

G.I.-30 SEPT. 1976

GEOCRES No. 30M12-209DIST. 6 REGION W.P. No. CONT. No. W. O. No. 88-11005STR. SITE No. HWY. No. 410LOCATION Williams Parkway N to
Bovaird Dr. - SettlementNo of PAGES - =====OVERSIZE DRAWINGS TO BE INCLUDED WITH THIS REPORT. REMARKS:



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FOUNDATION DESIGN SECTION

**foundation
investigation and
design report**

ENGINEERING MATERIALS OFFICE
FOUNDATION DESIGN SECTION

WO 88-11005

DIST 6

HWY 410

STR SITE

Hwy. 410 Settlements
Between
Williams Parkway - Bovaird Drive

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FOUNDATION INVESTIGATION REPORT

FOR

HWY 410 SETTLEMENTS

Between

Williams Parkway - Bovaird Drive

WO 88-11005, Hwy 410

District 6, Toronto

INTRODUCTION

This report summarizes the results of a geotechnical investigation implemented at the aforementioned site in response to a request submitted by the Central Region Geotechnical Section. The purpose of the study was to investigate the pavement settlements that have developed along Hwy 410 between Williams Parkway and Bovaird Drive in the City of Brampton. The pavement surface, underlain at some locations with up to 15 m of fill material, was completed in September, 1987 and has since experienced considerable subsidence.

The fieldwork was carried out between 88 12 13 and 88 12 16 and consisted of 4 sampled boreholes accompanied by dynamic cone penetration tests at selected locations within the affected area. Continuous flight hollow stem and solid stem augering techniques were used to advance the boreholes through the overburden to depths ranging from 7.7 m to 17.2 m. Subsoil samples were retrieved at selected depths, identified in the field and then transported to the laboratory for further examination and testing.

SITE DESCRIPTION AND GEOLOGY

The site is located along a section of Hwy 410 bounded by Williams Parkway and Bovaird Drive and spanning a distance of approximately 1.5 kilometres. The Franceschini Drive Overpass is located approximately equidistant from the boundaries indicated and provides access to the existing Fransechini Gravel Pit that is in active production west of Hwy 410. Land use elsewhere in the area is primarily residential and parkland. The highway corridor has been effectively isolated from the area by a series of embankment cuts and earth fills.

Prior to the construction of Hwy 410, the area consisted of very rugged terrain composed of abandoned gravel pits, ponds and marshy areas. Physiographically, the site is located in the region known as the "Peel Plain" and the Pleistocene deposits in the area are associated with the advance and retreat of the Wisconsin ice sheet. The primary deposit consists of a bevelled clay and silty till that rests on bedrock of the Dundas-Meaford Formation. A prominent esker consisting of variable deposits of gravel and sands and, in places, silt and clay extends in a southeasterly direction and intersects Hwy 410 at the site.

SUBSURFACE CONDITIONS

Considerable thickness of fill material was encountered at three of the four areas investigated, specifically at STA 15 + 781, STA 16 + 115 and STA 16 + 358 which correspond to BH's 3, 2, and 4 respectively. Underlying an upper sand fill of maximum thickness 0.5 metres, the predominant fill material which consists generally of an irregular mixture of clayey silt, sand and gravel varies in thickness from 6.1 m to 13.0 m. The native sand with gravel deposit underlies the fill material and was explored to a maximum thickness of 4.2 metres.

Fill material was not encountered at STA 16 + 920 (BH 1) but rather the highway subgrade appears to consist of a heterogeneous mixture of clayey silt, sand and gravel (glacial till). This surficial deposit was explored to a maximum thickness of 7.7m.

The boundaries between the various soil types, in-situ and laboratory test results, as well as stabilized ground water levels, are shown on the attached Record of Borehole Sheets. A plan of the site illustrating the locations of the boreholes are provided on Dwg. 8811005-A.

A detailed description of the subsurface conditions encountered is given below.

IRREGULAR MIXTURE OF CLAYEY SILT, SAND AND GRAVEL
(FILL MATERIAL)

The fill material encountered at the specified locations consisted primarily of an irregular mixture of brown clayey silt, sand and gravel. However, random zones and traces of organics were found throughout the fill. Organics present between 3.0 m and 5.8 m in depth at BH 4 was of significant concentration such that the fill exhibited an increased compressible behaviour more typical of a silty clay material. Random pockets of silt were also present in the fill. Grain size distribution curves illustrating the composition of the clayey silt, sand and gravel mixture and the silty clay, sand and gravel mixture are provided in Figures 1 and 2 respectively. Atterberg limits were also obtained to evaluate the behaviour of the fine grained portion of the material and the results are plotted in Figures 5 and 6 for the clayey silt and silty clay respectively. A summary of the indices of the basic cohesive material matrix is provided in Table 1 and Table 2 below. Unit weights are also included.

Table 1 - Clayey Silt Matrix

	<u>Range</u>	<u>Average</u>
Natural Moisture Content (w)%	12.0-18.0	14.0
Liquid limit (w_L)%	19.0-33.0	26.0
Plastic limit (w_p)%	13.0-17.0	14.0
Unit Weight (kN/m^3)	20.4-22.3	21.2

Table 2 - Silty Clay Matrix

	<u>Range</u>	<u>Average</u>
Natural Moisture Content (w)%	26.0-28.0	27.0
Liquid Limit (w_L)%	43.0-46.0	45.0
Plastic Limit (w_p)%	20.5-23.5	22.0
Plasticity Index (I_p)%	20.0-25.0	23.0
Unit Weight (kN/m^3)	19.4-20.1	19.8

The results reveal that the fill is primarily of clayey silt of low plasticity with random zones of silty clay of intermediate plasticity. The moisture contents and unit weights for the clayey silt mixture, in general, exceed the optimum moisture content and densities of the material. Figure 8 illustrates a standard Proctor curve produced by testing a collection of subsoil samples conglomerated from random depths in the fill. 'N' values obtained from the SPT indicate a broad range of states of compaction and in general varies randomly and inconsistently from low to high throughout the thickness of the fill.

