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ON THE SEISMIC PROTECTION OF ANCIENT MONUMENTS

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SUMMARY

The principles that, in the Authors' opinion, should govern the protection of ancient monuments, and in particular their restoration and seismic upgrading, are discussed in this paper. Two examples of restoration interventions are briefly presented, one pertaining to a Roman residential block recently uncovered in the excavations of Pompei, and the other to an 18.th Century large industrial building in the Region of Naples.

MODERN TECHNOLOGIES AND RESTORATION OF HISTORICAL BUILDINGS

From the beginning of the 20.th Century, the traditional construction techniques and typologies, that had been varying very slowly over the centuries but were greatly diversified from one geographical area of the world to the other, have been rapidly replaced by "modern" ones in which the "supporting structure" takes an independent life, often in the form of a "skeleton": at present, the new materials, reinforced concrete and steel, by far predominate al over the world, while the "know-how" regarding the construction methods and culture of the past has almost disappeared in engineers and workmen alike, and the methods of analysis and calculation (elastic and, more recently, plastic), essentially developed for "skeletal" structures, have become the only knowledge of young structural engineers. Thus, the new materials and techniques have increasingly been used acritically even for restoration of monumental buildings, often coupled with an effort to introduce (or imagine) a modern "skeleton" in the existing structure: this way of proceeding found fertile ground in the hasty operations made necessary by the recent earthquakes, that often had to be performed by technicians and firms who were much more familiar with "current" buildings than "monuments", and was promoted by the invention of specific techniques (like "injections", "reinforced seams", etc.) and synthetic materials ("epoxy resins", etc.) whose qualities and results are much too often praised without much consideration to their durability and their mechanical and chemical compatibility with the existing structure, nor to the reversibility of the operation.

THE ARCHAEOLOGIST'S APPROACH IN RESTORATION

In our country the last few years have seen a very lively cultural debate on this subject, to which these writers have actively participated (see e.g. Refs.1-4); during the same time the Ministers for Cultural Heritage and for Civil

Defence set up a "Committee for Protection of Monuments from Seismic Risk", who has worked hard and written tentative "Raccomandazioni" for the interventions on monuments is seismic areas, as an integration of the legally enforced "Seismic Rules" issued by the Minister for Public Works. This activity is making known in the technical world the three basic principles of a correct restoration, namely homogeneity of materials and technologies between "old" and "new" construction, durability of the results for a time comparable to the human life span, reversibility of the interventions.

Thus, the consciousness has begun to spread that the restoration of a historic building can be tackled by an approach analogous to that of the archaeologists, who try to save the primitive structures and materials as far as possible, and replace the missing or faulty parts with the smallest possible variation with respect to the original situation. Indded, in the Western World, while construction typologies have greatly changed, there has been rather little evolution from Greek times to the 19.th Century as far as materials are concerned, so that from a "materials engineering" viewpoint there is less difference between - say - a Greek temple and a 1700 Royal Palace than between the latter and a 20.th Century apartment building: therefore, nothing appears to prevent the systematic use of the "archaeologist's approach" in the restoration of historic buildings. However, to achieve this aim, it is necessary to recover the technological culture of the past, study how the structure under consideration was built and behaved, and try to adopt the same outlook as the original builders in all interventions: much research is still necessary on these lines, and each restoration site must become a true "research laboratory".

THE "IMPROVEMENT" CONCEPT

In short, the general aims of a "correct" restoration and retrofitting operation should be to improve the strength (including seismic resistance) of the structures, but at the same time to alter as little as possible the existing construction and in any case to assure the "reversibility" of the interventions, lacking which the monuments risk to be destroyed for ever rather than preserved for future generations. It is however clear that, operating in this way, it is often impossible to set the seismic resistance (with all the intrinsic uncertainties on its "calculation" for an old, repaired construction) up to the values required from new buildings. Therefore the concept of "strength improvement", as opposed to complete "seismic upgrading", becomes essential to this approach.

It is also to be noted that often many recognized damages are not really due to earthquakes, that have only worsened a state of decay related to bad maintainance: indeed, if a building has survived for centuries in a seismic area, it has experienced a number of quakes. Therefore, the "restoration" operations must be regarded as a whole, and the commitment for the "reduction of seismic risk" blended with that for careful maintainance; in any case, it must be clear that the "restoration" cannot assure the preservation of a building for ever, but its effects must be supported by continuous care.

In Italy, the new (1986) version of the "official" Seismic Rules has accepted the "improvement" concept, at least for existing masonry buildings: therefore, a compromise solution is now possible between the earlier drastic alternatives of either leaving the ancient construction deteriorate until its complete ruin, or intervening massively trying to bring its "calculated" resistance up to absurd levels. Not all is as yet clear in the practical (and legal) applications of the "improvement" concept, and how the apparent contrast between "safety" and "culture" can be solved, especially in case of buildings that are expected to be used or visited by a large number of people; the above cited Committee is at present working on these aspects.

