

#67-F-32

W.P. #178-64

Hwy #35 AT

BEACH RIVER

CROSSING

GENERAL DESCRIPTION OF WORK

The work consists of the following:

- (1) Driving Six 12-3/4" O.D. x 0.203" steel tube piles -
(four at 100', one at 80', and one at 50')

Two 12 BP at 53 steel H-piles -
(one at 80', and one at 50')

One #14 treated timber pile -
(50' long)

- (2) Supplying and fixing in position a suitable reaction beam and attaching it initially to four anchor piles, then carrying out load and extraction tests on five test piles. The beam should be capable of withstanding a vertical load of 200 tons at the centre.

- (3) Supplying and fixing in position and attaching to piles as required, a suitable yoke to be used in conjunction with a hydraulic jack and the reaction beam for the purpose of extraction tests on five test piles. The yoke must have a capacity of 150 tons.

- (4) Placing concrete in steel tube piles, splicing and cutting off piles as required.

- (5) Welding drive shoes to piles.

- (6) Carrying out one load and one extraction test on each of two 12-3/4" O.D. steel tube piles, two 12 BP at 53 steel H-piles, and one No. 14 timber pile, as directed by the Department, and in general, according to the National Building Code of Canada.

cont'd. /2 ...

(7) Supplying and fixing in position all materials and equipment necessary to:

- (a) Carry out the load and extraction tests.
 - (b) Extend, if necessary, the lengths of any piles in order to suitably adjust the height and level of the reaction beam and test piles.
 - (c) Install reference beams, gauge brackets and bearing plates for the load and extraction tests, as directed by the Department.
- (8) Providing access to the site from Hwy. #35.
- (9) Clearing site at completion of work to the satisfaction of the Department.

NOTE: If any material or equipment supplied by the Contractor proves to be inadequate or defective, it must be replaced or modified to the satisfaction of the Department at the Contractor's expense.

MATERIALS

The following materials and equipment will be supplied by the Department and made available to the Contractor at the designated points:

- (1) Steel Tube Piles -
12-3/4" O.D. x 0.203" wall - 12 pieces at 45' -
Available F.O.B., D.H.O. Central Stores, Downsview.
- (2) Steel H-Piles -
12 BP at 53 - 3 pieces at 45' -
Available F.O.B., D.H.O. Central Stores, Downsview.
- (3) Timber Piles -
No. 14 Treated Timber Pile - 1 piece at 50' -
Available F.O.B., D.H.O. Central Stores, Downsview.
- (4) One 200-ton Hydraulic Jack -
Available at D.H.O. Laboratory Building, Downsview.

cont'd. /3 ...

Materials: (cont'd.) ...

- (5) Four Deflection Gauges -
Available at D.H.O. Laboratory Building, Downsview.

The following may be supplied by the Department if available at the time of the contract:

Steel Reaction Beam - made up as follows:

36 W^f at 182 x 35' long reinforced by 11" x 1" x 18'-0" long and 11" x 3/4" x 15'-0" long cover plates on each flange, and 5" x 1/2" x 2'-9-7/8" stiffeners spaced at 2'-4" crs. (both sides of web).

If this item can be supplied by the Department, it will be made available F.O.B., Central Stores, D.H.O., Downsview.

All other materials and equipment necessary to carry out the above work must be supplied by the Contractor.

All materials and equipment supplied by the Department will remain the property of the Department at the completion of the work.

DRAWINGS

The site location and the layout of the test piles and anchor piles are shown on Drawing #67-F-32A and #67-F-32B, respectively. Subsoil stratigraphy is shown on Drawing #67-F-32C. The Contractor must include with his quotation, a sketch showing the details of:

- (1) Reaction Beam
- (2) Yoke (for extraction tests)
- (3) Method of attaching the yoke to the various types of pile.

QUOTATION

The Contractor should submit a quotation for carrying out the work as outlined above, such quotation to include for the provision of all personnel, equipment and materials except as provided for in the section headed 'Materials' above. The quotation should be itemized as follows, and the quantities shown will be the minimum pay quantities.

cont'd. 1/4 ...

- (1A) Supply all equipment and materials for pile driving and for load and extraction tests (Reaction Beam supplied by D.H.O.)

(Lump Sum)

- (1B) Supply all equipment and materials for pile driving and for load and extraction tests (Reaction Beam not supplied by D.H.O.)

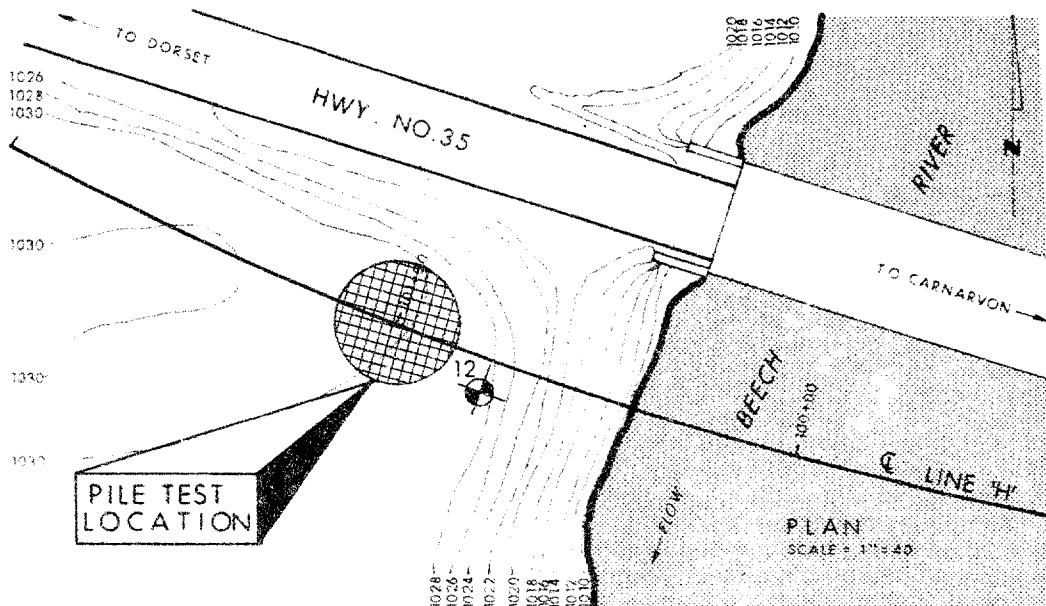
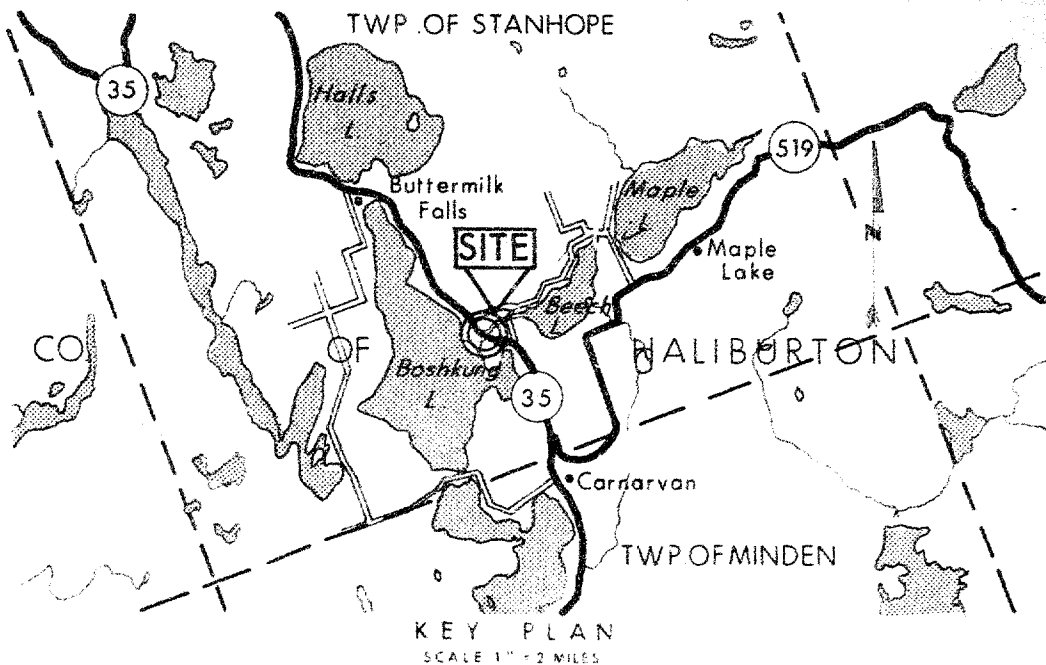
(Lump Sum)

- (2) Weld drive shoes to tube piles. (Quantity - 7 ea.)
- (3) Drive steel tube piles. (Quantity - 530 lin. ft.)
- (4) Drive steel H-piles. (Quantity - 130 lin. ft.)
- (5) Drive timber pile. (Quantity - 50 lin. ft.)
- (6) Place concrete in tube piles. (Quantity - 16 cu. yd.)
- (7) Carry out load tests. (Quantity - 5 ea.)
- (8) Carry out extraction tests. (Quantity - 7 ea.)

