Barron-Kjellman formula for radial drainage (Fellenius 8, 9):

$$t = (D^2/8C_h)\ [\ln(D/d_e) - 0.75]\ \ln[1/(1 - \bar{U})] \quad (1)$$

where

t = time,
C_h = horizontal coefficient of consolidation,
D = zone of influence of a drain,
d_e = equivalent diameter of a drain, and
$\bar{U}$ = average degree of consolidation.

This equation assumes that 1) both soil permeability and compressibility are constant 2) Darcy's law is valid; and 3) only radial and horizontal flow takes place.

In addition to proper wick drain selection, proper spacing and correct installation method, each installation project should include construction controls on rate of loading and a detailed instrumentation monitoring program to ensure stability during critical loading periods. Such a system is described by Walsh in his companion article on construction control. Also, a research film report by Caltrans, titled, "The Dumbarton Experience" is available. This film describes soils instrumentation and the use of wick drains and other technology such as lightweight fill and geotextiles to construct highway embankments over soft compressible bay mud soils.

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NEW YORK STATE DEPARTMENT OF TRANSPORTATION'S (NYSDOT) BASIS OF ACCEPTANCE AND SPECIFICATION FOR PREFABRICATED WICK DRAINS

By

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The basis of acceptance and a specification for the use of prefabricated wick drains on NYS DOT projects was developed following an extensive three stage testing program of thirteen (13) prefabricated wick drains presently on the market. The three stages of testing included large diameter consolidation (LDC), crimp, and lateral pressure (crush) tests. The following is a summary of that test program. Reference 1 provides a detailed review of this program.

Following this is the present NYS DOT wick drain specification which is an "Approved list" type of specification. The ten drains which were determined to be acceptable for use on NYS DOT projects in 1985 are listed.

The results of the LDC testing program indicated that most of the prefabricated drains tested produced average equivalent sand drain diameters of between 1.5 and 2.5 inches. A 2.5 inch equivalent diameter drain will drain a soil 20% faster than a 1.5 in. equivalent diameter drain. What this means in a field application is that a 2.5 in. equivalent diameter prefabricated drain installed at a 5.5 ft. drain spacing is as effective as a 1.5 in. equivalent diameter prefabricated drain installed at a 5 foot drain spacing. In other words, the range in the average equivalent diameter drains for most of the prefabricated drains tested had very little effect on the required prefabricated drain spacings. We therefore assumed prefabricated drains, with average equivalent diameter drains between 1.5 and 2.5 inches, to be equal in performance and to be acceptable.

Those prefabricated drains that were not allowed in the specification were those which had average equivalent sand drain diameters less than 1.5 inches or those which did not have a rigid core, or both. The laboratory crush tests have indicated a 12± percent loss in core flow capacity for rigid core prefabricated drains subjected to a crush load of 13.5± psi. On the other hand, a 50 to 90% loss in core flow capacity was experienced for the soft core prefabricated drains subjected to the same crush load.

The laboratory flow through the rigid core prefabricated drains noted in the specification in a crimped state ranged from 30 cc/sec to 210 cc/sec. The crimped flow for the soft core prefabricated drains was 16± cc/sec. The crush test further reduced this number to as low as 1.6 cc/sec. The flow was further reduced to 0.3± cc/sec when taking into account the theoretical loss in flow due to the length of a typical prefabricated drain field installation (60 ft. long in this study). This is considered insufficient to accommodate the consolidation flow of water emerging from the surrounding soil in a typical field application.

Based on the results of the testing program

described above, the following conclusions were drawn:

1. Wick drains were effective in increasing the consolidation rate of compressible soils in the LDC tests.

2. For the soils tested, the acceptable equivalent sand drain diameters of wick drains range from 1.5 to 2.5 in.

3. For the soils tested, the equivalent sand drain diameter range does not significantly affect typical field wick drain spacings.

4. Crimping alone would not reduce the core flow capacity of any of the wick drains enough to hamper flow of water to the drains due to soil consolidation.