RECENT EXAMPLES OF "CORRECT" RESTORATIONS

Although the examples of "bad" restorations are still numerous, the criteria that have been discussed above finally begin to be accepted and applied: an important and positive example on these lines is Prof. Giuffre's proposal for the reconstruction of the Cathedral of the epicentral town of the 1980 Irpinia earthquake (Ref.5). In the following of this paper, we shall briefly describe the restoration works of two constructions that are located in seismic areas, but have not received any significant damage from recent seismic events: therefore, the improvement of the seismic resistance was only a part of the restoration problem. Although 1700 years separate the two constructions and their scope was very different (the first being a block of residential buildings, the second a factory), the principles and techniques of the restoration are very similar in the two cases.

"Insula IX - Regio II" in Pompei The first example (Fig.1) refers to the recently completed reconstruction of the "Insula" (block) No.IX of Pompei, the town near Naples that was buried by the Vesuvius eruption of 79 A.D.. The excavation of Insula IX begun in the 1950's , and has been completed in the last few years with a rigorous "stratigraphic" methodology. The removal of the modern vegetal layer and of the vulcanic ashes exposed the level of the ancient roofs, which were accurately surveyed and photographed: this has allowed to dismantle the tile cover, individuate and reproduce the original wooden structure of the roofs (constituted over most areas by a single array of posts, with "main beams" added for larger spans: cf. the example in Fig.1b), and reassemble the covers using as far as possible the surviving tiles (after waterproofing) with the addition of new ones, clearly distinguishable but with analogous shape and dimensions. The new supporting structure is made by timber treated to resist atmospheric agents, and was calculated, for the larger spans, as a beam grillage.

In Insula IX, as in many buildings of Pompei, the original walls are between 3.5 and 6 meter high, approximately 40 cm thick, and made of lime stones and mortar ("opus incertum"); some examples of "opus listatum" can be referred to the latest phases of construction. There are traces of damages due to the historically known earthquake of 62 A.D., and perhaps to lighter seismic events between 62 and 79. In the surviving parts of the walls (example in Fig.1c), even where the mortar was pulverized, no dangerous crack patterns were recognized: it was thus possibile to preserve all the original masonry, dismantling and reassembling it wherever necessary (but without mechanical tools that would have caused vibrations and ruptures): to this aim, as shown diagrammatically in Fig.1d, the pulverized mortar is removed by pressurized water (1) and the continuity of the wall reconstitued by "live" stones and hydraulic mortar very similar to the ancient one (2); in case of deep cracks (3), the affected masonry is dismantled (4) and reassembled with mortar joints (5). Then, the missing parts of the walls have been reconstructed up to the original height by raw masonry similar to the ancient one; a reinforced concrete seaming beam, hidden inside the thickness of the masonry, ties the top of the walls together, acts as a support for the roof beams and contributes in an essential way to the seismic resistance. The stresses due to dead, live and environmental (quake and wind) loads have been calculated and are fully within the safe limits of the materials used.

"Belvedere" in S.Leucio (Caserta) This is (Fig.2) the main building of an industrial complex, where since the late 18.th Century a much renowned silk manifacture was housed. The central part of the building (prominent in the plan, Fig.2b) was a castle dating back to the middle of the 16.th Century; the other three wings were added in the second half of the 18.th Century with construction techniques similar to those of the contemporary Royal Palace ("Reggia") of Caserta by Vanvitelli. Although the destination of the S.Leucio complex was soon changed from the original Royal Residence and great modifications were therefore

Fig. 1: Reconstruction of an "insula" (block) in Pompei:
a) Plan of Insula IX - Regio II;
b) Plan of the cover structure of a building (House No.1) of Insula IX;
c) Typical wall reconstruction in House No.1:
Existing masonry (1.raw; 2.plastered; 3.frescoed) and new masonry (4).
d) Schematic procedure for restoration of damaged masonry (see text).

