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Editors

Engineering Geology for Society and Territory – Volume 7

Education, Professional Ethics and Public Recognition of Engineering Geology

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Education, Professional Ethics and Public Recognition of Engineering Geology

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Cover Illustration: San Felice sul Panaro, Modena, northern Italy. The San Felice Vescovo Church, built 1499, was completely destroyed by an earthquake, which struck a vast area of the Po Plain on 20 May 2014. As visible, many near ancient buildings did not suffer similar damages. This proves that the effect of the seismic shock is strongly dependent also from structural features of the building. *Photo*: Giovanni Bertolini.

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Foreword

It is our pleasure to present this volume as part of the book series of the Proceedings of the XII International IAEG Congress, Torino 2014.

For the 50th Anniversary, the Congress collected contributions relevant to all themes where the IAEG members have been involved, both in the research field and in professional activities.

Each volume is related to a specific topic, including:

1. Climate Change and Engineering Geology;
2. Landslide Processes;
3. River Basins, Reservoir Sedimentation, and Water Resources;
4. Marine and Coastal Processes;
5. Urban Geology, Sustainable Planning, and Landscape Exploitation;
6. Applied Geology for Major Engineering Projects;
7. Education, Professional Ethics, and Public Recognition of Engineering Geology;
8. Preservation of Cultural Heritage.

The book series aims at constituting a milestone for our association, and a bridge for the development and challenges of Engineering Geology toward the future.

This ambition stimulated numerous conveners, who committed themselves to collect a large number of contributions from all parts of the world, and to select the best papers through two review stages. To highlight the work done by the conveners, the table of contents of the volumes maintains the structure of the sessions of the Congress.

The lectures delivered by prominent scientists, as well as the contributions of authors, have explored several questions ranging from scientific to economic aspects, from professional applications to ethical issues, which all have a possible impact on society and territory.

This volume testifies the evolution of engineering geology during the last 50 years and summarizes the recent results. We hope that you will be able to find stimulating contributions which will support your research or professional activities.

Giorgio Lollino

Carlos Delgado

Preface

In the age of human activities, Engineering Geology plays a key role in the sustainable development of our societies: scientists, regulators, and practitioners of Engineering Geology are called to confront themselves with the purposes, methods, limitations, and findings of their works.

In this perspective, topic seven of the XII Congress of IAEG in Torino on 2014 was an opportunity to illustrate a wide-angle vision on several inter-related issues: the role of Engineering Geologists within the geoengineering profession; the best practice in professional ethics and communication in a changing world; the education and modern development of Engineering Geology profession and its professionals; resource use and reuse in managing risk prevention and impaction a complex framework; engineering our geological responsibility in an uncertain environment; Engineering Geology at tertiary level.

Five part topics were activated, presenting a total of 54 chapters, contributing to:

- stimulating the debate on professional responsibilities of engineering geologists,
- analyzing the interactions of engineering geologists with other professionals,
- evaluating the recognition of the engineering geological profession and its peculiar contribution to society, culture, and economy, and
- reporting examples of the empowerment of research groups and management activities by using web 2.0/3.0 technologies, thus enabling cooperation, knowledge sharing, and collaboration at all levels.

They highlighted implications for the use of the education of engineering geologists at tertiary level and in further education schemes. They also highlighted the importance of having the professionals organized into national groups which stimulate advances in Engineering Geology in their countries.

"Engineering Geological Models" (Part I) discussed the use of engineering geological models within the framework of the total geological approach (Fookes et al. 2000; Baynes et al. 2005; IAEG Commission 25). Such models allow the understanding and prediction of engineering geological conditions and processes, aiming at reducing uncertainties and their impact on our societies. The authors presented examples on innovative use of engineering geological models for different engineering projects, and for different geological and geomorphological environments, envisaging new perspectives and operational outcomes.

"Fifty-Year-Long History of IAEG in Events and Personalities" (Part V) focused on relevant facts and events (congresses, conferences, symposia) of the 50-year-long IAEG history, where many outstanding personalities played a fundamental role as founders of our association. Amongst those who participated in the IAEG work, since its early beginning, some gave great and acknowledged contribution to the development of engineering geology on a world scale. Many witnesses of the events that took place during 50 years, and there are still colleagues and disciples of the remarkable founders of IAEG, keep their historical memory. This part highlighted our duty to share this heritage, passing up the baton to the new young generation of geoscientists. In the 50th Anniversary Book which will be distributed to all participants in the Congress, parts are devoted to the birth of the IAEG and the relevant role of its founders, to the main events organized along the 50 years, to its outstanding activity all over the world, and to the awards that have been established to pay a tribute to those who most contributed to the development of our discipline. The book also includes a History of Engineering Geology which starts with its heritage and reports its evolution and the main achievements until today.

"Geoethics and Natural Hazards: Communication, Education and the Science-Policy-Practice Interface" (Part II) analyzed the critical ethical issues faced by Geoscientists and Engineers in relation to natural hazards (e.g., earthquake, volcano, landslide, and flood events) and risks, and their increasing death toll and social costs owing to population growth, occupation of marginal/unsafe land, and abandon or misuse of land. Sharing and communicating our knowledge more effectively, involving private and public stakeholders, could contribute to a sustainable development of human society and economic activities. In the Anthropocene, Geosciences represent the "connective tissue" of a wider multidisciplinary approach, to build a shared responsibility on the effects of human actions, and to better cope with uncertainties. This part highlighted many natural disasters could be prevented and/or their impact reduced, raising awareness and fostering a true interdisciplinary collaboration that could fulfill ethical obligations of the scientific community as a whole. This shows the growing importance of environment in the practice of engineering geology and also the need for its cooperation with other engineering and social subjects and professionals.

