

Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte
Band: 52 (1986)

Artikel: Additional pre-stressing for repairing and strengthening purposes
Autor: Avramidou, N. / Sparacio, R.
DOI: <https://doi.org/10.5169/seals-40357>

Nutzungsbedingungen

Die ETH-Bibliothek ist die Anbieterin der digitalisierten Zeitschriften auf E-Periodica. Sie besitzt keine Urheberrechte an den Zeitschriften und ist nicht verantwortlich für deren Inhalte. Die Rechte liegen in der Regel bei den Herausgebern beziehungsweise den externen Rechteinhabern. Das Veröffentlichen von Bildern in Print- und Online-Publikationen sowie auf Social Media-Kanälen oder Webseiten ist nur mit vorheriger Genehmigung der Rechteinhaber erlaubt. [Mehr erfahren](#)

Conditions d'utilisation

L'ETH Library est le fournisseur des revues numérisées. Elle ne détient aucun droit d'auteur sur les revues et n'est pas responsable de leur contenu. En règle générale, les droits sont détenus par les éditeurs ou les détenteurs de droits externes. La reproduction d'images dans des publications imprimées ou en ligne ainsi que sur des canaux de médias sociaux ou des sites web n'est autorisée qu'avec l'accord préalable des détenteurs des droits. [En savoir plus](#)

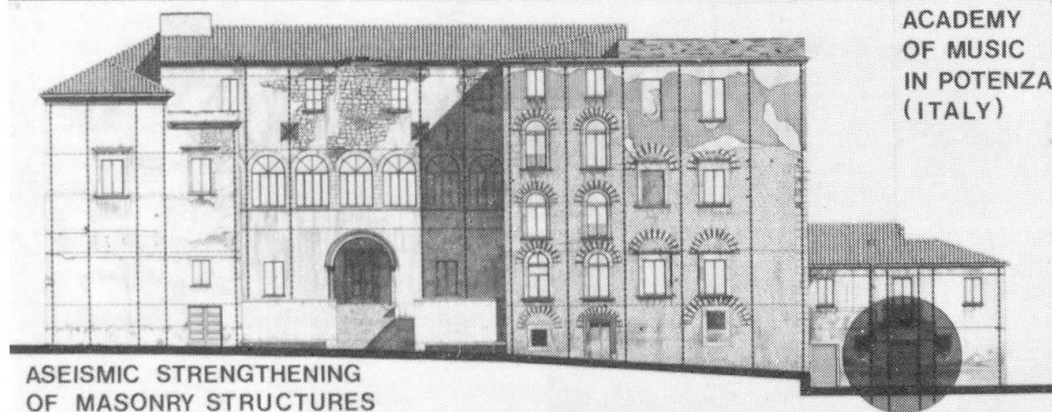
Terms of use

The ETH Library is the provider of the digitised journals. It does not own any copyrights to the journals and is not responsible for their content. The rights usually lie with the publishers or the external rights holders. Publishing images in print and online publications, as well as on social media channels or websites, is only permitted with the prior consent of the rights holders. [Find out more](#)

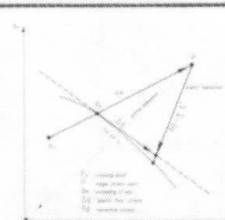
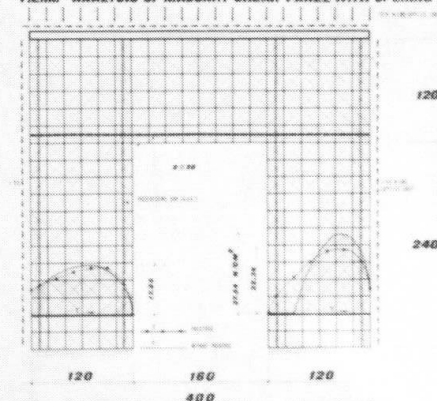
Download PDF: 17.01.2026

