Session 6

Environmental Control (incl. waste materials)

Problèmes d'Environnement (y compris stockage des déchets)

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Za-Chieh Moh, Chairman

INTRODUCTION

It is my great pleasure to open this Session 6 of the X ICSMFE. The title of this session as listed in the Conference Bulletins and Program. "Environmental Control (including waste materials)" might appear to be somewhat strange to many geotechnical engineers. Geotechnical engineering is a specialized branch of civil engineering or somewhat more broadly with a working knowledge of engineering geology. Geotechnical engineers in its classical sense are usually called upon to deal with a rather well defined and limited problem. By looking at the tasks and responsibilities of geotechnical engineers more broadly and deeply, one will easily realize that the development of geotechnical engineering must take a step forward in the whole process of planning and engineering human activities.

Environmental control or environmental impact of major civil engineering projects has started to receive attention from planners and engineers during the last two decades. However, the involvement of geotechnical engineers in these pre-engineering studies has been limited. On the other hand, it is so obvious that our activities are so closely related to the "environment" which we live in. In view of this, the International Society for soil Mechanics and Foundation Engineering took an unorthodox step in organizing a specialty session on "Geotechnical Engineering and Environmental Control" at the ninth International Conference held in Tokyo in 1977. I had the pleasure in organizing that session with Professor van der Veen of the Netherlands. Several of the gentlemen sitting on the stage today took active participation in that session.

Because the subject matter was a new one, It was rather difficult to define the scope or theme of that session. On the basis of returns of a questionnaire sent to all national societies, the theme of the Specialty Session was defined as:

- The role of geotechnical engineering in the protection of environmental quality, and
- The geotechnical aspects of environmental protection

Thirty two papers contributed by authors from 14 countries were accepted. In addition, three specially invited papers were presented at the session. All of these were published in two volumes of Proceedings. In the concluding remarks of Prof. van der Veen, Co-Organizer of the session, the following suggestions were made:

(1) To formulate a clear definition of the meaning of the word "environment" with respect to geotechnical activities.

(2) To narrow down and specify the subjects in geotechnical and environmental fields to a limited and clearly defined number.

(3) To consider if anything could be formulated that might serve as part of the legal and moral code of our profession.

Due to the enthusiastic participation of that Specialty Session, the Conference Advisory Committee of this Conference, the X ICSMFE, decided to include the topic "Environmental Control" as one of the 12 sessions. This is one of two sessions in this Conference which we may consider dealing with non-convential geotechnical problems.

The term of references as defined by the Conference Advisory Committee is:

Dealing with technical questions on

- Waste material in earth structures and protection against groundwater pollution
- Erosion protection
- Change of geotechnical properties due to pollution
- Subsidence due to lowering of the groundwater level and to the withdrawal of oil and mining

Either due to the somewhat poor definition of the themes or due to unconventional nature of the session, the number of papers submitted by the national societies was disappointedly low. A total of 21 papers was received. Unfortunately, large majority of the papers fall in rather limited catagory. In Table 1, a comparison of classification of papers presented at the 1977

Specialty Session and those presented at this Conference is made. It should be pointed out that my classification of the papers my be slightly different from that shown in the General Report which will be presented later. In view of this, the officers of the session, i.e. the Chairman, the Co-Chairman, General Reporter, Co-Reporter, and Technical Secretary have decided, in addition to the panel members, to invite several prominent engineers to present short discussions on subjects which are not covered by the papers.

Table 1 Classification of Papers

Classification IX ICSMFE Specialty Session 11	No.* of Papers	Classification X ICSMFE Session 6	No.* of Papers
Environmental problems associated with geotechnical activities	1(6)	Erosion control	
Geotechnical aspects of environmental protection	1(8)		
Interaction	(2)		
Geotechnical Utilization and control of wastes	11(11)	Waste material	11
Effect of environmental changes on soil behavior	3(4)	Change of geotechnical properties due to pollution	3
Modeling of geotechnical data	3(1)		
		Subsidence	1
Others	2	Others	6

*Numbers indicate number of papers submitted to the X ICSMFE.

Numbers in parentheses indicate number of papers submitted to the IX ICSMFE.

I. Sovinć, Panelist

THE PROTECTION OF ENVIRONMENT FROM THE EFFECTS OF MINING

This report is related to the protection of man's environment from the effects of underground mining. Some comments are offered on the problems of "environmental geotechnics", dealing with subsidence prediction and evaluation. This part of environmental geotechnics already includes complex technical, economical and social problems and requires multidisciplinary access to research work as well as to the transfer of research result into praxis. If according to the definition of the general reporters of this session environmental geotechnics will forecaste and minimise the entropy of a given process (for example the subsidence caused by

Fig. 1 View of the "Great Pond" formed by lignite stoping of the Velenje lignite mine

mining) through geotechnical knowledge, even more systematical and intensive studies of the mechanism of the rupture process is required and further research activities in this field to formulate the appropriate mathematical rheological material models are desirable. In most practical cases due to the specifity of the soil strata, the various thickness and forms of the ore or coal bodies and the various depths where they are mined and to the way of digging etc., it will hardly be possible to get universally valid solutions to predict accurately the subsidence above seams mined. However, the phenomena observed, compared with analyses of the foreseen rupture mechanism of the process, will clarify numerous, today still not satisfactority solved problems. Let me confirm this idea by taking two case records from my country.

In the Velenje lignite mine (Slovenia) the lignite seams are 30 to 120 m thick and lie 140 to 450 m under the surface. Because of the great thickness of the lignite,

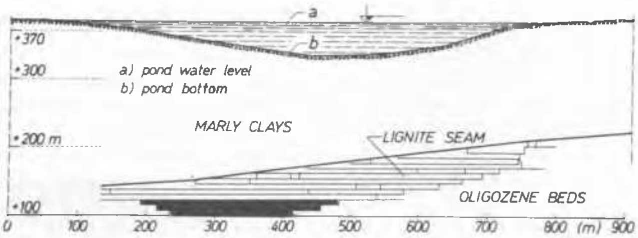

Fig. 2 Subsidence and pond water level in the eastern field

mined by the longwall face caving method in benches 7.5 to 11.0 m high, the subsidences are large and deep, reaching up to 50 m in depth. The lignite seam hanging wall consists of pliocene marls, sands, gravels and alluvial deposits. The footwall is composed of clay and sandy gravel clay ranging in thickness from a few meters up to 100 m. Below the lignite seam footwall are oligocene and triassic beds. According to hanging wall thickness and their geological composition the basin is divided into two parts - the eastern and western fields. The hanging wall of the eastern field is 200 to 250 m thick and is composed almost entirely of marly clays. The 300 to 450 m thick hanging wall of the western field whereas is composed partially of sandy gravels with clay intercalations and partially of marly clays.

As the ground water level is near the surface, the water forms lakes in the subsidence troughs. Around the lakes recreation areas are arranged and they are included in the urban plans of the town. Fig. 1 shows the "great pond" of over 300 000 m^2 of lake surface and over 4 milions of volume, formed due to lignite stoping in the eastern field. The stoping was finished about 20 years ago. Typical cross section with marked pond water level and subsided pond bottom is shown in Fig. 2. Fig. 3 was taken in April 1981 in the western field where stoping started in 1976 and shows the formation of a new pond, approaching the thermoelectric power plant.

Most of the existing general formulas predicting the subsidence are governed by experience taking into account the results of the preceding survey measurements. These relatively simple analytical methods, however, could be used for over thin mining fields only and cannot succesfully be applied to the high benches of the Velenje mine. Detailed survey measurements during recent decades show namely deep extension cracks in the surrounding zone due to enormous subsidence volumes.

Important efforts have been made therefore in the last years in order to elaborate the methods of the prediction of subsidence above thick coal seams (Sovinc 1970, 1974, 1975). Already the pretty rough model test performed in Sneebeli-Taylor dispositiv, lead to a useful information on subsidence prediction and evaluation at the Velenje lignite mine (Fig. 4). The hanging wall in the model is composed of three layers (I, II, III) having different shear characteristics. The mining of the coal is simulated by succesive pulling out the plates,

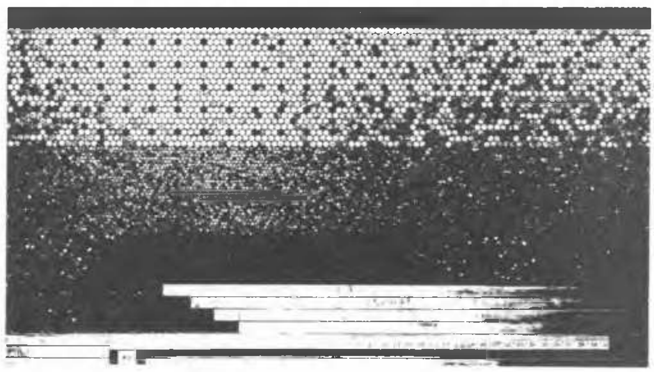

Fig. 4 Sneebeli-Taylor model test

Fig. 3 Formation of a new pond in the western field

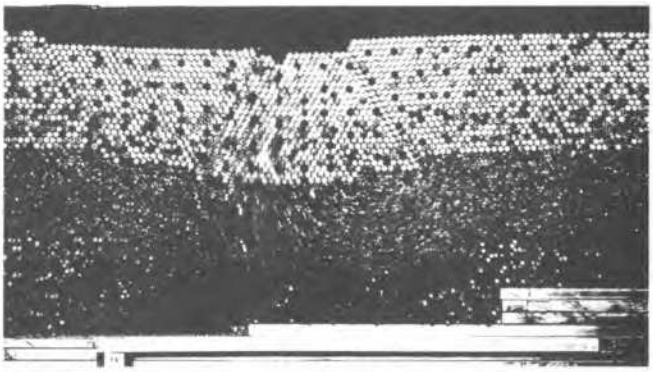

Fig. 5a

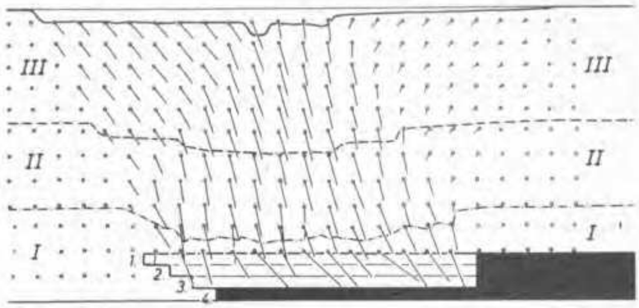

Fig. 5b

Subsidence, failure planes and displacement vectors for the stage 3 of mining

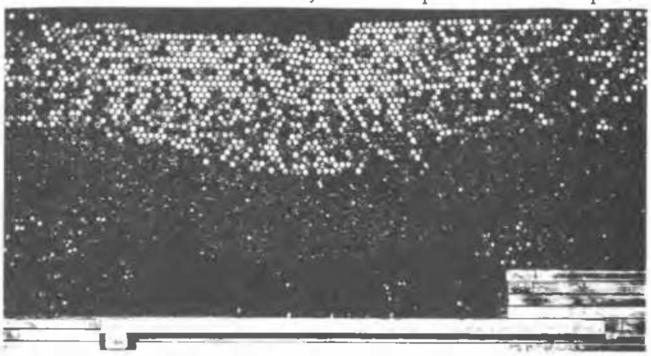

Fig. 6a

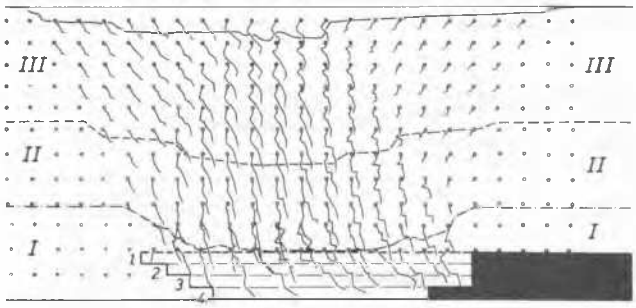

Fig. 6b

Subsidence, failure planes and total displacement vectors for the finale stage of mining

representing single coal benches being mined in steps like it is done by actual mining. Fig. 5a shows the stage when three benches have already been mined out and the Fig. 5b shows for the same stage of mining the measured displacement vectors. Fig. 6a shows the same phenomena for the finale stage of mining and Fig. 6b the total displacement vectors.

