

**FOUNDATION INVESTIGATION REPORT
TILTED RETAINING WALL PANEL NO. 16, NORTH SIDE OF E-N/S RAMP
HIGHWAY 401 WB COLLECTOR AT YONGE STREET INTERCHANGE
TORONTO, ONTARIO
W.P. 25-98-00**

CONTRACT No: 2002-2022

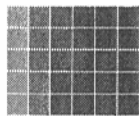
Prepared For:

EARTH TECH CANADA INC.

Prepared by:

SHAHEEN & PEAKER LIMITED

**Project: SPT1071
March 4, 2003**



shaheen & peaker
limited

**20 Meteor Drive
Toronto, Ontario
M9W 1A4**

Tel: (416) 213-1255

Fax: (416) 213-1260

WEB SITE: WWW.SHAHEENPEAKER.CA

Table of Contents

1. INTRODUCTION	1
2. SITE HISTORY	1
3. SITE DESCRIPTION AND GEOLOGY	1
4. METHOD OF INVESTIGATION	2
5. SUMMARIZED SUBSURFACE CONDITIONS	4
5.1 Backfill Behind the Retaining Wall.....	4
5.2 Sandy Silty Fill	5
5.3 Upper Silty Clay	5
5.4 Silty Clay Till	5
5.5 Silty Very Fine Sand	6
5.6 Lower Silty Clay	6
5.7 Groundwater Conditions.....	7

DRAWING NO.

BOREHOLE & TEST PIT LOCATION PLAN

1

APPENDICES

APPENDIX A: RECORD OF BOREHOLE LOG SHEETS & TEST PIT FINDINGS

APPENDIX B: LABORATORY TEST RESULTS

APPENDIX C: SITE PHOTOGRAPHS

APPENDIX D: EXPLANATION OF TERMS USED IN REPORT

**FOUNDATION INVESTIGATION REPORT
TILTED RETAINING WALL PANEL 16, NORTH SIDE OF E-N/S RAMP
HIGHWAY 401 WB COLLECTOR AT YONGE STREET INTERCHANGE
TORONTO, ONTARIO
W.P. 25-98-00**

1. INTRODUCTION

The retaining wall on the north side of the exit ramp to Yonge Street from 401 has tilted at Panel No. 16.

Shaheen & Peaker Limited (S&P) was authorized by Mr. Tak Wong of Earth Tech Canada Inc. to carry out a foundation investigation at the site. The purpose of the investigation was to obtain information at the site by means of boreholes.

The findings of the investigation are presented in this report.

2. SITE HISTORY

The existing retaining wall on the north side of Highway 401 WB Collector exit ramp to Yonge Street consists of individual panels.

Panel 16, along with the rest of the retaining wall was constructed in the mid 1960's. By the year 2001, this segment of the wall, which is approximately 2 m high had moved outward.

Photo No. 1 in Appendix C indicates the displacement of Panel 16 about two years ago. Photo No. 2 shows the present condition of Panel 16.

3. SITE DESCRIPTION AND GEOLOGY

The site is located on the north shoulder of the Yonge Street exit ramp of the westbound collector of Highway 401. The paved shoulder at this location measures approximately 3 m in width and a concrete curb is located between the edge of the paved shoulder and the face of the retaining wall.

This single lane exit ramp contains a grade separation structure, which allows eastbound traffic on Highway 401 to exit, and travel northerly towards Yonge Street. Further beyond this ramp structure the single lane of the exit ramp branches northerly and southerly allowing access to Yonge Street in both directions.

For identification purposes, the tilted retaining wall has been previously numbered 16. Alternatively, the tilted panel wall can be identified as the second panel after the west edge of the green painted noise barriers founded on the north side of this exit ramp.

Private property is located just north of this exit ramp and it is noted that this property is currently under condominium apartment building development.

The pavement elevation along this tilted retaining wall varies between 176.2 m at the west end and 176.0 m at the east end. Elevations vary between 176.8 m and 176.6 m at the top of this wall. The ground surface at the bottom of the retaining wall (north side near private property line) is generally at about Elevation 174.2 m. The exposed portion of the retaining wall is approximately 2 m in height.

The exit ramp site is located to the immediate north of Highway 401 and east of Yonge Street to the east of the Don River Valley in the North York District of the City of Toronto. Published geological information* indicates that the general area is underlain by deep glacial till deposits, the uppermost layer of which is the Wisconsin till sheet. The Wisconsin till is overlain in most places by a thin layer of modified till consisting chiefly of varved-like clay containing pebbles, stones and irregular layers of till. The tills are separated by various thicknesses of stratified clays, silt and sands.

The depth to the surface of the bedrock underlying the site is known to be about 70 m. The bedrock consists of grey Georgian Bay formation. This formation belongs to the Upper Ordovician Period of the Paleozoic Era and is approximately 450 million years old. The shale is interbedded with some limestone, siltstone, sandstone and dolostone layers and seams.

4. METHOD OF INVESTIGATION

The originally planned investigation, as proposed, consisted of drilling and sampling a total of two boreholes one from the top and one from the toe of the existing retaining wall. In order to gain a better understanding of the conditions, however, the number of boreholes was increased, as well as drilling probe holes and digging test pits, as follows:

From the top of the retaining wall	=	4 boreholes
	=	4 probe holes
From the toe of the retaining wall	=	3 boreholes
	=	2 test pits

* 'Pleistocene Geology and Groundwater Resources of the Township of North York, York County', A. K. Watt, 64th Annual Report of the Ontario Department of Mines, 1955.

All the borehole, probe hole and test pit locations are shown on the Borehole and Test Pit Location Plan, Drawing No. 1.

On July 15, 2002, three boreholes (Boreholes 2, 3 and 4) were drilled from the toe of tilted retaining wall, Panel 16. These boreholes were drilled to depths ranging from 5.0 to 6.6 m below the existing ground surface on the low side of the retaining wall. A piezometer was installed in one of these boreholes (i.e. the middle borehole), to enable us to monitor the groundwater level in the borehole without interference from surface water. The following day (July 16) two test pits were dug with the aid of a rubber-tire backhoe to enable us to expose the existing wall footing. Top and bottom elevations of the footing as well as its projection were measured to assess 'as-built' conditions as well as examining the soil immediately underlying the outer edge of the footing. The measured footing elevations at the test pit locations are shown on Drawing No. 1. The test pits were extended to a depth of about 0.3 m below the bottom of the exposed footing at each test pit location.

Because of restrictions for working from the exit ramp, boreholes from the top of the wall had to be drilled approximately four weeks later, on August 11, 2002. At this time, two boreholes were drilled from the top of the exit ramp immediately adjacent to the top panel of the tilted retaining wall. These two boreholes (Boreholes 1 and 5) and those drilled from the toe (Boreholes 2, 3 and 4) were advanced by standard drill rigs (adapted for soil sampling and testing) owned and operated by Groundworks Inc., under the full time supervision of geotechnical engineers from S&P. Sampling in the boreholes was effected continuously or nearly continuously by the Standard Penetration Test Method (SPT) as outlined in ASTM Method D1586. In essence, this consists of freely dropping a 63.5 kg hammer a vertical distance of 76 cm to drive a 51 mm O.D. split-spoon (split-barrel) sampler into the ground. The number of blows required to drive the sampler into the relatively undisturbed ground by a vertical distance of 300 mm is recorded as Standard Penetration Resistance or the N-value of the soil and this gives an indication of the consistency or the compactness condition of the soil deposit.

Boreholes 6 and 7 were advanced with a dynamic ram sounder owned and operated by Sonic Soil Sampling (Ontario) Inc., under the supervision of S&P personnel. In these boreholes, SPT tests were effected continuously (ASTM Method D1586) using a 63.5 kg hammer dropping freely over a vertical distance of 76 cm.

In addition, four probe holes were advanced (P1 through P4) to refusal depths or to anticipated top of footing elevations to gain a better understanding of the width of the wall footing. The equipment for these probe holes were also provided by Sonic Soil Sampling (Ontario) Inc..

The probes (threaded/coupled steel rods) were advanced vertically into the ground using a percussion hammer (Pionjar) and the corresponding depths were measured.

Upon completion, the soil samples were returned to S&P laboratory in Toronto where they were re-examined and laboratory testing was conducted on selected samples. Laboratory testing consisted of natural moisture content, bulk unit weight and Atterberg limits tests and grain size analyses. The results of the laboratory tests are presented on the appropriate Record of Borehole and Test Pit Sheets and also in Appendix B.

All the borehole, probehole and test pit locations were determined in the field by S&P personnel and the ground surface elevations are related to Benchmark BM#2940. The Benchmark is set on a limestone base located at the north wall of the southerly building of the Forest Lawn Mausoleum west of Yonge Street, and directly beneath the center of the first window from the northeast corner. The elevation of the benchmark is Geodetic Elevation 175.44 m.

