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W.P. No. 46-88-00

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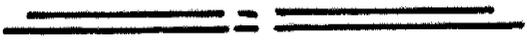
W. O. No. \_\_\_\_\_

STR. SITE No. \_\_\_\_\_

HWY. No. Q.E.W.

LOCATION Q.E.W. between Brant St.  
& Guelph line, HML Poles

No. of PAGES - \_\_\_\_\_



OVERSIZE DRAWINGS TO BE INCLUDED WITH THIS REPORT. \_\_\_\_\_

REMARKS: \_\_\_\_\_

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## FOUNDATION DESIGN SECTION

**foundation  
investigation and  
design report**

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ENGINEERING MATERIALS OFFICE  
FOUNDATION DESIGN SECTION

WP 46-88-00

DIST 4

HWY Q.E.W.

STR SITE

High Mast Light Poles and  
Sign Support Structures  
Q.E.W. from Brant Street to Guelph Line

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FOUNDATION INVESTIGATION REPORT  
For  
High Mast Light Poles and Sign Support Structures  
Q.E.W. from Brant Street to Guelph Line  
W.P. 46-88-00  
District 4, Burlington

INTRODUCTION

The subsoil information contained in this report was obtained from various foundation investigations carried out for existing and proposed structures in this area under W.P. 46-88-02, W.P. 46-88-03, W.P. 83-74-08, W.P. 154-62 and W.P. 43-56. No additional borings were carried out in the area where the high mast light poles and sign support structures are proposed to be constructed. Based on the existing information, this report provides recommendation pertaining to the design of the proposed structures.

SITE DESCRIPTION

The sites for the proposed high mast light poles and sign support structures are located between Brant Street and Guelph Line along Q.E.W. in the City of Burlington.

The topography of the project area, with the exception of the existing crossings (Embankment Fills) is generally flat to gently undulating. The majority of the sites in question are modified to the present condition by the construction of the existing overpasses and underpasses in this area.

The project area is located in shale plains and in this area, the soil is formed directly on the wave-eroded surface of the red shale. Physiographically, the area is located in the region known as the "Iroquois Plain".

SUBSURFACE CONDITIONS

The underlying subsoil in the project area consists of shallow cover of stiff clayey silt or heterogeneous mixture of clayey silt, sand and gravel (Glacial Till) underlain by shale bedrock of Queenston Formation, and in

the area where there are approach embankments, the compacted fill overlies the natural ground. The extent of the area involved covers more than a kilometre in length and it is not practical to give detail description for the individual strata. However, for classification purposes, the soils encountered in the project area can be divided into four different zones.

- a) Embankment Fill
- b) Clayey Silt
- c) Heterogeneous Mixture of Clayey Silt, Sand and Gravel (Glacial Till)
- d) Queenston Shale Bedrock

The subsurface conditions that may be expected at the locations of the proposed structures, together with the field and laboratory test results are shown on the Record of Borehole sheets contained in the Appendix of this report.

Based on the borehole information, it appears that the Queenston Shale Bedrock could be encountered at about 1.0 m to 2.0 m below the original ground level.

#### Groundwater Condition

The borehole information indicates that these holes were dry during the investigation. Since these boreholes were not advanced at the locations where the structures are proposed, the groundwater conditions may vary from those given in the Record of Borehole sheets.

DISCUSSION AND RECOMMENDATIONS

General

It is proposed to construct high mast light poles at eight locations and sign support structures at three locations between Brant Street and Guelph Line along Q.E.W. The location of the high mast light poles and sign support structures as well as the pedestal base elevations are as follows:

<u>Type of Structure</u>	<u>Station</u>	<u>Location</u>	<u>Pedestal Base Elevation</u>
HML P-1	12+237.5	31 m LT. Q.E.W.	111.25
HML P-2	12+438	30 m RT. Q.E.W.	112.75
HML P-3	12+639	33.5 m LT. Q.E.W.	110.75
HML P-4	12+840	34 m RT. Q.E.W.	107.75
HML P-5	13+040	46 m LT. Q.E.W.	105.45
HML P-6	13+240	53.5 m RT. Q.E.W.	104.75
HML P-7	13+378	62 m RT. Q.E.W.	105.00
HML P-8	13+533	105.5 m RT. Q.E.W.	108.50
SSS 1	12+625	Q.E.W. E.B	113.31
SSS 2	13+050	Q.E.W. E.B	106.49
SSS 3	12+420	Q.E.W. W.B	114.58

NOTE: HML P - High Mast Light Pole  
SSS - Sign Support Structure

Foundation Design

The design of the foundation for the proposed structures (single concrete caisson) should be in accordance with the method as outlined in the following papers.

