New concept for foundations of Saint Michael compound in Rome

New Concept for Foundations of Saint Michael Compound in Rome

Nouveau concept pour les fondations de Saint Michel à Rome

Neues Konzept für die Gründung des alten St-Michael-Komplexes in Rom

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SUMMARY

The ancient Saint Michael compound needed restoration. High compressibility of soils and varying water table levels, linked to the hydrological pattern of the Tiber, have damaged the masonry structure throughout the centuries. In order to compensate for future settlements, the new foundations are not connected to the old, and transmission of loads is regulated through hydraulic jacks placed between old and new structures. A monitoring program checks the behaviour of structure and foundations, the effectiveness of the remedial measures and the validity of the initial hypothesis of the project.

RÉSUMÉ

L'ancien bâtiment de Saint Michel a été restauré. La haute compressibilité des sols combinée avec le niveau variable de la nappe phréatique dépendant du profil hydrologique du Tibre ont causé de nombreux dommages au bâtiment en maçonnerie au cours des siècles. Afin de compenser les tassements futurs, les nouvelles fondations ne sont pas liées aux anciennes et la transmission des charges est réglée par des vérins hydrauliques placés entre la maçonnerie et la tête des pieux. Un programme de surveillance du comportement de la structure et des fondations a été réalisé afin de contrôler l'efficacité de l'intervention et la validité de l'hypothèse initiale du projet.

ZUSAMMENFASSUNG

Der Sankt-Michael-Gebäudekomplex ist kürzlich einer Restauration unterzogen worden. Die hohe Zusammendrückbarkeit des Baugrunds und die durch den Tiber beeinflussten Schwankungen des Grundwasserspiegels verursachten am Mauerwerk über Jahrhunderte grosse Schäden. Um künftigen Absenkungen vorzubeugen, wurden die neuen Fundamente nicht mit den alten verbunden. Für die Lastübertragung wurden hydraulische Pressen zwischen Mauerwerk und Pfahlköpfen eingebaut. Ein Computerprogramm überwacht das Verhalten der alten und neuen Bauteile, die Wirksamkeit der Massnahmen und überprüft die Gültigkeit der dem Projekt zugrunde liegenden Hypothese.

1. INTRODUCTION

This project is an example of functional restoration carried out with intergrated conservation criteria, with the aim of saving a building that was abandoned for incidental motives, but which retained its validity as part of the historical urban fabric of the city by adjusting its use to the different events that occurred. The St. Michael Complex, will become a "cultural zone" with the purpose of entertaining people within an accessible area for exhibitions and cultural displays. The project is the result of an interdisciplinary operation between the Sovrintendenza of Rome and the consulting engineering of Prof. Giorgio Croci, with the cooperation of eng. Valter Maria Santoro.

2.HISTORICAL SURVEY

The St. Michael Hospice (photo 1) was founded under a papal initiative to solve the problem of beggary and homelessness in Rome at the end of the seventeenth century, works continued for the following 150 years. Thus the St. Michael complex is architectonically fragmented in contrast to the formal and unified elevation along the Tiber river.

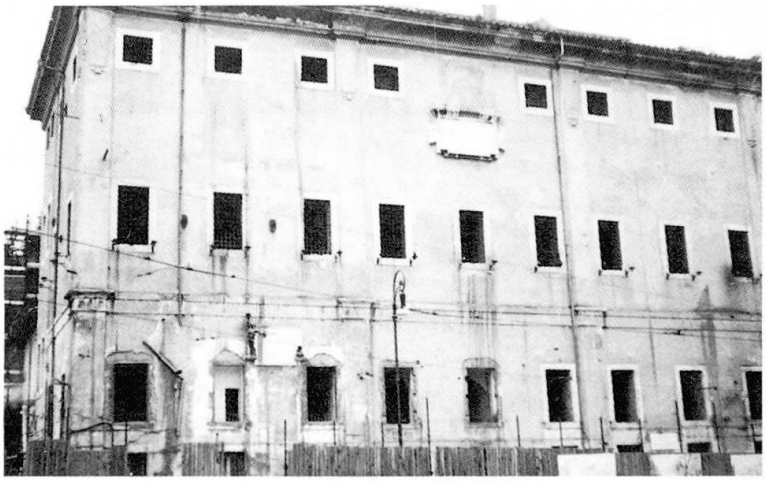


photo 1

The initial nucleus, contructed between 1686 and 1689 by Carlo Fontana and Mattia di Rossi consists of the buildings surrounding the "Cortile dei Ragazzi" (Courtyard of the Boys).

