is a proposal of codification for the use of such technologies in the seismic protection of existing constructions, which will meet the most up-to-dated codification issues at European level and will comply with layout, language and philosophy of structural Eurocodes.

Publications

Journals:

1. Vayas, I., Dasiou, M.-E., Marinelli, A. : Säulen Griechischer Tempeln unter Erdbebenbeanspruchung, Bautechnik 84 (2007), H. 6, 388-396 DOI: 10.1002/bate.200710034
2. S. K. Kourkoulis, S.-A. Papanicolopulos, A. Marinelli, I. Vayas: Restaurierung antiker Tempel: Experimentelle Untersuchungen zum Ausziehverhalten von Verankerungen im Marmor, Bautechnik 85 (2008), H. 2, 109-119 DOI: 10.1002/bate.200810010
3. A. Marinelli, I. Vayas, S.-A. Papanicolopulos, S. Kourkoulis: The pull-out problem in restoring marble fragments : A design criterion based on experimental results. Strain, Vol. 45, No. 5, (2009), p. 433-444. DOI: 10.1111/j.1475-1305.2008.00519.x

Conferences:

1. I. Vayas, M.E. Dasiou, A. Marinelli: Dynamic behavior of ancient columns, COMPDYN 07, ECCOMAS Thematic Conference on Computational Methods in Structural Dynamics and Earthquake Engineering, Rethymnon, Crete, Greece, 13–16 June 2007
2. M.E. Dasiou, C. Mouzakis, I. Psycharis, I. Vayas: Influence of metallic connectors on the seismic response of ancient monuments, 6th National Conference of Metal Structures, Ioannina, 2008. 419-42
3. M.E. Dasiou, C. Mouzakis, I. Psycharis, I. Vayas: Experimental investigation and analysis of the seismic behaviour of ancient Greek columns, 3rd Panhellenic conference on Seismic Technology, Athens, 2008, article 1832,1833.
4. I. Vayas, M. Papageorgiou: Innovative technologies for strengthening of an irregular r.c. building, PROHITECH 09 Conference, Rome, 1083-1088, CRC Press

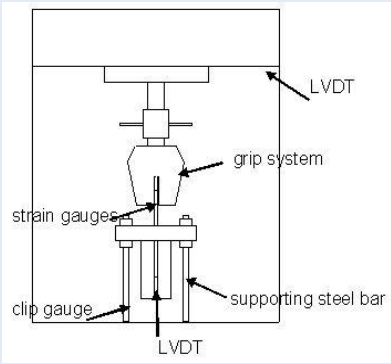
5. M.E. Dasiou, I. Psycharis, I. Vayas : Verification of numerical models used for the analysis of ancient temples, PROHITECH 09 Conference, Rome, 1269-1274, CRC Press
6. I. Vayas, A. Marinelli, S. Kourkoulis, S. Papanicolopoulos: The pull-out problem in restoring marble fragments, PROHITECH 09 Conference, Rome, 1357-1362, CRC Press
7. I. Vayas, A. Marinelli, S. Kourkoulis, S. Papanicolopoulos: Investigating the fracture behaviour of Dionyssos marble: An experimental study, PROHITECH 09 Conference, Rome, 1699-1704, CRC Press

Description (NTUA)

A pioneering method has been developed for joining together fragmented structural elements using threaded titanium bars inserted in the marble, in predrilled holes filled with cement mortar used as an adhesive material. A combined experimental and numerical analysis was undertaken in an effort to enlighten the failure mechanisms related to the possible pull-out behavior of such anchors and to study parametrically the various factors affecting the resulting response. The dynamic behavior of the ancient temples is ruled by the independent rocking and sliding of the stone blocks that during a strong earthquake creates an external energy absorption mechanism. Due to the highly non-linear behavior making an analytical approach almost impossible for such type of structures, an experimental and numerical investigation was undertaken to check the suitability of possible intervention methods in the restoration process of a classical monument.

Experimental investigations

The experimental work included series of 3P-B, 4P-B and DENT tests as well as pull-out tests on prismatic Dionysos marble specimens. The parameters studied included the depth and the pitch of the reinforcing bars' thread. It has been shown through the introduction of possible limit states that the form of the thread has an influence on the carrying capacity.



Three different geometrical configurations of the columns, characteristic for many ancient monuments found in the high-seismicity areas of the Eastern Mediterranean, were examined; the single freestanding columns and the columns in a row or in a corner connected with architraves. After the behavior of this temple sub assemblages was studied, a new series of experiments considering intervention methods was implemented.