Broms, B. B. "Lateral Resistance of Piles in Cohesive Soils" Journal of the Soil Mechanics and Foundation Division. ASCE Vol. 90 No. SM2, Paper 3285, March, 1964.

Broms, B. B. "Lateral Resistance of Piles in Cohesionless Soil" Journal of the Soil Mechanics and Foundation Division, ASCE Vol. 90 No. SM3, Paper 3909, May, 1964.

The design parameters are given in Table 1 appended to this report. The material located within the zone of frost penetration (1.2 m) should be neglected in the calculation of lateral resistance.

If possible, placing of foundation for the high mast light poles on slope should be avoided. However, if it is placed on slope, appropriate reduction factor should be applied to the parameters given in the table and in addition, the settlement effects as well as the reduction in the lateral resistance of the fill should be taken into consideration in designing the foundation.

In the absence of detail such as nature of fill, embankment slope, width of berm etc., a realistic value cannot be provided. However, at the design stage, this office may be contacted to obtain the necessary parameters.

#### MISCELLANEOUS

This report was prepared by M. Vasavithasan, Foundation Engineer, reviewed by P. Payer, Senior Foundation Engineer, and approved by M. Devata, Chief Foundation Engineer.



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Chief Foundation Engineer

APPENDIX

Table 1

Type of Structure	Soil Boundary Elevation	Soil Type	Design Parameters	
			$q_u$ (kPa)	$\gamma$ (kN/m <sup>3</sup> )
HML P-1	111.2-106.0	Fill	-	-
	106.0-104.0	Cohesive	100	18.5
	Below 104.0	Rock	500	21.0
HML P-2	112.7-104.5	Fill	-	-
	104.5-103.5	Cohesive	100	18.5
	Below 103.5	Rock	500	21.0
HML P-3	110.7-104.5	Fill	-	-
	104.5-103.0	Cohesive	100	18.5
	Below 103.0	Rock	500	21.0
HML P-4	107.7-104.5	Fill	-	-
	104.5-103	Cohesive	100	18.5
	Below 103	Rock	500	21.0
HML P-5	105.4-103.0	Cohesive	100	18.5
	Below 103.0	Rock	500	21.0
HML P-6	104.7-103.0	Cohesive	100	18.5
	Below 103.0	Rock	500	21.0
HML P-7	105.0-103.0	Cohesive	100	18.5
	Below 103.0	Rock	500	21.0
HML P-8	108.5-105.0	Fill	-	-
	105.0-103.0	Cohesive	100	18.5
	Below 103.0	Rock	500	21.0
SSS 1	113.3-104.5	Fill	-	-
	104.5-102.5	Cohesive	100	18.5
	Below 102.5	Rock	500	21.0
SSS 2	106.5-105.5	Fill	-	-
	105.5-103.0	Cohesive	100	18.5
	Below 103.0	Rock	500	21.0
SSS 3	114.6-105.0	Fill	-	-
	105.0-103.0	Cohesive	100	18.5
	Below 103.0	Rock	500	21.0

NOTE:  $q_u$  = Unconfined Compressive Strength (kPa)  
 $\gamma$  = Bulk Unit Weight (kN/m<sup>3</sup>)  
 Rock = Highly Weathered to Unweathered Bedrock  
 HML = High Mast Light  
 SSS = Sign Support Structure

RECORD OF BOREHOLE No 1 1 OF 1 METRIC

W.P. 46 - 88 - 00 LOCATION CO - ORDS. N 4 800 430.0; E 279 204.0 ORIGINATED BY L M  
 DIST 4 HWY QEW BOREHOLE TYPE CONE TEST, HOLLOW STEM AUGER & BW CASING COMPILED BY \_\_\_\_\_  
 DATUM GEODETTIC DATE 1985 07 28 CHECKED BY \_\_\_\_\_

