

62-F-224-C

W.P. # 73-60

HWY. # 101

INSTABILITY PIER

EXCAV^N GHOST

RIVER BRIDGE

GHOST RIVER W.P. 73-60

1.) EAST PIER.

Slopes were not trimmed according to Contract drawing before starting pier excavation.

Movement of slopes observed. Contractor drove timber piles on his own initiative - further movements followed.

Excavated material was piled up close to excavation but was subsequently removed.

Site visited - instructions given by K. Y. L.
See letter July 19 1962 to E. A. Fletcher Const. Engr.

Extras: Removal of Bailey Bridge

Sequence of H pile driving

(Possibly sequence of rip-rap placement)

NOTE: DIFFICULTIES EXPERIENCED ON THIS SIDE
WERE DUE TO THE CONTRACTORS FAULT
TO FOLLOW THE DESIGN (TRIMMING OF SLOPE)
NECESSARY RECOMMENDATIONS WERE
GIVEN TO CONSTR. ENGR. H. E. A. FLETCHER
VERBALLY ON JULY 17, 1962 AND CONFIRMED
BY LETTER DATED JULY 19, 1962

2) WEST PIER

Change of slope trimming. Add. trimming
Recommended add. bracing at bottom
Sand and Gravel blanket

Additional H pile outside excavation
(Sand for drains)

Removal i.e. relocation of earth dyke
Use of crane for drilling machine moving

NOTE: DIFFICULTIES EXPERIENCED ON THIS SIDE
COULD BE ASCRIBED TO THE LACK OF KNOWLEDGE
OF THE ARTESIAN CONDITIONS. THESE WERE
NOT DETECTED DURING THE INITIAL SOIL
INVESTIGATION (GEOCON)
THE CONTRACTOR WAS BUSY TRIMMING AND
FORMING THE SLOPES (ACCORDING TO NEW
REQUIREMENTS CONTAINED IN REPORT BY
H. G. GOLDBERG & ASSOC. OF SEPT 28, 1962 WHILE
SAND DRAINS WERE BEING PUT DOWN WITHIN THE
FOUNDATION EXCAVATION, SOME MEN AND
EQUIPMENT WERE USED DURING THIS WORK
BUT PURCHASE ORDERS WERE ISSUED EACH TIME

- | | | |
|-------------------|--|-----------|
| 1) SEPT. 6. 1962 | CRANE 15 MIN. | ~ 1/2 HR. |
| 2) SEPT. 7. 1962 | CARPENTER 45 MIN. | ~ 1 HR. |
| 3) SEPT. 11. 1962 | CRANE 30 - 40 MIN | ~ 1 HR |
| 4) SEPT. 13. 1962 | CRANE 40 MIN | ~ 1 HR. |
| | TWO MEN (CARPENTER & LABOURER) | 3 HRS. |
| | CRANE STAND-BY | 6 HRS |
| 5) | CRANE & MEN USED FOR
PULLING OUT PIEZOMETERS
WORK DONE BY DISTRICT
CONSTRUCTION PERSONNEL | |

FOR 1) TO 4) PURCHASE ORDER WAS GIVEN
BY B. GHADIALI PROJ. FOUND. ENGR.
FOR 5) WE DON'T KNOW

H. Q. GOLDER & ASSOCIATES LTD.

CONSULTING CIVIL ENGINEERS

**H. Q. GOLDER
V. MILLIGAN
L. G. SODERMAN**

**2444 BLOOR STREET WEST
TORONTO 9, ONTARIO
767-9201
763-4103**

September 28, 1962

Department of Highways, Ontario,
Materials and Research Section,
Parliament Buildings,
TORONTO 2. Ontario.

Attention: Mr. A. G. Stermac, P. Eng.
Principal Foundation Engineer.

RE: INSTABILITY OF PIER EXCAVATION,
GHOST RIVER BRIDGE, WP 73-60

Dear Sirs:

This letter accompanies three copies of a brief report on my inspection of the excavation at the west pier for Ghost River bridge near Matheson, Ontario. The report considers possible explanations of the cause of the instability of this excavation and details the recommendations which I gave at the site to your Messrs. K.Y. Lo, W. Aitken and C.H. Keyes.

We would be pleased to be kept informed of the progress of this work.

Yours faithfully,

H. Q. GOLDER & ASSOCIATES LTD.

V. Milligan
V. Milligan, P. Eng.

VM/jb
6243
Encs.

62-1-108-101

REPORT ON INSTABILITY OF PIER EXCAVATION
GHOST RIVER BRIDGE, MATHESON, ONTARIO.

