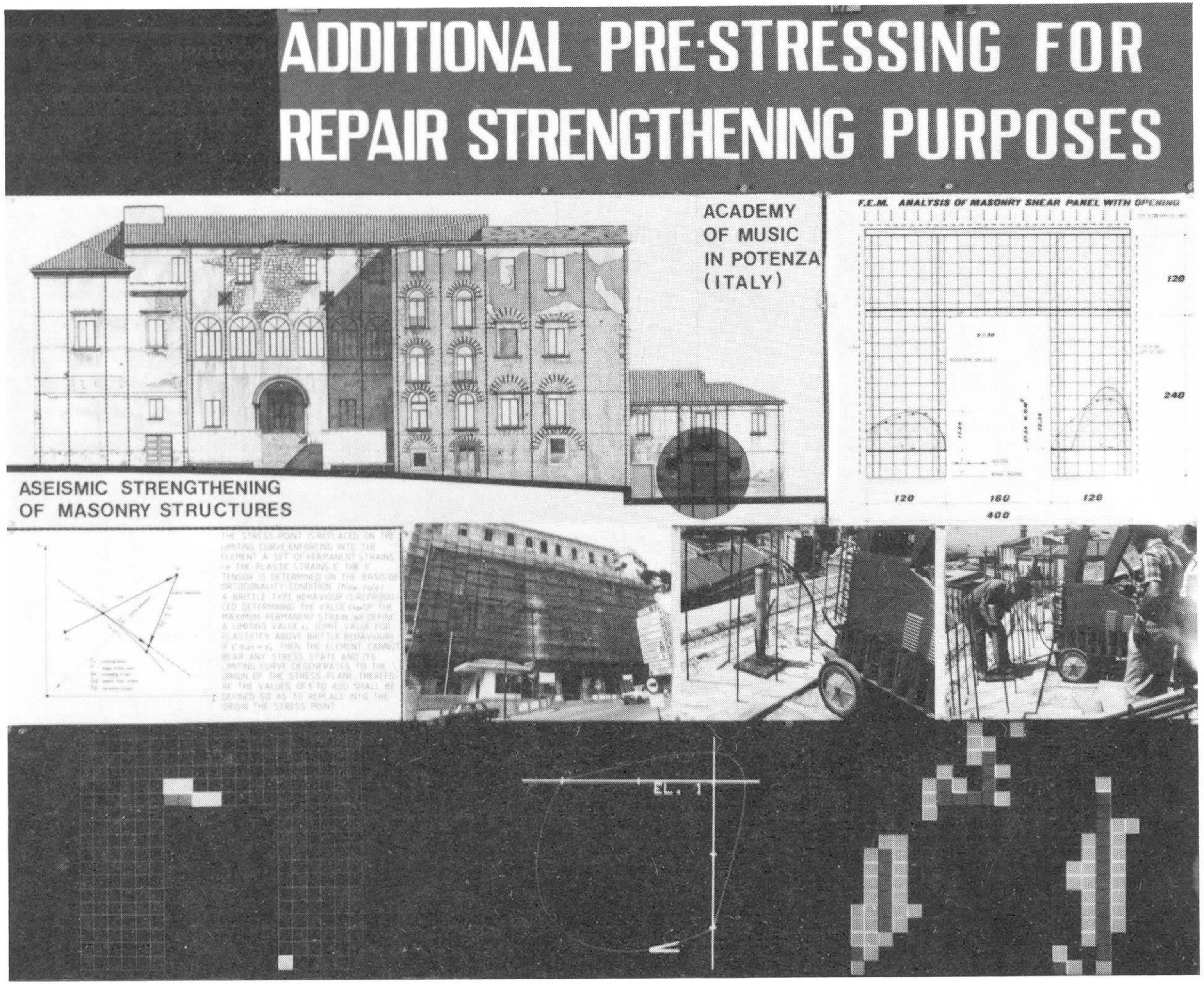
Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte
Band: 52 (1986)

Artikel: Additional pre-stressing for repairing and strengthening purposes

Autor: Avramidou, N. / Sparacio, R.

DOI: https://doi.org/10.5169/seals-40357


ADDITIONAL PRE-STRESSING FOR
REPAIR STRENGTHENING PURPOSES
ACADEMY
OF MUSIC
IN POTENZA
(ITALY)
F.E.M. ANALYSIS OF MASONRY SHEAR PANEL WITH OPENING
120
240
120
160
120
400
ASEISMIC STRENGTHENING
OF MASONRY STRUCTURES
EL. 1

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 finit element has been used to model masonry panel,and beam element or road 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 ilustrated 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:

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

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

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

where the coefficient Γ 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_o representing the maximum plastic strain,limit value for plasticity above brittle behaviour.If $\epsilon_{max}>\epsilon_o$,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 ϵ^* to be added must be defined to replace the stress-point into the origin.Such a cracked element cannot further contribute ot 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, were serious demages 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/mmq
- average compression stress in masonry due to pre-sterssing: -0,2 N/mmq
- shear forces distributed along panel's bounds: Γ*0,098 N/mmq
- width of the masonry wall: 500 mm

- total area of vertical pre-stressed reinforcements: 4*1.824 cmq
- masonry compressive strength: -2 N/mmq
- masonry tensile strength: +0.2 N/mmq
- limiting value for plasticity above brittle behavior: $\epsilon_o=5*10^{-4}$

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 vertification 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.