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT 7 kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			'N' VALUES	20						40
105.9	Ground Surface													
0.0	Heterogeneous Mixture of CLAYEY SILT, SAND & GRAVEL, Hard ( Glacial Till )	[Pattern]	1	SS	38									
104.4														
1.5	QUEENSTON SHALE BEDROCK  Weathered  Unweathered	[Pattern]	2	SS	40									
			3	SS	102	/20cm								
			4	RC BX	REC 77%									RQD 0%
			5	RC BX	REC 86%									RQD 0%
100.4			6	RC BX	REC 95%								RQD 63%	
5.5	End of Borehole  Note: Formerly BH# 12 of W.P. 83 - 74 - 08													

+3, x<sup>3</sup>: Numbers refer to Sensitivity 20 15-0-3 (%) STRAIN AT FAILURE 10

RECORD OF BOREHOLE No 2

1 OF 1 METRIC

W.P. 46 - 88 - 00 LOCATION CO - ORDS. N 4 800 447.8; E 279 317.5 ORIGINATED BY M.V.  
 DIST 4 HWY QEW BOREHOLE TYPE SOLID STEM AUGER AND BW CASING COMPILED BY M.V.  
 DATUM GEODETIC DATE 90 10 12 CHECKED BY P.P.

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT 7 kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			'N' VALUES	SHEAR STRENGTH kPa								
						20 40 60 80 100										
						o UNCONFINED + FIELD VANE										
						* QUICK TRIAXIAL * LAB VANE										
						20 40 60 80 100										
						10 20 30										
104.5	Ground Surface															
0.0	Topsoil															
103.5	CLAYEY SILT, Trace of Sand, Trace of Gravel, Stiff		1	SS	9											
1.0	Highly Weathered		2	SS	50											
			3	SS	93	/15cm										
	QUEENSTON SHALE BEDROCK Unweathered		4	RC BX	REC 87%											RQD 18%
			5	RC BX	REC 88%											RQD 26%
			6	RC BX	REC 82%											RQD 46%
96.9	End of Borehole															
7.8	Note: Formerly BH# 2 of W.P. 46 - 88 - 02															

RECORD OF BOREHOLE No 3

1 OF 1

METRIC

W.P. 46 - 88 - 00 LOCATION CO - ORDS. N 4 800 522.8; E 279 350.5 ORIGINATED BY M V  
 DIST 4 HWY 9EW BOREHOLE TYPE SOLID STEM AUGER AND BW CASING COMPILED BY M V  
 DATUM GEODETIC DATE 90 10 16 CHECKED BY P P

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT 7 KN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			'N' VALUES	20	40	60	80						100	SHEAR STRENGTH kPa o UNCONFINED + FIELD VANE • QUICK TRIAXIAL * LAB VANE
105.0	Ground Surface																	
0.0	CLAYEY SILT, Tr. Sand, Tr. Gravel, Sluff	Topsoil				DRY *												
104.5	Highly Weathered    QUEENSTON SHALE BEDROCK. Unweathered		1	SS	18	/15cm												
0.5			2	SS	81													
			3	SS	123		/23cm											
			4	RC BX	REC 71%													RQD 21%
			5	RC BX	REC 93%													RQD 70%
			6	RC BX	REC 94%													RQD 68%
98.2	6.8 End of Borehole																	
	Note: Formerly BH# 2 of W.P. 46 - 88 - 03																	

RECORD OF BOREHOLE No 4

1 OF 1

METRIC

W.P. 46 - 88 - 00 LOCATION CO - ORDS. N 4 800 638.5; E 279 534.5 ORIGINATED BY G.M.  
 DIST 4 HWY QEW BOREHOLE TYPE WASH BORING AND AX CASING COMPILED BY \_\_\_\_\_  
 DATUM GEODETIC DATE 1962 08 28 CHECKED BY \_\_\_\_\_

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT 7 kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			'N' VALUES	SHEAR STRENGTH kPa								
							20	40	60	80	100					
104.5	Ground Surface															
0.0	CLAYEY SILT, Hard					DRY *										
102.8																
1.7	Weathered ----- QUEENSTON SHALE BEDROCK Unweathered															
99.9																
4.6	End of Borehole  Note: Formerly BH# 1 of W.P. 154 - 62															

RECORD OF BOREHOLE No 5

1 OF 1 METRIC

W.P. 48 - 85 - 00 LOCATION CO - ORDS. N 4 800 638.0; E 279 549.5 ORIGINATED BY G.M.  
 DIST 4 HWY QEW BOREHOLE TYPE WASH BORING AND AX CASING COMPILED BY \_\_\_\_\_  
 DATUM GEODETIC DATE 1962 08 28 CHECKED BY \_\_\_\_\_

