REPORT OF PANEL DISCUSSION ON VERTICAL SAND DRAINS

1.0 INTRODUCTION

1.1 Background

This paper reports on the proceedings of a panel discussion on Vertical Sand Drains. The panel discussion was presented by the Geotechnical Section of the Boston Society of Civil Engineers on 13 May 1970 at Harvard University, Cambridge, Mass. The purpose of the panel discussion was to review and discuss recent developments and experiences of the panel members in the area of vertical sand drains.

The distinguished panel members were:

Dr. Leo Casagrande
Division of Engineering & Applied Physics
Harvard University
Cambridge, Mass.

Mr. Stanley Johnson, Special Assistant, Soils Division
Waterways Experiment Station
U.S. Army Corps of Engineers
Vicksburg, Mississippi

Dr. Charles C. Ladd
Associate Professor of Civil Engineering
Massachusetts Institute of Technology
Cambridge, Mass.

Mr. Martin S. Kapp
The Port of New York Authority
New York, New York

The moderator of the discussion was Dr. Harl P. Aldrich, Jr., Haley & Aldrich, Inc., Cambridge, Mass.

1.2 General Description of Vertical Sand Drains

Vertical sand drains are used in compressible soils where it is found necessary to increase the rate of consolidation under applied loads. They consist of vertical columns of pervious material (sand) extending into the compressible soil at regular intervals over the loaded area. These columns of sand are intended to provide a shorter drainage path within the compressible soil, thereby decreasing the time required for dissipation of excess pore-pressures resulting from applied loads. There are many methods of installing these sand columns, including driving, augering and jetting.

1.3 Scope of Discussion

Each of the panel members presented a brief review of his experiences as well as his philosophy concerning the use of vertical sand drains. A general discussion followed which was open to questions and comments from the floor.

Within the general area of vertical sand drains the following specific topics were discussed in detail:

1. The need for vertical sand drains at a given site.
2. The determination of soil properties and soil profiles at the sand drain site.
3. Procedures for design of sand drains.
4. Methods of installation and their effects.
5. Test sections.
6. Use of sand drains to increase strength.
7. Use of sand drains in organic soils.

The main points made by panel members concerning each of these topics are presented below.

2.0 TOPICS OF DISCUSSION

2.1 Usefulness of Sand Drains

All of the panel members generally agreed that sand drains can be an effective means of accelerating the rate of consolidation of compressible soils. However, their need in a specific situation should be carefully evaluated by means of field test sections and a thorough foundation investigation involving continuous sampling procedures.

Dr. Ladd clearly showed from the results of field data, that properly installed sand drains were very effective in a soft sensitive clay in Portsmouth, N.H. Mr. Johnson stated that sand drains are effective in soft soils and that they should be considered an economic alternative to other methods of foundation treatment. Dr. Leo Casagrande, however, felt that sand drains should only be used if their need can be clearly established from field test sections. Mr. Kapp mentioned numerous cases where sand drains were apparently used effectively but he emphasized that perhaps results equally as good could have been achieved without drains. He believes that only field test sections can tell us whether drains are required for a given situation.

2.2 Soil Profiles

All the members strongly emphasized that a thorough foundation investigation is the first step in evaluating the need for drains. Mr. Johnson and Dr.

Casagrande stressed that continuous samples should be obtained and examined for potential internal drainage layers. Likewise undisturbed samples should be obtained for determination of soil properties.

2.3 Determination of Soil Properties

The panel members generally agreed that laboratory tests on undisturbed samples provide good estimates of the vertical coefficient of consolidation.

Dr. Casagrande stressed the importance of field permeability tests in arriving at the relationship of c_h to c_v as well as the actual value of c_h. Dr. Ladd indicated that c_h can be estimated from laboratory permeability tests on vertical and horizontal samples.