In successive years the building was enlarged with the construction of the enclosing wall along the Via San Michele, a wool factory (1693), a men's prison (1701), all designed by the architect Fontana.

The part of the complex facing Porta Portese (1706-1709) was used for small shops and rented rooms, and following this, it became Customs Officers barracks; the building then became a shelter for the elderly (1708), the church of Our Lord Jesus Christ (1710) and the small church of Our Lady of the Good Voyage (1712).

In 1734, Pope Clement XII commisioned Ferdinando Fuga to design a women's prison next to the barracks. In 1796 the complex was further enlarged with the addition of the conservatory for unmarried women and between 1831 and 1834 with the construction of low buildings used as artisans' workshops.

The St. Michael complex retained it's proper functions, that of a place of rehabilitation and above all a site of important artisan activities from its creation at the end of the 1870's. Following the Unification of Italy and the loss of papal patronage it suffered a rapid decline culminating with the events of World Wars when it was used for the temporary housing of evacuees, which accelerated the natural process of degradation. It was in this precarius structural condition that the building was put up for sale in 1968.

The state, exercising the right of pre-emption, bought the building and converted it into the Ministry of Culture.

The complicated operations of restoration and strengthening, carried out by the Superintendent of Architecture for Rome, began in 1973.

The new function of the buiding meant an increase in the live loads which made the design of strengthening to the superstructure and substructure necessary.

The works on St. Michael's are continuing: the areas of the ex-men's and women's prisons as well as the barracks are being finished as they required an in-depth study and complex interventions to the foundations, carried on by the ICLA Enterprise.

3. GEOTECHNICAL CHARACTERISTICS OF THE SOIL

The geotechnical characteristics of the soil have rendered the interventions on the foundations very delicate.

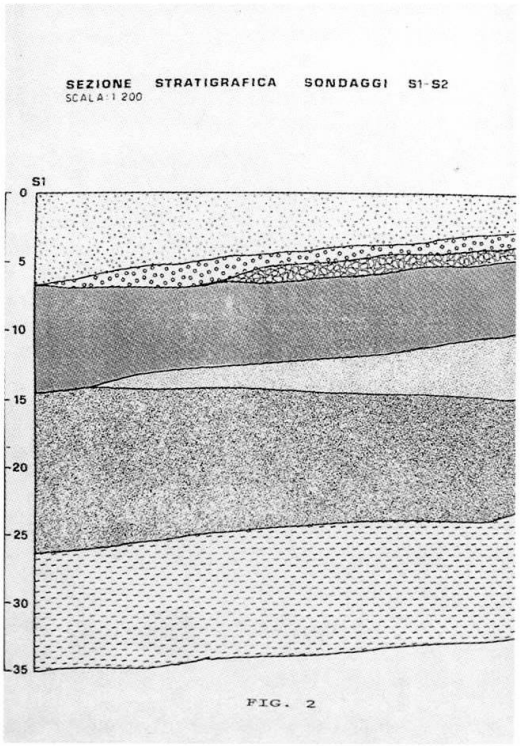


photo 2

The various buildings bear onto a stratum of alluvial sediments from the nearby Tiber river, consisting of a succession of highly compressible strata which have responded and continue to respond to the periodic oscillations of the level of the river. In fact from the geognostic tests carried out (in the course of which 4 "Casagrande"-type piezometers were installed) it was found that the hydraulic pattern of the area is constantly evolving and is directly connected to the variation in level of the river. In the case of the last few years, long periods of intense rain and longer periods of drought have occurred. All this together with the heavy weight of the complex has produced, throughout the history of the building, a series of static failures such as local fractures, distorsions and differential settlements, of which cracking is the most highly visible signal.