W.R. 73-60

September, 1962

6243

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REPORT ON INSTABILITY OF PIER EXCAVATION GHOST RIVER BRIDGE

INTRODUCTION

Keene Construction Company Ltd. are constructing Ghost River Bridge, near Matheson, Ontario for the Department of Highways, Ontario, Contract ~~W-3-10-60~~

WP. 73-60

At the request of Mr. A. Stermac, D.H.O., I visited the site of the bridge under construction on August 30, 1962 and there, accompanied by Mr. K.Y. Lo, D.H.O., made an examination of the sheeted excavation for the west pier. After discussing the extreme deformation of sheet piling which had occurred with various personnel of the D.H.O. at the site and in particular with Mr. K.Y. Lo, recommendations were made concerning the methods to be adopted to complete the construction of the pier with safety. This report discusses possible causes of the excavation instability and further details the recommendations which were given at the site.

Information concerning the site, the soil conditions and the proposed bridge structure is given in the references listed in Appendix II. This information is not reproduced in detail in this report.

STATEMENT OF PROBLEM

Following the driving of sheet piling around the approximate perimeter of the proposed west pier, the placing of an upper strutting frame and excavation to about 8 feet depth, five H-section steel foundation piles were driven within the excavation along the west face adjacent to the sheeting. During driving and immediately after these piles were driven some inward deflection of the sheeting at the base of the excavation was apparently observed. This deflection was not measured as the excavation was then flooded by a rapid rise of Ghost River. Upon pumping out the excavation several days later the sheet piling was observed to be deformed quite markedly, the foundation piles had also moved and two had been twisted from their original alignment and the base of the excavation was 'boiling' in several locations. The sequence of events as compiled from records at the site by Mr. R. Marin, D.H.O. is given in Appendix I. Significant details of the excavation, the site conditions and the measured deformation of the piles is shown on Figures 1 and 2. The maximum displacement of the sheet piles was along the west face of the excavation and was approximately 12 inches. Part of the waler flange at the west face of the sheeting was buckled; a photograph of this is shown on Figure 4.

The problem is to determine the cause of these movements and the instability and to decide on remedial measures that will enable the construction of the west pier to be safely completed.

POSSIBLE EXPLANATIONS OF MOVEMENT

- i) One possibility is that the movements are the first stage of a rotational slide of the west bank of the river. However, there were no indications of cracking in the ground or movement other than in the immediate area of the excavation.
- ii) A further possibility is that the deformation of the sheeting is caused by a simple base failure of the excavation. This may be termed an undrained case. (Bjerrum, Eide, 1956). The factor of safety against base failure in this case is a function of the undrained average shear strength of the varved clay, and can be expressed as, $F = \frac{N_c \cdot C_u}{\gamma D + q_r}$ where:
 - D = depth of excavation
 - q_r = surcharge
 - C_u = undrained average shear strength of the clay, silt
 - γ = total unit weight of soil
 - N_c = bearing capacity factor

Now, for an excavation 30 ft. x 15 ft. in plan and about 8 feet deep, allowing C_u to be 400 pounds per square foot to take into account the earth cofferdam around the excavation and the weight of construction equipment, F is about 2.5 if the average shear strength C_u is 500 pounds per square foot. (Refer (i), Appendix II.) This value

of P cannot explain the movement of the sheeting unless we assume that the average shear strength around a failure surface is reduced to 200 pounds per square foot. This is probably too severe an assumption and would imply a large degree of remoulding caused by pile driving both inside and outside the excavation. Further, the marked evidence of 'boiling' inside the excavation indicates anything but an undrained condition.

- iii) The observed deformation of the sheet piling and the boiling of the base of the excavation could be explained by considering that the passive earth pressure retaining the toe of the sheeting would be reduced markedly by the remoulding of the clay, silt strata inside the excavation in the driving of foundation piles and/or by excess hydrostatic pressures acting on the base of the excavation. These excess hydrostatic pressures could result partly from the pile driving or from another source.

It is considered that the third of these possibilities is the most likely and it is examined in more detail below

The Effect of Ground Water

The excavation for the east pier of the bridge also suffered some movement during construction. This was thought to be caused partly by the remoulding effect of timber piles driven to support construction equipment adjacent to the area of the excavation and partly by the lateral pressures induced

on the sheeted excavation by an existing Bailey bridge. (Refer (V), Appendix II). However it is significant to note that a boring (in 1960) in the general area of the east pier (Refer (i), Appendix II) showed a piezometric level of 882 in the lower sand, gravel. This piezometric level was about 4 to 5 feet above ground level and about equivalent to the maximum recorded river level of 883. At the site of the west pier the piezometric level in the underlying loose silt or in the deeper sand, gravel is not known, but as the sand, gravel stratum is apparently continuous across the site we could assume that the water level in the sand, gravel in the general area of the west pier is also at about elevation 883. This artesian level would induce a seepage gradient to ground surface something like that sketched on Figure 5(a) if there is drainage through the varved clay stratum. The seepage pressures exerted by rising ground water would reduce the effective unit weight of soil in contact with the excavation sheeting and as a consequence reduce the passive earth pressure or toe resistance of the sheet piling. (Terzaghi, 1954). For example, the effective stress at a depth z would be reduced to

$$\bar{p} = z\delta' - iz\delta_w \quad \text{where:}$$

z = depth below ground level

δ' = submerged unit weight of soil

δ_w = unit weight of water

i = the hydraulic gradient

In effect, the expression, $iz\delta_w = \Delta u$ the excess hydrostatic pressure.