The simple model test, like these just shown, obviously cannot fully satisfy the requirement to get more reliable predictions of the subsidence. To get better agreement between calculated and observed subsidence, at present time, a computer program by using the finite element method and taking into account non-linear analysis is developing for the prediction of subsidence above thick coal seams of the Velenje coal basin. The non-linearity in this case is due to material non-linearity in which the plastic behaviour of the hanging wall rock is characterised as well as to the non-linear effects which may arise from large displacements.

In the urban area of the old town Tuzla (Bosnia and Hercegovina) the subsidence is due to rock salt exploitation by uncontrolled leaching. The rock salt appears in four series of about 200 m in total thickness. The uppermost series of about 15 m in thickness, lying 100 to 300 m under the surface, is almost exhausted. The second series which is being mined, is about 60 m thick. With increased pumping of salt water the subsidence and the damage to the structures of the town became critical. The greatest subsidence in the last sixty years, up to 8 m in depth, is recorded. The subsidence caused rather complicated consequences of an economical, social, medical and urban character. Fig. 7 shows the damages on streets and houses due to uncontrolled salt leaching.

The survey measurements of the subsiding area, which have been done since a long time, do not permit reliable predictions of the effects of further leaching of the

Fig. 7 Damages due to rock salt exploitation by uncontrolled leaching

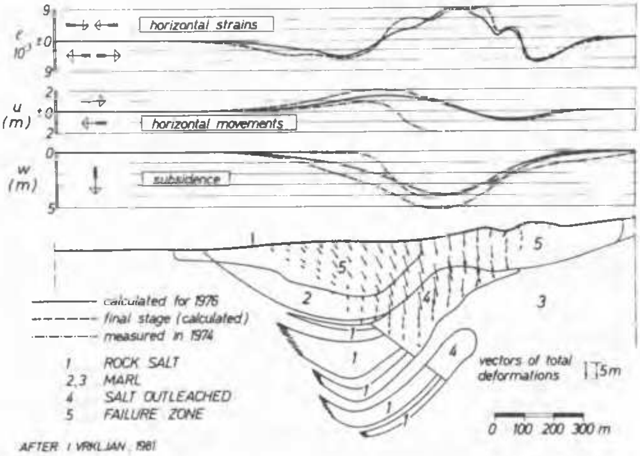

Fig. 8 Typical cross-section of the rock salt series. Comparaisson between measured and calculated displacements

rock salt onto the extent and intensivity of the surface deformations. To allow better forecasting of the consequences of the planned future exploitation, some stress-strain analyses had been developed by considering the soil as a heterogeneous hypoelastic medium of stress-dependent deformability, yielding at the failure envelope of stress states (Stević et al, 1979, Vrkljan, 1981). A better agreement between computed and measured actual surface displacements proves the reliability of the applied plane-strain finite element analysis, as shown in the upper part of the Fig. 8, where the values of computed and measured horizontal strains, horizontal movements and vertical subsidence as well as the vectors of total deformations are shown.

The cited problems led to the organisation of the Int. Symposium: The Protection of Man's Environment as the Consequence of the Exploitation of the Mineral Raw Material, held in Tuzla in 1975. The symposium was supported by the agencies of UNESCO: UN Fund for environmental control UNEP and the European Economical Commission UN. In the conclusion of the symposium it was stated that the international organisations are not yet involved enough in these problems and the proposal was adopted that the matter should be incorporated into the programs of activity of the domestic national and appropriate international organisations.

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G.E. Blight, Panelist

THE CONTROL OF ENVIRONMENTAL CHANGE

Introduction

It is business of geotechnical civil engineers to change the environment. It is also their business to ensure that these changes are as far as possible, beneficial. Every human action results in some effect on the environment, but because of the large scale of geotechnical civil engineering operations, in particular those related to road, rail and dam building, the geotechnical civil engineer produces more visible impact on the environment than most other professions.

Environmental impacts are, of course, not confined to visible effects, nor are they necessarily only of short-term duration. Many of the environmental changes brought about by development or new construction may have far reaching and long-term effects outside the immediate area of the works. They may also bring about profound social changes which are not always foreseeable by the technologically trained mind. Because of the far reaching nature and long lasting effect of environmental changes, it is essential that engineers should involve other disciplines in assessing the environmental effects of their actions. Thus the investigation of environmental effects should involve not only technologists, but also sociologists, life scientists, geographers and other professional groups who can bring their expertise to bear on a problem area, in which the engineer is usually limited in skill and knowledge.

There are many forms of development that may have profound consequences in terms of environmental change.

Table 1 lists some of the types of development that are likely to have very significant direct, indirect, short- and long-term impacts on the natural, rural, urban and social environments.

Table 1
Types of development that cause significant environmental change

- Freeways, roads, railway lines and associated works
- Telecommunications and utility routes and associated structures, bridges and crossings
- Dams and associated works
- Power stations
- Water purification plants, reservoirs
- Mines and mine waste disposal, quarries, gravel pits, brick-fields
- Petro-chemical and chemical industries
- Industrial areas
- Airports, harbours
- Extensions to towns, new towns, new townships
- Holiday resorts and facilities, marinas
- Large building complexes, tall buildings or tower structures
- Agricultural development, afforestation
- Military installations, military operations.

The geotechnical civil engineer is involved in most, if not all, of the above developments. In many cases, the first and most visible impact is caused during initial site clearing, the preparation of earth works etc., where the natural cover of vegetation is removed and the raw earth exposed. Thus the geotechnical civil engineer has obtained a name for being the arch-destroyer of the natural environment, and has become target No. 1 of the ardent conservationist.

The environment

The environment can be defined as that system of physical, biological and social factors which decides an individual's perception of his quality of life. The quality of life as perceived by an individual, depends on a number of inter-acting factors, including his educational and social background, financial status and environment of upbringing. An individual is far more likely to be concerned at an adverse environmental change, or at unsatisfactory environmental conditions if he is educated and conditioned by his life-style to accept a high standard as the norm, than if his primary attention is focused on survival at subsistence level. In particular, the environment includes the following elements:

(i) air, land and water ;
(ii) all forms of life including micro-organisms, plants, animals and humans;
(iii) all the physical changes produced by man;
(iv) social, economic and cultural conditions as well as the knowledge and learning that influence the life of man as an individual or in a community;
(v) combinations of the above and the inter-relationships between them.

For convenience, the environment can be classified according to the degree by which it has been affected by man's actions into:

(a) The natural environment, that system which has been almost unaffected by man's actions and in which physical and biological factors are paramount, e.g. nature reserves and wilderness areas.

(b) The rural environment, that system which has been modified by man, but which lacks substantial development in the form of man-built structures. In such a system, physical and biological, and to a lesser extent, social factors interact, e.g. agricultural, farming and forestry areas.

(c) The urban environment, that system that has been so extensively modified by man via man-made structures and facilities that it can be regarded as almost completely a man-made environment.

By definition, human actions can have only an adverse effect on the natural environment. The natural environment is a relic of the pre-human past which is disappearing all too rapidly, and conservationists are quite correct in the strenuous efforts they make to protect the few remaining areas of natural environment from disturbance of any kind.

The rural environment has been very extensively modified by man and in many cases, no longer even remotely resembles the natural environment from which it was created. In the rural environment man's actions can be either adverse or beneficial. For example, any action leading to large-scale siltation of streams or soil erosion is definitely adverse; whereas an action leading to conservation of soil or water, or to improvement of the social, financial and living conditions of the rural inhabitants, can be regarded as beneficial.

In the urban environment development actions may have either beneficial or adverse effects, depending on the nature of the action, the existing quality of the environment etc., but even here one must be careful how one judges the success or otherwise of the development action. For example, the re-development of a slum area would be regarded by most as an environmental improvement, but might be bitterly resented by the local inhabitants, who prefer their shabby, but to them, homely and comfortable surroundings.

Environmental awareness, concern and professional responsibility

During the past twenty years there has been a growing awareness on the part of the general public that developments and, in particular, civil engineering developments, may have a profound effect on their environment and that this effect may be disastrously adverse. Too often in the past, civil and other engineers have put technical and economic factors first, and have completely ignored environmental and sociological factors. This is the reason we have become, in their eyes, the arch enemies of the environmentalists and conservationists. There is no doubt that geotechnical civil engineers have in many cases not been truly professional in their approach to their work, in that we have not seriously considered the full range of consequences of our actions. This wider consideration should become an essential part of our professional out-look.

The responsibilities of a geotechnical civil engineer in planning, designing or implementing a project that brings environmental change in train are to:

(i) be aware of the environmental issues involved;
(ii) be concerned about the results of adverse changes to the environment;
(iii) take whatever steps possible to eliminate or minimize adverse impacts on the environment and wherever possible to enhance or maximize favourable changes to the environment.

Civil engineers are involved in altering the environment. For many years it has been an accepted philosophy to plan, design and implement projects in order to improve human welfare based on criteria of economic and technical efficiency. It is not proposed that the importance of these basic criteria be diminished, but that the additional criteria of acceptability of environmental and sociological change be added to them. Geotechnical civil engineers must respond to the challenge of the times and the demand of the general public for due consideration to be paid these additional criteria.

Geotechnical civil engineers should develop a genuine concern for the changes to the environment which result from their schemes. Concern should involve not only a sympathetic approach to the environment, but a realization of the necessity for obtaining accurate and correct information and knowledge about the relevant natural processes of phenomena, and the effects that the proposed development will have on these. Engineers as well as the client body need to be concerned about the consequences of unrestricted growth and development. Concern should not only be directed at eliminating or reducing damage to the physical and social environment, but also at promoting efforts to improve environmental quality and the quality of life in general.

Much of the current general lack of concern for the environment amongst geotechnical civil engineers can be traced back to their education, where far too much emphasis has in the past been placed on the technological and economic aspects of engineering, while very little attention has been given to the sociological and environmental aspects of engineering activity. It is essential to remedy this for the future by introducing courses with a relevant content of sociology and environmental studies. To be effective, these courses should be introduced at a late stage of the undergraduate's career, preferably in the final year of study. They should not be lightweight courses, but should have a considerable philosophic and scientific content. They should carry sufficient weight towards the requirement of passing the final year of study that students will take them seriously and not dismiss them as irrelevant frills to their education. It is only by this process that we will be able to improve our abysmal public image as destroyers of the environment.

Environmental assessment

Awareness and concern are essential for due consideration to be given to the effects of environmental change but they are only part of the requirement. Without the technology necessary to assess the effects of development actions on the environment, both in the short and long term, there is little point in being concerned or aware. To produce controlled, largely beneficial changes to the environment, the geotechnical civil engineer should include the assessment of environmental impact as an essential component in the planning and designing process.

As the environment is highly complex and its understanding requires the fields of study of ecology, air and water quality, economics, land use, aestetics, sociology and many others, environmental assessment must, of necessity, be a multi-disciplinary activity. No adequate environmental study can be performed without being conducted in a systematic manner by an inter-disciplinary team that includes all relevant disciplines. It is vitally necessary that both in the planning and design stage, engineers should work together with natural and social scientists to achieve adequate understanding of the impacts of their proposed actions. This analysis by inter-disciplinary teams should take place at two stages:

The planning stage and the project design stage.

An environmental assessment should be completed at the planning stage of any proposed developement which is likely to have an environment impact, and an environmental impact assessment at the project design stage.

Environmental assessments are preliminary investigations undertaken to identify actual or potential environmental problems. They would normally be undertaken by the planning professionals concerned with the proposed development in consultation with relevant environmental experts, such as biologists, botanists, sociologists etc.

Environmental impact assessment are more detailed investigations of the effects of a proposed development which are undertaken by a full team of appropriate environmental experts and the planning professions as a multi-disciplinary venture. The results of these assessments will show potential adverse as well as beneficial impacts and it is the responsibility of the engineer to communicate to the client, the developer or the public agency concerned, any potential environmental damage that may result. He should also be responsible for recommending any steps that are necessary to eliminate or reduce damage to the environment, and to modify the proposal and detailed designs accordingly.

