General Report du TC 301
Monuments, historic sites and case histories

Rapport général du TC 301
Monuments, sites historiques et études de cas

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ABSTRACT : This general report presents and discusses papers dealing with the preservation of monuments and historic sites, as well as with some case studies related to problematic soils and to the design challenges they pose. The papers deal with a variety of issues and sometimes report different design approaches. They show that the themes discussed in this session are among the most challenging the geotechnical engineers and researchers have to face. In some cases, solutions have to be found taking into account the essential contributions of experts from different cultural fields.

RÉSUMÉ : Ce rapport général passe en revue une série d'articles portant sur la conservation des monuments et des sites historiques, ainsi que sur quelques études de cas concernant les sols difficiles et les défis qu'ils posent à l'ingénieur géotechnicien. La grande variété de problématiques traitées dans ces articles montre bien que les thèmes abordés dans cette session figurent parmi les plus complexes que les chercheurs en géomécanique et les ingénieurs géotechniciens soient appelés à résoudre. Souvent des solutions ne peuvent être trouvées qu'à travers les efforts combinés d'experts issus de différentes cultures disciplinaires.

KEYWORDS: Monuments, historic sites, preservation, problematic soils, case studies, seismic protection.

1 INTRODUCTION

This session combines two themes: *Preservation of Monuments and Historic Sites* and *Case Studies*. While the five papers that belong to the previous theme are homogenous, the nine papers belonging to the Case Studies theme can be conveniently subdivided in two categories: soil characterization (3 papers), and geotechnical design (6 papers).

Table 1 reports the list of the 14 papers belonging to the session. In the report, the papers will be presented and discussed following these categories, in the order adopted in Table 1. Citations of papers belonging to this session will be mentioned in Italics in the text.

2 PRESERVATION OF MONUMENTS AND HISTORIC SITES

2.1 *General considerations*

This topic has always been of interest to geotechnical engineers and, after the X ICSSMFE in Stockholm (1981) in which for the first time a full session was devoted to it, a technical committee was appointed (at that time TC19, now TC301) to work specifically on the preservation of monuments and historic sites. Since then, it has become an increasingly important topic in our community, along with the increasing awareness of the importance of heritage in our life.

Two specific conferences have been dedicated to the theme by the technical committee (Napoli, 1997 and 2013), and a theme lecture dedicated to Jean Kerisel has been established starting from this International Conference.

Furthermore, TC301 has produced a volume (Geotechnics and Heritage 2013) collecting a number of relevant case histories on the role of Geotechnical Engineering in the preservation of monuments and historic sites. The volume can be considered as the outcome of many years of activity of TC 301 (previously TC19): in fact, because of the complexity of the topic, it is difficult to imagine mandatory guidelines or recommendations summarizing what should be done and prescribing activities to carry on, intervention techniques, design methods. Therefore, the technical committee concluded that it is probably more effective to offer, as the volume does, a collection of well described examples of preservation activities which may inspire the geotechnical engineer dealing with monuments and historic sites, suggesting an approach rather than a solution.

Dealing with valuable sites and buildings poses a number of peculiar problems, and it has been recognised for a long time that their preservation is an interdisciplinary activity. The general principles of restoration and maintenance, and the constraints to interventions, have been stated in time from the Athens Charter (1933) first and Venice Charter (1964) subsequently. The principles contained in these fundamental reference documents apply not only to the superstructure but to the whole Ground-Monument System (Jappelli 1991), and their relevance for geotechnical engineering has been recalled many times (*e.g.* Jappelli 1997, Viggiani 1997, Aversa 2005).

The Nara Document (1994) and, more recently, the Krakow Charter (2000) have added complementary information and principles to these documents, recognising that the concept of preservation and even the definition of authenticity and heritage are somewhat elusive, and must be referred to considering the different cultural contexts existing around the world and not only in Europe, where the culture of preservation originally started.

Some of the papers belonging to this session deal directly or indirectly with authenticity, and different interpretations of its meaning are shown. An enlightening example of the elusiveness of the concept can be taken with reference to the conservation of some structures in Japan: up to the mid of the 19th century, several wooden Shinto shrines periodically underwent complete reconstruction ever since the inception of this custom in the 7th century. Such a practice had the character of an important religious ritual, but was probably answering to the need of

Table 1. List of papers belonging to the session on the Case Studies, Monuments and Historic Sites.