In Figure 5, the effect of a hydraulic gradient at the tips of the sheet piling between 0.5 and 0.6 (equivalent to a piezometric level of 883 at depth) is examined in detail. The passive resistance of the silt stratum is reduced to a negligible amount and if the clay stratum within the excavation is remoulded by the driving of foundation piles then the factor of safety of the sheeting against rotation about the top strutting is reduced to well below unity. The question of whether the clay stratum would be remoulded by pile driving or not is debatable; however the varved clay is quite sensitive (Liquidity index, $L_I \geq 1$ for the silty layers), the bulk sensitivity, S_t , of the stratum has been measured at from 2 to 5 and the sensitivity of individual layers could well be much greater than 5. Further, field evidence has shown that in similar sensitive clay soils (S_t from 2 to 5), the remoulding caused by driving foundation piles within a sheeted excavation has reduced the shearing strength of clay restrained at the base of the excavation by 85 percent of its initial value. (Skempton, Ward, 1952). Consequently the net earth pressure diagram sketched on Figure 5(d) can explain the extreme deformation of the sheeting.

If the varved clay at the site is impermeable, then the gradient sketched on Figure 5(a) through the silt stratum would be steeper. Where the water pressure in the silt is high then the base of the excavation could fail by heaving. This mode of failure is examined in Figure 6. It may be seen that, for a

variation in possible piezometric levels in the lower sand, gravel from about 877 to 883 the factor of safety, F, against heave of the base is close to 1.0 or less. Heave of the base, due to excess hydrostatic pressures, would reduce the toe resistance of the sheeting and induce deformation.

At present the piezometric levels within the silt and sand, gravel strata on the west bank are not known. While there is evidence to suggest that these water levels would be high this should be checked by installing piezometers. This was recommended to Mr. K.Y. Lo at the site. In addition the recommendations below were detailed.

RECOMMENDATIONS

The base of the excavation is now at elevation 864. No further piles are to be driven until the measures listed in sequence are completed.

- 1) A steel frame should be placed at 864, similar to that at 871. The base of the excavation and frame should be covered with two feet of sand, gravel available from a pit at the site. (This will mean the base of the pier footing is raised. This has been checked with the Bridge Office, D.H.O. It further ensures the base dimensions of the excavation.)

- 2) The west bank of the river is to be trimmed to 872 for at least 25 feet from the edge of the excavation. The remaining bank back to chainage 40+15 is then to be trimmed in steps 5 feet high at a slope of 2 horizontal to 1 vertical with flat benches 10 feet wide. The level of the bank at chainage 40+15 will then be approximately 884.
- 3) The earth cofferdam to the south of the excavation is to be moved away from the pier excavation to follow a line parallel to the edge of the river and to reach the existing highway embankment. The remainder of the cofferdam is to be re-located along the river edge at least 10 feet from the edge of the excavation. This cofferdam should be given an adequate rip rap cover to protect it in the event of further flooding from Ghost River.
- 4) The general site should be drained of surface water to a sump dug to the north of the pier excavation.
- 5) At least three wells, 9 inch in diameter should be put down into the lower sand, gravel stratum some 5 feet to the west of the pier excavation. The spacing between wells would be about 8 feet on each side of the bridge centre-line. The wells are to be put down in cased holes filled with water and slowly filled as the casing is withdrawn with concrete sand to within 4 to 5 feet of the top where they should be filled with fine gravel. It is

anticipated these wells would be about 40 feet in depth. The wells would serve to partially dissipate excess hydrostatic pressures at depth.

- 6) Similar wells to (5) above should be put down within the excavation as far as is practicable. (There is some precedent in the use of relief wells to relieve water pressure at the base of excavations. See Ward, 1957). It is hoped that wells within the excavation would also serve to dissipate possible excess pore water pressures set up by pile driving. Excess water within the excavation is to be removed by pumping SLOWLY from a gravel filled sump within the sand and gravel case.
- 7) The pile driving equipment should be moved from the west edge of the pier excavation to the north edge.

Should these simple measures not be successful then it may be necessary either to pump from the deep relief wells or flood the excavation. If required, this can be discussed.

