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INGEOKRING NIEUWSBRIEF

Zomer editie 92

IngeoKring Nieuwsbrief *zomer editie 92*

INHOUDSOPGAVE

VAN DE REDAKTIE

In de vorige Nieuwsbrief was aangekondigd dat we aandacht zouden besteden aan het vierde lustrum van de IngeoKring. We hebben de eerste nummers van de NieuwsBrief er een op nageslagen met het idee er een paar "leuke" momentopnamen uit te halen. Dat idee hebben we om verschillende redenen laten varen.

Het Bestuur het echter niet stil gezeten. Er wordt van 22 - 25 april 1993 een excursie georganiseerd door Nederland. Het thema: "**Seismiciteit en Oppervlakte verzakking**". Het is de bedoeling dat onze Belgische- en Engelse collega's worden uitgenodigd om deel te nemen. De lustrumdatum is overigens **24 april 1993**. Het Bestuur denkt er tevens over een symposium te organiseren rond die tijd.

Deze Nieuwsbrief is verzorgd door een nieuw team van studenten (M.v.d.Bosch en T. Brouwer). Twee artikelen (Marwa en Contreras) zijn literatuurstudies. Deze studies zijn een onderdeel van de "Ingenieursgeologische workshop" van de TUD/ITC-opleiding. Drie van deze studies zijn als beste uitgekozen en - zonder enige tekstuele of andere wijzigingen - geplaatst. De kwaliteit spreekt voor zich. In het volgende nummer wordt het artikel van de derde prijswinnaar (M. Giezen) geplaatst.

de redaktie:

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METHANE GAS, ITS NATURAL FORMATION AND ITS ROLE IN CEMENTING BEACH ROCK

By E.M.M. Marwa. Employed from 1983 to 1986 as a geologist dealing with exploration work for the Ministry of Water, Energy & Minerals in Tanzania. Since 1986 he is working in the Rock & Soil Mechanics Laboratory as a Engineering Geologist. Currently he is following the Engineering Geology Msc. course at ITC Delft. This article is part of the Special Topics workshop.

The paper discusses in brief the formation of methane and its role in cementing marine sediments into a rock resembling recent 'beach rock' forming in tropical and subtropical beaches. The most reported 'beach rock' is sandstone. It is cemented by carbonate material. Some few mudstones cemented by similar material are also present in some beaches. The carbonate cement is either aragonite or magnesian calcite. Aragonite cement is commonly found associated with marine organisms especially mollusc shells. The carbon which form part of the aragonite and magnesian calcite is originating from methane. Confirmation has been done with the aids of carbon isotope analysis and radiocarbon dating technique. The main sources of methane are microbiological and thermocatalytic decomposition of organic matter. In some places, methane is associated with volcanic and geothermal activities. In the sediments, methane occurs as free gas bubbles or dissolved in the interstitial water. Under special cases, it is found in a solid form as gas hydrates.

INTRODUCTION

Recently carbonate cemented rock with similar mineral composition and textural characteristics of some modern beach rock has been reported from various parts of the world. The main rock reported by many people is sandstone cemented by aragonite and magnesian calcite. Some few cemented mudstones have also been noted along the Dutch north sea coast (Van Straaten,1957). The sandstones without or with few mollusc remains are usually found cemented by Mg-calcite only, whereas the cement of the stones with many shells consists exclusively of aragonite. The Mg-calcite appears as euhedral rhombic crystals on the surface of the cemented grains. The aragonite normally takes the form of single needles or clusters of needle like crystals (Alexandersson,T.,1974).

The carbon which form part of both the aragonite and Mg-calcite is radiocarbon dated to be approximately far older than the cemented sediments and fossils. This peculiar behaviour has been described from many places. For example, the cement of the aragonite cemented sandstone from the outer continental shelf off Dewalare bay was found to be 15,600 years old whereas the cemented molluscan shells contrasts with a date of 4,390 years (Allen et al, 1969). Also samples taken from several localities in the Kattegat sea and the adjoining coasts (Denmark) showed the age of 18,000 years for the cement and 4,000 years for the cemented skeletal carbonate (Jorgensen, N.O., 1976).

The cement is greatly enriched in the light stable carbon isotope of nearly the same range as that of methane. The typical values for the carbon of the methane is frequently recorded in the interval of -40 to -80 %. PDB (Jorgensen, N.O.,1976). The strongly negative C values of the cement of the same range as that of methane described from many countries support the concept that the source of the carbon is from methane (Hathaway and Degens,1968).

In the Netherlands, this rock has been found washed ashore on the Dutch North Sea coast and in France, it has been reported on the beaches of the Rhone delta, near Saites Maries at the mouth of the Petit Rhone. In both cases, it occurs as slabs of sandstones with or without mollusc shells (Van Straaten, 1957). The same type of rock has been dredged from a few localities on the continental margin off the northeastern United States (Hathaway and Degens, 1968). Similar type of rock has been described from the beach sediments of the Mississippi river delta (Roberts and Whelan, 1975). Recent cemented beach sediments has been reported as well from the Polish coast of the southern Baltic (Muller and Rudowski,1967) and along the Danish coasts (Jorgensen,N.O., 1976)

METHANE

Methane is a hydrocarbon compound belonging to the paraffin group. It is odourless and inflammable with a boiling point of 256 F (Burcik,E.J.,1957). It consists of a single carbon atom and four hydrogen atoms with a molecular formula CH_4 . To indicate its structure one writes the structure formula as

$$\begin{array}{ccccc} & & H & & \\ & & | & & \\ H & — & C & — & H \\ & & | & & \\ & & H & & \end{array}$$

Methane is commonly found in bogs, brackish-water marshes, dung heaps and anaerobic sewage digesters, poorly-drained swamps, bays, paddy fields and anoxic fresh water lake bottoms and marine sediments beneath the zone of active sulphate reduction. With other hydrocarbons, it is also found in conjunction with liquid petroleum oils.

In marine sediments, methane is found either dissolved in the interstitial water or exists as free gas bubbles. However, the interpretation expounded by Stoll et al (1971), is that it may also exist in a solid form as gas hydrates. Methane hydrates are solid clathrate compounds, resembling ice or wet snow in appearance. The hydrates are formed when methane and other gaseous substances in marine sediments combine with water under proper conditions of temperature and pressure. Methane acts as the guest molecules while water provides the host molecules.

In general, according to Kaplan,I.R. (1974), hydrates form at high pressure and low temperature, if the methane is supersaturated under the conditions specified. Hence, assuming supersaturation of methane and bottom temperatures near zero, methane hydrates can form beneath a water column of 260 meters. Along the continental shelves or shallow seas in the temperature regions where bottom temperatures may be typically about 5°C, methane hydrates would be stable under a 500 meters column of water (Kaplan, I.R., 1974). The stability of the hydrates within the sediments is in part controlled by hydrostatic pressure of the overlying water and in part by the geothermal gradient within the sediment. For example, where bottom temperatures are 2°C and the depth of water column is 2 km, Claypool and Kaplan (1974) have indicated that methane hydrates will be present to a depth of about 1000 meters in the sediments assuming a geothermal gradient of 0.035 C°/m. In water depths between 500 and 5000 meters, hydrostatic pressures are sufficient for the gas hydrates to be stable up to 10 -30°C (Hesse, R.,1990). The gas-hydrate zones can attain a thickness of up to 1 km or more depending on the availability of methane especially in the outer deeper continental margin environments (Hesse, R.,1990)

FORMATION OF METHANE

In nature, methane arises from three major sources:

* Microbiological decomposition of organic matter (Biogenic methane)
* Thermocatalytic cracking of organic compounds (Thermocatalytic methane)
* Volcanic or geothermal activities (Volcanogenic methane)

Thermocatalytic methane

At temperatures greater than 75°C, methane and other hydrocarbons are produced by non-biological, thermocatalytic reactions (Hesse, R., 1990). The mechanism involves thermal conversion of organic matter trapped at greater depth in sedimentary formation into carbon dioxide and hydrogen which under suitable temperature and pressure unite to form methane and other related hydrocarbons.

With increasing burial depth, the temperature of the host rock also increases and at a given temperature the organic matter (kerogen) transforms either into oil and or gas depending on the sedimentary environment and the nature of the buried organic matter. The activation energy for the thermocatalytic methane generation is estimated to be about 40.3 kcal/mole (Hoering and Abelson, 1963).

Volcanogenic methane

Methane is among the gases produced in geothermal wells or during volcanism. Other gases are carbon dioxide ($C0_2$), nitrogen (N_2), hydrogen sulphide (H_2S), Sulphur dioxide (SO_2) and halogens. Carbon dioxide constitutes about 90% of the gases discharged during volcanic eruptions. Hydrocarbons other than methane are probably not present in high amounts because no mention is made of them by many writers. The fluids containing these gases originate from a parent magma or rocks undergoing metamorphism. In these fluids, which are very hot, various chemical reactions are taking place, among them is the reduction of CO_2 by hydrogen to methane (fig.1). Therefore, part of the methane gas found in marine sediments may also in some places be linked with submarine volcanism and geothermal activities.

Biogenic methane

Biogenic methane under sedimentary environment is produced by the aid of methane-producing bacteria.These bacteria are strict anaerobes and do not grow in the presence of oxygen and of dissolved sulphate. Therefore, among other things, the necessary condition for the formation of methane is rapid deposition of sediments with sufficient organic carbon ($\geq$ 0.5%) to allow an anoxic condition to be established (Claypool and Kaplan, 1974). This limitation effectively confines the activity of these microorganisms to a highly specialized and restricted environment.

In marine organic-rich sedimentary environments, Claypool and Kaplan (1974) have postulated three biogeochemical zones based on ecological factors. These zones are: the aerobic zone, the anaerobic sulphate reducing zone and the anaerobic carbonate reducing zone (fig.II). In each of these zones, there are different biochemical processes that are taking place and each zone favours a particular type of species. The position of the individual zone is not fixed, but changes depending on the sedimentation rate. Of all these zones, methane production is restricted to the carbonate zone.

The exact process involved for the formation of methane is not known, but it is believed that reduction of carbon dioxide by biologically produced hydrogen is the single most important mechanism (Claypool and Kaplan, 1974). The chemical equation representing this process is:

$$CO_2 + 4H_2 \longrightarrow CH_4 + 2H_2O$$

The hydrogen in the anaerobic ecosystem is assumed to be produced by specialized organisms that catalyze energetically unfavourable oxidation, such as:

$$\underset{\text{(Ethanol)}}{CH_3CH_2OH} + \underset{\text{(water)}}{HO_2}$$

$$\longrightarrow \underset{\text{(Acetic acid)}}{CH_3COOH} + \underset{\text{(Hydrogen)}}{2H_2}$$

and by fermenting bacteria that can produce hydrogen instead of a more reduced organic compound. Both processes are accelerated if hydrogen-utilizing species are also present (methane-producing bacteria). The removal of hydrogen from the system favour further organic degradation by these hydrogen producing bacteria. The methane bacteria depend largely on interspecies electron transfer in the form of dissolved hydrogen as their energy source (Claypool and Kaplan, 1974).

In the sulphate reducing environment methane is not forming possibly because the hydrogen sulphide found in this zone is toxic to methane bacteria and at the same time there is no free hydrogen available for CO reduction in the presence of dissolved sulphate.

METHANE OXIDATION AND CEMENTATION OF MARINE SEDIMENTS

The recent cementation of marine sediments and species into rock which looks like beach rock involves oxidation of methane gas followed by the precipitation of the carbonate cement in the pore spaces. The oxidation of methane occurs when oxygen or sulphate bearing waters penetrate into shallow gas reservoirs or when methane migrates upward into overlying diagenetic zones (Hovland et al, 1987). The process occurs either in an anoxic environment, where methane is assumed to be utilized as an energy source by sulphate bear-

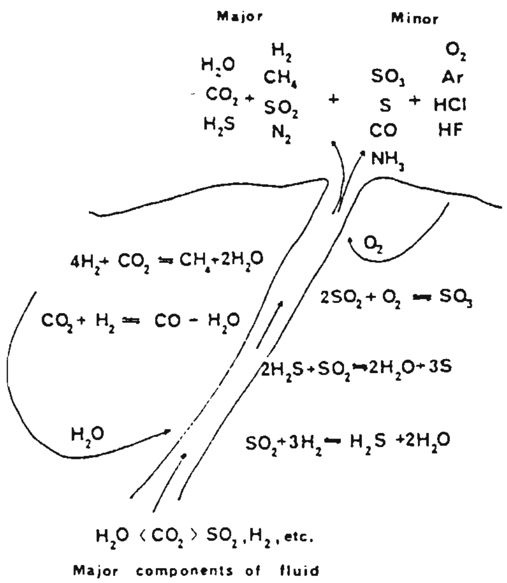

Figure I. Some chemical reactions in a fumarolic conduit. (Lyon, G.L., 1974)

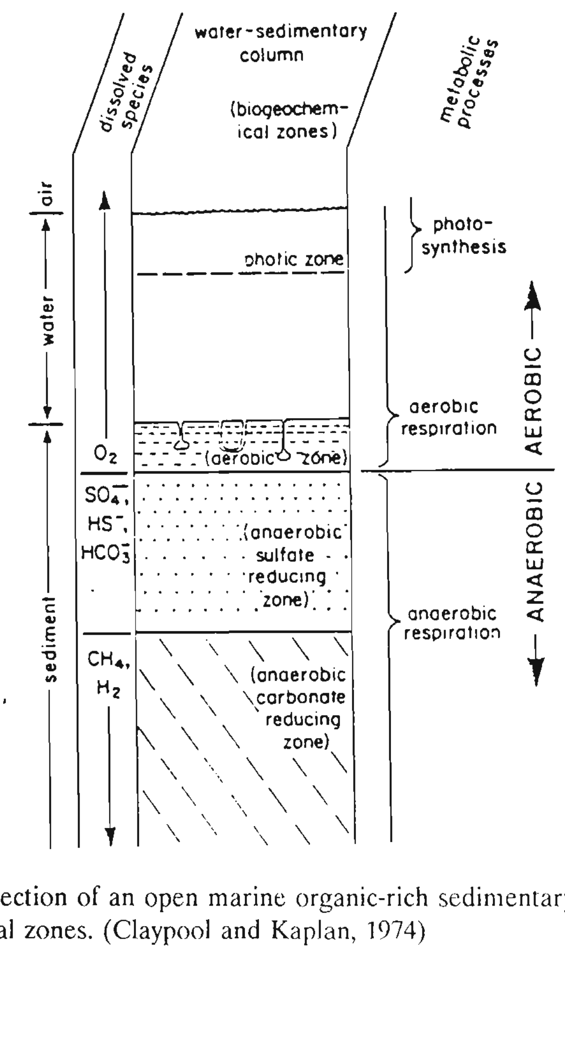

Figure II. A section of an open marine organic-rich sedimentary environment showing biogeochemical zones. (Claypool and Kaplan, 1974) ing bacteria, or in oxic environments through the activities of aerobic methane oxidizing bacteria. This thinking is supported by Rudd and Taylor (1980), Reeburgh (1983), Iversen and Jorgensen (1985) and Whiticar and Faber(1986) as quoted by Hovland et al (1987).