5. Taking into account large lateral pressures (144± kPa) applied in the field due to in-place and normally applied embankment loads, the core flow capacity of the soft core wick drains was reduced to an insufficient capacity to handle the expected flow rate of water from the soils tested.

6. A combination of crimping and lateral pressure will not seriously affect the core performance of rigid core wick drains installed in a typical field situation.

Based on the results of the testing program the following specification was developed for use of prefabricated drains on NYS DOT project. The specification calls for drains not appearing among the ten listed drains to be submitted to the N.Y. Soil Mechanics Bureau for evaluation and approval. The drains will be evaluated in the same manner as summarized above. Based on the results of the test program they will be determined as being acceptable or not acceptable. As there are some drains on the list which have not yet been installed in the US, the Contractor is required to install trial drains to demonstrate his ability to produce a satisfactory installation according to the specification. The mandrel or sleeve is limited to a maximum area of ten in. to minimize disturbance effects on the soil around the perimeter of the wick drains.

Prefabricated Vertical Drain Specification - New York State D.O.T.

Item 17203.1201, Prefabricated Vertical Drains

Description

This work shall consist of furnishing and placing Prefabricated Vertical Drains at locations shown on the plans or as ordered by the Engineer.

Materials

The prefabricated drain shall consist of a continuous plastic drainage core wrapped in a non-woven geotextile material. The prefabricated drains used shall be one of the following products:

1. Ali-Drain
2. Amerdrain (Type 407)
3. Colbond (CX-1000)
4. Geodrain
5. Hitek
6. Mebra-Drain (7407)
7. SolCompact
8. Vinylex
9. Bando
10. Castleboard

The above drains shall be accepted based on the certification by the manufacturer.

For other materials, the Contractor shall submit samples of the prefabricated drain for evaluation and approval to the Director of Soil Mechanics Bureau at least one month prior to start of work under this item.

Construction Details

The prefabricated drain shall be installed within a protective mandrel or sleeve which shall be intruded into the soil and retracted after each drain is installed. The mandrel or sleeve shall have a maximum cross-sectional area of ten (10) square inches.

Prior to the installation of prefabricated drains, the Contractor shall stake out the proposed locations of the drains and then take all reasonable precautions to preserve the stakes. The location of the drains shall not vary by more than six (6) inches from the locations indicated on the plans or as directed by the Engineer. The Contractor shall then demonstrate that his equipment, method and materials produce a satisfactory installation in accordance with this specification. For this purpose, the Contractor will be required to install trial drains at locations within the work area designated by the Engineer.

The prefabricated drains shall be installed in a sequence such that equipment will not travel over previously installed drains. Any drains that are damaged by the Contractor's operations shall be replaced at his own expense.

The prefabricated drains shall be installed vertically from the working surface to the elevations shown on the plans or as ordered by the Engineer.

The Contractor shall provide the Engineer with a suitable means of verifying the plumbness of the equipment and determining the depth of the drain at any time.

Splices or connections of the prefabricated drain material shall be done so as to insure continuity of flow through the prefabricated drain material as approved by the Engineer. The prefabricated drain material shall be cut such that at least a six (6) inch length protrudes above the working surface at each prefabricated drain location.

It may be necessary to pre-auger or use some other method to clear obstructions and facilitate the installation of the drains. The depth to which pre-augering is used shall be subject to approval by the Engineer.

Method of Measurement

The quantity of prefabricated drain shall be the number of linear feet satisfactorily installed from the top of the working surface to the design elevation of the tip of the drain.

Basis of Payment

The unit price bid per linear foot shall include the costs of furnishing all equipment, labor and materials to properly install the prefabricated drains. No payment will be made for pre-augering or other methods used to facilitate the installation of the drain.

