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Rehabilitation of Masonry Buildings and Monuments

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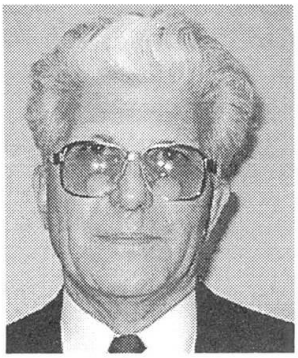

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Summary

The poster brings new proofs, obtained by static and dynamic testing, for using the innovative method of reinforcing both ancient and new masonry members with polymer grids. Synthetic reinforcement replaces masonry lack of ductility and enhances its intrinsic resources of strength. In this way *the non-homogenization* of masonry buildings and monuments with RC and steel members is avoided. The poster also presents the non-destructive method impact-echo for discovery and location the hidden damages and calls for using the language of official provisions in all rehabilitation works.

Keywords: confining, jacketing, preserving, reinforcing, remodeling, repairing, restoring, retrofitting, shaping, strengthening.

Rehabilitation means reconstruction or renewal of a damaged building to provide the same *level of function* that the building had prior to the damage. When from all possible functions only the structural function is concerned then it uses the term of retrofitting, and it includes strengthening, repairing and remodeling. When only monuments and historical sites are concerned or the meaning of the two keywords is combined then a more general and holistic concept of *restoring* is used.

Sometimes rehabilitation works change either the original shapes of masonry buildings or spatial distribution of their masses. The influence of such changes on building equilibrium in gravitational field is checked with the aid of gravity or mass center. In seismic zones the other intrinsic point of major interest is rotation or shear center.

For safety reasons the relative distances between the two centers, before and after rehabilitation, should be carefully checked. Few damages are visible, most of them are in a way or other hidden. They should be located and accurately mapped. Ancient builders used light hammers for this purpose. Many of still existing masonry buildings have been checked by auscultation. Nowadays, among non-destructive methods the Impact - Echo proved efficient and easy to handle. It was

produced by Cornell University and is based on propagation of stress waves through solid members. Internal flaws and voids reflect stress waves, and the crossing times are registered. By knowing the speed of waves in the checked material the positions and dimensions of flaws are immediately identified.

During last years new retrofitting techniques have been checked. Most of them are based on different kinds of fibers. Polymer grids are also convenient for their simplicity of applying and low cost. In the new parts of masonry buildings they are inserted in the horizontal layers of bricks, while the old parts of those buildings should be covered or confined. In both cases, with the aid of polymer grids, the original homogeneity of masonry is preserved. The relative distance between the two intrinsic centers is also maintained, while by replacing from mortar and plasters the cement with lime both aesthetics and comfort of masonry buildings is highly increasing.

The program of static testing continued with six wall panels of reinforced and confined masonry. Three of them were tested to axial compression, while the others to diagonal tension. Compression testing shows that $\sigma_{el.}/\sigma_{max} = 0.76 > 0.33$, $\sigma_u/\sigma_{max} = 0.87 > 0.66$, and the ductility $\varepsilon_u/\varepsilon_{el.} = 8.44$ since $\varepsilon_u = 13.5$ ‰ >> 3.5 ‰. Diagonal tension testing shows that $\tau_{el.} \approx \tau_{max}$, $\tau_u = 0.5\ \tau_{max}$, and the ductility $\gamma_u/\gamma_{el.} = 19.6$ with a drift $\gamma_u = 23.2$ ‰. The relation between elasticity modules is $G_{el} = 0.45\ E_{el}$, close to the value recommended by EC6 ENV 1996-1-1: 1995, clause 3.8.3, and for Poisson ratio $\upsilon = 0.12$ it was found.

The program of dynamic testing started several years ago with a two-stored masonry building. The model scaled at 1:2 was tested on ISMES' shaking table in Bergamo, Italy, and testing details together with the main results obtained have been recently presented in Paris. After the first series of testing the masonry model was dramatically damaged. Most of the cracks have developed between the openings for windows and door as well as near the corners at the bottom and top of model, being caused by shearing stresses. During retrofitting the model the cracks have not been treated in any way, neither by filling them with mortar. The two zones strongly cracked have been simply covered with polymer grids, well fixed with stainless nails and then plastered. Tested again on the same shaking table according to the same testing program the retrofitted model resisted to a much higher seismic intensity. The program was stopped when at the surface of the two belts vertical cracked appeared. No more inclined cracks were observed. The reinforced plaster works like in the static test. These new cracks have been clearly caused by the tension stresses developed in the two belts. In this way it was definitely proved that polymer grids replace masonry lack of ductility and enhance its intrinsic resources of strength.

There are strong reasons, proved by static and dynamic testing, to use polymer grids for rehabilitation of masonry buildings and monuments. The proposed method allows preserving the original homogeneity of masonry with the lowest financial effort, maintains the relative distance between the two intrinsic centers of gravity and rotation, while both aesthetics and comfort of buildings are increasing by replacing cement with other binders. For rehabilitation of masonry buildings and monuments one recommends to confine the damaged structural members, while in the case they are replaced to with new ones to reinforce the masonry in horizontal layers between bricks before confining.