The series of geotechnical tests have, between them, identified and characterized the principal lythotypes of the soil which may be summed up in the following manner (photo 2):

a) SOFT SILTY CLAY: (immediately below the surface fill of variable thickness) is around 10m thick and is defined as brown [undrained shear strength $c_{u\ max}$ = 25 KPa];

b)SAND: from -13m to -23m below ground level: condensed medium-fine brown with thin weak silty layers [angle of friction ϕ' = 33°-43°; drained cohesion c' 0-9 KPa];

c) CLAYEY SILT: blue-grey with thickness exceeding 10m [angle of friction ϕ' = 27°-34°; drained cohesion c' = 2-15 KPa].

4. INTERVENTION CRITERIA RELATING TO SOIL DEFORMATION

The whole St. Michael complex has been the object of various reinforcement interventions during the last decades; these concerned the strengthening of the superstructure (masonry, vaults, slabs) and foundations. The latter have mainly been reinforced by widening the contact surface of the soil in order to reduce the average pressure under the foundations.

The lengths of the individual buildings (upto 150m) and the mutual interconnections related to the essential geotechnical problems, resulted in an overall approach which invisaged the segmentation of the buildings into several parts, each one capable of resisting the potential settlement caused by the compressibility of the soils (rather than subsidence phenomena). Thus a project which involves the creation of a joint between the Restoration Institute wing and the ex-Men's Prison is now in progress, as well as one between the Barracks and the building along the Tiber.

The sensistivity of the surface soils to the pore pressure linked to the hydrological situation of the Tiber river, lead to the design of partial underpinning of the building in order to isolate the building from the more compressible layers

Because of the change of use and the increase in load to the foundations, a new system of foundations "*parallel*" which could carry the new loads without effecting the upper strata was realized.

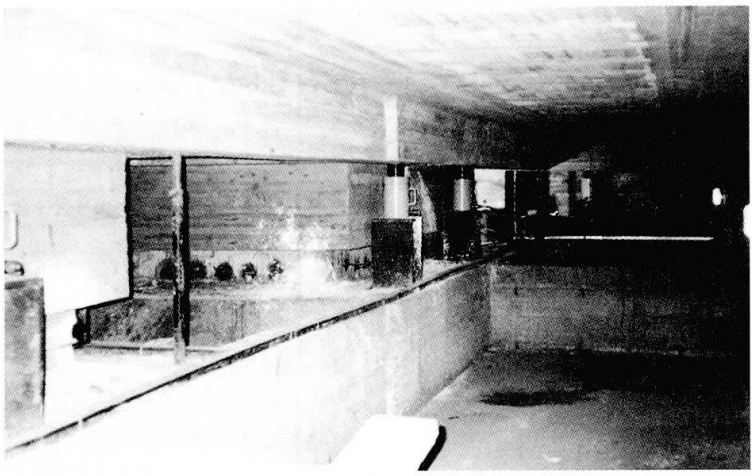


photo 3

This system (photo 3) was carried out using micropiles of diameter 200mm, placed next to the the perimeter load-bearing wall and connected by means of a strong ring beam (0.50 m x 0.80 m) and was loaded by oleodynamic jacks (photos 4-5) which lifted the building, reducing the load to the existing foundations which were also reinforced with a layer of concrete and finally some prestressed Dywidag bars.

