The soft approach to saving Monuments and Historic Sites

L'approche doux à la conservation des monuments et des lieux historiques

G. Calabresi
Università di Roma "Sapienza"

ABSTRACT

The flexibility and abundance of technical means and their progressively decreasing costs are often making easier a coarse approach to the restoration of heritage buildings, which alters their original design and construction materials. When an intervention is necessary, the focus should be on reinstating the conditions that enabled them to reach us and preserve their material integrity, also in the parts that are not visible, since the ancient monuments are not mere icons, but tangible, material witnesses of the history of mankind. The geotechnical solutions and technologies developed in recent years offer new and interesting ways to a respectful restoration of heritage buildings. This approach, which can be defined as a soft approach, is gradually gaining ground, as it can be seen in some cases, but it is still not generally understood.

RÉSUMÉ

L'abondance et la flexibilité des moyens techniques disponibles pour la restauration des bâtiments anciens et leur coût décroissant facilitent le recours à solutions brutes, loin du juste approche, qui veut qu'ils soient sauvés sans effacer leur conception originale et les matériaux de construction. Les solutions et les technologies récemment développées dans le domaine de la géotechniques offrent aujourd'hui la possibilité d'adopter un approche doux, respectueux de l'identité des monuments, qui sauve le témoignage de l'histoire de l'humanité. Il semble que cet approche soit gagnant progressivement terrain, mais il n'est pas encore bien compris.

Keywords: Restoration, preservation, historic site, monument.

1 INTRODUCTION

The geotechnical aspects of the conservation and restoration problems of mankind's heritage were raised in the 1980s by Jean Kerisel and Arrigo Croce. The Symposium held in Naples in 1996 in the name and in honour of Arrigo Croce [1], marked a first step in the acquisition at the international level of Case Histories, experiences and visions on this issue, while in the following years, the Technical Committees of ISSMGE contributed to keeping members' attention focused on this subject.

In the years since the Naples Symposium, there have been constant advances in soil and foundation intervention technologies. The most recent equipment and technologies can modify soil properties by increasing soil strength and stiffness: chemical or nano-cement injections can now be used also in fine soils, which in the past could not be treated; deep underground and covered zones, hitherto inaccessible to vertical or inclined drillings, can now be reached by directional drillings and by equipment providing real-time control of the probe position; massive soil volumes can be modified by jet-grouting; controlled volumetric deformations can be imposed by using compensation grouting; deep subfoundations by micro-piles and insertions of nails, tie rods and anchors in restricted spaces are now possible and commonly used.

Specialty sessions of geotechnical conferences are devoted to the preservation of monuments and historic sites and provide forums where experts from different countries can compare their solutions to the most challenging problems: indeed today there seems to be a solution for just any restoration problem.

2 THE SOFT APPROACH

However, the flexibility and abundance of technical solutions and their progressively decreasing costs (thanks to technological progress and increasing competition) are making for easy but coarse restoration works, far from the correct approach which requires that heritage buildings and sites be maintained and preserved without altering their original design and construction materials.

Indeed, making a correct diagnosis of the phenomena that have produced the damage or that are causing or speeding up the progressive degradation of a historic building, and searching for ways to stop or offset those effects is always a difficult, time-consuming and expensive task. On the contrary, for a typical damage caused by foundation soils, various effective and quickly implementable solutions are available to repair it, underpin the building and stop the spreading of the deformation.

Paradoxically, the cost, but above all the technical commitment required to make a thorough and scientifically sound study of the phenomena involved, often turns out to be much greater than the cost of a radical structural intervention that saves the ancient building by preserving only its external aspect. However the latter choice has a negative impact on the conservation of the historic, architectural and archaeological value of the work.

On the contrary it is important to hand down to posterity a real and tangible witness of the concepts and techniques that produced the monuments and historic sites, that have been preserved so far. J. Kerisel and A. Croce indeed, just to mention once again the two illustrious colleagues who opened up this field of Geotechnical Engineering, did not devote their efforts to the development of innovative technical solutions for preventing the degradation or collapse of monuments, but rather they stimulated us to intervene by studying their history in depth and the solutions adopted by their designers to ensure their stability and overcome the construction difficulties. When an intervention is necessary, the focus should be on reinstating the conditions that enabled them to reach us and preserve their material integrity.

This approach, that can be defined as a soft approach, is gradually gaining ground, but it is still not generally understood, and the prevailing attitude is in favour of substantial interventions on the static design, structures and foundations of the monument, which preserve only its outer appearance.

3 THE CASE OF MILVIUS BRIDGE

In this connection, the 1978 restoration of Milvius Bridge in Rome is an enlightening example.

