installations are designed and installed by a wide variety of means which are based mostly on judgement and empiricism. As a result of this review a research contract was initiated between FHWA and Haley and Aldrich, Inc., in September 1983, to conduct analytical and laboratory studies to facilitate the development of an engineering manual of practice containing comprehensive technical guidelines for the design and installation of wick drains.

The study began with a literature search to identify important case history studies and engineering guidelines available in documented form. It was also hoped (and later found to be true) that other research studies would be in progress that could lead to answers to some of our questions. A series of in-depth interviews with leading consultants, specialty contractors, and wick drain manufacturers was also conducted to obtain current state-of-the practice information. Based on the above studies and interviews, a working draft of the manual was developed that included design procedures, specifications, laboratory test methods and construction guidelines. In addition a detailed laboratory evaluation plan was developed to obtain information necessary to improve the draft manual and to develop quantitative, generic criteria for the selection and design of wick drain systems.

The major specific objectives of the laboratory researach study are to 1) investigate the key parameters that affect wick drain performance, and 2) develop new and/or adapt standard laboratory test procedures that can be used to measure selected drain characteristics.

The key parameters and uncertainties associated with their determination have been identified as follows:

- Equivalent diameter (d_w) -- the effects of drain shape and of restricting the area of the drain exterior surface to inflow will be studied.

- Discharge capacity (q_w) -- flow capacity and head loss effects in specific wick drains will be quantified.

- Disturbance effects (d_s) -- extent and influence on design equations caused by insertion and withdrawal of the mandrel will be investigated.

- Permeability of the drain jacket (K_d) -- a threshold value will be determined to establish a specification of appropriate minimum K_d values.

- Jacket clogging -- effect on drain performance will be investigated (clogging is complicated by the presence of a void produced by the mandrel, which will subsequently collapse against the drain).

The equivalent diameter is believed to be a function only of the drain configuration itself; i.e., a geometric property that can be calculated for a given drain. Finite element analyses will be performed to confirm the validity of this hypothesis and to model the effect of restricted inflow area on the consolidation process. Criteria will be established relative to restricted inflow area that can be incorporated into design analyses and wick drain specifications.

Head loss and discharge capacity of 6 wick drains will be tested in a manner similar to European investigations wherein a test device and procedure will be developed that simulates the flow system in an isolated drain as a function of lateral pressure surrounding the drain. If test results compare favorably with those of previous investigators, the test will be proposed as a standard for determination of wick drain discharge capacity.

Primarily, insight into disturbance effects will be obtained from prior research on effects of penetration of piles and cone penetrometers on the surrounding soil. Recommendations may also be developed on optimal mandrel shapes and sizes. Disturbance effects will be evaluated by performing laboratory permeability tests on soils of various sensitivities, organic content, gradation and consolidation pressure. These soils will then be subjected to various levels of shear strain (disturbance) and permeability tests repeated.

Jacket permeability will be evaluated by a parametric study which will identify a threshold value and by a water permeability test recently adopted by ASTM for fabric testing. Jackets whose permeability is less than the threshold value will be considered to adversely retard the consolidation process. Preliminary results show that as long as the jacket permeability is at least equal to that of the surrounding soil, jacket permeability itself should not be a limiting factor.

Jacket clogging will be evaluated by reviewing the geotextile literature and research testing on clogging of fabrics which is applicable to wick drains. The existing results will be used to determine the feasibility of performing further specialized testing to evaluate the importance and/or likelihood of clogging of wick drain jackets.

The results of the laboratory program will be evaluated and used to confirm and/or enhance the procedures given in the technical manual. Possible additional lab testing and/or a field testing program will be considered and proposed for a future study, if appropriate. The research study is expected to be completed by the spring of 1986.

REFERENCES AND SUGGESTIONS FOR ADDITIONAL READING ON WICK DRAINS

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Although wick drains are a relatively new development, especially in the U.S., there is already a significant number of articles and technical papers written about them and related topics. The following list is selected from this extensive published literature. First articles of a more general descriptive nature as well as comprehensive groups of papers and reports are given. The second section lists some case histories and individual research papers which can provide additional valuable information to the design engineer.

I. General Articles, Collections, and Important Reports

Jamiolkowski, M., Holtz, R.D., and Lancellotta, R. (1986) "Performance of Prefabricated Band-Shaped Drains," Construction Industry Research and Information Association (CIRIA) Report, London, England (to be published).