5. SUMMARIZED SUBSURFACE CONDITIONS

In general, below some fill, the boreholes contacted cohesive soils consisting of silty clay and silty clay till.

Details of the subsurface conditions encountered in boreholes drilled for the investigation are presented on the Record of Borehole Sheets in Appendix A. Test pits results are also given in Appendix A. The individual soil strata encountered in the boreholes drilled for the present investigation are briefly described in the following paragraphs.

5.1 BACKFILL BEHIND THE RETAINING WALL

Boreholes 1, 5, 6 and 7 which were drilled from the ramp (0.8 to 1.5 m from the retaining wall) contacted, below a layer of 150 mm thick asphaltic concrete or concrete, a granular backfill extending to depths ranging from 1.8 to 2.4 m below the ground surface (Elevation 174.1 to 173.7 m). The fill consisted of sand with traces of gravel. The presence of occasional small pockets or lenses of clay was also noted within the fill.

The grain-size distribution of three samples from the granular fill is given in Figure B-1, Appendix B. The results indicate the following grain size distribution:

Gravel:	1-4%
Sand:	91-95%
Silty and Clay:	3-5%

Standard Penetration Tests performed in the deposit yielded N-values ranging from 6 to 24 blows/0.3 m indicating a loose to compact condition. The results suggest that some degree of compaction was applied to the backfill.

Underlying the granular backfill, the boreholes drilled from the ramp (i.e. Boreholes 1, 5, 6 and 7) encountered a layer of cohesive material which was identified as probable fill. It was noted to contain some gravel and organics. Its thickness was found to be 0.6 to 1.2 m in Boreholes 1, 5 and 7 where it extended to Elevations ranging from 173.1 and 172.9 m.

N-values recorded in this material generally ranged from 6 to 10 blows/0.3 m, indicating a firm to stiff consistency.

5.2 SANDY SILTY FILL

Boreholes 2, 3 and 4 drilled from near the toe of the retaining wall contacted a 0.4 to 0.7 m thick layer (extending to Elevation 173.9-173.5 m) of mixed fill material ranging primarily from sandy silt to silty clay and clayey silt. Test Pits A and B, which were dug adjacent to the footing of the wall, also contacted a sandy silt fill with construction debris and occasional topsoil. This basically fine-grained granular (i.e. non-cohesive) material is related to the previous construction activities and the construction including the present rehabilitation of the existing retaining wall and extended to depths ranging from 0.9 to 1.5 m below the ground surface or to Elevation 173.4-172.9 m).

From observations made during digging the test pits, the fill is considered uncompacted.

5.3 UPPER SILTY CLAY

Underlying the fill, an upper silty clay deposit with slight to high organic content was contacted in Boreholes 2 and 4. This material was found to be 0.4 to 0.5 m thick and extends to Elevation 173.3 and 173.5 m in Boreholes 2 and 4, respectively. This is a cohesive material and from recorded N-values of 8 blows/0.3 m its consistency is described as firm to stiff.

5.4 SILTY CLAY TILL

In Boreholes 2, 3 and 4 and Test Pits A and B put down from the toe of the wall and in Boreholes 1, 5 and 7, drilled from the top (back) of the wall, a major deposit of silty clay till was contacted.

This material was contacted at the toe of the wall, at depths ranging from 0.7 to 1.5 m below the ground surface (i.e. at Elevation 173.5-172.9 m) and at 3.0 m depth (Elevation 173.1 and 172.9 m) in Boreholes drilled from the back (top) of the wall.

In Boreholes 2, 3 and 4, the stratum was fully penetrated where it was found to be 2.4 to 3.5 m thick and extended to depths of 3.2 to 4.2 m or to Elevation 171.1-170.0 m.

The grain size distribution of three samples from this deposit is given on Figure B-2, Appendix B. These show the following grain size distribution for this cohesive deposit of glacial origin:

Gravel:	1 - 2%
Sand:	28 - 32%
Silt:	45 - 48%
Clay:	18 - 22%

Atterberg limits tests performed in the laboratory on seven samples gave the following index values (Figure B-3, Appendix B)

Liquid Limit:	22 - 45%
Plastic Limit:	13 - 22%
Plasticity Index:	9 - 23%

These results are characteristic of clayey soils of low to intermediate, but generally low plasticity. The measured natural moisture contents are generally near or below the measured plastic limit values, indicating some degree of over-consolidation.

N-values recorded in this deposit ranged from 8 to in excess of 100 blows/0.3 m. Pocket penetrometer tests performed on the recovered soil samples and in the test pits gave undrained shear strength values which generally ranged from 100 to in excess of 200 kPa, except in Test Pit B, in an approximately 0.1 m thick zone immediately underlying the wet silty very fine sand layer beneath the footing, which yielded values between 25 and 50 kPa. Based on these values, along with visual and tactile examination of the soil, the consistency of the deposit is considered to be generally stiff to very stiff near the top, becoming very stiff to hard with increasing depth. As mentioned before, an exception to this is a firm to stiff zone (approximately 0.1 m thick) in Test Pit B.

Measured bulk unit weights of samples from the deposit range from 21.1 to 22.1 kN/m³.

5.5 SILTY VERY FINE SAND

The presence of a 0.05 m thick wet silty very fine sand material was noted immediately underlying the wall footing in Test Pit B. From probing with a bar, this material appeared to be in a very loose condition.

5.6 LOWER SILTY CLAY

Underlying the silty clay till, all three boreholes drilled from the toe of the wall (i.e. Boreholes 2, 3 and 4) contacted a silty clay to clay deposit at depths of 3.2 to 4.2 m or below Elevations 171.1-170.0 m. This is a laminated material containing very thin silt seams.

The grain size distribution curve of a sample from the deposit is presented in Figure B-4, Appendix B.

As shown in Figure B-5 in Appendix B, the following Atterberg limits values were obtained on a sample from the deposit.

Liquid Limit:	43%
Plastic Limit:	21%
Plasticity Index:	22%
Natural Moisture Content:	20%

These results indicate clayey soils of intermediate plasticity. The measured natural moisture content of the sample is below the measured plastic limit value which suggests an over-consolidated material.

From the recorded N-values which range from 28 to 45 blows/0.3 m, the consistency of this cohesive deposit is described as very stiff to hard.

5.7 GROUNDWATER CONDITIONS

All the boreholes were dry upon their completion, except for Borehole 3 in which a water level was recorded at 4.4 m (Elevation 169.8 m). Due to the clayey (impervious) nature of the soil, however, these observations are unlikely to represent the stabilized groundwater conditions.

In the piezometer installed in Borehole 3, the groundwater level rose to 3.4 m depth or Elevation 170.8 m after the installation and subsequently to 2.3 m (Elevation 171.9 m) about one week and also four weeks after the installation of the piezometer. In this borehole, the color of the soil changed from brown to grey at about Elevation 171 m and therefore, it is likely that at the time of our investigation the groundwater level was generally at about Elevation 172 to 171 m.

It should, however, be pointed out that the groundwater is subject to seasonal fluctuations and in response to major weather events. In addition, it should also be pointed out that the presence of a perched water condition could also occur due to the accumulation of surface water in the more pervious fill and other deposits overlying the clayey soils. Evidence of this was found in the wet silty very fine sand layer immediately beneath the footing in Test Pit B, and also the wet condition of the fill in Borehole 5, below 1.8 m.

Shaheen & Peaker Limited



K. R. Peaker, Ph.D., P.Eng.



Z.S. Ozden, P.Eng.