Category	Authors	Country	Title
Preservation of Monuments and Historic Sites	Akazawa Y. *et al.*	Japan	Reconstitution of foundation platform of Prasat Suor Prat by compaction of original soil with slaked lime, Angkor Ruins, Cambodia
	Iwasaki Y. *et al.*	Japan, Kazakhstan	Authenticity of Foundations for Heritage Structures
	Mimura M. and Yoshimura M.	Japan	Geotechnical Assessment for the Restoration of Garandoya tumulus with the Naked Stone Chamber
	Sesov V. *et al.*	Macedonia	Geotechnical aspects in sustainable protection of cultural and historical monuments
	Valore C. and Ziccarelli M.	Italy	The preservation of Agrigento Cathedral
Case Studies: soil characterization	Hawkins A.B. and St John T.W.	England	Importance of understanding the development and significance of sulphates in the London Clay
	Puppala A.J. *et al.*	USA	Heaving Mechanisms in High Sulfate Soils
	Vasquez A. *et al.*	Chile	Geotechnical characteristics of glacial soil deposits at Punta Arenas in Chilean Patagonia
Case Studies: geotechnical design	Hofman R. *et al.*	Austria, Germany	Rockfall-protection embankments – design concept and construction details
	Fedorovsky V. *et al.*	Russia	Geotechnical aspects of design and construction of the mountain cluster Olympic facilities in Sochi
	Petrukhin V.P. *et al.*	Russia	Geotechnical features of Sochi Olympic facilities project designs
	Slyusarenko Y. *et al.*	Ukraine	Modern methods of geotechnical defence of buildings in the difficult geological conditions of Ukraine
	Usmanov R.A. *et al.*	Tajikistan	Geotechnical problems at development of territories in the conditions of the Republic of Tajikistan
	Zhussupbekov A.Z. *et al.*	USA, Kazakhstan, India	Geotechnical issues of megaprojects on problematic soil ground of Kazakhstan

Figure 1. Ise shrine, which undergoes ritual reconstruction every 20 years ever since the 7th century.

Figure 2. The façade of the library of Celsus in Ephesus (Turkey), a magnificent example of *anastylosis*.

substituting spoiled or damaged parts. Later on, all the Shinto shrines but one (Ise shrine, Figure 1) stopped the periodic reconstruction because of political and economic changes.

Nowadays, while the Ise shrine still keeps its ritual reconstruction every 20 years, all the other shrines are protected by law as architectural heritage, assuming as an indicator of their relevance the material value. In fact, the interruption of the rebuilding process was an accident and not the norm, the Iso shrine being the only one to follow its originally conceived life cycle. So, the question is: what is authentic in this case? The frozen material situation of the 19th century or the immaterial heritage preserved by the ritual reconstruction of the Ise shrine?

Out of such a peculiar case, the preservation of authenticity usually asks to avoid reconstruction of monuments, which as explicitly stated by the Venice Charter "should be ruled out a priori". Only *anastylosis* (meaning in Ancient Greek "to erect a structure again"), that is to say, the reassembling of existing but dismembered parts can be permitted (Venice Charter, article 15). However, it can be done only when possible without misinterpreting the original structural scheme (Figure 2).

If static problems univocally indicate that interventions are necessary, clearly recognizable additions of new materials or elements should be preferred, which may eventually contribute to a long lasting life of the monument.

Nice examples can be found in the past, as shown by the Royal Palace of Napoli (Figure 3), whose façade may appear homogeneous but underwent a number of modifications in a period of about three centuries, some of which were caused by static problems, or in the present, as shown for instance by the

Figure 3. The Royal Palace of Napoli, built in the 17th century, whose façade was modified blinding some of the arches in the 18th century by architect Luigi Vanvitelli. Statues were added in the blinded arches in 1888.

Figure 4. Neues Museum, Berlin, in which the restoration project be architect David Chipperfield has been carried out with new materials.

nice restoration of the Neues Musem in Berlin (Figure 4) with completely new and recognizable materials.

As proposed by Jappelli (1991) and explicitly stated by the Krakow Charter, the basic requirements to be fulfilled when using new techniques in monument restoration are:

- chemical and mechanical *compatibility* between new and existing materials;
- *durability* of the new materials;
- *reversibility* of the intervention, in order to have the possibility of removing it without causing damages to the structure.

Indeed, most times the latter requirement seems impossible to fulfil for geotechnical engineers, who are often involved in restoration when possible critical mechanisms may involve the Ground-Monument System. In such cases, most times the geotechnical contribution is required to solve the static problem, and as a consequence additions (for instance, underpinning) may be tolerated, even though the ideal geotechnical solution would obviously be to mitigate the risk of failure without modifying the foundation scheme. The worldwide famous Pisa tower is an enlightening example, as the preservation was successfully obtained by careful underexcavation (Burland *et al.* 2013), therefore just removing some soil. However, it may also be seen as a misleading example, in the sense that it was obtained after almost one century of careful and detailed studies, investigations and monitoring, with no major economic constraints, with the support of politics and public opinion, involving world leading experts in different disciplines. Such an exceptional circumstance is rarely reproducible and cannot be considered as a routine situation, even in the case of extremely valuable monuments or historic sites. If foundation reinforcement may solve the problem, therefore, it should not be excluded *a priori*, and the solution should be considered case by case, obviously taking into account all the possible alternatives and privileging the least invasive ones.

