



## Safeguard or enhance the earthquake resistance of a historic structure.

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### IS IT:

*Product*

*Technology*

*Equipment*

### APPLICABLE FOR:

*Restoration*

*Rehabilitation*

*New Construction*

### APPLICABLE ON:

*1. Foundations and underground structures*

*2. Vertical structures*

*3. Horizontal structures and vertical connections*

*4. Roof and terraces*

*5. Façade and building envelope*

*6. Finishes and completion elements*

*7. Integrated services*

*8. General strategies for building recovery*

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***Related companies:*** No companies; university research; structural study.

## DESCRIPTION

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Simple steel members (tension wires) applied to load bearing masonry in order to improve the seismic behavior of a historic structure.

## WHY TO USE

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Tension wires are used in cases of intersecting walls or building corners that are splitting up / being pulled apart, due to existing structural mishandling of loads borne. They are also applied to improve the behavior of a structure by connecting opposite parts of it. They are usually placed horizontally below the bearing levels of the roof or floors. The thickness of the masonry must be greater than 45 cm for their application.

The use of these elements leads to an improvement in the behavior of masonry against horizontal seismic movements. As a rule, it can be said that these are used only in cases of serious damage to the masonry.

## HOW TO USE AND APPLY

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These simple steel members (tension wires) are visible in the interior as a rule and sometimes on the exterior of a historic building.

### PERFORMANCE METHODOLOGY

**Step 1:** The tension wires' adjustment positions are selected and the adequacy of the masonry elements (local compression control) for receiving the pre-tensioning forces is checked. Otherwise local reinforcement is provided.

**Step 2:** Holes should be drilled in the mass of opposite walls, at the same level. For corrosion protection, the tension wires are placed in standard insertion tubes or in holes drilled along the middle surface of the wall, or along grooves that open symmetrically on both sides of the wall to achieve a central application of the pre-tensioning force.

**Step 3:** A continuous prestressing rod enters the hole.

**Step 4:** The tension wires are anchored (high strength and large diameter rods) to properly sized anchor plates.

**Step 5:** The rod is permanently anchored at one end and pulled at the other with a hydraulic jack or other instrument.

**Step 6:** After the tension wires are installed, the inner holes are filled with mortar as warranted. The gap between the tension wires and their lining tube is filled with mortar unless it is advisable to omit the connection of the tension wire so that it can be observed, re-tensioned or even removed in the future.

**Step 7:** The tension wires should be anchored to the outer surfaces of the walls. Due to the low bearing capacity of the masonry, the prestressing force is usually transferred to the masonry through rigid metal plates, which distribute it over a large area of the wall. Anchoring devices and plates are usually mounted in a recess in the wall or on the surface of it. The anchors after the application of appropriate paint or other protected layer remain uncovered and accessible. Alternatively, they are covered with a coating. The number of tension wires that are required depends on the thickness of the wall. For thin masonry walls one tension wire is needed, while for larger thicknesses two or more tension wires are required (so that the force may be distributed as evenly as possible throughout the width of the wall).

## TECHNICAL CHARACTERISTICS

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The pre-stretched (pre-tensioned) wires are usually made of prestressed steel (structural steel is not adequate in these cases).

By prestressing, the flow of forces down walls may be corrected. These elements have minimal dimensions and so have little negative effect on the continuity and / or on the form of the original structure and they are easily reversible.

Tension wires are anchored to steel plates in order to spread loads evenly along a wall's surface.



## **RECOMMENDATIONS AND OTHER INFORMATION**

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This solution should be used when stabilizing the structure is advisable for safety reasons.

### *ADVANTAGES*

- In general, prestressing improves the behavior of masonry in potential horizontal dislocations as a result of e.g. seismic loading.
- This technique is used as a means of reinforcement mainly in monuments where its application does not cause major interventions on the visible surfaces.
- This method is easily reversible.

### *DISADVANTAGES*

- The tension wires are loosing over time, so systematic monitoring is required.
- As a method of intervention, pre-tensioning does not radically solve the rehabilitation problem by itself, so it is usually a complementary form of intervention.
- The steel used may experience corrosion problems over time, while the use of stainless steel or comparable usually increases costs. The use of stainless steel is generally not recommended when large amounts of bronze, brass or copper chlorides are present in the atmosphere. In this case titanium or suitably shielded steel is recommended.

## **EXAMPLES**

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The Cyprus University of Technology Library, a Church.  
[See attached images at the end of this sheet].

## **REFERENCES / SOURCES AND LITERATURE**

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Philokyrou, M. 2014 "Adaptation of New University Uses in Old Buildings. The Case of Rehabilitation of Listed Buildings in Limassol Cyprus for University

Purposes", International Journal of Architectural Heritage: Conservation, Analysis and Restoration (Taylor and Francis) 8:5, pp.758-782.  
(<https://doi.org/10.1080/15583058.2012.738282>).

