

69-F-106

W.P. 163-64-03

Q.E.W. AND

CENTRAL AVENUE

INTERCHANGE

RETAINING WALLS #1, 2 AND 3B.

DEPARTMENT OF HIGHWAYS ONTARIO

MEMORANDUM

To: Mr. B. R. Davis,
Bridge Engineer,
Bridge Office,
Admin. Bldg.

FROM: Foundation Section,
Materials & Testing Office,
Room 107, Lab. Bldg.

ATTENTION: Mr. S. McCombie

DATE: February 19, 1970

Our File Ref.

IN REPLY TO

MAR 2 1970

SUBJECT:

FOUNDATION INVESTIGATION REPORT
For
Proposed Retaining Walls #1, 2 & 3B
At the Proposed Q.E.W. and
Central Ave. Interchange (Fort Erie)
District No. 4 (Hamilton)
W.J. 69-F-106 -- W.P. 163-64-03

Attached, we are forwarding to you our detailed foundation investigation report on the subsoil conditions existing at the above structure site.

We believe that the factual data and recommendations contained therein, will prove adequate for your design requirements. Should additional information be required, please do not hesitate to contact our Office.

AGS/MdeF
Attach.

A. G. Stermac
A. G. Stermac
PRINCIPAL FOUNDATION ENGINEER

cc: Messrs. B. R. Davis
H. A. Tregaskes
D. W. Parren
G. K. Hunter (2)
H. Greenland
W. S. Melinyshyn (2)
T. J. Kovich
B. A. Singh

Foundations Files ✓
Gen. Files

McCormick & Rankin Ltd.

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FOUNDATION INVESTIGATION REPORT
For
Proposed Retaining Walls #1, 2 & 3B
At the Proposed Q.E.W. and
Central Ave. Interchange (Fort Erie)
District No. 4 (Hamilton)
W.J. 69-F-106 -- W.P. 163-64-03

1. INTRODUCTION:

The Foundation Section was requested to carry out an investigation for three retaining walls at the proposed crossing of Central Ave. (formerly North St.) and the Queen Elizabeth Way, in the Town of Fort Erie, County of Welland, Ontario. The request was contained in a memo from the Bridge Location Section (Mr. W. S. Melinyshyn, Regional Bridge Location Engineer), dated September 12, 1967. An investigation was subsequently carried out by this Section to determine the subsoil conditions existing at the retaining wall locations.

This report contains the results of the investigation, together with recommendations pertaining to the foundation design of the proposed retaining walls.

2. DESCRIPTION OF THE SITE AND GEOLOGY:

The site is located in the Town of Fort Erie about 1700 ft. west of the Peace Bridge over the Niagara River. At this location the Q.E.W. enters a cut section approximately 6 to 10 ft. below the surrounding ground surface elevation. The highway slopes towards the Niagara River, and consists of three westbound lanes (two leading from the bridge and one from Fort Erie), and two eastbound lanes which branch off on an embankment towards the south. The highway has a gravel shoulder on the north side of the westbound lane, with curb and gutter elsewhere. The area surrounding the highway is grass-covered, with a shallow drainage ditch on the north side and a deeper one

2. DESCRIPTION OF THE SITE AND GEOLOGY: (cont'd.) ...

starting east of the eastbound lane embankment. The surrounding terrain is generally level with a gradual slope towards the river. Approximately 100 ft. east of the site the ground slopes steeply towards the river. The immediate area to the north of the Q.E.W. is about 10 ft. above the Q.E.W. centre-line grade; the slopes of these cuts are approximately 2:1. A frame house is located about 100 ft. north of the top of the bank, while the remainder of the area is covered with evergreens. The immediate area to the south of the Q.E.W. is about 6 ft. above the Q.E.W. centre-line grade, and the associated embankment slopes are flatter than those above. This area is clear except for Main Street which runs in an east-west direction. This street has been abandoned east of the Q.E.W. eastbound lane.

Physiographically, the site is situated in the "Haldimand Clay Plain". Based on available geological information, it is known that the overburden of this region consists of lacustrine clay deposited in glacial Lake Warren which was formed during the retreat of the most recent continental glacier.

