Geotechnical engineering in South Africa

The papers in this volume are devoted to geotechnical engineering in South Africa and more particularly to specific problems encountered in this region and their treatment. It is, therefore, appropriate to review the development of the art and science of this branch of civil engineering, with particular reference to the local scene as the introduction to this special issue.

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The development of soil mechanics

From his very earliest beginnings, man has been involved with geotechnical materials (soil, rock and water), either in assessing natural structures or in making his own structures. The art developed slowly by experience gained in practice. In the late 18th century, Coulomb made the first attempt to provide a scientific/mathematical basis for analyzing soil structures (1776). There followed contributions by engineers and researchers including Collin (1846), Rankine (1857), Boussinesq (1876), Mohr (1906), Krey (1918) and Fellenius (1922). Despite these advances in analytical approaches, failures still occurred in structures designed according to these theories, while some apparently arbitrarily designed structures were successful.

The publication in 1925 of 'Erdbaumechanik auf bodenphysikalischer Grundlage' by Terzaghi in Germany has since been recognized as signalling the introduction of a new approach to soil engineering. In all the preceding work, soils had been treated as single phase materials in the same way as timber or iron, but Karl Terzaghi had recognized that soil was a two-phase material consisting of the solid soil or rock particles and water in the pore spaces in the case of saturated materials, or a three phase material in partially saturated materials where the pore spaces contain both water and air. The distribution of applied stress between the phases in the material is all-important in understanding the engineering behaviour of soils. It is often forgotten that Terzaghi's interest in soil mechanics was based on his desire to find a link between geology and civil engineering.

Thus 1925 is generally accepted as the birth date of soil mechanics in the modern concept as a separate specialist branch of engineering. After a spell teaching at the University of Istanbul, Terzaghi accepted a professorship at Harvard University where he was joined by another leading figure in the field, Arthur Casagrande. Simultaneously Prof D W 'Don' Taylor was installed at the Massachusetts Institute of Technology to head the soil mechanics department.

Road engineering relies on the provision of a sound base to carry the pavement and thus it was not unnatural that parallel with the development of classical soil mechanics there were also great advances made in the evaluation of compaction and bearing strength of earth materials. Proctor and others led the field in the USA. Thus soil mechanics was burgeoning in the USA with the subject becoming established in university curricula and significant contributions being made by other exponents of the science and art such as Hvorslev at the US Army Waterways Experiment Station at Vicksburg and Prof W S Housel at the University of Michigan. Soil mechanics as a science was truly established.

The early South African scene

The long distances and the need to cross mountain ranges and escarpments to reach the interior of the country had taxed the ingenuity and skills of engineers in South Africa from the moment that the settlement at the Cape started spreading into the interior. The achievements of the pioneers in this field are epitomized by the achievements of Andrew Geddes Bain, 'the born builder of roads', whose name is commemorated by the Bains Kloof Pass near Wellington, and of his son, Thomas Bain, recently honoured by the publication of the book *A Colossus of Roads*.

It is important to note that although Andrew Geddes Bain had had no formal training in engineering, his intuitive skill in selecting road alignments and constructing mountain passes was supplemented by an avid study of the comparatively new science of geology. In fact he has been named the 'Father of Geology in South Africa.'

In contrast to the northern hemisphere where geologically recent glaciation has covered the earth's surface with vast areas of relatively uniform deep materials which may be analyzed by applying classical soil mechanics theory, the shallow soil mantle found in most parts of Southern Africa brings about a close relationship between engineering behaviour and the underlying geology. Thus it can be seen that from the very beginning an understanding of the geological factors was an essential part of successful geotechnical engineering in this region.

The art and science, as elsewhere, were developed largely from practical experience gained by the state departments responsible for road and railway construction and later irrigation. This situation continued until late in the 1930s. At the end of 1933 a brilliant young civil engineer, J E B 'Jere' Jennings, graduated from the University of the Witwatersrand. His main interests were dams and water, but vacation work on an earth dam had introduced him to the sheepsfoot roller — a new invention then — and to the theories of compaction. This had kindled an interest in soil mechanics and led to his first paper on the subject, 'A few notes on earth dams and the soil mechanics related thereto', being published in the *Journal of the S A Institution of Engineers* in October 1935 — possibly the first paper ever on this specific subject to be published in South Africa.