H. Q. GOLDER & ASSOCIATES LTD.

6243

V. Milligan
V. Milligan, P. Eng.

GOLDER & ASSOCIATES

REFERENCES

- BJERRUM, L., EIDE, O. 1956. "Stability of Strutted Excavations in Clay". Geotechnique. Vol. VI. pp.32-47.
- SKEMPTON, A.W., WARD, W.H. 1952. "Investigation Concerning a Deep Cofferdam in the Thames Estuary Clay at Shellhaven". Geotechnique, Vol. III. pp. 119-139.
- TERZAGHI, K. 1954. "Anchored Bulkheads". Trans. ASCE. Vol. 119. pp. 1243-1280.
- WARD, W.H., 1957. "The Use of Simple Relief Wells in Reducing Water Pressure beneath a Trench Excavation". Geotechnique. Vol. VII. pp. 134-139.

APPENDIX ICOMPOSITE DIARY TAKEN FROM ALL JOB DIARIESAugust, 1962

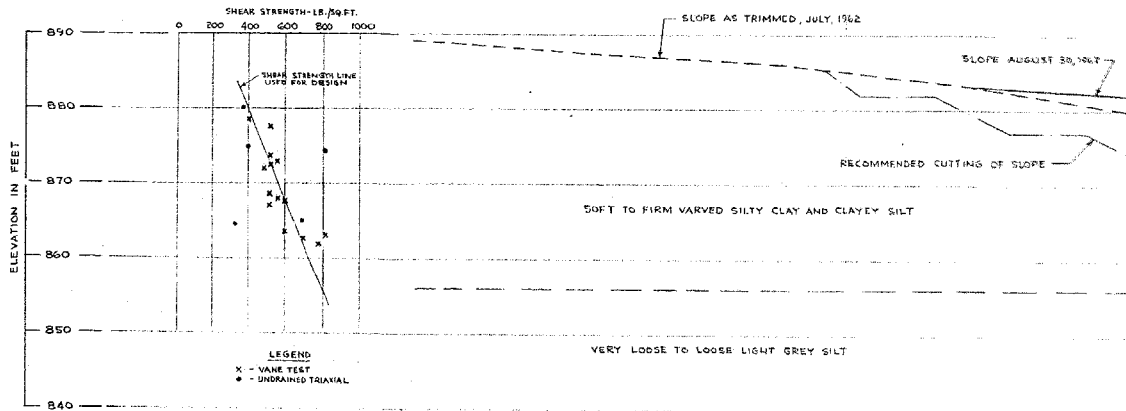
- 16 Steve Farrell requested that Pier No. 1 be laid-out by survey party because he wants to start on it to-day. Koehring 3/4 C.Y. worked at Pier No. 1 from 11:00 A.M. to 9:00 P.M.
Cat. 933 Loader moving 12" x 12" timber to Pier No. 1.
- 17 Contractor erecting falsework for Sheet Piles at Pier No.1, all day.
Koehring 30-A crane working on falsework at Pier No. 1.
- 18 Falsework for Sheet Piling at Pier No. 1 completed at 11:00 A.M.
Cat. 933 Loader hauling Sheet Piles to Pier No. 1 all day.
Started placing Sheet Piles at Pier No. 1 to-day from 6:00 to 9:00 P.M.
Koehring 30-A crane worked on Sheet Piles at Pier No. 1.
- 19 Koehring 30-A crane placing and started to drive Sheet Piles at Pier No. 1, until 6:30 P.M.
- 20 Koehring 30-A crane driving Sheet Piles at Pier No. 1. Quick sand started to come up along side of Sheet Piling at 7:00 P.M.
Sheet Piles in Pier No. 1 driven to 18" higher than final grade.
- 21 Silt and quick sand at Pier No. 1 was referred to S.J. Ford who took pictures of it.
Steve Farrell requested to use 2 - 32' Steel H-Piles for his steel ring at Pier No. 1. He already has a ring made up of 12"x12", but they were breaking.
We replace by a Steel ring.
Koehring 30-A excavating Pier No. 1 from 7:30 to 11:00 A.M.
Koehring 30-A placing Steel ring in Pier No. 1 till 4:00 P.M. then standby till 9:00 P.M.
Welgind Steel ring in Pier No. 1 for 4 hours.
- 22 Contractor finished with Steel ring at Pier No. 1. and started excavating in Pier No. 1, from 5:00 to 9:00 P.M.
Koehring 30-A driving Sheet Piles to elevation, from 7:00 till 11:00 A.M.
1 - Scraper hauling waste from Pier No. 1, 5:00 to 9:00 P.M.
- 23 Bridge crew placing falsework at Pier No. 1, all day and started to place H-Piles in Pier No. 1 after supper.