HETEROGENEOUS MIXTURE OF CLAYEY SILTY, SAND AND GRAVEL
(GLACIAL TILL)

As mentioned earlier, the subgrade at STA 16 + 920 (BH 1) consists of native soil composed of a heterogeneous mixture of

clayey silt, sand and gravel (Glacial Till). A grain size distribution envelope illustrating the composition of the till material is provided in Figure 3. Atterberg limits were also obtained to evaluate the behaviour of the fine grained portion of the material and the results are plotted in Figure 7. A summary of the indices of the basic cohesive material matrix is provided in Table 3.

Table 3

	<u>Range</u>	<u>Average</u>
Natural Moisture Content (w)%	10.0-16.0	12
Liquid Limit (w_L)%	21.0-32.0	25
Plastic Limit (w_p)%	13.0-16.0	14
Plasticity Index (I_p)%	8.0-16.0	11

The results reveal that the deposit is primarily of low plasticity and has the properties inherent of a competent till deposit.

The consistency of the deposit as indicated by 'N' values of the Standard Penetration Test ranges from stiff to hard but generally can be considered to be very stiff.

SAND WITH GRAVEL

Underlying the native till deposit at BH 1 and the fill material at the other locations of the investigation, a natural deposit of primarily sand with gravel exists. Typical grain size distributions are provided in Figure 4. Random zones of clayey silt of maximum thickness 0.3 m were also found interbedded in this deposit.

Based on 'N' values obtained from the Standard Penetration Test, the deposit has a relative density ranging from compact to very dense and in general can be considered to be very dense.

GROUNDWATER CONDITIONS

Monitoring of the groundwater level was carried out by measuring the water level in the open boreholes. Measurements revealed stabilized levels at an elevation ranging from 224.3 m to 230.5 m indicating that the water level was within the cohesionless sand deposit at BH's 3 and 4 (depths of 7 m, 15.5 m below ground surface respectively) and within the fill at BH 2 (at a depth of 5.0 m below ground surface).

DISCUSSION AND RECOMMENDATIONS

The section of Hwy 410 between Williams Pkwy and Bovaird Drive was constructed and completed in 1987. The highway, advanced through an abandoned gravel pit that occupied the area previously, has since experienced multiple pavement settlements. The magnitude of the settlement has been visually approximated at 150mm.

The probable causes of the settlements are summarized below. Recommendations for restoration of the section of highway affected are then provided.

CAUSES OF SETTLEMENT

Fill Material

The cohesive clayey silt material used for the fill characteristically exhibits settlement under self weight, and based on historical test data, the magnitude is traditionally predicted as summarized in Table 4.

Table 4

<u>Height of Fill (H_{FILL})</u>	<u>Total Settlement (S_T)</u>
0- 7m	$0.5 \% \times H_{FILL}$
7-10m	$0.75\% \times H_{FILL}$
10-12m	$1.0 \% \times H_{FILL}$

In view of the significant thickness of the fill material in the area (5.6m to 11.8m), it is apparent that considerable settlements can develop. Furthermore, the settlements listed on Table 4 are based on achieving the specified compaction or "soil densification". It follows that if this specification is not achieved, the compressibility and permeability of the fill increases, hence producing greater settlements. Achievement of the maximum dry density is contingent on the moisture content of the soil. If the plasticity index (I_p) is greater than 7 as is primarily the case of the fill used at this site, the moisture content should not exceed 3% above optimum to ascertain the strength of the soil and hence resistance to deformation under stress. Laboratory tests revealed in situ moisture contents of the clayey silt material ranging from 12% to 18% which indicates zones where the material is above optimum as determined by a Proctor test on the material.

Random zones of silt-clayey silt [CL-ML] are also included in the fill material at moisture contents above optimum. Typically, siltier materials with low plasticity ($I_p < 7$) at above optimum moisture contents are extremely difficult to compact, as the material tends to "roll" under the compactive efforts. This effect also contributes in decreasing soil strength and resistance to deformation under stress. The result is additional settlements.

Inclusions of organics were found randomly in the fill material and a distinct layer, 2.8m in thickness, was found at a depth of 3.0m at BH 4. Organic concentrated soils are compressible

material. The installation of the lightweight fill should be planned and coordinated with an effective drainage system to prevent surface water infiltration to the underlying lightweight fill. All surface water should be efficiently drained away from the affected area and directed to existing storm sewers in the area.

As an alternative to the slag material, styrofoam lightweight insulation may be used as replacement backfill. The styrofoam insulation is to be placed on a compacted levelling course, possess the required structural properties and durability qualities and integrated in the pavement design. Expanded polystyrene styrofoam insulation has a unit weight typically of 8kN/m^3 and consequently subexcavation at a temporary slope of 1H:1V can be reduced to 2.5 metres.

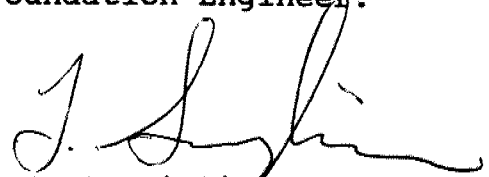
The most cost effective alternative should be selected. For cost comparison purposes, the cost of expanded pelletized blast furnace slag is currently \$25-30 per cubic metre whereas the styrofoam has a cost of \$75-80 per cubic metre.

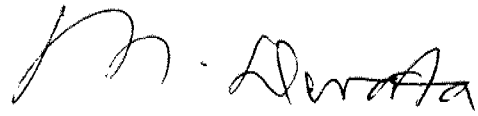
Alternative 3 - Lime Stabilization

The lime column method is advantageously used both in expediting and limiting settlement by reducing the water content of the soil and hence increasing its strength. However, in view of the fact that the settlements are not widespread and has occurred in isolated areas, this alternative may not prove to be the most economical and practical alternative.

MISCELLANEOUS

The fieldwork for this investigation was carried out under the supervision of F. Pinder, Engineering Trainee, utilizing equipment owned and operated by Master Soils Investigation, Toronto. This report was written by T. Sangiuliano and F. Pinder and reviewed by Mr. M.S. Devata, Chief Foundation Engineer.