Persuasion versus enforcement

Most modifications to designs or schemes on environmental grounds entail additional costs which will be for the account of the client. How then is one to ensure that more than lip service is paid to the protection of the environment? In the U.S.A., Canada and Australia, legislation has been introduced to control environmental quality. In Britain, environmental impact analysis has been used as an aid to the development control system for a small number of major projects. There appears to be general agreement in South Africa that legislative control should be avoided if possible, and that environmental quality control should be exercised as a voluntary self discipline by the planning professions, and should not be enforced by legislation.

With this approach, however, it becomes essential that environmental protection be sold to the client as a desirable aspect of his development or project, for which it is worth paying. The possible benefits in any situation might be as follows:

The major benefit to a developer may be an overall cost saving. For example, in a coastal environment, effluent discharged into the sea may result in claims for compensation from sea-fisheries and the eventual closure of the offending industry. An environmental impact assessment would be able to predict the effects of the effluent on fish life, and measure could be taken in the design and construction of the project to eliminate or satisfactorily reduce the impact.

A further benefit to developers is that they can demonstrate their public conscience. By using information from an environmental assessment, they can explain to interested parties and the public in general, what they intend doing to reduce the deterioration or even to improve the quality of the environment as a result of the proposed development.

As far as the decision makers are concerned, the advantage are that they will benefit from an environmental assessment in that the information on which they base their decisions will be more comprehensive and more accurate. It will give them knowledge of the side-effects and long-term effects of a proposed development. It will also provide them with a basis for insisting that any proposal approved by them will minimize environmental impact and maximize improvement to the natural or social environments.

The public should be kept fully informed of the process of environmental assessment, so that they know that any planning or developmental decision is made on the basis of a rational assessment aimed at identifying, minimizing or correcting potential damage to the environment.

As far as the geotechnical civil engineer is concerned, environment assessment should improve the quality of planning and design of their projects. Projects should fit better into the environment. Not only will the beneficial effect of any project be maximized but detrimental side effects should be reduced to a minimum.

Conclusion

A case has been made for the control of environmental change by the professional skills of the geotechnical civil engineer working in collaboration with members of related planning professions and natural and social scientists. This is a policy that must be accepted as desirable by the civil engineering profession and should be embodied in the training of civil engineers.

It is also a policy that will add to project costs in the short-term, but which will bring valuable benefits in the long-term. The aspect of additional cost without immediate tangible or quantifiable benefit means that the engineer will be obliged to persuade his client that environmental protection measures are worth paying for. This may prove to be a difficult and frustrating exercise but one that is worthwhile undertaking if the public image of the geotechnical civil engineer is to be improved and the spectre of draconian environmental legislation is to be laid.

R.M. Quigley Panelist, and V.E. Crooks

CONTAMINANT MIGRATION THROUGH CLAYS
Migration des Polluants â Travers des Argilles

SYNOPSIS Pollution migration through clays is controlled by diffusion processes rather than seepage or convective transport. The actual rate of migration of any specific substance is a very complex function of waste composition, oxidation-reduction conditions and relevant chemical reactions including precipitation, adsorption, dilution, temperature and biodegradation. Two chemical profiles from a domestic waste landfill on clay are presented and discussed very briefly.

INTRODUCTION

The authors' view of environmental geotechnique is a very chemical one since we believe that contamination of the earth's soil and water resources is the biggest single problem facing the next several generations of mankind.

Selected chemical profiles in a clayey soil below a domestic landfill are presented. Knowledge of migration of contaminants through clayey soils is increasingly important as the use of clayey liners increases around the world. At the landfill in question, the low permeability of the clay (~ 10^{-7} cm/sec) combined with a low downward hydraulic gradient has created a situation in which migration by diffusion dominates that caused by convective or seepage flow (Goodall and Quigley, 1977).

The relative importance of diffusion has been studied by many groundwater geochemists. A review by Ogata, 1970 provides charts for calculating the time rate of advance of the 50% concentration front. Desaulniers et al, 1981 present a figure for their study system showing that for average linearized seepage velocities less than about 0.1 cm/a, molecular diffusion dominates the rate of advance of the 50% concentration front.

Figure 1 shows curves of chemical flux exiting from the base of a thin clay liner flushed at its base by groundwater flow. With no hydraulic flow (V_S = 0) and a typical diffusion coefficient of 10^{-6} cm^2/s, the chemical flux is retarded for many years. Such a system, although ideal, is nearly impossible to achieve since infiltration generally creates a groundwater mould so that a hydraulic gradient is established and flow occurs. Modern efforts to create an undersaturated zone below landfills likewise creates a gradient and flow which may or may not be beneficial in clay.

CHEMICAL PROFILES

Chemical profiles for Na^+ and $C\ell^-$ are presented in Figures 2 and 3, respectively. In Figure 2, Na^+ profiles are presented for 1974 and 1980 (6 and 12 years since disposal of domestic waste) relative to the position of the seepage

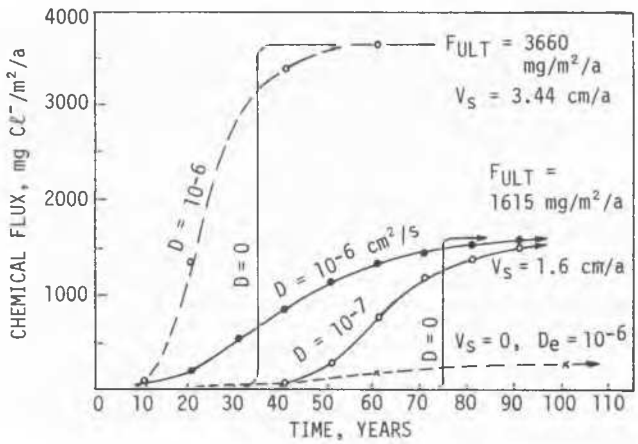

Figure 1. Chemical flux through 1.2 m liner

front. It is very clear that chemical migration by diffusion has dominated the system for the first 12 years of its existence. The average velocity of the solute front at 50% concentration (C/C_O = 0.5) is 3.5 cm/a at 6 years and 6.6 cm/a at 12 years. This acceleration is perhaps due to the increase in Na^+ concentration in the leachate over the last six years or other phenomena such as anaerobic bacterial activity (U.K. Dept. Environment, 1978).

Ca^{++} profiles show C/C_O = 0.5 to be well in advance of the Na^+ front at a depth of up to 2 m after 12 years, depending on the borehole. This very rapid advance is believed to be a hardness halo created by a combination of cation exchange and chemical reaction.

The typical $C\ell^-$ profile shown in Figure 3 (Crooks, 1981) also illustrates migration in advance of the seepage front. Since $C\ell^-$ is considered to be a conservative (non-reactive) substance, one would expect it to be well in advance of the Na^+ front, which is not the case (see Figure 2). The Na^+ and $C\ell^-$ curves illustrate contamination of the clays to a depth of about 100 cm compared to a calculated seepage front at 3 cm.

Phenol migration studies are in a very pre-

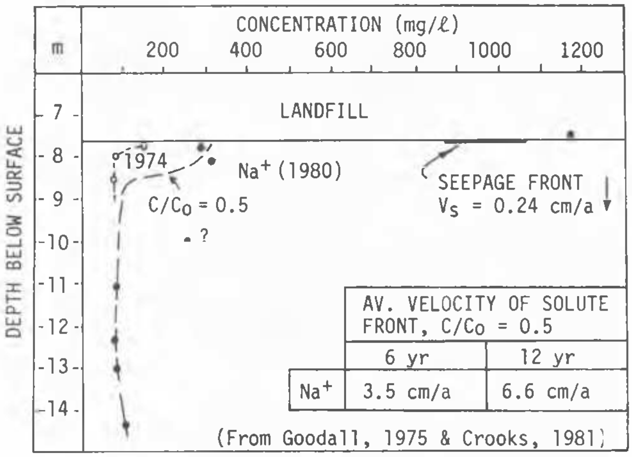

Figure 2. Concentration profiles for Na^+ below landfill (t = 6 and 12 years)

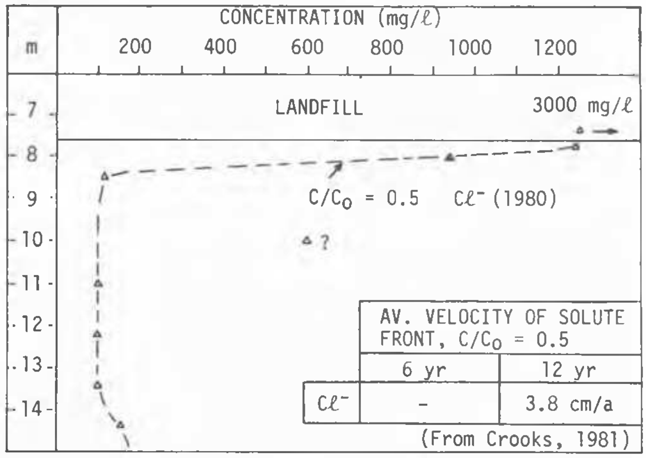

Figure 3. Concentration of $C\ell^-$ below landfill (t = 12 years)

liminary state but suggest migration as far as 4 m into the clay at levels of up to 1 mg/ℓ just twelve years after disposal of domestic waste. This is a very rapid rate of advance and is believed to be somehow related to bacterial activity within the clay itself. Normal drinking water standards require less than 0.001 mg/ℓ. Another severe problem was phenol degradation by bacteria during sample storage in a 20°C laboratory. Such samples should be kept cold and tested as soon after sampling as is practical.

CONCLUDING REMARKS

Migration of pollutants through clayey soils and liners below landfills is a problem rarely addressed by papers in geotechnical engineering journals. The main purpose of this discussion has been to illustrate the importance of diffusion relative to seepage and to encourage much greater geotechnical input into liner design and other waste disposal problems in clay. Providing that we can rationalize the complex chemistry of this study, the results will be detailed elsewhere.

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L. Monition, Panelist (not present, contribution read by G. Sanglerat)

IMPACTS DES AMENAGEMENTS SUR LES EAUX
Impacts of Human Activities on Water

RESUME:

Cette brève communication se limite a signaler quelques actions d'aménagements anthropiques sur les eaux et ne traite pas des problèmes liés aux actions directes sur l'eau (pompages, tassements, ...).

Les interactions entre le milieu et les activités humaines doivent être considérées suivant deux directions:

- Celle des contraintes imposées par le milieu aux activités de l'homme en raison:
  . des sensibilités naturelles: instabilité du sol et du sous-sol, vulnérabilité aux mouvements de terrains (glissements, écroulements, affaissements), vulnérabilité des nappes d'eau souterraine à la pollution (suivant la nature lithologique de l'aquifère et des terrains de couverture), risques de crues de rivières et inondations, écosystème animal et végétal à protéger, ressources diverses à conserver,
  . de l'occupation actuelle de l'espace et de l'existence de sites aménagés déjà anciens,
  . de facteurs socio-économiques liés à l'activité des populations déjà en place.

- Celle des incidences ou impacts des activités humaines sur le milieu naturel (ou milieu récepteur), naturellement intact ou déjà partiellement aménagé. Les aménagements peuvent agir sur:

  . les fragilités ou faiblesses du milieu en les atténuant (opération de drainage amenant une stabilisation de talus) ou en les aggravant (pompages d'eau souterraine mal contrôlés, créant des tassements préjudiciables aux constructions),

  . la qualité du milieu par altération des ressources (pollution des eaux et des paysages).

Pour apporter une certaine clarification parmi les différentes sciences intervenant dans le domaine pluridisciplinaire de l'environnement, on considèrera les sciences de l'environnement comme étant les sciences des interactions entre le milieu et les activités humaines; elles se distinguent des sciences de la Nature, essentiellement descriptives et explicatives des phénomènes naturels, et des sciences de l'Aménagement, particulièrement orientées vers la maîtrise du milieu naturel et les faisabilités techniques et économiques des constructions humaines de types variés.

Si l'on considère parmi les interactions celles qui intéressent plus particulièrement les sciences de la terre et de l'eau, on peut dire que l'analyse et l'expression des contraintes relèvent de la géologie de l'Aménagement (géologie du génie civil, génie géologique, géotechnique au sens large), tandis que seront attribuées à la géologie de l'Environnement, l'analyse et la prévision des impacts.