3. FIELD AND LABORATORY WORK:

Six boreholes and six dynamic cone penetration tests were carried out during the course of the recent field work. The data from two additional boreholes, one of which was accompanied by a dynamic cone penetration test, is included in this report. These two boreholes were carried out during the period of September 27 to October 3, 1967 by this Section for the investigation of the underpass structure (W.J. 67-P-85). Boring was achieved by means of two conventional diamond drill rigs adapted for soil sampling purposes. Samples were recovered at required depths in 2-inch O.D. split-spoon samplers which were hammered into the soil, or, where possible, in 2-inch I.D. Shelby tubes which were manually pushed into the soil. The method of driving the split-spoon samplers conformed to the requirements of the Standard Penetration Test.

3. FIELD AND LABORATORY WORK:

The same method was used to advance the cone in the dynamic cone penetration tests. Bedrock was proven in five boreholes by obtaining BXL size rock core samples. In one borehole, the bedrock surface was assumed to be the level at which practical refusal occurred. During sampling and drilling operations, detailed logs of the borings were made which described drilling and sampling techniques, soil types encountered, and groundwater observations.

The locations and elevations of all borings were surveyed in the field by personnel from Central Region Engineering Surveys Section, and are shown on Eng. #62-F-106A, together with the estimated stratigraphical profile.

All samples were subjected to a careful visual inspection in the laboratory prior to any tests being carried out. Following this inspection, tests were carried out on certain samples to determine the following physical properties of the various soil types:

- Natural Moisture Contents
- Bulk Densities
- Grain-Size Distributions
- Atterberg Limits
- Undrained Shear Strengths

The results of these tests are summarized and plotted on the Record of Borelog sheets contained in the Appendix of the report.

On completion of laboratory testing, the various soil samples were classified as to type and consistency, or relative density, in general, according to the Unified Soil Classification System (Oct. 1963).

4. SUBSOIL CONDITIONS:

4.1) General:

Subsoil at the sites generally consist of 1 to 3 ft. of topsoil or fill material followed by 19 to 39 ft. of firm to hard clayey silt with some sand and traces of gravel, the upper 11 to 25 ft. of which has been desiccated to a hard crust. The clayey silt stratum directly overlies limestone bedrock. The boundaries between the various soil strata are shown on the Record of Borelog sheets contained in the Appendix of the report. The inferred stratigraphical profiles shown on Dwg. #69-F-106A are based on this information. From ground surface downwards, the different soil types are described in detail as follows:

4.2) Clayey Silt with Some Sand and Traces of Gravel:

The surficial cover over the majority of the sites is a clayey silt topsoil about 1 foot thick. However, at boreholes 1, 2, 3 and 5, a surficial layer of fill some 2 to 3 feet thick was encountered. This fill is composed of a stiff clayey silt with some sand and gravel.

Underlying the surficial deposits at the sites is the predominant overburden stratum consisting of brown to grey clayey silt with some sand and traces of gravel. The upper 11 to 25 ft. of this deposit has been desiccated to a hard crust. The overall thickness varies from 19 feet at borehole 4 (R.W. #2) to 39 feet at boreholes 1 and 2 (R.W. #1). At most of the boring locations, occasional thin seams of clay and silt were encountered below the desiccated crust. Grain-size distribution curves obtained from typical samples of the clayey silt stratum are shown in the Appendix of this report.

4. SUBSOIL CONDITIONS: (cont'd.) ...

4.2) Clayey Sil' with Some Sand and Traces of Gravel: (cont'd.)..

Physical properties of the overall deposit as determined from laboratory tests, are summarized below:

		<u>Upper Desiccated Zone</u>	<u>Lower Zone</u>
Bulk Density	:	139 PCF	127 - 136 PCF
Liquid Limit	:	19 - 30%	20 - 39%
Plastic Limit	:	13 - 19%	12 - 20%
Moisture Content	:	11 - 22%	13 - 30%
Undrained Shear Strength	:	-	1080 - 3845 PSF
'N' Values (blows/ft.)	:	20 to >100	5 to 33

The Atterberg limit test results indicate that the cohesive soil is inorganic and generally of low plasticity (CL).

The undrained shear strength results, as well as 'N' values, indicate that the consistency of the stratum varies from very stiff, immediately below the desiccated crust, changing to firm with depth. The consistency of the crust is very stiff to hard.