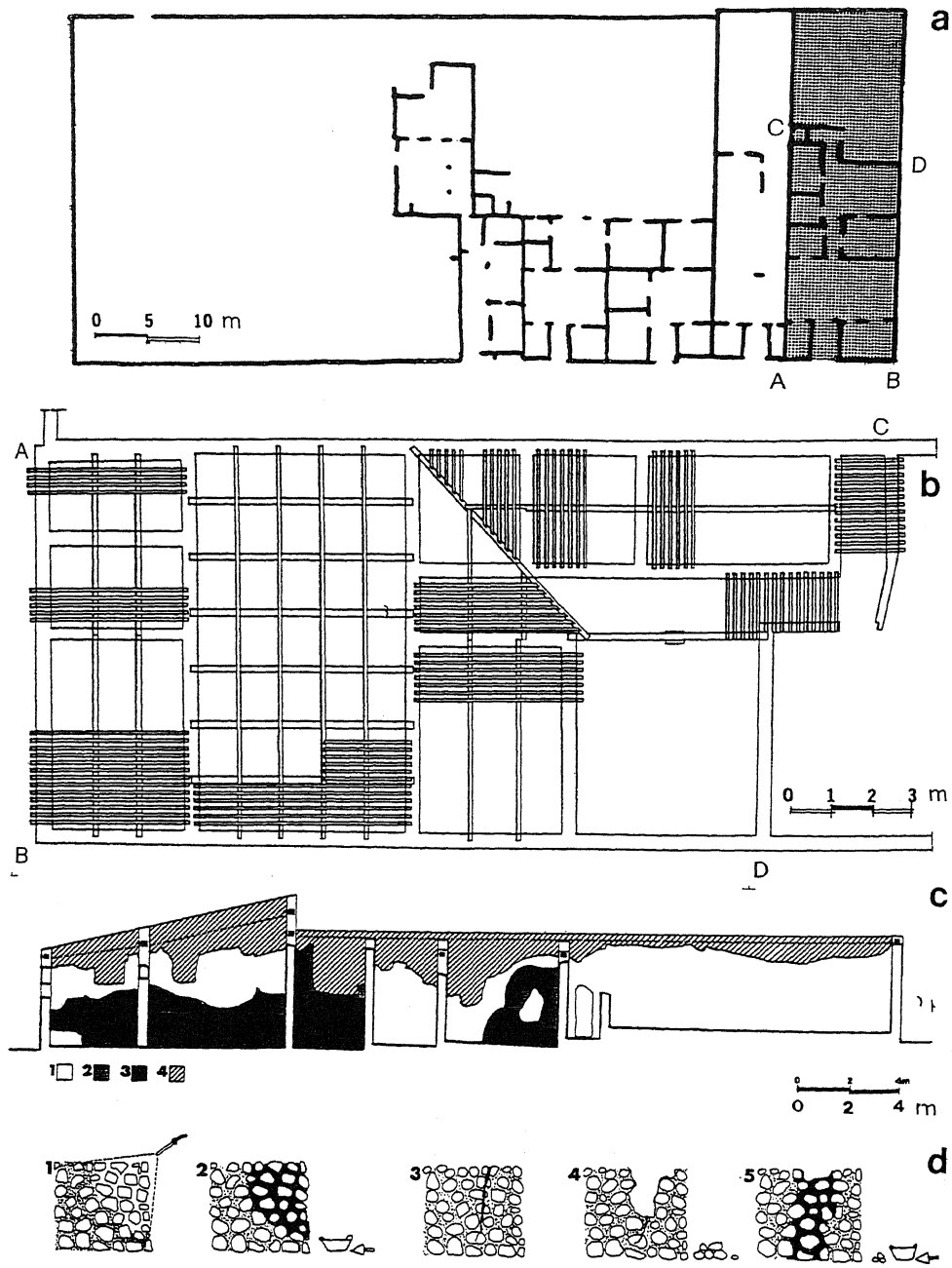
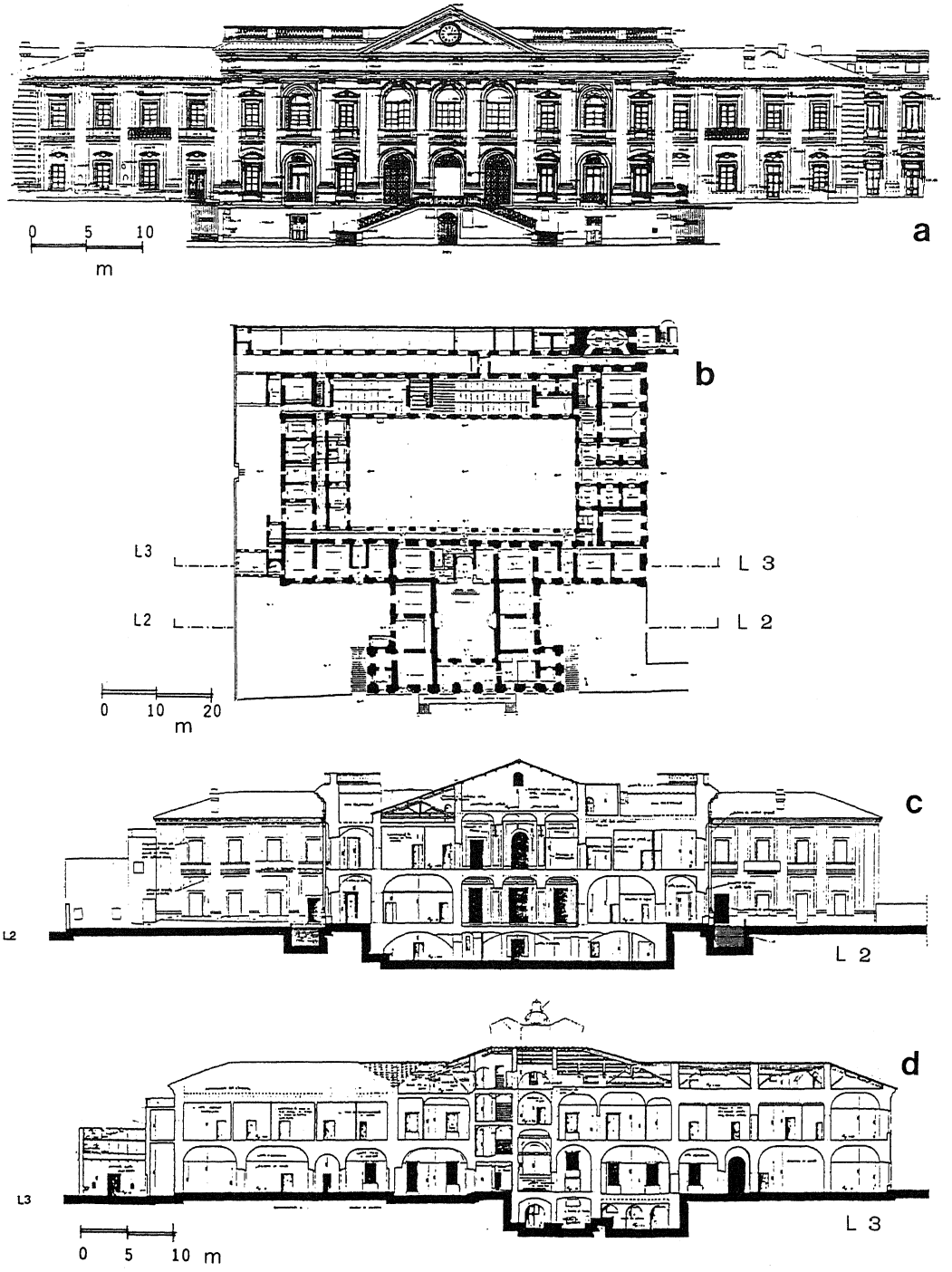