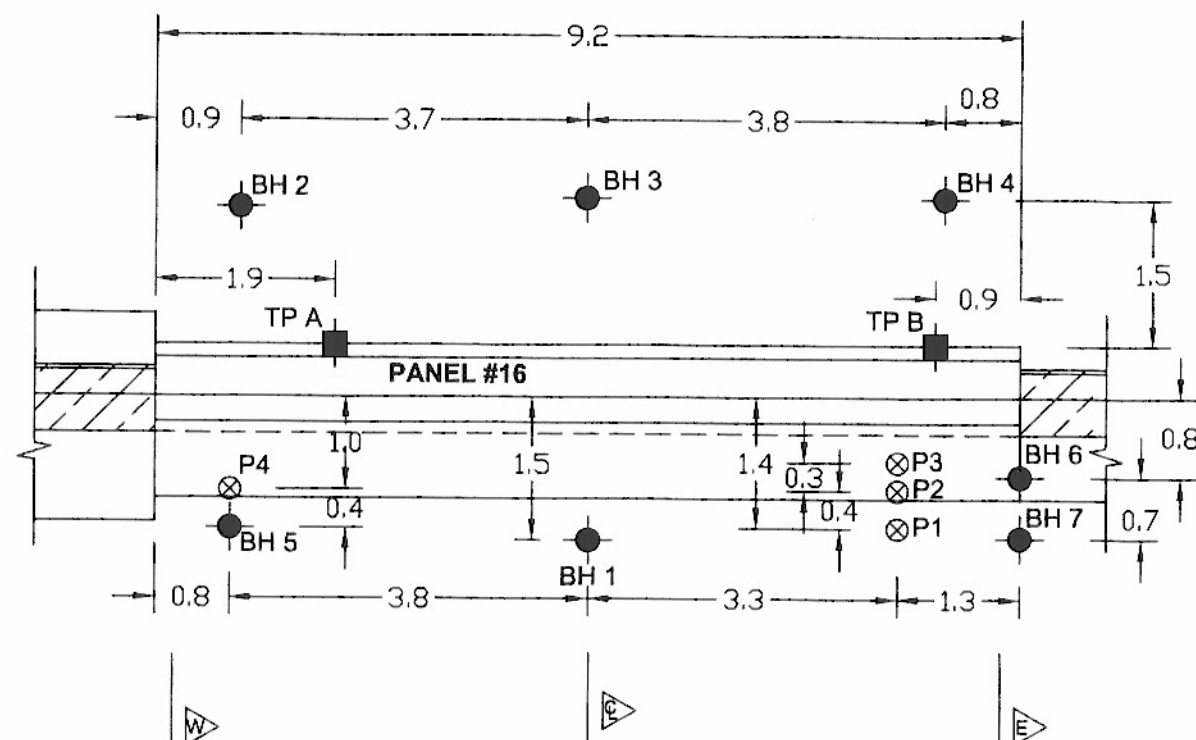
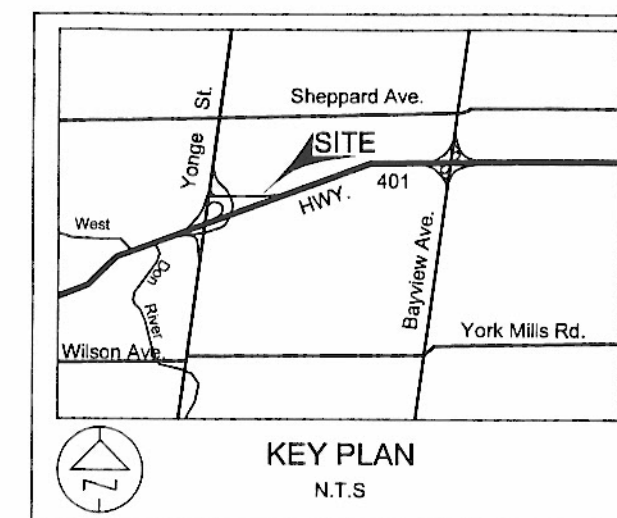


KRP:tr/hd

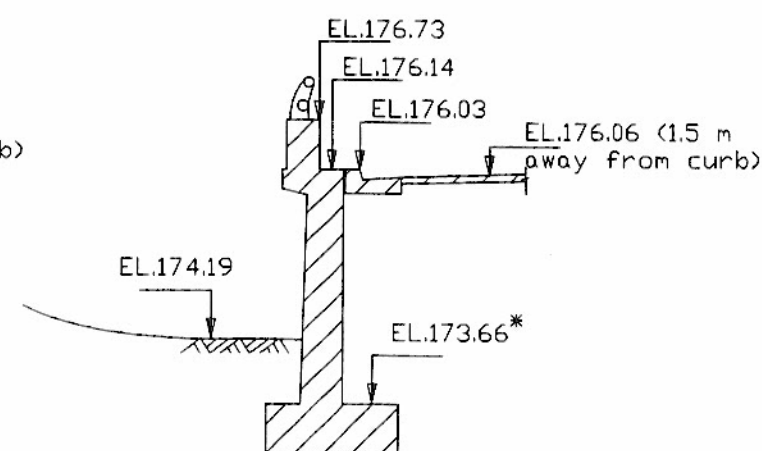
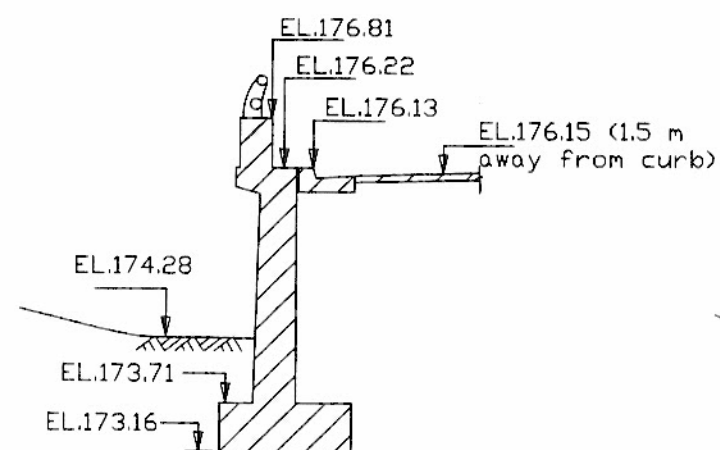
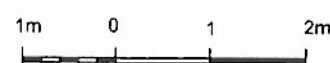
Drawing

BOREHOLE & TESTPIT LOCATION PLAN

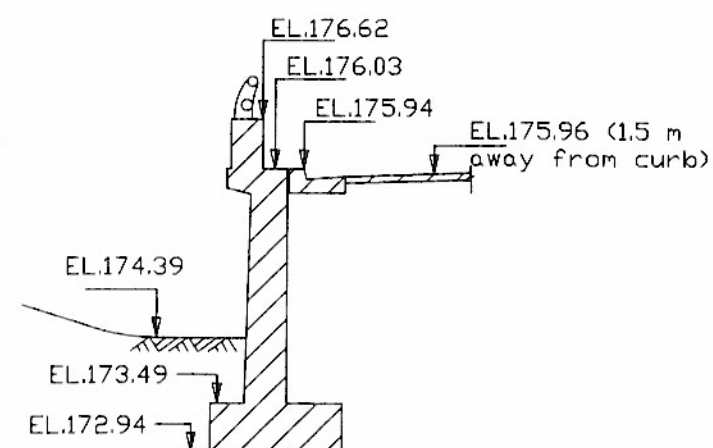
TILTED RETAINING WALL AT YOUNG ST.
AND HWY 401



BOREHOLE & TESTPIT LOCATION PLAN



* Inferred from probe hole refusal



LEGEND	
	Bore Hole
	Probe Hole
	Test Pit
No	ELEVATION (m)
BH1	176.1
BH2	174.3
BH3	174.2
BH4	174.3
BH5	176.1
BH6	175.8
BH7	175.9
P1	175.9
P2	175.9
P3	175.8
P4	176.0
TP A	174.3
TP B	174.4

SCALE	AS SHOWN	DRAWING No. 1	WP 25-98-00
CHECKED BY	ZO	DRAWN BY YL	PROJECT NO.:
DATE	JULY, 2002	SHEET 1 OF 1	SPT1071

Appendix A

Record of Borehole Log Sheets and Test Pit Findings

SPT 1071

RECORD OF BOREHOLE No 1

1 OF 1

METRIC

WP 25-98-00 LOCATION Exit Ramp of 401 West Bound Collector to Yonge Street ORIGINATED BY R.A.
 DIST Central HWY 401 BOREHOLE TYPE Solid Stem Augers COMPILED BY G.T.
 DATUM Geodetic DATE 8/11/2002 CHECKED BY Z.O.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
176.1	Ground Surface													
0.0	150 mm Asphaltic Concrete FILL: sand, trace fine gravel, occasional silty clay pockets, trace organics, trace rootlets below 1.8 m, loose to compact brown, damp grey brown moist		1	SS	24		176							
			2	SS	11		175							
			3	SS	22		174							
173.7			4	SS	9		173							
2.4	PROBABLE FILL: silty clay, trace gravel, some sand, rootlets and some organics, grey brown, damp to moist, stiff		5	SS	6		172							
173.1			6	SS	20									
3.0	trace organics, grey/brown damp brown SILTY CLAY TILL occasional silty fine sand partings, very stiff to hard		7	SS	50/29									
171.1			8	SS	92/23									
5.0	End of borehole * Borehole dry (not stabilized) and hole open to full depth on completion													

SPT 1071

RECORD OF BOREHOLE No 2

1 OF 1

METRIC

WP 25-98-00 LOCATION Exit Ramp of 401 West Bound Collector to Yonge Street ORIGINATED BY Y.L.
DIST Central HWY 401 BOREHOLE TYPE Solid Stem Augers COMPILED BY M.L.
DATUM Geodetic DATE 7/15/2002 CHECKED BY Z.O.