La distinction entre les deux types d'interaction est commode pour l'analyse et l'exposé des idées et des démarches, mais elle ne traduit pas toute la complexité de ces interactions. Il importe de bien prendre en compte le fait que les impacts des activités humaines sur le milieu entraînent à leur tour des impacts sur ces activités elles-mêmes. Ainsi, un captage d'eau potable dans une nappe alluviale avec un périmètre de protection surdimensionné pour des raisons de sécurité, aura pour conséquence immédiate le mise hors utilisation de terrains qui pourraient être valorisés par des constructions industrielles.

Il apparaît donc à l'analyse une série de conséquences à la première conséquence, soit une chaîne d'impacts synergiques et/ou rétroactifs qui, en définitive, vont modifier l'activité humaine, initiatrice d'impacts, pouvant aller pour des raisons économiques jusqu'à la remise en cause du projet ou, au contraire, à l'allègement des mesures de correction des impacts.

Ce rapport se limitera aux aspects physiques des impacts liés à l'eau, sans prise en considération des aspects socio-économiques.

L'eau, source de vie, occupe la première place dans le milieu naturel; elle est sensible aux influences anthropiques, que ces influences soient liées directement à l'exploitation ou à l'utilisation des ressources en eau ou qu'elles influencent directement les eaux du milieu (Monition, 1977).

L'eau est aussi un vecteur qui transmet les influences mécaniques, thermiques et transporte diverses substances en solution ou en suspension.

Dans toute action sur les eaux, il importe de tenir compte des effets externes qui ne font pas partie des objectifs de l'action elle-même. Ainsi, le rabattement des niveaux consécutif à des pompages est un effet externe non recherché, alors que la baisse des niveaux liée au drainage est bien le résultat attendu.

Mais l'effet interne d'une opération insuffisamment évaluée peut avoir des conséquences externes comme le dénoyage d'une mine se répercutant hors du champ de la zone minéralisée.

Les actions sur le milieu naturel (action d'aménagement) et leurs répercussions sur les éléments sensibles de l'environnement, ont été analysées dans une matrice d'incidence (figure 1).

ACTIONS SUR LE MILIEU ET REPERCUSSION SUR LES EAUX

* Accroissement de l'alimentation des nappes d'eau souterraine par fuites des réseaux de distribution

Les fuites d'adductions peuvent constituer des apports importants aux nappes:

- exemples de fuites des réseaux de distribution des grandes villes:

  Paris et banlieue 260.10^6 m^3/an, soit 8 m^3/s
  Lyon et banlieue 25.10^6 m^3/an, soit 0,8 m^3/s
  Marseille 300.10^6 m^3/an, soit 10 m^3/s

- les pertes des réseaux de distribution des villes moyennes (population inférieure à 100.000 habitants) sont estimées à:

  10 à 15 m^3/an/habitant (Commission de l'eau, 1965).

* Impacts d'un stockage saisonnier d'eau chaude en milieu poreux naturel

La Société Technip envisage la réalisation de dispositifs de stockage d'eau chaude provenant de centrales classiques industrielles ou nucléaires... suivant un procédé pour lequel un brevet d'invention a été déposé. L'eau chaude (90 - 95°) rejetée par la centrale sera stockée dans les dépôts flandriens - sables fins avec passées de silts - reposant sur un substratum d'argiles des Flandres (Yprésien); elle pourra être utilisée en hiver pour le chauffage urbain.

Les impacts géochimiques de l'injection d'eau chaude dans le sous-sol, évalués à partir de la composition chimique des eaux d'injection, des eaux de la nappe et de la nature minéralogique de l'aquifère, peuvent se traduire par des précipitations (phlogopite et montmorillonite) et des mises en solution (feldspath) entraînant une modification de la porosité et de la perméabilité du réservoir.

Les impacts des cycles successifs de chauffage et de refroidissement sur le matériau poreux ont été estimés au laboratoire. Pour les sables, le seul phénomène en cause est la dilatation thermique se traduisant par des déplacements très faibles et réversibles. Pour les passées silteuses, il faut s'attendre, par contre, à des tassements irréversibles.

* Impacts des irrigations sur les eaux souterraines

Des irrigations mal contrôlées peuvent entraîner des remontées de nappes telles que le système radiculaire des végétaux s'en trouve altéré et que, en zone aride, les remontées capillaires se trouvent accélérées sous l'effet thermique extérieur et amènent une salinisation des terres.

Les irrigations dans la plaine des Beni Moussa dans le Tadla (Maroc), localement mal conduites, ont amené la péjoration des cultures (orangers notamment, à l'Ouest du canal coursier).

La mise en valeur de l'Indus à partir d'aménagements

ACTIONS SUR LE MILIEU NATUREL (AMENAGEMENT) / ELEMENTS SENSIBLES DU MILIEU NATUREL (ENVIRONNEMENT)		Milieu marin			Sol			Eaux de surface					Eaux souterraines					
		Qualité Biologique	Erosion des côtes	Courants et sédimentation	Stabilité	Erosion	Humidité	Caractéristiques chimiques des eaux	Caractéristiques physiques des eaux	Débit étiage	Débit moyen	Niveau	Caractéristiques de l'aquifère	Caractéristiques chimiques des eaux	Caractéristiques physiques des eaux	Alimentation des nappes	Débit écoulement	Niveau des nappes
ACTION DIRECTE SUR LES EAUX SOUTERRAINES	Prélèvement - Captage				×		×			×	×	×	×				×	×
	Drainage de nappe - exhaure				×		×			×	×	×	×				×	×
	Injection - Alimentation artificielle (eau de qualité physico-chimique # eau de nappe)												×			×	×	×
	Injection - Alimentation artificielle (eau de qualité physico-chimique ≠ eau de nappe)												×	×	×	×	×	×
	Rejet d'eau (température plus élevée que eau de nappe)												×		×	×	×	×
	Stockage de fluide en aquifère												×	×	×			×
ACTION DIRECTE SUR LES EAUX SUPERFICIELLES	Prise - barrage							×	×			×	×					×
	Canalisation - Endiguement									×			×		×			×
	Surcreusement du lit - Dragage												×				×	×
	Assainissement - Drainage du ruissellement										×			×			×	×
ACTIONS DE L'AMENAGEMENT DE L'ESPACE	Modification de la surface du sol et du couvert végétal (remembrement, banquettes anti-érosion, forestation,...)				×	×	×									×	×	×
	Urbanisation, zones industrielles routes, aéroports						×	×	×	×	×	×		×	×	×	×	×
	Irrigation - Drainage agricole					×	×	×	×	×	×	×	×	×	×	×	×	×
	Agriculture et épandages engrais				×	×	×							×	×			
	Stockages sur place de substances utiles polluantes (sels)							×	×					×	×			
	Stockages de déchets urbains et industriels							×	×					×	×			
ACTION SUR LE SOUS-SOL	Excavations à ciel ouvert (carrière, fouille, tranchée)				×												×	×
	Excavations souterraines (mines, galeries, tunnels, parkings)				×												×	×
	Fuites de canalisation d'eau				×		×						×	×	×	×	×	×
	Traitement du sous-sol (étanchement, consolidation)															×	×	×
	Stockage souterrain en cavité				×									×	×		×	×
ACTION SUR LA FRANGE LITTORALE (MER, ESTUAIRE)	Aménagements portuaires - ouvrages de protection	×	×	×													×	×
	Rejets urbains et industriels	×																
	Rejets eau douce	×		×														
	Exploitations de sables et granulats	×	×	×														
	Forages pétroliers "off shore"	×																

FIGURE 1 : MATRICE D'INCIDENCES (RÉELLES OU POTENTIELLES)

modernes s'est traduite, dans de nombreuses zones, par une salinisation des eaux et des sols.

CONCLUSION

La résolution des problèmes liés à la nature des répercussions des aménagements sur l'eau au sens large, est possible grâce aux outils de simulation qu'il est possible de mettre en oeuvre suivant les cas à traiter. Il est ainsi possible d'analyser et de prévoir tous ces effets quantitatifs avec la précision des caractéristiques des systèmes aquifères. La modélisation des phénomènes à prendre en compte est au point, mais des difficultés subsistent dans l'identification, à un coût raisonnable, de paramètres plus complexes d'ordre hydrocinématique ou hydrogéochimique.

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E.W. Brand, Panelist

GEOTECHNICAL ASPECTS OF SANITARY LANDFILL

Sanitary landfills, often called "controlled tips", represent the most economical means for the disposal of household and industrial solid waste. The siting of these landfills is largely a planning and environmental matter, and judicious siting can ensure that they can ultimately be landscaped to fit into a rural or semi-rural environment. Rarely do sanitary landfills present challenging engineering problems, because they are usually left dormant and are not used for building development purposes for many decades after formation.

Very special engineering problems, which are possibly unique, arise with sanitary landfills in Hong Kong. With a population of over 5 million people and a total land area only slightly in excess of 1,000 km², land values are extremely high, reaching US$20,000/m² in the most sought after districts. Because of the very hilly terrain, much of the land is difficult to develop, and access is often excessively difficult and prohibitively expensive. The economic use of land is therefore of paramount importance.

By the very conjested nature of Hong Kong, sanitary landfills are necessarily most often sited in urban or semi-urban areas. Sloping, hanging valleys are the most common landfill sites, but some large fills have also been formed by coastal tipping into the sea, and some of these have been included into areas reclaimed for the purpose of urban development. At present, Hong Kong controlled tips vary in finished volume from about 100,000 m³ to about 3,500,000 m³, but because of the pressure on land, tips of up to 12,000,000 m³ are planned. Heights (depths) of finished tips are now between 20 m and 30 m, but planned heights are up to 150 m.

Completed sanitary landfills in Hong Kong are only used at present for recreational purposes after suitable landscaping treatment has been applied. It might become expedient in the future, however, to use completed tips as sites on which to build much needed high rise housing.

In Hong Kong, as elsewhere, a piece of land which has been formed as a controlled tip, presents the following main problems to the potential developer :

(a) the methane gas production from the decaying refuse represents both a health hazard and a severe fire risk,

(b) the leachate from the tip pollutes water courses and is severely corrosive to services,

(c) the large surface settlements which take place in the fill cause damage to structures and services, and

(d) special and expensive foundation designs are required because of the unknown engineering properties of the tip material.

There is very little published literature available as guidance for feasible solutions to the problems inherent in development on sanitary landfills. The Author knows of six conferences and symposia which have been held specifically on the general subject area of 'environmental geotechnics', and some portions of the Proceedings of these provide limited assistance of a general kind. Full references to these Proceedings are included in the attached reference list under the 'authorship' of National Research Council of Canada (1973a, 1973b), American Society of Civil Engineers (1977), Moh (1977), Midland Geotechnical Society (1979) and International Society for Soil Mechanics and Foundation Engineering (1981).

Information about the engineering properties and behaviour of urban refuse is particularly scarce. Papers by Sowers (1968), Mabry (1977), York et al (1977), Harris (1979) and Smith (1979) give a limited amount of engineering guidance, largely on the basis of experience and case histories. In addition, the problems of compressibility and settlement have been the subject of papers by Sowers (1973), More & Pedler (1977) and Rao et al (1977). To the Author's knowledge, only the paper by Fang et al (1977) deals with the question of the load bearing capacity of refuse, and even this only presents data about tests at a single tip.

In addition to the four problems listed above, Hong Kong faces an especially difficult and unusual engineering problem, for which no guidance whatever appears to be available in the published literature or elsewhere. Some of the sanitary landfills that exist in Hong Kong, and increasingly for those to be built, are unconfined on one or more of their sides. In some locations, high slopes composed of refuse exist (or will soon exist) close enough to occupied buildings to pose a safety hazard from a slope stability viewpoint.

Hong Kong experiences severe seasonal rainfall of very high intensity, and landslips occur frequently. The Author knows of no way, however, of assessing the stability of a controlled tip slope nor of designing one to an acceptable factor of safety. Because of the heterogeneous nature of fill, and the changes in its physical properties with time due to degradation, there is little doubt that classical methods of slope stability analysis are inapplicable. It would appear that future design practice must therefore be based on engineering judgement and prudence, coupled with sufficient experience of the measured behaviour of such fills.

The Author does not know of a single recorded case of a failure of a slope of a sanitary landfill. Perhaps anyone who has information of this kind would be willing to provide it?

