SUB-SECTION XII c

NATIONAL EXPOSITION OF THE LATEST DEVELOPMENT AND IDEAS IN THE SPHERE OF SOIL MECHANICS, WITH A REPORT OF LITERATURE

XII c 1

SOIL MECHANICS IN GREAT BTITAIN.

BRITISCH NATIONAL COMMITTEE.

1. DEVELOPMENT

In common with a number of other countries Great Britain has a long tradition of interest and activity in the study of the behaviour of soils in civil engineering works. Before outlining the course of development of the more modern studies included under the term Soil Mechanics it may therefore be of interest to make brief reference to some of the more important soil studies of the past to indicate the historical background into which the more recent studies fit. In the 19th century soil studies were concerned with two main aspects namely the purely theoretical study of earth pressures, typified by the work of Rankine (1857), and the essentially practical approach of the observation of the behaviour of soils in actual construction works. Many examples of the latter are included in the early volumes of the Proceedings of the Institution of Civil Engineers and are typified by the writings of Gregory (1844) and Sir Benjamin Baker (1881). As elsewhere in the world, the experimental study of the properties of soils received only sporadic attention until the early part of the present century. In this field mention may first be made of the work of Bell (1915) who carried out some of the most successful early experiments to measure the shearing characteristics of clays In 1925-26 the British Association for the Advancement of Science set up an Earth Pressures Committee which sponsered the work of Prof. C.F. Jenkin, F.R.S. on the lateral pressure of granular materials, the results of which were published in 1931. In 1933 the Department of Scientific and Industrial Research started a small soils laboratory at the Building Research Station to study soil problems in relation to roads and buildings.

Then in 1936 the Institution of Civil Engineers took over the functions of the Earth Pressures Committee of the British Association. This, combined with the widespread interest aroused by the publication of the Proceedings of the First International Conference on Soil Mechanics and Foundation Engineering (Harvard 1936) resulted in a rapid growth of Soil Mechanics in Great Britain. In 1937 an additional soils laboratory in the Department of Scientific and Industrial Research was started at the Road Research Laboratory. In 1938 a number of Universities began to look into the possibility of including instruction in Soil Mechanics in their degree courses. In the same year the Main Railway Companies became actively interested in the application of soil mechanics methods to the study of their practical problems. In subsequent years interest in the subject continued to grow rapidly not only as regards the means of studying soil properties but also in the appreciation shown by practising engineers of the possibilities presented by the new techniques when applied to the consideration of practical problems. Reference to the brief selected bibliography of the literature will illustrate this point. During this period a number of soils laboratories were set up by Contracting Engineers to assist in the efficient carrying out of construction works, a feature in Great Britain which calls for special mention. In addition soils laboratories were started by a number of Government Departments and Ministries to study urgent problems in relation to wartime needs.

Briefly stated, the present position of the subject in Great Britain is that there is not only an active group of people who may be said to specialize in Soil Mechanics but that there is also a substantial body of practising engineers who give their encouragement and support to the development of the subject. This position is reflected in the papers submitted to the present Conference. In addition mention may be made of a number of Codes of Practice, relating to various aspects of Civil Engineering and Public Works, which are in course of preparation; an attempt is being made to incorporate the main findings of modern soil mechanics into these codes whose purpose is to outline what is recognised as good practice. The future therefore promises increasing interest in the subject and especially so since instruction in Soil Mechanics is now included in the syllabus of at least ten of the Engineering schools of the Universities.

2. SPECIAL PROBLEMS AND TECHNIQUES

Es is well known the geology of Great Britain is characterized by its extraordinary variability ranging as it does from recent alluvium through the complete geological time scale to PreCambrian rocks. In consequence there exists a wide range of soils and soil conditions. The most common problems are, however, those relating to clay soils.

In the South of England large areas are covered by clays of the following formations: -London Clay, Weald, Gault, Kimmeridge, Oxford and Lias and the drift derived from them. These are clays of the fat, plastic type which are very shrinkable and special problems therefore arise with shallow foundations, such as for dwellings and roads, due to seasonal variation in moisture content and the effect of trees. Shrinkage problems also arise under industrial buildings such as kilns retorts etc.