4.3) Limestone Bedrock:

Bedrock directly underlies the clayey silt stratum. Bedrock was established by drilling 3 to 5 ft. of BXL core in B.H.'s 1, 2, 4, 5 and 6. In B.H. 3, bedrock surface was assumed where practical refusal to the split-spoon sampler was met. The depth at which bedrock surface was encountered ranged from elev. 591 (R.W. #1), decreasing to the east to elev. 579 (R.W. #2 and #3B) - i.e., some 41 to 19 ft., respectively, below the existing ground surface. The rock cores obtained, show the rock to be generally grey limestone with dark brown chert nodules and some chertified patches. The bedrock is generally sound, as indicated by the relatively high core recovery of 70% to 100%.

5. GROUNDWATER CONDITIONS:

Groundwater level observations carried out during the period of the field investigation, indicate that the water level in the borings generally ranged from elev. 629 (R.W. #1) to elev. 585 towards the Niagara River, which is some 2 to 14 ft. below existing ground surface. The exact water levels observed during the time of the field investigation, are shown on the enclosed drawing as well as on the borehole logs (Appendix 1).

6. DISCUSSION AND RECOMMENDATIONS:

6.1) General:

It is proposed to construct an interchange at the crossing of Central Avenue Extension (formerly North St.) and revised Queen Elizabeth Way. This will necessitate the construction of an underpass structure and three retaining walls for this proposed interchange complex. Recommendations pertaining to the underpass structure have been submitted in our Foundation Report #W.J. 63-F-85. The recommendations pertaining to various retaining wall foundations will be described in the following sub-section.

The predominant deposit across the site is a 19 to 41 ft. stratum of firm to hard clayey silt with some sand and traces of gravel, which is underlain by limestone bedrock.

6.2) Retaining Wall Foundations:

As mentioned elsewhere, three retaining structures will be constructed, and they are designated as R.W. #1, R.W. #2 and R.W. #3B. Recommendations for the respective walls are as follows:

6. DISCUSSION AND RECOMMENDATIONS: (cont'd.) ...

6.2) Retaining Wall Foundations: (cont'd.) ...

Retaining Wall #1 -

The proposed retaining wall will have an approximate height of .7 ft. above the existing ground surface. Since the subsoil conditions are generally favourable at this location, the proposed retaining structure can be founded on spread footings within the desiccated portion of the clayey silt stratum at or below elev. 626, using a safe bearing pressure of 3.0 t.s.f. A minimum cover of 4 ft. should be provided to the underside of the footing for frost protection purposes.

The settlement that will occur in the foundation subsoil, due to the induced footing pressure, will be of a compression nature and the magnitude will be negligible.

It is assumed that a granular material will be used behind the retaining wall and, in such a case, a coefficient active with pressure (K_a) of 0.33 can be used for design computations. A value of 2000 p.s.f. be used in the computations to determine the sliding resistance between the base of the footing and the underlying cohesive stratum.

Retaining Wall #2 -

This structure will retain the ramp to Central Avenue as it leaves the E.B.L. of the Queen Elizabeth Way. At this location the off ramp as well as the Q.E.W. will be in a cut section. The top of the retaining wall varies from elev. 594 (West side) to elev. 599 (East side) and at the deepest portion it will retain a maximum depth of cut of 12.5 ft.

The proposed retaining structure can be founded on spread footings within the stiff to very stiff clayey silt stratum

6. DISCUSSION AND RECOMMENDATIONS: (cont'd.) ...

6.2) Retaining Wall Foundations: (cont'd.) ...

Retaining Wall #2 - (cont'd.) ...

or on sound limestone bedrock, depending upon the respective location of the footing. The portion of the retaining wall located within the clayey silt stratum may be designed for a safe load of 1.5 t.s.f., whereas for spread footings founded on rock, an allowable load of 10 t.s.f. may be used. An earth cover of 4 ft. should be provided for the footings founded in the clayey silt stratum.

The differential settlements between the footings founded on rock and clayey silt stratum should not exceed 1 inch.

In computing the lateral pressure due to granular fill, a value of 0.33 should be used as coefficient active earth pressure (K_a). For computing sliding resistance between the base of the footing and the underlying clayey subsoil, a value of 1500 p.s.f. may be used. The horizontal resistance of the retaining structure founded on rock may be computed using a value of 0.6 as coefficient of friction.