Prefabricated Vertical Drain Sources

Ali-drain	Dougherty Foundation Products, Inc. 7 Washington Avenue, Patterson, New Jersey 07503 (201) 337-5748
Mebra-drain	International Construction Equipment, Inc. 301 Warehouse Drive, Matthews, N.C. 28105 (800) 438-9281, (704) 821-7681 L. B. Foster Co., 415 Holiday Drive, Pittsburgh, PA 15220 (412) 928-3475
Geodrain	Terrafigo A.B., Kungsgatan 32, S-111 35 Stockholm, Sweden (08)-11-03-32
Bando	Harry Fukuzawa & Associates, 6129 Queenridge Drive Rancho Palos Verdes, CA 90274 (213) 377-4735
Sol Compact	Moretrench American Corporation, P.O. Box 316 Rockaway, NJ 07866 (201) 627-2100
Colbond (CX-1000)	American ENKA Company, Enka, NC 28728 (704) 667-7110
Amerdrain (Type 407)	International Construction Equipment, Inc. Corporate Offices, 301 Warehouse Drive Matthews, NC 28105 (800) 438-9281
Vinylex	Vinylex Corporation, P.O. Box 7187 Knoxville, TN 37921 (615) 690-2211
Hitek	Burcan Manufacturing, Inc. 100 Union Street, Suite 16 Bridgeville, PA 15017 (412) 257-2751 Attention: Alvin W. Berthold
Castleboard	Harquin International Corporation 3112 Los Feliz Boulevard Los Angeles, CA 90039 (213) 669-8332

Field Experiences

Since the start and completion of the described test program, the New York State DOT has had three installations of wick drains. These were installed on two separate projects in the central part of the state, one in the vicinity of Syracuse, New York, the other near Utica, New York.

The Utica installation involved the construction of 30± ft high embankments over 20 ft of soft, wet, organic soils. Of concern was the potential for instability of the foundation soils. This was compounded by long-term settlement of the embankments.

The wick drain selection to stabilize the foundations soils through rapid consolidation and strength gain was made over the conventional excavation of these soils and replacement with granular material at a savings of over $3 million.

The wick drains were installed in a triangular pattern, with 4 ft spacings. The performance of the installation verified the anticipated results based on the previously described laboratory test program.

The two installations on the Syracuse project involved the construction of 35 to 40 ft. embankments over 15± ft. of miscellaneous fill, underlain by 20± ft. of marl over 30± ft. of soft silts and clays.

The wick drains were installed on spacings ranging from 4 to 7 ft. Previous construction in the area had used a conventional sand drain installation to accelerate the consolidation of the weak, fine grained foundation soils. At this time there is no estimate of total savings by the use of the wick drains, although, they are estimated at approximately half the cost of conventional sand drains.

As in the Utica project, the wick drains performed as anticipated from the laboratory test program.

References

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CONSTRUCTION CONTROL
for
WICK DRAIN SYSTEMS

by
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In most cases, wick drains will be installed on projects involving questionable foundation stability. Indeed, the function of the drains is to provide a relatively rapid drainage path in order to accelerate consolidation and thus improve the strength of soft foundation soils. Strip load embarkment construction such as that for highways and railroads is particularly vulnerable because failure can occur on both side slopes and foreslopes. Good construction control is essential in order to assure success.

In "high risk" situations, such as that where wick drains are installed for ground improvement, a well conceived instrumentation system to monitor ground movements and pore water pressures is essential. Carefully selected instruments, installed by qualified personnel and continuously observed will provide data to confirm design assumptions or indicate potential problems; to indicate the drainage wicks are functioning properly and to control construction rates, so construction can proceed as rapidly as is consistent with project safety.

For construction control, certain basic instrumentation is essential. The amount and sophistication of any instrumentation should be related to the size and importance of a project and to the consequences of failure.

On the Caltrans project at Dumbarton in the South San Francisco Bay, where wick drains were installed, various instruments were employed; some being primarily for research purposes.

Instrument stations were set up at 500 foot intervals.

The instruments used were:

- o pipe riser settlement platforms
- o open tube piezometers
- o horizontal profile gages
- o anchor post settlement gages
- o inclinometers
- o heave stakes

A reliable monitoring system is dependent upon the quality of the instruments, the care of installation, the competence of the installer-observer-recorder; and of course the interpretation being made by an experienced, knowledgeable engineer.

Of these, the settlement platforms and piezometers are considered essential on projects of this type.