Furthermore, often monuments as we see now are the result of continuous transformations that have taken place in time. Therefore, modifications based on sound cultural and mechanical bases should not scare the designers, being possible to consider them as part of the life of a monument, which should not be necessarily frozen to the present, intrinsically assumed as a reference time out of an historical pattern. The lack of a general theory and therefore of a clear indication of the best solution to preserve monuments impose the need to be extremely more cautious than with new constructions, and technical convenience or cost effectiveness must not be the guiding lights in this case. Engineers have to cope with values usually out of their skill, and have to agree on the solutions with archaeologists, architects, art historians and officials in charge of monuments preservation. Indeed, "a satisfactory equilibrium between safety and conservation, between engineers and restorers, may be found only in the development of a shared culture" (Viggiani 2013).

The role of research is fundamental to this aim, as new monitoring and investigation capabilities or new technical solutions may come to help in finding solutions as soft as possible, thus making the compromise simpler to reach. A good example is the seismic protection of monuments, which is a key issue often approached with extremely invasive solutions: recent experimental and numerical research activities seem to prove that by introducing a grouted layer with a low dynamic impedance at a certain distance from the building to protect (Figure 5), a relevant mitigation of seismic risk can be obtained (Kirtas and Pitilakis 2009; Lombardi *et al.* 2013). Ground improvement (actually, worsening in this case!) of the soil with appropriate grouts (Lombardi *et al.* 2013) then becomes a fully satisfactory solution, as it is carried out far from the structure to protect, therefore preserving its authenticity.

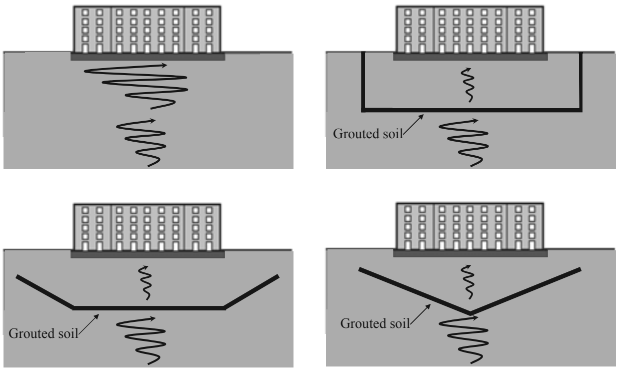


Figure 5. Different geometrical examples of grouted curtains realized to mitigate seismic risk on an existing building, which fully preserve the integrity of the structure (Lombardi *et al.* 2013).

2.2 *Papers presented to this session*

The subsession on the preservation of monuments and historic sites gathers five papers, all dealing with case studies.

The first, interesting case is presented by *Akazawa et al. (2013)*, concerning the restoration of a tower (named N1, Figure 5) belonging to the Angkor ruins (Cambodia). The tower is a three story masonry structure made of laterite blocks, about 10x10 m^2 at the base and 20 m in height. The tower is founded on a 5 m thick mound of compacted sand, overlaying a natural formation made of silty sands with clayey layers. It has experienced in time large settlements, with the largest value of

Figure 5. N1 tower in the Angkor ruins (Cambodia) before reconstruction (*Akazawa et al. 2013*).

about 40 cm measured on the side facing a nearby pond. The large structural damages, with wide cracks and a clear tilting of the structure towards the pond, were ascribed to a local bearing capacity failure of the wall facing the pond (Figure 6). As a consequence, it was decided to strengthen the compacted sandy foundation layer, mixing it with slaked lime and inserting layers of geotextiles, which was done completely dismantling the tower and reconstructing it after ground improvement completion. Even though this may seem an extremely invasive intervention and may pose problems in terms of the overall integrity and authenticity of the structure, it solved the static problems posed by the differential settlements experienced by the structure, which was on the verge of collapse.

The theme of overall integrity and authenticity is also dealt with in this session by *Iwasaki et al (2013)*.

Mimura and Yoshimura (2013) present the very interesting case of the preservation works to be carried out on a monumental structure in Hita (Japan), one of the so called Garandoya Tumuli. These earth mounds were erected over stone chambers, in some cases with coloured mural paintings. Nowadays, the mounds have been destroyed and the stone chambers are exposed at the atmosphere. In order to protect from weathering one of them adorned with colourful paintings, it has been recently decided to rebuild its earth mound, introducing a large curved shelter between it and the stone chamber (Figure 7).