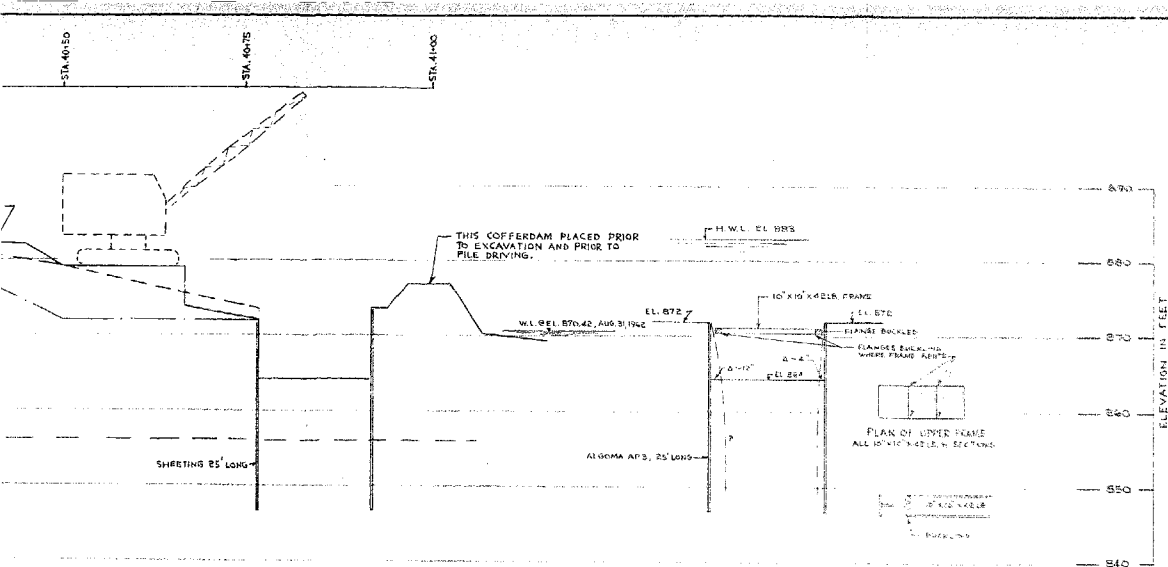
August, 1962

- Place No. 1 H-Pile at 40' to see to determine depth and found it necessary to splice extra on top of the 40 feet. Bridge crew cleaning up around Pier No. 1 till 9:00 P.M. We drove a 40' H-Pile at 7:00 P.M. which sank out of sight, a 32' H-Pile was welded on top, and was driven down 8.7', making an overall length of 48.7' at that particular spot.
- 23 Sheet Piles at Pier No. 1 are coming in at bottom of excavation after H-Piles were driven in. This matter was referred to Mr. Ford, Mr. Keyes and Mr. Aitken.
- 24 Bridge crew driving H-Piles in Pier No. 1 all day. H-Piles are being driven in at approximately 48' to cut-off. Mr. Aitken and Mr. Keyes were told about the Sheet Pile at Pier No. 1. Heavy rain on that night.
- 25 Advised by Mr. Farrell that if water goes down, he will get men and equipment working on Pier No. 1 and will try to build a sand-dike so that the H-Piling operation may be continued.
- 26 No work because of flood conditions.
- 27 Water started to go down. Contractor trying to pull 30-A crane from Pier No. 1 because of wash-out by flood. Water elevation:-A.M. - 877.51; P.M. - 876.12.
- 28 Mr. Lo, Mr. Keyes and R. Marin went to inspect Pier No. 1 but were unable to arrive at any decisions because of flood. Ron Marin requested Mr. Farrell to have Pier No.1 pumped out and sand-diked so that work could be resumed the next day on this same Pier. One 3" pump at Pier No. 1 pumping from 7 A.M. to 11:30 A.M. Water Elevation:- A.M. - 874.92;-P.M. - 873.81.
- 29 30-A crane at Pier No. 1 moving water pumps and went on to clam out material that had been brought in by the flood and material that had been needed during the H-Pile driving operation. Mr. Lo and R. Marin checked the movements of H-Piles and sheet Piles. Advised by Mr. Lo that Mr. V. Milligan come to site. Water Elevation:-A.M. - 871.52; P.M. - 871.37.
- 30 Water Elevation:-A.M. - 870.91; P.M. - 870.72
- 31 Water Elevation:-A.M. - 870.42

APPENDIX IIINFORMATION RECEIVED CONCERNING THE SITE

- i) Report; "Soil Conditions and Foundations, Proposed Ghost River Bridge", by Geocon Ltd, No. S7124, dated October 6, 1960.
- ii) Report; "Stability Analyses, Relocated Ghost River Bridge", by Geocon Ltd, No. S7175, dated January 12, 1961.
- iii) Drawing; "Ghost River Bridge, General Plan (Preliminary)", by D.H.O. Bridge Office, No. D-4808-P1, dated January, 1961.
- iv) Drawing; "Hydrologic Layout, Proposed Crossing at Ghost River and Highway No. 101", by D.H.O. Planning and Design Branch, No. BW-389, dated November, 1959.
- v) Various memoranda; L. G. Soderman to S. McCombie, October 27, 1960.
B. Wilkie to S. McCombie, November 30, 1960
K.Y. Lo to E.A. Fletcher, July 19, 1962.