Where the reaction of the jacks could have produced highly eccentric forces with consequent tilting moments, a horizontal bracket connected to the

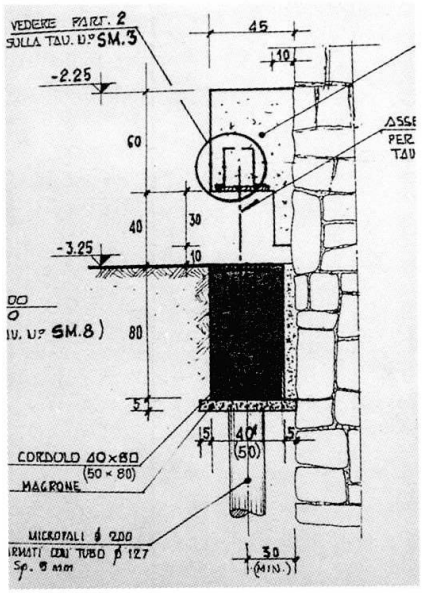


photo 4

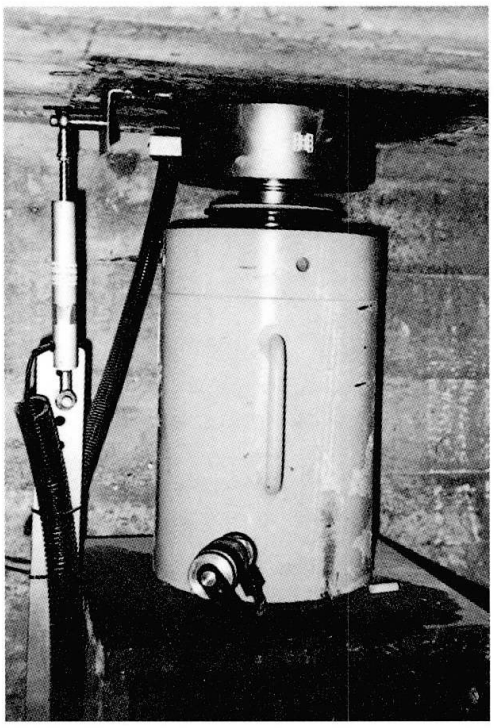


photo 5

head of the micropiles, was placed in niches made in the wall, so that the load could be received close to the baricentre of the wall.

In such way only some loads will apply to the micropalesinstead of total trasmission through passive underpinning that would have acquired more extensive intervention with much more micropales.

In the course of the works, very strong vertical load tests were carried out on the micropiles, much higher than the true working loads to be carried by the piles, in order to guarantee the resistance.

The gradual transfer of loads to the new foundations was carried out during the evolution of the interventions to the super-structure.

The new foundations were loaded in phases. Some phases coincided with the increase in load due to the restructuring works at the various floor levels and therefore with the different phases of the super structure works. Initially, the removal of the fill from the vaults and some floors partially unloaded the existing foundation (picture 1 a,b) , then, as the repair works were carried out, the new foundations began to function by carrying all the new loads themselves (picture 1 c,d).

During the adaptation of the old foundations, also in the course of various loading phases of the foundations, a control of the structure was preprepared by means of a monitor of various physical quantities the knowledge of which was necessary for the evaluation the phenomena of differential settlements between the various zones of the foundations or to interpret the effect of a variation in loading transmitted over time. The monitoring system was carried out by Tecnocontrolli s.r.l., of Rome.