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P.L. Ivanov, Panelist

CONSTRUCTION OF TAILING DAMS

The General Reporters of the Session, professor Sembenelli and professor Ueshita, solve in their reports a new and complicated problem to define a role and a place of Soil Mechanics in the widest human problem of an environment protection.

In the General Report it is fairly indicated to the limited and specialized character of problems of Classical Soil Mechanics as a branch of Mechanics and Civil Engineering as well as the complexity of application of Soil Mechanics in solving problems of environment protection. Taking into account the necessity of using all the opportunities of Soil and Rock Science, and particularly Soil Mechanics, in solving environment protection problems, one should acknowledge that the General Reporter offers an interesting proposal to apply a fairly wide and capacious term "Environmental Geotechnics". This proposal should be supported and used in the future to name sessions at following international and regional Conferences on Soil Mechanics and Foundation Engineering. This term reflects to a greater degree a heterogeneous and polyhedric character of the problem in the Science of Soils.

As a result of much work done by the general reporters, it is for the first time, that in one article have been collected and systematized the main trends, composing the subject of Environmental Geotechnics.

In my report I'll dwell on one of the trends of Environmental Geotechnics, mentioned in the report (which is close to my subject of research), namely, solids accumulation on surface, particularly on the problems of environment protection, arising at the construction of tailing dams.

To study all those problems, "a special research laboratory of soil mechanics and tailing stability", financed by the Ministry of Non-ferrous Metallurgy of the Soviet Union, was established more than ten years ago at the Leningrad Polytechnical institute for the institutions of non-ferrous metallurgy. I am the head of the laboratory. Perhaps it is worth changing the name of the laboratory at present, taking into consideration a new terminology, given in the General Report.

At the present time in the Soviet Union at the mine concentration mills of a non-ferrous metallurgy, are being exploited more than one hundred tailing dams, including fortynine hydraulic tail dams which have a volume of more than one milliard of cubic meters of tails. More than 30% of hydraulic tail dams are being constructed now of the tails containing more than 60% (in some cases about 100%) of fine materials having the size of less than 0.074 mm. The height of a number of hydraulic tail dams at present amounts 100-150 meters, and their area is more than 10 square kilometers. As it is all over the world, there is a certain tendency for the material of the tails to become finer, as well as the tendency to increase tail heights. The former is caused by a greater amount of metals extracted from ores, and the latter is due to the reduction of areas removed from agriculture.

These tendencies sufficiently complicate design methods and exploitation of such structures, which assure the necessary structure stability and reliability. The main factors that determine detrimental effects of tailing dams on the environment are as follows:

1) removal of landscape areas, including the areas useful for agriculture;

2) pollution of surface and underground waters by seepage of polluted and toxic waters from tailing dam ponds;

3) air contamination resulted from a wind erosion of tail dam surfaces and tail dusting;

4) damages and failures of tail dams, accompanied by a formation of lique facted soil flows or by a pond water pollution.

The minimum detrimental effects of stored solid waste material, tails in particular, on the environment can be assured by means of a complete interception (drainages and shields) of filtration waters as well as by providing for a system of complete water circulation at enterprises (a closed water circulation system) and for a simultaneous utilization of solid waste materials (tails), that is by creating an ideal system of wasteless production.

Unfortunately, at present, a complete tail utilization is not as a rule carried out, especially as, tail dams contain residual metals and they may be considered as a reserve for the future. That is why one should take into consideration the development of tail dams and a full application of all the possibilities of Environmental Geotechnics.

Almost complete prevention of surface and underground water pollution by tailings may be achieved by means of a complex of measures which imply:

1) preliminary dewatering of tailings in order to reduce the volume of water, fed to the tailing dams;

2) special measures against seepage; shielding of foundations and tailing dams in particular;

3) interception of seepage waters by means of drainages and their return to a water circulation of an enterprise.

It should always be taken into account, that measures to improve the situation concerning detrimental effects of one factor can deteriorate the situation due to other criteria and factors. In many cases, for example, shielding results in a sufficient rise of a phreatic line and in a reduction of a structure slope stability. Drainages, on the contrary, dry hydraulic tailing beaches which can promote a wind erosion of the slopes (dusting). Pulp condensation results in a reduction of layer compactness of tailings, which in its turn, reduces strength characteristics, and a tailing slope stability.

Shielding of a tailing foundation bed with polythylene films, clay, asphalt concrete and others is employed to reduce underground water pollution. This measure is the most effective for external, more pervious zones of a tailing body. In a central fine-grained part of a tailing as a result of tail compaction - consolidation the role of a shield eventually decreases. As the studies showed, in these parts of tailings seepage polluted water losses became three times less in a period of 5 years, and 5-10 times less in 10 years of tailing exploitation. In external zones, on the contrary, polluted water losses eventually increase. Therefore, it is desirable in every particular case to consider feasibilities of shielding tailing foundation with small tails: special shields being placed in external more pervious parts of tailings.

During water seepage of tailing ponds through a body of a dam and a foundation of self purification of sewage occurs by means of sedimentation of detrimental additions on soils. Soils of fine dispersion such as ground layers, clays, sand soils have the best refining properties with comparatively high AL_2O_3 content in their composition (A.A. Kolesnikov).

Sorption of heavy metal ions on the grounds is greater than sorption of components reagents used for technological purposes, for example, cyanides, chlorine in a natural state and others. While flowing through soils, sewage waters change their chemical composition approaching the chemical composition of natural waters as a result of their dilution, their biological self purification and processes of adsorption of detrimental components on soils.

It enables to use these sewage waters for technological purposes intercepting them by drainages and by returning them into water circulation.

The role of soil self-purification abilities can be illustrated on the example of a tailing dam belonging to one of the factories of Uzbekistan (A.A. Kolesnikov).

Natural ground waters were not present, that is there was no dilution of filtrating sewage waters. Simultaneous water sampling out of the pond and holes, situated at a distance of 50 and 100 meters from the pond enabled to fix a concentration of dry residuum: 1.5; 1.2; 0.4 g/l; cyanides: 8.0; 0.08; 0.07 mg/l; copper: 3.4; no, no, respectively.

Sampling was also carried out in a spillway channel along which sewage waters were discharged. Simultaneous sampling in ponds and in a channel at a distance of 1 km and 1.5 km from the dam showed the reduction of a dry residuum, that is: 1.5; 1.2; 1.1 g/l; cyanides: 8.0; 1.2; 0.2 mg/l; copper: 3.3; 0.5; 0.04 mg/l. Comparison of the data, given above, shows a leading role of soils in a process of self-refining of filtration waters.

It is feasible to prevent wind erosion of tailings by physical, chemical and biological methods and their combination. This problem should be solved by joint activities of experts in the field of Soil Mechanics, soil science, chemistry, biology, and others. Unfortunately, very few investigations and studies are available in this field.

As the main physical technique of tailing surface protection from wind erosion (dusting), surface water damping is usually employed during the process of tailing silting. Keeping tailing surfaces in a moist state can result in the increase of the phreatic line. Moreover, to fix the surfaces in a physical sense, surface silting up of clay materials with water suspension can be of practical use.

Here are suggested some techniques to impregnate tailing surfaces with astringent solutions and to introduce various chemical structure forming substances such as: polyacrylamide, polyacrylonitrile, carbomide resins, bitumen emulsion, waste materials of oil industries. Water permeability of a coating being created, is of great importance in fixing soil surfaces of exploited tailings. The presence of fixed soil strata in the body of a hydraulic structure whose permeability coefficient is less than that of a soil (tails), may considerably increase phreatic lines. Contact stregth of a fixed layer is also of a considerable importance.

All these factors while reducing wind erosion (dusting) can also reduce the slope stability of tailings. In Bulgaria (P. Gadziev) scientists are developing provisional consolidating compositions and techniques thanks to which these substances (after they have been washed off by tails (soils) dissolve and do not have any detrimental effect on slope stability.

Unfortunately, a world practice of tailing exploitation has many examples of tailing failures and even damages. An analysis of failure causes of more than 40 tailing dams (A.B. Kolpachkova) shows that 25 percent of failures occur as a result of water running over a dam crest: 26% due to a poor quality of tailing slope soils; 6% due to a poor quality of foundation soils and 42% due to disturbances in the performance of intake and spillway structures.

In some cases it is necessary to estimate consequences of possible tailing failures, particularly, to estimate the boundaries of a moving silt flow and its parameters (speed, depth and pressure on obstacles) which would permit to design special engineering measures to protect settlements and buildings getting into a zone of a possible flow movement.

The formation of silt flows starts with tailing slope failures and pond water flowing over a dam crest of the barrier dams. Very soon there appears a breach in a structure body, through which the pond water and upper layers of deposits run out. Then a further movement of the flow depends on the features of the country (topography, the presence of a bed net, flora and so on) as well as on the initial parameters that the flow will have at a slope toe.

The laboratory of the Leningrad polytechnical institute (G.T. Trunkov and A.B. Kolpachkova) carried out field tests to study the process of silt flows spreading about the country adjacent to tailings.

The investigations were carried out on test sites and there were made limited cases of the movement of the flow, having the volume of 2000 cubic meters, on a wide plain with a small dip and under the conditions of a narrow plain, which served at the same time as the bed of the moving flow.

On the basis of the analysis of the field data taken from tailing failures, and of the data on the properties of tailing soils as well as of the results of the studies of the flow movement made on large-scale models, the technique for approximate evaluations of boundaries and parameters of a silt flow due to tailing failures has been suggested. On the basis of these data, it is possible to design protective measures reducing tailing failure consequences (barrier dams, stream directing dams, channels, and chutes as well as dams which form reservoirs for silt flow accumulations.

This example also shows, that complicated problems of environment protection, as well as conditions for failures and for silt flow movements due to tailing failures, can be solved only by complex employment of all the means of Soil Mechanics, Hydrology, Hydraulic Engineering Hydro-Mechanics and others.

One of the main conditions to prevent tailing failures is a comprehensive research of properties of tailing soils and working out methods of calculation. As the studies show, tailing fine materials, thanks to their mineralogical composition and particle shapes, sufficiently differ in their properties, from natural soils having the same particle size. Tails similar in their grain-size distribution to natural loams and even clays, have large angles of internal friction and a poor cohesion, that is, they are close to fine natural sands in their strength properties, but they have low coefficients of permeability and high compressibility.

During the process of consolidation, tailing materials due to action of their dead load, change their characteristics in a wide range, which never occur in other hydraulic structures. Thus, for example, a unit weight of a soil skeleton can vary from 0.3-04 g/cm^3, in the initial period of particle sedimentation in a pond, up to 1.8-2.0 g/cm^3 after finishing tailing construction works. As to the coefficient of permeability, it becomes one hudred or even one thousand times less. Therefore, calculation schemes for tailings are, as a rule, more complicated than those for usual earth structures. It is necessary to take into consideration the unsteadiness in time and in space of tailing material property characteristics as well as their substantial nonlinearity. In many cases the usual simplest engineering calculation methods appear as inapplicable to tailings.

It should also be taken into account, that unlike usual hydraulic structures tailing construction and exploitation is a simultaneous process and takes a long period of time, sometimes 20 or 30 years. Therefore, an effective environment protection and tailings' stability can be assured only by creating automatic systems of remote control of tailing states. It is necessary, in particular, to control displacements, density, pore water pressure, a phreatic line position, water level in a pond and so on.

In my speech I've considered only one of the aspects of the complicated problem of environment protection from the position of Soil Mechanics, that is storing of solid waste industrial materials, particularly, tailing construction.

Giving tailings as an example, I've tried to illustrate the main theses of the General Report - complexity and multicomponental character of a new branch of science - Environmental Geotechnics.

K.M. Skarżyńska and P. Michalski (Written discussion)

COAL MINE WASTE MATERIALS IN EARTH STRUCTURES
Utilization des Refus d'Houillères en les Terrassements

INTRODUCTION

An intensive hard-coal exploitation on the mining-damage area in South-West Poland has resulted the subsidence of the ground level even by scores of meters at some places. Practically every bigger water-course, river or stream on the subsident ground require planned regulation or embankments what investments are very costly because of soil transportation at long distances. At the same time larger and larger parts of agricultural areas are covered by industrial wastes what not only disfigures the landscape but also adversely affects the habitat. The District Board of Water Economics has therefore started to exploit the dumps and instructed our Institute to conduct the study of above mentioned materials with respect to usability for river embankments and industrial water reservoirs.