Retaining Wall #3B -

This wall will be located on the south side of the interchange ramp (W.-Central N.) in the vicinity of Riceland Ave. The proposed retaining wall will be approximately 180 ft. long and retain nominal height of fill up to 7 ft. The grades for the ramp and Riceland Ave. are such that Retaining Wall #3B will be founded within existing fill or new fill material. Since the proposed wall retains a nominal height of fill, the footings for the retaining structure may be constructed on a 12" granular pad in order to maintain a smooth transition between the old and new fill material. Adequate earth cover should be provided for frost protection of the footings. A safe load of 1.0 t.s.f. may be used for footing design purposes.

6. DISCUSSION AND RECOMMENDATIONS: (cont'd.) ...

6.2) Retaining Wall Foundations: (cont'd.) ...

Due to the relatively impermeable nature of the subsoil, no major dewatering problems are anticipated in any of the aforementioned retaining wall (R.W.'s #1, #2 & #3B) footing excavations. Any seepage or surface run-off could readily be handled by pumping from sumps.

The following measures should be taken into account with regard to drainage and backfill material for the retaining structures:

i) To relieve the build-up of excess hydrostatic pressure behind the retaining wall, suitable weep holes be provided at the base of the wall at a maximum spacing of 10 ft.

ii) Backfilling requirements suggested for Hw., 401 Toronto Bypass (D.E.O. Standard SD-4-58) may be used for design and construction purposes.

7. MISCELLANEOUS:

The field work, performed during the period November 11 - 21, 1969, was carried out by Mr. V. Korlu, Project Foundation Engineer, who also prepared this report.

Equipment used was owned and operated by Peninsula Soils Investigations, Welland, Ontario.

General supervision of the project and review of the report were undertaken by Mr. M. Devata, Supervising Foundation Engineer.

February, 1970

APPENDIX I

FOUNDATION SECTION

JOB	69-F-106	LOCATION	Co-ords. 590, 557N 154, 465E	ORIGINATED BY	VK
W.P.	163-64-03	BORING DATE	November 17, 1969	COMPILED BY	VK
DATUM	Geodetic	BOREHOLE TYPE	Drill BX Casing & Wash.	CHECKED BY	<i>[Signature]</i>

[illegible]

FOUNDATION SECTION

CHECKED BY

[illegible]

DEPARTMENT OF HIGHWAYS- ONTARIO
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 3

FOUNDATION SECTION

JOB 69-F-106

LOCATION Co-ords. 590, 463N 156, 208E

ORIGINATED BY VK

W.P. 163-64-03

BORING DATE November 19, 1969

COMPILED BY VK

DATUM Geodetic

BOREHOLE TYPE Drill BX Casing & Wash

CHECKED BY

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE					LIQUID LIMIT — w_L			BULK DENSITY	REMARKS	
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS / FOOT		BLOWS / FOOT					PLASTIC LIMIT — w_p					
							20	40	60	80	100	WATER CONTENT — w					
							SHEAR STRENGTH P.S.F.					w_p — w — w_L			WATER CONTENT %		
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB. VANE										
							400 800 1200 1600 2000					10 20 30					
605.0	Ground Level																
603.5	Fill Material	X	1	SS	11												
1.5			2	SS	30												
	Desiccated					600											
	Stiff to Hard		3	SS	33												
593.0	(Brown)		4	SS	12												
12.0	(Grey)																
	Clayey silt with sand and trace of gravel. (occ. thin seams of silt)		5	SS	17	590											
	Stiff to V. Stiff		6	SS	10												
580.5			7	SS	10/6"												
24.5	End of Borehole (Probable Bedrock)					580											