The bridge was built in 119 B.C. by the Censor Marcus Emilius Scaurus, replacing a previous wooden bridge. Notwithstanding various restoration and modification interventions (in 1450 two masonry arches were rebuilt, in 1849 one of the arches was blown up by Garibaldi as he retreated northwards) Milvius Bridge, which is still in operation, with its stone arches, its piers and its extraordinary foundation remains a unique example of ancient Roman design and construction techniques (Fig. 1, 2).

The foundation soil is a succession of silt sand deposits with scattered clay inclusions. The piers are founded on a continuous footing of large stone blocks (*travertine*) that extends out for the entire length of the bridge and acts as a hydraulic threshold to the river flow.

In the last century the construction of three hydroelectric dams upstream on the river Tiber begot a decrease in sedimentation and progressive erosion to its bed. As a consequence of the outcropping of the bridge footing, in the 70s a deep trough took shape in the riverbed downstream from the bridge.

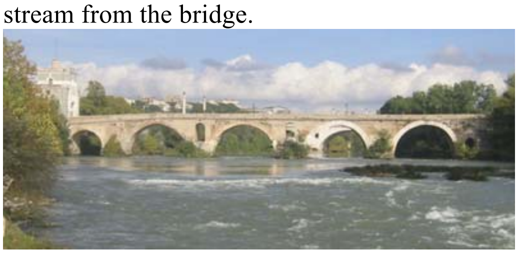

Figure 1. View of Milvius Bridge.

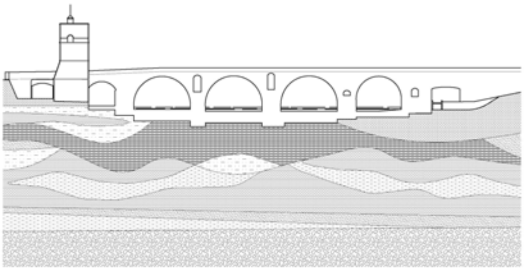

Figure 2. Longitudinal Section of Milvius Bridge.

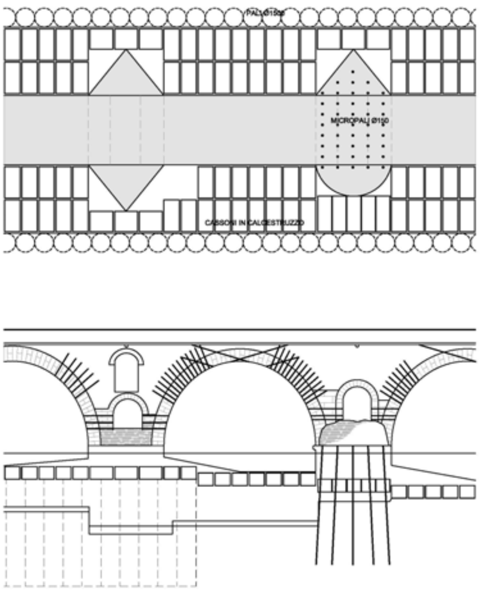

Figure 3. A restoration proposal.

During those same years, the periodic levelling of the bridge had raised some concerns for its safety and so the Municipality of Rome launched a tender for the design and execution of consolidation works, but without performing the preliminary structural and geotechnical investigations. The competing firms submitted traditional solutions consisting in strengthening the arches with iron nails and underpinning the piers with micro-piles, plus large diameter piles and cassons to protect the foundation slab (Fig. 3).

Luckily enough the Committee that had been assigned the task of judging the bids felt the need to study the problem in greater depth and it hence cancelled the tender so that all the investigations required by the case could be performed. These showed that the periodic settlements of the bridge were due to changes in the average water level and to the effects of the trough excavated in the riverbed, downstream from the bridge footing.

Actually, owing to the low permeability of the foundation soil, the effective stresses underneath the footing were affected by the water level changes. The downstream bed scour was producing the slow but steady increase in the settlements as shown by the levelling of the piers, thus threatening the stability of the monument.

A submerged weir was then built downstream from the trough. It quickly produced the trough fill, caused an increase in the average water level, stopped the bed scour and reinstated the original flow conditions. The structures of the bridge were not changed in any way. The arch fills, modified by the previous interventions, were partially redone using concrete made of lime, pozzuolanic sand and tufa fragments (*opus cementicium*) as that used by the ancient Romans.

Therefore the bridge was restored only be removing the cause that was producing changes in its century-old behaviour, and in this way its integrity was fully preserved.

The interventions proposed by the bidders would have substantially changed its static conditions by transferring the load of the piers from the original footing to the micro piles and they would have modified the pressure line of the arches. The bridge would never have been the same again and a marvellous testimony of the Romans' construction techniques would have been lost.

Milvius Bridge was an easy case; new techniques are now available to cope with more complex situations.

4 THE MEXICO CITY CATHEDRAL AND THE TOWER OF PISA

The consolidation of the Mexico City Cathedral and of the Tower of Pisa are recent, well documented examples of very difficult consolidation tasks performed out by subtracting small volumes of soil in carefully identified points, without altering the original structures. This conceptually simple solution was made possible by the progress achieved in the last few decades in geotechnical engineering technology.