SITE

The site is located on Hwy. #35 some 4.7 miles north of the junction with Hwy. #530 at Carnarvon (Lot 14, Con. 3, Twp. of Stanhope, Co. of Haliburton).

The Contractor is responsible for providing access to the site for all materials and equipment necessary to carry out the work.



ONTARIO

DEPARTMENT OF HIGHWAYS
MATERIALS and
CONSTRUCTION
DIVISION

HWY. 35 & BEACH RIVER PILE TEST LOCATION

W.P. 178-64

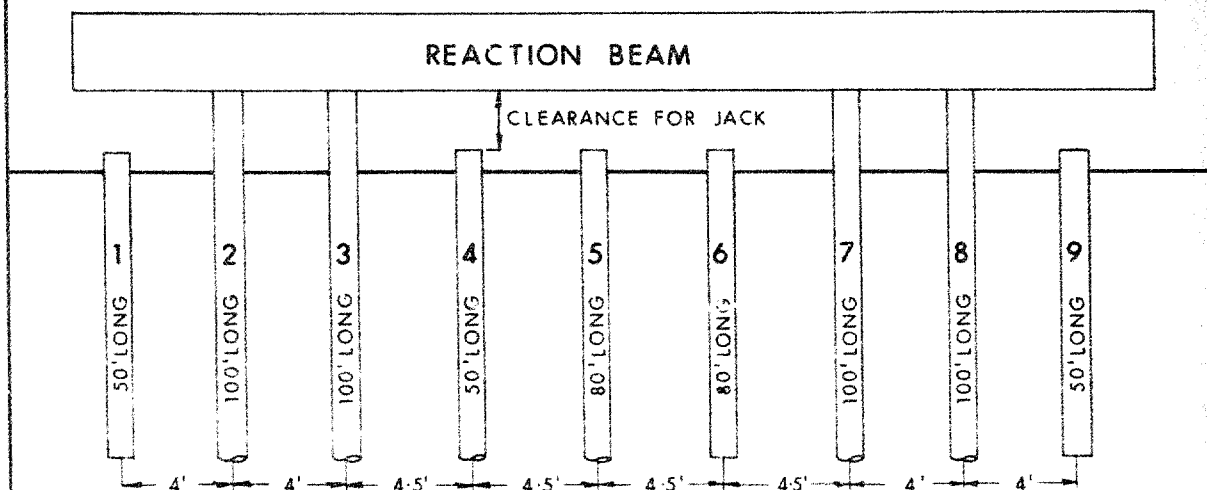
DIST. 11

JOB. 67-F-32

DATE 17 APRIL 67.

APPROVED

DRAWING NO. 67-F-32 A



NOTE AFTER LOAD TEST ON PILE NO. 5
SECURE PILE NO. 5 TO REACTION BEAM.

PILE LENGTHS APPROX. ONLY

PILE NO. 1 TREATED TIMBER NO. 14

PILES 6 & 9 STEEL 'H' PILES (12 B P @ 53)

PILES 2, 3, 4, 5, 7, & 8 TUBULAR STEEL PILES 12³/₄ X 0.203

SEQUENCE OF OPERATIONS

- (1) DRIVE PILES
- (2) PLACE CONCRETE IN PILES
- (3) ATTACH REACTION BEAM TO ANCHOR PILES
- (4) FIX REFERENCE BEAM AND DIAL GAUGES
- (5) LOAD TEST PILE NO. 5
- (6) ATTACH REACTION BEAM TO PILE NO. 5
- (7) LOAD TEST PILE NO. 6, 4, 1, & 9 (IN THAT ORDER)
- (8) EXTRACTION TEST ON PILES 5, 6, 4, 1 & 9
- (9) CLEAR SITE TO SATISFACTION OF D.H.O.



DEPARTMENT OF HIGHWAYS
MATERIALS and
TESTING
DIVISIC

ONTARIO

HWY. 35 & BEACH RIVER

ARRANGEMENT OF TEST PILES ANCHOR PILES & REACTION BEAMS

W.P. 178-64

DIST. 11

JOB 67-F-32

DATE 17 APRIL 67.

APPROVED

Handwritten signature

DRAWING NO. 67-F-32B

1030

1020



1000

980

960

940

920

'N'

5

14

11

14

17

14

15

20

8

14

12

18

18

10

25

9

24

FINE TO MEDIUM SAND
Loose To Compact

LAYERS OF SILT & SAND
Compact

FINE TO MEDIUM SAND
TRACES OF FINE GRAVEL
Compact

LAYERS OF SILT & SAND
Compact

PROBABLY COMPACT SAND
(CONE PENITRATION ONLY)

900



ONTARIO

DEPARTMENT OF HIGHWAYS
MATERIALS and
TESTING
DIVISION

HWY. 35 & BEACH RIVER

SOIL STRATIGRAPHY AT B.H.12

W.P. 178-64

DIST. 11

JOB. 67-F-32

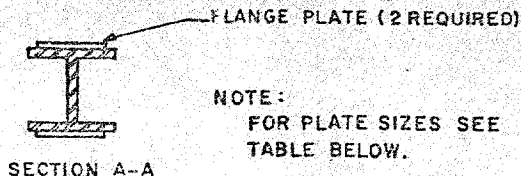
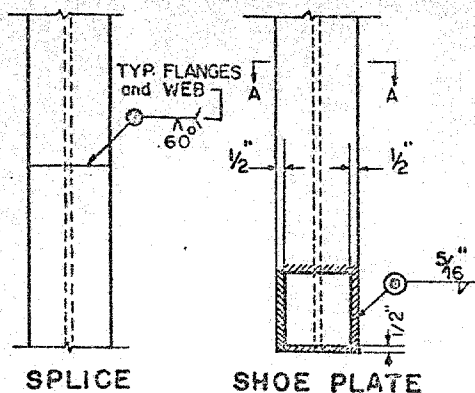
DATE 17 APRIL 67.

APPROVED

Handwritten signature

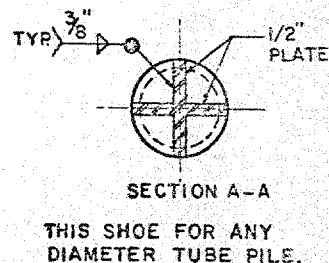
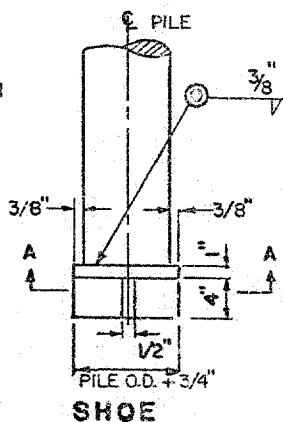
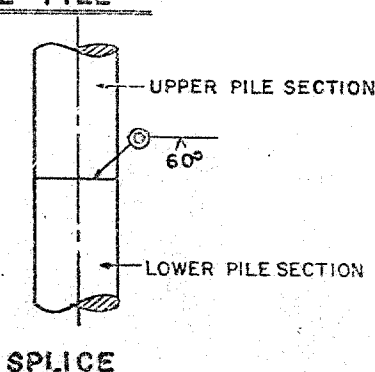
DRAWING NO. 67-F-32C

STEEL H PILES

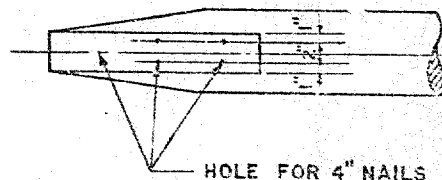
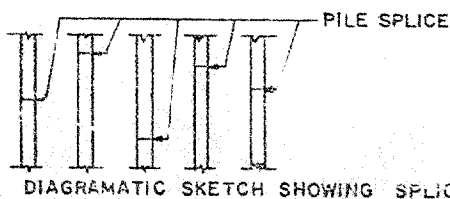
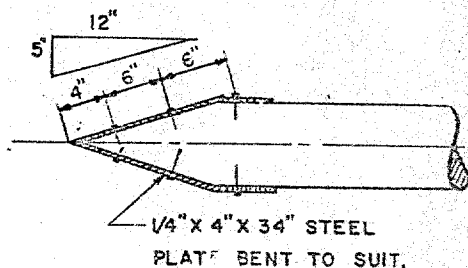
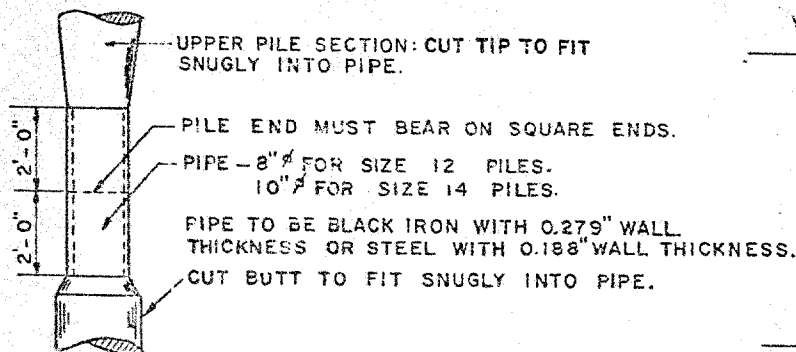


PILE	10 B.P. 42	12 B.P. 53	14 B.P. 73
FLANGE PLATES	9"x1/2"x12"	11"x1/2"x12"	13"x1/2"x12"

TUBE PILE



TIMBER PILES



DIAGRAMATIC SKETCH SHOWING SPLICE STAGGERING.