▼ 593.5
11.5

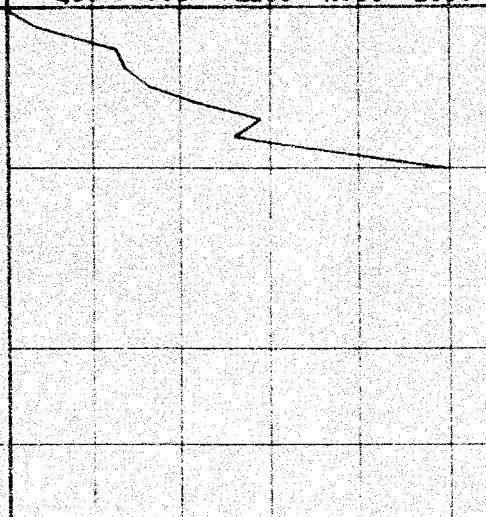
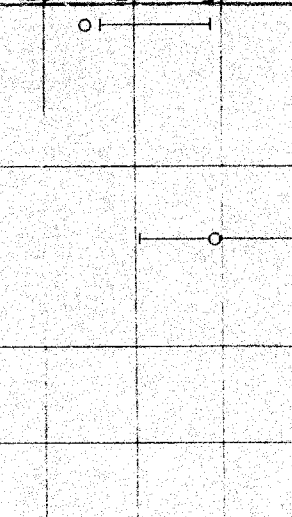
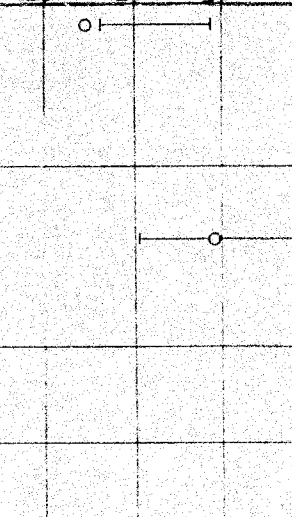
DEPARTMENT OF HIGHWAYS- ONTARIO
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 4

FOUNDATION SECTION

JOB 69-F-106 LOCATION Co-ords 590, 362N 156, 387E
 W.P. 163-64-03 BORING DATE November 19, 1969
 DATUM Geodetic BOREHOLE TYPE Drill BX Casing & Wash

ORIGINATED BY VK
 COMPILED BY VK
 CHECKED BY

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT					LIQUID LIMIT ——— w_L PLASTIC LIMIT ——— w_p WATER CONTENT ——— w			BULK DENSITY γ P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS / FOOT		20	40	60	80	100	w_p	w	w_L		
599.0	Ground Level						400	800	1200	1600	2000	10	20	30		
0.0	Desiccated V. Stiff		1	SS	28	590										
587.0	(Brown)		2	SS	24											
12.0	(Grey)		3	SS	24											
580.0	Clayey silt with sand and trace of gravel V. Stiff		4	SS	32	580										
19.0	Sound Limestone		5	SS	28											
575.0	Bedrock		6	BXL	100% Rec	570										
24.0	End of Borehole															

585.0
14.0

FOUNDATION SECTION

CHECKED BY *CK*

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE					LIQUID LIMIT ——— w _L PLASTIC LIMIT ——— w _p WATER CONTENT ——— w			BULK DENSITY Y P.C.F.	REMARKS	
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS / FOOT		BLOWS / FOOT					SHEAR STRENGTH P.S.F.					WATER CONTENT %
							20	40	60	80	100	P.S.F.					
												P.S.F.					
						○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB. VANE					w _p ——— w ——— w _L						
						400 800 1200 1600 2000					10 20 30						
607.5	Ground Level																
0.0	Desiccated		1	SS	20	600									129	▽ 601.5 6.0	
	V. Stiff to Hard		2	SS	29												
	(Brown)		3	SS	38												
592.5			4	SS	20												
15.0	(Grey)		5	SS	5	590									129		
	Clayey silt with sand		6	TW	PH												
	and trace of gravel- occ. thin seams of clay and silt		7	TW	PH												
580.0	Firm to Stiff					580											
27.5	Bedrock - Sound		8	BXL	100%	570											
577.0	Limestone				Re:												
30.5	End of Borehole																

RECORD OF BOREHOLE No. 7 (7, 67-F-85) FOUNDATION SECTION

JOB	69-F-106	LOCATION	Co-ords 590, 451N 156, 109E	ORIGINATED BY	HQG
W.P.	163-64-03	BORING DATE	August 13-15, 1966	COMPILED BY	PBS
DATUM	Geodetic	BOREHOLE TYPE	Power Auger Boring	CHECKED BY	<i>[Signature]</i>