Fig.2: 18.th Century industrial building ("Belvedere") in S.Leucio (Caserta): a) Front view; b) Plan (ground floor); c) Section L2; d) Section L3.



necessary, the "Belvedere" and the other buildings maintained the monumental character that intended to celebrate the industrial power and greatness of the Kingdom of Naples (Figs.2c, 2d). This is shown by the design of the structures (thick tuff walls and vaults that cover the ground floor, while the other floors and the roof are supported by wooden beams), by the accurate workmanship evident in the joints and other details, and in general by the quality of construction. Thus, the "Belvedere" survived in very good conditions for almost two Centuries and did not experience any apparent damage during the 1980 Irpinia earthquake, but decayed rapidly in the later years, when the manifacturing activities in the S.Leucio complex decreased drastically and most buildings remained practically abandoned. Thus, a systematic operation of restoration became essential for their survival.

The restoration of the Belvedere, currently in progress, has been conceived in the "improvement" outlook: therefore the first aim was to reinstate the carrying capacity of the original structures. As far as masonry (walls and vaults) is concerned, this aim is pursued by

a) cleaning by pressurized water and reconstructing the joints with lime mortar, and then plastering the surface (this type of operation is performed only where the original plaster is fallen or so much blown out to denounce the substantial decay of the underlying mortar);
b) repairing deep and/or diffuse cracks and reconstructing the relevant parts of masonry in accord with the traditional "stitching" technique;
c) inserting traditional "chains" between vertical masonry elements, which reduce drastically horizontal thrusts.

Also the timber structures of the floors and roofs are saved wherever possible, after adequate treatment against fire and biological decay. In some instances, the roof trusses are reinforced by metal elements; a continuous beam of concrete made by lime mortar and stones is poured on top of the walls, to realize a good support for the roof trusses. When the original timber is deteriorated beyond repair, new structures, analogous but clearly distinguishable from the originals, are built. The tile cover is dismantled and reassembled, making use of old and "new" tiles, with a technique similar to that used in Pompei.

CONCLUSIONS

As a closing remark, a multi-century monumental building is generally able to withstand the exceptional actions due to an earthquake, provided it is carefully maintained in good conditions. The maintainance works, including possible "extraordinary" ones, must however always respect the building history and therefore its peculiar identity and its original costructional concepts.

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