The award of a Union post-graduate scholarship in 1935 enabled him to study soil mechanics at M I T and also attend classes at Harvard, where he became a firm disciple of Terzaghi. After gaining the MSc degree in engineering and attending the 1st International Conference on

George William Donaldson, *Pr Eng, born in 1928, was educated at the Swartland High School in Malmesbury and later at UCT where he graduated in 1950 with a BSc in Civil Engineering. He joined the Soil Mechanics Division of NBRI and after working on expansive soils for 18 months, was sent to Imperial College in 1952 where he was awarded a DIC. On his return to South Africa, he conducted research into the stability of slimes dams for which his Alma Mater awarded an MSc in Civil Engineering in 1960. His wide experience of all aspects of soil mechanics research in South Africa led to his promotion to Head of the Geotechnical Division of NBRI in 1961 and later to Assistant Director of NBRI in 1980. At the end of 1981 he was transferred to the position of Director, now Chief Director, of the Estate Services Department. He is a Fellow of the Institution and has served on the Committee of the Geotechnical Division and the Council of the Institution for many years and for the last two years has held the post of Honorary Treasurer of the Institution.*

Soil Mechanics and Foundation Engineering which was held in Boston, he spent a further period studying at the University of California before returning to South Africa. In 1937 he joined the South African Railways and Harbours as a junior engineer in the research section. Here he had little time to devote to soil mechanics.

Not long before the outbreak of the Second World War and shortly after the creation of the National Roads Board, the Board had sent two engineers, J H Edwards and A A van Niekerk, to the U S A to attend a three-month course on soil mechanics, while P C Lewis of the Natal Provincial Roads Administration was on a similar tour. The ideas brought back by these men were readily accepted and used in the design of roads. South Africa gained an excellent reputation for the standards of both its highways and low-cost roads.

The advent of the Second World War caused many engineers to don uniforms and proceed to East Africa, the Middle East, North Africa and Italy on military service, while those remaining in the Union were hard pressed to maintain and expand the existing infra-structure, leaving no time for research. This period was by no means all negative, as the need for airfields, roads and the assessment of the 'going' for military vehicles led to advances in apparatus and techniques for evaluating soil properties as well as the development of the accompanying analytical and prediction techniques.

Post-1945

The immediate post-war years saw the greatest advances in geotechnical engineering in South Africa. The teaching of soil mechanics in South African universities was generally at a very low level, covering only rudimentary knowledge in the undergraduate courses and with no provision for post-graduate study. On completion of their military service, several young engineers went overseas for graduate studies, notably D J 'Dave' Henkel to Imperial College, London, under Prof A W 'Alec' Skempton, and B.A. 'Basil' Kantey to the University of Michigan under Prof Housel. At this time L C 'Leslie' Wilson was employed on the construction of the new Jan Smuts Airport and then proceeded to Northwestern University to study soil mechanics under Dr Philip Rutledge.

The Building Research Station at Garston had instituted a Soil Mechanics Division under Leonard Cooling during the 1930s and Alec Skempton had received his early training there as had many who were later to follow to positions of leadership in the U K. When the Council for Scientific and Industrial Research was established in 1945, it was decided to follow the British example and cater for building and civil engineering research in the formation of the National Building Research Institute.

Jere Jennings, who had spent the last years of the war supervising bridge construction in Natal for the SAR & H, was invited to join the staff of NBRI and in August 1947 he was appointed Director.

Despite the many urgent problems where research was needed, Jennings also found time to build up a strong Soil Mechanics Division within the institute by recruiting persons of the calibre of Henkel, Kantey and later Dr Keeve Steyn, who had returned to the Union after studying at MIT. Here was a centre of excellence which was not only to be of great benefit to civil engineering in South Africa, but was to earn world-wide recognition in several fields of geotechnical engineering.

The Department of Irrigation, realizing the need for the application of current soil mechanics principles to the design and construction of earth dams, seconded an engineer, B G A 'Basil' Lund, and two laboratory assistants to work with NBRI in 1948. This led to the design of the Rooikrantz Dam near King Williamstown — the first fully engineered soil dam in South Africa.

At the same time the classical soil mechanics approach was being applied to an investigation into foundation conditions on the deep estuarine clays in the Durban Bayhead area for the SAR & H. An investigation into foundation conditions in the sandy soils on the site of the Table Bay Power Station at Salt River saw the introduction to South Africa of the cone penetrometer or deep sounding apparatus commonly referred to as the 'Dutch Probe.'

Soil mechanics in South Africa was burgeoning.

The Geotechnical Division

The intention to hold regular International Soil Mechanics Conferences, after the first in 1936 in Boston, was thwarted by the intervention of the 2nd World War. But the threads of international co-operation were soon picked up again and the 2nd International Conference on Soil Mechanics and Foundation Engineering was planned for 1948 in Rotterdam. At the same time interested parties were approached to consider the formation of an international body and with this object in view, a meeting under the chairmanship of Col W P F McLaren was held at which J E Jennings was appointed as the official South African delegate.