"Resilience Two Citizens and Citizens Four Resilience" (Part III) focused on how engineering geology could benefit from knowledge sharing of natural hazards and collaborative risk management. As natural risks are part of our reality, the authors highlighted how preparedness, as an interdisciplinary issue, could envisage a more effective disaster resilience. The "common and shared knowledge" approach empowered by web 2.0/3.0 technologies, embodies the idea of citizen sciences and the purpose to build a new people-centred resilience: Crowdsourcing and VGI, citizens engagement and participatory practices are a new frontier and a matter of fact. Despite any critics, they have the merit to arouse a debate on cooperation, knowledge sharing, and collaboration at all levels. This part faces, out from the crowd, applicability, opportunity, and constraints of these new approaches, procedures, and technologies for preparedness actions: (A) The "web 2.0 wave": threat or opportunity for disaster resilience? (B) Two-way emergency communications: empower or menace for governmental organizations. (C) ICT laws and regulations: dinosaurs in a glass store? (D) Is research ready for Open Data and Open Knowledge (E) Cultural vs. technological challenges in disaster resilience (E) Web and mobile technologies: experiences and tools.

"Standards, Guidelines and Best Practices for Engineering Geology" (Part IV) offered to professionals an overview of specialized documentation on Engineering Geology: the best practice case studies and compilations, recommended technical procedures in more formal guidelines, rigid regulatory, or prescriptive standards that are legally binding. Such documentation resulted appropriate for a variety of topics relevant to the engineering geology community, and for a suite of topics, including construction materials studies, landslide risk management and land planning, subsurface mining, infrastructure construction, and groundwater extraction. An international open exchange of ideas and knowledge was gained by this part, where authors illustrated their personal, national, or specialized experiences, lessons learned, successes, and failures with fellow professionals. The authors provided much needed guidance and structure to practicing engineering geologists and they underlay our professional obligations to ensure the health, safety, and well-being of society. In the IAEG, this has been best achieved through publication in the Bulletin which was created in 1970 and is today a reference journal in the area, as well as the work produced by the IAEG Commissions.

Interesting points emerged from the IAEG 2014-Topic 7 on "Education, Professional Ethics and Public Recognition of Engineering Geology." A comprehensive view of the proposed contributions fosters the idea of engineering geologists playing the role of acknowledged "interface" between man and nature. They are not only scientists and professionals able to "interpret" both the environmental and the territorial processes, but they also have attitudes and capabilities to communicate information to the general public and to develop guidelines for the correct and safe use of land, namely for the social welfare and economic development of society. The issues proposed by the Topic's sessions, and the way they were discussed within the proposed contributions also highlighted the important role Engineering Geologists can play in disaster resilience. As a conclusion, interesting discussions have been stimulated on the relationships between ethic, science, politics, and citizenship.

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Contents

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The Istituto di Ricerca per la Protezione Idrogeologica (IRPI), of the Italian Consiglio Nazionale delle Ricerche (CNR), designs and executes research, technical and development activities in the vast and variegated field of natural hazards, vulnerability assessment and geo-risk mitigation. We study all geo-hydrological hazards, including floods, landslides, erosion processes, subsidence, droughts, and hazards in coastal and mountain areas. We investigate the availability and quality of water, the exploitation of geo-resources, and the disposal of wastes. We research the expected impact of climatic and environmental changes on geo-hazards and geo-resources, and we contribute to the design of sustainable adaptation strategies. Our outreach activities contribute to educate and inform on geo-hazards and their consequences in Italy.

We conduct our research and technical activities at various geographical and temporal scales, and in different physiographic and climatic regions, in Italy, in Europe, and in the World. Our scientific objective is the production of new knowledge about potentially dangerous natural phenomena, and their interactions with the natural and the human environment. We develop products, services, technologies and tools for the advanced, timely and accurate detection and monitoring of geo-hazards, for the assessment of geo-risks, and for the design and the implementation of sustainable strategies for risk reduction and adaptation. We are 100 dedicated scientists, technicians and administrative staff operating in five centres located in Perugia (headquarter), Bari, Cosenza, Padova and Torino. Our network of labs and expertizes is a recognized Centre of Competence on geo-hydrological hazards and risks for the Italian Civil Protection Department, an Office of the Prime Minister.

Optimization of Large Civil Engineering Projects from an Environmental Point of View

1

Ricardo Oliveira

Abstract

Without exception, the construction and operation of civil engineering projects have resultant environmental impacts. However, in most cases the projects are essential to the economic and social development of the regions where they are located and for some, their sole purpose is to protect people and goods from natural hazards such as floods and landslides. In general, the media and environmentalists tend to enhance the negative impacts of the projects and very seldom make reference to their positive impacts. In this context, the need for high quality studies and designs is assuming increasing relevance for engineering projects, to ensure solutions with the least negative impacts are selected and subsequently constructed and operated by suitably qualified staff. The role of geotechnics in the optimization of civil engineering projects is therefore as important as is the efficient and early intervention of specialists, and their decisions, on the technical, economic, social, environmental and operational aspects of the works. To illustrate that it is often possible to optimize projects from an environmental point of view, several examples are presented in relation to construction materials, hydraulic developments, linear works (roads, railways, airways, and waterways), underground works, maritime works, bridges and viaducts, and natural and excavation slopes. In each case, emphasis is placed on the environmental concerns that require optimization of the design in order to minimise the negative impacts without diminishing the economic and social benefits of the works.

Keywords

Design improvement • Engineering projects • Environment

1.1 Introduction

Until the 70s/80s the design of large engineering projects had to be satisfactory from both technical and economic points of view. This meant that, until that time, the best design solutions were selected by only taking into consideration those points of view. However, quite often those responsible for the design did study different alternatives, some of which had less interference with the environment, but generally only selected them if they were the least cost alternative.

Large engineering projects were constructed all over the world; however people in more developed countries tended to be more sensitive to their environmental impacts.

The primary environmental impacts were related to the archeological, biological, paleontological and physical aspects of the affected region and concerned communities started to contest the projects. In spite of the negative impacts, the construction of those projects was considered essential to the

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economic and social development of the population affected. Examples include the construction of infrastructure like dams (for water supply, irrigation, clean and renewable hydroelectric energy, leisure, and flood control), canals, motorways, railroads, bridges, tunnels and other underground works, airports and ports. Moreover, some of these works had the objective of protecting people and goods from natural hazards such as landslides, floods and earthquakes.