Mr. C. S. Grabaki,
Bridge Design Engineer,
Bridge Division,
Admin. Bldg.

Foundation Section,
Materials & Testing Div.,
Room 107, Lab. Bldg.

October 31, 1967

*** BEACH RIVER BRIDGE ***

W.P. 178-64 -- Site 40-2 -- W.J. 67-P-32
Hwy. 35 -- Dist. #11 (Huntsville)

We have recently completed the pile load and extraction tests at the above location, and have re-reviewed your Preliminary Bridge Plan Drawing #D-6026-P1 in the light of the new information. Following is a summary of the test results:

<u>Pile</u>	<u>Type</u>	<u>Load</u>	<u>Settlement (2 Hrs.)</u>	<u>Pull</u>	<u>Deflection</u>
1	No. 14 Timber (46'-8 $\frac{1}{2}$ ")	70 Tons 90 Tons	0.55" 1.14"	30 Tons 35 Tons	0.12" 0.87"
2	12 $\frac{1}{2}$ O.D. Tube (50'-6")	60 Tons 80 Tons	0.29" 1.25"	40 Tons 40 Tons	0.20" 1.06"
3	12 $\frac{1}{2}$ O.D. Tube (73'-6")	80 Tons 90 Tons	0.75" 2.0"	40 Tons 50 Tons	0.22" 0.50" +
4	12 BP @ 53 (73'-6")	160 Tons 170 Tons	1.33" 2.34"	40 Tons 50 Tons	0.40" 3.20"
5	12 BP @ 53 (50'-6")	70 Tons 80 Tons	0.43" 0.94"	20 Tons 30 Tons	0.15" 0.82"

NOTE: The lower values are less than the failure load (or pull), whilst the higher values are deemed to be in excess of the failure load (or pull).

It is of interest to note that the design as shown on Drawing #D-6026-P1, utilizes steel tube piles with a design load of 70 Tons/pile. If this design had been proceeded with, some of the piles would probably have been loaded to beyond their ultimate capacity.

cont'd. /2 ...

Mr. C. S. Grebski,
Bridge Design Engineer,
Bridge Division,
Admin. Bldg.

October 31, 1967

Beach River Bridge ...

Based on the pile test results, it appears that the most suitable type of pile to use in the new structure would be 12 BP @ 53 steel H-piles with reinforced tips. These piles should be driven into the subsoil so as to have an embedded length of about 75 feet. A safe load of 70 tons/pile may be assumed for design purposes.

As an alternative, consideration should be given to the use of Franki-type displacement caissons, details of which are given in the Foundation Report by H. Q. Golder and Associates Ltd.

We will be forwarding to you, our complete report on the pile tests in the near future.

If you have any further queries regarding this project, please contact this Office.

KCS/wdeP

H. G. Selby
K. G. Selby,
SUPERVISING FOUNDATION ENGR.
For:
A. G. Stermac,
PRINCIPAL FOUNDATION ENGR.

cc: Messrs. S. McCombie
J. B. Curtis
W. S. Aitken

Foundations Files
Gen. Files

23-70-227

RE: Pile Load &
Extraction Tests
At Beech R. Cross
On Hwy #35

W. S. Aitken
District Engineer
Huntsville

Foundation Section
Materials & Testing Div.
Room 107, Lab. Bldg.
Downsview

Attn: W. Ham
Construction Engineer

September 21, 1967

File Load and Extraction Tests at
Beech River Crossing on Hwy. #35
W.O. 67-31964 & W.O. 67-31963
W.P. 178-64 -- W.J. 67-F-32
Extras to the contract

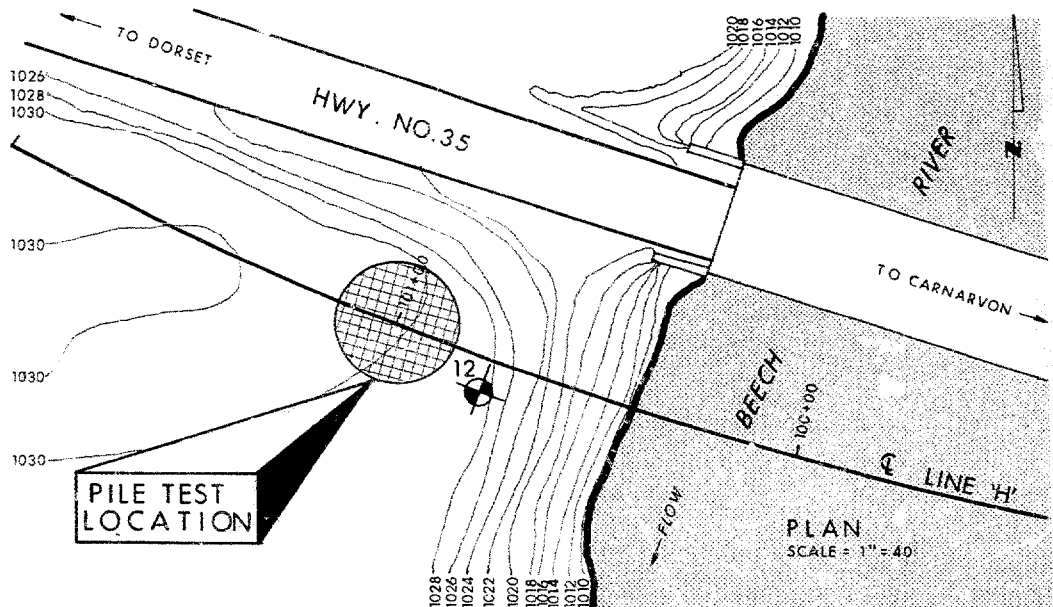
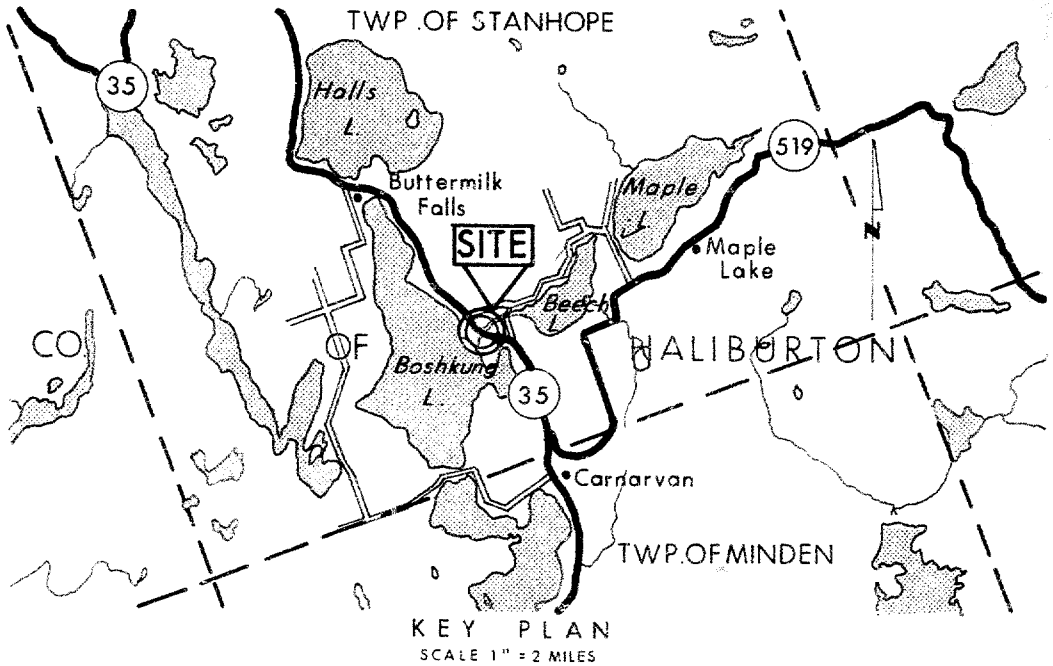
As discussed with you by phone recently, we are enclosing the written confirmation of Franki of Canada's price for supplying and installing 3/4 inch ϕ pipes and 1/4 inch ϕ rods in two tube piles for purposes of measuring differential deflections. This work was not included in the original estimate.

There should be sufficient money in Sundry Construction to take care of this extra.