The strategy seems convincing, as the mound will somehow resemble the outside original earth structure, hiding and preserving the chamber, but the large shelter (18 m in diameter) will keep the chamber clearly separated from the new structure, ensuring a clear distinction between the new and the original structure, thus preserving its authenticity. The paper shows the careful investigations carried out to study the isolation effectiveness of the proposed restoration works against water and temperature changes.

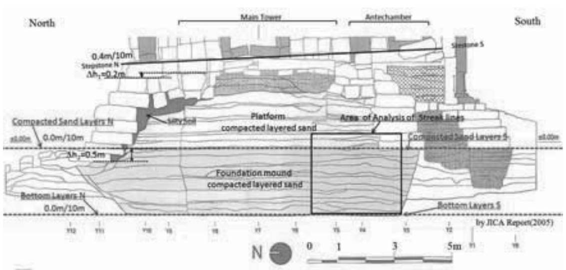


Figure 6. Local failure mechanism observed at the base of the N1 tower in the Angkor ruins (Cambodia) (*Iwasaki et al. 2013*).

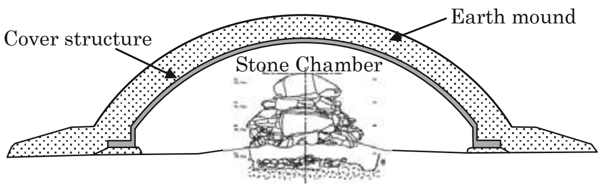
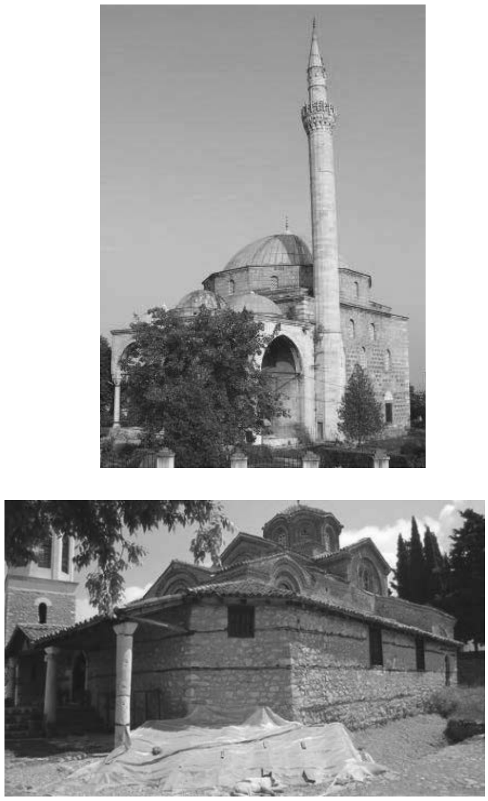


Figure 7. Schematic view of the restoration plan for the Garandoya Tumulus (*Mimura and Yoshimura 2013*).

As previously mentioned, seismic risk assessment of historic buildings is becoming a relevant issue, and procedures to get to reliable quantifications have been proposed in literature (e.g. D'Ayala and Ansal 2013). *Sesov et al (2013)* deal with this up to date topic in their paper, reporting on the efforts made in Macedonia to set up a rational procedure to assess seismic risk of some valuable historic buildings. The relevance of seismic site amplification analyses is addressed in the paper, and showed reporting some examples (Figure 8) of relevant structures having different natural frequencies and resting on different soils. Even though the approach is certainly appropriate, the paper does not give details on the considered case histories, and some of the conclusions appear obscure.



a)

b)

Figure 8. a) Mustafa pasha Mosque (15th century), b) St. Mary Peribleptos church (13th century) (*Sesov et al. 2013*).

However, the paper remarks the need to carry out seismic performance analyses expressing the seismic demand via comprehensive functions as the spectral acceleration Sa(T). The damages suffered during the different earthquakes experienced by the analysed structures could be somehow explained by the analyses briefly reported in the paper.