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 kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● POCKET PENETR. x LAB VANE						
174.3	Ground Surface													
0.0	FILL: sandy silt, some topsoil, some clay pockets													
173.8														
0.5	SILTY CLAY high organic content, dark brown to black, stiff		1	SS	8									
173.3														
1.0	darkish grey		2	SS	10									
	some organic content													
	brown		3	SS	29									
	very stiff													
	hard		4	SS	46									
	Heterogeneous mixture of silty clay, some sand and gravel (SILTY CLAY TILL)													
	grey		5	SS	100/15									
			6	SS	100/20									
170.1														
4.2	SILTY CLAY laminated structure, grey, hard													
169.3			7	SS	41									
5.0	End of borehole													
	* Borehole dry (not stabilized) and hole open to 3.8 m on completion													

+ 3, X 3: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

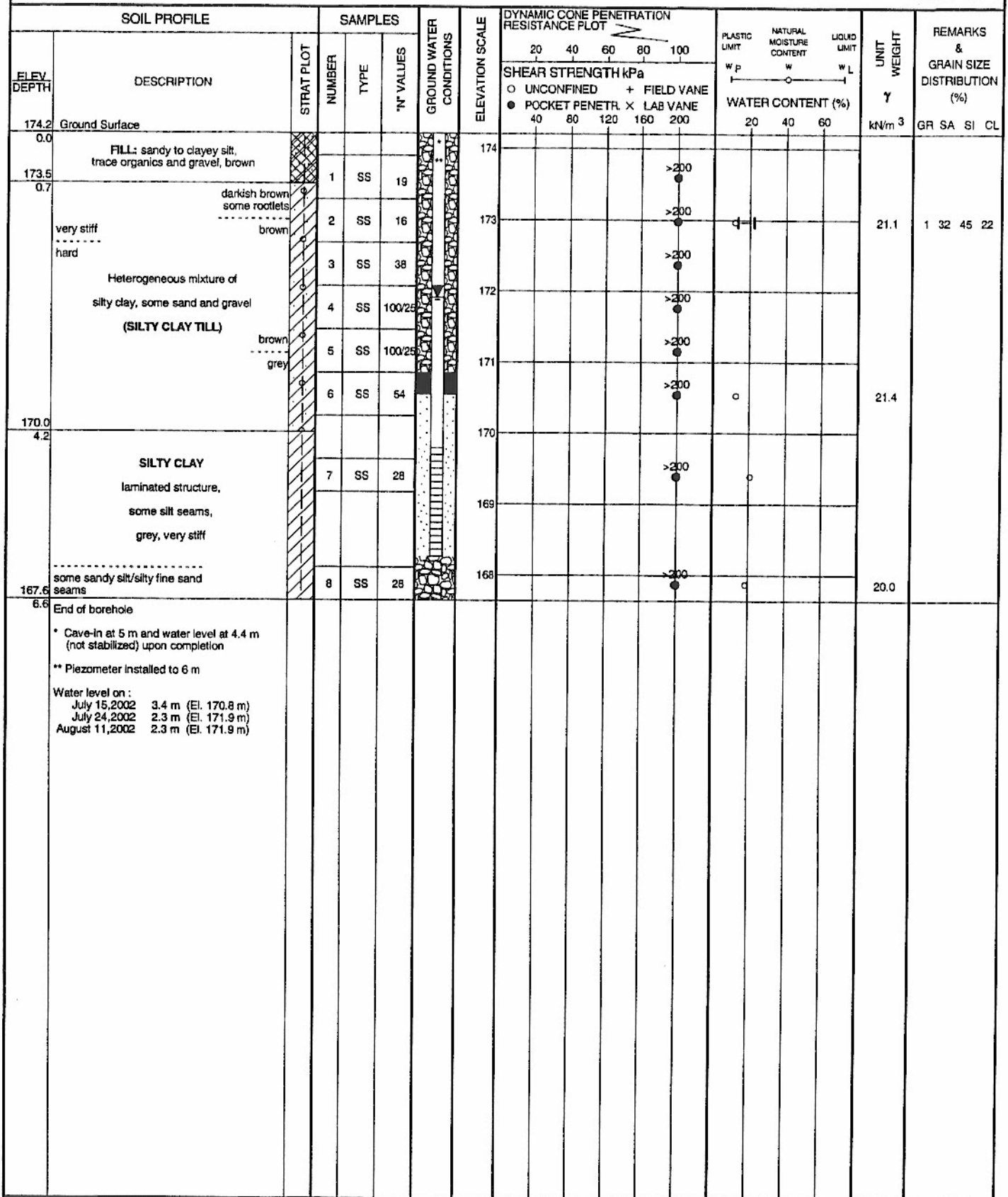
SPT 1071

RECORD OF BOREHOLE No 3

1 OF 1

METRIC

WP 25-98-00 LOCATION Exit Ramp of 401 West Bound Collector to Yonge Street ORIGINATED BY Y.L.
 DIST Central HWY 401 BOREHOLE TYPE Solid Stem Augers COMPILED BY M.L.
 DATUM Geodetic DATE 7/15/2002 CHECKED BY Z.O.



SPT 1071

RECORD OF BOREHOLE No 4

1 OF 1

METRIC

WP 25-98-00 LOCATION Exit Ramp of 401 West Bound Collector to Yonge Street ORIGINATED BY Y.L.
 DIST Central HWY 401 BOREHOLE TYPE Solid Stem Augers COMPILED BY M.L.
 DATUM Geodetic DATE 7/15/2002 CHECKED BY Z.O.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				
								○ UNCONFINED + FIELD VANE ● POCKET PENETR. X LAB VANE				
174.3	Ground Surface						20 40 60 80 100	PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L		
0.0	FILL: silty clay and topsoil, dark brown						40 80 120 160 200	WATER CONTENT (%)				
173.9												
0.4	SILTY CLAY		1	SS	8							
173.5	somewhat organic, dark brown, firm											
0.8												
	Heterogeneous mixture of silty clay, some sand and gravel (SILTY CLAY TILL)		2	SS	20						21.6	
			3	SS	23							
			4	SS	56						21.1	
171.1			5	SS	33							
3.2	SILTY CLAY											
	laminated structure, some silt seams, grey, very stiff to hard		6	SS	29							
169.3	some sandy silt/silty fine sand seams		7	SS	45							
5.0	End of borehole											
	* Borehole dry (not stabilized) and hole open to full depth on completion											

SPT 1071

RECORD OF BOREHOLE No 5

1 OF 1

METRIC

WP 25-98-00 LOCATION Exit Ramp of 401 West Bound Collector to Yonge Street ORIGINATED BY R.A.
DIST Central HWY 401 BOREHOLE TYPE Solid Stem Augers COMPILED BY G.T.
DATUM Geodetic DATE 8/11/2002 CHECKED BY Z.O.

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 kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	*N* VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● POCKET PENET. x LAB VANE						
176.1	Ground Surface													
0.0	150 mm Asphaltic Concrete		1	SS	15	*	176							
	FILL		2	SS	11		175							
	sand, trace fine gravel, occasional silty clay pockets, damp to 1.8 m, moist to wet below, compact		3	SS	19									
174.0			4	SS	6	**	174							
2.1	PROBABLE FILL: silty clay, trace gravel, some sand, brown, damp, firm to stiff		5	SS	50/13									
173.1														
3.0	trace organics and rootlets grey/brown, damp brown, damp to dry		6	SS	14		173							
	SILTY CLAY TILL		7	SS	37		172							
	occasional sandy silt and silt partings, very stiff to hard		8	SS	82/28									
171.4														
4.7	End of borehole * Borehole dry (not stabilized) and hole open to full depth on completion ** Sampler wet at 2.0 m													

SPT 1071

RECORD OF BOREHOLE No 6

1 OF 1

METRIC

WP 25-98-00 LOCATION Exit Ramp of 401 West Bound Collector to Yonge Street ORIGINATED BY R.A.
 DIST Central HWY 401 BOREHOLE TYPE Continuous Penetration with Dynamic Ram Sounder COMPILED BY G.T.
 DATUM Geodetic DATE 8/11/2002 CHECKED BY Z.O.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
175.8	Ground Surface													
0.0	150 mm Concrete													
	FILL													
	sand, trace fine gravel to 2.0 m, brown, damp, loose to compact		1	SS	10		175							2 95 (3)
			2	SS	11									
173.8			3	SS	8		174							
173.7														
2.1	PROBABLE FILL: silty clay, trace gravel, some sand, rootlets, trace organics, brown, damp, firm End of borehole Sampler refusal probably on top of wall footing * Borehole dry (not stabilized) and hole open to full depth on completion													

+³, X³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE




SPT 1071

RECORD OF BOREHOLE No 7

1 OF 1

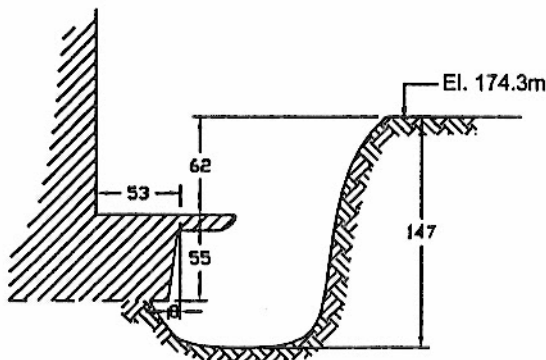
METRIC

WP 25-98-00 LOCATION Exit Ramp of 401 West Bound Collector to Yonge Street ORIGINATED BY R.A.
DIST Central HWY 401 BOREHOLE TYPE Continuous Penetration with Dynamic Ram Sounder COMPILED BY G.T.
DATUM Geodetic DATE 8/11/2002 CHECKED BY Z.O.