In due course a very successful conference was held and the International Society for Soil Mechanics and Foundation Engineering (ISSMFE) was formed. The Society was to be formed with membership by national societies who would each look after their own affairs within the country concerned. The SAICE accepted that the role of a national society could best be fulfilled by the formation of a technical division within the Institution.

Thus in 1950 the Division of Soil Mechanics and Foundation Engineering, later changed to Geotechnical Division, became the first technical division of the SAICE. The Division since its inception has played a notable role in furthering not only the cause of geotechnical engineering, but engineering in general. This is evidenced by the fact that in the 34 years since the establishment of the Division no fewer than five former chairmen of the Division have progressed to become President of the Institution, viz J E Jennings (1958), L C Reynolds (1961), R D Hawkins (1962), B A Kantey (1967) and K Knight (1977).

International Society of Soil Mechanics and Foundation Engineering

The Geotechnical Division of the SAICE as a founder member of ISSMFE has played its full role in all the activities of the Society. Members have submitted the full quota of papers to international conferences and there has been good attendance by members at all these meetings, barring Moscow in 1973 when South African passport holders could not obtain visas, but a few of our members still managed to attend.

The Executive Committee of ISSMFE meets every four years coincident with the conferences and recently has held an intermediate meeting as well. The Executive Committee meeting in 1953 took two decisions that were of great importance to national societies. In order to allow the geographically more remote areas a greater share in the activities of the Society and to generate a greater interchange of ideas on localized geotechnical matters, it was decided to divide the national societies into six geographical regions, each with its own Vice-President who would serve a four year term of office coincident with that of the President of ISSMFE. The second related decision called for regional conferences to be held between the international conferences.

In 1953 the African region comprised Egypt, South Africa, Rhodesia and Portugal Ultramar (Angola and Mozambique) and the first Vice-President for Africa was Prof Hanna of Egypt. In the succeeding years Egypt dropped out of ISSMFE and so did Angola and Mozambique. Morocco, Ghana and Nigeria were admitted, as was Tunisia which subsequently also dropped out, and Egypt has been readmitted. The Geotechnical Division has provided three Vice-Presidents for Africa in J E Jennings (1957-61), B A Kantey (1965-69) and L C Wilson (1981-85).

South Africa immediately reacted to the decision on regional conferences and the First African Regional Conference was hosted at NBRI in 1955, with delegates from Kenya, Uganda, Nyasaland, Belgian Congo, Angola, Mozambique, Portugal, Rhodesia and the United Kingdom, as well as a strong South African attendance.

These conferences have continued at regular four year intervals with South Africa hosting the fourth in Cape Town in 1967 and the sixth in Durban in 1975. Unfortunately only a few South Africans could attend the seventh Regional Conference held in Ghana in June 1980 so a South African Geotechnical Conference was held in Silverton in October of that year where the 24 South African papers were used as the basis of discussion. South Africa participated fully in the eighth Regional Conference held in Harare in 1984.

Education and training in geotechnical engineering

As already stated, geotechnical education at South African universities was rudimentary prior to 1954, in which year J E Jennings left NBRI to become Professor of Civil Engineering at the University of the Witwatersrand. There a much larger component of soil mechanics and engineering geology was introduced into the under-graduate courses, and post-graduate study was initiated. Among the early recipients of masters degrees were many who have since become

leaders in the field such as Burland, Rauch, Dehlen, Blight, Wagener and Sparks to name but a few.

'Ken' Knight joined the university as a lecturer and developed his own expertise in tackling research problems, notably collapsing sands. The Wits team in addition played the leading role in studying the geotechnical problems associated with deep basements for multi-storey buildings, leading to the SAICE Code of Practice on Lateral Support in Surface Excavations. Other major projects were research into foundations on dolomite and sinkhole formation, slimes dams and opencast mining.

In this period N B Hobbs had joined Natal University as a specialist lecturer in soil mechanics, and among his students was N E 'Noel' Simons. It was not long before all engineering faculties in South Africa were able to include meaningful geotechnical engineering courses at both under-graduate and post-graduate level. This has continued to provide a steady stream of senior post-graduate students to overseas universities where they have achieved very good results and provide a valuable feed-back when they return to practise in the Republic. In this way practice in South Africa keeps up with the latest developments.

The net result of improved university training was that young engineers, eager to apply their geotechnical skills, had difficulty in having meaningful dialogue with their seniors who did not really understand the subject. In order to meet this difficulty, the Geotechnical Division, in co-operation with the universities, introduced a series of short courses in 1961 which aimed to bring practising engineers up to date with the best practice in a specific aspect. Topics covered included: soil profiling, shallow foundation design, expansive soils, shear strength of soils, bearing capacity and settlement, etc. These have proved popular and beneficial and are still offered today to meet the various levels of expertise in the profession.