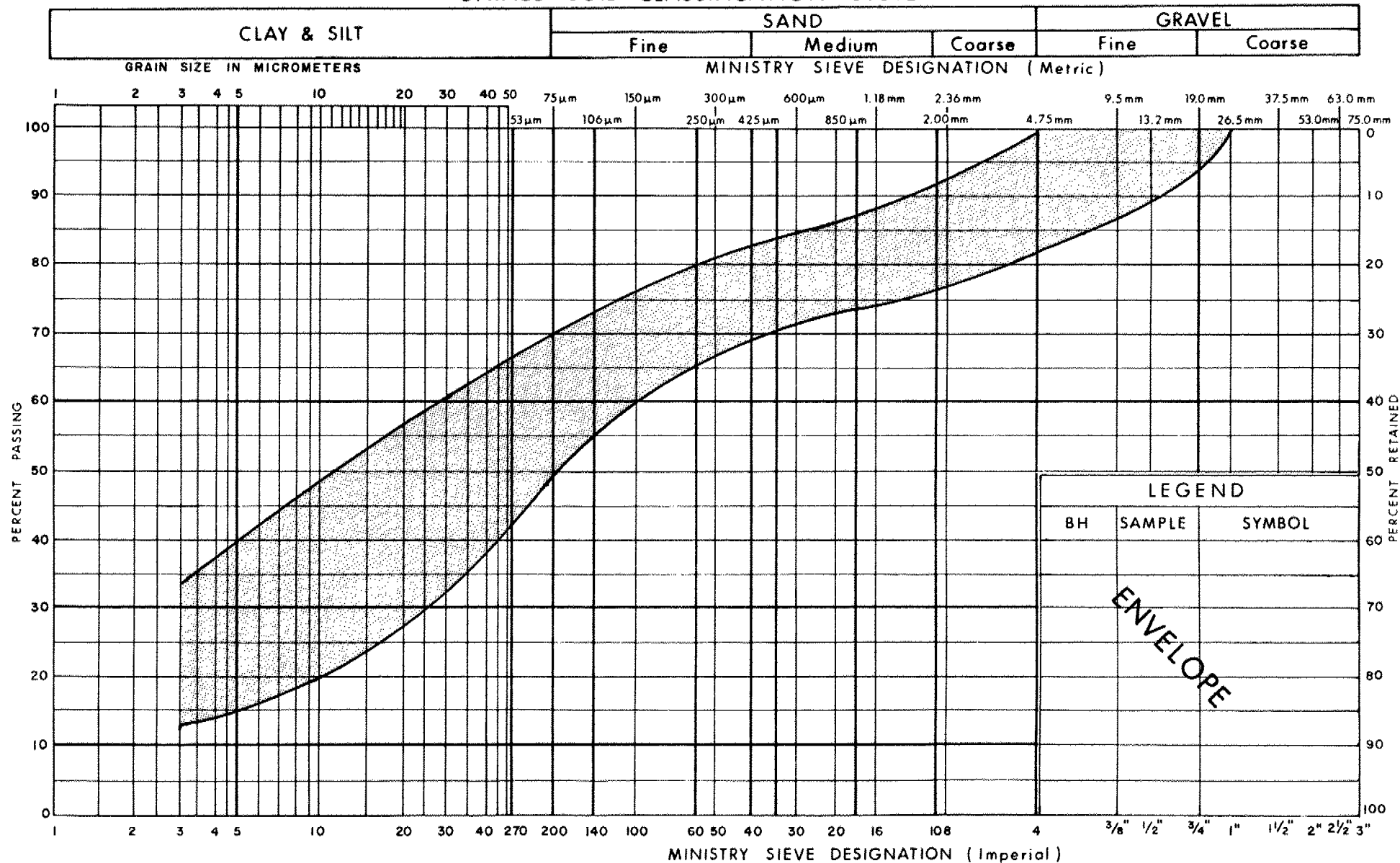

T. Sangiuliano, P. Eng
Foundation Engineer


M.S. Devata, P. Eng
Chief Foundation Eng.