The media and environmentalist organizations tended to enhance the negative impacts of the projects and very seldom made reference to their positive effects.

Taking into consideration the fact that the implementation of all large engineering projects will generate some negative impacts, it is fundamentally important to develop, both at the feasibility and design stages, solutions that minimize negative environmental impacts and to propose compensatory measures.

In the past, studies and designs conducted by qualified professionals have taken those aspects into consideration, trying to balance the technical and economic feasibility of projects with environmental preservation.

However, we must acknowledge that, in the past, when faced with more than one feasible alternative engineering solution, most project owners selected the least expensive solution, even where this would imply greater environmental impacts on the affected area.

These facts outlined above explain the origin of legislation that has been created in the most developed countries and regions, to mandate that environmental impact assessments are conducted for all large engineering projects and that the results are considered in balance with the social and economic aspects of their implementation, to determine the best design solution Oliveira (1997).

For example, European Commission Directive 85/337/CEE was agreed in June 1985 and soon transposed to many countries even outside the EU. In Portugal, the first decree was Law 186/90, which was first updated in 2000 (Law 69/2000), and its most recent version is from 2013 (Law 151-B/2013). This last version decrees that the environmental impact study of a given project must be terminated at the same time as the completion of its basic design and that the two studies include, wherever possible, the analysis of alternative solutions. The authorities take those studies into consideration and they only approve the design when a favourable Declaration of Environmental Impact (DEI) is issued, based upon them.

For a large number of such projects, the engineering geological and geotechnical engineering roles are fundamental, depending on the degree of interference of the project with the ground as well as, often, with the groundwater. These roles are especially relevant when the studies are conducted by experienced professionals who make decisions based on the economics of the project as well as on its social, environmental and operational consequences Oliveira (2008).

Table 1.1 List of Engineering Works

Construction materials
Hydraulic undertakings
Linear surface works (highways, canals, pipes)
Underground works (tunnels, caverns)
Marine works (earth fills, breakwaters)
Bridges and viaducts
Natural and excavation slopes

1.2 Examples of Geotechnical Project Optimization that Takes Environmental Issues into Consideration

In order to give some examples of how it is possible to optimize civil engineering projects, taking environmental issues into consideration, while still preserving their economic and social value, a list of topics and works is shown in Table 1.1.

Most of the examples were constructed years ago and they show how it is possible for both sides of the problem to be compatible.

The first example relates to the use of geological construction materials, which is a subject transversal to most engineering works. In general their extraction is only possible through the excavation of soils (borrow areas) or the blasting of rock masses (quarries). These procedures always interfere, although to different degrees, with the environment and the landscape, and at the end of extraction the rehabilitation of the degraded areas should be mandatory. Unfortunately, in many countries the legislation does not yet mandate the rehabilitation of those areas, but that will certainly change in the near future.

In order to avoid using large volumes of geological materials for construction, research has been conducted recently to find ways to replace the natural geological materials with alternative products, such as recycled materials, quarry debris and geosynthetics.

Other important topics related to construction materials and the optimization of their use, both from economic and environmental points of view, are the management of the materials during construction and the compensation of volumes (excavations and fills) that have to be considered at the design stage. Good volume compensation reduces the amount of materials used and avoids unnecessary deposit of non-used materials, which requires free areas and generally interferes with the landscape.

Table 1.2 Construction materials

Dams	Extraction of soils and rocks in the reservoir area
Linear works	Excavations and embankments
	Compensation of volumes and materials management
Bridges versus embankments	Foundation conditions and the availability of embankment materials
Land reclamation	Dredging, hydraulic fills, borrow areas

In order to support the concept of optimization of the use of geological construction materials, Table 1.2 presents examples of dams, linear works (motorways and canals), bridges and coastal land reclamation.

With respect to hydraulic undertakings (i.e. dams and hydraulic structures), environmental impacts may be experienced during the construction stage (e.g. the excavation of large spillways) and/or during operations, upstream and downstream (e.g. landslides of reservoir slopes and waves, sedimentation of the reservoir, erosion of slopes).

An interesting example of an environmental impact caused during construction was the excavation of the 90 m high spillway of the Gargar dam in Algeria (Fig. 1.1). In this case, the impact could be minimized as a result of the sub-horizontal structure of the karstic limestone, that permitted a very steep slope, and also by the use of controlled blasting of the rock mass.

A very well-known example of environmental impact during operations relates to the large sedimentation of the reservoir in the Three Gorges dam, in China. To deal with the erosion of soils from the hydraulic basin, which are mainly transported to the reservoir by the tributaries, additional dams have been constructed in several of the water lines to retain sediments and thus to avoid them reaching the reservoir. A program of forestation upstream has also been implemented. Furthermore the design of the main dam takes into consideration the detrimental aspect of sedimentation by incorporating 22 vanes and 23 bottom outlets in order to allow the sediments to be expelled downstream when floods occur. Large discharges or floods, if uncontrolled, may erode the base of the natural slopes of valleys, downstream of dams, provoking instability of the ground.

With regards to surface linear works, examples of environmental optimization include the layout of alternative routes, crossing karstic zones, open excavations versus tunnels and landscaping, all of which must be considered while also taking into account the social and economic aspects of the land expropriation for each solution.

Good examples that show how the optimization of engineering solutions can improve the environmental conditions of the area include: the motorway A1, in the region of Fatima, the Lisbon Regional Outer Circular (CREL) and the motorway 24 to the Douro valley, all in Portugal and the Anilio tunnel part of the Egnatia highway in Greece. Figure 1.2 shows two alternatives which were studied 25 years ago, for the crossing of motorway A1, near Fátima, through a karstic limestone rock mass. The decision taken, based on the relative costs, was for the surface excavation of the rock mass with slopes of approximately 30 m high (Fig. 1.3). Nowadays this solution would not have been approved by the environmental authorities.