The last paper belonging to this subsession is the one by *Valore and Ziccarelli (2013)* on the preservation of the Agrigento Cathedral, in Italy. The cathedral was built in the 11th century on the top edge of a steep slope (Figure 9). It soon

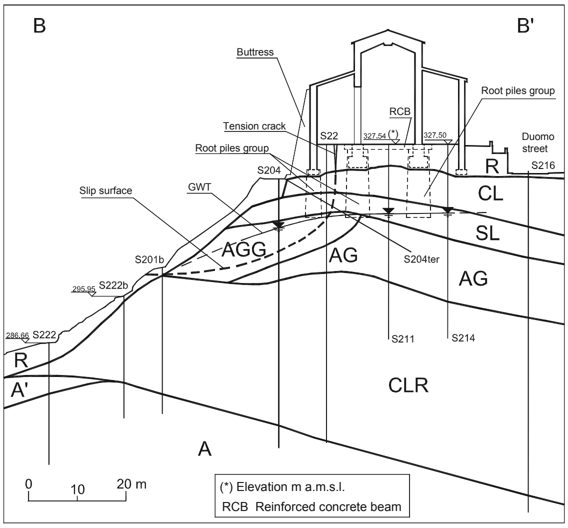


Figure 9. The Agrigento Cathedral, with an indication of subsoil stratigraphy and the supposed slope sliding mechanism (dotted line) *(Valore and Ziccarelli 2013)*.

started to suffer differential settlements and structural problems which led to a number of modifications from the 14th to the 17th century. In a completely unsuccessful attempt to solve the problems, in the period 1976-1980 a large underpinning intervention with root piles was carried out.

The paper is a nice example of the correct geotechnical approach to the preservation of monuments, and is paradigmatic in the sense that shows how useless – or even detrimental – an intervention without a clear understanding of the mechanisms do be faced can be. Underpinning had no positive effects because it was conceived assuming that the settlements were due to the high deformability of the upper soils.

By simply monitoring with inclinometers the slope, *Valore and Ziccarelli (2013)* demonstrate that an active and extremely slowly evolving shear surface exists, mostly developing in a clayey soil stratum (AGG in Figure 9). This slope movement is consistent with the observed pattern of fissures, and can be considered responsible of the observed displacements. Back calculations of the slope safety factor indicate that the safety margins are actually low and reduce as the displacements increase and the shear strength tends to its residual value, for which global equilibrium would not be granted.

Monitoring, careful characterization of the subsoil and of the superstructure and a sound mechanical interpretation of the observed mechanisms are indeed the only tools geotechnical engineers have in their hands to tackle problems as the one of the Agrigento Cathedral.

It is also worth pointing out that in this case a timely correct interpretation of the observed settlements would have led to interventions aimed to stabilize the slope more than to underpin the structure, eventually contributing to preserve the overall integrity of the structure.

3 CASE STUDIES

3.1 *Characterization of problematic soils*

Soil characterization is an essential part of the activity of geotechnical engineers, and the success in design or in the interpretation of mechanisms often depends more on it than on the calculation methods adopted. Therefore, the topic never ends to be of great interest. This subsession includes three papers dealing with soil characterization, with reference to some peculiar cases.

In their paper, *Hawkins and John (2013)* report on the behaviour of the very well known London Clay, looking at it from an unusual point of view as they investigate the chemical properties of the unsaturated/seasonally aerated zone of the formation. The London Clay Formation is a silty clay deposit which, in its upper part, is weathered and mostly aerated, thus getting a typical brown colour. The deeper part of the deposit, saturated, is grey. In the transition (mottled) zone among the brown and the grey London Clay, peculiar chemical conditions exist, often with the presence of enriched acid soluble sulphate with a corresponding low pH. As well known, this is a rather aggressive environment for buried structures and foundations, and may lead to their deterioration, as demonstrated for instance by the case history of the St. Helier Hospital in Surrey. *Hawkins and John (2013)* have monitored the sulphate content in the soil during the construction of an underground car park at different depths, confirming that the upper brown London Clay has a certain amount of sulphate, whose largest values correspond to the brown-grey mottled transition zone. The authors argue that the heat generated by concrete hydration may enhance the formation and mobilization of sulphates, and appropriate countermeasures should be taken to protect concrete from its attack in underground construction activities.

In their paper, *Puppala et al. (2013)* focus on the heave mechanisms occurring in high sulphate soils after the addition with calcium based stabilisers (lime and/or cement), as a consequence of the formation of two expansive compounds (namely ettringite and thaumasite). The authors show several experimental results on two high sulphate soils treated by hydrated lime, highlighting the advantages of the mellowing technique - firstly proposed by Harris *et al.* (2004) - in reducing the swelling behaviour due to the expansive compounds formation. The role played by factors such as soil mineralogy and treatment parameters are clearly discussed in the paper.

A large scale geotechnical and geological soil characterization project for the city of Punta Arenas, in the Chilean Patagonia, is described by *Vasquez et al (2013)*. The urban expansion of Punta Arena has posed a number of geotechnical problems, as soft and complex soils are spread out in the area. *Vasquez et al (2013)* propose a classification of the city area in different zones having homogeneous properties and characteristics. Even though specific investigations are always necessary and large scale classifications cannot give design parameters at the scale of the single structure, an overall picture of the subsoil characteristics and the problems they pose may be of great help in planning urban development.