APPENDIX

UNIFIED SOIL CLASSIFICATION SYSTEM

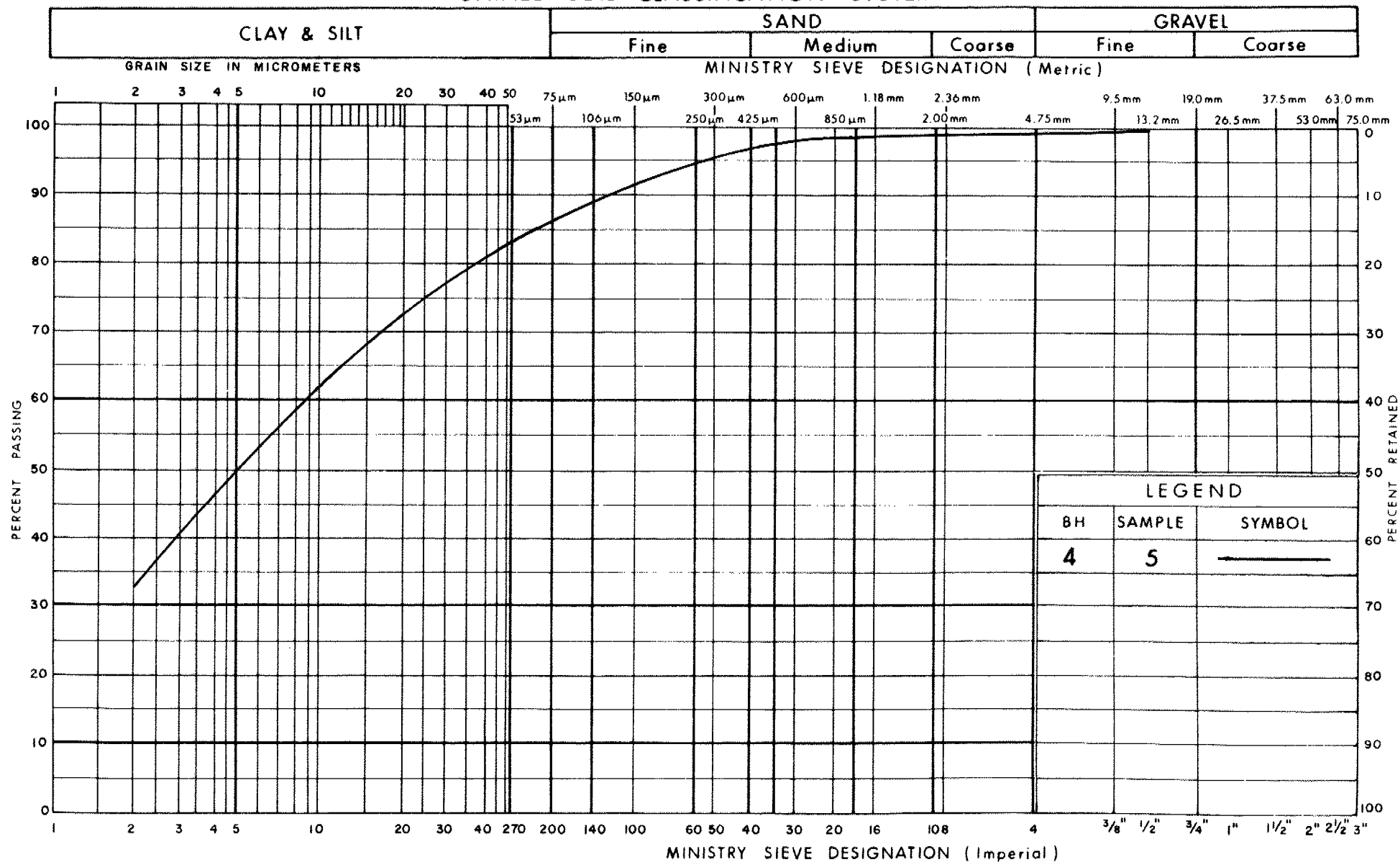

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GRAIN SIZE DISTRIBUTION
 IRREGULAR MIXTURE OF CLAYEY SILT, SAND & GRAVEL
 (FILL MATERIAL)

FIG No 1

WO 88-11005

UNIFIED SOIL CLASSIFICATION SYSTEM



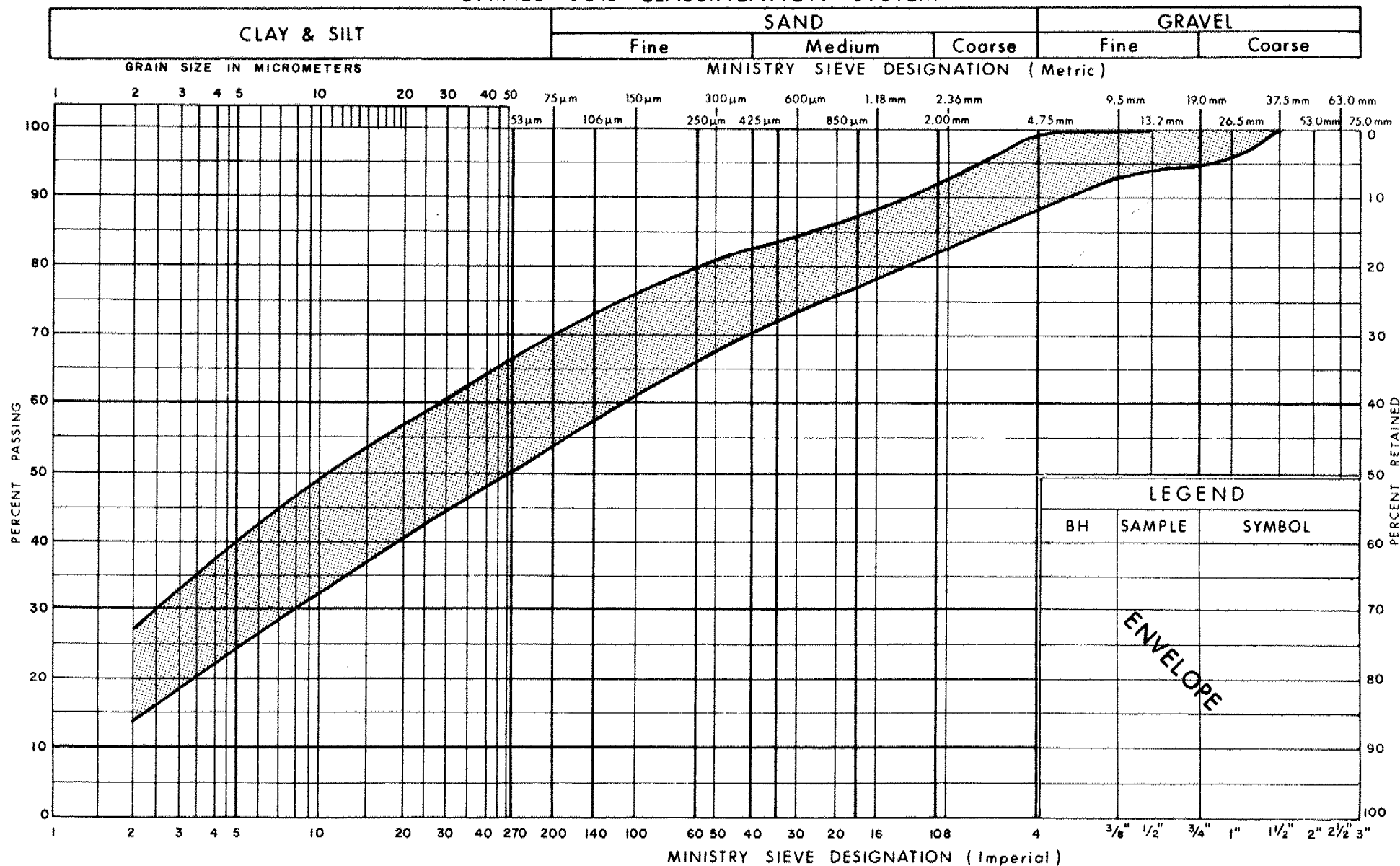
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GRAIN SIZE DISTRIBUTION
IRREGULAR MIXTURE OF SILTY CLAY, SAND & ORG'S
(FILL MATERIAL)