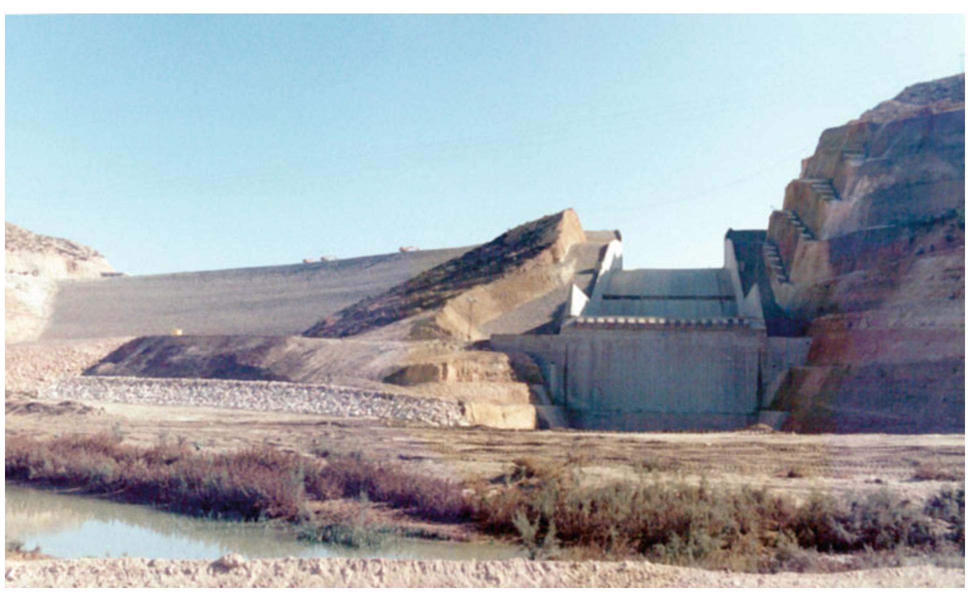

Fig. 1.1 Gargar dam (Algeria). Spillway

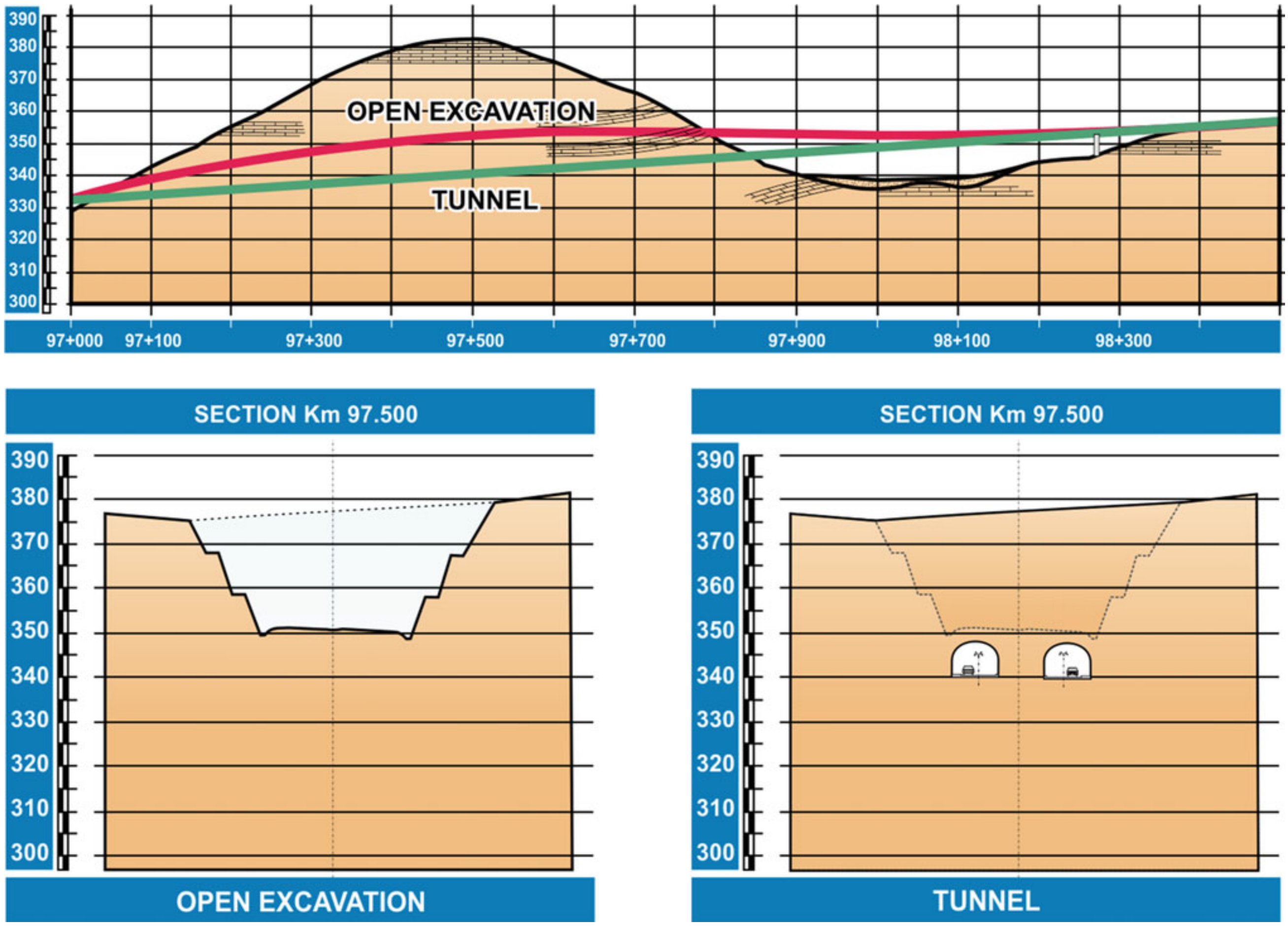

Fig. 1.2 Motorway A1. Alternative solutions

Fig. 1.3 Motorway A1. Solution open excavation

The excavation of tunnels, as part of engineering works, can create significant environmental problems that have to be anticipated at the design stage and solutions have to be found to mitigate their impact. Examples include their interference with the hydrogeological conditions of the geologic formations they cross and the destination site for any materials resulting from the excavations.