H. G. Selby

KGS:mt

K. G. Selby
Supervising Foundation Engineer
for: A. G. Stermac
Principal Foundation Engineer



DEPARTMENT OF HIGHWAYS
**MATERIALS and
 TESTING
 DIVISION**

ONTARIO

HWY. 35 & BEACH RIVER PILE TEST LOCATION

W.P. 178-64

DIST. 11

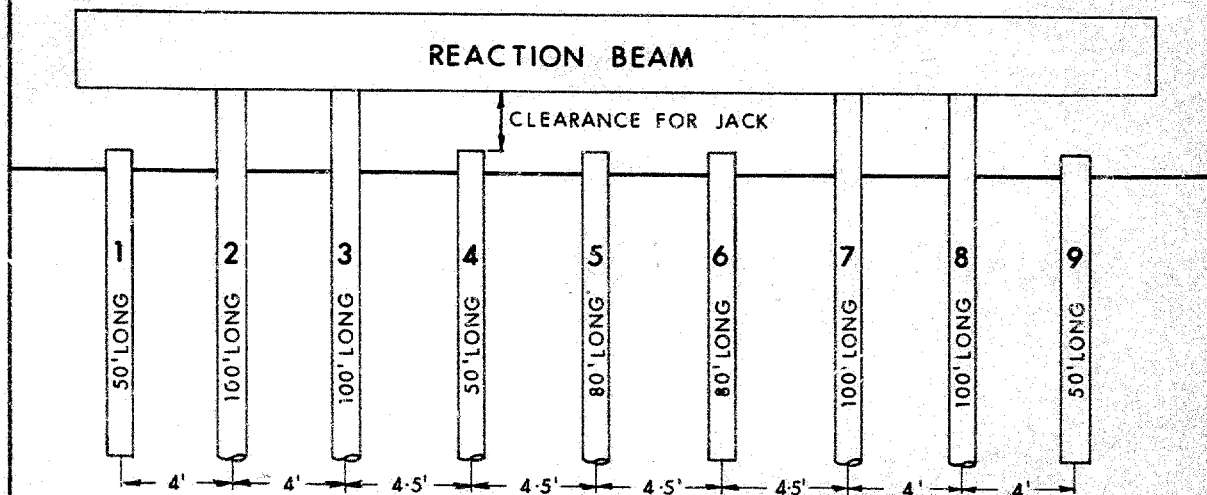
JOB. 67-F-32

DATE 17 APRIL 67.

APPROVED

sk to S.W.

DRAWING NO. 67-F-32 A



NOTE AFTER LOAD TEST ON PILE NO. 5
 SECURE PILE NO. 5 TO REACTION BEAM.
 PILE NO. 1 TREATED TIMBER NO. 14
 PILES 6 & 9 STEEL 'H' PILES (12 B.P. # 53)
 PILES 2, 3, 4, 5, 7, & 8 TUBULAR STEEL PILES 12³/₄ X 0.203

PILE LENGTHS APPROX. ONLY

SEQUENCE OF OPERATIONS

- (1) DRIVE PILES
- (2) PLACE CONCRETE IN PILES
- (3) ATTACH REACTION BEAM TO ANCHOR PILES
- (4) FIX REFERENCE BEAM AND DIAL GAUGES
- (5) LOAD TEST PILE NO. 5
- (6) ATTACH REACTION BEAM TO PILE NO. 5
- (7) LOAD TEST PILE NO. 6, 4, 1, & 9 (IN THAT ORDER)
- (8) EXTRACTION TEST ON PILES 5, 6, 4, 1 & 9
- (9) CLEAR SITE TO SATISFACTION OF D.H.O.



DEPARTMENT OF HIGHWAYS
**MATERIALS and
 TESTING
 DIVISION**

DATE 17 APRIL 67.

W.P. 178-64

APPROVED

HWY. 35 & BEACH RIVER

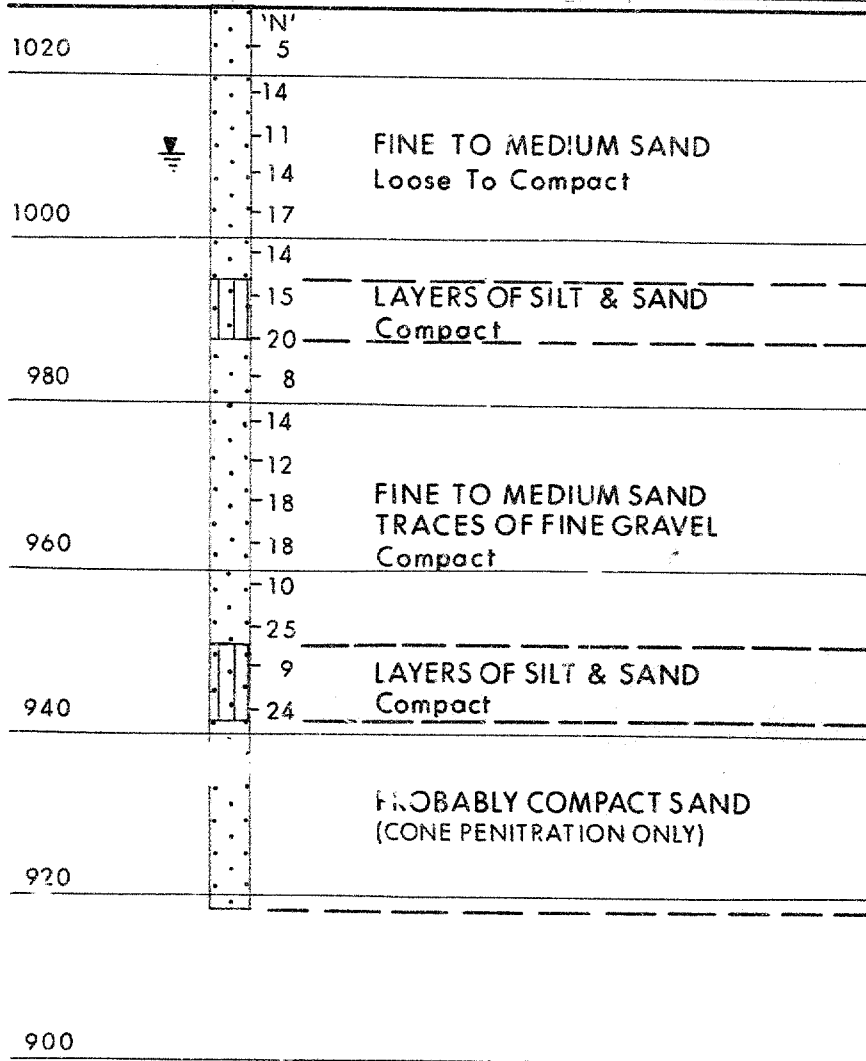
ARRANGEMENT OF TEST PILES ANCHOR PILES & REACTION BEAMS

DIST. 11

JOB 67-F-32

DRAWING NO. 67-F-32B

1030



DEPARTMENT OF HIGHWAYS
MATERIALS and
TESTING
DIVISION

ONTARIO

HWY. 35 & BEACH RIVER

SOIL STRATIGRAPHY AT B.H.12

W.P. 178 - 64

DIST. 11

JOB. 67 - F - 32

DATE 17 APRIL 67.

APPROVED

Handwritten signature

DRAWING NO. 67 - F - 32G

Hwy. 401 & Keesle St.,
Downsview, Ontario.

Tel. 248-3282
(Area Code 416)

Materials and Testing Division

April 19, 1967

Birmingham Construction Ltd.,
Ft. Wellington N.,
Hamilton, Ontario.

W.P. 178-64

Attention: Mr. W. Birmingham

Dear Sirs:

WJ6; F2

Please supply us with a firm quotation for carrying out the work outlined on the attached sheets.

The work described will be carried out under the technical supervision of the D.H.O. Foundation Section, and will be subject to the conditions contained herein and to the current relevant D.H.O. specifications.

The prices quoted should be exclusive of Federal Sales Tax, but should include Ontario Sales Tax.

It is intended that the work be commenced early in June 1967.

We would like to receive your quotation within two weeks. Please include your time schedule.

Very truly yours,

K. G. Selby

KGS/MdeF
Attach.

Note: Identical
correspondence
sent to the following:

K. G. Selby,
SUPERVISING FOUNDATION ENGR.
For:
A. G. Stermac,
PRINCIPAL FOUNDATION ENGR.

1. W. C. Pietz, Ltd. - 234 Eglinton Ave. E.,
Toronto, Ontario.

Attn: Mr. W. C. Pietz

2. A. Johnson Co. (Canada) Ltd.,
Piling Division,
48 Cornforth Rd., Toronto 16, Ont.

Attn: Mr. P. Wilson

3. Franki (Canada) Ltd.,
214 Merton Street,
Toronto, Ontario.

Attn: Mr. A. Prior

qf

PILE LOADING TESTS
AT THE SITE OF THE PROPOSED CROSSING
OF HWY. #35 OVER THE BEACH RIVER
DISTRICT #11 (HUNTSVILLE)
W.O. 67-F-32 -- W.P. 178-64

Reprinted from

Canadian Geotechnical Journal

Revue Canadienne de Géotechnique

Pile tests at Beech River

K. G. SELBY

Volume 7 • Number 4 • 1970

Published by The National Research Council of Canada

**DEFECTS IN NEGATIVE DUE TO
CONDITION OF ORIGINAL DOCUMENT**

Pile tests at Beech River¹

K. G. SELBY

Materials and Testing Office, Department of Highways, Downsview, Ontario

Received July 8, 1970

A program of pile loading tests has been carried out by the D.H.O. Foundation Section, at the site of the proposed new bridge over Beech River on Hwy. 35 near Carnarvon, Ontario. Subsoil consists of deep deposits of sands and silts. Five piles of various lengths were tested to failure, these being 12 $\frac{1}{2}$ -in. O.D. (32.4 cm) steel tubes, 12 BP 53 steel H-piles, and one No. 14 timber pile.

