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EXPANSIVE SOILS AND MOISTURE MOVEMENTS IN PARTLY SATURATED SOILS
SOLS EXPANSIFS ET MOUVEMENT DE L'HUMIDITE DANS LES SOLS PARTIELLEMENT SATURES

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 Jan Smuts Avenue,
 Johannesburg, South Africa.*

Date Session Held: Tuesday, 26 August 1969
 Time: 14:30 - 18:00
 Place: Auditorium B-7

SUMMARY AND CONCLUSIONS

J. E. Jennings: Gave an introduction, outlining the program and pointing out that the session constituted a prolongation of, and at the same time, a conclusive summary of the Second International Research and Engineering Conference on Expansive Clay Soils, held at Texas A & M University, College Station, Texas, 18-20 August 1969, with professor Spenoer J. Buchanan as Conference Chairman.

W. G. Holtz (Consulting Civil Engineer, formerly with U. S. B. R., DENVER, Colorado) gave a talk on "The Engineering Problems of Expansive Clay Soils". He noted the influence of various factors which influence the amount of volume change which can occur in a natural or remolded expansive clay, describing methods which the U. S. B. R. and others had developed to determine the influence of these factors quantitatively and control them in design and construction. He described some of the damage which had occurred to hydraulic and other engineering structures, and referred to current design and construction practices which had been developed to deal with the problem. Holtz particularly indicated the recent development of construction methods of limiting the expansive behavior by lime treatment which produce treatment of subsoil to as much as 4 feet in depth.

J. G. Zeitlen, furnished excerpts and conclusions from portions of his general report, based on previous publications, but more directly on the papers and discussions of the Texas A & M Conference the week before (Appendix A). He noted the strong influence of both formal and informal discussions with Professor Jennings, Dr. Gordon Aitchison, and their associates. He listed a number of recent publications and conferences which furnish extensive detailed references on the problems of expansive soils, (See Appendix B). The problem of defining an expansive soil was presented, and it was pointed out that various criteria for expansiveness based on such factors as clay mineralogy, chemical composition and Atterberg limits are insufficient, even when soil structure, density, moisture and initial stress and suction were considered. The anticipated future environment must be predicted, and the definition offered was "an expansive soil is one which pore pressure differences exactly reproduced the real suction

values existing in the field, but no other alternative has yet been developed. By sampling undisturbed materials, or preparing remolded specimens, at the same condition as would be found initially in the field, and then exposing them to various suctions during wetting, functions of per cent swell versus applied stress could be developed. Such curves could be interrelated over the range of pressures expected, for the predicted suction values, to give total movement in any direction.

Mention was also made of the ISRAEL approach of predicting final equilibrium values of moisture content based on water content/plastic limit ratios. Optimism was expressed as to the further development of general methods for predicting future equilibrium conditions, based on various approaches used in Australia as field suction observations, analytical and theoretical analyses, and climatological studies. The presentation closed with examples of successful detailed building and foundation design methods which had evolved in South Africa in response to their conditions and environment. Each region would have to establish the initial and final environmental conditions peculiar to their own structures, but could do so on the basis of scientifically based methods common to the problem of expansive soil throughout the world.

PANEL DISCUSSION:

G. D. Aitchison (Chief, Division of Soil Mechanics, CSIRO, Australia) described Australian conditions and research approach, based extensively on the use of the suction variable as a potential in a flow equation, as a component in an effective stress equation and as a quantity measurable in the field and in the laboratory and also controllable in the laboratory. He touched on methods of estimating final equilibrium suction values, and stated that it was now possible to predict movements by proper selection of initial and final equilibrium suctions, and then making laboratory measurements in which the relevant stresspaths were followed. He emphasized the danger of assuming that a suction decrease (as moisture increase) would necessarily follow the construction of a building and cited an example of very high suction measured beneath an 80 years old building.

J. J. Hamilton (Officer-in-Charge, Prairie Regional Station, Division of Building Research, National Research Council, Saskatchewan, Canada) gave information of regional climatic and moisture conditions, showed data on observed movements, and mentioned

the importance of thermal gradients for Canadian conditions. He described some of the construction methods used for expansive soil areas.

A. Komornik (Israel Institute of Technology, Haifa, Israel) showed some cases of structural damage in Israel, referred to methods of analysis for structures, which take into account differential movements, and particularly stressed the importance of measuring horizontal swelling pressures and movements so that they may be taken into account in the design of piles, walls and similar structures.