3.2 *Geotechnical design in problematic soils*

The papers belonging to this subsection report design considerations or experimental results mostly with reference to new geotechnical structures. Some of the papers refer to peculiar regional problems, some to specific projects, and some to specific structures. In most of them, reference is made to codes, either existing or missing, as they represent some of the design constraints.

A paper analysing a specific geotechnical structure is the one by *Hoffmann et al. (2013)*, in which the authors deal with the very interesting case of embankments conceived as rock-fall protection elements. Such structures may be more convenient than rock-fall protection nets, because they may absorb larger impact energies and usually present advantages in terms of longevity and construction cost. The paper briefly describes the results of a large number of 1g small scale experimental tests (Figure 10) carried out on model embankments having different characteristics (unreinforced, reinforced with geotextiles, or unreinforced with a rip-rap up-hill facing).

The tests allowed to find interesting correlations between the geometry of the embankment, its characteristic and the energy and position of the impact. Based on the experimental observations, the authors give geometric indications to avoid the hitting rock block (or sphere, in the small scale experiments) to roll on or jump over the embankment crest, and also propose a simple design chart to estimate the penetration δ into the embankment as a function of a non dimensional energetic parameter E* (Figure 11).

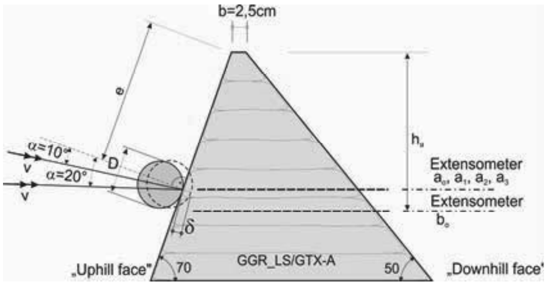


Figure 10. Small scale model rock-fall protection embankment used in the tests (*Hoffmann et al. 2013*).

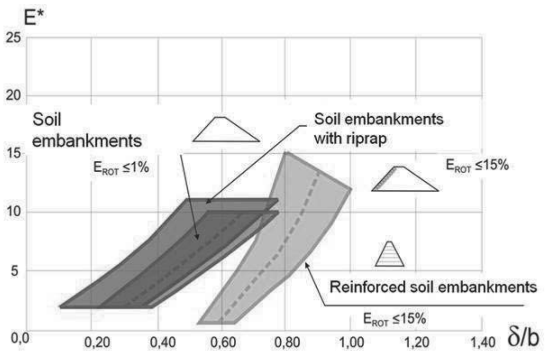


Figure 11. Summary of the results of the rock-fall experimental tests on small scale embankments (*Hoffmann et al. 2013*). E* is a dimensionless energetic parameter defined by the authors as relative impact energy, δ is the depth of penetration of the hitting sphere and b is the crest width (see Figure 10).

The other five papers belonging to this subsession share the characteristic of referring to geotechnical problems encountered in the problematic soils and in the extremely seismic areas of Eastern Europe and Western Asia, in states which were recently born after the collapse of Soviet Union.

Two of these papers deal with the large works under course in Sochi (Russia), where the XXIIth Winter Olympic Games and the XIth ParaOlympic Games will be held in 2014. The papers describe the geological and geotechnical features of the sites in which the Olympic Village and the sport facilities will be located. Two clusters are under construction: one in the coastal area and one on the mountains, giving rise to what claims to be the most compact venue ever for such an event. The whole area is highly seismic.

Fedorovsky et al. (2013) describe the complex geological conditions of the mountainous cluster, with chaotic, widely graded superficial soils over a base argillite formation. Since in some cases the facilities had to be realized operating slope cuts, slope stability analyses were carried out using different methods. Eventually, stabilizing interventions were conceived to meet safety requirements: soil nails were adopted to avoid local instability around the slope cuts, while rows of piles (in some cases anchored at the top) were used to stabilize the slope. No details are given in their paper on the design of the stabilizing interventions, and more than one doubt exist on the effectiveness of the adopted numerical approach for the design of rows of slope stabilizing piles. As a matter of fact, it is well known that piles give a contribution only if the slide is active, as the stabilizing shear forces they generate are the result of soil-structure interaction. What they usually do is slowing down more than stopping the slide (Lirer and Flora 2008, Lirer 2012), unless extremely heavy structures are realized. A realistic numerical calculation should allow soil flow among the piles, otherwise completely unrealistic interaction pressures may be calculated. Even though this seems to indicate than only complex 3D analyses are necessary, some codes allow such a flow even in 2D analyses.