The results of the tests have been compared with predictions based on theoretical and empirical conventional methods and, also, by a method using information obtained in the field using the Geoprobe. The results of the load tests illustrate clearly the difficulties involved in attempting to assess loading capacities of piles in cohesionless soils by means of the conventional methods based on soil properties determined during routine foundation investigations.

Un programme d'essais de chargement de pieux a été exécuté par la section "Fondations" du DHO sur le site d'un pont projeté au dessus de la rivière Beech sur l'autoroute 35 près de Carnarvon, Ontario. Le sol est constitué de dépôts épais de sables et silts. Cinq pieux de différentes longueurs ont été chargés à la rupture, soit des pieux tubulaires en acier de 12 $\frac{1}{2}$ po. (32.4 cm) de diamètre extérieur, des pieux H, 12BP53 et un pieu de bois no. 14.

Les résultats des essais ont été comparés aux prévisions basées sur l'utilisation des méthodes conventionnelles, théoriques ou empiriques, de même que d'une méthode ayant recours aux résultats d'essais in situ au géoprobe. Les résultats des essais de chargement montrent clairement les difficultés liées à toute tentative de calcul de la capacité portante de pieux, forcés en milieu pulvérulent, au moyen des méthodes conventionnelles basées sur l'utilisation des propriétés du sol déterminées lors de reconnaissances géotechniques classiques.

A series of pile load and extraction tests was carried out in August/September, 1967, at the site of the proposed crossing of Hwy. 35 and the Beech River by Franki (Canada) Ltd. under the supervision of the D.H.O. Foundation Section. The purpose of these tests was to determine the most suitable type of pile and the working loads to be used for the new bridge structure. A description of the site, subsoil conditions, pile driving, test procedures, and results, follows.

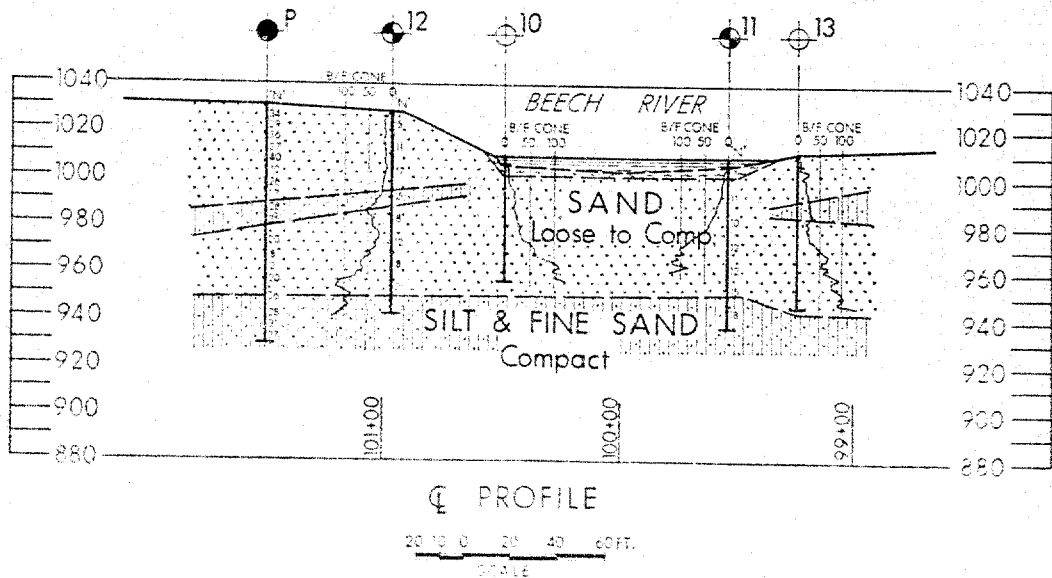
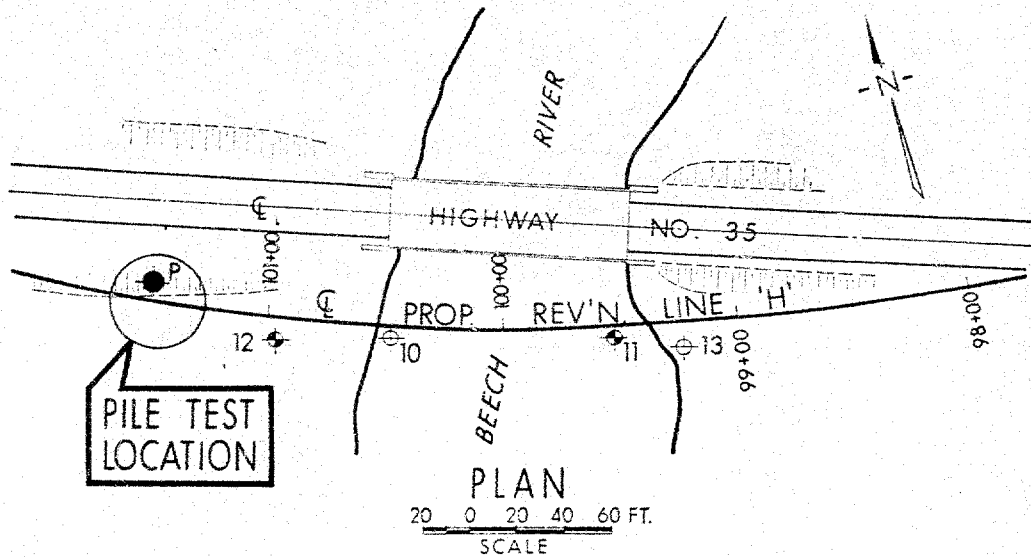
The site is located on the west bank of the Beech River just south of the existing single-span bridge. At this location, the river is some

125 ft (38 m) wide and about 9 ft (~3 m) deep, and flows in a southerly direction into Boshkung Lake. The topography of the area is sharply undulating with much outcropping bedrock. The site and much of the surrounding countryside is quite heavily treed. At the river crossing, Hwy. 35 follows a fairly sharp curve: the new alignment (Rev'n Line 'D') follows a much flatter curve and is some 50 ft (15 m) south of the center-line of the existing road.

From available geological information, it is believed that the subsoil in the site area consists of extensive fluvial deposits of sands and silts of post-glacial origin. Bedrock in the area is metamorphic in type and is comprised chiefly of granite gneiss of Precambrian Age.

A detailed description of subsoil conditions

¹Presented to the Geotechnical Society, Toronto, February 1970.



in the general site area is given in a foundation report prepared by H. Q. Golder & Associates Ltd. Briefly the conditions as described in the report, are as follows: Below the topsoil, subsoil consists of a 50 to 90 ft (15 to 27 m) thick deposit of loose to compact fine to medium sand. This deposit contains a 7 to 15 ft (2 to ~5 m) thick zone of compact layers of silt and fine sand, and is also underlain by a similar

deposit. Groundwater level is at or slightly above the river level.

In addition to the original foundation investigation by H. Q. Golder, one borehole designated B.H. P, was drilled at the actual site of the test piles. This borehole revealed conditions substantially the same as described above. Figures 1 and 2 show the site plan and the stratigraphical profile along the center-line of

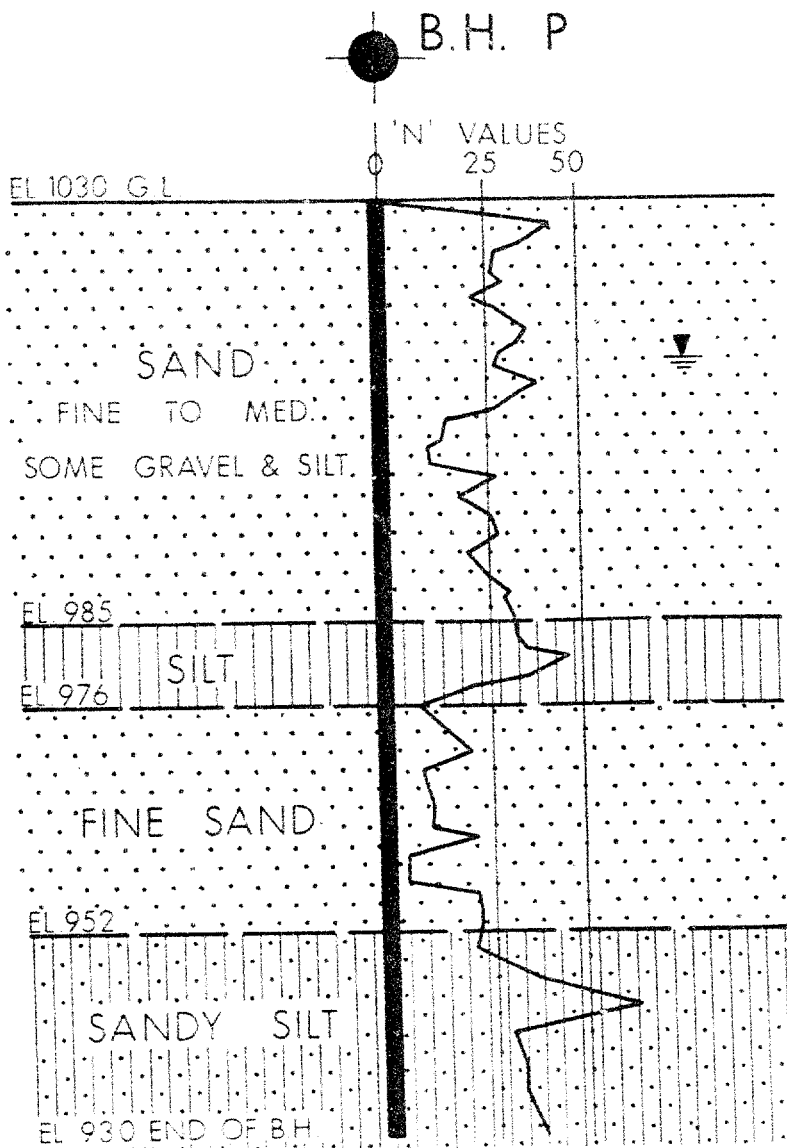


FIG. 3. Stratigraphy at pile test location.

the new structure, and Fig. 3 shows the stratigraphy at the pile test location (B.H. P).