These clays are also of the stiff-fissured type and many problems arise in relation to the stability of cuttings and retaining walls. Under the conditions obtaining in cuttings and behind retaining walls, the clay undergoes a long-term deep-seated reduction in strength and failures have occurred many decades after the original construction. The problem is particularly important in relation to the main-line railways running into London where a high condition of maintenance is essential because of the valuable land and structures adjoining the railway. Special studies have therefore been made of the behaviour of stiff fissured clays.

In many of the river valleys and estuaries in different parts of the country there exist deep beds of alluvial clays and silts, some of

them 100 ft. thick. These deposits present difficult soil conditions for engineering works and since the large ports and harbours are situated in these areas stability problems arise in connection with docks, quays and large buildings.

Owing to the importance of clay soils special techniques have been developed for the study of problems relating to clays. In this connection mention may be made of the Building Research Station Portable Compression Apparatus which was developed for the field and laboratory measurement of unconfined compression strength. The technique of its use in relation to foundation and stability problems and the design of road pavements has been described in a number of papers. In problems where the clay was apt to soften up, the shear box test under equilibrium conditions has been used to investigate shearing characteristics.

The peat deposits of the Fen Districts of East Anglia and of Somerset give rise to problems of long term consolidation and its effect on roads and structures. The embankment rivers of the Fens also introduce problems of flood protection and erosion of the banks and channels. Along many miles of the coastline of South and East England, comparatively soft rocks are exposed to sea attack and the problems of coast erosion and landslips assume importance in these areas.

The climate of the country also introduces special considerations particularly in regard to the construction of earthworks. The rainfall is spread more or less uniformly over the whole year and prolonged dry spells cannot be relied upon, so that it is difficult to maintain close control over the water content of the soil during construction. Special studies were made in this field as the result of the impetus given by the war to problems of airfields and military roads. While attention was given to the methods already developed in U.S.A. for such problems as soil compaction and soil stabilization, special study was needed to assess the applicability of these methods in relation to the rainfall conditions and the soil types obtaining in Great Britain. In the study of these and other problems the valuable contributions made by Mr. A.H.D. Markwick call for special mention and his death in March 1946 was a very serious loss to Soil Mechanics in this country.

Owing to the equable nature of the climate troubles arising from frost action do not normally present serious problems. A few cases of damage to road and house foundations did however occur during the exceptional weather of the early part of 1947.

Among other special problems are those resulting from the considerable amount of mineral working, such as coal mining, carried out in heavily populated areas which give rise to subsidence and damage to structures in these areas.

In the broad field of civil engineering construction the long tradition and the wide background of experience in Great Britain militates against the rapid absorption of new techniques into general practice. For instance the design of structures can often be satisfactorily based on experience with similar structures built in the past and methods of dealing with difficult soil conditions have been absorbed into traditional practice. This applies particularly to such problems as :- deep excavation and the support of the sides; treatment of waterlogged sites and groundwater lowering; foundations of large structures, bridges etc.; piled foundations; earth dams; docks and harbour works. However in cases where special conditions exist, either in relation to the type and size of structure or concerning the site conditions, soil mechanics investigations have been called for to assist in the consideration of problems in all these field. Also, experience in the last few years is showing that a more widespread use of these methods is being made not only for special cases but in the more general cases too.

Similarly while considerable experience has been gained in the past with the construction of works in the Dominions and Colonial Empire, the application of soil mechanics methods to supplement this experience is now being more extensively used particularly in new development areas.

From the above brief survey it can be seen that there is in Great Britain a wide range of civil engineering problems to which soil mechanics methods can be applied with advantage. The extent to which these methods have been used may be judged from the following brief summary of the literature which includes the more important papers involving soil mechanics discussions published since 1936 together with the few classical papers mentioned in the first section.

Finally it may be mentioned that a complete bibliography on Soil Mechanics is being prepared by the Institution of Civil Engineers Committee on Soil Mechanics and Foundations.