Under normal conditions methane diffuses slowly upwards, through the marine sediment column and first encounters the sulphate reducing bacteria which consume the gas molecules. Excess methane if present will enter the zone of aerobic bacterial activity. In the zone of aerobic bacterial activity the oxidation of methane is carried out by marine bacteria called microaerophiles. These bacteria require oxygen concentration of more than 1 - 3 Mg/liter (Rudder and Taylor,1980). Such a low oxygen concentrations should prelude methane oxidation on the floor of shallow, well-mixed seas like the north sea. The process of oxidation is supposed to take place within the pores of the near-surface sediments.

The oxidation of the methane in the anoxic zone is believed to take place beneath the sediment - water interface near the base of the sulphate reduction zone. The process is often accompanied by early formation of pyrite. On the other hand the anoxic condition usually favours the preservation of organic material (Gautier, 1985). The carbonate precipitated in this zone therefore frequently has pyrite association with it and the host sediments are relatively enriched in organic matter. The precipitation of carbonate cement is assumed to be due to raise in pH of the pore water caused by the oxidation products of methane. The calcium (Ca) which forms part of the cement comes from sea water.

Jorgensen, N.O. (1976) believed that the precipitation of interstitial cement is the result of supersaturation of the pore fluid with respect to both aragonite and Mg-calcite. The carbon that takes part in the formation of the carbonate cement at least in part originates from oxidized methane conveyed by methane-enriched meteoric water. The whole mechanism involved as proposed by Jorgensen (1976) is expressed by these chemical equations:

$$CH_4 + SO^{2-}_4 \longrightarrow CO^{2-}_3 + H_2S$$

Whereby:

$$CO^{2-}_3 + H_2O + CO_2 \longrightarrow 2HCO^-_3$$

The hydrogen sulphide (H_2S) generally escapes as gas or reacts with metal-ions in solution. The bicarbonate (HCO^-_3) formed rises the alkalinity of the water (pH) leading to carbonate precipitation. The carbonates (interstitial cement) with a wide range of C^{13} (Carbon thirteen isotope) values are therefore expected due to mixing with isotopically heavier CO_2 as well as possible subsequent fractionation. That is why along the Danish coasts, the C^{13} values for the cementing materials were found ranging between -25 %. and -55 %. PDB (Jorgensen, 1976) as compared to -40 %. to -80 %. PDB for pure methane.

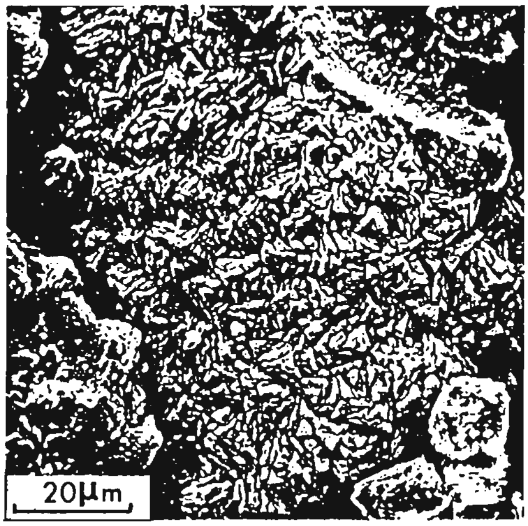

Fig. III. Mg-calcite aggregate from carbonate cemented sandstone from Frederikshvn, Denmark (Jorgensen, N.O., 1976)

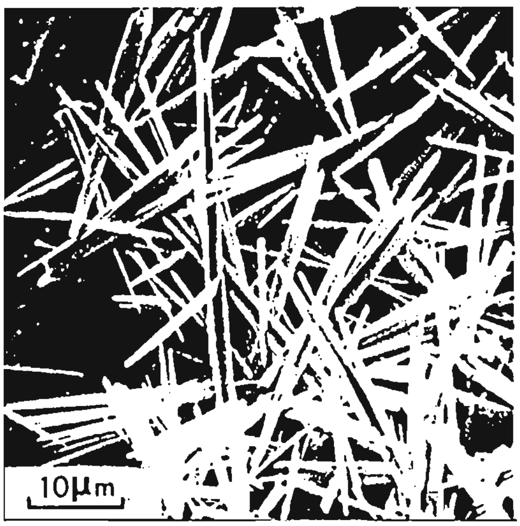

Figure IV. Aragonite needles in carbonate cemented shell breccia from the beach of Sublaek, Denmark. (Jorgensen, N.)., 1976)

Beach rock, according to Jorgensen (1976), results of carbonate precipitation that takes place when the meteoric water meets the marine brine in the topmost part of the beach sediments. The chemical processes involved are believed to be restricted to relatively closed environment of the pore system. The question whether aragonite or Mg-calcite is precipitated has been experimented and found to be ruled by the concentration of the Mg^{2+} in the solution (Monaghan and Lytte, 1956 and Katz, 1973 as quoted by Jorgensen, 1976). The critical point of the Mg^{2+} concentration in water for the precipitation of aragonite or calcite at normal temperature and pressure was suggested by Lippmann (1973) to be 0.01M. Aragonite is supposed to precipitate at a high molarity greater than 0.01M Mg^{2+} while calcite precipitation occurs below that concentration. Seawater has a molarity of 0.054M Mg. Hence favours the precipitation of aragonite. Jorgensen (1976) strongly believes that Mg-calcite is the primary phase formed by the precipitation of the outflowing bicarbonate-enriched meteoric water and the formation of aragonite is caused by the higher nucleation rate of that polymorph when proper nuclei are present (ie mollusc shells). This explains why aragonite cement is restricted to sediment bodies of accumulated marine shells and Mg-calcite is usually poor in marine fossils (fig.III & IV). Because aragonite precipitation is favoured in seawater condition, its cement is relatively stable in normal marine environment as compared with that of Mg-calcite. The calcite cemented materials are commonly found preserved under marine clays due to the low permeability of those sediments preventing an immediate dissolution. Under seawater environment, in the absence of clay sediments, magnesian calcite is preserved only for a short time (Jorgensen, N.O., 1976).

CONCLUSION

Methane is a hydrocarbon belonging to the paraffin group with a chemical formula CH_4. It originates from both microbiological and thermocatalytic decomposition of organic matter. It is among the gases associated with volcanic and geothermal activities. In marine sediments it occurs in different physical states as either in dissolved state, or as free gas bubbles, or in a solid form as gas hydrates.

Radiocarbon-dating technique and carbon isotope analysis have confirmed that the carbon forming part of the aragonite and Mg-calcite in the beach rock and related marine sediments is from methane. The formation of these polymorphs involves oxidation of methane followed by production of bicarbonate. Methane is utilized as an energy source by bacteria during oxidation process. The process takes place either in anoxic environment or in oxic condition. The precipitation of the carbonate cement in the interstitial spaces is the results of the raise in the pH (alkalinity) of the pore water.

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FIRST CIRCULAR

GENERAL INFORMATION

Place and Date

The Organizing Committee of the 29th International Geological Congress (IGC), authorized by the Japanese National Committee of Geology, in collaboration with and under sponsorship of the International Union of Geological Sciences (IUGS), has the honor of inviting you to participate in the

29th SESSION OF THE INTERNATIONAL GEOLOGICAL CONGRESS IN THE KYOTO INTERNATIONAL CONFERENCE HALL FROM 24 AUGUST TO 3 SEPTEMBER 1992

The Congress site, Kyoto International Conference Hall, is located in the northern part of Kyoto City, the ancient capital of Japan.

President of the 29th Session of the IGC

Kiyoo Wadati, Japan Academy, Tokyo Geographical Society

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Conditions for Membership in the Congress

According to the Statutes of the Congress, no professional qualifications are required in order to register for the Congress. In filling the quotas for the geological excursions organized before and after the Congress, however, priority will be given to persons engaged in geological studies or in the practice of a branch of the earth sciences.

Registration Fees

	Preregistration	On-site registration*
Participating member	¥ 45,000	¥ 55,000
Accompanying member	18,000	22,000
Student in 1992	15,000	18,000
Non-attending member	15,000	——

*Currency exchange rate as of March 1990 is US$ 1.00=¥150.

The prices quoted are subject to revision in the event of changes in the world economic conditions; however, it is the intent of the Organizing Committee to maintain the registration fees at or below those quoted above.

The fees include the rights to attend scientific events associated with the Congress, to receive Congress publications, and to take part in social events especially organized for the Congress.

First Circular Response

Please return the Preliminary Questionnaire by 15 July 1990. Those who reply after 15 July 1990, will still receive the Second Circular. Early responses are important to the Organizing Committee because they aid in setting the Science Program, Field Trips, and Short Courses and Workshops.

Geohost

Geohost is a program that will explore ways of helping to defray expenses for individual attendees in need of assistance. The program may include subsidizing registration fees (and/or field trip fees), travel expenses, and beds during the period of the meeting. The funds are expected to come from various international, governmental and private donors for these purposes. Persons interested in contributing to this program should write to the IGC-92 Office.

Travel and Visa

Registrants from outside Japan are encouraged to contact their local travel agent or air carrier regarding travel to Japan.

Registrants who are not Japanese nationals should contact their travel agent or the Japanese Embassy in their country regarding the need for visas to enter Japan. Field trip participants who anticipate entering South Korea or the Philippines during the Congress are advised to obtain multiple-entry Japanese visas.

Accommodations in Kyoto

Hotels, ranging in size and rates, have been reserved in Kyoto. Some are within walking distance, while others are a ride on public transport or a taxi ride from the International Conference Hall. A Japanese Inn (Ryokan) is a hotel in the Japanese style, with a 'Tatami' matfloor and a 'Futon' bed; meals are commonly served. Hostel-type rooms are also being held in some of the temples, youth hostels, governmental dormitories and 'Minshuku (private house providing lodging and meals)' for those who would prefer this type of accommodation.

Hotel room rates cannot be quoted firmly until the third circular, but will range between ¥5,000 and ¥25,000 per night, not including meals, but with taxes and service charges. Breakfast and dinner as well as taxes and service charge are included in the rate of most Japanese Inns. Hostel-type rooms will be considerably less expensive, but will not include meals.

Appointment of Official Delegates to the Congress

National Committees and/or appropriate authorities of participating countries will appoint delegates (in accordance with article 5.7 of the statutes) to represent them on the Council of the Congress, which will sit for the duration of the session.

30th Session of the Congress

At the 28th IGC in Washington, D.C., U.S.A., July 1989, the Geological Society of China extended an official invitation to host the 30th Session in the People's Republic of China in 1996. This proposition will be examined at the Council meeting of the forthcoming 29th Session in Kyoto in 1992.

29TH INTERNATIONAL GEOLOGICAL CONGRESS
KYOTO, JAPAN, 24 August—3 September 1992

PRELIMINARY QUESTIONNAIRE

PLEASE RETURN THIS FORM TO:

IGC-92 OFFICE
P.O. BOX 65
TSUKUBA, IBARAKI 305, JAPAN

BEFORE 15 JULY 1990

Please complete this questionnaire in capital letters and check the boxes.

NAME Ms. ☐ Mr. ☐ ____________________
(Family Name) (Given Name)

ORGANIZATION: ____________________ TITLE: ____________________

ADDRESS: ____________________
____
(City) (Postal Code) (Country)

My attendance at the Congress is ☐ Very probable ☐ Probable ☐ Unlikely

In 1992, I plan to register as ☐ Participating member ☐ Student member ☐ Accompanying member ☐ Non-attending member

Numbers of accompanying persons: Adults ______ Children ______

CLASS OF HOTEL DESIRED: (Per day, including tax and service charge)	A (¥25,000–15,000)	B (¥15,000–12,000)	C (¥12,000–9,000)	D (¥9,000–5,000)	Dormitory
Number of single rooms					
Number of double rooms					

CLASS OF JAPANESE INN DESIRED (Per day and per person including tax and service charge, breakfast and dinner included in A, B and C)	A (¥25,000–15,000)	B (¥15,000–10,000)	C (Minshuku) (¥10,000–8,000)	D (¥6,000–5,000)
Number of single rooms				
Number of double rooms				

Currency exchange rate as of March 1990 is US$1.00=¥150.

Scientific Program

Symposia: Please list symposia numbers for which you might submit abstracts. Use numbers in the First Circular.

	1st	2nd	3rd	4th	5th
Oral Presentations					
Poster Sessions					

If you might present papers not covered in symposia listed in the First Circular, please write the titles and topical fields.