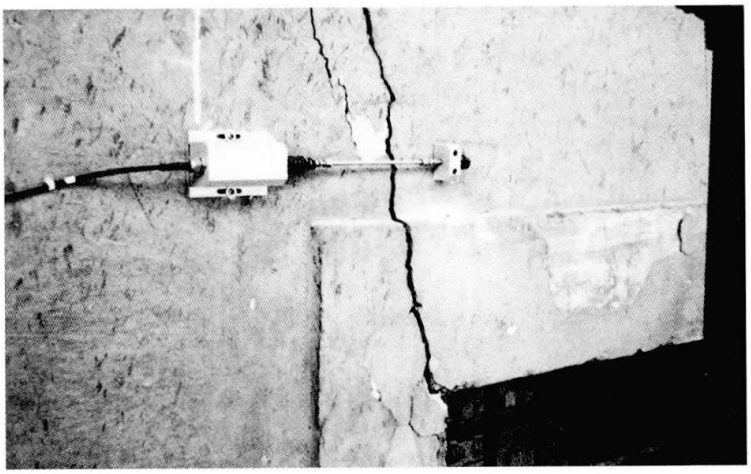
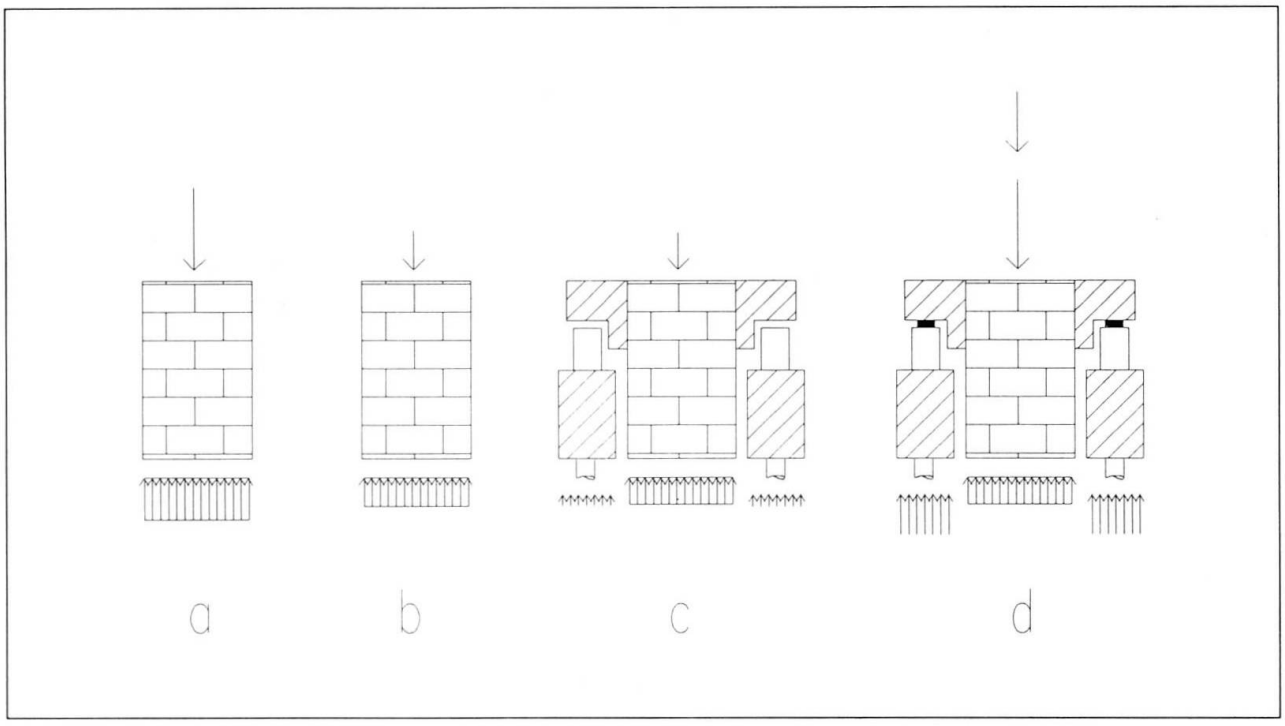


photo 6

In particular, 12 "load sensors" were placed (photo 5) between the piston of the jack and the steel plate set inside the bracket of the old foundation (they gave an indication of the load transmitted by the jacks), 12 displacement sensors capables of indicating the relative displacement between the new and old foundations and 10 deformometers (photo 6) placed on the larger cracks present in the upper levels were used to verify that unforseen detrimental effects would not occur during the loading



picture 1

phases.

A manual control was carried out on a larger scale alongside the automatic control, with high precision optic instruments and read every 20-30 days, in order to indicate any absolute movements and any relative displacement between the measuring points (90 in number) placed on the façade and in the courtyard.