Mr. Johnson indicated that the results obtained from the use of vertical sand drains in the field will be at least as good as results predicted on the basis of laboratory tests wherein c_h is assumed equal to c_v computed from the log time method, provided that the coefficient of consolidation is selected at or near the maximum effective stress to be imposed by the surcharge loading. He also stated that c_v values for design frequently correspond to initial in situ or average stresses but this results in too high design values. He stated that this conclusion results from experience and is compatible with recent theoretical analyses that consider the variation of the coefficient of consolidation during loading, as the effective stress increases.

In determining c_v from lab data, Dr. Ladd prefers to average the value obtained from the log time and the square root time methods.

2.4 Installation Method

The panel members disagreed over the benefits of non-displacement type drains. The only general conclusion reached by all panel members in this regard was that field test sections appear to be the only way of resolving this question.

Mr. Johnson emphasized that there is no evidence to date that any installation method affects the average shear strength of the compressible soils. Displacement drains do disturb a small zone of soil near the drains, but this zone re-consolidates rapidly since it is so close to the drain. He pointed out that a zone of reduced permeability must exist around even a perfectly installed sand drain because of rapid consolidation around the drain and the consequent reduction in permeability and void ratio. While the displacement method must cause some undesirable effects on rate of consolidation, the economic effects can be evaluated only by field test sections such as described by Dr. Ladd.

Dr. Casagrande indicated that displacement type drains remold the soil near the drain and reduce its permeability such that it destroys the drainage capability of the drains. He also stated that this disturbance could adversely effect the strength of the soil.

Dr. Ladd discussed the results of two field test sections in Portland, Maine. Incomplete results from one test section involving a sensitive clay showed that displacement type drains were less effective in accelerating the rate of settlement than non-displacement type drains; however, field data from the other test section involving a less sensitive, slightly organic clay did not establish clearly the superiority of augered or jetted drains over driven drains, and the resulting rates of settlement obtained by each method were practically identical (final settlements were not available).

2.5 Test Sections

There was general agreement among the panel members on the need for test sections in designing sand drain installations. The results of test sections can be used to determine the usefulness of sand drains, and the effects of various spacings, sizes and methods of installation. It was pointed out by several panel members that test sections should always have a control area where no sand drains are placed in order to properly evaluate the effects of sand drains. Mr. Johnson noted that test sections should be incorporated into the final embankments. Mr. Kapp stated that the best test section is the final embankment; and monitoring post-construction behavior would provide valuable information on the effectiveness of sand drains. Dr. Casagrande also cautioned on the premature interpretation of results of test sections or final embankments.

Concerning instrumentation of test sections, Mr. Johnson felt that it should be kept as simple as possible, using "Casagrande" or "Bureau of Reclamation" piezometers. He also felt that, where large settlements were anticipated, there was a strong possibility of malfunction and funds for replacement piezometers should be budgeted.

Dr. Ladd stated that piezometers should be placed at a number of different elevations within the compressible layer and should be used in conjunction with settlement measuring devices.

2.6 Use of Sand Drains to Increase Strength

There was no consensus among the panel members on the use of sand drains to increase shear strength. Both Mr. Kapp and Mr. Johnson felt that this was a valid use for sand drains; however, Mr. Johnson cautioned on the anticipation of strength increases during loading. He felt that stage construction was the proper method of taking advantage of shear strength increases. Neither Dr. Casagrande nor Dr. Ladd commented directly on this aspect except to mention that there could be a loss of shear strength resulting from an installation method causing displacement (i.e. driven drains), especially in sensitive soils. (See Section 2.4)

2.7 Use of Sand Drains in Highly Organic Soils

There was general agreement on the inapplicability of sand drains in highly organic soils, especially fresh water peats. The reasons were twofold: first, such soil deposits generally compress so rapidly that sand drains are not required and; secondly, sand drains *per se* do nothing for the problem of secondary compression (or creep) which in these soils is of the same order of magnitude as the compression due to dissipation of excess pore pressure.

Mr. Johnson pointed out that highly organic surface soils are frequently underlain by soft clays, in which sand drains may be required even though of little or no benefit in the overlying organic material. He also stated that postconstruction settlements in organic or other soils can be reduced by surcharge loading.