____
____

Short Courses and Workshops: Which topics are you interested in and wish to participate in ? Please note the themes or fields of interest to you.

____
____

Field Trips: Please list the numbers of field trips which you might attend. Use the numbers in the First Circular.

	1st	2nd	3rd
Field Trip A (Pre-Congress)			
Field Trip B (During-Congress)			
Field Trip C (Post-Congress)			

Are there any areas not covered in the First Circular that are of special interest to you?

____
____

____________________ Signature ____________ Date

ONEROUS BEDDING PRESENTS CHALLENGE TO CUT-AND-COVER TUNNELLING PROJECT

GEOTECHNICAL IMPLICATIONS OF THE DUNDEE INNER RING ROAD STAGE XII

By M. Kam (James Williamson & Partners). Maarten Kam graduated from Delft University of Technology, Department of Mining and Petroleum Engineering, in 1988. Since 1990 he has worked as a Graduate Engineering Geologist for James Williamson & Partners, now part of the Mott MacDonald Group, and has been involved with the Dundee Inner Road Stage XII since construction in October 1990.

The final stage of the Dundee Inner Ring Road is being constructed. The route includes a 450m long excavation through Devonian lavas and sedimentary deposits, of which 150 metres will be a cut-and-cover tunnel. Highly variable ground conditions, resulting from faulting and different weathering properties of the rocks encountered, and unfavourable orientation of low shear strength bedding planes in the sedimentary sequences present onerous geotechnical conditions for both the contractor and the designer of the project. In this context, the activities of the geotechnical consultant are discussed.

Introduction

The city of Dundee is situated on a hill side on the northern banks of the Firth of Tay, on the east coast of Scotland (Figures 1 & 2). The city, which recently celebrated its 800th anniversary, is currently upgrading its image and seeking to develop its role as a centre of commerce in the region.

The necessity for traffic management improvements has been recognised for quite some time. The construction of sections of the Inner Ring Road commenced in the 1960s and their opening coincided with the completion of the Tay Road Bridge in 1965. Over the years, additional sections of the dual carriage way were completed, providing satisfactory links between the arterial roads. For a period there was no pressing requirement to complete the final, most complex stage.

Towards the end of the 1970s, increased traffic demands confirmed the need for construction of the final stage of the Inner Ring Road. This stage would include two new roundabouts, a level junction with traffic lights, a 140m long embankment and a 450m long rock cut (Figure 3). The cut would be 22m wide, with a maximum height of 14m, and roofed over a length of 150m. In the years that followed two public inquiries were held, planning permission was obtained and properties along the proposed road alignment were purchased.

Earlier ground investigations, carried out in 1969 and 1983, had not yielded any congruent picture of the complex geology, and in 1989 Tayside Regional Council (TRC) commissioned Glasgow based civil engineering and geotechnical consultant James Williamson & Partners (JWP) to design and supervise a comprehensive site investigation.

Geological Desk Study

The published regional map of the solid geology (Figure 4) indicates the presence of Lower Devonian sedimentary rocks at the locality of the site and possibly igneous rocks. Dundee is situated on the northern flank of an anticline, the axis of which runs parallel to the Sidlaw Hills, and little structural folding was anticipated. Faulting, however, is a widespread feature in the region and the previous ground investigations indicated that a major fault intersects the road alignment in the Hilltown area.

Site Investigation (SI)

The 1989 SI comprised 13 boreholes, seven of which had piezometers installed in them, and 7 trial pits to aid in interpreting the geology along

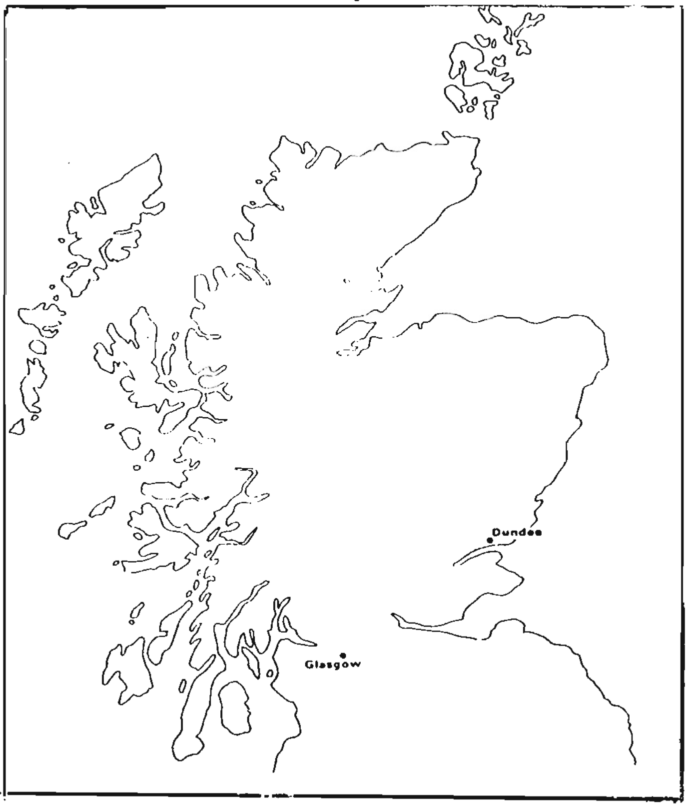
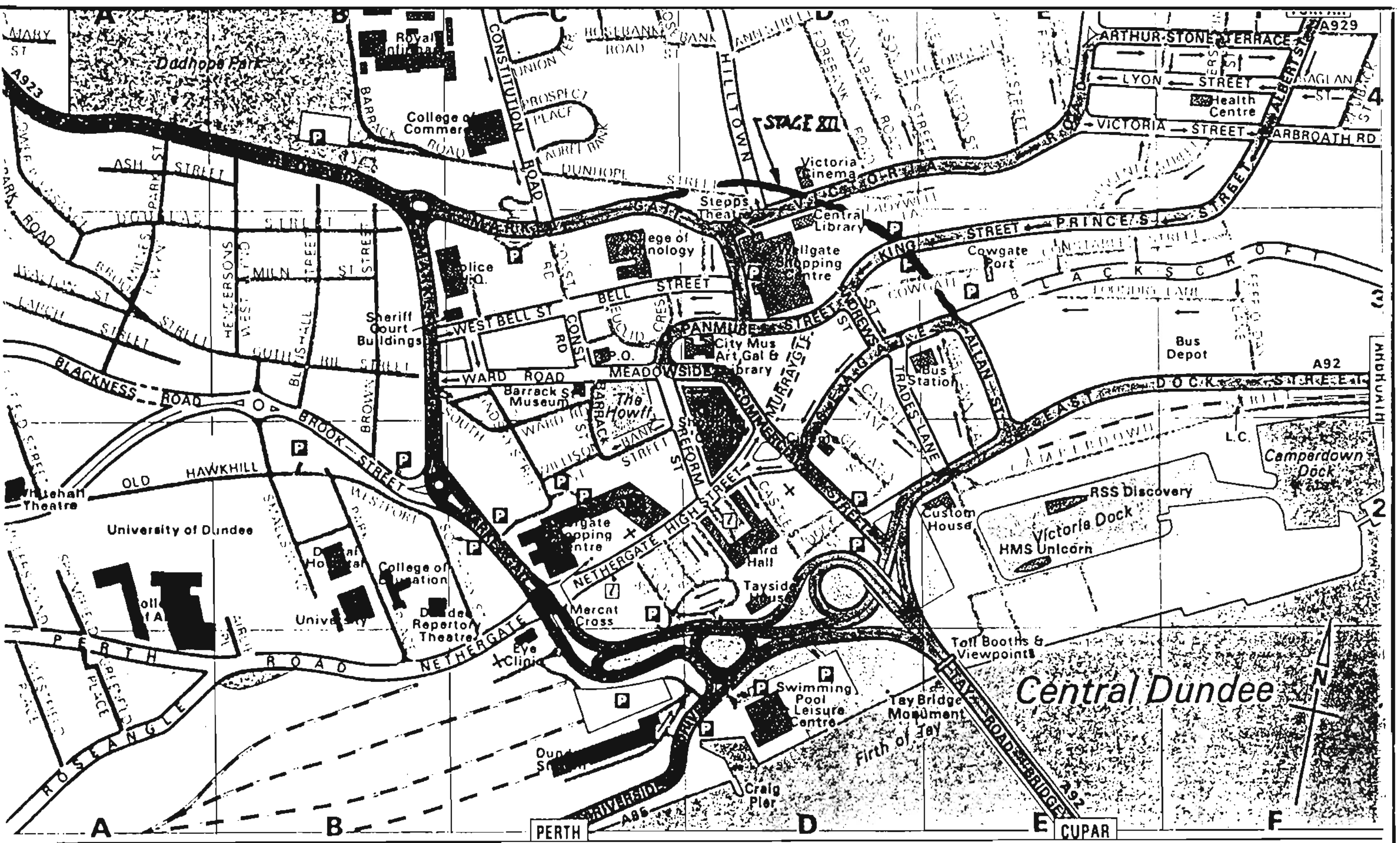


Figure 1 Dundee, situated on the east coast of Scotland



Brook Street A3-B3-B2 | Mary Ann Lane E2-E3 | Walton Street A3

Figure 2 Dundee City Centre, with Stage XII in the north-eastern corner

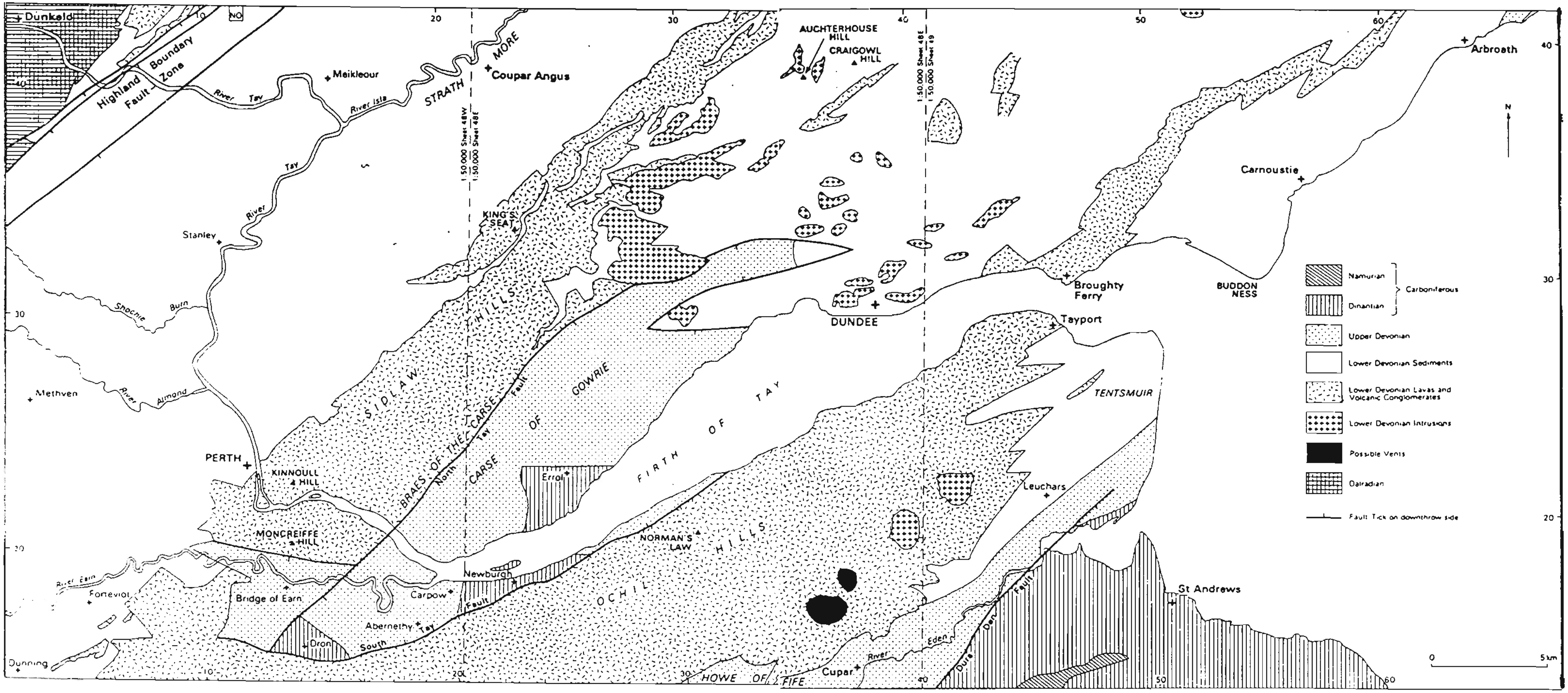


Figure 4 Solid geology of the Perth and Dundee District
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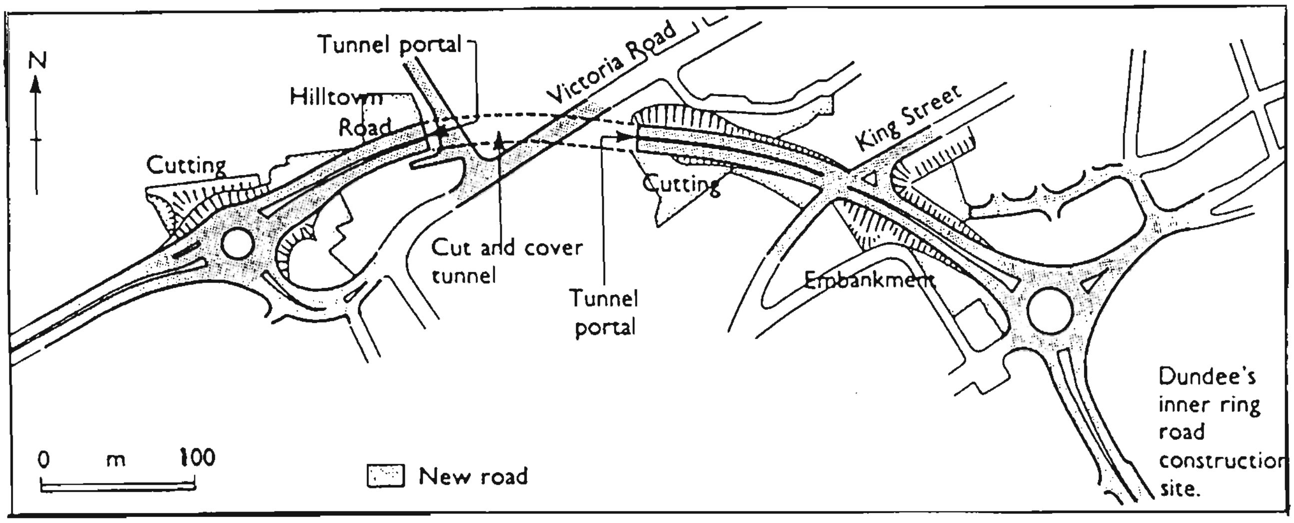

Figure 3 Stage XII of the Inner Ring Road

the proposed route. Disused water wells were known to be present in the area; 4 borehole packer tests were carried out to assess the permeability of the rock mass, in particular in the vicinity of the major fault zone. Two trmxl anchors were installed and tested to investigate the suitability of anchors as temporary support. Furthermore, blast trials and excavatability assessments, including inter-borehole sonic velocity tests and rock mass classifications, were carried out to establish the most effective method of excavation.