Ferretti, E. Wire Ropes and CFRP Strips to Provide Masonry Walls with Out-Of-Plane Strengthening

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6747587/>

G. Mavratzonis and Back Ntezi, "Reinforcement of Historic Buildings with load bearing masonry with the use of metal member", presented in the 10th Student Conference on "Structural Repairs", March 2004, in greek (Φοιτητικό Συνέδριο «Επισκευές Κατασκευών – 04», Μάρτιος 2004 . 27-1 Εργασία Νο 27 ' Ενίσχυση Ιστορικών Κτιρίων από Φέρουσα Τοιχοποιία με χρήση μεταλλικών στοιχείων», Μαυρατζώνης Γιώργος και Μπακ Νταΐζη)

## **WEBSITE OF THE COMPANY**

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N/A

## IMAGES AND CAPTIONS

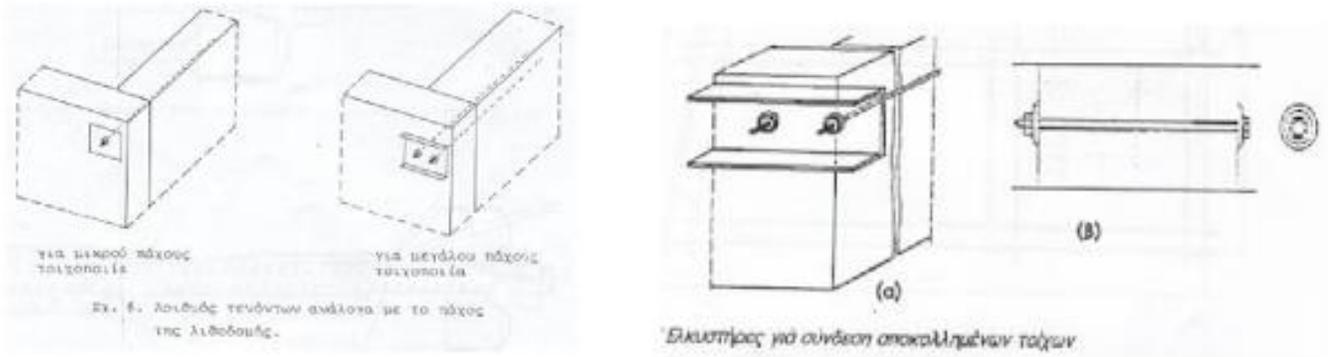


Fig.1-2: Sketches showing the application of the tension wires in masonry walls.

©G. Mavratzonis and Back Ntezi, "Reinforcement of Historic Buildings with load bearing masonry with the use of metal member".



Fig.4: Tension wires visible in the interior of a church. ©Chrysanthos Pissarides



Fig.5-6: Tension wires placed in the interior and exterior of the Library of the Cyprus University of Technology, Limassol, Cyprus. ©Maria Philokyprou, <https://doi.org/10.1080/15583058.2012.738282>



Fig.7: Tension wires steel plates visible at the exterior of a church. ©Chrysanthos Pissarides



Fig.8: Showing How the ferrule modifies the load centering on the two clips (source: Ferretti, Elena. 2019. "Wire Ropes and CFRP Strips to Provide Masonry Walls with Out-Of-Plane Strengthening".

©Materials 12, no. 17: 2712. <https://doi.org/10.3390/ma12172712>)

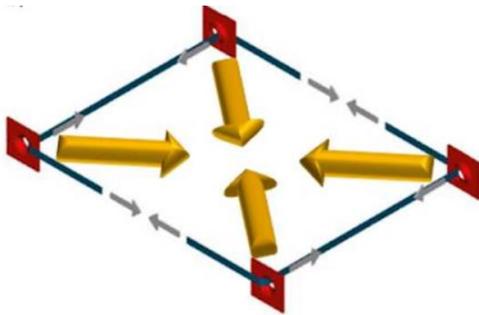


Fig.9: The CAM system: how a pre-tensioned steel ribbon compresses the masonry (SOURCE: Ferretti E, Pascale G. Combined Strengthening Techniques to Improve the Out-of-Plane Performance of Masonry Walls. Materials (Basel).

©2019 Apr 10;12(7):1171. doi: 10.3390/ma12071171. PMID: 30974848; PMCID: PMC6479454).

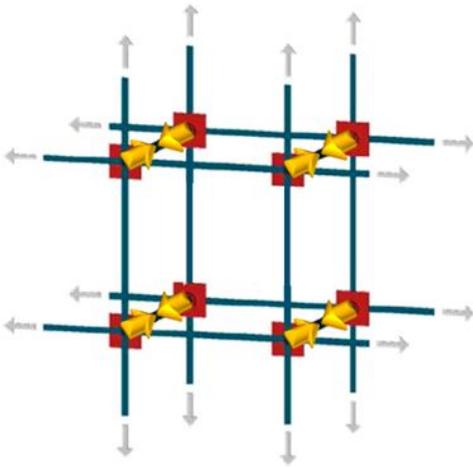


Fig.10: Showing Nodal forces transferred by the CAM straps: Balanced forces in gray and not balanced forces in yellow (source: Ferretti, Elena. 2019. "Wire Ropes and CFRP Strips to Provide Masonry Walls with Out-Of-Plane Strengthening" ©Materials 12, no. 17: 2712. <https://doi.org/10.3390/ma12172712>)