The second paper on the new constructions in Sochi is the one by *Petrukin et al. (2013)*, who describe some of the geotechnical problems posed by the design of three large buildings in the coastal area, gives some information on the foundation solutions proposed, and briefly discuss the issue of pipelines design. The first building is the Big Ice Arena, seating 12000 people, resting on a complex deposit composed of layers ranging from coarse gravels to sandy clayey. Shallow foundations were chosen for this large building, made of a number of rafts having thicknesses from 0.6 m to 1.4 m, separated by joints. The displacements induced by the construction were monitored, and compared with the predicted ones (Figure 12). The reported comparison refers to the end of construction, and shows a general underestimate of the values of the absolute displacements. The authors do not say anything on the progress of consolidation settlements, and therefore it is not said if further displacements are expected in time because of pore pressure increments dissipation. However, the calculations were able to give the order of magnitude of the absolute and relative settlements. The second case described in this paper is the one of a tall building hosting the Organizing Committee of the Olympic Games. The building is founded on a thick layer of clay which,

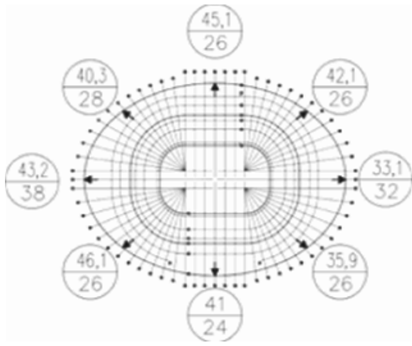


Figure 12. Mean values (mm) of measured (numerator) and calculated (denominator) settlements of the Big Ice Arena raft footing in Sochi (Russia) (*Petrukin et al. 2013*).

below a depth of few meters, has extremely poor mechanical properties. Consequently, the building has been founded on piles, whose seismic design was the geotechnical challenge. A refined solution was chosen in this case (Figure 13): a layer (40 cm) of dense sand reinforced with geogrids was interposed between the piles and the foundation raft. With such an elegant solutions, the piles solve the static problem in terms of bearing capacity and settlements, but do no interact (neither kinematically nor inertially) with the superstructure during earthquakes, thus avoiding the risk of large seismically induced bending moments at the piles caps.

A similar solution was adopted for part of the foundations of a hotel, which is the third building analysed in this paper, while the remain part of the foundations were shallow, because directly resting on a thick deposit of sand and gravel. *Petrukin et al. (2013)* claim that the interposition of an intermediary sand

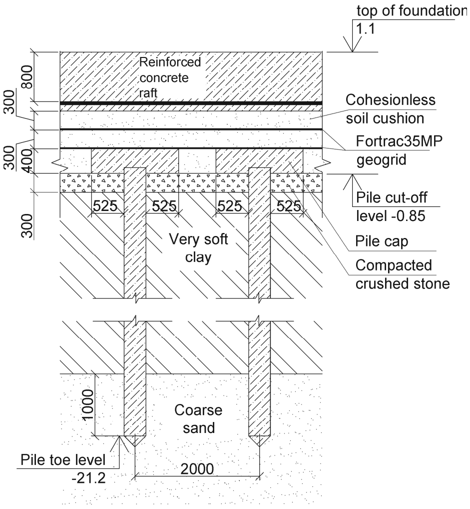


Figure 13. Foundation of the Organizing committee Building in Sochi (Russia). Detail of the pile foundation disconnected from the raft (*Petrukin et al. 2013*).

layer between piles and raft has started in seismic areas of the USSR in the 1960s, and this is very interesting as only few, and more recent, experiences (e.g. Thornburn *et al.* 1983, Jamiolkowski *et al.* 2009) are described in literature.

The critical geological conditions of the territory of Ukraine are described by *Slyusarenko et al. (2013)*, which are of concern as about 60% of the territory is interested by formations of collapsible soils or unstable slopes. Considering the geotechnical problems posed by such soils, the authors describe two case histories: one pertaining to an underground parking lot realized with a top-down procedure, the other referring to the reparation works carried out to preserve a valuable 18th century baroque church. As far as the latter is concerned, a number of static problems affected the structure in time, with leaning parts and diffused crack patterns. The church is positioned on top of a hill, which was found to be not far from limit equilibrium conditions. *Slyusarenko et al. (2013)* shortly report the list of investigations and of the numerical analyses carried out. They also describe in some detail the adopted solutions, even though no details on soil properties, slope geometry and stability analyses are given in the paper. Along with extensive restoration of the superstructure, it was finally decided to underpin the church with jet grouting (Figure 14). As previously discussed (see §2.1), this is a rather invasive intervention which irreversibly compromises *authenticity* of the monument. Even though underpinning cannot be excluded a priori, it should be carried out only if no alternatives are available which would induce similar beneficial static effects. Since slides were observed along the slope, and slope stability safety margins were extremely reduced, it would have been interesting to know if slope superficial and deep displacements were monitored, for instance with inclinometers. In fact, such displacements may have caused at least part of the static problems experienced by the church, as shown in this session by *Valore and Ziccarelli (2013)* with reference to the similar case of a church placed on top of a hill with a slope close to failure.