The results from the SI were presented in an interpretive report. Interpretation of the geological data revealed the presence of a sedimentary-igneous-sedimentary sequence; the igneous rock consisting of andesitic and basaltic lavas, deposited conformably between interbedded lacustrine sandstone, siltstone and mudstone sequences (Figure 5). These rocks, which form part of the extensive terrestrial deposits of the lower Old Red Sandstone Formations, were found to dip 20° to 30° south. Planar, clayey bedding planes within the sedimentary rocks, with exceptionally low friction angle values, had been tested during the 1983 investigation and it was apparent that there was a serious potential for sliding failure along the bedding in the north face of the excavation.

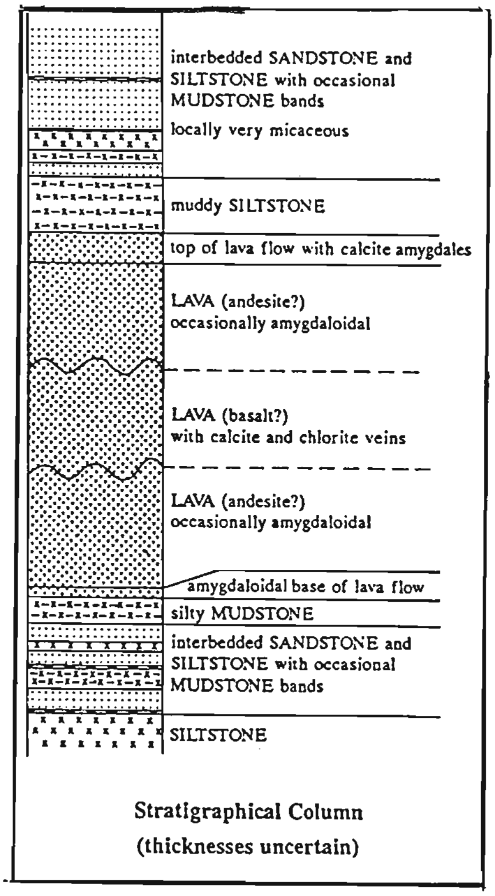

figure 5 Stratigraphy of rock types encountered on the site.

Weathering characteristics of the different rock types varied considerably and the presence of faults, which had been established from a number of boreholes, increased irregularity of the rock head profile, yet, in order to generate a geological model consistent with the data, additional faults had to be postulated. These varying ground conditions could have implications for the method of excavation adapted.

The conclusions presented in the interpretive report served as a design basis for the support designs, which were carried out by TRC. Due to the presence of the unfavourable bedding features, closely spaced anchor patterns were designed as temporary support and substantial concrete retaining structures were chosen for the permanent support. JWP carried out the independent check of both designs.

Excavation and Construction

Before excavation commenced in October 1990, a traffic management programme was devised to cope with the disruption of normal traffic flow patterns in the City Centre.

The contractor, Shanks & McEwan, chose to excavate overburden and bedrock using excavators and hydraulic hammers; blasting was employed only for driving some of the sewer tunnels. Due to the sensitive location of the site, a number of constraints have been imposed on the works. In order to take up as little ground area as possible, a rock cut with vertical faces had been proposed, which involved more elaborate stabilisation measures. There is very little space available to the contractor outside the road alignment and consequently temporary storage of construction material and construction of reinforcement steel works all have to take place within the site, while access to the excavation and construction locations also has to be maintained. A main sewer, crossing the alignment below Hilltown, had to be diverted. This involved the construction of three new manholes and the driving of a 30m long tunnel. These excavations provided some of the earliest exposures of the geology on site, and because they were located within the Hilltown fault zone, the initial mapping results were difficult to interpret.

As the excavation progressed the true extent of faulting became evident; a total of 12 possible fault structures have been identified over a length of 400m. It is probable that not all planar features with highly weathered and altered rock represent true faults; 'pseudo faults', may reflect ancient veins of volatile volcanic fluids and gases. In engineering terms, however, these pseudo faults my be considered as faults.

The fault zone in the Hilltown area (Chainage 250m area) extended over a width in excess of 20m and revealed complex interior faulting with blocks of disrupted and brecciated lava and sedimentary deposits. This resulted in a lateral succession of sedimentary-igneous-sedimentary-igneous rock over a 27m long section in the south face. Mineralisation with haematite and calcite, associated with the fault, has been extensive and several barite veins were also encountered. The abundant presence of haematite in the rock mass and the groundwater has stained most of rock mass in this area of the site red, which has hampered identification of the exposed rock types.

The SI indicated that groundwater would be encountered within two metre of ground level, and high groundwater flows were expected within the Hilltown fault zone. During excavation, however, the water table in the rock faces appears to have been drawn down rapidly and significant water ingress has only been observed at the invert level of the excavation. It was noted that groundwater levels vary greatly over short distances. This may reflect that some faults, particularly those in igneous strata which often contain high amounts of clay minerals, provide lateral aquitards.

Unfavourably dipping sedimentary rock dominates the cut in the Chainage 270-340m area. As a result of these onerous geotechnical conditions, the contractor was initially only allowed to excavate and install temporary support over a length of not more than 15m, without erecting the permanent reinforced concrete retaining structure and backfilling the void between the rock face and the structure with concrete. This restriction allowed little flexibility in the programme of the works within this section of the cut. As the rock was being excavated and geotechnically assessed, and additional shear strength testing on rock samples was carried out, it proved possible to partly relax this restriction. The contractor was then able to carry out excavation works along the upper part of the north face and the full height of the south face of the excavation without interruptions.

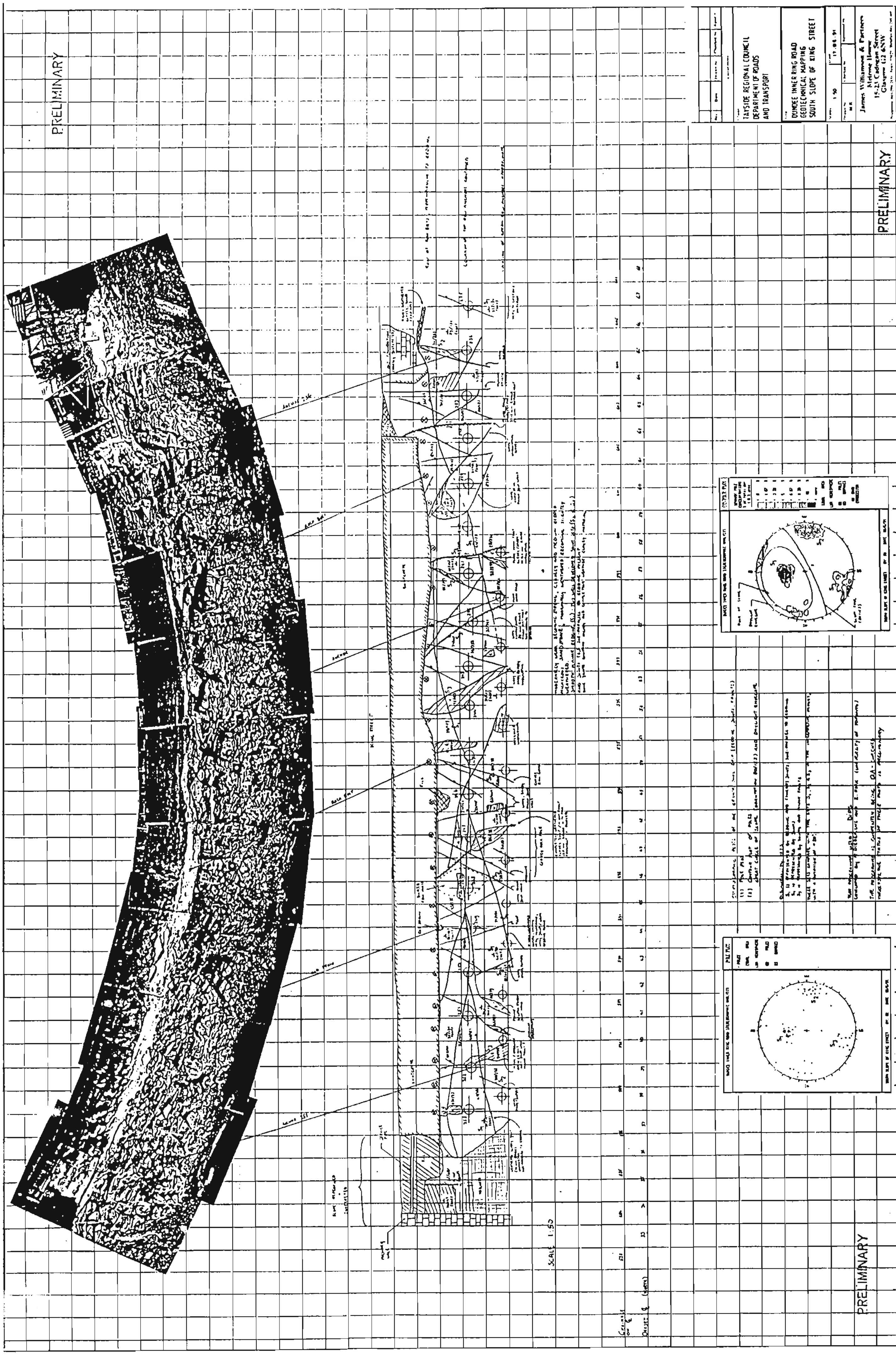

Figure 6 Example of a composite geotechnical drawing of a rock face

Geotechnical Aspects

During the construction phase, JWP have been providing specialist geotechnical consultant services to TRC. Foremost, their assistance involves monitoring and mapping of the geology as it becomes exposed and comparing it with the conditions predicted in the interpretive report, which served as the basis for the designs, and subsequently report to TRC. Furthermore, situations or features that could jeopardise the integrity of the excavated faces or present safety hazards to the employees on site are brought to the supervising engineer's attention without delay.

In order to efficiently convey the geotechnical information, formal Site Visit Reports are issued to the supervising engineer. These reports include log sheets, which present information on lithology, rock strength, degree of weathering, dominant joints and joint sets present in the rock face and presence of water. They are drawn on squared paper on a 1:50 scale, with each square representing $1m^2$ of rock face. To facilitate the extraction of information relevant to the designers, 'interpreted logs' are provided; copies of the 'factual' log sheets with important features, such as potentially weak bedding planes, potential wedge configurations and high ground water flows, highlighted with fluorescent pens. A-0 size drawings (Figure 6) are subsequently issued to TRC. These present compiled log sheets and photographs of the rock face, together with stereographic plots of the discontinuities encountered in the faces. It should be recognised that large areas of rock face are rarely exposed at one single time, as temporary support, (anchors, dowels and meshed shotcrete), is installed as soon as possible upon exposure. Due to this short exposure of the rock, the logs, photographs and drawings represent the only records of the rock faces.

Present Development

Completion of the final link in the Dundee Inner Ring Road is programmed to take place in October 1992. Some delay has occurred in the sewer diversion, which has retarded advancement of the western excavation across Hilltown. The eastern end of the excavation is at present within the sedimentary rock of the cut-and-cover section, where the previously mentioned relaxation of the 15m restriction should assist the contractor to make up time.

At either end of the traverse roundabouts are being constructed, services installed and road finishes applied, whilst landscaping of the areas outwith the route is due to commence shortly.

Conclusions

Both from a civil engineering and a geotechnical point of view Stage XII of the Dundee Inner Ring Road is a challenging project. The location of the site within a highly urbanised area imposes a range of restrictions on the works that would not apply at a rural site.

The project is to a great extent dictated by the geology; hence fast feedback of observations to the designers is essential.This requires close liaison with the designers, to achieve effective means of presenting relevant information.For this project, the pragmatic approach adopted has accomplished this successfully.

Acknowledgement

The author acknowledges the efforts of the JWP geotechnical team and wishes to express his thanks to TRC site staff and in particular to the Resident Engineer, Mr T. Smith.