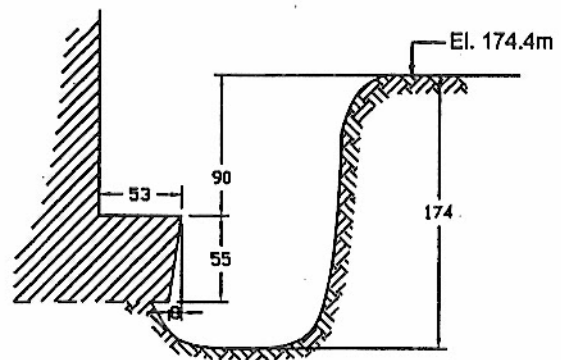
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● POCKET PENET. × LAB VANE							
175.9	Ground Surface							20	40	60	80	100			
0.0	150 mm Asphaltic Concrete FILL sand, trace fine gravel, occasional silty clay pockets, damp to 1.7 m, moist below, compact		1	SS	21										
			2	SS	14										
174.1															
1.8	PROBABLE FILL mixed silty clay, trace gravel, trace organics, trace rootlets, grey brown, moist, stiff		3	SS	8										
			4	SS	10										
172.9															
3.0	SILTY CLAY TILL brown, damp, hard		5	SS	43										
172.4															
3.5	End of borehole * Borehole dry (not stabilized) and hole open to full depth on completion														

TEST PIT FINDINGS

Test Pit Number	Surface Elevation (m)	Soil Profile	Laboratory Testing
A	174.3 Note: Bottom of footing elevation 173.16 m.	0 - 0.9 m (174.3-173.4) Fill, sandy silt with construction debris, brown, dry to damp.	0.08 m below footing (Elev. 173.08 m): Liquid limit = 33%; Plastic limit = 16%; Plasticity index = 17; Natural moisture content = 17.0%. 0.11 m below footing (Elev. 173.05 m): Natural moisture content = 22.5%.
		0.9 - 1.1 m (173.4-173.2) Silty clay, dark brown to black, damp to moist.	
		1.1 - 1.5 m (173.2-172.8) Silty clay Till, brown to grey, moist. Shear strength from pocket penetrometer results 125-150 kPa.	
B	174.4 Note: Bottom of footing elevation 172.94 m.	0 - 1.46 m (174.4-172.94) Fill, sandy silt, brown, dry to damp.	0.03 m below footing (Elev. 172.91m): Natural moisture content = 18.1%*, Nature moisture content = 16.3%*. * Note: Saturated Silty Very Fine Sand. 0.08 m below footing (Elev. 172.86 m): Liquid limit = 24%; Plastic limit = 14%; Plasticity index = 10; Nature moisture content = 15.8%.
		1.46 - 1.51 m (172.94-172.89) Silty very fine sand, traces of clay, wet.	
		1.51 - 1.74 m (172.89-172.66) Silty clay Till, brown, moist. Shear strength from Pocket penetrometer results, 25kPa immediately below the footings, increasing to 150 kPa 0.15 m below the footing.	