ETH-Bibliothek Zürich, E-Periodica, <https://www.e-periodica.ch>

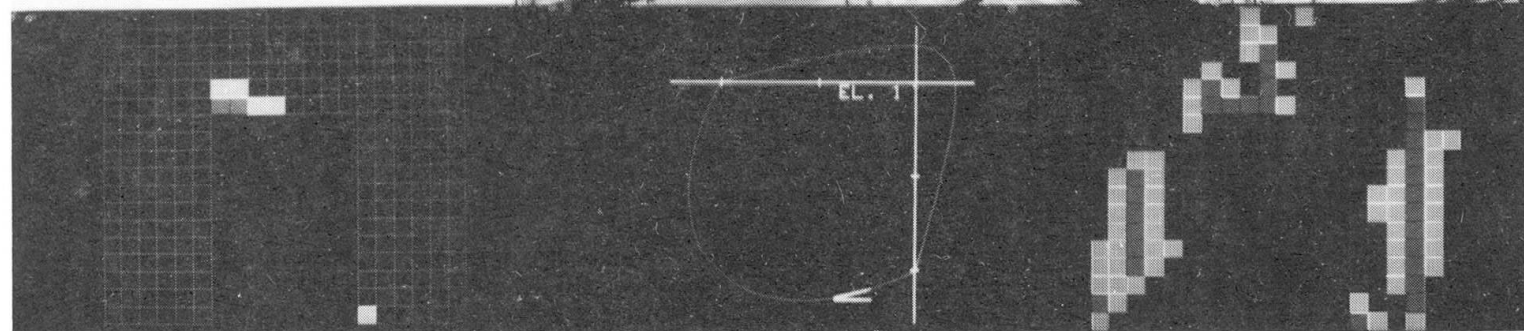
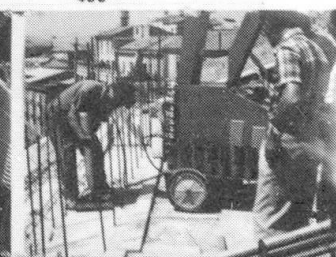
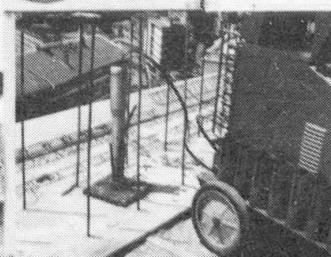
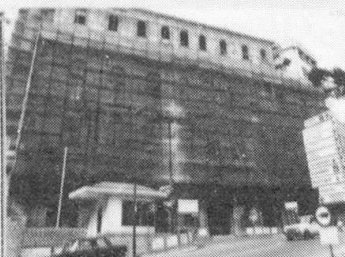
ADDITIONAL PRE-STRESSING FOR REPAIR STRENGTHENING PURPOSES



F.E.M. ANALYSIS OF MASONRY SHEAR PANEL WITH OPENING



THE STRESS POINT IS REPLACED ON THE LIMITING CURVE ENFORCING INTO THE ELEMENT A SET OF PERMANENT STRAINS. THE PLASTIC STRAINS ϵ_p THE TENSOR IS DETERMINED ON THE BASIS OF ORTHOGONALITY CONDITION ($\sigma_p \epsilon_p = 0$). A BRITTLE TYPE BEHAVIOUR IS REPRESENTED DETERMINING THE VALUE ϵ_{max} OF THE MAXIMUM PERMANENT STRAIN. WE DEFINE A LIMITING VALUE ϵ_c (CRIT. VALUE FOR BRITTLE BEHAVIOUR). IF $\epsilon_p > \epsilon_c$ THEN THE ELEMENT CANNOT BEAR ANY STRESS STATE AND ITS LIMITING CURVE DEGENERATES TO THE ORIGIN OF THE STRESS PLANE. THEREFORE THE VALUES OF ϵ_c TO ADD SHALL BE DEFINED SO AS TO REPLACE INTO THE ORIGIN THE STRESS POINT.



Additional Pre-Stressing for Repairing and Strengthening Purposes

N. AVRAMIDOU

Prof.
Fac. Archit, Univ. Firenze
Firenze, Italy

R. SPARACIO

Prof.
Fac. Eng., Univ. Napoli
Napoli, Italy

A design criterion for repairing damaged masonry buildings, in order to attain a desired safety level, must give schemes as "box-type" or "folded structures". For this purpose, effective connections between orthogonal walls are obviously required, as well as tie-beams running through wall elements at all floor levels, in order to get slabs infinitely rigid in their own plane. Such a criteria allow to evaluate the safety factor by analysing just the vertical walls, to determine the plane-stress distribution under monotonically increasing shearing forces and constant vertical load. Such a non-linear analysis, useful for seismic design, has been performed via computer program "N.IN.F.E.A." [1]; a two-dimensional plane-stress finite element has been used to model masonry panel, and beam element or rod element for tie-beam and concentrated reinforcement. This way it is possible to evaluate the seismic behaviour of walls provided of pre-stressed steel cables as in the project illustrated in this poster. The stress state is defined in a bi-dimensional continuum membrane loaded by forces acting in the middle plane of panel. The membrane may have holes with openings, as in the case of masonry panel of buildings.