References

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The 1993 ISRM International Symposium 21-24/06/1993

Safety and Environmental Issues in Rock Engineering

Problèmes de Securité et d'Environnement en Mécanique des Roches

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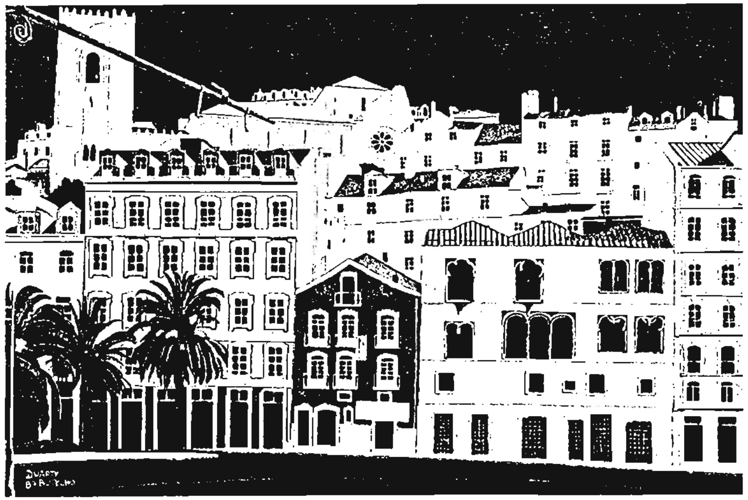

2nd International Workshop 25/06/1993

Scale Effects in Rock Masses

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Sociedade Portuguesa de Geotecnia

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Bulletin 1

Call for Abstracts

International Symposium

SAFETY AND ENVIRONMENTAL ISSUES IN ROCK ENGINEERING

FOREWORD

The theme chosen for the Symposium reflects the concern of society about questions of safety and environmental protection, which are deeply related to Rock Engineering activities. It is the purpose of the Symposium to provide the opportunity for presentation and discussion of ideas on those questions.

There will be four sessions on specific themes. Each session will have the contribution of guest specialists on the theme, followed by the presentation of papers submitted to the Symposium. Specialized workshops will be organized, where guest speakers will introduce their own points of view, in order to promote discussion. Relevant papers submitted to the Symposium may be selected for presentation in the workshops.

SYMPOSIUM THEMES

T1 – Modelling in Safety Evaluation

Methodologies for safety evaluation; simulation of discontinuous media; probabilistic methods; modelling and control of groundwater flow; models for mechanical and hydromechanical behaviour; dam foundations; interpretation of monitoring data.

T2 – Influence of the Environment in Rock Engineering

Global environmental effects; heat and mass transport in fractured rock; contaminant migration; waste disposal; underground storage of waste, hydrocarbons and energy; control of vibrations.

T3 – Stability of Large Underground Structures

Rock mass characterization techniques; rock salt mechanics; design of tunnels and caverns; blasting and TBMs; monitoring and data analysis; maintenance.

T4 – Contribution of Failures and Incidents to the Progress of Rock Engineering

Hazard scenarios in Rock Engineering; criteria for the detection of incidents and failures; deterioration of dam foundations; instability of underground structures and rock slopes; case histories.

SPECIALIZED WORKSHOPS

W1 – Uncertainty, Reliability and Risk

W2 – Back-Analyses in Rock Engineering

W3 – Expert-Systems as a Tool for Safety Evaluation

W4 – Fluid-Rock Interaction and Grouting

The Workshops will be grouped in two periods, each of them will include two workshops in simultaneous sessions: W1 and W2 in the first period; W3 and W4 in the second.

PLACE AND DATE

The Symposium will take place at LNEC's conference centre in Lisbon, Portugal, from 21 to 24 June 1993.

CALL FOR PAPERS

Papers on the Symposium themes are invited. Abstracts of about 300 words and no more than two figures in English, French or German should be received by the Organizing Committee by 30 September 1992, together with the final wording of the title, as well as the address and Fax number of the authors. The authors will be notified by 15 November 1992, whether their Abstracts have been accepted. Final papers must be received by the Organizing Committee by 28 February 1993.

OFFICIAL LANGUAGES

English, French and German are the official languages of the Symposium. Papers may be written and presented in any of the three languages. Simultaneous translation from French and German into English will be provided. The Specialized Workshops will be in English.

TECHNICAL TOURS

During the Symposium, technical tours will be organized. A provisional list is:

TT1 – Aguieira and Castelo do Bode arch dams (full day)

TT2 – Neves-Corvo underground mine (full day)

TT3 – Lisbon Subway (half day)

TT4 – Visit to the LNEC (half day)

TECHNICAL EXHIBITION

Indoor and outdoor space will be available for exhibition of equipment and documentation. Organizations interested in the exhibition are asked to complete and return the preliminary registration form by 30 September 1992.

ISRM BOARD, COUNCIL AND COMMISSION MEETINGS

According to the ISRM By-Laws, the Symposium will host the Board, Council and Commission Meetings. They will be held on Saturday and Sunday, 19-20 June 1993.

SOCIAL PROGRAMME

The social activities for the participants will include a reception by the Lisbon Municipality, a boat trip on the River Tagus, and the Conference Banquet.

A full programme will be organized for accompanying persons, including sightseeing tours and visits to places of historical importance around Lisbon, as well as the social activities for the participants.

POST-SYMPOSIUM TOURS

Post-Symposium tours will be organized, starting on Saturday, 26 June 1993.

CORRESPONDENCE

All correspondence regarding the Symposium should be directed to the Organizing Committee, to the following address:

Luís Ribeiro e Sousa
EUROCK '93
c/o LNEC
Av. do Brasil, 101
P-1799 LISBOA CODEX
PORTUGAL

Phone: (351) 1 8482131
Fax: (351) 1 897660
Telex: 16760 LNEC P

The 1993 ISRM International Symposium

SAFETY AND ENVIRONMENTAL ISSUES IN ROCK ENGINEERING
PROBLÈMES DE SECURITÉ ET D'ENVIRONNMENT EN MÉCANIQUE DES ROCHES
SICHERHEITS- UND UMWELTSFRAGEN IM FELSBAU

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21-24/06/1993

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Lisboa – Portugal

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THE SECOND TUNISIAN MEETING ON APPLIED GEOLOGY

May 17-19, 1993
Sfax (Tunisia)

ORGANIZED BY

Association Tunisienne de Géologie Appliquée

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Symposium TAAG Secretariat :
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Bulletin N°1

April, 1992

Deuxièmes Journées Tunisiennes de Géologie Appliquée

The Second Tunisian Meeting on Applied Geology

Sfax (Tunisia) 17-19 Mai 1993

Participation Form

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Paper title/ Titre de la note..
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THE SECOND TUNISIAN MEETING ON APPLIED GEOLOGY.

The Tunisian Association of Applied Geology takes pleasure in inviting you to attend the The second Tunisian meeting on applied geology.

OBJECTIVES OF THE SYMPOSIUM.

Recent advance in geology is described, by which a real revolution has been obtained. In fact concepts and methods have changed and now, geology is not considered only as descriptive science but is also extended to the field of exact science in many of its applications. Indeed, geological researches are presently conducted by interdisciplinary approach and by technics which have increased the precision of the results and have permitted a better exploration of these results. However, access to samples and to analyses technics and the exploration of results require high technology and investment, which are partly missed in many applied research institutions.

In this way the TAAG organizes the second symposium on applied geology to point out the recent knowledges evolution in this domain and to discuss possible future orientation for the applied geological researches.

Thus, this symposium is an occasion for scientists to present their recent works, to exchange their ideas, knowledges and experiences and to have information on the progress in used methods and technics.

Considering the great contribution of geology in many vital and sensitive domains, we hope to orientate this symposium toward applied researches especially on works in urban areas, water and environment research, energetic and mine materials, geological tools and cases in environment and management fields.

PLACE AND DATE.

The symposium will take place in Sfax, the second town of Tunisia, from **17 to 19 May 1993**, at the Ecole Nationale d'Ingénieurs de Sfax (ENIS). Participants will be welcomed as from Sunday 16 May, either at Tunis (the capital of the country), or at the aeroport of Sfax.

OFFICIAL LANGUAGES.

The official languages of the symposium will be English and French. No simultaneous translation will be provided. Papers and discussions have to be presented in French or in English.

CALL FOR PAPERS.

Prospective authors who wish to submit papers are requested to submit a summary of their project to the secretariat of the symposium by **30 september 1992**.

The authors should :

- write in French or in English;
- limit their summary to about 200 words typed in double space.

The selection of papers will be made by the scientific committee by **31 october 1992.** The authors of the selected papers should submit the full and final text to the organizing committee by **31 january 1993** (papers must be preparated according to instructions to be given at a later date). The final acceptation and definitive program should be sent to the authors by **31 mars 1993**.

TRANSPORT, RECEPTION, ACCOMODATION.

Most of the airlines compagnies pass throw Tunis. The airport of Sfax is weekly served by direct flights from Paris, each Thursday and Sunday.

Sfax is connected to Tunis by a train three times a day; it takes approximately 4 hours to cover the 300 km separating the cities.

Tunisia is equiped with hotels of an international level. For Sfax, existing hotels offer a very avantageous services, with prices ranging between 15 and 50 US \$. Detailed prices and hotels categories will be provided in the Bulletin N°2.

REGISTRATION FEES.

The registration fee is as follows : (1 Tunisian Dinar ≈1 US \$)

Participants	100 DT
Students	60 DT
Accompanying persons	70 DT

The registration fee includes :
- participation in the symposium and proceedings of the symposium;
- 3 lunches (served at the restaurant of the university) and coffee breaks;
- welcome cocktail;
- closing dinner;
- transportation between Sfax hôtels and ENIS.

The companion fee includes :
- special programme;
- lunches and coffee breaks;
- welcome cocktail and closing dinner.

SOIL REINFORCEMENT WITH GEOSYNTHETICS

By L.F. Contreras. Mr. Contreras is a civil engineer from Colombia, working for Integral S.A., consulting engineers in Medillin, currently he is following the MSc. course Engineering Geology at ITC-Delft.

INTRODUCTION

Soil reinforcement and ground improvement techniques were in practice in the past. Reinforcement was used by Babylonians more than three thousand years ago to build ziggurats. Romans constructed reed-reinforced earth levees along the Tiber River. Introduction of modern fabrics for road construction was made as early as 1926 by South Carolina Dept. of Highways in USA. Use of synthetic materials in civil engineering constructions began in the late fifties for coastal work in The Netherlands, and in the sixties modern uses of soil reinforcement appeared with the development of reinforced earth retaining walls in France and with the use of geotextiles for stabilization of roads in several countries. Today the use of geosynthetics for various purposes in geotechnical works is widely accepted which is manifested by the availability of new products and the organization of International Comitees and conferences on the subject. This paper initially presents a brief summary of basic concepts related with the characteristics of synthetic materials used in construction engineering, including types, functions and properties. Then, a description of the use of these materials for soil reinforcement is presented, including type of applications and design criteria for two of the most common types of reinforced structures (reinforced slopes and reinforced soil walls).

GEOSYNTHETIC MATERIALS

Geosynthetics are defined as thin, bidimensional, flexible, anticorrosive and non-biodegradable elements made of synthetic polymers, which are manufactured to be installed in the ground in order to modify its engineering behaviour. Some geosynthetics, like geotextiles, can fulfill several functions when installed in the ground and consequently have a wide range of applications. Others are intended to accomplish specific functions such as reinforcement (geogrids), drainage (geodrains) or water retention (geomembranes). This factor has an effect on the production volumes and consequently on the cost of the various products.

Raw materials

The biodegradability characteristics of the natural fibres has led to the use of plastic materials for the manufacture of geotextiles. Plastics are synthetic organic materials, based on carbon, and generally obtained by chemical processes. Plastics can be divided into two main groups: the thermoplastics which can be softened and rehardened by heating and cooling, and the thermosets which can not be resoftened once they have hardened. Thermoplastics are the raw material of geosynthetics. These materials are composed by large molecules (polymers) which in turn are build up from a large number of small and uniform molecules called monomers. The most common polymers used in the manufacture of geosynthetics are: polyamides (nylon), polyesters and polyolefins (polypropylene and polyethilene).

Each raw polymer has its own strengths and weaknesses. The polyamides have great resistance to abrasion and to chemical attack but in wet environments they can loose strength. Polyesters have great strength and resistance to creep and are chemical stable but are sensitive to basic compounds when the pH is above 11. The polyolefines have high resistance to chemical attack but relatively low modulus of elasticity.

Geotextiles

Geotextiles are fibrous materials used to improve soils. These materials are made of elements such as individual fibres, filaments, yarns, tapes, etc, that are long, small in cross section and strong in tension. They are characterized by their flexibility, tensile resistance and porous nature. Their fibrous character is an important feature as it appears that it is in this way as the highest tensile resistance from a material is obtained. This fact is associated with a high degree of molecular orientation which is obtained by stretching or drawing with polymers or by natural growth in natural fibres.

Synthetic fibres are the most common type of fibres used in geotextiles and geogrids, nevertheless according to the definition given above they could be made of natural fibres such as flax or jute, giving products that might be suitable in situations where the long term stability is not important as in temporary works.

According to the manufacturing process, two main types of fabrics can be distinguished: woven and non-woven fabrics.

Woven fabrics

They are flat structures of at least two sets of threads obtained by conventional weaving processes using a mechanical loom. One of the sets is referred to as the warp, running in a lengthwise direction, and the other, the welft, running across. The common types of threads used are monofilaments, tapes, fibrillated film yarns and multifilament yarns. Combinations of them in a particular fabric are possible. The resulting structures are typically one millimeter thick and with a regular distribution of pores.

Non-woven fabrics

These are structures produced by bonding or interlocking of staple fibres, monofilaments or mutifilaments, accomplished by mechanical, chemical or thermal means. The mechanical bonding is achieved by means of barbed needles and for that reason the resulting fabric is termed 'needlepunched'. Thermal bonding imparts cohesion to the web by fusion of the filaments at their cross-over points. Chemical bonding generally follows a needling process and involves the addition of a chemical binder, commonly acrylic.