3. SUMMARY OF LITERATURE

Gregory C.H. 1844
On railway cuttings and embankments with an account of some slips in the London Clay on the Line of the London and Croydon Railway. Min. Proc. Instn. Civ. Eng. 3:135-145.

Rankine W.J.N. 1862
Manual of Civil Engineering.

Baker B. 1881
The actual lateral pressure of earthwork. Min. Proc. Instn. Civ. Eng. 65 (Part 3):140-186.

Bell A.L. 1914
The lateral pressure and resistance of clay and the supporting power of clay foundations. Min. Proc. Instn. Civ. Eng. 199:233-272.

Ackermann A.S.E. 1919
Experiments with clay in its relation to piles.
Trans. Soc. Eng. 37-80.

Ackermann A.S.E. 1920
Physical properties of clay.
Trans. Soc. Eng. 196-226.

Lordly H.R. 1920
The lateral and vertical pressure effect of piles in clay.
Trans. Soc. Eng. 171-193.

Ackermann A.S.E. 1921
Physical properties of clay.
Trans. Soc. Eng. 87-114.

Ackermann A.S.E. 1922
Physical properties of clay; and a supplement on pile-setting gauges.
Trans. Soc. Eng. 151-173.

Chatley H. 1922
Physical properties of clay-mud.
Trans. Soc. Eng. 133-150.

Jenkin C.F. 1932
The pressure on retaining walls.
Min. Proc. Instn. Civ. Eng. 234:103-154.

Glanville W.H. Grime G. & Davies W.W. 1935
The behaviour of reinforced concrete piles

during driving.
J. Instn. Civ. Eng. 1:150-202.

Cooling L.F. & Smith D.B. 1936
The shearing resistance of soils.
J. Inst. Civ. Eng. 3:333-343.

Cooling L.F. 1936
Report on the First International Conference on Soil Mechanics & Foundation Engineering.
J. Instn. Civ. Eng. 4:135-147.

McCarthy J. 1937
Soil Mechanics - Concrete pile driving.
Struct. Eng. 15:268-272.

Hiley A. 1938
Some apparatus for specialised use on sites of new foundations.
Struct. Eng. 16:14-26.

Knight R.G. 1938
The Subsidence of a Rockfill Dam and the remedial measures employed at Eildon Reservoir, Australia.
J. Instn. Civ. Eng. 8:111-191.

Seaton T.H. 1938
Engineering problems associated with clay, with special reference to clay slips.
J. Inst. Civ. Eng. 8:457-474.

Institution of Civil Engineers 1938
First Interim Report - Joint Sub-Committee on Pile Driving.
J. Instn. Civ. Eng. 9:331-345.

Pimm G.B.R. 1938
Recent developments in deep ground testing.
Struct. Eng. 16:210-222.

Burns R.V. & White C.M. 1938
The Protection of dams weirs and sluices against scour.
J. Instn. Civ. Eng. 10:23-46

Markwick A.H.D. 1939
Soil problems in road construction.
J. Instn. Civ. Eng. Notices 12(7):23-38.

Terzaghi K. 1939
Soil Mechanics: A new chapter in engineering science.
J. Instn. Civ. Eng. ;2:106-141.

Cooling L.F. & Golder H.Q. 1940
A portable apparatus for compression tests on clay soils.
Engineering 149:57-58.

Wooltorton F.L.D. 1940
Foundations in Mandalay.
Struct. Eng. 18:659,676, 683-696, 712-722.

Duvivier J. 1940
Cliff stabilization works in London Clay
J. Instn. Civ. Eng. 14:412-426.

Bagnold R.A. 1940
Beach formation by waves: some model experiments in a wave tank.
J. Instn. Civ. Eng. 15:27-52.

Binnie G.M. & Price J.A. 1941
An apparatus for measuring the lateral pressure of clay samples under a vertical load.
J. Instn. Civ. Eng. 15:297-313.

Markwick A.H.D. & Starks H.J.H. 1941
Stresses between tyre and road.
J. Instn. Civ. Eng. 16:309-325.