FIG No 2

WO 88-11005

UNIFIED SOIL CLASSIFICATION SYSTEM



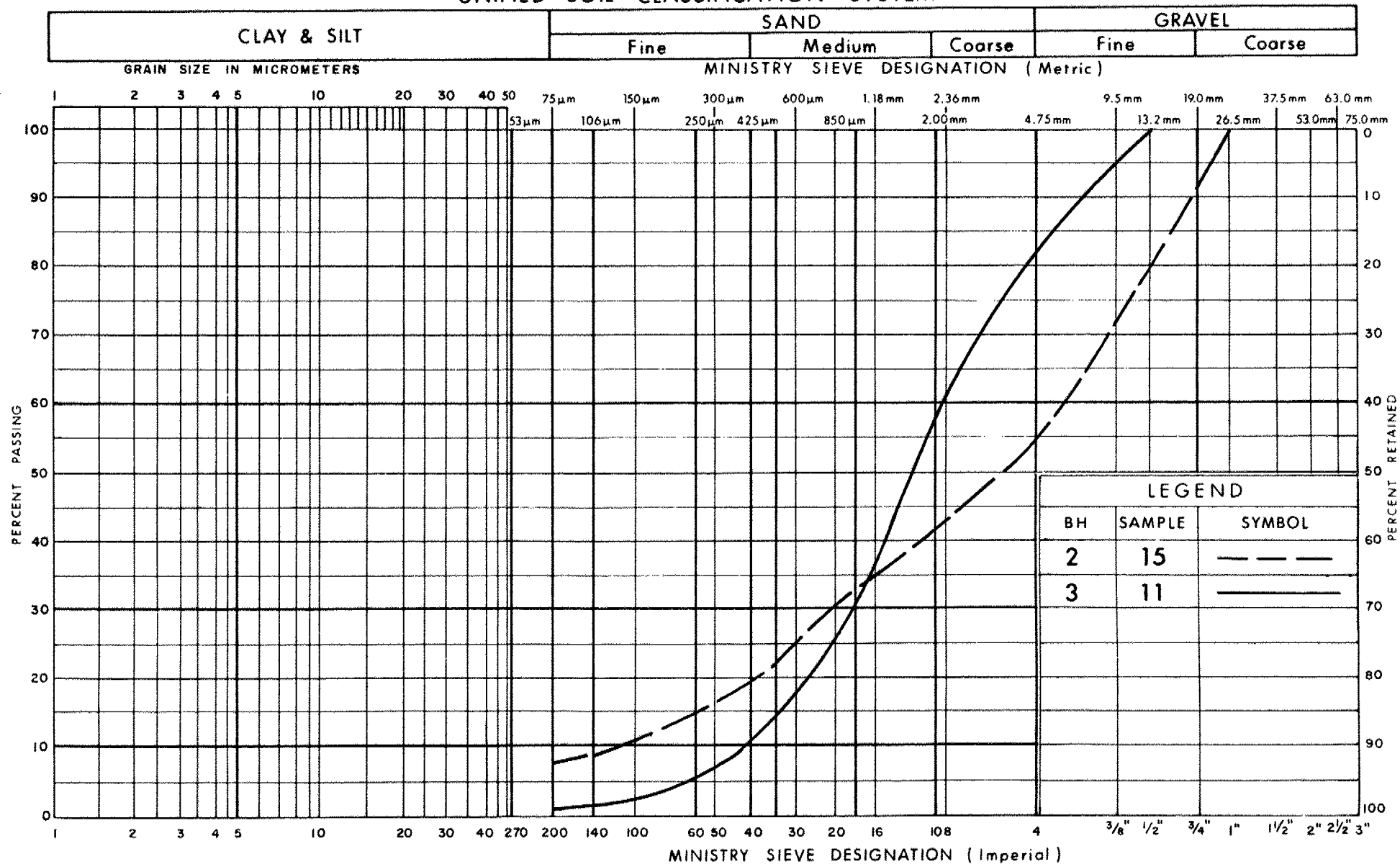
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GRAIN SIZE DISTRIBUTION
HET MIXTURE OF CLAYEY SILT, SAND & GRAVEL
 (GLACIAL TILL)