Functions

The geotextiles can fulfill the following functions when in contact with water, soil and/or stone:
- Separating: The geotextile separates layers of different physical properties (grain size, density, consistency).
- Filtering: The geotextile retains fine particles when the water flows from fine to coarse grain materials.
- Draining: The geotextile (non-woven) itself functions as a drain because it has a higher water transporting capacity than the surrounding materials.
- Reinforcing: The geotextile increases the stability of the soil mass by adding strength.

Geogrids

Geogrids are polymeric lattices made from extruded sheets, whose fundamental function is ground reinforcement. The raw materials are polypropylene or high density polyethilene (UV stabilized). The polymer sheets are first perforated, the form, size and distribution of holes being determined by the end product. The perforated sheets are then stretched in the lengthwise direction, which results in the extension of the polymer. In this way the long chain molecules are also orientated in the lengthwise direction and a uniaxial grid is obtained, which is used for reinforced soil structures. When in a second stage the sheet is stretched in the crosswise direction, the polymer is reorientated and a biaxial geogrid is produced which is used for ground stabilization. Normally the openings of the geogrids are larger than the soil particles with which they are associated, resulting in favourable conditions for the soil-reinforcement friction characteristics.

Properties

They can be grouped in three categories:
durability, mechanical and hydraulic properties.

Durability

Refers to the ability of the geosynthetic to maintain with time a required degree of integrity. This presupposes that the geotextile or geogrid has been selected on the basis of being sufficiently robust to endure the rigmxrs of handling and installation associated with a particular service environment. If there is some inevitable form of degradation then its rate must be assessed with a view to allowing for it in the design. Some of the tests used to assess the durability of a geosynthetic include: resistance to chemical attack, ultraviolet light stability, abrasion resistance, resistance to biological attack, tear and puncture resistance, etc.

Mechanical properties

They can be grouped in tensile load-deformation characteristics and soil-geosynthetic interaction characteristics.

The tensile load-deformation characteristics can be divided in short term and long term:

Short term tensile characteristics are determined by axial tensile tests performed at a constant rate of strain. The measured tensile strength and particularly the rupture strain are a function of many test variables, including sample geometry, strain rate, temperature and confinement applied to the geotextile. In figure 1, sketches corresponding to some common test arrangements are presented together with the typical tensile force-strain curve obtained. In general woven fabrics are strong and stiff, with tensile strengths up to 100 kN/m and rupture strains around 12%. In contrast non-woven fabrics tend to have tensile strengths in the range of 5 to 20 kN/m and rupture strains around 120%.

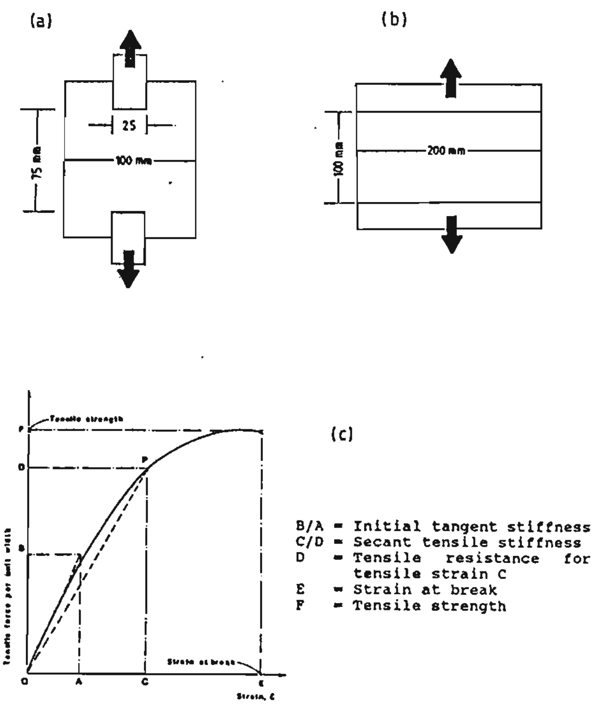

Figure 1. Tension tests for geotextiles. (a) Grab method (ASTM D-1682, DIN 53858). (b) Wide strip method (ASTM D-4595). (c) Typical tensile force per unit width-strain curve.

Long term load deformation characteristics refers fundamentally to the occurrence of creep. In figure 2 a group of conventional creep curves is presented for different stress levels. The sample at the highest loading will come to ducti,e failure first, with the time to ductile dcreep increasing as the applied load decreases. It is important that excessive deformations do not occur in the geosynthetic during the design life of the structure and for that reason the strain is limited to some predetermined value during the design.

The soil-geosynthetic interaction characteristics refers to the determination of the parameters associated with friction between the two materials. These parameters are important in reinforcement applications. They can be evaluated using either direct shear tests or pullout tests. Results are presented as a plot of maximum apparent shear stress versus normal stress. In figure 3, test arrangements and typical results are presented.

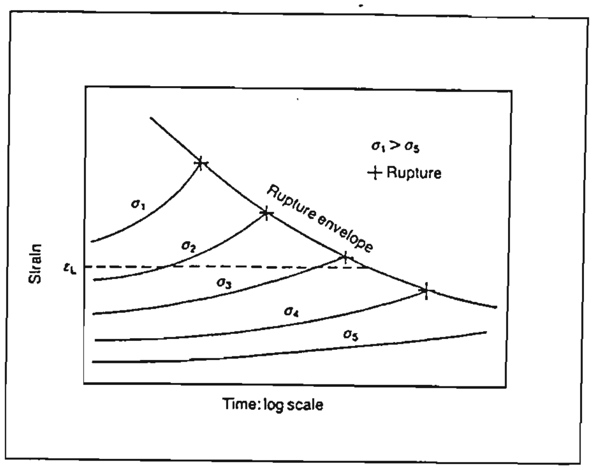

Figure 2. Generalised creep curves for geotextiles. (From ref. 9)

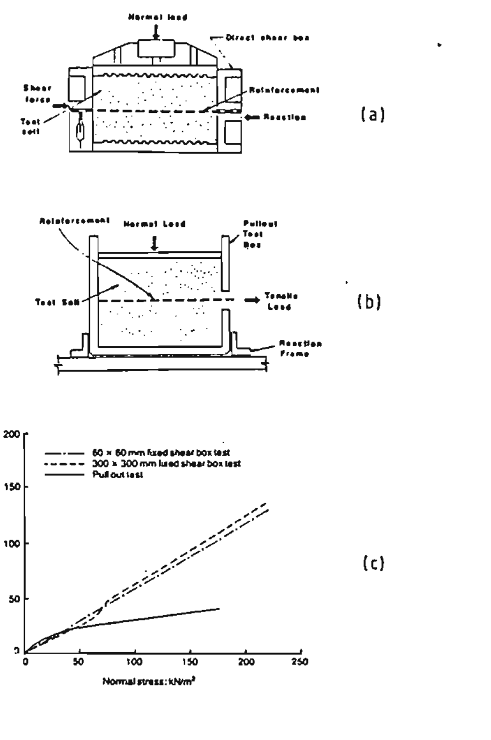

Figure 3. Measurement of reinforcement-soil interaction characteristics: (a) Direct shear test. (b) Pullout test. (c) Typical results (heatbonded non-woven geotextile). (From ref. 9)

Direct shear tests model the condition of soil sliding over the reinforcement. Depending on the soil and geotextile characteristics, the angle of interface shearing resistance (δ) measured in a direct shear test is less than or at most equal to the angle of internal friction of the soil (ϕ). The value is rarely less than 3/4 ϕ and is often close to unity. Pullout tests model conditions associated with reinforcement slip. The pullout test failure mechanisms is appropriated for the determination of the required reinforcement embedment length.

Hydraulic properties

They are directly related to filtration and drainage functions of geotextiles. Filtration properties are related to the porometry characteristics which can be evaluated by means of tests such as the Apparent Opening Size (AOS) and the Equivalent Opening Size (EOS). Drainage properties are related to the permeability characteristics which are determined by means of permeability tests, wherein the flow rate of water through the fabric in a direction normal to its plane is measured.

SOIL REINFORCEMENT

Soil reinforcement with synthetic materials can be classified in different ways. According to the relative size of the reinforcing elements,micro-reinforcement and macro-reinforcement can be distinguished. The soil reinforced structures can be grouped according to their fundamental function in earth structures and load supporting structures. According to the location of the reinforcement within the structure this can be localized or distributed. In this paper design aspects will be described only for earth structures with distributed macro-reinforcement.

Types of soil reinforcement

There are two basic types of soil reinforcement:

1. Microreinforcement.

This type of reinforcement is achieved by mixing into the soil, small, usually randomly oriented reinforcing elements such as staple fibres, filaments, yarns and minigrids. Because the individual microreinforcing elements influence a relatively small volume of soil, a very large number of these elements is needed. Typically the amount of reinforcement is less than 1% by weight of the amount of soil. Reinforcement elements are small and have large surface areas and consequently they are in contact with many individual soil particles. There is an analogous action to that of soil stabilization with admixtures such as cement or lime, where ideally every soil particle is in contact with the stabilizing agent. However the fundamental difference is that stabilization with admixtures is due to chemical reactions resulting in soil cohesion whereas microreinforcement is based on mechanical interaction (friction and passive resistance).

2. Microreinforcement

In this case the reinforcement is achieved by placing into the soil elements that are large compared to the soil particle size. These elements include strips, bars, grids and fabrics. Individual macroreinforcing elements influence a relatively large volume of soil and consequently a limited number of these elements is needed. Typically the number of macroreinforcing elements varies from one or two for embankments on weak foundations, to 20 or more for large reinforced earth walls.

Types of reinforced soil structures

As already mentioned, the main types of reinforced soil structures can be grouped into two main categories:

Earth structures

They include reinforced slopes, soil walls and embankments on weak foundations. They do not normally support significant external loads, and the primary design consideration is the stability of the structure under its own weight. In figure 4a sketches of these types of structures are included.

Reinforced slopes and soil walls are typically constructed with alternating horizontal layers of compacted soil and reinforcement. With reinforced soil walls and very steep reinforced slopes, a facing may be necessary to prevent localized surface erosion and sloughing along the exposed side of the reinforced soil mass. Many types of facings can be used. Two of the most common include concrete panels (segmental or full-height) and "wrap around" facings (obtained by wrapping the reinforcement around the vertical face of the adjacent compacted soil layer). In these applications, the role of the reinforcement is to add tensile strength to the soil mass and to increase soil strength through increased soil confinement. In this way it is possible to construct steeper and higher stable structures than would be possible without reinforcement.

In the case of embankments on weak foundations, one or several layers of reinforcement are placed at or near the base of the embankment, and then, the rest of the structure is constructed in the conventional manner. When the foundation is uniform (soft clay or peat deposits), the object of the reinforcement is to increase the factor of safety against sliding along a slip surface through embankment and foundation, and to reduce lateral movements and cracking. When the foundation is locally weak (peat lenses or sinkholes) the effect of the reinforcement is to bridge the weak spots (membrane effect and soil arching promotion) in order to reduce the risk of localized failure and differential settlements.

Load supporting structures.

They include flexible pavements, unpaved roads and railroad track structures. These structures are usually stable under their own weight, and the primary design consideration is the structure's ability to support the applied loads (usually traffic loads) with limited deformation. In figure 4b this type of structures is illustrated.

In this type of applications, one or more layers of reinforcement are incorporated at various levels in the road structure, either at the base/subgrade interface, in the baselayer, or in the asphalt surface course. In railroad track structures, reinforcement is placed at the ballast/subgrade interface or within the ballast layer. In these cases the main purpose of the reinforcement is to reduce lateral and vertical aggregate and subgrade movements caused by traffic loads. In addition the reinforcement might accomplish a separation function, preventing penetration of aggregates into the subgrade soil and in this way improving the long term behaviour of the structure.

Design considerations

Structures with localized reinforcement, such as embankments on weak foundations, are almost always designed by adding the contribution of the reinforcement to a classical design approach. Design of structures with distributed reinforcement (micro and macro-reinforcement) consider the external stability of the entire structure acting as a monolith as well as the internal stability of the reinforced mass. External stability is usually checked using classical limiting equilibrium methods. For the internal stability two approaches are possible which are described next.

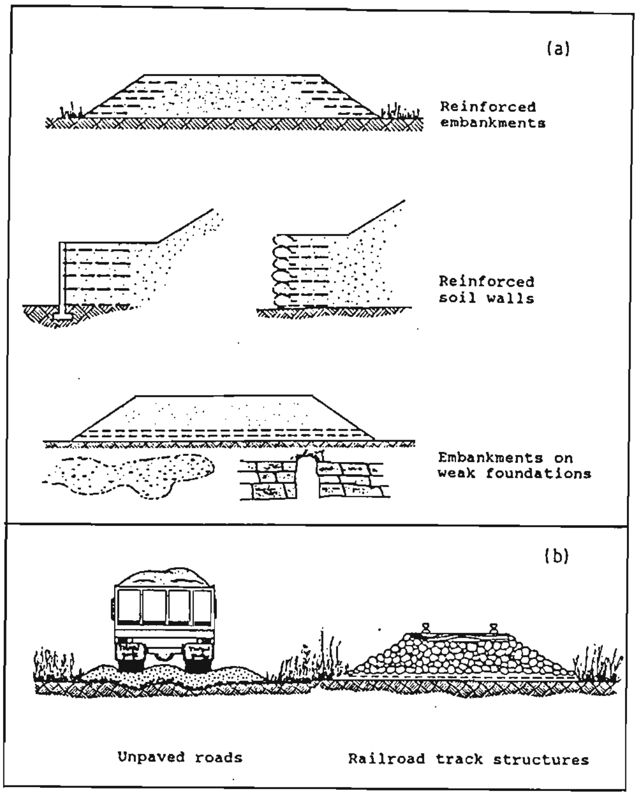

Figure 4. Types of reinforced soil structures. (a) Earth structures. (b) Load-supporting structures. (From ref. 12).