Those concerns also apply to the construction of underground caverns, which are opened for several engineering purposes, such as hydroelectric power plants, metro stations, fluid storage and dangerous waste disposal. Moreover, reference should also be made to the problems of ground pollution, subsidence and collapse that reflect at the surface of the ground.

One important issue mentioned previously in this paper is the final treatment given to excavation debris that is not used as a construction material, and is therefore a waste product; effective modelling during the design phase can enable proper landscaping of the storage area that will be affected. An interesting example is the study conducted by Eletricidade de Portugal (EDP) for the power plant Venda Nova II, located in the north of Portugal. The construction of the tunnels and of the deep power plant required the extraction of more than half a million cubic meters of rock that were not appropriate for construction. The deposit materials were modelled in such a way as to give the area a pleasant landscape (Fig. 1.4).

Finally, the topic of natural and excavated slopes is discussed. Firstly, some comments on the geological risks, resultant from the instability of natural slopes, which often affect people and property. In such cases, studies have to be conducted for the design of support works which assure the safety of the ground, while ensuring that the necessary works have minimum interference with the environment

Fig. 1.4 EDP Venda Nova II power plant. Modelling of deposit materials

Fig. 1.5 Serra da Arrábida. Retaining works and false tunnel

and the landscape. An interesting example is shown in Fig. 1.5, which presents stabilization works being conducted on a natural slope, more than 100 m high, of the Serra da Arrábida, south of Lisbon, as a result of large limestone blocks having fallen on the road below, from time to time, which imposed the closure of the road to all traffic for 2 years.

As this area belongs to a natural reserve, the solution chosen had to take into consideration that no significant excavation works could be performed to improve the stability

Fig. 1.6 Motorway CREL. Retaining curtain

of the rock mass. For excavated slopes, the stability analysis has to consider the geological, hydrogeological and geotechnical conditions of the ground for the feasibility study of possible solutions. The optimal solution will assure the stability of the slope, while requiring the least possible interference with the environment. Figure 1.6 shows an example of a high and long retaining structure constructed on an excavation slope of the Lisbon motorway CREL, supporting a very fragmented limestone rock mass, which was selected after taking into consideration the concern to choose a solution that would be well-framed in the landscape.

1.3 Conclusions

The rapid growth in the world's population (which has increased four times in the 20th century) and its concentration in urban areas (more than 50 % of the actual total world population) with many people living in megacities, continues to necessitate the construction of new infrastructure of all types in order to create adequate conditions for the economic and social development aspired to. However, such construction must be done with a mind to environmental preservation Oliveira (2000).

The purpose of the examples presented in this paper is to show that it is possible to reconcile development with environmental preservation, if and when qualified engineering geologists and geotechnical engineers use their knowledge to find the best possible solutions for the required engineering works.

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Part I

Engineering Geological Models

Convener: Dr. Jan Novotny—*Co-conveners*: Steve Parry

The session will discuss the use of engineering geological models within the framework of the total geological approach (Fookes et. al. 2000; Baynes et al. 2005; IAEG Commission 25). Such models allow the understanding and prediction of engineering geological conditions and processes, and allow uncertainties to be defined. Examples of the use of engineering geological models for different engineering projects and for different geological and geomorphological environments are expected.

Engineering Geological Models: Some Examples of Use for Landslide Assessments

2

Jan Novotný

Abstract

The Commission C25 of the International Association for Engineering Geology and the Environment is currently working on "The use of engineering geological models". This article presents examples of engineering geological models for landslides using both a conceptual and an observational approach. Generally speaking, the conceptual model forms the basis for the development of the observational model. However, there are cases where the relationship between the conceptual model and the observational model is not so unidirectional. The experience gained in developing the observational model in these cases can facilitate considerably the development of future conceptual models in the same type of engineering geological conditions.

Keywords

Landslides • Engineering geological model • Conceptual • Observational

2.1 Introduction

This paper constitutes a contribution to the discussion currently taking place within the Commission C25 of the International Association for Engineering Geology and the Environment, which is currently working on a paper entitled "The use of Engineering Geological Models" (Parry et al. 2014). The C25 considers two different methodologies for developing the models:

The *conceptual approach*, according to Parry et al. (in press), is based on understanding the relationships between engineering geological units, their likely geometry and anticipated distribution. This approach, and the models formed, are based on concepts formulated from knowledge and experience and are not related to real three-dimensional (3D) space or time. Importantly, the model is largely based on consideration of *geological concepts* such as age, stratigraphy, rock type, unconformity and weathering.

The *observational approach* is based on the observed and measured distribution of engineering geological units and processes. These data are related to actual space or time and are constrained by surface or sub-surface observations.

To illustrate these concepts, the article will present several examples from Cretaceous sedimentary regions of the Czech Republic.

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2.2 Conceptual Models of a Slope Structure Comprising a Rigid Layer Above a Plastic Layer

In the Czech Republic, slope movements relatively often occur in a rock structure characterized by an upper layer (No. 1 on Fig. 2.1) consisting of rigid (competent) rock broken into blocks by the Tertiary tectonics, and by a thick

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lower layer (No. 2 on Fig. 2.1) consisting of plastic (incompetent) rock. Typically, the upper layer is composed of massive sandstone and the lower layer of plastic claystone.

Figure 2.1 represents a conceptual model of a long-term evolution of a slope with this structure, as seen in various stages of development (Rybář and Nemčok 1968). In Fig. 2.1a erosion processes start to cut through the rigid layer. Figure 2.1b demonstrates that a narrow valley is prone to bulging (Varnes 1978). Further deepening and widening of the valley (Fig. 2.1c) leads to cambering—block-type movement on plastic underlying rock (Varnes 1978; Nemčok et al. 1972) in the upper part of the valley and to landslides of plastic rocks and derived soils in the lower part of the valley. Figure 2.1d represents a denudated slope prone to landslides triggered by river erosion at its base.