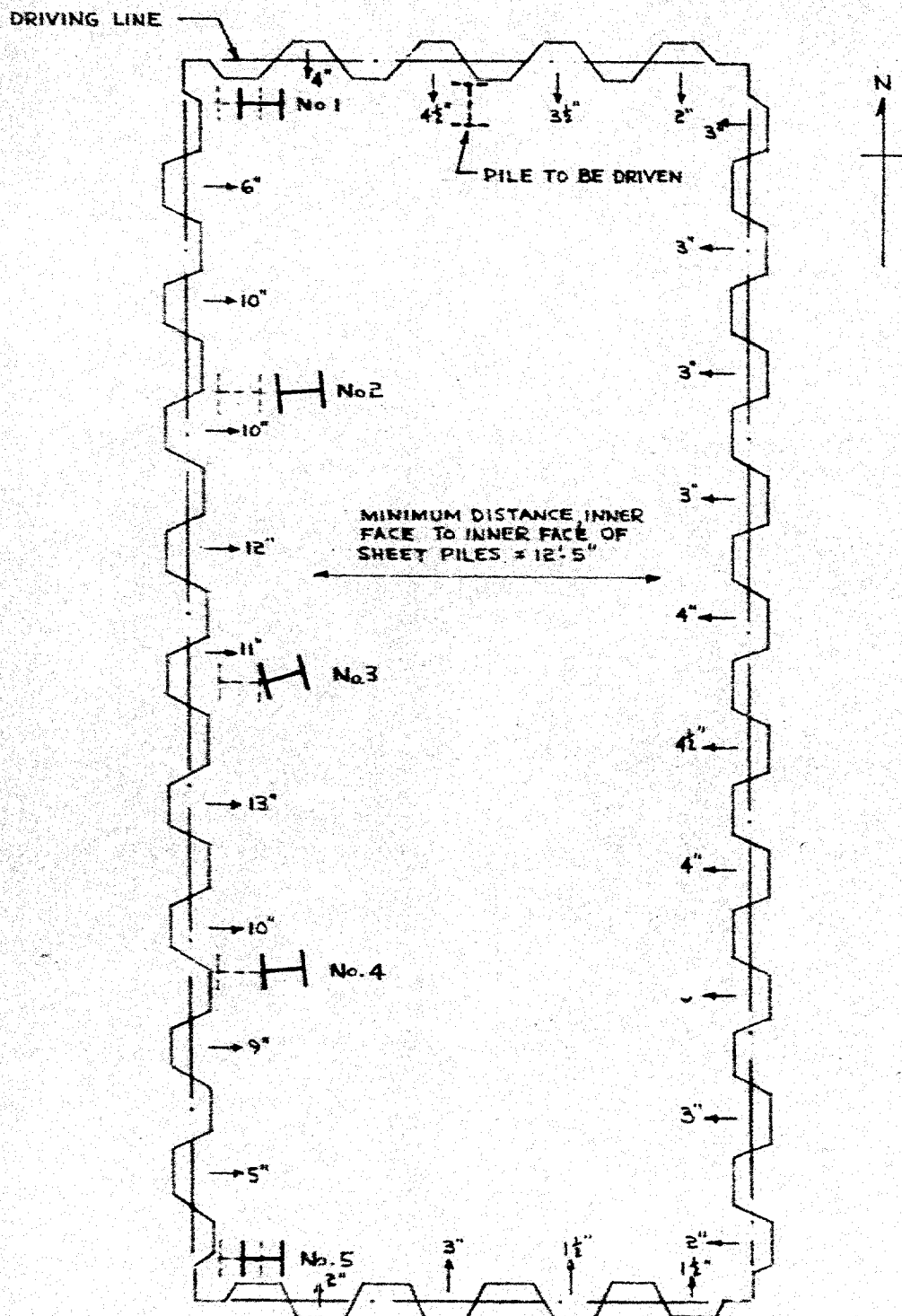


SECTION FROM WEST TO EAST
SCALE: 1" TO 10'-0"

REFERENCE	
DRWG. No.	DESCRIPTION
REPORT No. 57124	REPORT BY GEOCON LTD ON SOIL CONDITIONS AND FOUNDATIONS - PROPOSED GHOST RIVER BRIDGE. DATED OCT. 6, 1960.