Jamiolkowski, M., Lancellotta, R. and Wolski, W. (1983) "Precompression and Speeding Up Consolidation," General Report, Specialty Session No. 6, Proceedings of the 8th European Conference on Soil Mechanics and Foundation Engineering, Helsinki, Vol. 3, pp. 1201-1226. Discussions and Closure, pp. 1227-1245.

Hansbo, S. (1975), "Consolidation of Clay with Special Reference to be Use of Geodrains," Paper presented at the 1st Baltic Conference on Soil Mechanics and Foundation Engineering, Gdnask, reprinted by Terrafigo AB, Stockholm, 8 pp.

Hansbo, S. (1979), "Consolidation of Clay by Band-Shaped Prefabriced Drains," Ground Engineering, Vol. 12, No. 5, pp. 16-25.

Morrison, A. (1982), "The Booming Business in Wick Drains," Civil Engineering, Vol. 53, No. 3, pp. 47-51.

Symposium in Print on Vertical Drains, Geotechnique, Vol. XXXl, No. 1 March 1981, (contains 5 good papers).

Proceedings of the 8th European Conference on Soil Mechanics and Foundation Enginering, Helsinki, Vol. 2. Papers to Specialty Session No. 6 (17 of 32 papers to this session involve wick drains).

II. Selected Additional References

Suits, L.D. Gemme, R.L., and Masi, J.J. (1985), "The Effectiveness of Prefabricated Drains on the Laboratory Consolidation of Remolded Soils," presented at the ASTM Symposium, January, Ft. Lauderdale, Florida (to be published).

Burke, H.H. and Smucha, S.S. (1981), "Geodrain Installation at Lornex Tailings Dam," Proceeding of the 10th International Conference of Soil Mechanics and Foundation Engineering, Stockholm, Vol. 3, pp. 599-602.

Casagrande, L. and Poulos, S., "On the Effectivenss of Sand Drains," Canadian Geotechnical Journal, Vol. 6, 1969, pp. 287-326.

Chalmers, A. and Harris, A.B. (1981), "Six-storey Building on Soils Improved by Sand Drains," Proceedings of the International Conference on Soil Mechanics and Foundation Engineering, Stockholm, Vol. 3, pp. 611-616.

de Jagerm W,F,H, and Termaat, R.J. (1977), "Test Areas with Several Vertical Drainage Systems in State Highway No. 19 at Schipluiden, the Netherlands," Proceedings of the

International Conference on the Use of Fabrics in Geotechniques, Paris, Vol. 2, pp. 257-263.

Fellenius, B.H. and Wager, O. (1977), Discussion of "Theoretical and Practical Aspects of the Behavior of Vertical Drains with Special Reference to Geodrains," Proceedings of the 9th International Conference on Soil Mechanics and Foundation Engineering, Tokyo.

Hansbo, S. and Torstensson, B.A. (1977), "Geodrain and other Vertical Drain Behavior," Proceedings 9th International Conference on Soil Mechanics and Foundation Engineering, Vol. 1, pp. 533-540.

Holtz, R.D. and Boman, P. (1974), "A New Technique for Reduction of Excess Pore Pressures During Pile Driving," Canadian Geotechnical Journal, Vol. 11, No. 3, pp. 423-430.

Johnson, S.J. (1968), "Foundation Precompression with Vertical Sand Drains," Proceedings ASCE Conference on Placement and Improvement of Sil to Support Structures, Cambridge, Massachusetts, pp. 9-39.

Kjellman, W., "Discussion: Consolidation of Fine-Grained Soils by Drain-Wells," Trans. American Society of Civil Engineering, Vol. 113, 1948, pp. 748-751.

Moran, Proctor, Mueser, and Rutledge (1958), "Study of Deep Soil Stabilization by Vertical Sand Drains, "Washington, D.C., Bureau Yards and Docks, Department of Navy.

Richart, F.E., "Review of Theories for Sand Drains," Transactions American Society of Civil Engineers, Vol. 124, 1959, pp. 709-39.

Rowe, P.W. (1968), "The Influence of Geological Features of Clay Deposits on the Design and Performance of Sand Drains," Proceedings Institution of Civil Engineers, Supplementary Volume, paper 7058S, pp. 1-72.

Sowers, G.F., "Fill Settlement Despite Vertical Sand Drains", Proceedings ASCE,. J. Soil Mechanics and Foundation Division, Vol. 9, No. SM5, September 1964.