Numerical investigations

A potential failure mechanism of the proposed intervention for the connection of marble fragments, was modeled in the form of debonding between the binding mortar and the inner surface of the connected marble structural members. The sensitivity of the pull-out behavior was checked with regards to parameters such as the thread pitch, depth and anchorage length. A simplified model was created using the code ABAQUS and was calibrated to architrave multi-point bending experiments, to provide an easy-to-use tool for the design of different intervention scenarios.

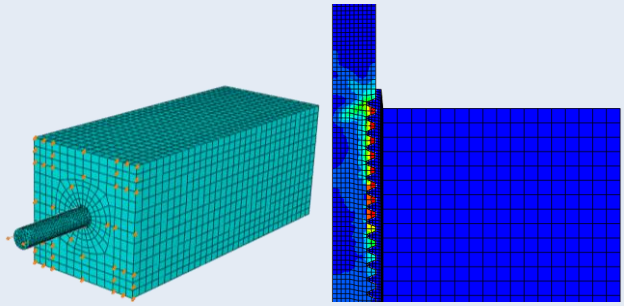


Fig. 1: ABAQUS 3D and axisymmetrical models of pull-out test

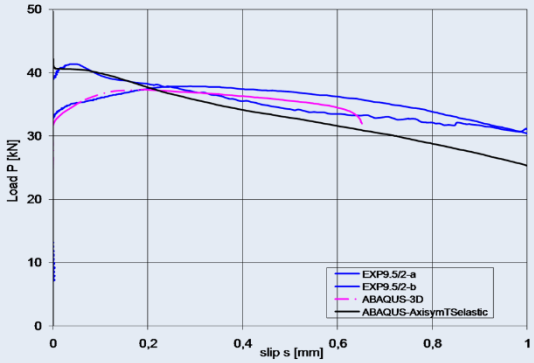
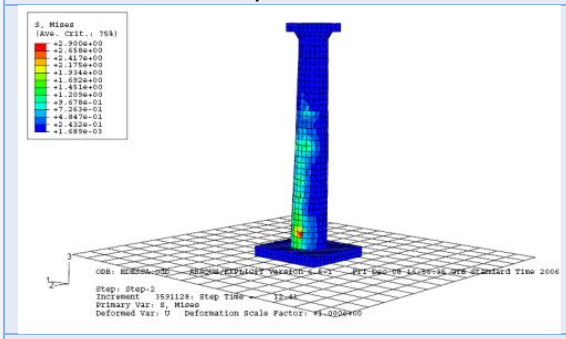


Fig. 2: Pull-out experimental vs numerical results as Load-Slip curves

At a larger scale, the verification, calibration and selection of the most suitable numerical modeling technique were obtained by comparing the numerical results with corresponding experimental ones. Three alternative modeling methods were used by application of the general purpose Codes ABAQUS and 3DEC and their results are compared with the results obtained from experiments, on the 6-degree-of-freedom earthquake testing facility of the Earthquake Engineering Laboratory of the National Technical University of Athens.



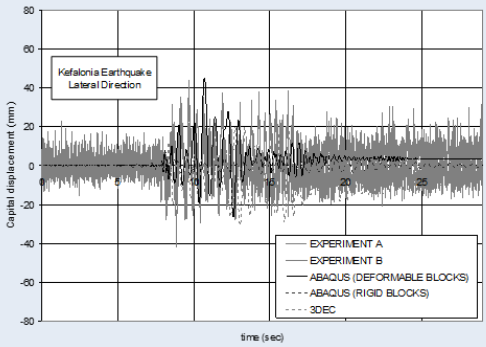


Fig. 3: ABAQUS model: experimental vs numerical results (displacement w.r.t time)

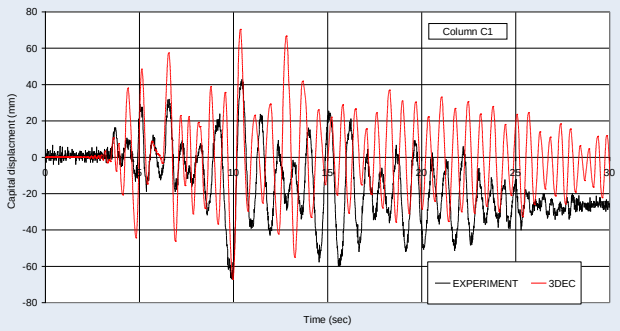


Fig. 4: 3DEC model: experimental vs numerical results (displacement w.r.t time)