Cooling L.F. & Skempton A.W. 1941
Some experiments on the consolidation of clay.
J. Instn. Civ. Eng. 16:381-398.

Wilson G. 1941
The calculation of the bearing capacity of footings on clay.
J. Instn. Civ. Eng. 17:87-96.

Golder H.Q. 1941
The ultimate bearing pressure of rectangular footings.
J. Instn. Civ. Eng. 17:161-174.

Markwick A.H.D. 1941
Soil classification and its bearing on soil stabilization.
J. Inst. Petrol. 27:313-328.

Skempton A.W. 1942
Some principles of foundation behaviour.
J. Roy. Inst. Brit. Archit. 50:3-6.

Cooling L.F. & Skempton A.W. 1942
A laboratory study of London Clay.
J. Instn. Civ. Eng. 17:251-276.

Allen J. 1942
An investigation of the stability of bed materials in a stream of water.
J. Instn. Civ. Eng. 18:1-34.

Cooling L.F. 1942
Soil Mechanics and site exploration.
J. Instn. Civ. Eng. 18:37-61.

Markwick A.H.D. 1942
Soil Mechanics in road and aerodrome construction.
J. Instn. Civ. Eng. 18:62-87.

Skempton A.W. 1942
An investigation of the bearing capacity of a soft clay soil.
J. Instn. Civ. Eng. 18:307-321.

Golder H.Q. 1942
An apparatus for measuring the shear strength of soils.
Engineering 153:501-503.

Cooling L.F. & Golder H.Q. 1942
The analysis of the failure of an earth dam during construction.
J. Instn. Civ. Eng. 19:38-55.

Wynne-Edwards R.M. 1942
Earthwork in Embankments.
Instn. Civ. Eng. Road Paper No. 6

Markwick A.H.D. & Keep H.S. 1942
The use of low-grade aggregates and soils in the construction of bases for roads and aerodromes.
Instn. Civ. Eng. Road Paper No. 9

Wilson G. & Grace H. 1942
The settlement of London due to underdrainage of the London Clay.
J. Instn. Civ. Eng. 19:100-127.

Groves G.L. 1943
Tunnel linings with special reference to a new form of reinforced concrete lining.
J. Instn. Civ. Eng. 20:29-42.

Buckton E.J. & Cuerel J. 1943
The new Waterloo Bridge.
J. Instn. Civ. Eng. 20:145-178.

Bryan J.J. 1943
Methods of testing the bearing capacity of soils and runways as used by the Central Public Works Department, India.
J. Instn. Civ. Eng. 21:121-122.

Reynolds H.R. 1943
Soil Mechanics and the Railway Engineer.
Instn. Civ. Eng. Railway Paper No. 10

Barboy M.F. 1943
Some soil mechanics problems on the London Midland and Scottish Railway.
Instn. Civ. Eng. Railway Paper No. 11

Andrews W.C. 1944

Foundations in combustible material.
Struct. Eng. 22; 53-65, 262.

Morgan H.D. 1944
The Design of Wharves on soft ground.
J. Instn. Civ. Eng. 22:5-25.

Bendelow L. 1944
Remedial works in connexion with the Waldershelf slip - Broomhead Reservoir.
J. Instn. Civ. Eng. 22:95-106.

Skempton A.W. 1944
Notes on the compressibility of clays.
J. Geol. Soc. London 100:119-135.

Cooling L.F. & Ward W.H. 1944
Damage to cold stores due to frost heaving.
Proc. Inst. Refrig. 41:37-47.

Glossop R. & Golder H.Q. 1944
The construction of pavements on a clay foundation soil.
Instn. Civ. Eng. Road Paper No.15.

Markwick A.H.D. 1944
The basic principles of soil compaction and their application.
Instn. Civ. Eng. Road Paper No. 16.

Mitchell A.J. 1945
Soil Stabilization for roads in Tanganyika Territory.
J. Instn. Civ. Eng. 24:134-144.

Skempton A.W. 1945
A slip in the West Bank of the Eau Brink cut.
J. Instn. Civ. Eng. 24:267-286.