The examination of the curves obtained from the data provided by the monitoring system and by the reading of the manual instruments confermed the validity of the initial hypotheses and thus gave an indication that the structure was behaving correctly.

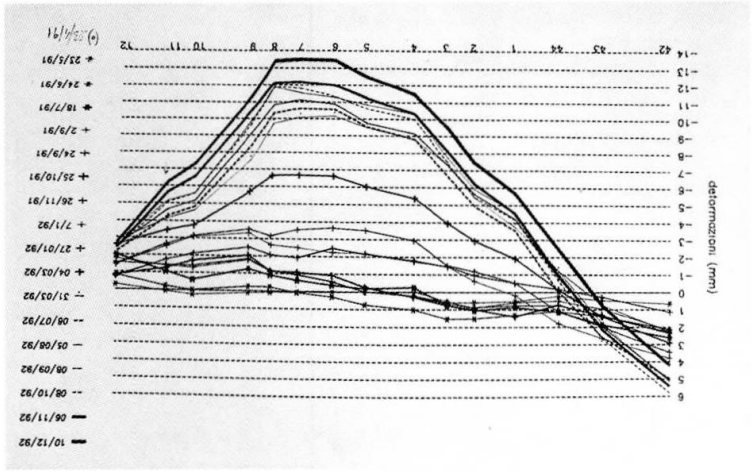
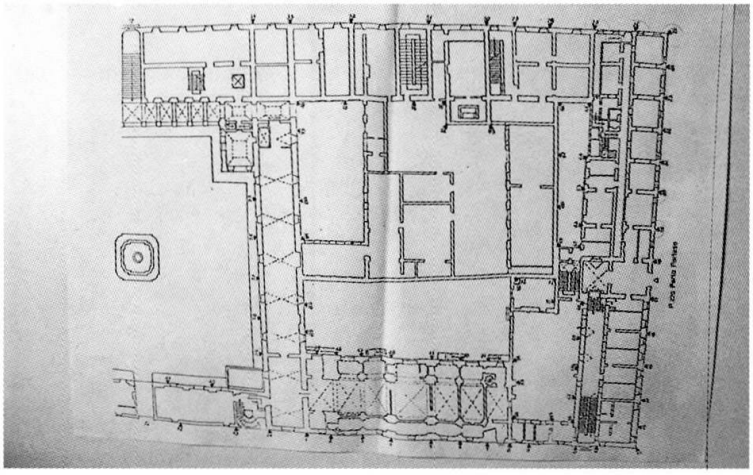