In Czech Cretaceous sediments, the most common slope state corresponds to the model stage "c" (Fig. 2.1c), which can be encountered also in Prague. Using archival research data, the general conceptual model can be further developed into a site-specific conceptual model for a particular location. Common features of site-specific models for the stage "c" comprise: (1) upper slope consisting of sandstone, often affected by block movements; (2) groundwater horizon developed in the sandstone above the impermeable clay, often drained ahead of the sandstone blocks on slopes consisting of fine grained soils; (3) ahead of the sandstone blocks, potential occurrence of landslides in the slope composed of fine grained soils.

An example of a site specific conceptual model is given in Fig. 2.2. In the village of Hrubá Skála, located in the NE of the Czech Republic, family houses were built on a seemingly favourable flat terrain which in reality consisted of unrecognized old landslides. A correct use of the principle of engineering geological models would have easily prevented damage to the houses (Novotný 2009).

A similar site specific conceptual model in Fig. 2.3 characterizes the Prosek district in the north of Prague (Pašek 2000 in Novotný 2009), affected not only by slope movements but also by historical undermining (Cílek 1999 in Novotný 2009), which should be taken into account when determining the scope of site investigation works needed for the correct development of the observational model. Houses constructed near the slope edge with disregard of the model were damaged by fissures and one of them had to be demolished (Lešner 2004 in Novotný 2009).

Generally speaking, all site investigation works should aim to answer questions raised by the conceptual model, and thus to elaborate the observational model. At the same time, the conceptual model itself can be used to determine efficiently the type and scope of site investigation works needed (when compared to a "grid-like" site investigation planned without knowledge of the site geology and processes).

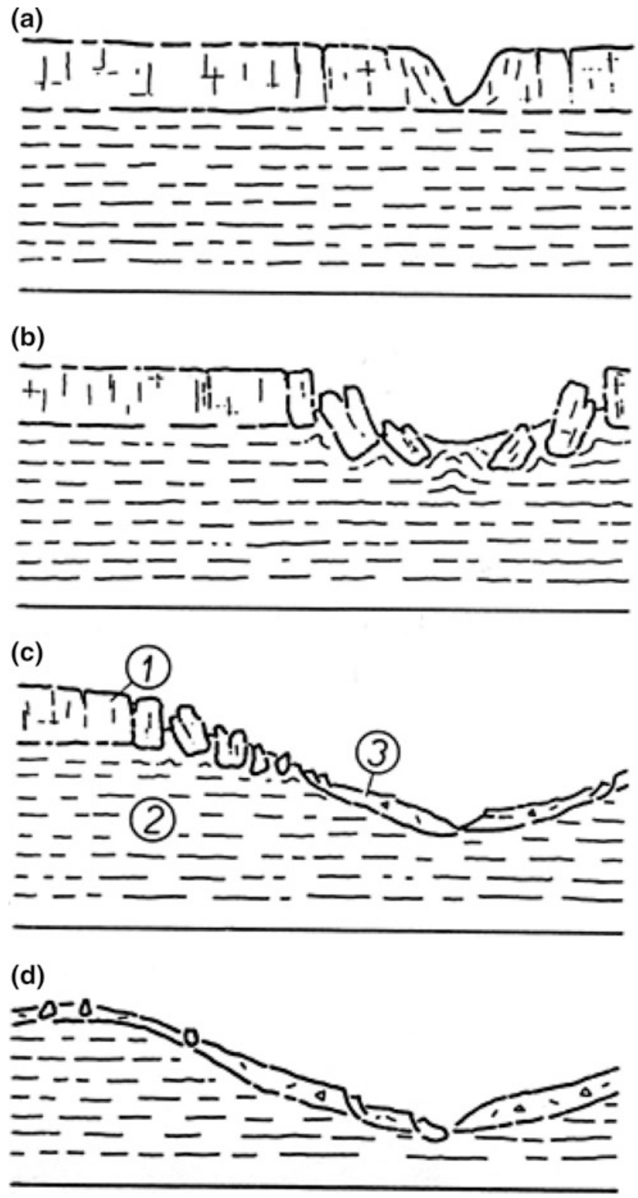

Fig. 2.1 Development stages of a slope comprising a rigid upper layer and a plastic lower layer (according to Rybář and Nemčok 1968)

2.3 Observational Model of the Březno Rotational Landslide

Figure 2.4 presents an example of an observational model of the central part of the Březno u Postoloprt landslide. The model was constructed by the author using a cross section from a site investigation report (in Pašek 1974), aerial view by Google and field mapping carried out by the author.

By sliding along the rotational surface of rupture ("rock slump" according to Varnes 1978, rotational landslide according to Nemčok et al. 1972), the Cretaceous marlstone block was pushed into the river bed, substantially narrowing

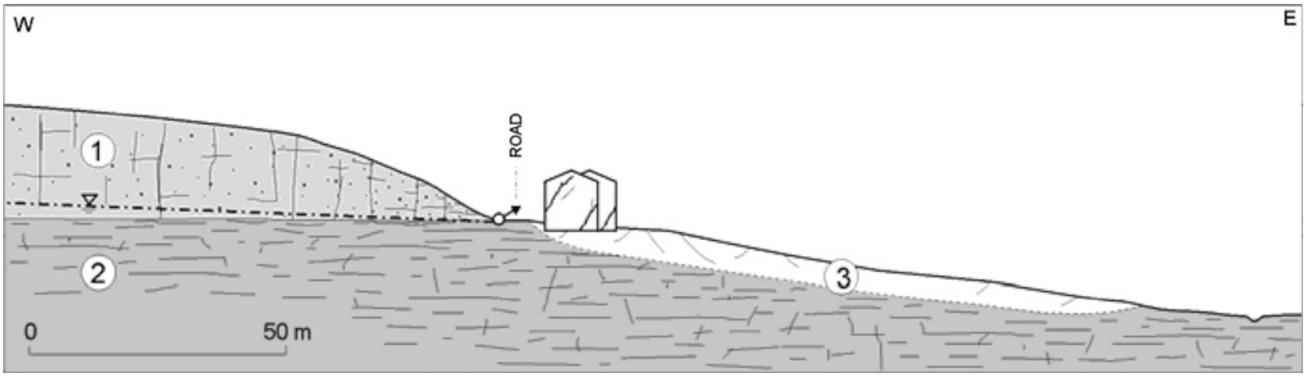

Fig. 2.2 Conceptual model of a slope in Hrubá Skála. *1* Cretaceous sandstones, *2* Cretaceous claystones, *3* landslide