G. W. Donaldson (Head, Soil Mechanics Division, National Building Research Institute, C. S. I. R., Pretoria, South Africa), suggested submitting his remarks in writing on the relation between the expansiveness of the soil and the structural design and other methods necessary to be employed.

DISCUSSION FROM THE FLOOR

H. J. Gibbs (Chief, Soil Engineering Branch, U.S. Bureau of Reclamation, Denver, Colorado) spoke on a simplified method for field engineers to identify if clays are at a critical density with regard to future expansion. The U. S. B. R. method, developed empirically by field experience and correlation of performance with Atterberg limits, suggests only on obtaining the field moisture content and liquid limit, for practical, rapid field observations and suggests the field moisture to be minimum amount based on the empirical relationship with liquid limit.

G. E. Retamal (Professor of Soil Mechanics, University of Chile, Santiago, Chile) discussed expansive soil problems in his country, and particularly presented the case of a site in a desert area where many light structures had suffered extensive damage since the area was built up 10 years earlier. Some soil data was presented, and reference made to the research work which is in progress.

Awtar Singh (Dept. of Engineering, University of California, Los Angeles) raised the question of the effect on structures of founding on undisturbed clay, pointing out that in some oases, houses had shown appreciable distress, although the expansiveness was much lower than for remolded material. He also brought out the problem of stability of slopes in swelling material, where the shear strength was much reduced by the swelling of the clay.

J. A. J. Salas (Professor, Escuela Ingenieros de Caminos, Ciudad Universitaria, Madrid) brought out the importance of horizontal movements in the swelling clay area in Spain. Instead of the "doming" of structures, as reported usually in South Africa, he has found that the buildings tend to remain horizontal, but are pulled apart. Also, he noted that the movements were predominantly seasonal, to depths of 4 to 8 feet. He suggested analysis of the movements by a theoretical approach based on the equations of thermal stresses applied by an area on an elastic medium.

S. J. Buchanan (Consulting engineer, and Professor, Texas, A & M University, College Station, Texas) referred to the vast experience in Texas with expansive soils and the development of methods which have allowed competent engineers to build in such areas. He stressed the need of developing guide lines which would be of immediate

benefit to the small homeowners, who could not bear the cost of extensive investigations.

PROCEEDINGS

The foregoing report includes only a summary of the lectures and discussions of the Specialty Sessions. However, the complete report of this meeting with the contributions in full, will be printed as an Appendix to the Proceedings of the Second International Research and Engineering Conference on Expansive Clay Soils, which was held at Texas A & M University, 18-20 August 1969. Copies of the Proceedings will be available at \$25.00 per copy from:

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Appendix A List of Contributions to the Second International Research and Engineering Conference on Expansive Clay Soils," Texas A & M University, College Station, Texas 18-20 May 1969

Session 1 "Expansive Soils--Are We Meeting the Challenge?" Keynote address by Willard J. Turnbull.

Session 2 "A Statement of the Problems the Engineer Faces with Expansive Soils" by G.D. Aitchison.

"The Engineering Problems of Expansive Soils" by J. E. Jennings.

Session 3 "The Occurrence of Problems of Heave and the Factors Affecting its Nature" by G. W. Donaldson.

"Contribution to the Study of Expansive Clays of Peru" by A. C. Gil.

"Planned Field Testing of Expansive Clay" by G. J. Gromko.

"Factors Affecting Damage Due to Movements of Expansive Clays in the Field" by A. Komornik.

Session 4 "The Fundamental Mechanisms Involved in Heave and Soil Moisture Movement and The Engineering Properties of Soils Which Are Important in Such Movements" by G. D. Aitchison.

"Subgrade Moisture Variations in Expansive Soils" by T. A. Haliburton and B. D. Marks.

"Studies of In-Situ Moisture and Swelling Potential Profiles" by A. Komornik, G. Wiseman, Y. Ben Jaacob.

"The Performance of Pavement Materials on The Grey Brown Soils of Western Queensland" by P. O. Morris.

"Flow of Water in Partially-Saturated Expansive Soil" by R.N. Yong and B.P.

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Session 5

"The Influence of Structure on the Collapse of Compacted Clay" by L. Barden and G. R. Sides.

"Swelling of Soils in Contact with Water at a Negative Pressure" by V. Escario.

"A New Method for In-Situ Measurement of Pore Water Tension" by V. Escario.

"Consolidometer Test Procedural Factors Affecting Swell Properties" by D. G. Fredlund.