METHODS AND RESULTS

The research connected with utilization of coal mine unburnt waste materials for earth structures aims at the qualification and their usefulness and behaviour before and after building up in the embankments.
The waste material from hard-coal mine is not typical from geotechnical point of view and is not included in today's standards.

The important problem regarding the complex recognition of wastes is to state character of changes in their properties caused by natural weathering as well as mechanical factors. During the long time /usually over 10 years/ of storing the wastes in heaps increase the amount of small particles occurred. In the course of building process the transport of materials and their compaction in structures induce further crushing of wastes. Tested materials consisted of coal shales, laminated micaceous siltstones, sandstones and mudstones. The used methods of investigations based on defining the properties of:

- dump material under its actual formation /regarding its suitability for embankments,
- dump material formed 15 years ago /to determine changes taking place during long-term storage/,
- material of the embankment /to determine the changes occurring during transport and earthern works/.

Approximate dump dimensions and slope inclination angles were measured in the field as well as bulk density and the permeability coefficient by means of Giryński's in situ method. In the laboratory apart from routine tests the permeability coefficient tests were conducted with the help of

- standard apparatus on material finer than ⌀ 25 mm with density similar to field value and highest possible to attain in the laboratory conditions,
- high dimension apparatus /95.5 cm in diameter and 50 cm in height/ on natural graining wastes with density as determined "in situ" and maximum from Proctor tests.

Table 1

properties		heaped up recently	long term stored	built in embank-ment
bulk density	T/m^3	1.72	1.62	1.87
m/c	%	7.0	10.0	7.0
opt. m/c	%	11.0	14.0	11.0
compaction index		0.86	0.95	0.95
permeability				
k_{10}	m/s	10^{-3}	10^{-5}-10^{-4}	10^{-6}-10^{-5}
slope angle	°	39	39-40	30
particle size:				
boulder		33.4	19.1	28.1
gravel		51.9	39.7	60.1
sand		12.4	36.0	7.8
silt		2.3	5.2	4.0

The results obtained from the tests /shown in Table 1/ clearly indicate changing in properties of tested wastes.

In the same time wastes were examined by means of six times repeated Proctor test to find out their susceptibility on crushing during compaction. In addition to that some tests were carried out by means of pouring material in the water tank /for different periods of time/ up to one year to estimate the changing in grain size distribution and other parameters.

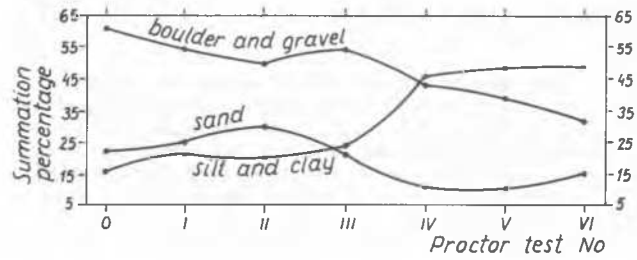

Fig. 1. Changes in fraction composition of tested wastes in course of repeated compaction test

CONCLUSIONS

The results enabled to distinguish some variations in wastes properties caused by their aging and technological processes in the course of embankment erecting. They also allowed to determine the influence of petrographic composition and weathering on the crushing of materials, as well as the optimum conditions for compaction of coal mine unburnt wastes. The applied methods give a possibility for approximate prediction of the bank behaviour during exploitation time.

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J.N. Hutchinson (Written discussion)

FAILURES OF FLOW-SLIDE TYPE IN TIPS OF FLY ASH

The increasing, world-wide problem of disposing safely of fly ash is reflected by the presence of four papers on this material in Session 6 (Ballisager & Sørensen (6/1), Broś (6/3), Gatti & Tripiciano (6/5) and Vasquez & Alonso (6/19).

Although Professor Broś discusses failures of fly ash slurry lagoons, none of the papers refers to the danger of catastrophic failures of flow-slide type in tips of fly ash. It is important to be aware that such failures can occur, despite the well attested tendency of fly ash, even when loosely deposited, to improve its strength with time by chemical auto-cementation (viz. Ballisager & Sørensen, op. cit.; Vasquez & Alonso, op. cit.).

Examples of flow slides in fly ash tips are provided by the failure at Jupille, Belgium, in 1961 in which 11 persons were killed (Calembert & Dantinne 1964, Calembert 1969 and Bishop 1973) and by that in South Wales in 1964 (Hutchinson 1967). In both cases the fly ash was loosely packed having recently been tipped from lorries: the in situ dry densities were, respectively, 77 and 79% of the Proctor Optimum (Hutchinson, op. cit.). Provided, however, that proper attention is paid to the natural strata which form the foundation and that the fly ash itself is sufficiently compacted at the correct water content, waste dumps of this material can be constructed quite safely.

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S. Velchamy, I. Mehrotra and R.P. Mathur (Written disc.)

"MECHANISMS FOR DETOXIFYING SOIL"
(Paper 6/8, Vol. 2)

The authors have looked the detoxification processes involving only adsorption. The authors contention from the experimental studies is that the decrease in adsorption of phenol, arsenic and PCB's in soils are due to the decrease in solubilities of the above compounds in water. This is only partly true because of the following reasons.

1. If an organic compound is ionic in nature and small in size the adsorption will be normally high in presence of organic matter. Phenols are highly soluble in water and ionic in aqueous solutions. Hence the removal of phenol is much higher (5000 times)more when the soil has an organic contamination of 18% than the inorganic soil which has only sand, silt and clay.

The above fact is also demonstrated, that adsorption isotherm of solid liquid interaction is always referred to only phenol adsorption an organic matter.

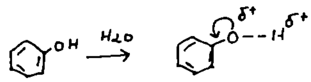
2. The second element studied by the authors arsenic or any other cations can be replaced through exchange property of clay than straining of clay, this is what the past studies had shown.

In this particular system also it should be more of an exchange of ions with other cations while a little is entrapped into the soil structure.

In this particular kind of system, only Chemical or ionic exchange method would be the right choice for the detoxification of the soil which the authors have failed to indicate.

3. The third compound understudy is high molecular weight insoluble PCB compounds. As it is not ionic in nature Chemosorption is not possible, since higher in molecular weight trapping into the soil structure is also not possible then the only possibility is surface accumulation in the soil. So, for this kind of adsorption, detoxification can be done by flushing using jet system or leaching.

The ionization of phenol



4. In case of detoxification of smaller ionic radii metal ions, the methods which are to be adopted should be more specific. The smaller ionic radii ions like Cd goes into the inner cors of the soil. The detoxification of this ions may be more difficult than arsenic unlike, the detoxification technique adopted for As a more accurate technique may have to be adopted. The detoxification process is also dependent upon the ionic size of the texicant present in the soil, which the authors failed to pin point.

5. It is for the interest of all the scientists and Engineers that the research work has been initiated in NRC Canada that many texicants either cationic or amonic including isotopes are adsorbed at the soil and damped into the sea or buried underground.

6. The same paper mentions that the detoxification of the organic soil is best done using suitable organic solvent and the efficiency attained are really better. Thus, it confirms that there is Chemsorption between phenol and organic matter present in the soil. Hence, Chemosorption is more responsible for the higher phenol removal than of solubility. Because of the economic reasons the procedure may not be implemented in large scale.

7. Finally, if the soil pollution is beyond detoxifying limit or if the economic reasons dampen the detoxification process, it is always advisable that these soils may be used as a building materials where its mechanical strength would also increase if it is containated with metal Oxides, over that plastic coatings may be applied, so that it does not create any further pollution problem and thus, solving the solid waste problem too.

S. Ando and G. Miki (Invited discussion)

ENVIRONMENTAL IMPACTS OF CHEMICAL GROUTING TO GROUND WATER

SYNOPSIS In order to study the environmental impacts of chemical grouting to ground water, several experiments from a basic point of view were performed, including the development of a monitoring system of the quality of ground water and the development of a mathematical model to simulate the behaviors of grouts in ground water. From their results the following conclusions were obtained: (1) Electric conductivity (EC) is one of the useful monitoring indicies; (2) The monitoring system presently developed is useful to practical purposes; (3) Not-solidified grout behaves as a density current; (4) When monitoring water quality by use of any monitoring index, the response characteristics peculiar to its index should be carefully took into account to examine the measurements; (5) A three-dimensional unsteady simulation model presently developed is useful to predict the behaviors of grouts in ground water.

INTRODUCTION

In Japan, the ground water pollution accidents happened in 1974 by the results of chemical grouting, and they became a great social problem. From this occasion Japanese government has strictly controled the use of chemical grounting methods, and concurrently started to promote studies on fundamental aspects of the chemical grouting impacts to ground water. This discussion briefly refers to their most important results, particularly the qualitative aspects of chemical grouting impacts to ground water and the development of systems to monitor the impacts.

POLLUTION POTENTIAL OF CHEMICALS

Under an idea that electric conductivity (EC) may be an effective index to monitor ground water, EC-values were measured for several chemicals. Three chemicals were adopted and each was arranged to have the gel time of 3 minutes. The measurement results were as follows: 117,120 $\mu℧$/cm at 25°C for water glass type chemical, 130,340 $\mu℧$/cm at 25°C for urea resine type chemical, and 4,380 $\mu℧$/cm at 25°C for acrylamide type chemical.

These results show that EC-value can be effectively used as a monitoring index as far as it is used in the no-tidal area in which background EC-value is less than 500-1,000 $\mu℧$/cm at 25°C.

DEVELOPMENT OF CONTINUOUS MONITORING SYSTEM

EC-value as well as pH-value can be readily measured as electric changes, and hence two types of continuous monitoring device to pick up their values were developed. One device is a throw-in type, and five sensors (1-pH and 4-EC) are installed in a monitoring well. Another one is a flow-cell type, in which a small amount of water is sampled from a well and its pH-value and EC-value are measured by each sensors above ground. Through several pit tests and field tests both devices proved useful for practical uses.

TEST RESULTS BY A LARGE-SCALE TEST PIT

In order to examine the response characteristic of several monitoring indices (pH, EC, Na, SiO_2), two series of tests were carried out by use of a large-scale test pit. In this test pit many monitoring points were selected with an equal interval in the three directions; the direction of water flow, the direction normal to the flow, and the direction of depth.

SETTLING CHARACTERISTICS OF NOT-SOLIDIFIED CHEMICALS

In order to observe the behaviors of not-solidified and run-out chemicals urea resine type chemical was injected into a small-scale test pit (3-2-2 meter), in which 48 sensors for EC had been installed to catch the movement of the chemical. The results showed that the not-solidified chemical behaved as a density current and moved downward because of its density larger than water.

This indicates that when monitoring the behavior of chemical it is important to take account of the downward movement of chemical.
The chemical of waterglass type was injected by use of an actual injection apparatus at an upper stream side of the water flow, and the changes in the concentration of pH, EC, Na, and SiO_2 were measured at the many monitoring points.

In the first series of test, grouting was carried out under the condition of perfect solidification. In this case, only a slight change in Na and EC was observed at the monitoring points nearest to the injection point (2.5 m apart).

In the second series of test, grouting was performed under the condition of no solidification; i.e., the main chemical and the additive one were separately injected. This test caused great changes in water quality during a long period and over the whole area of down stream side of injection point.

The time records of monitoring indices obtained showed that the changes first appear in Na and EC-value and then in pH and SiO_2-value. The change in Na propagates nearly with the velocity of ground water. Near the injection point therefore it very sharply responses; its concentration rapidly increases to its maximum and then rapidly decreases to its background value. But as the monitoring point becomes far from the injection point, its response becomes dull and draws a gently-sloping hill curve. On the other hand, pH-value slowly increases after the increase in Na, and keeps a high value even after the Na and EC-value drop to their background values.

From these results it is concluded that when examining the measurements from monitoring wells it is necessary to take account of each special response characteristics peculiar to each monitoring index.

EXAMINATION OF SIMULATION MODEL

Based on these various test results obtained, a three dimensional unsteady simulation model was developed to predict the behaviors of components involved in a chemical grout. Calculation results showed a good coincidence with the behaviors observed in the large-scale test pit.