Actually, in the case of the Tower of Pisa, a similar proposal had been advanced as early as 1962, but, at that time, it would not have been possible to perform precisely guided drillings to reach the pre-defined points in order to remove pre-fixed amounts of soil, nor to preview the Tower behaviour during and after the intervention by means of a numeric model.

It is nevertheless interesting to observe that the solution eventually adopted for consolidating the Tower is the outcome of a most recent evolution towards the soft approach to the conservation of historic buildings.

Indeed, at the first tender launched for the consolidation of the Tower just after the geotechnical investigations and the research work had been carried out by a Special Committee between 1965 and 1971, all the proposed solutions considered underpinning the Tower with piles or anchoring it with tie-beams (Fig. 4, 5). A new project of this type was proposed again in the '80s.

Actually an essay published in 1991 [2] that criticized any solution that were not to respect the integrity of the monument, its original design, its foundation and its material components, was not generally understood.

The final solution was the result of a lively debate among the members of the international Committee that had been assigned the task of proposing the consolidation intervention.

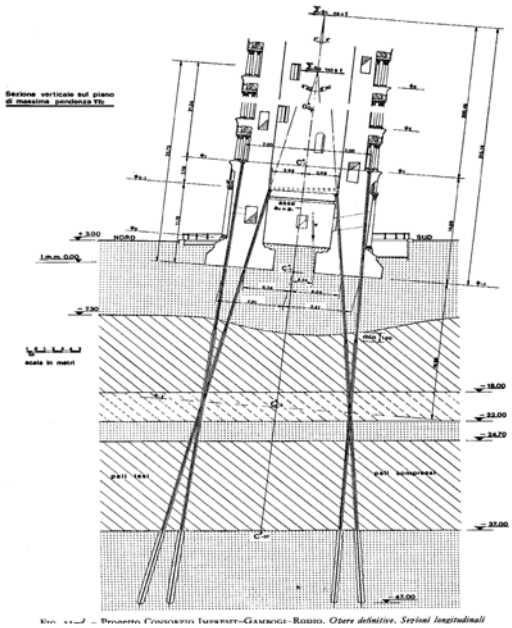

Figure 4. The Tower of Pisa: a proposal of anchoring

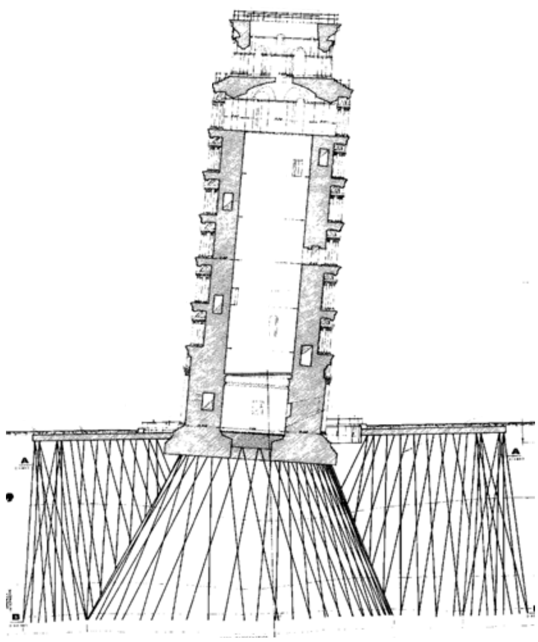

Figure 5. The Tower of Pisa: a proposal of underpinning

5 CONCLUSIONS

There are many applications of the soft approach that have been made possible by the progress in geotechnical engineering. Let us mention two examples.

The compensation grouting technique adopted in London for the Big Ben to offset, in real time, the foundation settlements that would have been caused by the construction of an underground line, is known worldwide and has been adopted in many other cases thereafter.

Many old buildings with shallow footings that suffer the effects of the shrinkage and swelling of unsaturated foundation soils are often consolidated by means of underpinning piles and reinforced concrete structures. However it has been recently proposed and implemented a control system of the saturation degree of the foundation soil, which avoids the differential settlements due to its volume changes.

Luckily enough the value of protecting monuments without affecting their original design and construction (also in the parts that are not visible) is gaining ground.

The overarching idea is that ancient monuments are not seen to be mere icons but the tangible witnesses of the history of mankind. This change of mind can be easily observed by comparing recent papers on the issue with those published in the Proceedings of the 1996 Naples Symposium.

6 REFERENCES

[1] C. Viggiani, Editor. A.N. Author, *Geotechnical Engineering for the Preservation of Monuments and Historic Sites*, Balkema, Rotterdam, 1996.

[2] G. Calabresi & C. Cestelli Guidi, Le attuali condizioni di stabilità della Torre di Pisa, *Materiali e Strutture,* **1** (1990), 2-11.