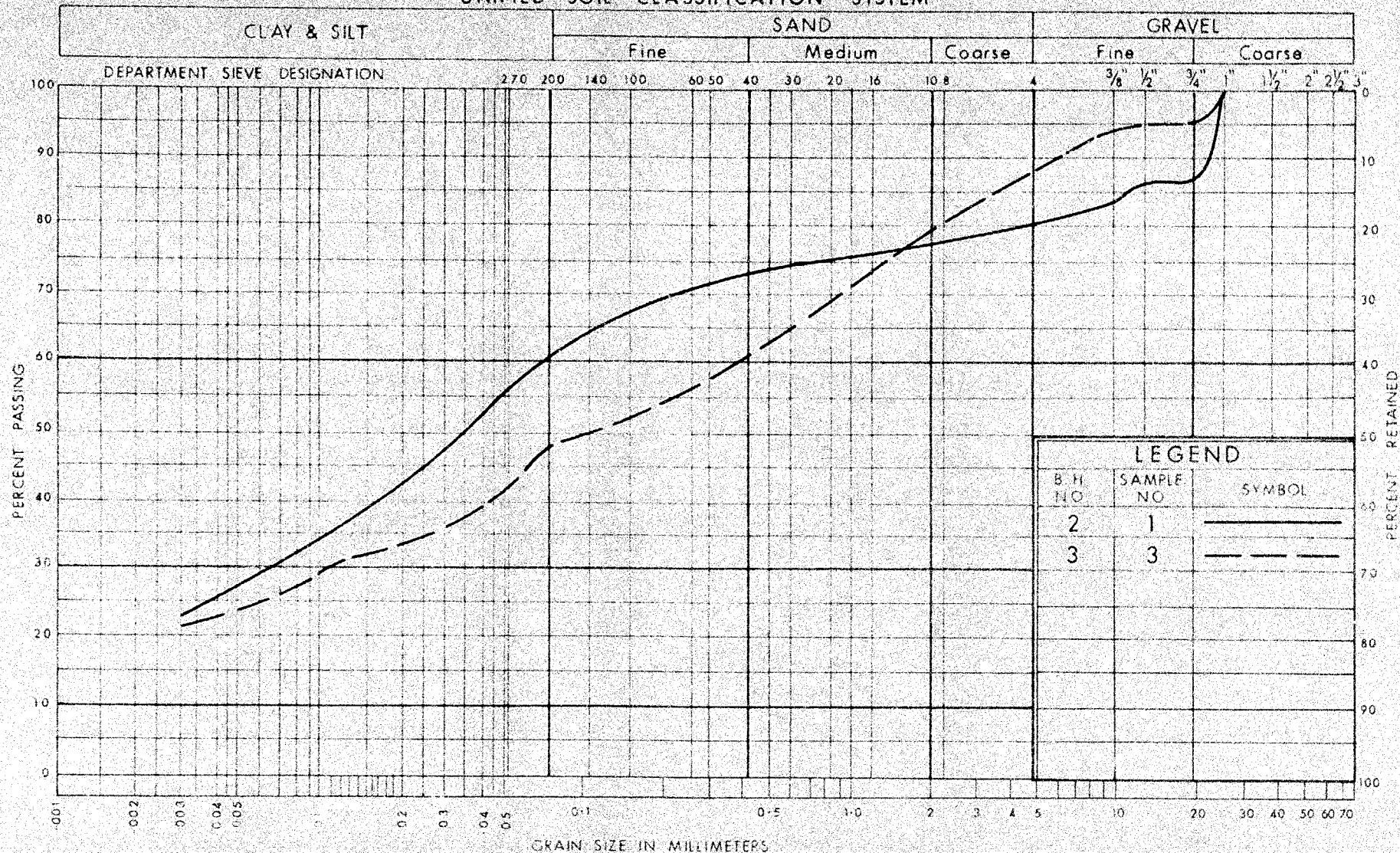
SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE					LIQUID LIMIT ——— w_L PLASTIC LIMIT ——— w_p WATER CONTENT ——— w			BULK DENSITY γ P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT		SHEAR STRENGTH PS F					WATER CONTENT %				
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE					w_p ——— w ——— w_L				
						500	1000	1500	2000	2500	10 20 30					
610.8	Ground Level															
0.0	Desiccated		1	SS	45	610									135	▼ 601.
	Brown		2	SS	96											
	Hard		3	SS	100	600										
			4	SS	49											
593.8			5	TW	PH	590	●	+ 2				○				
17.0	Clayey silt with some sand and trace of gravel. Firm to Stiff		6	SS	9		+ 2.3	+ 1.4								
			7	SS	PH		+ 1.7									
581.3			8	ART	41%	580										
29.5	Sound Limestone		9	RC	90%											
576.3	Bedrock		10	RC	83%											
34.5	End of Borehole		11													
						570										