The question also arose as to the need for removal of surface organic soils when a sand drain installation was planned for underlying compressible soils. There was no general agreement on this question. Mr. Johnson felt that surface organic soils generally should be left in place for economic reasons. He also felt that such soils could be stabilized by proper design.

Mr. Kapp felt that economic considerations might dictate whether these soils should be removed or stabilized. He felt that organic deposits 3 to 4 feet thick should be removed while in deposits 10 to 15 feet thick efforts to stabilize the soil were worthwhile. He also noted that the Port of New York Authority generally does not remove surface organic soils.

Dr. Casagrande felt that the class of highway should be the determining factor in the removal of surface organic soils. He felt that organic soils could not be adequately stabilized because of secondary compression; therefore, for major highways, these soils should be removed and for secondary roads these soils could be left in place with the prospect of continual maintenance. He also noted that high fills on organic soils were apt to cause displacement.

3.0 SUMMARY AND CONCLUSIONS

The results of the panel discussion on vertical sand drains can be aptly summarized by noting the major areas of agreement and disagreement among the panel members.

3.1 Points of General Agreement

The points on which most of the panel members were in general agreement can be summarized as follows:

A. Field test sections are extremely useful in evaluating the need for sand drains as well as the effectiveness of the different types of installation methods.

B. A thorough foundation investigation is the first step in evaluating the need for sand drains. This investigation should include the determination of a detailed soil profile and soil properties.

C. Sand drains are only useful in eliminating primary consolidation. They do nothing to eliminate secondary compression per se. They can be used in conjunction with surcharging, however, to reduce secondary compression.

D. Sand drains are not applicable to highly organic soils since such deposits compress rapidly without drains, and the magnitude of secondary compression in these soils is quite large.

E. Sand drain installations require careful stability analyses, thorough field inspection, and extensive field instrumentation.

3.2 Points of Disagreement

No general agreement was reached among the panel members on the following topics:

A. *Usefulness of sand drains* – Although sand drains are an effective method of treating poor foundation materials, some panel members believed they are often used in cases where they are not needed (i.e., varved clays) or in cases where they do more harm than good (i.e., driven drains in sensitive soils).

B. *Installation method* – The panel members did not agree on the effect that the installation of displacement type drains has on the strength and compressibility of poor subsoils. However, all agreed that field test sections are highly desirable for resolving this question.

C. *The use of sand drains to increase the shear strength of soils* – There was no consensus among the entire panel on this point.

D. *Excavation of highly organic soils – especially fresh water peats* – Some panel members felt that this material should be left in place and others believed it should be excavated. No one felt, however, that sand drains were needed in this material.

4.0 REFERENCES

The following references are useful in pointing out the development and usefulness of sand drain theory (Ref. 1 & 6) and in presenting design procedures

(Ref. 4 & 5). Ref. 3 presents an excellent "State of the Art" discussion on vertical sand drains. Ref. 2 presents some interesting case histories relating to the use of sand drains.

4.1 References

1. Barron, R.A. (1948) "Consolidation of Fine Grained Soils by Drain Wells" Transactions, ASCE, Vol. 113, 1948, pp 718-754.
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3. Johnson, S.J. (1970) "Foundation Precompression with Vertical Sand Drains" ASCE, JSMFD, Volume 96, SM1, pp 145-175.
4. Moran, Proctor, Mueser, & Rutledge (1958) "Study of Deep Soil Stabilization by Vertical Sand Drains, Report to Bureau of Yards and Docks," Department of the Navy.
5. Navdocks DM-7 (1962), "Design Manual, Soil Mechanics, Foundations and Earth Structures" Department of the Navy, Bureau of Yards and Docks.
6. Richart, F.E., Jr. (1957), "Review of the Theories for Sand Drains" Transactions, American Society of Civil Engineers, Volume 124, pp 709-739.

5.0 ACKNOWLEDGEMENTS

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