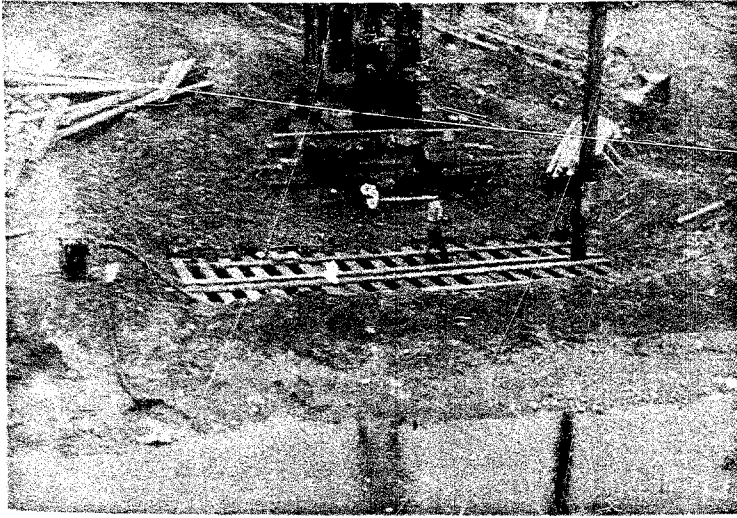
DEPARTMENT OF HIGHWAYS, ONTARIO
TORONTO ONTARIO
EXCAVATION FOR WEST PIER
PROPOSED GHOST RIVER BRIDGE
MATHESON ONTARIO
SHOWING MOVEMENTS OF SHEETING

GOLDER & ASSOCIATES	
CONSULTING CIVIL ENGINEERS	
DATE: SEPT. 20, 1962 SCALE: 1" TO 10'-0"	
MADE J.A.	CHKD. APPD. FIGURE 1

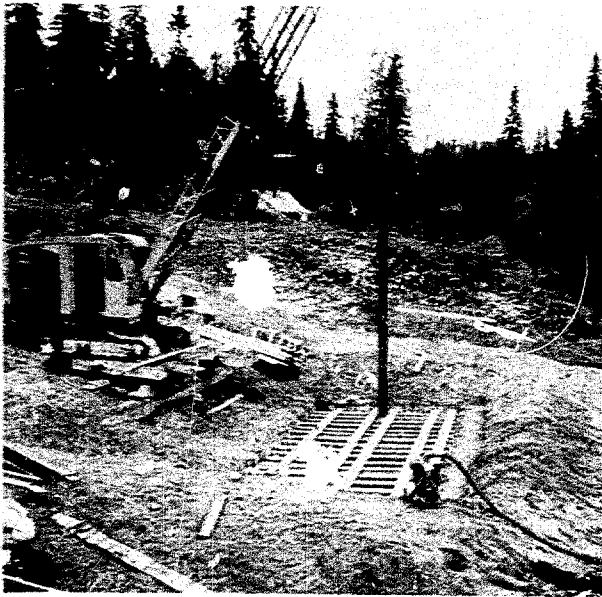


NOTE:

MEASURED BY R. MARIN, D.H.O. AUGUST 29-31, 1962



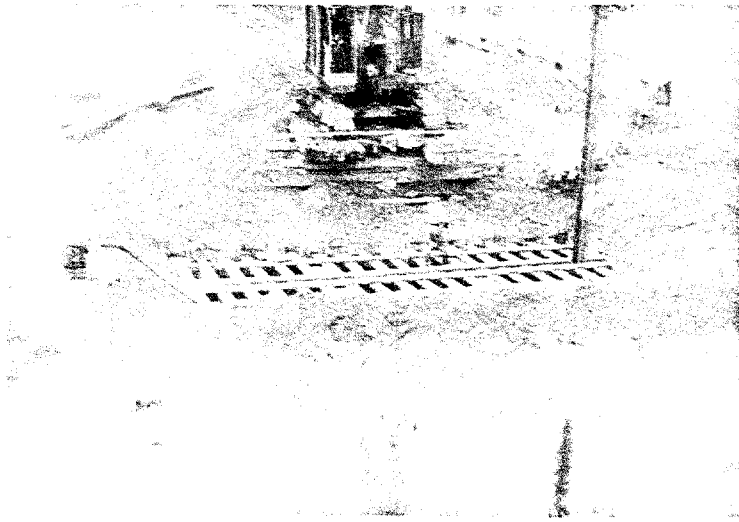
General view of excavation, looking west