photo 7



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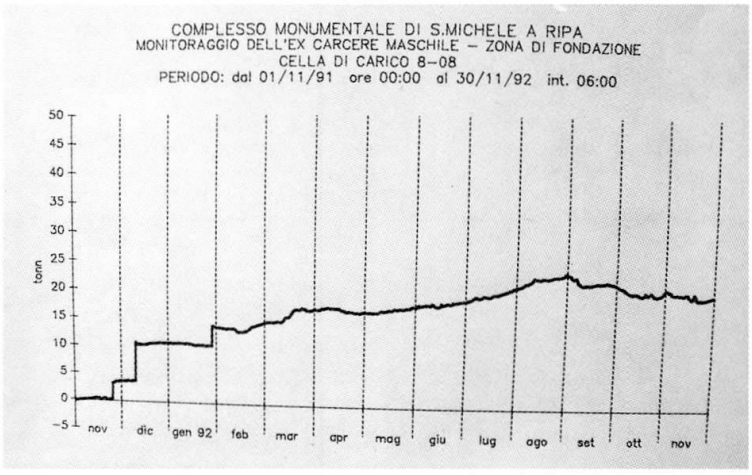
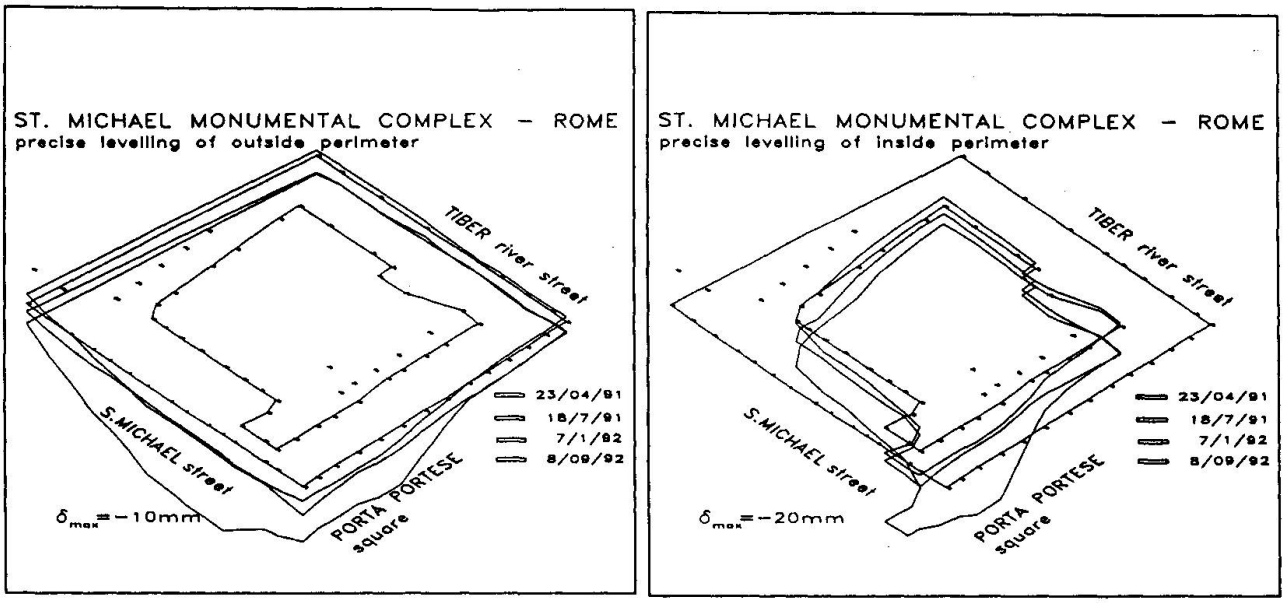


photo 9

The results of the topographical measurements are represented in the diagram (photo 7); they were precisely measured at key positions along the perimeter wall (photo 8) (picture 2), with reference to the façade of the ex-men's prison on Via San Michele. These graphs were made after the first phase of the transfer of loads to the micropiles. In the diagram the development of the settlements in correspondance with the key positions along the façade (each curve represents a measurement), they become closer and therefore the increments in the settlements tend towards zero .This trend clearly indicates that the transmission of the loads to the parallel foundations is very effective. In fact we can observe a partecipation of the micropiles to the bearing capacity of the existing foundations although they are not called to support the total load.

This result is confirmed by the diagram of the load sensor which indicates the value of the loads on the foundations in correspondance to the jacks (photo 9). In this diagram the different phases of the load transfer, through the jacks, are evident from the variations of the forces. During the monitoring period it is possible to detect a gradual increase of the pressure in the jacks, corresponding to the trend observed in the adjustment of the settlements of the structures which, together with the sudden variations verified during the loading phases, appear to have a positive drift: the load on the foundation structure increases over time.



picture 2

5.CONCLUSION

The intervention described represents a criterion for the strengthening of foundations using a new concept that has provided excellent results. In fact, notwithstanding the difficulties connected with the inferior characteristics of the soil and the precarious state of the super-structure, the result was so satisfactory that we are proposing its use for the Poli Palace: the building just behind the famous Trevi Fountain. The success of the project was ensured by the use of the monitoring system, above all for the verification of the correspondance between the theoretical scheme and the real results, and the possibility to "adjust" the loads in the various phases of the works.

ACKNOWLEDGEMENTS

The authors would like to thank Eng. Fabio Macrì and Lesley Goldfinger B.Eng. for their help in preparing this report.

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