FIG No 3

W O 88-11005

UNIFIED SOIL CLASSIFICATION SYSTEM

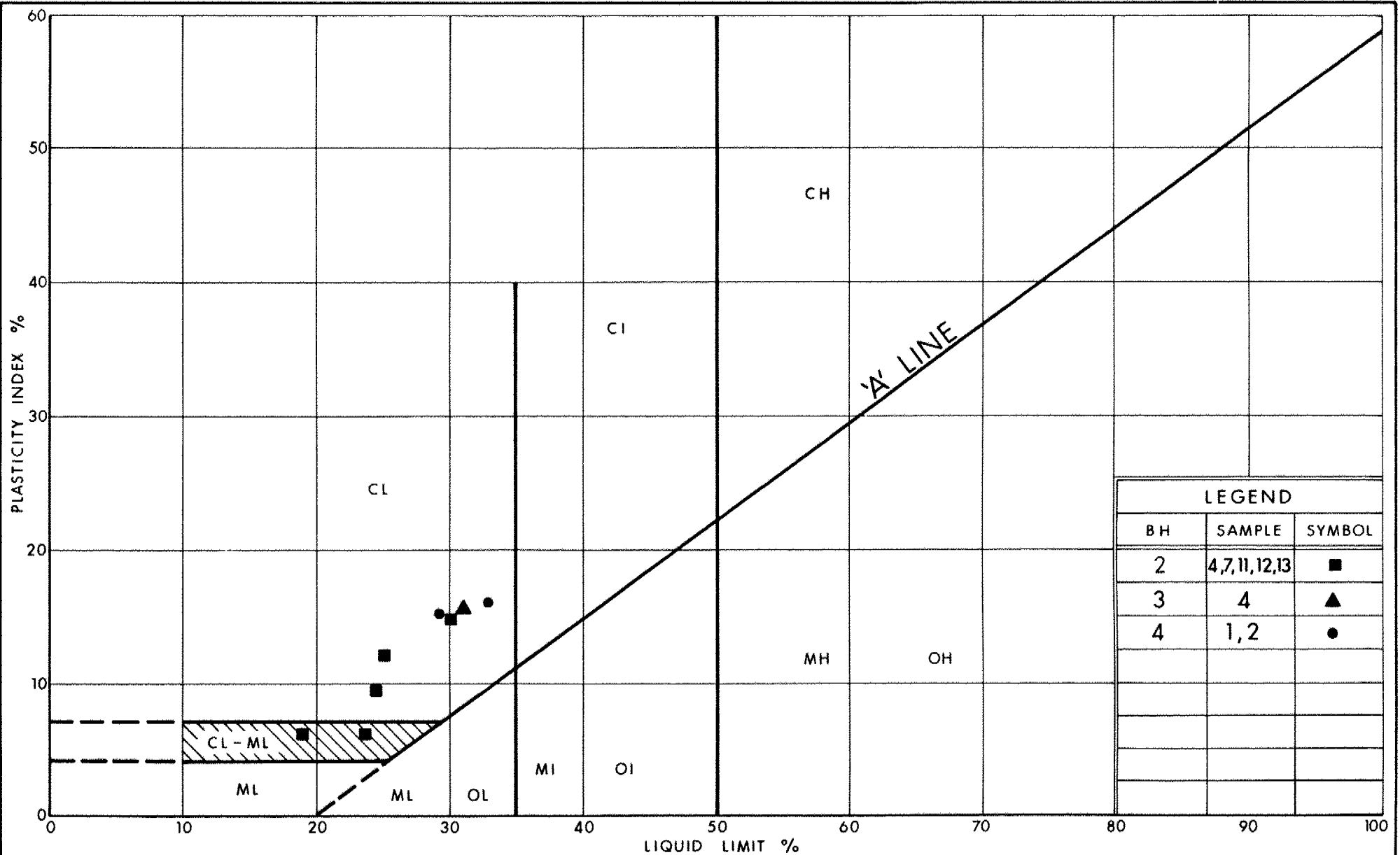


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GRAIN SIZE DISTRIBUTION SAND WITH GRAVEL

FIG No 4

WO 88-11005



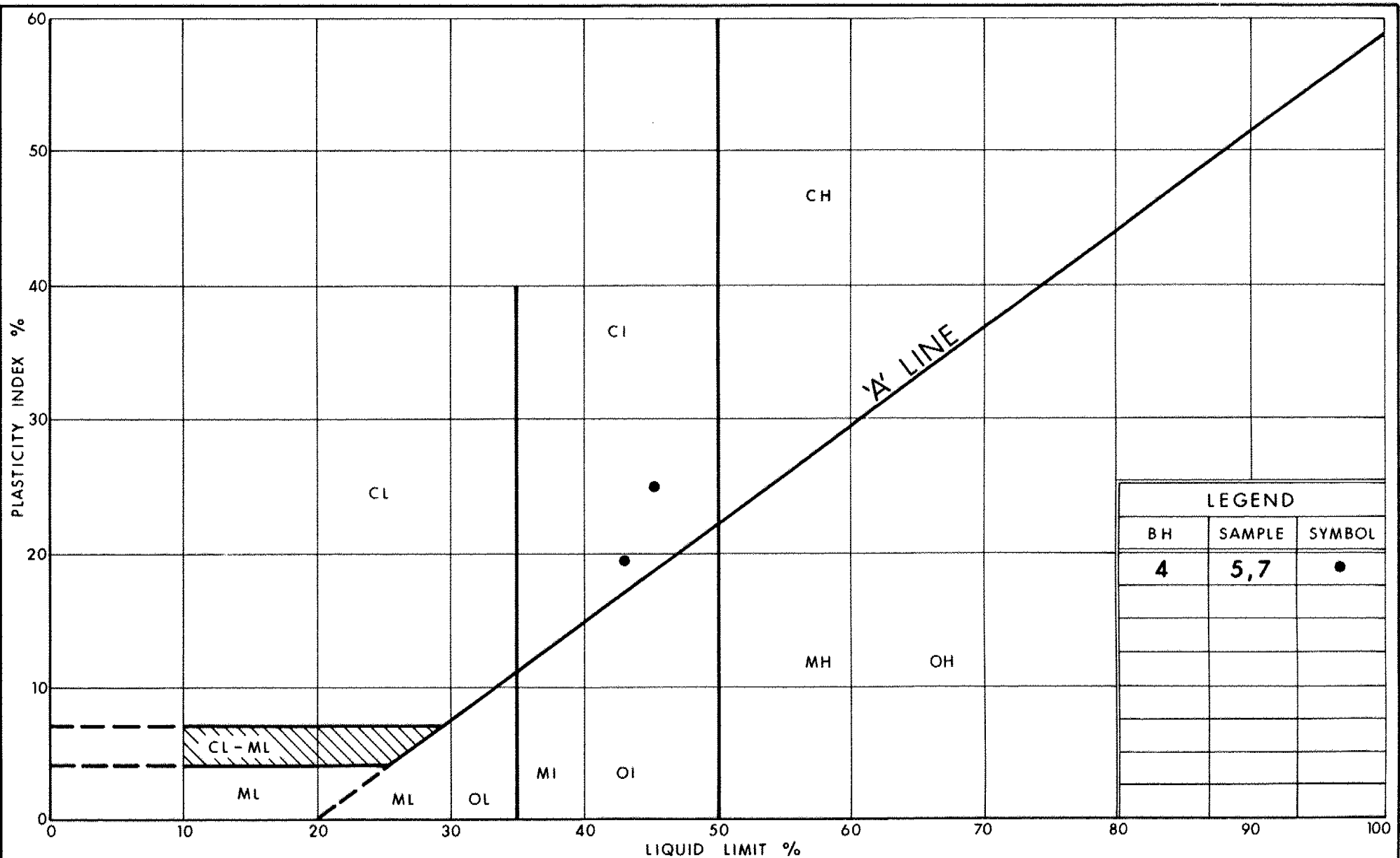
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PLASTICITY CHART
IRREGULAR MIXTURE OF CLAYEY SILT, SAND & GRAVEL
(FILL MATERIAL)