RECORD OF BOREHOLE No. 8 (3, 67-F-85) FOUNDATION SECTION

JOB	69-R-106	LOCATION	Co-ords 590, 460N 156, 048E	ORIGINATED BY	ZO
W.P.	163-64-03	BORING DATE	September 29, 1967	COMPILED BY	WH
DATUM	Geodetic	BOREHOLE TYPE	Cont. Flight Auger	CHECKED BY	✓

[illegible]

UNIFIED SOIL CLASSIFICATION SYSTEM



DEPARTMENT OF HIGHWAYS
MATERIALS and
TESTING
DIVISION

GRAIN SIZE DISTRIBUTION CLAYEY SILT

WP No. 163-64-03

JOB No. 69-F-106

FIG 1

ABBREVIATIONS USED IN THIS REPORT

PENETRATION RESISTANCE

STANDARD PENETRATION RESISTANCE 'N' - THE NUMBER OF BLOWS REQUIRED TO ADVANCE A STANDARD SPLIT SPOON SAMPLER 12 INCHES INTO THE SUBSOIL, DRIVEN BY MEANS OF A 140 POUND HAMMER FALLING FREELY A DISTANCE OF 30 INCHES.

DYNAMIC PENETRATION RESISTANCE :- THE NUMBER OF BLOWS REQUIRED TO ADVANCE A 2 INCH, 60 DEGREE CONE, FITTED TO THE END OF DRILL RODS, 12 INCHES INTO THE SUBSOIL, THE DRIVING ENERGY BEING 350 FOOT POUNDS PER BLOW.

DESCRIPTION OF SOIL

THE CONSISTENCY OF COHESIVE SOILS AND THE RELATIVE DENSITY OR DENSENESS OF COHESIONLESS SOILS ARE DESCRIBED IN THE FOLLOWING TERMS :-

<u>CONSISTENCY</u>	<u>'N' BLOWS / FT.</u>	<u>c LB. / SQ. FT.</u>	<u>DENSENESS</u>	<u>'N' BLOWS / FT.</u>
VERY SOFT	0 - 2	0 - 250	VERY LOOSE	0 - 4
SOFT	2 - 4	250 - 500	LOOSE	4 - 10
FIRM	4 - 8	500 - 1000	COMPACT	10 - 30
STIFF	8 - 15	1000 - 2000	DENSE	30 - 50
VERY STIFF	15 - 30	2000 - 4000	VERY DENSE	> 50
HARD	> 30	> 4000		

TYPE OF SAMPLE

S.S.	SPLIT SPOON	T.W.	THINWALL OPEN
W.S.	WASHED SAMPLE	T.P.	THINWALL PISTON
S.B.	SCRAPER BUCKET SAMPLE	O.S.	OESTERBERG SAMPLE
A.S.	AUGER SAMPLE	F.S.	FOIL SAMPLE
C.S.	CHUNK SAMPLE	R.C.	ROCK CORE
S.T.	SLOTTED TUBE SAMPLE		
	P.H. SAMPLE ADVANCED HYDRAULICALLY		
	P.M. SAMPLE ADVANCED MANUALLY		

SOIL TESTS

Qu	UNCONFINED COMPRESSION	L.V.	LABORATORY VANE
Q	UNDRAINED TRIAXIAL	F.V.	FIELD VANE
Qcu	CONSOLIDATED UNDRAINED TRIAXIAL	C	CONSOLIDATION
Qd	DRAINED TRIAXIAL	S	SENSITIVITY