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			'N' VALUES	SHEAR STRENGTH kPa								
						20	40	60	80	100						
104.5	Ground Surface															
0.0	CLAYEY SILT, Hard					DRY +										
102.8																
1.7	Weathered ----- QUEENSTON SHALE BEDROCK, Unweathered															
100.8																
3.7	End of Borehole  Note: Formerly BH# 2 of W.P. 154 - 62															

+<sup>3</sup>, x<sup>3</sup>: Numbers refer to Sensitivity 20 15-25 (%) STRAIN AT FAILURE 10

RECORD OF BOREHOLE No 6 1 OF 1 METRIC

W.P. 48 - 88 - 00 LOCATION CO - ORDS. N 4 800 595.5; E 279 544.5 ORIGINATED BY G.M.  
 DIST 4 HWY GEW BOREHOLE TYPE WASH BORING AND AX CASING COMPILED BY  
 DATUM GEODETTIC DATE 1962 08 29 CHECKED BY

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT			UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			'N' VALUES	20	40	60	80	100	W <sub>p</sub>	W			W <sub>L</sub>	γ	GR SA SI CL
104.5	Ground Surface																		
0.0	CLAYEY SILT, With Occasional Sand and Gravel. Trace of Organics, Hard				DRY														
102.5																			
2.0																			
100.8	Weathered ----- QUEENSTON SHALE BEDROCK, Unweathered																		
3.7	End of Borehole  Note: Formerly BH# 3 of W.P. 154 - 62																		

RECORD OF BOREHOLE No 7

1 OF 1

METRIC

W.P. 48 - 89 - 00 LOCATION CO - ORDS. N 4 801 148.5; E 280 155.0 ORIGINATED BY A.T.  
 DIST 4 HWY QEW BOREHOLE TYPE AUGER AND ROCK CORING COMPILED BY \_\_\_\_\_  
 DATUM GEODETIC DATE 1955 11 09 CHECKED BY \_\_\_\_\_

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT 7 kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			'N' VALUES	20	40	60					
105.4	Ground Surface														
0.0	CLAYEY SILT, Hard				DRY •	105									
104.8															
0.8	QUEENSTON SHALE BEDROCK, Highly Weathered to Weathered					104									
103.6															
1.8	End of Borehole														
	Note: Formerly BH# 3 of W.P. 43 - 56														

## EXPLANATION OF TERMS USED IN REPORT

**N VALUE:** THE STANDARD PENETRATION TEST (SPT) N VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51mm O.D SPLIT BARREL SAMPLER TO PENETRATE 0.3m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5kg, FALLING FREELY A DISTANCE OF 0.76m. FOR PENETRATIONS OF LESS THAN 0.3m N VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N VALUE IS DENOTED THUS  $\bar{N}$ .

**DYNAMIC CONE PENETRATION TEST:** CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51mm O.D 60° CONE ANGLE) DRIVEN BY 475 J IMPACT ENERGY ON 'A' SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

**CONSISTENCY:** COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH ( $c_u$ ) AS FOLLOWS:

$c_u$ (kPa)	0 - 12	12 - 25	25 - 50	50 - 100	100 - 200	>200
	VERY SOFT	SOFT	FIRM	STIFF	VERY STIFF	HARD

**DENSENESS:** COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS OF DENSENESS AS INDICATED BY SPT N VALUES AS FOLLOWS:

N (BLOWS/0.3m)	0 - 5	5 - 10	10 - 30	30 - 50	>50
	VERY LOOSE	LOOSE	COMPACT	DENSE	VERY DENSE

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCTURAL FEATURES AND / OR STRENGTH.

**RECOVERY:** SUM OF ALL RECOVERED ROCK CORE PIECES FROM A CORING RUN EXPRESSED AS A PERCENT OF THE TOTAL LENGTH OF THE CORING RUN.