FIG No 5

WO 88-11005



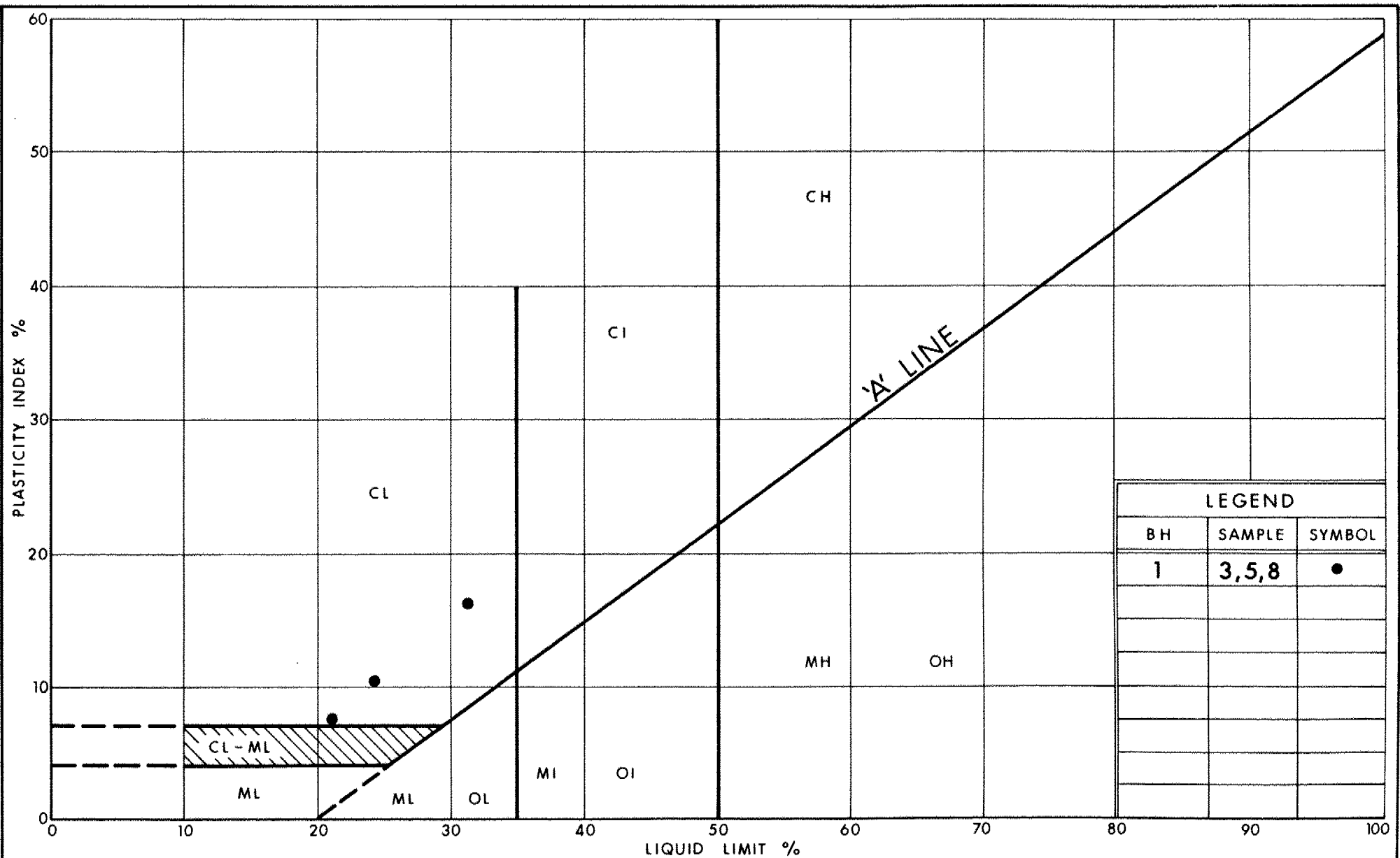
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Ontario

PLASTICITY CHART IRREGULAR MIXTURE OF SILTY CLAY, SAND & ORG'S (FILL MATERIAL)