Six 12½-in. (32.4-cm) O.D. steel tube piles with closed ends, two 12 BP @ 53 steel H-piles and one No. 14 treated timber pile were driven at the site by means of a 4000-lb (1815-kg) drop hammer having a free fall of 4.0 ft (1.2 m). In the case of the timber pile, the fall was reduced to 3.0 ft (1 m). Four of the steel tube piles numbered 6, 7, 8, and 9 were driven some 73 ft (22 m), 77 ft (23 m), 84 ft (26 m),

and 74 ft (23 m) into the soil for the purpose of anchoring the reaction beam system. The remainder of the piles—1, 2, 3, 4, and 5 were the actual test piles and were driven to various depths. The steel tubes were fitted with standard 13½-in. (34.3-cm) diameter by 1-in. (~2.5-cm) thick shoe plates and were filled with concrete after driving. A complete record of hammer blows and penetration was made during driving operations.

The following table gives the types, lengths,

TABLE I
Types, lengths, and cut-off elevations

No.	Type of pile	Tip el.	Length in ground ft	Driving time min.	Driving energy ft-lb./Blow
1	No. 14 Timber	982.5	46.7	54	12000
2	12 $\frac{1}{2}$ \times 0.203 Tube	978.9	50.5	52	16000
3	12 $\frac{1}{2}$ \times 0.203 Tube	956.0	73.5	91	16000
4	12 BP @ 53	956.0	73.5	71	16000
5	12 BP @ 53	978.8	50.5	31	16000
6	12 $\frac{1}{2}$ \times 0.203 Tube	956.5	72.8	75	16000
7	12 $\frac{1}{2}$ \times 0.203 Tube	952.3	77.0	120	16000
8	12 $\frac{1}{2}$ \times 0.203 Tube	945.6	83.7	86	16000
9	12 $\frac{1}{2}$ \times 0.203 Tube	955.5	73.8	59	16000

and cut-off elevations of all piles driven, together with the continuous driving times.

One load test and one extraction test were carried out on each of the five test piles. Loads were applied to a particular pile under test, by means of a hydraulic jack acting between the pile top and a steel reaction beam which was attached to the anchor piles. The extraction tests were performed by jacking between the top of the reaction beam and the upper beam of a specially fabricated steel yoke, the lower end of which was attached to the test pile. Vertical deflections of the pile under test were measured by means of four gauges which were mounted on the head of the pile, one at each quarter point on the circumference. These gauges measured the pile movement relative to two independently supported reference beams. The average reading of the four gauges was taken to be the pile deflection.

Application of loads to the piles was carried out as follows: The loads were applied in increments ranging from 10 to 20 tons (9070 to 18 140 kg). After each increment was added, the prevailing load was maintained for a period of 2 h. or until the rate of settlement fell below 0.01 in./h, whichever was the shorter period. Loading was continued in this manner until the pressure in the hydraulic jack could no longer be maintained due to rapid vertical displacement and hence, failure of the pile. At this point the load was removed in increments of 50%, 25%, 12.5%, and 12.5% of the maximum load achieved.

During the application and removal of the loads a complete record of load, time, and deflection was maintained.

The extraction tests were carried out using similar procedures regarding application and

removal of extraction forces and measurement of vertical deflection of the pile, to those followed for the load tests.

In addition to the measurements of the vertical deflections of the pile tops, an attempt was made to observe and measure the internal compression of the two steel tube piles #2 and #3 during the application and removal of the loads. In order to achieve this, the following installation was prepared: As the concrete was placed in the tube test piles, four $\frac{3}{4}$ in. (1.9 cm) diameter steel pipes with closed lower ends were placed vertically around the circumference inside each tube at the quarter points. The lengths of the pipes projecting below the pile tops were 100%, 75%, 50%, and 25% of the length of the pile. It was assumed that the compression of the pipes would be equal to the compression in the concrete, and this was measured during the test by means of tell-tale rods placed inside the pipes. The movement of the tell-tale rods, relative to the pile tops, was measured by means of sensitive deflection gauges. To increase the sensitivity of the system, and to reduce friction, the $\frac{3}{4}$ in. (1.9 cm) pipes were filled with oil.

The results of the load and extraction tests in the form of load/settlement/time curves, are shown in Figs. 4-8, inclusive. The most surprising feature of the results is the very great difference between the long tube pile and the long H-pile.

The ultimate capacity of piles is defined in most literature as the load beyond which the pile will begin to break into the ground, or expressed mathematically, when $\Delta s/\Delta p$ approaches ∞ , that is, when the tangent to the load settlement curve becomes vertical with the settlements plotted as ordinates. In engineering

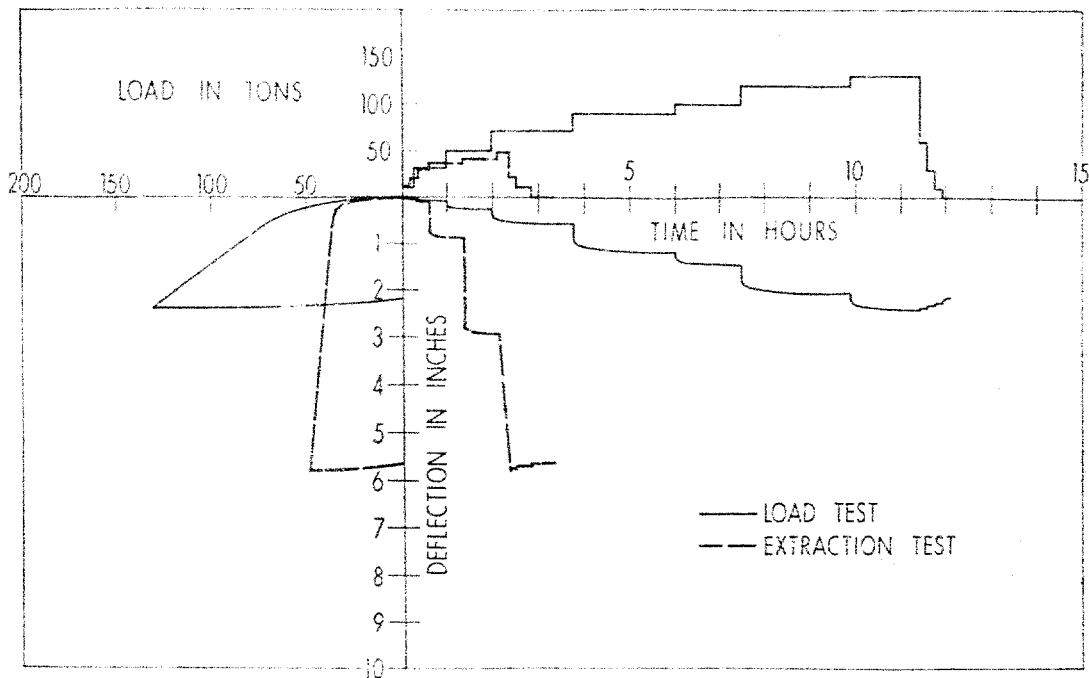
PILE NO 1: No 14 TREATED TIMBER LENGTH 46'-9"

FIG. 4. Test results—Pile 1.