**MODIFIED RECOVERY:** SUM OF THOSE INTACT CORE PIECES, 100mm+ IN LENGTH EXPRESSED AS A PERCENT OF THE LENGTH OF THE CORING RUN. THE ROCK QUALITY DESIGNATION (R Q D), FOR MODIFIED RECOVERY, IS:

RQD (%)	0 - 25	25 - 50	50 - 75	75 - 90	90 - 100
	VERY POOR	POOR	FAIR	GOOD	EXCELLENT

**JOINTING AND BEDDING:**

SPACING	50mm	50 - 300mm	0.3m - 1m	1m - 3m	>3m
JOINTING	VERY CLOSE	CLOSE	MOD. CLOSE	WIDE	VERY WIDE
BEDDING	VERY THIN	THIN	MEDIUM	THICK	VERY THICK

## ABBREVIATIONS AND SYMBOLS

### FIELD SAMPLING

S S	SPLIT SPOON	T P	THINWALL PISTON
W S	WASH SAMPLE	O S	OSTERBERG SAMPLE
S T	SLOTTED TUBE SAMPLE	R C	ROCK CORE
B S	BLOCK SAMPLE	P H	T W ADVANCED HYDRAULICALLY
C S	CHUNK SAMPLE	P M	T W ADVANCED MANUALLY
T W	THINWALL OPEN	F S	FOIL SAMPLE

### STRESS AND STRAIN

$u_w$	kPa	PORE WATER PRESSURE
$u$	1	PORE PRESSURE RATIO
$\sigma$	kPa	TOTAL NORMAL STRESS
$\sigma'$	kPa	EFFECTIVE NORMAL STRESS
$\tau$	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
$\epsilon$	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
$\mu$	1	COEFFICIENT OF FRICTION

### MECHANICAL PROPERTIES OF SOIL

$m_v$	$kPa^{-1}$	COEFFICIENT OF VOLUME CHANGE
$C_c$	1	COMPRESSION INDEX
$C_s$	1	SWELLING INDEX
$C_\alpha$	1	RATE OF SECONDARY CONSOLIDATION
$c_v$	$m^2/s$	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
$T_v$	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
$\sigma'_{VO}$	kPa	EFFECTIVE OVERBURDEN PRESSURE
$\sigma'_p$	kPa	PRECONSOLIDATION PRESSURE
$\tau_f$	kPa	SHEAR STRENGTH
$c'$	kPa	EFFECTIVE COHESION INTERCEPT
$\phi'$	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
$c_u$	kPa	APPARENT COHESION INTERCEPT
$\phi_u$	-°	APPARENT ANGLE OF INTERNAL FRICTION
$\tau_R$	kPa	RESIDUAL SHEAR STRENGTH
$\tau_r$	kPa	REMOULDED SHEAR STRENGTH
$S_t$	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

### PHYSICAL PROPERTIES OF SOIL

$\rho_s$	$kg/m^3$	DENSITY OF SOLID PARTICLES	e	1, %	VOID RATIO	$e_{min}$	1, %	VOID RATIO IN DENSEST STATE
$\gamma_s$	$kn/m^3$	UNIT WEIGHT OF SOLID PARTICLES	n	1, %	POROSITY	$I_D$	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
$\rho_w$	$kg/m^3$	DENSITY OF WATER	w	1, %	WATER CONTENT	D	mm	GRAIN DIAMETER
$\gamma_w$	$kn/m^3$	UNIT WEIGHT OF WATER	$S_r$	%	DEGREE OF SATURATION	$D_n$	mm	n PERCENT - DIAMETER
$\rho$	$kg/m^3$	DENSITY OF SOIL	$w_L$	%	LIQUID LIMIT	$C_u$	1	UNIFORMITY COEFFICIENT
$\gamma$	$kn/m^3$	UNIT WEIGHT OF SOIL	$w_p$	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
$\rho_d$	$kg/m^3$	DENSITY OF DRY SOIL	$w_s$	%	SHRINKAGE LIMIT	q	$m^3/s$	RATE OF DISCHARGE
$\gamma_d$	$kn/m^3$	UNIT WEIGHT OF DRY SOIL	$I_p$	%	PLASTICITY INDEX = $\frac{w_L - w_p}{w - w_p}$	v	m/s	DISCHARGE VELOCITY
$\rho_{sat}$	$kg/m^3$	DENSITY OF SATURATED SOIL	$I_L$	1	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	i	1	HYDRAULIC GRADIENT
$\gamma_{sat}$	$kn/m^3$	UNIT WEIGHT OF SATURATED SOIL	$I_C$	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	k	m/s	HYDRAULIC CONDUCTIVITY
$\rho'$	$kg/m^3$	DENSITY OF SUBMERGED SOIL	$e_{max}$	1, %	VOID RATIO IN LOOSEST STATE	j	$kn/m^3$	SEEPAGE FORCE
$\gamma'$	$kn/m^3$	UNIT WEIGHT OF SUBMERGED SOIL						