Design approaches

The two basic design approaches are:

1. The global approach, which involves analysis of the behaviour of an equivalent continuum having definable mechanical properties. This approach is used almost exclusively for soils with microreinforcement since measurement of the properties of these soils can be performed on samples of relatively small size. Also, the mechanical properties of this type of reinforced soil is more or less isotropic, enabling the use of classical methods of analysis.

2. The discrete approach consists of analyzing stress transfer between soil and reinforcement. With this approach, classical soil mechanics design methods can be used by incorporating the reinforcement effects into the appropriate equations. This approach can be used for both, limit

equilibrium analyses (for example slope stability analyses) and stress deformation analyses (for example finite elements analyses). This approach is almost always used for macro-reinforced soil structures because of the difficulty in evaluating the properties of the reinforced soil material needed for the global approach.

Design criteria for reinforced slopes

The primary design criterion is to guarantee adequate stability against sliding of the soils comprising the slope. Sliding can occur within the reinforced soil mass (internal stability) or outside it (external stability). The parameter used to define the relative stability of a slope is the factor of safety computed for limit equilibrium conditions.

The internal stability is analyzed in order to prevent either reinforcement rupture or reinforcement pullout or a combination of both. Reinforcement rupture can occur if the tensile force required to maintain equilibrium at any elevation within the slope exceeds the available tensile strength of the reinforcement. Reinforcement pullout can occur if the frictional and/or passive resistance forces developed along the length of reinforcement behind the failure surface are less than the tensile forces required to maintain equilibrium.

Reinforcement forces can be incorporated into the slope stability analyses in two ways as indicated in figure 5. These are: (1) the reinforcement is assumed to act as a free body tensile force which does not affect soil strength but which contributes to force and moment equilibrium (fig. 5a) or, (2) the reinforcement is assumed to increase the strength of the slope fill (fig. 5b). With the second assumption the reinforcement force is normally decomposed into vector components normal and tangent to the slip surface. The normal component is assumed to increase the soil shear resistance and the tangent component to act as an extra cohesion along the slip surface. In both cases ß is the assumed orientation of the reinforcement at failure.

A comparison of the two assumptions shows that for circular failure surfaces, the first one is more conservative, although for reinforcement at failure tangent to the slip surface they both coincide. On the other hand, the assumption of horizontal reinforcement at failure produce more conservative results than those for orientation of the reinforcement tangent to the slip surface. So these two considerations (reinforcement action and reinforcement orientation at failure) have different effects on the calculations.

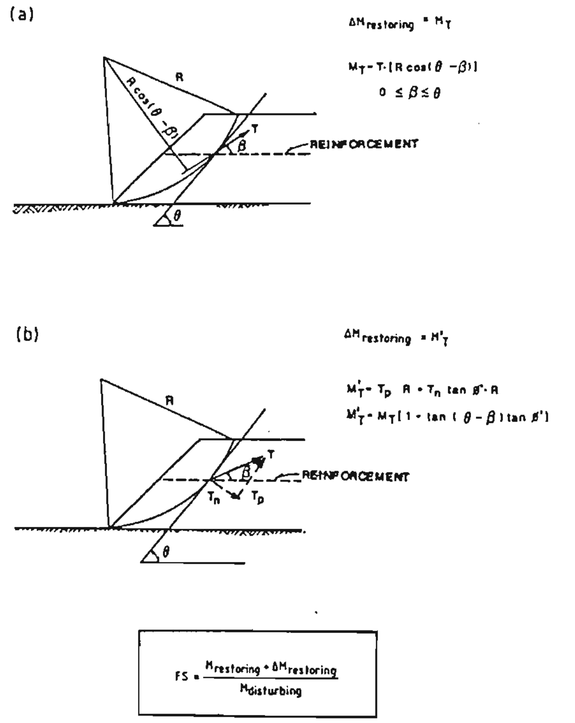

Figure 5. Design criteria for reinforced slopes. (From ref. 12) (a) Reinforcement force assumed to act as independent force. (b) Reinforcement force assumed to increase soil strength.

According to Bonaparte et al [12], the assumption of reinforcement increasing the fill strength together with an horizontal orientation at failure, is recommended for design of slopes with regularly spaced layers of reinforcement. In contrast, for the design of embankments on soft soils, the assumption of reinforcement acting as independent free body tensile force is recommended. In this case a horizontal orientation of the reinforcement at failure is recommended if the foundation is constituted for brittle or sensitive soils, whereas that some degree of reorientation of the reinforcement at failure can be assumed in not so critical situations.

External stability is evaluated using classical methods and considering potential failure surfaces outside the reinforced mass.

For slopes supporting structures, it might be necessary to ensure that the movements required to mobilize the working shear resistance of the soil and the working tensile resistance of the reinforcement, are within the permissible limits of the structure being supported. In practical terms, slope deformations are limited by means of use of well-compacted granular fill and suitably large factors of safety.

Design criteria for reinforced soil walls

The primary design criterion is to guarantee adequate stability which includes prevention of internal and external failure. Again the parameter used to define the relative stability of the structure is the factor of safety calculated for limit equilibrium conditions.

The two most common approaches to the evaluation of the internal stability are the semiempirical coherent gravity method and the tie-back wedge design procedure. The first one is the most commonly used method for design of earth walls with metallic reinforcement. The second is the recommended method [12] for design of soil walls with reinforcement of polymeric materials.

Evaluation of the internal stability using the tie-back wedge method involves the calculation of the lateral earth pressures that must be resisted by the reinforcement tensile forces. The lateral earth pressures are assumed to act on the Rankine failure surface which is also assumed to be the locus of the maximum reinforcement force as indicated in figure 6a. The type, length and number of layers of reinforcement are selected to prevent either their rupture or pullout.

Evaluation of these two internal failure mechanisms using the tie-back wedge method of analysis, (see fig. 6) is carried out using the following steps.

1. The maximum vertical stress induced at every level in the reinforced soil by gravity, surcharges, and the active thrust from the retained fill (fill behind the reinforced zone) is calculated. Classical soil mechanics methods for stress distribution are used in this step. In the equation shown in figure 6b. The vertical stresses induced by the thrust of the retained fill are calculated using the Meyerhof's recommendation for eccentrically loaded footings.

2. The maximum horizontal stress versus depth that must be resisted by the reinforcement is obtained by multiplying the maximum vertical stress by the coefficient of active lateral earth pressure, Ka.

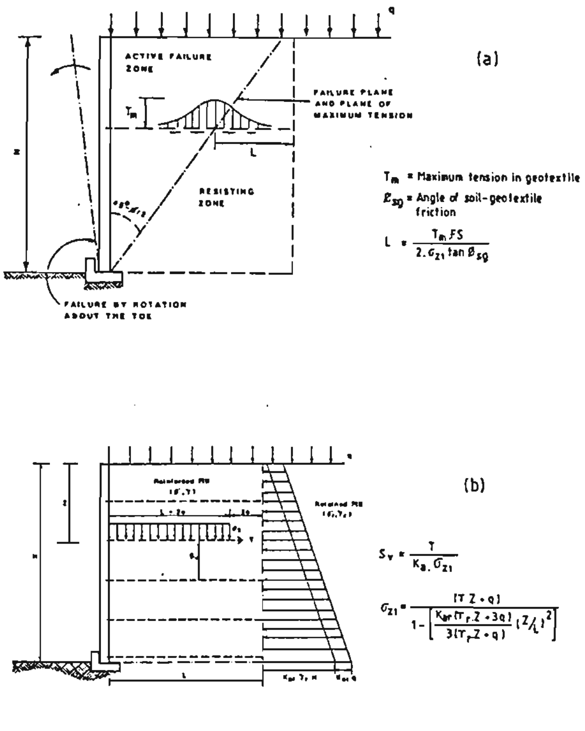

Figure 6. Design criteria for reinforced soil walls. (From ref. 12). (a) Rankine failure surface and calculation of reinforcement anchor length. (b) Vertical stresses behind reinforced soil wall and calculation of reinforcement spacing.

3. The required tensile resistance at any reinforcement level is equal to the maximum horizontal stress multiplied by the vertical spacing between reinforcement layers at the considered level.

4. A reinforcing material is selected and, based on its characteristics, a practical reinforcement spacing and layout is determined.

5. The reinforcement length is calculated based on the required length of reinforcement behind the assumed failure surface to prevent pullout.

External stability is evaluated assuming that the reinforced soil mass acts as a rigid body which resists external loads. It should include analyses of sliding along the base of the reinforced soil mass, overturning, bearing capacity and general slope failure. Classical soil mechanics methods are used for these analyses.

Reinforced soil walls normally have more rigorous specifications regarding permissible deformations, and consequently the movements required to mobilize the working shear resistance of the soil and the working tensile resistance of the reinforcement, should be limited. This is normally achieved by specifying good quality, well compacted granular fills. In some situations it might be advisable to perform a stress-deformation analysis under working conditions, to evaluate soil settlements and wall movements.

CONCLUSIONS

1. Geosynthetic is a generic term applied to all the products manufactured with polymeric materials intended to be installed in the ground in order to modify its engineering behaviour. Geotextiles are products made of synthetic materials(although eventually they might be made of natural fibres), which can fulfill several functions when installed in the ground. Geogrids are geosynthetic products whose fundamental function is to provide reinforcement to the ground.

2. The variety of manufacturing processes and properties of the various polymers commonly used in the geosynthetics industry, has resulted in the availability of a great diversity of products with a wide range of uses as engineering construction materials, and with a variety of mechanical, hydraulic and durability related properties. As a result of this, an important aspect in the design process is the selection of the most suitable product for a particular application. This selection should be the result of a comprehensive evaluation of the relevant material characteristics for the adequate performance of the engineering structure in which they are going to be installed.

3. There are several ways in which geosynthetic materials can be used as soil reinforcement elements, (distributed microreinforcement, distributed macro-reinforcement and localized macro-reinforcement), and there are different types of reinforced soil structures (earth structures and load supporting structures). There is not a unique approach to consider the reinforcement mechanisms. Different assumptions and design methodologies exist, even for a particular type of application, therefore design considerations should be adjusted on the basis of evaluation of behaviour of constructed structures.

It appears that the use of geosynthetic products as construction materials in civil engineering works, constitutes an attractive alternative in many situations, considering costs and technical performance aspects.

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AGID IAEG INQUA

INTERNATIONAL CONFERENCE ON GEOSCIENCE IN URBAN DEVELOPMENT

(LANDPLAN IV)

11–15 August, 1993

Beijing, China

BULLETIN No.1

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by
The Chinese Academy of Sciences

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OBJECTIVE

Urbanization is one of the most dominant aspects of human activity and social development. A series of problems appear in connection with rapid concentration of population and large scale of urban reconstruction. A number of world megacities is faced to serious environmental deterioration and risk of disasters. In addition in many cities the residence, recreation and urban areas are to be expanded. The reconstruction of large number of cities is needed for improvement of the systems of transportation, water supply and waste disposal. The systematic and detailed geoscience study may play an essential part in the investigation and appraisal of both the reconstruction of old cities and the development of new towns by providing a scientific basis for its planning and construction.

The main objective of the proposed International Conference is to offer an opportunity to meet geoscientists, engineering geologists, geotechnical and civil engineers woking in the field of urbanization with focusing on the integrated consideration of geo–hazards, geo–environment and geotechnical conditions for urban planning and development.

ACADEMIC SESSIONS

Symposium A: General Problems

Plenary session A

General Review on Geoscience in Urban Development

Session A1

Instability of Large Cities I:

Natural Disasters–Earthquake, Volcanic Eruption, Landslides and Debris Flow

Session A2

Instability of Large Cities II:

Geo-environmental Change and Induced Geohazards–Subsidence, Ground Cracking, Collapse, Water environment problems

Session A3

Problems in Reconstruction of Large Cities:

Underground Space, Water Supply System, Transportation and Construction of other Infrastructures

Session A4

Pollution and Hazardous Waste Disposal in Large Cities:

Soil and Water Pollution, Waster Disposal, Recreation and Residence Area Planning

Session A5

Engineering Geological and Geo-environmental Investigation for Urban Planning and Construction:

Mapping, Testing and Monitoring Techniques, Evaluation System, Microzonation

Symposium B: Chinese Megacities

Beijing, Shanghai, Tianjin, Nanjing, Xian, Chongqing, Guangzhou, Wuhan, Chengdu,

Lanzhou, etc.

Symposium C: World Magacities

Moscow, Toronto, Tokyo, Paris, San Paolo, Bangkok, Hongkong, etc.

PUBLICATION

The proceedings will be published before the Conference. Full paper should be submitted in time and in a format defined by the Bulletin No.2.

POST CONFERENCE TOUR

There are selected 7 routes for post conference tour including 10 major Chinese cities. Visit to construction and geoenvironmental sites will be organized, number of participants is limited 20, while the tour will be cancelled if the number is less than 4.

T1.
- T1a. Beijing—Xian—Chongqing—Beijing
- T1b. Beijing—Xian—Chongqing—Hongkong

T2.
- T2a. Beijing—Xian—Kunming—Beijing
- T2b. Beijing—Xian—Kunming—Hongkong

T3.
- T3a. Beijing—Xian—Chengdu—Beijing
- T3b. Beijing—Xian—Chengdu—Hongkong

T4.
- T4a. Beijing—Wuhan—Guiling—Beijing
- T4b. Beijing—Wuhan—Guiling—Hongkong

T5.
- T5a. Beijing—Wuhan—Guangzhou—Beijing
- T5b. Beijing—Wuhan—Guangzhou—Hongkong

T6.
- T6a. Beijing—Nanjing—Shanghai—Beijing
- T6b. Beijing—Nanjing—Shanghai—Hongkong(or Tokyo)

T7. Beijing—Tianjin—Tangshan—Beijing

The tour routes will be fixed upon the issue of the Bulletin No.2. The ticket of departure from China should be booked in the international flight. The preliminary estimation of the cost of post conference tour is about US Dollars 600–800.