TEST PIT A



TEST PIT B

Note: NTS. Dimensions in centimeter

SKETCH DEPICTING TEST PIT EXCAVATIONS

Appendix B

Laboratory Test Results

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY AND SILT

SAND

GRAVEL

GRAIN SIZE IN MICROMETERS

1 3 5 10 30 50 75 #200

Fine

Medium

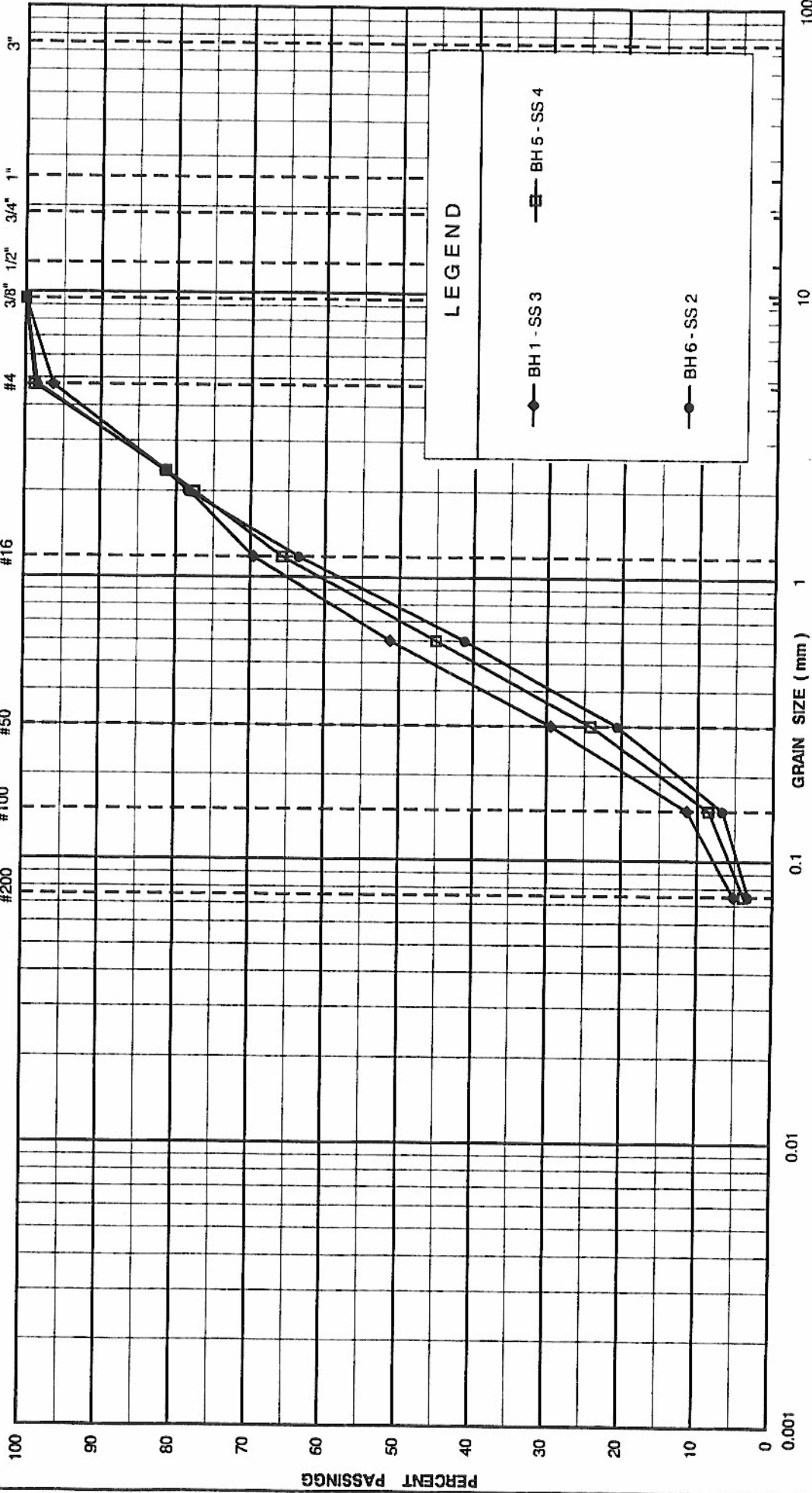
Coarse

Fine

Coarse

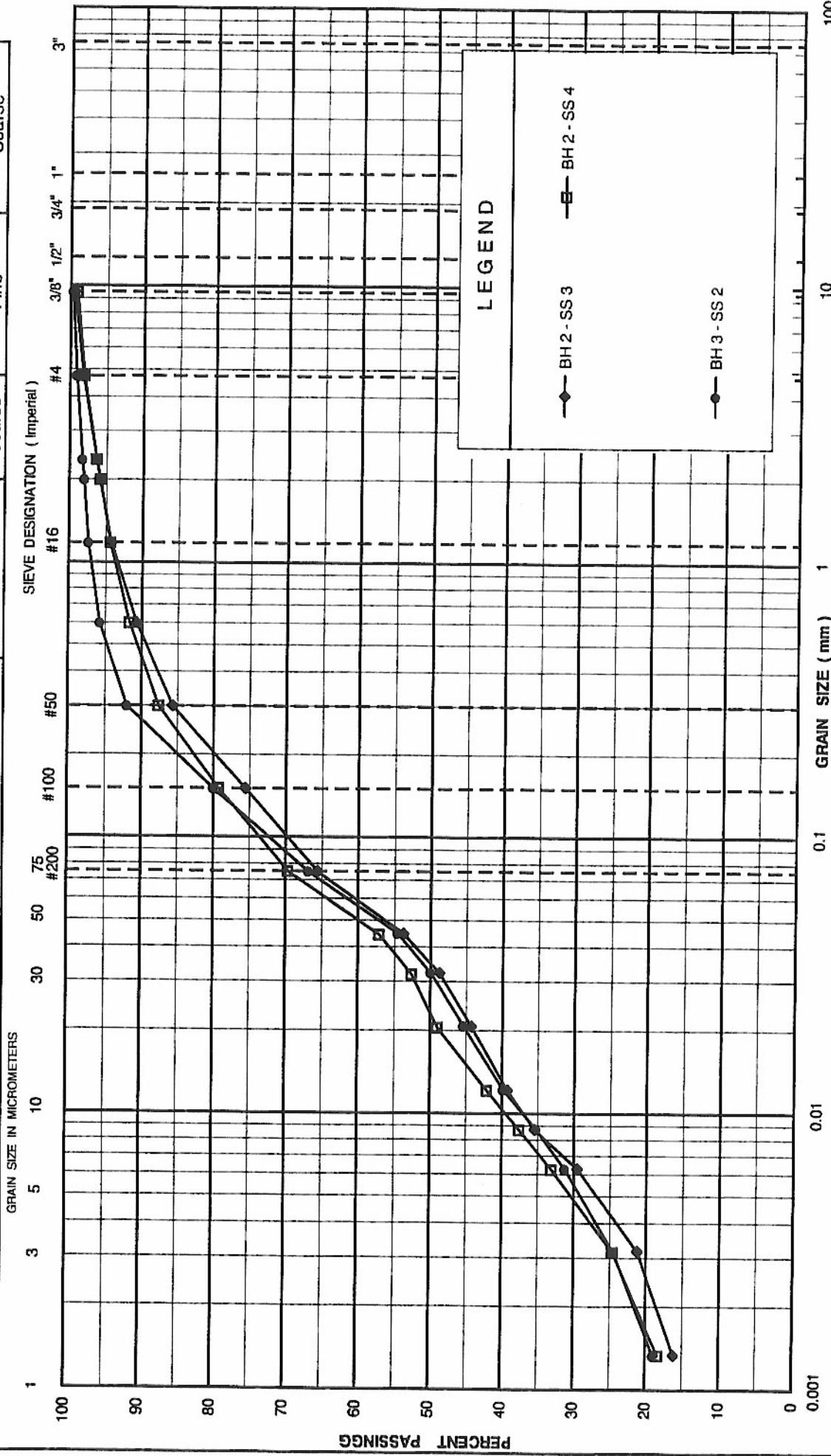
SIEVE DESIGNATION (Imperial)

#4 3/8" 1/2" 3/4" 1" 3"



UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY AND SILT		SAND			GRAVEL		
		Fine	Medium	Coarse	Fine	Coarse	



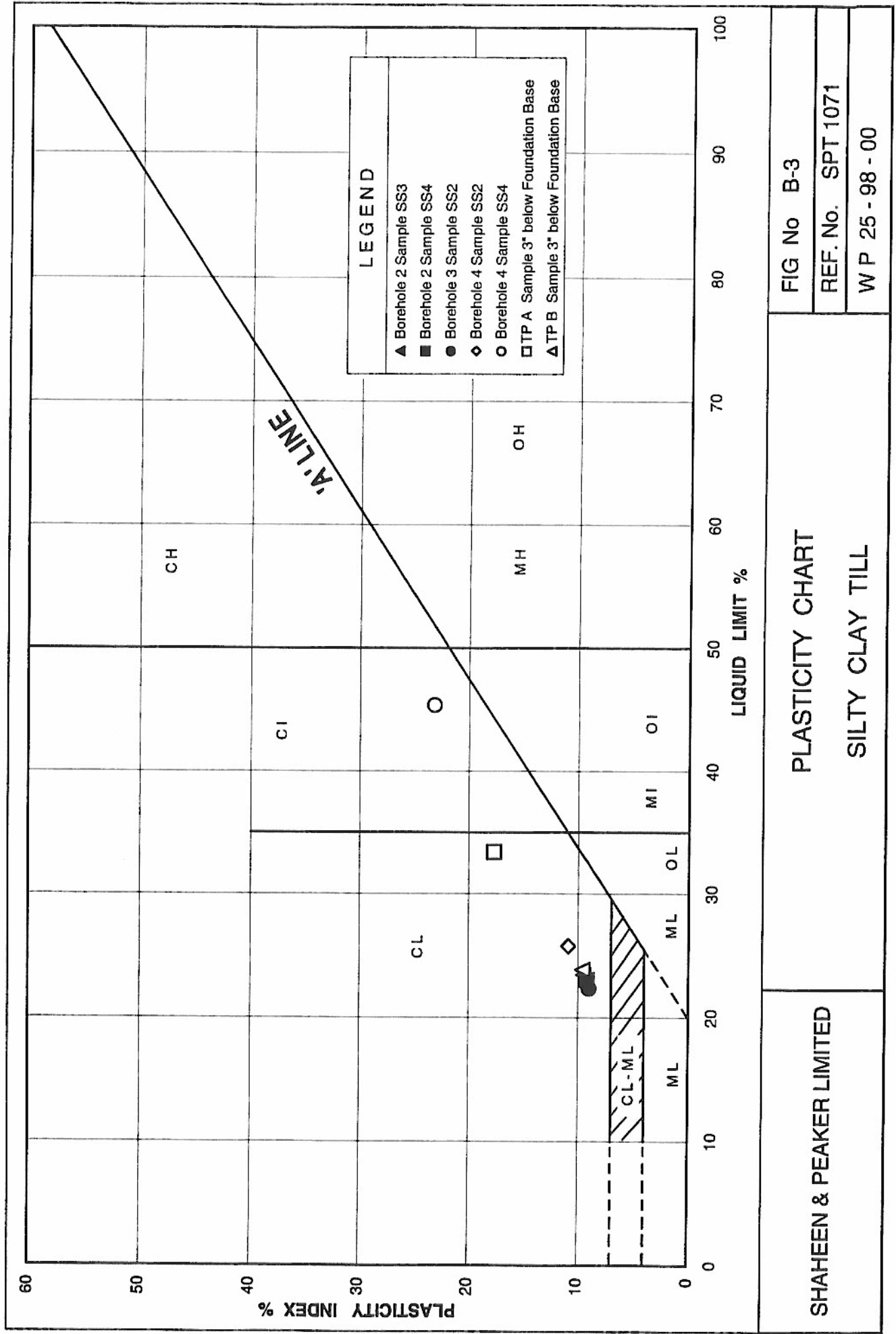
GRAIN SIZE DISTRIBUTION SILTY CLAY TILL

SHAHEEN & PEAKER LIMITED

FIG. No. B-2

REF. No. SPT 1071

W P 25 - 98 - 00



UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY AND SILT		SAND			GRAVEL		
		Fine	Medium	Coarse	Fine	Coarse	