Specific courses for engineering geologists took somewhat longer to arrange, but pressure by the Association of Engineering Geologists, ably supported by the Geotechnical Division, resulted in these courses being introduced at the University of the Witwatersrand and later at Pretoria University.

Geotechnical engineering consultancies

Before 1945 there had been only a relatively small number of consulting engineering firms, but post-war the number increased and quite a few entered the road design and soil mechanics field. It was only in the mid-fifties and early sixties that specialist geotechnical consultancies came into their own. Even then it was said that a firm could not exist on geotechnical work alone, but needed an added interest in roads, structures or hydraulics to be economically viable.

In 1984 there are several large consultancies which are almost exclusively geotechnical, and every significant firm has a strong geotechnical component, with the result that by far the greater proportion of geotechnical engineers are now in private organizations. These groups are themselves making notable contributions to research and development and keeping the standard of geotechnical engineering expertise at a high level in South Africa. In association with the National Institute for Road Research in the person of A A B 'Tony' Williams, Consultants Basil Kantey and Tony Brink introduced the concept of soil engineering mapping based on aerial photography to South Africa.

Geotechnical engineering consultancies

As the consulting engineering firms grew in size and expertise, so the contracting civil engineering companies developed their skills in handling geotechnical matters and today there are specialist companies dealing solely with geotechnical work. Often new techniques were developed jointly through theoretical analysis by consulting or research engineers and practical application by contracting companies.

Piling for providing foundations in weak soils is a long-established procedure and piling companies have operated in South Africa for many years. It was, therefore, only natural that such firms were the first to take a particular interest in geotechnical engineering. They provided specialist drilling and sampling services and later undertook in-situ testing programmes.

The joint research-design application approach has led to the introduction of new techniques to South Africa. A forerunner to dynamic compaction was the use by Hobbs of a 'breakers ball' to compact soil under an oil tank in Durban in the fifties. Mention must also be made of Dr Arthur Moss-Morris, who for many years worked on piling for Christiani and Milsen, and of Ross Parry-Davies, who has been behind the introduction of many geotechnical processes such as vibroflotation, dynamic compaction and the use of soft-earth anchors.

The National Building Research Institute

It is appropriate to end this short history close to where it began, at the NBRI. In its early years the Soil Mechanics Division of NBRI employed five geotechnical engineers, which represented at least half the trained manpower in this field in the country. It was little wonder that NBRI was considered to know all the answers or to find them if necessary. Besides the classical soil mechanics approaches mentioned earlier, the Institute was soon into the field of building on expansive soil, where a major effort is still being devoted in 1985.

Subsequent topics where major investigations were carried out included: the stability of slimes dams, soil moisture relationships in non-saturated soils, shear strength of non-saturated soils, dispersive soils in earth dams, and to a lesser degree foundations on dolomites and collapsing sands. In addition to the persons already mentioned, NBRI has also for longer or shorter periods employed persons such as Lou Collins, George Donaldson, Tony Brink, Tony Williams, Derek Sparks, Dirk van der Merwe, Geoff Blight and Ian Brackley in its research teams where each made his own valuable contributions.

NBRI policy has always been to investigate a problem, to find a solution for that problem, to introduce the solution into practice, to assist in the commercial application of the solution and then when it is an accepted procedure to withdraw from the scene. In this way NBRI introduced the 'Dutch Probe' to South Africa in 1949 and then withdrew from this service when it became commercially available a few years later. Similarly, NBRI provided soil sampling and laboratory testing facilities for the fledgling consulting groups until drilling companies and consulting engineers' laboratories were able to offer these services. Thus the Institute nurtured the growing geotechnical industry.

It is with nostalgia and some sadness that one has to accept that the great days of NBRI have passed, largely as the result of its success in fostering geotechnical engineering. Whereas five engineers represented more than 50 per cent of the geotechnical effort in South Africa in 1950, in 1985 five engineers represent about two per cent. This is not to say that two per cent is not of the same high standard as before, and it makes a significant contribution to those fields of research to which the Institute has been forced to limit its research.

Conclusion

Geotechnical engineering in South Africa has always been characterized by the efforts of a dedicated band of enthusiasts. The pioneer group of 1947 and before are now mostly retired and many are no longer with us. The second wave is now reaching maturity and there is a little concern that the next group of enthusiasts is slow in appearing, perhaps because other interests are being more enthusiastically taught to under-graduates.

The past 35 years have shown that with excellent co-operation between universities, consulting engineers, state bodies, contractors and research establishments, the Geotechnical Division has devoted detailed attention to special domestic problem areas in which it is a world leader.

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