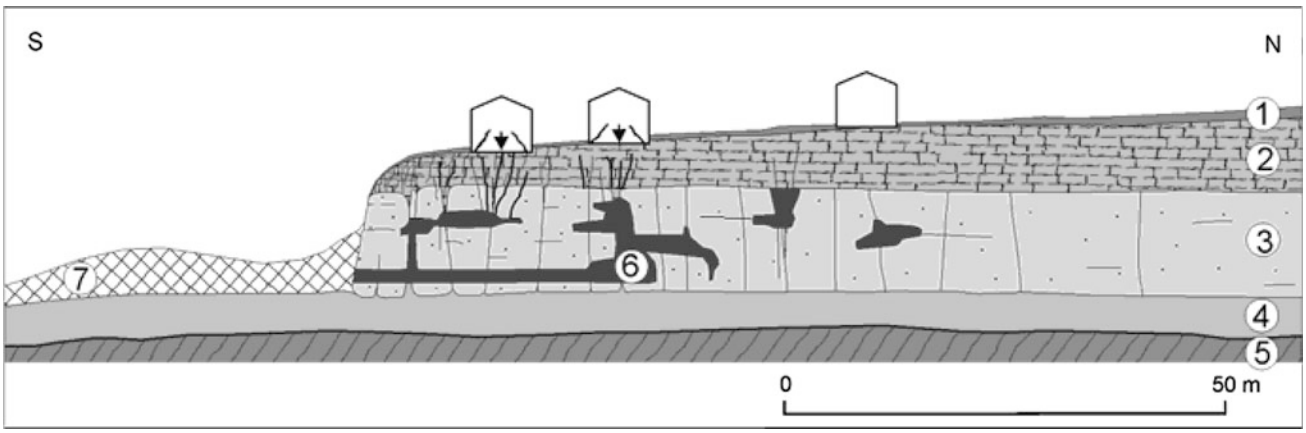

Fig. 2.3 Conceptual model of the edge of the Czech Cretaceous Formation in Prosek (after Pašek 2000 and Lešner 2004 in Novotný 2009). *1* Quaternary loess soils, *2* Turonian marls and marlstones, *3* Cenomanian sandstones, *4* Cenomanian claystones, *5* Ordovician shales, *6* mining cavities, *7* mounds

it in this area. The main cause of the landslide, besides lithology prone to sliding, is primarily the erosive action of the Ohře river which to this day maintains the whole landslide in an unstabilized state. A layer of baked clays located in shallow depth below surface also plays an important role, preventing the area from being denuded into a gentle slope less prone to sliding.

Unlike the simple structure of the rotational landslide, the morphology of the main scarp, resulting from various slope processes, is considerably complex. The main scarp above the rotated block is divided into a series of ridges separated by areas with periodical occurrence of minor landslides and notably earth flows. In long-term conditions, the ridges themselves are also unstable, prone to rock fall and opening of vertical tension cracks which can lead to rock topples of large blocks. The material from minor landslides, earth flows, rock falls and rock topples accumulates in the head area, adding weight here and destabilizing the entire landslide. In the upper part of the accumulations, minor scarps are formed; above them, the terrain locally dips towards the slope, creating undrained basins that further destabilize the slope by the process of water infiltration into the unstable masses.

2.4 Conceptual Model of the Head Area of the Březno Landslide

During the development of the observational model of the Březno landslide, a conceptual evolutionary model of processes in the main scarp area was also established. Without knowledge of the slope's history and evolution, the model would be much simpler in comparison with the following concept (Fig. 2.5).

Figure 2.5(1): State after the development of the rotational landslide. Figure 2.5(2): Irregularly, minor landslides and rock falls occur in the main scarp area, creating partial ridges in the scarp area and accumulations at the base of the scarp. Fig. 2.5(3a): In long-term conditions, local rock falls repeatedly occur in the ridges, heavily fractured by