Ward W.H. 1945
The stability of natural slopes.
Geographical J. 105:170-191.

Glossop R. & Skempton A.W. 1945
Particle-Size in Silts & Sands.
J. Instn. Civ. Eng. 25:81-105.

Taylor F.N.G. 1945
Methods of constructing deep land foundations.
Instn. Civ. Eng. Works Construction Paper No. 1

Toms A.H. 1946
Folkestone Warren Landslips: Researches carried out in 1939 by the Southern Railway Company.
Instn. Civ. Eng. Railway Paper No. 19.

Packshaw S. 1946
Earth pressure and earth resistance.
J. Instn. Civ. Eng. 25:233-256.

Dobbie C.H. 1946
Some sea defence works for reclaimed lands.
J. Instn. Civ. Eng. 25:257-274.

Wilson G. 1946
Some applications of soil test results to the design of simple foundations.
Instn. Civ. Eng. Structural Paper No. 15.

Mussche H.E. & Waddington J.C. 1946
Applications of the freezing process to Civil Engineering works.
Instn. Civ. Eng. Works Construction Paper No. 5.

Glossop R. 1946
Soil drainage with particular reference to road engineering.
Instn. Civ. Eng. Road Paper No. 21

Golder H.Q. 1946
The Relationship of runway thickness and undercarriage design to the properties of the subgrade soil.
Instn. Civ. Eng. Airport Paper No. 4.

Harding H.J.B. 1946
The choice of expedients in civil engineering construction.
Instn. Civ. Eng. Works Construction Paper No. 6.

Road Research Laboratory 1946
Soils, Concrete and Bituminous Materials.
H.M. Stationery Office.

Markwick A.H.D. & Webb S.B. 1946
Soil Survey procedure and its application in road construction.
Bull. Road Res. No. 4
H.M. Stationery Office.

Cooling L.F. 1946
Some foundation troubles with small houses.
J. Inst. Sanitary Eng. 45:327-347.

Maclean D.J. & Rolfe D.W. 1946
A laboratory investigation of electro-osmosis in soils.
Phil. Mag. 37:863-873.

Cooling L.F., Skempton A.W., Glossop R. & Markwick A.H.D. 1946
The principles and application of Soil Mechanics.
The Institution of Civil Engineers.

Turner L. 1947
Foundation problems in relation to soil mechanics.
Instn. Civ. Eng. Structural Paper No. 16

Ward W.H. 1947
House foundations.
J. Roy. Inst. Brit. Archit. 54:226-235.

Faber O. 1947
A new piling formula.
J. Instn. Civ. Eng. 28:5-54.

Duvivior J. 1947
The problem of Coast Erosion.
Instn. Civ. Eng. Maritime & Waterways Paper No. 8

Crockett J.H.A. & Hammond R. 1947
Reduction of Ground Vibrations into structures.
Instn. Civ. Eng. Structural Paper No. 18

Ward W.H. 1947
The effects of fast growing trees and shrubs on shallow foundations.
J. Inst. Landscape Archit.

Ward A.M. & Bateson E. 1947
The New Howrah Bridge, Calcutta; Design of the Structure, Foundations and approaches.
J. Instn. Civ. Eng. 28:167-210.

Armstrong C.F. 1947
The use of plant in soil stabilization.
Instn. Civ. Eng. Road Paper No. 24.

Institution of Structural Engineers 1947
Interim report on mining subsidence and its effect on structures.
Struct. Eng. 25:315-334.

Meyerhof G.G. 1947
The settlement analysis of building frames.
Struct. Eng. 25:369-409.

Casagrande L. 1947
The application of electro-osmosis to practical problems in foundations and earthworks
Building Research Tech. Paper No. 30
H.M. Stationery Office, London.

Maclean D.J. & Bailey R.S. 1947
Compaction of Soil. Full-scale investigations with various types of roller. I.Brick-earth.
Roads and Road Const. 25:12-16, 55-59, 88-90

Markwick A.H.D. & Debson A.F. 1947
Application of electro-osmosis to soil drainage Engineering 163:121-123.