ABBREVIATIONS USED IN THIS REPORT

SOIL PROPERTIES

γ	UNIT WEIGHT OF SOIL (BULK DENSITY)
γ_s	UNIT WEIGHT OF SOLID PARTICLES
γ_w	UNIT WEIGHT OF WATER
γ_d	UNIT DRY WEIGHT OF SOIL (DRY DENSITY)
γ'	UNIT WEIGHT OF SUBMERGED SOIL
G	SPECIFIC GRAVITY OF SOLID PARTICLES $G = \frac{\gamma_s}{\gamma_w}$
e	VOID RATIO
n	POROSITY
w	WATER CONTENT
S_r	DEGREE OF SATURATION
w_L	LIQUID LIMIT
w_p	PLASTIC LIMIT
I_p	PLASTICITY INDEX
s	SHRINKAGE LIMIT
I_L	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$
I_c	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$
e_{max}	VOID RATIO IN LOOSEST STATE
e_{min}	VOID RATIO IN DENSEST STATE
I_D	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
	RELATIVE DENSITY D_r IS ALSO USED
h	HYDRAULIC HEAD OR POTENTIAL
q	RATE OF DISCHARGE
v	VELOCITY OF FLOW
i	HYDRAULIC GRADIENT
k	COEFFICIENT OF PERMEABILITY
j	SEEPAGE FORCE PER UNIT VOLUME
m_v	COEFFICIENT OF VOLUME CHANGE = $\frac{-\Delta e}{(1+e)\Delta\sigma}$
c_v	COEFFICIENT OF CONSOLIDATION
C_c	COMPRESSION INDEX = $\frac{\Delta e}{\Delta \log \sigma}$
T_v	TIME FACTOR = $\frac{c_v t}{d^2}$ (d, DRAINAGE PATH)
U	DEGREE OF CONSOLIDATION
τ_f	SHEAR STRENGTH
c'	EFFECTIVE COHESION INTERCEPT
ϕ'	EFFECTIVE ANGLE OF SHEARING RESISTANCE, OR FRICTION
c_u	APPARENT COHESION
ϕ_u	APPARENT ANGLE OF SHEARING RESISTANCE, OR FRICTION
μ	COEFFICIENT OF FRICTION
S_r	SENSITIVITY

GENERAL

π	= 3.1416
e	BASE OF NATURAL LOGARITHMS 2.7183
$\log_e \sigma$ OR $\ln \sigma$	NATURAL LOGARITHM OF σ
$\log_{10} \sigma$ OR $\log \sigma$	LOGARITHM OF σ TO BASE 10
t	TIME
g	ACCELERATION DUE TO GRAVITY
V	VOLUME
W	WEIGHT
M	MOMENT
F	FACTOR OF SAFETY

STRESS AND STRAIN

u	PORE PRESSURE
σ	NORMAL STRESS
σ'	NORMAL EFFECTIVE STRESS ($\bar{\sigma}$ IS ALSO USED)
τ	SHEAR STRESS
ϵ	LINEAR STRAIN
γ	SHEAR STRAIN
ν	POISSON'S RATIO (μ IS ALSO USED)
E	MODULUS OF LINEAR DEFORMATION (YOUNG'S MODULUS)
G	MODULUS OF SHEAR DEFORMATION
K	MODULUS OF COMPRESSIBILITY
η	COEFFICIENT OF VISCOSITY

EARTH PRESSURE

d	DISTANCE FROM TOP OF WALL TO POINT OF APPLICATION OF PRESSURE
δ	ANGLE OF WALL FRICTION
K	DIMENSIONLESS COEFFICIENT TO BE USED WITH VARIOUS SUFFIXES IN EXPRESSIONS REFERRING TO NORMAL STRESS ON WALLS
K	COEFFICIENT OF EARTH PRESSURE AT REST

FOUNDATIONS

B	BREADTH OF FOUNDATION
L	LENGTH OF FOUNDATION
D	DEPTH OF FOUNDATION BENEATH GROUND
N	DIMENSIONLESS COEFFICIENT USED WITH A SUFFIX APPLYING TO SPECIFIC GRAVITY, DEPTH AND COHESION ETC. IN THE FORMULA FOR BEARING CAPACITY
k_s	MODULUS OF SUBGRADE REACTION

SLOPES

H	VERTICAL HEIGHT OF SLOPE
D	DEPTH BELOW TOE OF SLOPE TO HARD STRATUM
β	ANGLE OF SLOPE TO HORIZONTAL