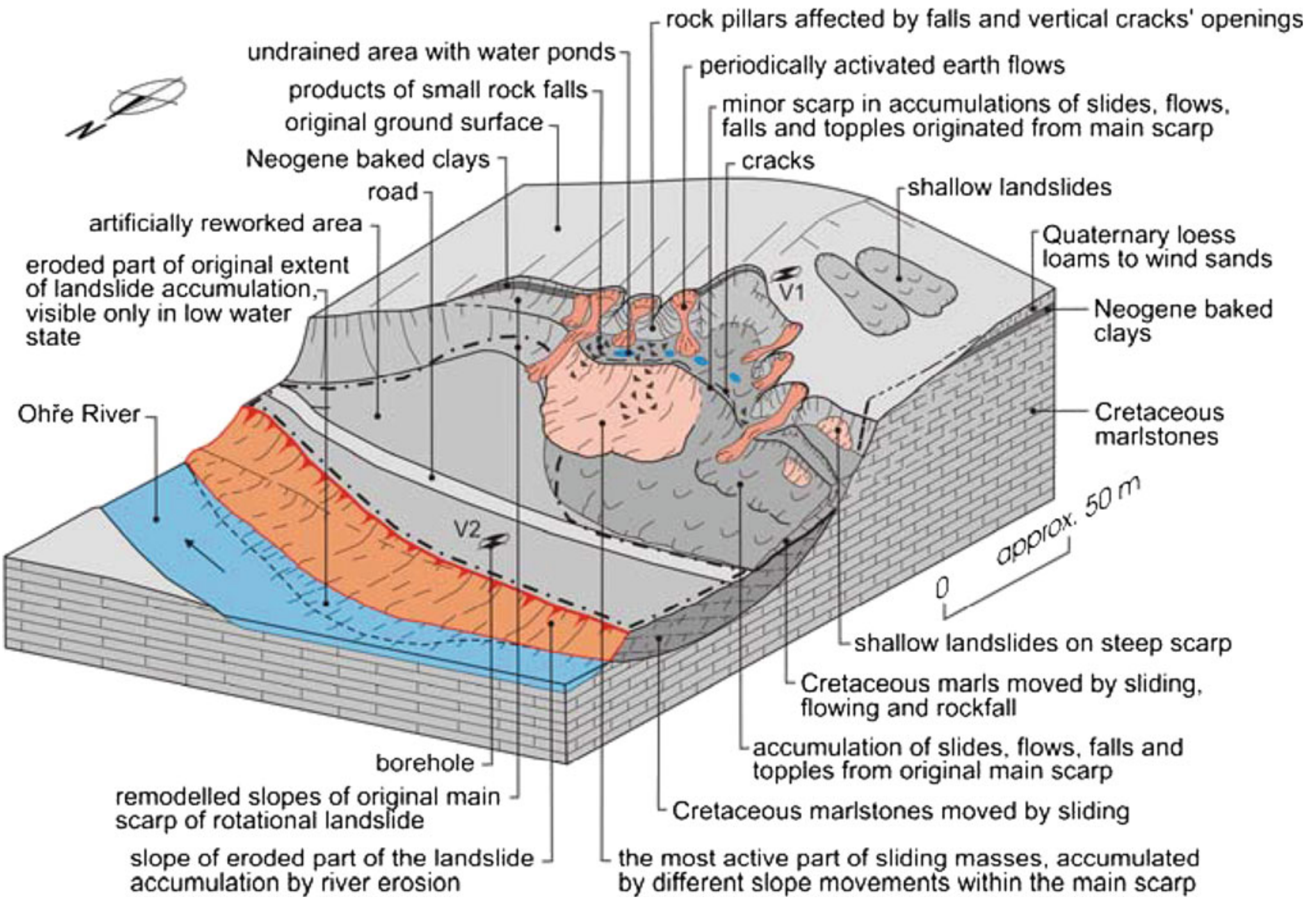

Fig. 2.4 Observational model of the Březno landslide in Cretaceous marlstones

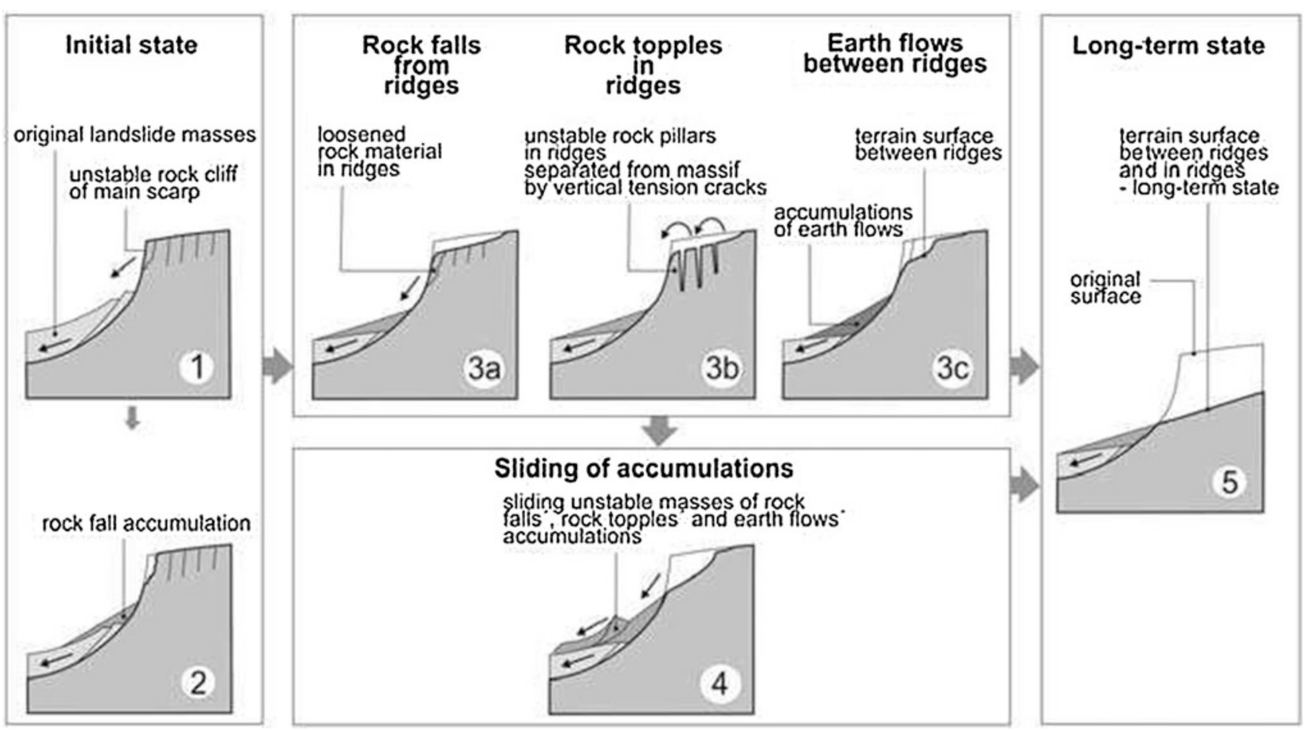

Fig. 2.5 Conceptual model of processes in the head area of the Březno landslide