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C. van der Veen (Invited discussion)

Let me first thank dr. Moh mentioning at his opening-speech our collaboration at the Tokyo Congress, when I was a co-organising chairman. This was not only a great pleasure but the way, Dr. Moh, you have carried on, deserves the admiration and gratitude of the International Society. You were kind in mentioning my recommendations at the end of the Tokyo session. I think they have been taken into account in the organisation of this meeting. This is also a great pleasure to me.

I came as a so-called prepared speaker, but I was not prepared for the general report of Dr. Sembenelli and that in a very pleasant way. I would like to congratulate him and express the hope his proposals will be taken up by the International Society, especially as concerns the concept of environmental geotechnics and his proposal to look upon our work not as a number of specialities, but as a group of activities. Also I would like to underline the necessity that the geotechnical engineer is involved at an early stage of the process of planning or designing.

Sometimes this happens. Since about thirty years it is a fixed rule in the city of Amsterdam, the Netherlands, that each major town extension is preceded by an extensive soil mechanical investigation. This has proved to be very beneficial to planners and engineers.

I would now like to take up my third recommendation at the Tokyo Conference: to see if anything can be said about the moral or professional involvement of the engineer in questions of environment.

It's a very general question that is not limited to environment. It might strike you that, at the same time of our Congress, there is in Stockholm a conference of crime writers. There seem to be a thousand of them. I would not be surprised if some of these writers would come up with a story in which the crime is the descruction of the human environment. Who will appear as the hideous murderer on the last page of the book? It might well be the engineer.

I don't know if this would be reasonable. Engineers are not such a bad lot of people. On the other hand in many parts of the world the natural environment is being influenced if not destroyed by unlimited growth of sometimes ugly or non descript cities, dams and highways are built that in the eyes of some people take away the beauty of the landscape; spoil material of industrial activities, poison the clean air and water without which life is not possible.

Therefore there is good reason to discuss environmental control among engineers. Beacuse we are involved. In what way?

I will concentrate on new projects.
The engineer usually in this field works for a client. This can be a person, a group, a company, the government and so on. There are two extremes by which the position of the engineer can be defined:

1. The engineer builds or constructs what he is asked to build; his sole responsibility is that his calculations are correct.
2. He is involved in the responsibility for the project and if he is the chief designer he is responsible for the project, not only to his client but also to the community at large and to himself.

It is difficult to make an immediate choice between these two positions.

Of course the engineer is a member of a community and he cannot neglect the wishes of the community that for instance wants roads and motor cars for quicker transport. On the other hand if he is only a calculator, his role is very limited if not virtually nil in the overall decision process.

So probably his position is somewhere in between the two extremes. That also holds for environment control. I will try to state that position, as it seems right to me. In my mind the engineer and therefore also the soil mechanics engineer, wherever he is faced with environmental impact of his works, has to try to find solutions that protect the natural environment as much as possible. This attitude should be part of his code of practice. In a number of countries laws on the environmental protection instruct him on this point. But I think he should also adopt this attitude, as best as he can, when no such laws have been established. Why? Because in my opinion the maintenance of our natural environment is a generaloverriding principle and we, engineers, are very much on the scene. We have a responsibility there. I would advocate that we try, in our ISSMFE, to define this responsibility and lay it down in a recommendation.

S.I. Tsien (Oral discussion)

SOME REMARKS ON INVESTIGATING LAND SUBSIDENCE PROBLEMS

The problem of land subsidence due to groundwater pumping has been becoming a real concern in rapidly developing industrial cities. As more pumping wells in the district are installed, the affected areas and depths increase. Good balance between water consumption and yearly permissible subsidence is always a challenging problem facing to city planners. They aim to use more groundwater but less subsidence. The following are my viewpoints as how to investigate this special type of problems.

(1) Since the problem concerns with big area and great depth, entire soil mass in a given location should be considered. Therefore, in-situ observation and measurements are particularly valuable. The observed data can be regarded as the results of a large-scale in-situ test. Soil parameters used in subsidence studies should be mainly determined from these field data. In the meanwhile, laboratory testing should also carried out to study the mechanism of subsidence, soil models as well as relationships between various soil parameters. The analyses may be based on some semi-empirical approaches, i.e. by using appropriate classical or modified consolidation theory with boundary conditions and soil parameters mainly determined from field data. By so doing, the accuracy of predicting subsidence could be greatly improved. This approach has been successfully adopted in China. General concepts on settlement predictions under ordinary structures based on laboratory testing of small soil specimens and conventional load-increment ratios can not be applied to this type of problems. Soil mechanics analysis must be collaborated closely with geological investigations,site explorations and field observations.

(2) Measures effective to control subsidence can not be determined without thorough understanding the mechanism of subsidence. Pore water pressures and deformations occurred in each compressible layers are the two most important factors to understand the process of stress re-distribution among various soil phases and its consequences. Only based on these observations in field, can the effectiveness of control measures, such as recharging of groundwater be evaluated in course of time. In China, recharging has been demonstrated as one of the most effective control measures to combat subsidence. However, this method can not be regarded as a cure-for-all remedy. Blind recharging not only wastes of time and money, but also, may upset ground thermal regime and cause serious pollution problems. Therefore, determination of most effective recharging program as to its applying time, depth, frequency and intensity deserves careful consideration.

(3) As groundwater recharging into aquifer goes on, hydrostatic excess pressures in compressible soil layers gradually approaches to zero. Secondary time effect,then, becomes the primary role in causing continuous subsidence. There seems to be no effective and inexpensive solution to this end. It certainly causes serious trouble since minor subsidence could last for a great number of years and apparently, no ultimate estimation has yet been successfully established. Could secondary compression be partially eliminated by some means e.g. intensified recharging?

(4) Computer may be considered as supplementary tool to conventional soil testing and analysis to determine the optimum water-pumpage plan and recharging program for a given project by inputing various combinations of working conditions. It can also help to better understand the mechanism of subsidence. Large-scale model tests are also helpful in this respect. To sum up, a joint effort of careful laboratory investigations, well-planned and conducted field observations, model tests together with computer trial analyses seems to be the proper way to solve the subsidence problem due to subterrean pumping.

R.L. Brown (Oral discussion)

CONTROLLED REFUSE TIPS

The congestion in Hong Kong had led to controlled tips of domestic and industrial rubbish being located within current or future urban areas. The shortage of land also means that the volume in each tip has to be maximised by using steep side slopes and building up to 80 m high. As failure could cause loss of life and damage to property there are strong reasons for using good construction techniques and close control. Normal geotechnical design processes cannot be applied directly to rubbish tips because of the heterogeneity of the rubbish, time dependent effects of decay and decomposition causing changes in properties and the difficulty of quantifying parameters for effective stress assessment of stability and consolidation.

However, the normal observational techniques can be utilised provided that instrumentation and a framework of monitoring are established during construction. If these are adequate and well documented then some progress can be made in rational prediction of future behaviour. In particular, old tips (and even new ones) are being considered for recreational use and modest building. The rate and extent of settlement would affect the structural approach but persistence of methane gas emissions would probably govern the feasibility of safe development on or adjacent to old controlled tips.

Sowers (1973) suggested that the rate of secondary settlement of controlled tips is similar in form to that of secondary consolidation of clays as expressed by the equation

$$\frac{\Delta H}{H} = \frac{\alpha}{(1+e_o)} \log_{10} \frac{t_2}{t_1}$$

where H is settlement in the period $t_1 - t_2$ measured after loading a depth H of fill with initial void ratio e_o . The coefficient varies between 0.03 e_o and 0.09 e_o for anaerobic and aerobic decomposition conditions respectively.

Values of $c_\alpha = \frac{\alpha}{(1 + e_o)}$ quoted by various authors range between 0.014 and 0.07. In Hong Kong limited observation only are available but give higher coefficients than these suggesting more settlement over a given period. The data are summarised as:-

Tip	H	H	t_1	t_2	α	c_α
	metres		months			
Ngau Chi Wan	21	1.1	1	5	0.15	0.075
	21	0.8	2	5	0.19	0.095
Ngau Tam Mei						
(SM2)	9.3	0.54	2.5	34	0.10	0.050
(SM6)	15.4	0.37	12	34	0.11	0.055

The present information is insufficient to predict an average rate of settlement for Hong Kong sanitary landfills or to predict for how long settlement will continue. In addition the observations show very different behaviour at points above similar thicknesses of refuse and also subject to the same additional load. At Ngau Yam Mei points SM1, 2 and 4 are founded on about 15 m of material that was partly old dumped refuse and partly controlled tip placed between December 1973 and March 1975. Day zero is 1st October 1975. The largest settlement is more than twice the least. At Shuen Wan a sharp drop occurred after 600 days of tipping.

Controlled tips are capped by a layer of compacted decomposed granite and the slopes are grassed with surface U-channels to collect surface runoff. Both features are susceptible to movement and tend to crack. Dense decomposed granite fill can sustain a crack even when wet so that the upper surface can be infiltrated by rainfall. Measurements of leachate volume show increased flows following heavy rain.

Substantial differential and sudden movements of old refuse tips would inevitably require carefully designed and probably relatively expensive foundation which would be a large proportion of the total cost of subsequent low rise developments. Consideration should be given to improving the post-construction behaviour and scope for early development by carefully selecting, mixing and treating the refuse at the time that it is incorporated in the controlled tip. The heterogeneity can be reduced by excluding particularly difficult materials from certain areas, in situ mixing and controlled compaction. Small changes in construction techniques could lead to very substantial benefits later where lack of good natural areas for development will inevitably lead to pressure to build on top of old controlled tips. That pressure is already substantial in Hong Kong.

R.P. Chapuis (Written discussion)

PERMEABILITY TESTING OF SOIL-BENTONITE MIXTURES
Essais de Perméabilité sur des Mélanges Sol-Bentonite

In recent years, many National Environment Boards have passed regulations to prevent groundwater pollution by community or industrial wastes.

Consequently, the new waste sites must be located in impervious clayey deposits or they must be sealed by artificial impervious blankets. Presently, plastic membranes are facing problems related to their durability, and there seems to be a trend to consider natural or artificial clayey blankets, like soil-bentonite mixtures, as a safer solution.

Usually Environment regulations require a maximum hydraulic conductivity for the blanket, depending on the type of waste. The paper by Lundgren (6/11) is dealing with different questions related with soil-bentonite mixtures, and the discusser would like to elaborate on two major points : permeability testing and durability.

PERMEABILITY TESTING

There are at least three methods to determine the hydraulic conductivity of these impervious materials : the variable head or constant head tests within a rigid-wall permeameter , and the constant head test within a triaxial cell. The results shown on Fig.1 indicate that the constant head permeameter and triaxial tests gave equivalent results for two different mixtures.

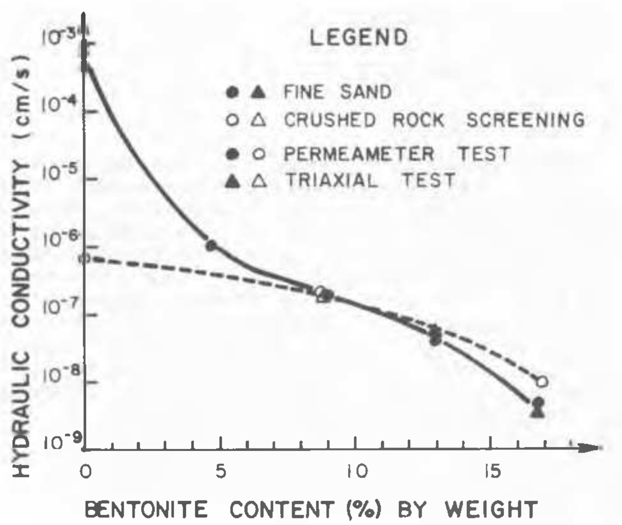


Fig.1 Results of permeability tests for two bentonite mixtures

It is worth noting that a steady flow condition was obtained only after complete saturation and hydration of bentonite. From our experience, 2 to 6 days are necessary in a triaxial cell, and 4 to 12 days in a permeameter. If this unusually long delay for steady flow condition is not respected, the hydraulic conductivity that is measured may be much lower than during the steady flow. Then it is obvious that the variable head permeameter test is totally inadequate with such mixtures, as stated by Zimmie and al (6/21).