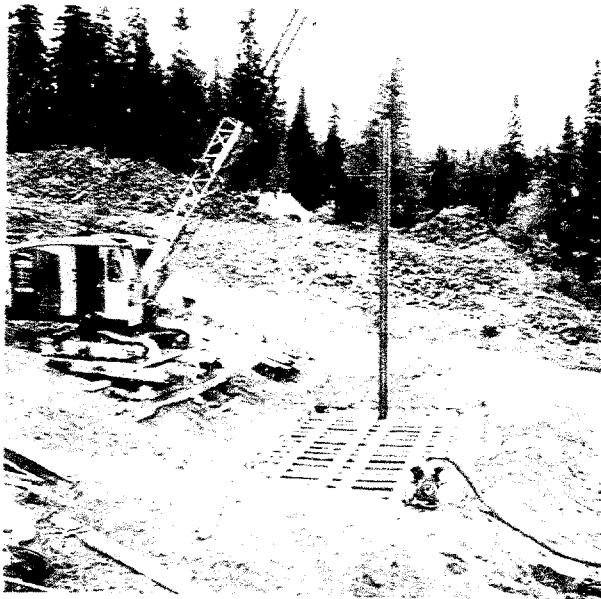
View of excavation, looking north



**Portion of H pile No. 3
in relation to sheeting, west face**



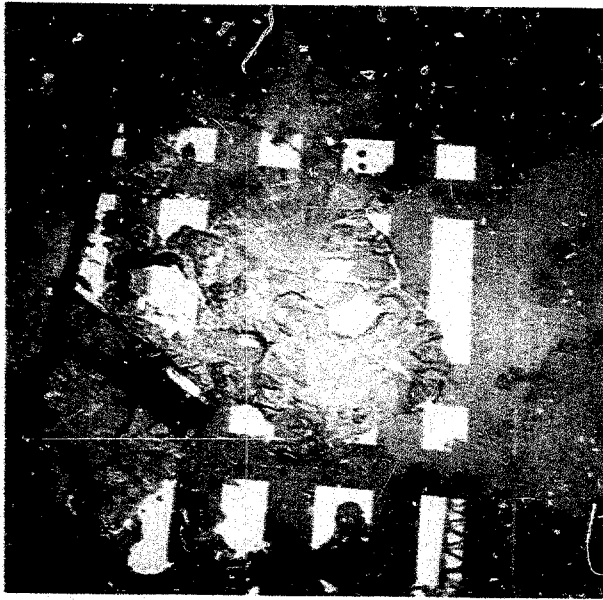
General view of excavation, looking west



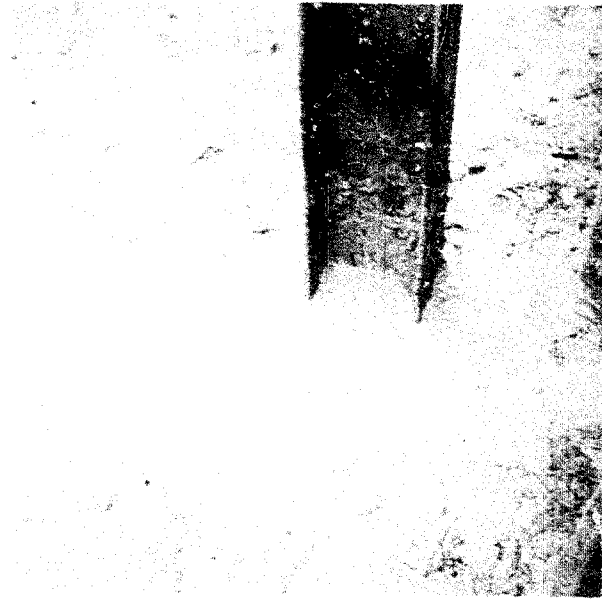
View of excavation, looking north



Portion of H pile No. 3
in relation to sheeting, west face



Boiling at base of excavation



Boiling beside H pile



Buckling of flange, top strutting
west face of excavation



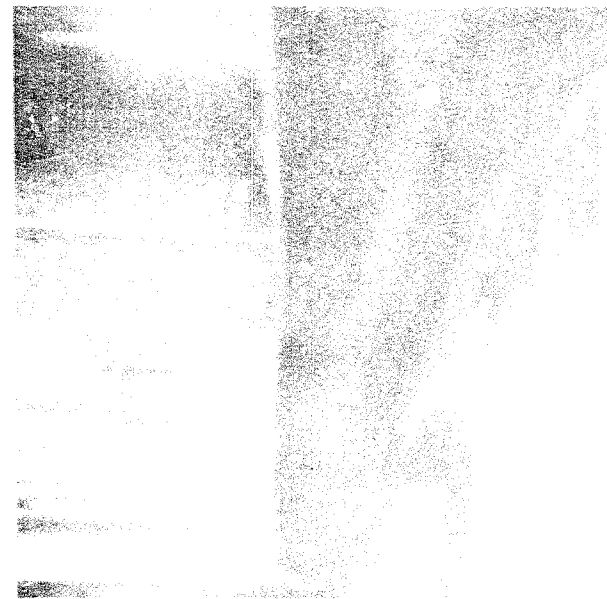
West face of excavation
sheet piles looking south



Boiling at base of excavation



Boiling beside H pile



Buckling of flange, top strutting
west face of excavation



West face of excavation
sheet piles looking south