Hunt A. 1947
Compaction of soil. Full-scale investigations with various types of roller.
II. Clayey-gravel.
Roads & Road Const. 25:91-95.

Maclean D.J. 1947
The application of Soil Mechanics to problems in road construction.
J. Instn. Munic. Eng. 71:449-479.

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XII c 2

SOIL MECHANICS IN CANADA

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At the First Internal Conference on Soil Mechanics and Foundation Engineering held in 1936, seven Canadians only were present despite the fact that the Conference was held at Harvard University, but two hundred miles from the Canadian border. At that meeting, only one Canadian paper was presented. In that year, instruction in the subject was being given in only one Canadian University. These facts reflect the general attention devoted, at that time, to the subject throughout the Dominion.

At this Second Conference, there will be an appreciable delegation from Canada despite the fact that the Conference is being held in Europe. A selection of seven papers from Canada is being submitted, the papers being representative of Canadian work in Soil Mechanics and of a suitably general character for presentation to an international meeting. Some attention is being given to the subject in all the Civil Engineering Departments of Canadian Universities Correspondingly, foundation investigations and soil studies are now generally an integral part of all major Canadian construction operations.

This change in the position of Soil Mechanics in Canada, which has developed during the last decade, can be attributed very largely to the influence of the First International Conference. Canada presents many special soil problems and it is therefore fitting that progress in the Dominion should have kept pace with that in other countries. Despite the limited facilities for scientific research and investigation available in Canada, due to her relatively small and scattered population, some definite contributions to the scientific study of soils have already been made which are of general importance, and similar progress may be anticipated in the future.

Considering the position of the subject in the curricula of the Universities, the first Canadian course in Soil Mechanics was given at the University of Alberta by Professor I. F. Morrison, starting in 1932. Dean C.R. Young initiated a corresponding course at the University of Toronto in 1936, following his participation in the First International Conference. Thereafter, the other Civil Engineering Schools in the Canadian Universities took similar action, and today there is either a special course on Soil Mechanics or a special section in a more general course in the undergraduate curricula for Civil Engineering in each of the Canadian Universities.

It is usual for Canadian graduates to undertake their postgraduate studies at leading American Universities, and this has been the case with studies in Soil Mechanics. There are now an appreciable number of young Canadians who hold postgraduate degrees in Soil Mechanics from well-known American institutions. At the same time, a start has been made at postgraduate work in the subject in Canada. Graduate degrees have already been awarded in the subject by the University of Alberta, the University of Toronto, and Ecole Polytechnique, (the famous French Canadian engineering school in Montreal which is on an equal footing with the Engineering Faculties of the English-speaking Universities of Canada)

The principal Soil Mechanics laboratories of the Universities are located at the University of Alberta, the University of Saskatchewan (in conjunction with the Prairie Farm Rehabilitation Administration which is mentioned below), the University of Toronto, and Ecole Polytechnique. These laboratories are reasonably well equipped, but they contain no unusual apparatus calling for special mention in such a brief review as this. Laboratory work has also been started at the Universities of British Columbia and Manitoba, Queen's and McGill Universities, the University of New Brunswick, and the Nova Scotia Technical College. When the laboratories in the last mentioned group of colleges are developed as is now planned, there will be available soil testing and research facilities in all provinces of the Dominion with the exception of Prince Edward Island.

Correspondingly, attention has been given to the provision of laboratory facilities in a number of the larger engineering organizations of the Dominion. Naturally, the Provincial Highway Departments are among the leaders in this new field, most of the Departments having available some soil testing facilities. Because of the size and importance of their provincial road systems, the provinces of Quebec and Ontario have perhaps the most outstanding Soil Mechanics Laboratories, located respectively in Quebec City and at Toronto. A great deal of valuable work in connection with highway construction has been performed by these two laboratoties. As an example, it may be noted that for the construction of a new limited-access highway leading from Toronto fifty miles north to the town of Barrie, nine parties have been at work exclusively on field soil studies. Similar progress is being made in other provinces and much advance may be anticipated in view of the fact that almost ninety per cent of the highway mileage of Canada still consists of