"Depth Effects in Expansive Clays" by R. K. Katti, R. K. Lal, S. K. Fotedar, S. K. Kukarni.

"Shear Strength and Swelling Pressure Characteristics of Expansive Soils" by R. K. Katti, S. K. Kulkarni and S. K. Fotedar.

"A Note on Experimental Investigation on Cohesive Nonswelling Soil Layer as an Intercepting Media for Footing on Expansive Soil" by R. K. Katti, S. K. Kulkarni and J. M. Kate.

"Influence of Granular Constituents on the Swelling Characteristics of Expansive Clays" by A. Komornik and M. Livneh.

"Some Properties of Expansive Clays from Western Canada" by E. L. Matyas.

"Behavior of Expansive Soil Treated or Cushioned with Sand" by B. Satyanarayana.

"A Laboratory Study of the Swelling Properties of Sodium and Calcium Modifications of Lake Edmonton Clay" by S. Thomson and P. Ali.

"The Laboratory Testing of Expansive Soils" by H. L. Uppal.

"Measurement of Swelling Pressure of Expansive Soils" by H. L. Uppal and R. M. Palit.

Session 6

"Controlling the Expansion of Desiccated Clays During Construction" by J. P. Bara.

"The Prediction of Amount and Rate of Heave Likely to be Experienced in Engineering Construction on Expansive Soils" by J. E. Jennings.

"The Use of Index Properties in the Design of Pavements on Expansive Clays" by M. Livneh, G. Kassiff and G. Wiseman.

"Status of Art and Engineering of Identification, Design and Construction on

Expansive Soils in USA" by H. M. Reitz.

"Predicting Heave of Buildings on Unsaturated Clay" by R. A. Sullivan and B. McClelland.

Session 7

"Performance and Economics of Various Foundation Designs for Volume Changing Subsoils in Western Canada" by J. J. Hamilton.

"Foundation in Expansive Marl" by M. Katzir and D. David

"Foundations and Structural Treatment of Buildings on Expansive Clays in South Africa" by D. L. Webb.

"Foundation Failures on Collapsing Soils in the Tucson, Arizona, Area" by H. A. Sultan.

"Some Approaches to Foundation Design for Structures in an Expansive Soil Area" by J. G. Zeitlen.

Session 8

"Modification of Expansive Soils of Western Canada with Lime" by K. O. Anderson and S. Thomson.

"Volume Change in Expansive Clay Soils and Control by Lime Treatment" by W.G. Holtz.

"Stabilization of Active Clays by Injection and Replacement Methods" by M. Katzir.

"Modification of Expansive Soils for Use in Road Work" by H. L. Uppal.

"The Effect of Lime on the Physical Properties of Black Cotton Soil" by H. L. Uppal and B. R. Malhotra.

Appendix B

SOME RECENT CONFERENCES AND GENERAL REVIEW REFERENCES

1.- Regional International Conferences including papers on expansive clay: Pan-American Conference on Soil Mechanics and Foundation Engineering, Venezuela, 1967.

Fourth Regional Conference for Africa on Soil Mechanics and Foundation Engineering, December, 1967.

Third Asian Regional Conference on Soil Mechanics and Foundation Engineering, (Session 4, Division 3, "Expansive Clays-Properties and Engineering Problems", 16 papers in Vol. I; Discussion, Vol. II) Haifa, September, 1967.

2.- Woodward-Clyde and Associates, "A Review Paper on Expansive Clay Soils", Volume I, Prepared for Portland Cement Association, Los Angeles District, 1967.

3.- Johnson, L. D., "Review of Literature on Expansive Clay Soils", Miscellaneous Paper S-69-24,

SPECIALTY SESSION 3

- U. S. Army Engineer Waterways Experiment Station, Corps of Engineers, Vicksburg, Mississippi, June 1969
- 4.- Engineering Foundation Research Conference for discussion of "Expansive Soils" held 15-19 July 1968 at Wayland Academy, Beaver Dam, Wisconsin.
- 5.- "Symposium on Characteristics of and Construction Techniques in Black Cotton Soil" held in College of Military Engineering, Poona, 6-8 May 1969, (For Proceedings, Prof. M. S. Shetty, Construction School, C. M. E., Dapodi, Poona - 12, INDIA)
- 6.- Kassiff, G. M. Livneh and G. Wiseman, Book, "Pavements on Expansive Clays" Jerusalem Academic Press, Jerusalem, Israel, 1969.