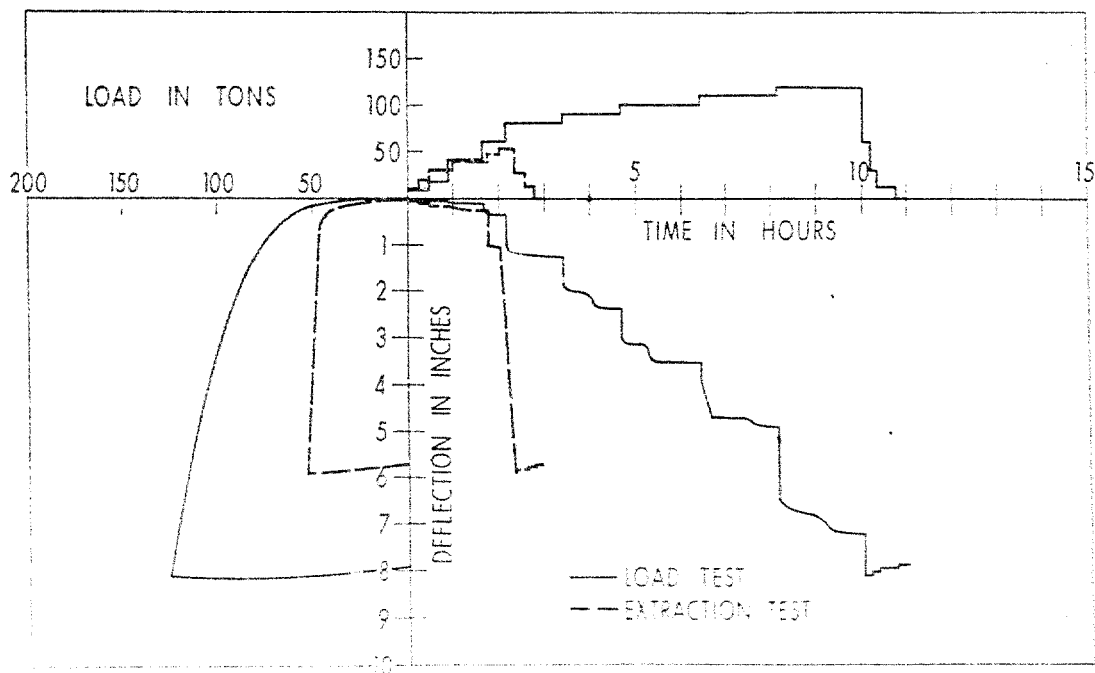
PILE NO 2: 12 $\frac{3}{4}$ " STEEL TUBE LENGTH 50'-6"

FIG. 5. Test results—Pile 2.

PILE NO 3: 12 3/4" STEEL TUBE LENGTH 73'-6"

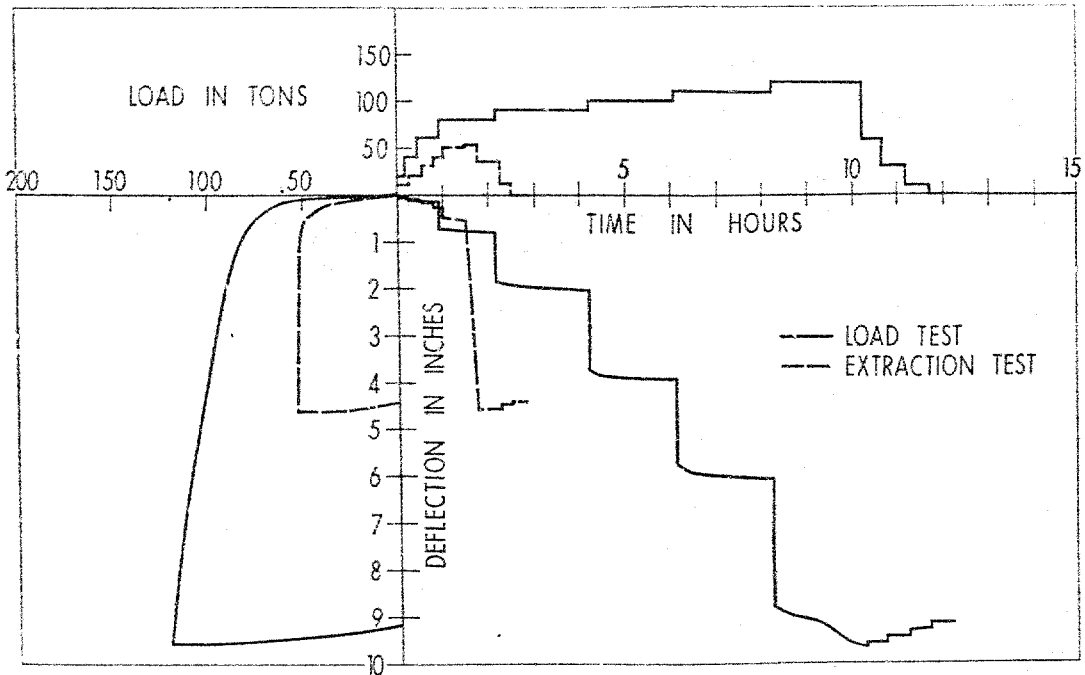


FIG. 6. Test results—Pile 3.

PILE NO 4: 12 BP 53 STEEL 'H' LENGTH 73'-6"

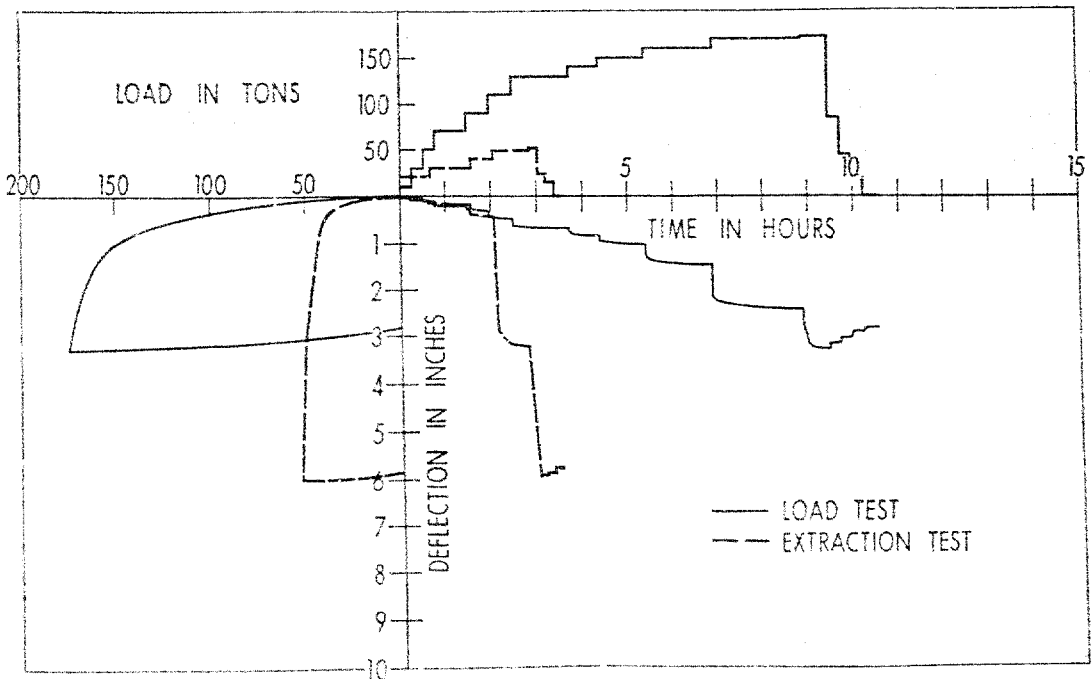


FIG. 7. Test results—Pile 4.

PILE NO 5: 12 BP 53 STEEL 'H' LENGTH 50'-6"

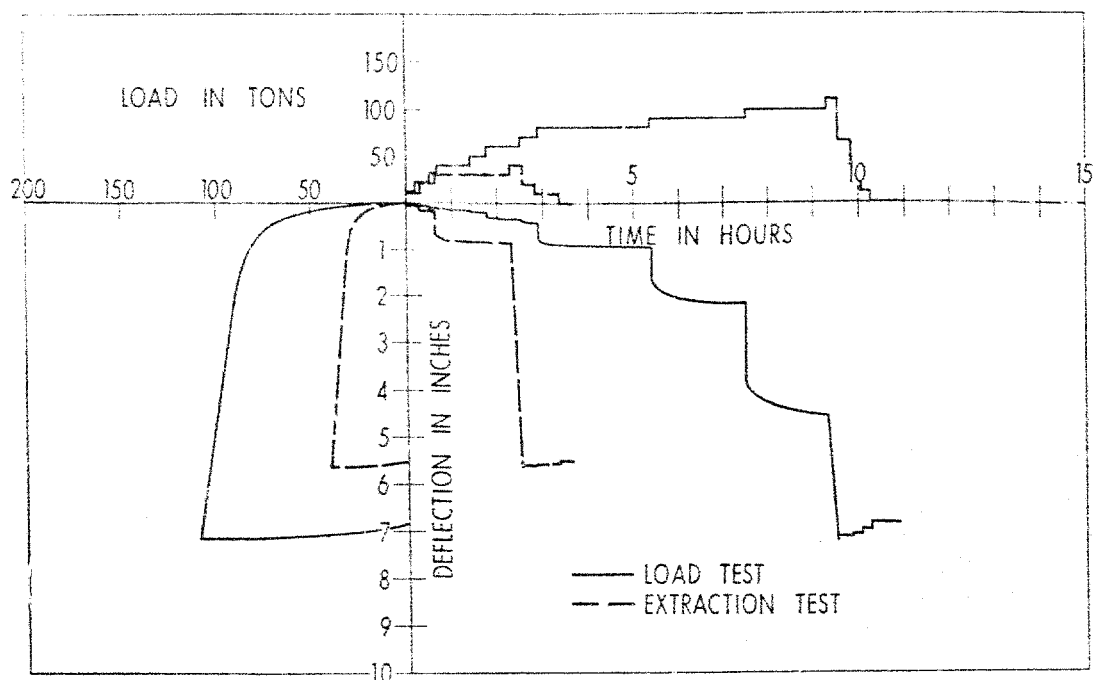


FIG. 8. Test results—Pile 5.