EXHIBITION

As a part of the conference there will be an exhibition of environmental maps of world megacities and systems of software used in landplan evaluation.

In addition there will be a display of instrumentation for urban environmental management and equipements for geotechnical investigation.

The exhibition is expected to promote the discussion on use of engineering geological mapping and geo–environmental systems for urban planning. The exhibition area may be booked according to special request reached to the Conference Secretariat.

SOCIAL PROGRAM

A social program will be organized for accompany members including visits to sites of historic interest and Chinese ancient cultural and scenic spots in Beijing. And some spcical arrangement may be offered to upon individual requests.

ACCOMMODATION

The accomodation in the Hotel Friendship has been reserved for delegates attending the Conference and should be booked at the time of registration by putting a certain amount of deposit with indicating your preference on the registration form which will be attached to the Bulletin No.2.

VISA

The official invitation for visa will be issued upon the registration or special request made by the deleates attending the conference. The delegates can proceed visa with handling the invitation to the Chinese Embassy or Consulate in their country.

BULLETIN No.2

The detailed information of the conference will be given in the Bulletin No.2. Delegates will receive the Bulletin no.2 upon returning the pre–registration form attached.

DEADLINES

Abstract submission ······················ 31 July 1992
Notice on acceptance of
abstract ······························ 31 Aug 1992
Issue of Bulletin No.2 ·················· 31 Aug 1992
Full paper submission ········· 31 December, 1992
Date for reduced registration fee ··· 31 April, 1992

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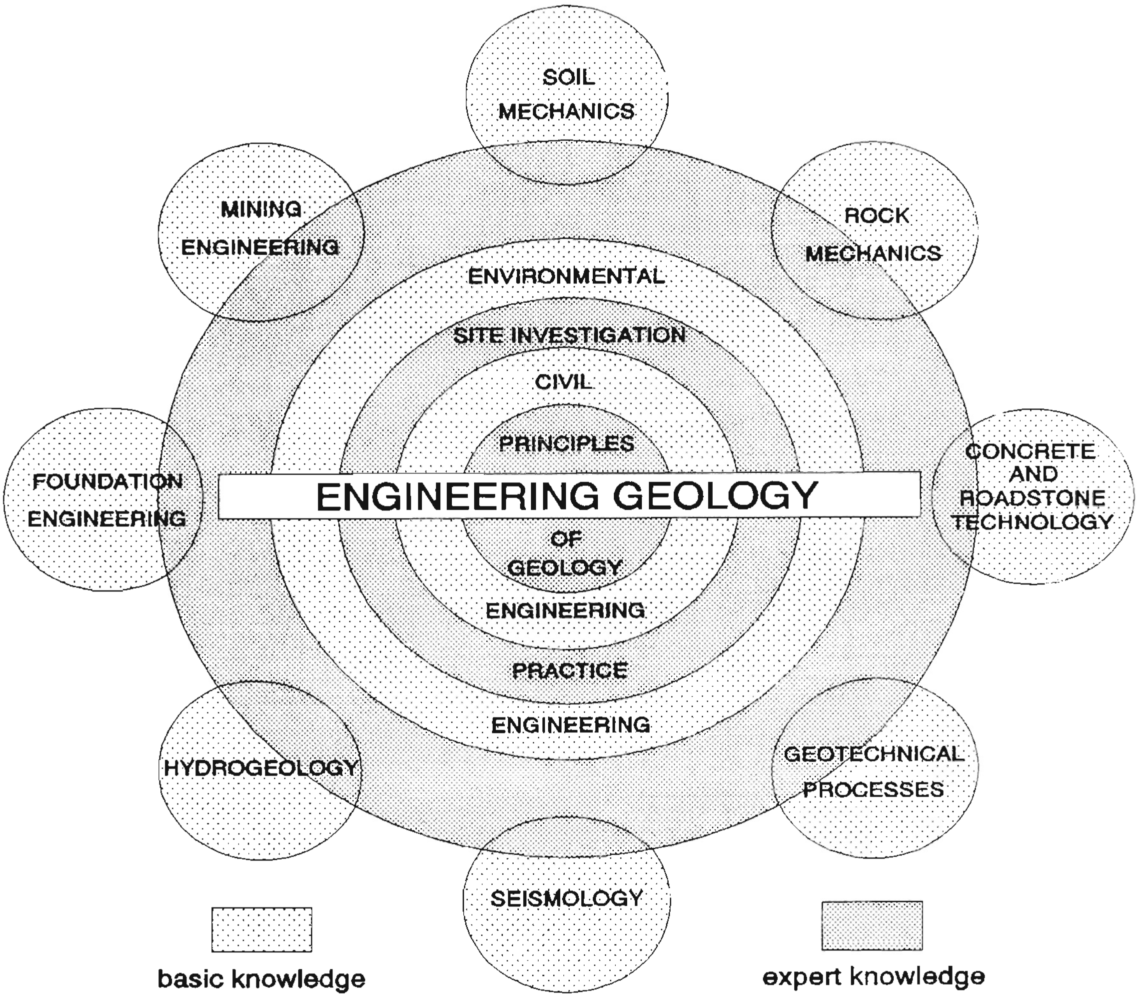

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1992

International Symposium: Engineering Geology of Karst
July 6 - 8
Perm, USSR
Topics: Influence of karst processes on engineering geological properties of rocks; Karst territory stability; Surface and subsurface water interaction with soluble rocks; Forecast methods of karst processes development under industrial, civil and hydrotechnical construction; Rational territory use and environmental protection in karst areas.
Info: Pechorkin, Perm State University, Bukirev St., 15, Perm, 614600, GSP, USSR.

5th International Conference on Underground Space and Earth Sheltered Structures
August 2 - 7
Delft, The Netherlands
Topics: The use of underground space and earth sheltered structures within urban national and environmental development concerning: Planning, Design and use; Construction; Economy; Law and politics.
Info: Congress Office ASD, P.O. Box 40, 2600 AA Delft, The Netherlands, Tel. 015-120234, Fax 015-120250.

International Geological Congress
August 24 - September 3
Kyoto, Japan
Topics: History of the Earth, from its origin to the evolution of island arcs and active continental margins. Origin and evolution of the biosphere. Frontier Geoscience studies for Human Survival, including Research on Energy, Resources, Natural Hazards and the Environment.
Info: Sectary General, IGC-92 Office, P.O. Box 65, Tsukuba, Ibaraki 305, Japan. Tel. 81-298-54-3627, Telefax. 81-298-54-3629. Telex. 3652511 GSJ J.
(zie ook blz. 10 en 11)

Eurock '92 ISRM International Symposium on Rock Characterisation
September 14 - 17
Chester, U.K.
Topics: Site investigation; Input to design; Rock engineering and the environment; Rock properties; Monitoring and back analysis.
Info: Professor J.A. Hudson, Eurock '92, department of Mineral Resources Engineering , Imperial College, London U.K. Fax: (44) 707 375912

GEOTECH '92
September 16 - 19
Tokyo, Japan
Topics: Underground development and engineering exhibition and symposium.
Info: Mitori Kikuchi, Geotech Secretariat, World Import Mart Co Ltd, 3-1-3 Higashi-Ikebukaro, Toshima-ku, Tokyo 170, Japan. Tel: (+81) 3 987 3161. Fax: (+81) 3 987 1248. Overseas Secretariat office: L Roy Wilson Associates Ltd, 8A West Smithfield, London EC1A 9JR, UK. Tel: 071-329 0588. Fax: 071-329 1590.

4th International Conference on the Application of Stress-Wave Theory to Piles
September 21 - 24
The Hague, The Netherlands
Topics: Soil mechanics aspects of stress-wave propagation and/or pile installation; Influence of driving or vibrating piles on the environment; New devolpments testing equipment and vibrators during pile installation; Reliability of predictions based on measurement and interpretation of stress-wave propagation.
Info: Stress-wave Conference, c/o KIVI, P.O. Box 30424, 2500 GK The Hague, The Netherlands. Fax: 070-391840, Tel 070-3919890

Intertunnel
November 24 - 26
Basle, Switzerland
Topics: The theme of this conference is "Tunnels for Transport". Geotechnical sessions on the following topics; Machines and methods - shields roadheaders, full-facers, drill-and-blast, NATM, cut-and-cover, immersed tube, and research and development; Geotechnical topics - site investigation, ground treatment, lining and support, ground movements and measurement; Services - planning, surveying, contractual and legal aspects, materials supply and handling, safety and health; Case histories - design, construction, maintenance and refurbishment of tunnels and underground excavations for the transportation of people, goods, services and materials, including road and rail; management and control of cost, time and quality.
Info: The Institution of Mining and Metallurgy, 44 Portland Place, London WIN 4BR, UK. Tel. (44) 71-580-3802. Fax: (44) 71-436-5388.

1993

The Second Tunisian Meeting on Applied Geology
May 17 - 19
Sfax, Tunisia
Topic: Applied researches on works in urban areas, water and environment research, energetic and mine materials, geological tools and cases in environment and management fields.
Info: Department of Geology, Ecole Nationale d'Ingénieurs de Sfax, P.O. Box W - 3038 Sfax, Tunisia
(zie ook blz. 22 en 23)

19th General Assembly of the ITA
April 18 - 22
Amsterdam, The Netherlands
Topics: Soft ground tunnelling (cut-and-cover methods, underground methods, immersed tunnels and comparative case studies); Rock tunnels (conventionally driven, mechanically driven and comparative case studies); Submerged floating tunnels; General topics (cost optimisation of the total tunnel project, private financing of tunnels, research).
Info: Congress Office KIVI, P.O. Box 30424, 2540 GK, The Hague, The Netherlands, Tel. 1070-3919890. Fax. 070-3919840.

Third International Conference on Case Histories in Geotechnical Engineering
June 1 - 6
St. Louis, Missouri, USA
Info: Shamsher Prakash, Conference Chairman, Department of Civil Engineering, University of Missouri-Rolla, MO 65401-0249, USA.

EUROCK '93, 2nd International Workshop (Scale Effects in Rock Masses)
June 21 - 24
Lisboa, Portugal
Topics: Modelling in Safety Evaluation, Influence of the Environment in Rock Engineering, Stability of Large Underground Structures, Contribution of Failures and Incidents to the Progress of Rock Engineering.
Info: António Pinto da Cunha, Int. Workshop on Scale Effects, c/o LNEC, AV. do Brasil 101, P-1799, Lisboa Codex, Portugal. Tel. (351) 1 8482131, Fax. (351) 1 897660, Telex. 16760 LNEC P.
(zie ook blz. 19 tot/met 21)

International Conference on Geoscience in Urban Devolpment (Landplan IV)
August 11 - 15
Beijing, China
Topics: The main objective of the proposed International Conference is to offer an opportunity to meet geoscientists, engineering geologist, geotechnical and civil engineers working in the field of urbanization with focusing on the integrated consideration of geo-hazards, geo-environment and geotechnical conditions for urban planning and development.

Info: Prof. Wang Sijing, Chairman LANDPLAN IV, Institute of Geology, academia Sinica, P.O. Box 634, Beijing, china 100029. Tel. 86-1-2027729. Fax. 86-1-4919140. Telex. 22474 ASCHI CN c/o Institute of Geology.
(zie ook blz. 33 tot/met 35)

International Symposium on Hard Soils-Soft Rocks
September 20 -24
Athens, Greece
Topics: Geological features; Mechanical properties and behaviour; Foundation, excavations and retaining structures; Slope stability and protection; Fills and embankments; Tunnelling and underground openings.
Info: Dr. N. Kalteziotic, HS-SR Symposium, P.O. Box 20034 GR, 11810 Athens, Greece

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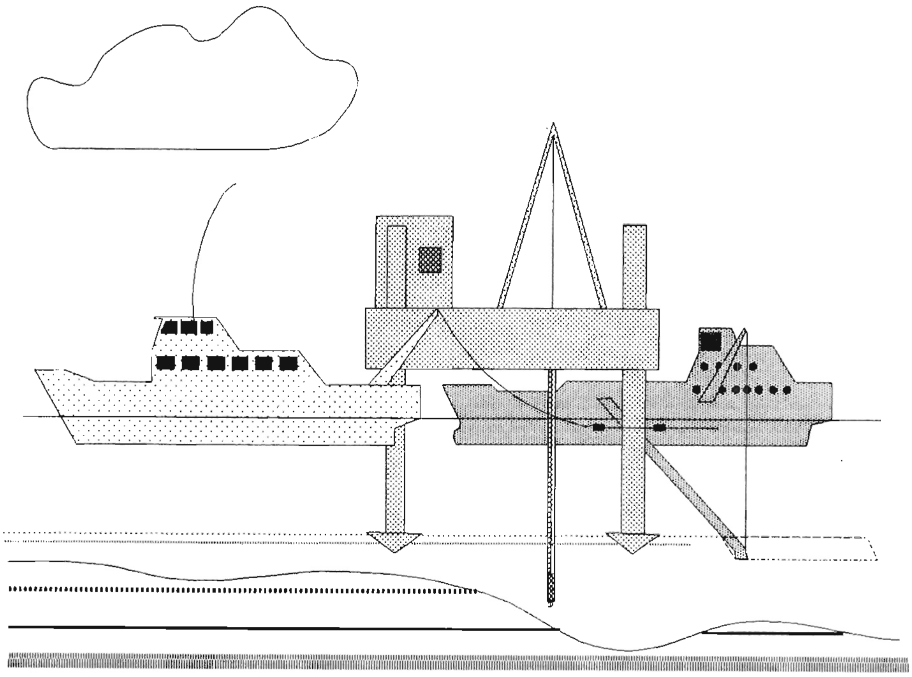

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