FIG No 6

WO 88-11005

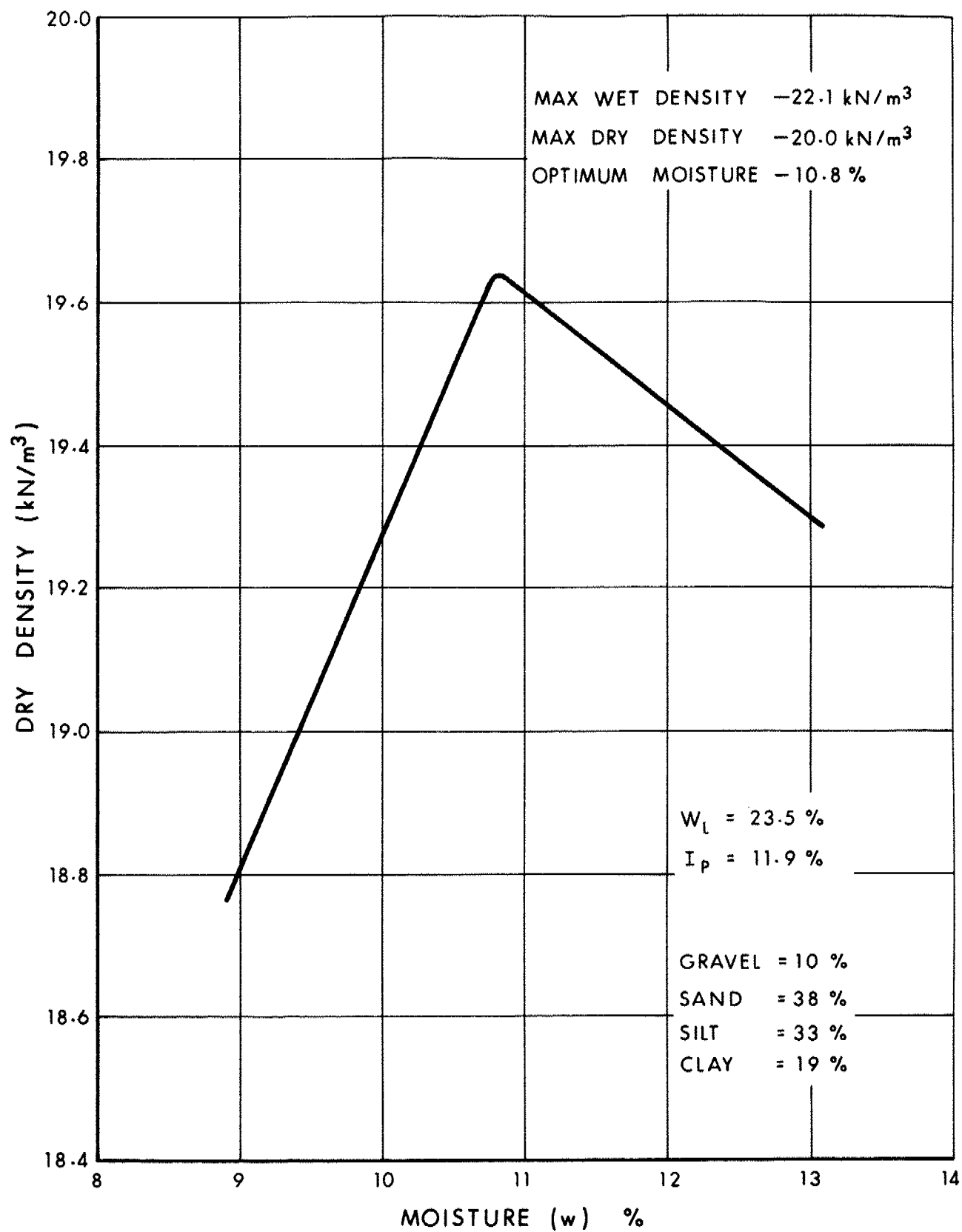


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PLASTICITY CHART
HET MIXTURE OF CLAYEY SILT, SAND & GRAVEL
(GLACIAL TILL)

FIG No 7

WO 88-11005



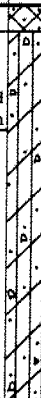
WO 88-11005

Fig 8

RECORD OF BOREHOLE No 1

METRIC

W O 88-11005 LOCATION Sta. 16+920; o/s 24.0m Rt of Hwy 410 4 ORIGINATED BY F.P.
 DIST 6 HWY 410 BOREHOLE TYPE Cone Test, Solid-Stem Augers COMPILED BY F.P.
 DATUM Geodetic DATE 88 12 13 CHECKED BY D.D.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	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	WATER CONTENT (%)
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE							
243.4	Asphalt Surface														
242.9	Sand (Fill)					*									
0.5	Heterogeneous Mixture of Clayey Silt, Sand and Gravel (Glacial Till) Stiff to Hard		1	SS	10										
			2	SS	32										
			3	SS	50										
			4	SS	23										
			5	SS	19										
			6	SS	18										
			7	SS	16										
			8	SS	9										
			9	SS	93										
			10	SS	60	8cm									
235.7															
7.7	End of Borehole *GWL Not Established														

OFFICE REPORT ON SOIL EXPLORATION

RECORD OF BOREHOLE No 2

METRIC

WO 88-11005 LOCATION Sta. 16+115; o/s 23.0m Rt. of Hwy 410 ORIGINATED BY F.P.
 DIST 6 HWY 410 BOREHOLE TYPE Cone Test, Solid-Stem Augers COMPILED BY F.P.
 DATUM Geodetic DATE 88 12 14 CHECKED BY DD

OFFICE REPORT ON SOIL EXPLORATION

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100							W _p	W	W _L			
								SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE												
236.0	Asphalt Surface											10 20 30								
235.5	Sand Compact																			
0.5	Irregular		1	SS	20															

RECORD OF BOREHOLE No 3

METRIC

WO 88-11005 LOCATION Sta. 15+781; o/s 15.0m Rt. of Hwy 410
 DIST 6 HWY 410 BOREHOLE TYPE Cone Test, Hollow-Stem Augers
 DATUM Geodetic DATE 88 12 15
 ORIGINATED BY F.P.
 COMPILED BY F.P.
 CHECKED BY DD

OFFICE REPORT ON SOIL EXPLORATION

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100	PLASTIC LIMIT Wp	NATURAL MOISTURE CONTENT W	LIQUID LIMIT Wl	UNIT WEIGHT Y kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES								
231.5	Asphalt Surface												
231.0	Sand Compact												
0.5			1	SS	47								
			2	SS	15								
	Irregular Mixture of Clayey Silt, Sand and Gravel (Fill)		3	SS	13								
			4	SS	4								
			5	SS	12								
	Brown Grey-Brown		6	SS	8								
	Soft to Stiff Random Pockets of Silt		7	SS	3								
			8	SS	4								
225.4			9	SS	58								
6.1	Sand with Gravel Grey Very Dense		10	SS	69								
222.4			11	SS	85								
9.1	End of Borehole												

RECORD OF BOREHOLE No 4

METRIC

W O 88-11005 LOCATION Sta. 16+358; o/s 14.0m Rt of Hwy 410 4
 DIST 6 HWY 410 BOREHOLE TYPE Cone Test, Hollow-Stem Auger
 DATUM Geodetic DATE 88 12 16
 ORIGINATED BY F.P.
 COMPILED BY F.P.
 CHECKED BY DD

OFFICE REPORT ON SOIL EXPLORATION

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT Y	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100					
240.7	Asphalt Surface													
240.2	Sand (Fill)													
0.5			1	TW	PH		240						22.3	0 41 39 20
			2	TW	PH								20.4	0 34 44 22
			3	SS	21									
			4	SS	16									
237.7	Brown						238							
3.0	Irregular Grey Mixture of Silty Clay Sand and Organics (Fill) Stiff to V. Stiff		5	SS	11									0 14 53 33
			6	SS	21								20.1	
			7	SS	14								19.4	1 15 52 32
234.9			8	SS	22									
5.8	Irregular Mixture of Clayey Silt, Sand and Gravel (Fill) Trace Organics Random Pockets of Silt Brown Very Stiff to Hard		9	SS	23									
			10	SS	30									
			11	SS	27									
			12	SS	30									
			13	SS	34									
227.7							230							
13.0	Sand With Random Zones of Clayey Silt Grey Compact to Dense		14	SS	26									
			15	SS	22									3 52 31 14
223.5			16	SS	34									
17.2	End of Borehole													0 68 26 6