The unknowns of the problem are the nodal generalized displacements; the equations are the equilibrium conditions for the nodal points under the actions of external and internal forces. These forces are related to elemental deformation and therefore they are expressed in terms of unknown displacements.

The numerical procedure is a typical step-by-step incremental loading analysis; for each element of the assemblage the elastic compatibility has been checked in every step. This means that the representative stress-point $P(\sigma_1, \sigma_2)$ is contained within the "elastic domain", which is defined by the coupling between two well-known limiting curves, Drucker and von Mises.



If the stress-point is beyond the limiting curve, the stress state is "illegal", and the point must be replaced on the limiting curve (which is assumed as plastic potential), adding into the element a set of permanent strains $\underline{\epsilon}^*$, i.e. the plastic strains $\delta \underline{\epsilon}_p$. The $\underline{\epsilon}^*$ tensor is determined on the basis of "orthogonality condition", respect to the plastic stress variation. Such determination of tensor $\underline{\epsilon}^*$ is performed, at first instance, on the element with fixed nodes; the stress tensor originated is:

$$\delta \underline{\sigma} = -\underline{K} * \underline{\epsilon}^*$$

where \underline{K} is the "stiffness matrix" of masonry (here supposed isotropic), for plane-stress state. It must be verified that

$$\delta \underline{\sigma} = -\underline{K} * \underline{\Gamma} * \begin{bmatrix} \delta F / \delta \sigma_1 \\ \delta F / \delta \sigma_2 \end{bmatrix}$$

where the coefficient $\underline{\Gamma}$ is determined to allow the stress-point P to return on the limiting curve $F(\sigma_1, \sigma_2) = 0$.

$\delta \underline{\sigma}$ originates a set of fixed nodes unbalanced reactions; therefore, this phase is followed by a "relaxation" cycle consisting of their diffusion within the whole system. Each of these relaxational cycles generally produces a new incompatible state of stress. To obtain the elasto-plastic equilibrium several relaxational cycles are necessary within each loading step. Once the convergence has been achieved, the displacements of all the nodes, the stress state, the permanent strains stored and the energy dissipation in each element are obtained. It is also possible to reproduce a brittle type behaviour; the value ϵ_{max} of the maximum permanent strain is determined; we define a limiting value ϵ_0 representing the maximum plastic strain, limit value for plasticity above brittle behaviour. If $\epsilon_{max} > \epsilon_0$, then the element cannot bear any stress state and its limiting curve degenerates to the origin of the stress plane $\sigma_1 - \sigma_2$. Therefore the value of $\underline{\epsilon}^*$ to be added must be defined to replace the stress-point into the origin. Such a cracked element cannot further contribute to the energy dissipation process.

This poster deals with the strengthening of a masonry building in Potenza (Italy), (see illustration and photographs). The design criteria are the same applied in several other buildings the authors have restored in this country, where serious damages were suffered for the earthquake of Nov. 1980.

The more significant details of the project are shown; the stress analysis of a masonry panel with opening, provided of pre-stressed steel cables, is illustrated. To evaluate the safety-factor in the panel, and to calibrate the design parameters, more than one analysis has been carried out.

For the shown example we have:

- average compression stress in masonry for gravity load:
-0.19 N/mm²
- average compression stress in masonry due to pre-stressing:
-0.2 N/mm²
- shear forces distributed along panel's bounds: $\Gamma * 0.098$ N/mm²
- width of the masonry wall: 500 mm

- total area of vertical pre-stressed reinforcements: $4 \times 1.824 \text{ cm}^2$
- masonry compressive strength: -2 N/mm^2
- masonry tensile strength: $+0.2 \text{ N/mm}^2$
- limiting value for plasticity above brittle behavior: $\epsilon_0 = 5 \times 10^{-4}$

It is illustrated the assumed "elastic domain" for masonry, and the "mesh" for the f.e.m. analysis, the shear-stress diagrams with, and without, prestressing. Some pictures have been taken from the computer-display, and they show plastic and cracked zones for more values of Γ .

The results of the analysis allow to state that enough safety is assured by the adopted values. The procedure avoids a verification exclusively based on simple geometrical design rules, and introduces also for masonry more modern criteria about structural safety and reliability.

- [1] Russo-Spena F., Sparacio R. = Verifica di un intervento di restauro statico con il metodo degli elementi finiti = Convegno ASSIRCO Palermo 1979.

Leere Seite
Blank page
Page vide