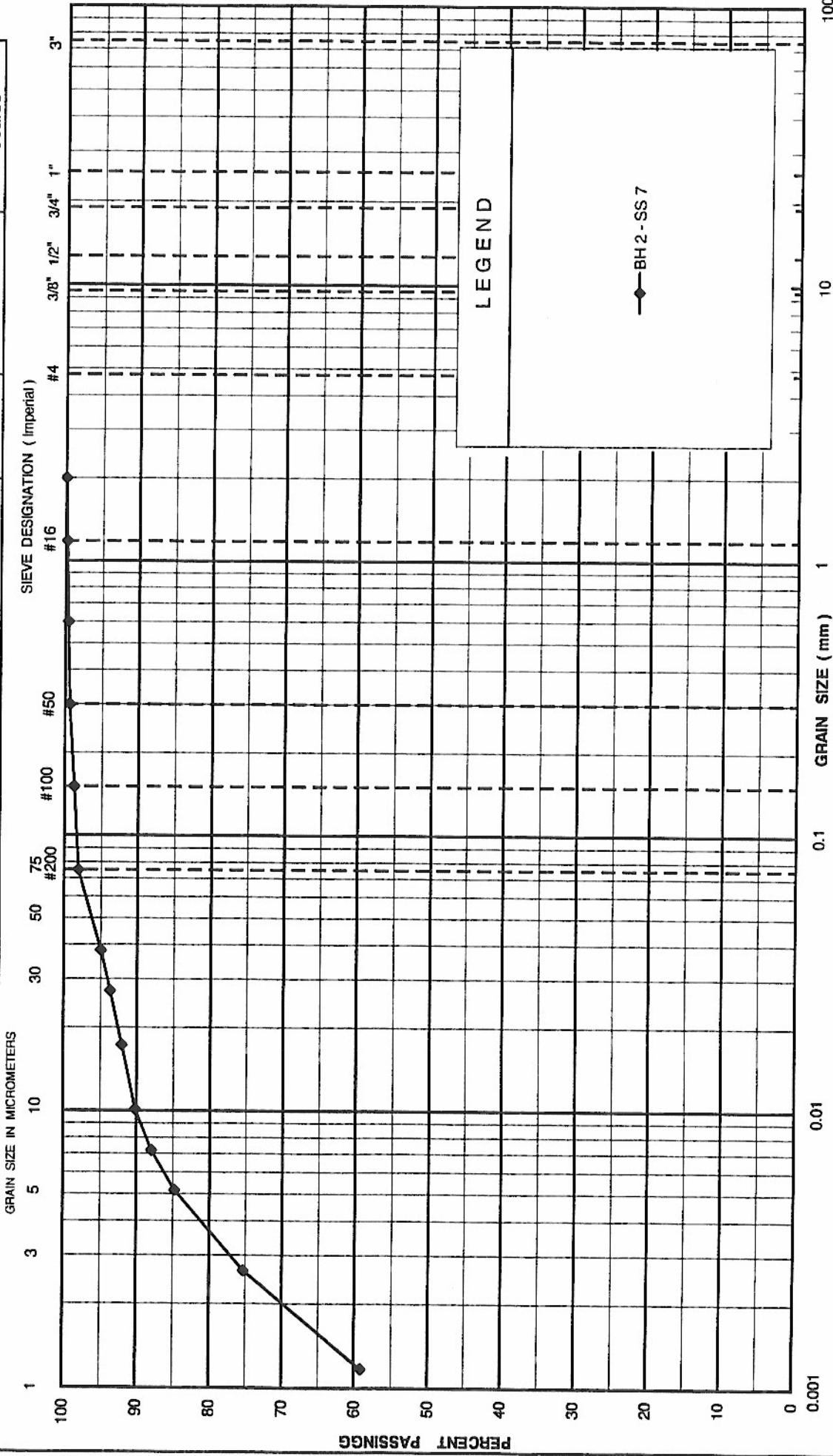


FIG. No. B-4
REF. No. SPT 1071
W P 25 - 98 - 00

SHAHEEN & PEAKER LIMITED

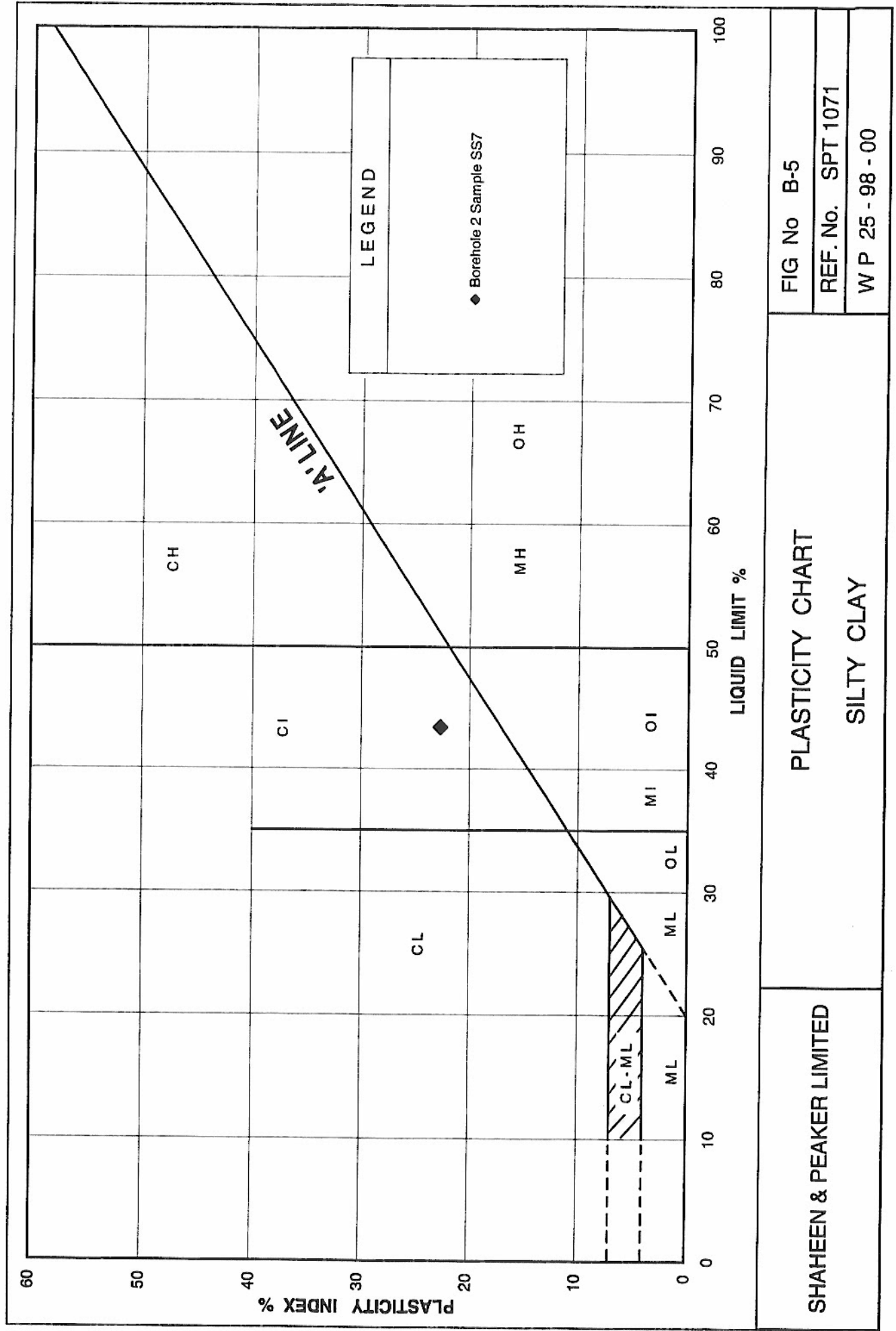


FIG No B-5

REF. No. SPT 1071

W P 25 - 98 - 00

PLASTICITY CHART

SILTY CLAY

SHAHEEN & PEAKER LIMITED

Appendix C

Site Photographs



Photo 1: Displacement of Panel 16 during year 2000



Photo 2: Present condition of Panel 16

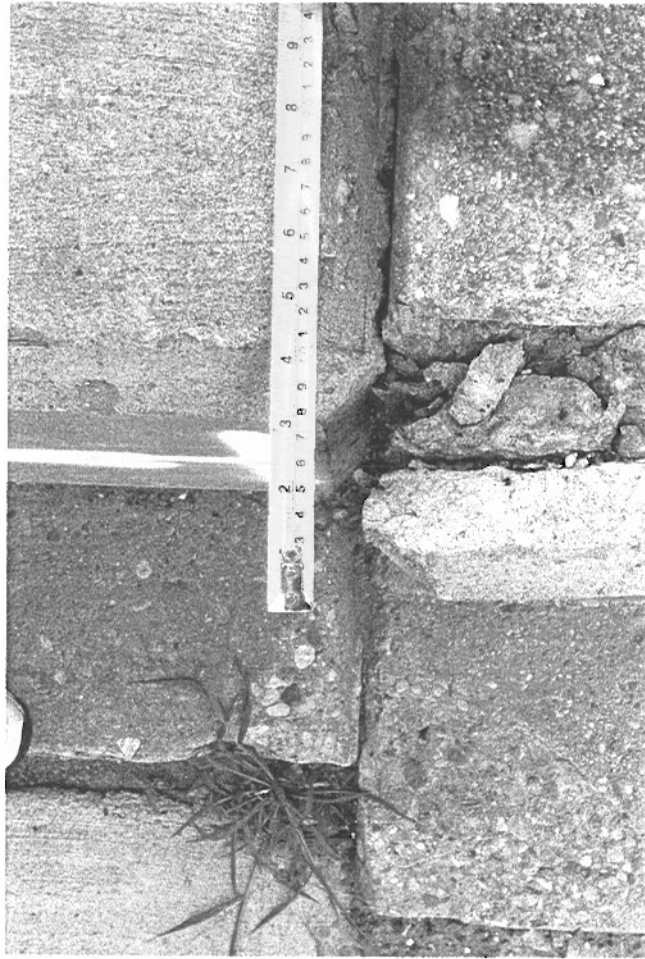


Photo 3

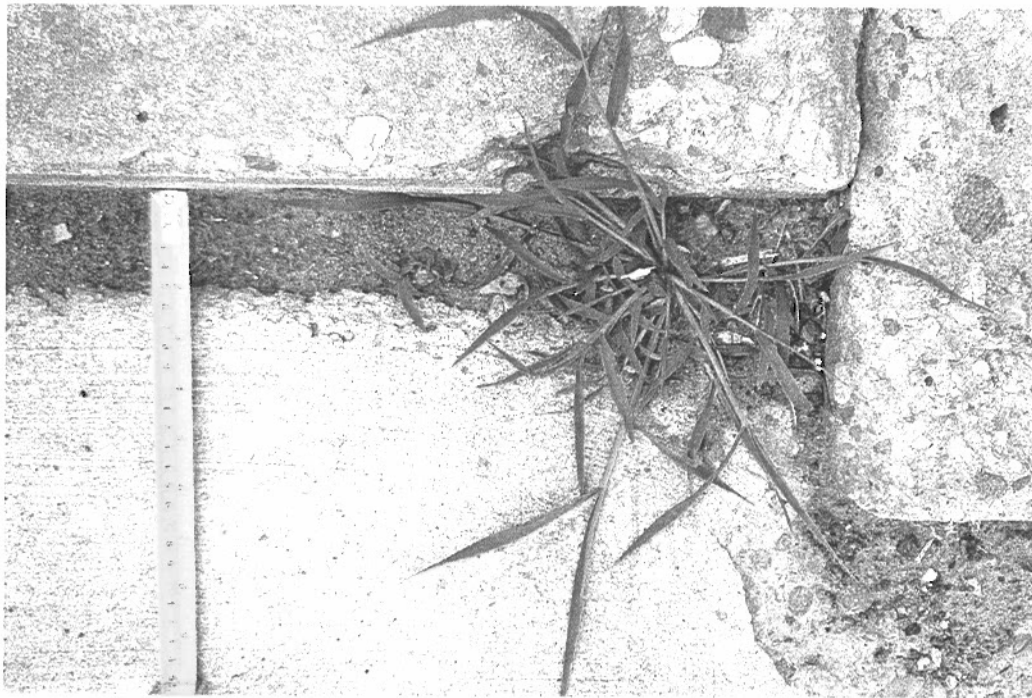


Photo 4

Photo 3 and 4: Easternmost End of Panel 16



Photo 5



Photo 6

Photo 5 and 6: Westernmost End of Panel 16



Photo 7: Test Pit A



Photo 8: Test Pit B

Appendix D

Explanation of Terms Used in Report

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 475J 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 (RQD), 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

SS	SPLIT SPOON	TP	THINWALL PISTON
WS	WASH SAMPLE	OS	OSTERBERG SAMPLE
ST	SLOTTED TUBE SAMPLE	RC	ROCK CORE
BS	BLOCK SAMPLE	PH	TW ADVANCED HYDRAULICALLY
CS	CHUNK SAMPLE	PM	TW ADVANCED MANUALLY
TW	THINWALL OPEN	FS	FOIL SAMPLE

STRESS AND STRAIN

u_w	kPa	PORE WATER PRESSURE
r_u	1	PORE PRESSURE RATIO
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ϵ	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	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_α	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
σ'_{vo}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
ϕ'	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	-°	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_t	1	SENSITIVITY = c_u / τ_r

PHYSICAL PROPERTIES OF SOIL

ρ_s	kg/m ³	DENSITY OF SOLID PARTICLES	e	1, %	VOID RATIO	e_{min}	1, %	VOID RATIO IN DENSEST STATE
γ_s	kN/m ³	UNIT WEIGHT OF SOLID PARTICLES	n	1, %	POROSITY	I_D	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
ρ_w	kg/m ³	DENSITY OF WATER				D	mm	GRAIN DIAMETER
γ_w	kN/m ³	UNIT WEIGHT OF WATER	w	1, %	WATER CONTENT	D_n	mm	n PERCENT - DIAMETER
ρ	kg/m ³	DENSITY OF SOIL	S_r	%	DEGREE OF SATURATION	C_u	1	UNIFORMITY COEFFICIENT
γ	kN/m ³	UNIT WEIGHT OF SOIL	w_L	%	LIQUID LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
ρ_d	kg/m ³	DENSITY OF DRY SOIL	w_p	%	PLASTIC LIMIT	q	m ³ /s	RATE OF DISCHARGE
γ_d	kN/m ³	UNIT WEIGHT OF DRY SOIL	w_s	%	SHRINKAGE LIMIT	v	m/s	DISCHARGE VELOCITY
ρ_{sat}	kg/m ³	DENSITY OF SATURATED SOIL	I_p	%	PLASTICITY INDEX = $(w_L - w_p)$	l	1	HYDRAULIC GRADIENT
γ_{sat}	kN/m ³	UNIT WEIGHT OF SATURATED SOIL	I_L	1	LIQUIDITY INDEX = $(w - w_p) / I_p$	k	m/s	HYDRAULIC CONDUCTIVITY
ρ'	kg/m ³	DENSITY OF SUBMERGED SOIL	I_C	1	CONSISTENCY INDEX = $(w_L - w) / I_p$	j	kN/m ³	SEEPAGE FORCE
γ'	kN/m ³	UNIT WEIGHT OF SUBMERGED SOIL	e_{max}	1, %	VOID RATIO IN LOOSEST STATE			

**FOUNDATION DESIGN REPORT
TILTED RETAINING WALL PANEL NO. 16, NORTH SIDE OF E-N/S RAMP