PILE CAPACITIES BY DIFFERENT METHODS

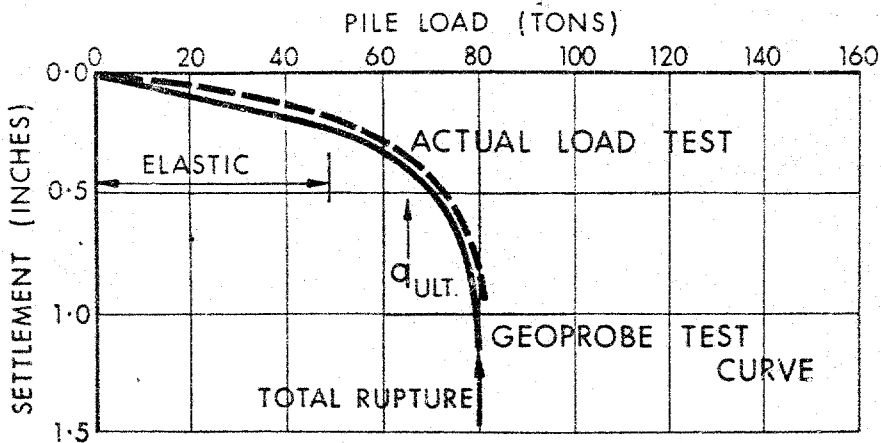
PILE	TYPE	ULTIMATE LOAD IN TONS			
		HILEY	MEYERHOF	TERZAGHI	LOAD TEST
1	46.7' TIMBER	155	160	123	80
2	50.5' TUBE	97	143	66	67
3	73.5' TUBE	137	187	128	85
4	73.5' H-PILE	109	80	141	165
5	50.5' H-PILE	88	69	63	75

HILEY FORMULA $Q = \frac{\pi W_s}{5 + C_u}$

MEYERHOF " $Q = 4Nab + \frac{\bar{N} A_s}{K}$

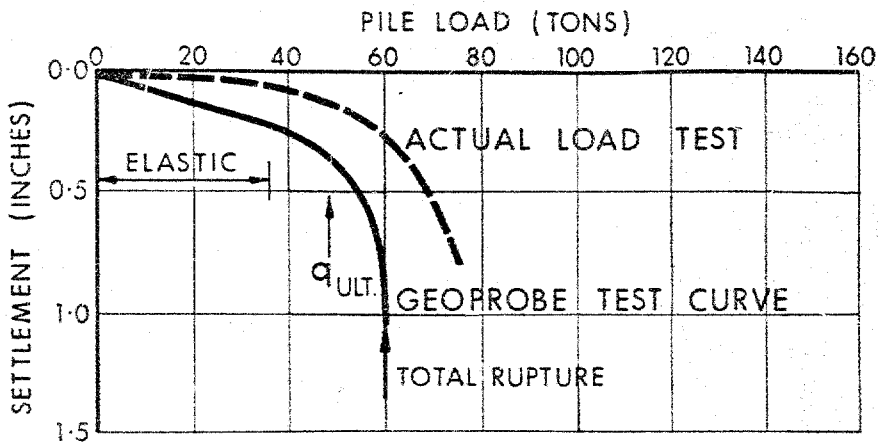
TERZAGHI " $Q = \frac{1}{2} K_0 L \bar{\gamma} \tan \phi_a A_s + \bar{\gamma} L (N_q - 1)$

FIG. 9. Comparison of actual and predicted pile capacities.



STEEL H-PILE AT 50.5 FEET

FIG. 10. Predicted and actual load/settlement curves—Pile 5.



STEEL TUBE PILE AT 50.5 FEET

FIG. 11. Predicted and actual load/settlement curves—Pile 2.

practice, however, it is customary to select the point beyond which the settlement increment increases markedly in comparison to the load increment and denote this as failure, and then apply a factor of safety. The following table shows the deflections at each of two loadings between which the failure point has been reached according to the latter criterion.

In estimating the ultimate capacities of piles without benefit of load tests, the engineer has to rely on theoretical or empirical methods

TABLE II. Deflections

Pile	Load	Settlement	Pull	Deflection
1	70T	0.55 in.	30T	0.12 in.
	90T	1.14 in.	35T	0.87 in.
2	60T	0.29 in.	40T	0.20 in.
	80T	1.25 in.	46T	1.06 in.
3	80T	0.75 in.	40T	0.22 in.
	90T	2.0 in.	50T	0.50 in.
4	160T	1.33 in.	40T	0.40 in.
	170T	2.34 in.	50T	3.20 in.
5	70T	0.43 in.	20T	0.15 in.
	80T	0.94 in.	30T	0.82 in.

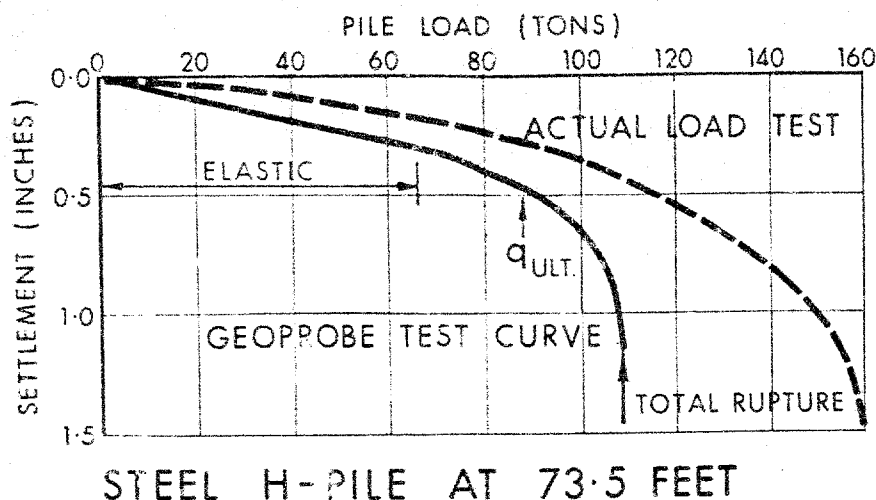


FIG. 12. Predicted and actual load/settlement curves—Pile 4.

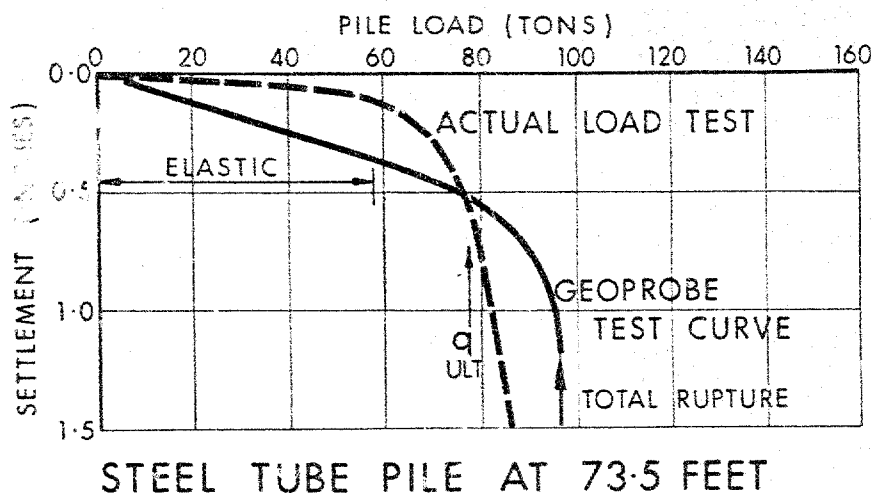


FIG. 13. Predicted and actual load/settlement curves—Pile 3.

using parameters determined during foundation investigations, or by using dynamic pile driving formulae such as the Hiley Formula. For each of the five piles tested at this site, the ultimate capacity Q has been computed according to three conventional methods, the results being shown in Fig. 9, together with the actual load test results determined according to the failure criterion described above.²

In addition to the foundation investigation

using conventional techniques carried out at this site, one borehole at the pile test location was drilled and tested with a pressuremeter. Based on measurements thus obtained, the predicted load/settlement curves for the tube piles and H-piles were constructed by Mr. Y. Broise of Geoprobe Ltd. The actual test results were added when these became known. The curves are shown on Figs. 10–13, inclusive.

With regard to the attempt to measure compression in the tube piles, results were inconclusive, mainly due to the fact that the required geometrical accuracy of the test set-up was not

²For explanation of symbols the reader is referred to Broms (1966).

achieved. In order to measure accurately compression in this way, it is essential that the pile be perfectly straight and that the direction of the applied load be exactly coincident with the pile center-line. Due to the large loads applied, even slight eccentricities can result in significant bending movements within the pile. The net result of this is an extremely complex stress distribution within the pile. Since the driving of piles undoubtedly results in deformations, it is concluded that compression measurements

obtained in this way can be extremely misleading and should be viewed with caution, even if seeming to be of the right order of magnitude.

Space allocation does not permit the presentation of all detailed field measurements. Interested parties who desire more information should communicate with the author.

BROMS, GENG T. B. 1966. Methods of calculating the ultimate bearing capacities of piles—a summary. Sols Soils No. 18-19, 1966.