In any case, *Slyusarenko et al (2013)* have used jet grouting to underpin the church instead of more traditional techniques, as for instance micropiles. This choice may be convenient, because large columns can be formed drilling small holes into the soil by correctly tuning the treatment energy (Flora *et al.* 2013). However, extreme caution should be adopted when using jet grouting close to very sensitive buildings (Croce *et al.* 2013). Furthermore, it is well known that the highly energetic grout jet may cause undesired settlements when used in unsaturated collapsible soils as the upper ones seem to be under the church. In any case, the authors report that the underpinning works were successful, as the displacements have stopped.

Referring to similarly problematic soils, *Usmanov et al. (2013)* summarise the typical foundation systems in the very critical geotechnical conditions encountered in most of the territory of the Republic of Tajikistan. Even though the described systems are traditional, the site conditions in which they are applied are sometimes extreme, being the area highly seismic, with largely spread thick layers of unsaturated collapsible loess and weak saturated soils. The authors report that even in such critical conditions, the foundation solution reported in the paper have proven to be successful for medium rise buildings (up to 12 storeys).

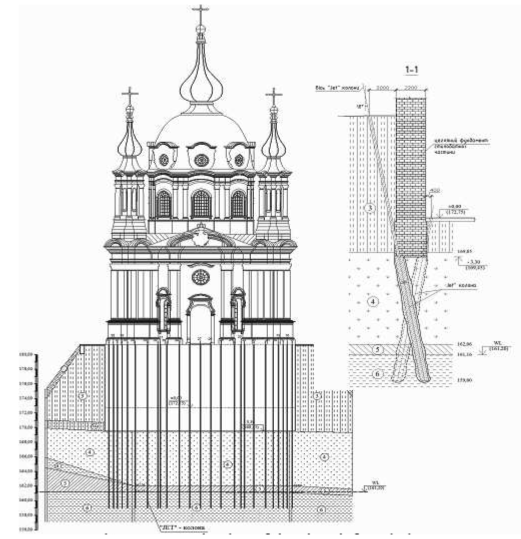


Figure 14. Underpinning with jet grouting columns of St. Andrew Church in Kyiv (Ukraine) (*Slyusarenko et al. 2013*).

Recently, a number of large projects has started in the new born state of Kazakhstan, and in its capital Astana in particular. The town is located in the Kazakh steppe, and the subsoil is constituted of erratic layers of soft and hard soils; in the most superficial part, soil freezes during the extremely severe winter. Because of these complex geotechnical conditions, deep foundations are usually adopted, and new technologies in pile construction and testing considered too. *Zhussupbekov et al. (2013)*, for instance, in their paper summarize some experiences relative to continuous flight auger piles (CFA piles, usually classified as replacement piles, even though the soil is partially displaced during installation) and displacement screw piles (in the paper named DDS piles). They show an interesting comparison between static and dynamic loading tests: in the cases reported in the paper, the dynamic tests largely underestimate the ultimate axial load of the piles, being also very sensitive to the kind of hammer adopted in testing. The authors also discuss the use of alternative testing procedures which may be more convenient, as the Osterberg Cell tests (Russo, 2013). Even though the paper contains interesting experimental data, it is very difficult to get an insight on them as information are given neither on the properties of the soils in which the test piles were realized, nor on the piles themselves.

4 CONCLUSIONS

The session deals with a number of complexities, related to the structures to preserve (monuments and historic sites), to the soils to characterize or to the design constraints posed for new structures by difficult regional conditions in highly seismic areas. Indeed, some of the most challenging issues for geotechnical engineers and researchers.

Generally speaking, and with some exceptions, the papers do not deal with new design methods or new technologies. They present case studies in which traditional tools were used to try and face complexity, the interest of the papers essentially being in the engineering solutions proposed. As obvious, the ones adopted for monuments and historic sites are usually less invasive than the ones conceived for new constructions, confirming that the design strategies have to be different in the two cases. This key issue certainly needs to be discussed.

In some cases, the differences in the approaches and in the solutions depend on different cultural backgrounds and environments. The discussion should deal with such differences. With specific reference to monuments and historic sites, it should be also debated to what extent interventions may alter integrity and authenticity, posing a question on its final goal: to preserve heritage or to the aim of touristic fruition?

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