The respective characteristics of the two correct testing methods may be summarized as follows :

a) both tests can and must include the lower and upper transition layers which will be placed in situ under and above the impervious blanket;
b) the compaction requirements may be easily reproduced within a permeameter; possible leakage between the permeameter wall and the mixture may be prevented by a thin coating of pure bentonite; the permeameter does not allow an effective stress control within the soil;
c) the triaxial cell allows a faster test, an effective stress control, but the compaction requirements are more difficult to met.

DURABILITY OF SOIL-BENTONITE MIXTURES

The durability of such mixtures depends on relative physico-chemical properties of bentonite and polluted water. Few data are available on the long term stability of bentonite as a sealant when exposed to a contaminated water, and it seems necessary to rely on special tests. An artificial ion-exchange test is presented by Lundgren (6/11). In our opinion, it is difficult to reproduce a certain long time of exposure with such a method. The main reason is that the soil-bentonite mixture is first hydrated with fresh water, and that it is not directly and equally exposed to all components of polluted water throughout its thickness. In fact the propagation of a non-radioactive pollutant within a soil is a complex phenomenon involving transportation, dispersion and adsorption of pollutants. This last action may affect the physico-chemical properties of the bentonite. However, as indicated before, the mixture is not equally exposed throughout its thickness because adsorption delay and may considerably reduce the propagation of a pollutant. Consequently, after a superficial adsorption, the soil-bentonite mixture may be "self-protected" against the polluted water (as certain metals may be self-protected against corrosion), which the proposed test cannot reproduce. An alternate test is to expose a thin layer (1cm) of the mixture, after hydration with fresh water, to higher hydraulic gradient and pollutant concentrations than in situ, to measure hydraulic conductivity and analyze periodically percolated water for a period of at least one month. The period should be long enough to have a large displacement of water throughout the mixture, in order to determine how adsorption modifies the transportation of the various pollutants through the soil-bentonite mixture. Finally, it should be noted that ion-exchange capacity is only one of the many physico-chemical aspects that are involved in long-term stability, and that we must be very careful when extrapolating any lab result to periods of fifty years.

The last aspect the discusser would like to underline is that, if a soil-bentonite blanket is effective to retain a given pollutant, it may be ineffective for another one. So it would be hazardous to accept, in a site, wastes different with those for which the site was approved, unless a previous special study was performed.

H.L. Jessberger and R.A. Beine (Written discussion)

IMPERMEABILIZATION OF DISPOSAL SITES BY IMPERVIOUS BLANKETS CONSISTING OF MINE REFUSE

Impermeabilizing the base of disposal sites for urban and industrial wastes to protect the ground water table against pollution is increasingly paid attention to in the Federal Republic of Germany as well as in many other countries. The choice of locations for disposal sites with a natural impervious underground becomes more and more difficult. Therefore the construction of artificial proofing layers gets high signification. This topic nowadays is an important task for geotechnical engineering, especially in environmental impacted industrial overcrowded regions.

In the Ruhr-District in Germany positive experiences on proofing layers consisting of mine refuse were gained at several projects. The used mine refuse is country rock, which is obtained from coal washing. It mainly sonsists of shale. A typical grain size distribution is shown in Fig. 1. The shape is nearly that of Fuller's curve. By adding suitable materials to be admixed the coefficient of permeability of the mixture can be decreased from about $1 \cdot 10^{-8}$ m/s to about $1 \cdot 10^{-9}$ to $1 \cdot 10^{-10}$ m/s. These coefficients of permeability require a dry density above Proctor's density.

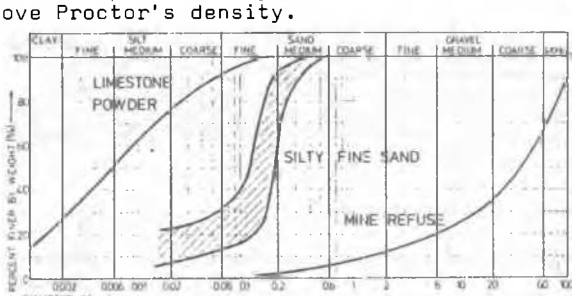


Fig. 1: Grain size distribution

Highly active bentonites in addition with fine grained fillers as limestone powder or rather silty fine sand have proved to be suitable materials to be admixed. The quantity of the bentonite added amounts to 1 % related to the dry mass of the mine refuse, the quantity of the filler depends on its type and grain. Quantities up to 8 % can be taken as a guide.

In construction of the proofing layer first the mine refuse is distributed in a thickness up to 40 cm. On this layer the additives are spread equally and mixed to the mine refuse by the mixed-in-place method (Fig. 2). It has been proved that one passage of a powerful mixing unit produces a homogeneous mixture. After mixing the mixture is watered if necessary.

Fig. 2: Mixing-in-place

The water content should surmount the optimum. Subsequently the layer is well compacted. The degree of compaction has a strong influence on the coefficient of permeability, Proctor's density must be exceeded. A schematic description of the working procedures is given in Fig. 3.

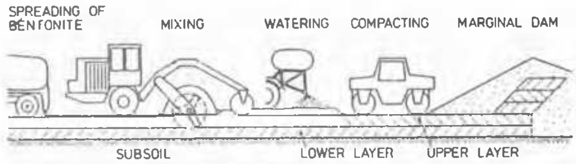


Fig. 3: Working procedures

The described impermeable layer has a high compression strength, but it can also succeed subsidence caused by inhomogeneous ground or underground mining activities without leakage. It is insensitive to conventional harmful materials, resistant to acids, bases, and solvents.

This construction method is a succesful and low cost solution for proofing layers independent on the subsoil where mine refuse can be ordered nearby.

E. Ledeuil (Oral discussion)

PROTECTION ANTI-EROSION ET ANTI-DEPOT DE RIVES EN SABLE D'UNE RETENUE AVEC FLUCTUATIONS JOURNALIERES DU PLAN D'EAU

RESUME Désirant exploiter journèlement 400.000 m^3 d'eau sous 2 mètres de marnage dans le réservoir de compensation de FERRIERES (09) à LABARRE, il convient de créer des zones d'écolement et de stabiliser les rives en même temps.

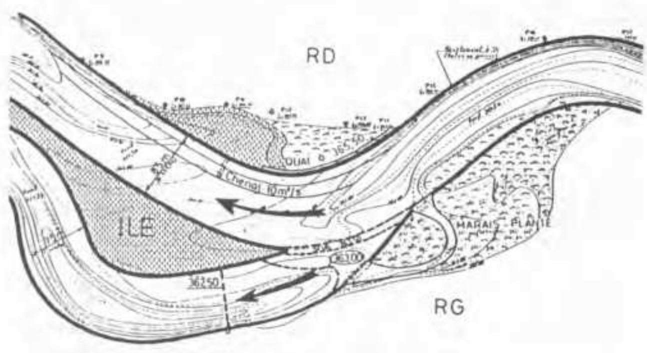
1. ORIGINE DU PROBLEME :

1.1. En fait le réservoir de LABARRE est fortement envasé et diverses solutions de curages par dragage ou sussion se sont heurtées au lieu du dépôt de ces "vases", extraites dans les zones urbanisées et, oü personne n'est disposé à accepter de tels matériaux.

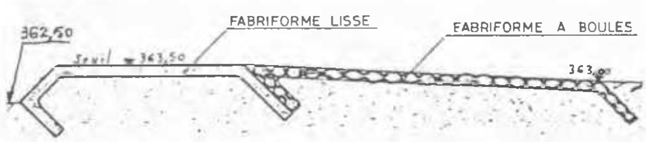
1.2. La solution adoptée sera donc une solution qui laisse sur place tous les matériaux en se contentant de les réorganiser afin de répondre au double but, de capacité d'exploitation dans les limites du marnage admissible et, de permettre de conserver une solution stable évitant l'envasement et les difficultés remarquées en 1957 (vidange de fond...)

2. PLAN DE MASSE ADOPTE :

2.1. La rivière faisait une boucle sur la rive gauche avant la construction du barrage de LABARRE (12 mètres de hauteur) on laissera donc à l'exploitation de - 2 m un chenal conforme à celui qu'elle utilisait et qui avait du reste laissé de fortes empreintes.



2.2. Un chenal sur la rive droite étant amorcé il conviendra de le créer et d'en favoriser la conservation par des seuils, imposant le passage (donc le curage naturel) de l'eau à une vitesse supérieure à celle du dépôt dès les basses eaux.



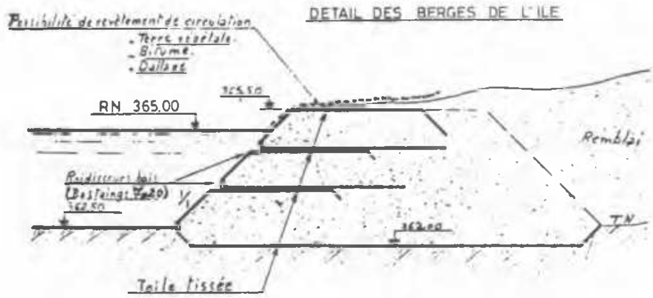
2.3. Ces canaux à créer ne devront pas être trop profonds afin de s'auto-nettoyer, les rives doivent être stables et assez raides afin d'éviter les dépôts. Dans la partie centrale du lac ces rives formeront une île, qui en fait est partiellement créée à fleur d'eau par l'envasement. Sur le plan de l'environnement la nouvelle exploitation serait très discutable (l'exploitation habituelle était faite depuis 1957 à plan d'eau fixe) alors que la création d'une île peut être un élément d'amélioration.

2.4. Conservation et création en l'isolant d'une zone marécageuse pour oiseaux migrateurs. La protection de cette zone est aussi formée par les mêmes berges objet de cette étude.

3. PRINCIPE DES BERGES :

3.1. Les reconnaissances réalisées devaient permettre de voir que les vases étaient très localisées et que l'essentiel était formé de sables, quelques zones proches du barrage possédaient des magmas de feuilles d'arbres en décomposition mêlées au sable. En fait se sont des magmas qui, en 1957 lors de la dernière utilisation de la vidange de fond, avaient créé des dégats à l'aval, aux poissons et aux stations de pompage.

3.2. Les berges sont bâties à 1 pour 1 pour éviter tout dépôt. La confection se fait en gabions de tissus (genre non tissé complété en surface soit par du tissé soit par un revêtement végétal). Le travail est fait à sec en été après canalisation des eaux. La fouille d'enclos puis la digue étant réalisés une simple exploitation de dragage (100.000 m3) permet de déplacer les matériaux.



Le bois traîté est incorporé au tissus afin de rendre l'aspect plus régulier ce qui est aussi favorable à l'écoulement des eaux.

Za-Chie Moh, Chairman

CONCLUDING REMARKS AFTER ORAL DISCUSSION

I am very pleased to note that the discussions which we have had today are both interesting and lively. This clearly demonstrates the importance of the subject matter of our Session. I wish to take this opportunity to express my personal thanks to all of those who have taken a part both prior to and during the session.

The General Reporters, Dr. Sembenelli and Prof. Ueshita, have made a most significant contribution by proposing the term Environmental Geotechnics to identify A Tool that contains all the different branches of soil and rock mechanics. With this, the geot. engineering profession is moving into a new horizon.

This proposal has clearly fulfilled one of the suggestions made at the 1977 Specialty Conference to formulate a clear definition of the meaning of the word "environment" with respect to geotechnical activities.

Discussions offered by the various panel members, invited discussors and audience covered the many aspects of the problem. Besides the recommendations and suggestions made in the State-of-the-Art Report and subsequent discussions regarding the needs for further research in various aspects of the problem, your Chairman, together with the Co-Chairman, General Reporter, Co-Reporter, and Panelists would like to propose to the International Society for Soil Mechanics and Foundation Engineering to establish a Subcommittee on Environmental Geotechnics with the following tasks:

1. To further clarify and delineate the scope of environmental geotechnics.
2. To compile a comprehensive bibliograph on the subject.
3. To investigate the possibility and to suggest ways & means that the ISSMFE can outline legal and moral standards relating to environmental geotechanics to various authorities.
4. To investigate the possibility and to suggest ways & means that a central depository library be established for compilation of geotechnical maps.
5. To discuss the organization of a session on Environmental Geotechnics at the next International Conference.

I hope that you will support this proposal.

With these remarks, Ladies & Gentlemen, I hereby declare that Session 6 of the X ICSMFE is now closed. Thank you for your participation and attention.