HIGHWAY 401 WB COLLECTOR AT YONGE STREET INTERCHANGE
TORONTO, ONTARIO
W.P. 25-98-00**

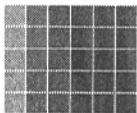
Prepared For:

EARTH TECH CANADA INC.

Prepared by:

SHAHEEN & PEAKER LIMITED

**Project: SPT1071
March 4, 2003**



**shaheen & peaker
limited**

**20 Meteor Drive
Toronto, Ontario
M9W 1A4**

Tel: (416) 213-1255

Fax: (416) 213-1260

WEB SITE: WWW.SHAHEENPEAKER.CA

Table of Contents

6.	DISCUSSION AND RECOMMENDATIONS	9
6.1	General	9
6.2	Fill/Till Contact.....	9
6.3	Construction Issues	10
6.4	Engineering Considerations	11
6.5	The assumptions Used in Overturning Calculations	11
6.5.1	The Groundwater Level	11
6.5.2	The Earth Pressure Coefficient.....	12
6.5.3	Passive Resistance	12
6.5.4	Surcharge	12
6.5.5	The Estimated Safety Factor Against Overturning	12
7.	CONCLUSIONS	12
8.	CLOSURE	13

APPENDICES

APPENDIX E: OVERTURNING CONSIDERATIONS

APPENDIX F: LIMITATIONS OF REPORT

**FOUNDATION DESIGN REPORT
TILTED RETAINING WALL PANEL 16, NORTH SIDE OF E-N/S RAMP
HIGHWAY 401 WB COLLECTOR AT YONGE STREET INTERCHANGE
TORONTO, ONTARIO
W.P. 25-98-00**

6. DISCUSSION AND RECOMMENDATIONS

6.1 GENERAL

The top of pavement/curb elevation at the top of the approximately 9 m long section (Panel No. 16) of the retaining wall is approximately 176.1 m, while the ground elevation at the low (north) side (i.e. toe) of the wall is about 174.3 m, giving a clear retained height of about 2 m. Our visual observations showed that the top of the wall has tilted by about 20 to 24 cm in relation to the adjacent panels. Further details of the wall and its history are given in Sections 2 and 3 of this report.

As shown on the sketches of the test pits in Appendix B, the test pits dug to expose the front of the footing at the low (toe) side showed a slant of 8 cm from the top to the bottom of the wall footing. If the face of the wall was originally constructed vertically straight, this finding is consistent with a tilting pattern (i.e. overturning).

The test pits also indicated a footing projection of about 0.50 m. The presently existing frost cover (i.e. height of the soil above the bottom of the footing at the two test pit locations) was measured 1.12 and 1.45 m in Test Pits A and B, respectively.

The test pit findings also indicate that the fill immediately in front of the footing is of variable quality (i.e. included topsoil, construction debris, etc.) and appeared to be uncompacted (i.e. was not properly engineered). We also noted the presence of buried cable in front of the footing, indicating construction activities and disturbance probably subsequent to the original construction of the footing. From these findings, it can be concluded that while there is generally an adequate frost protection, the fill directly in front of the footing cannot be relied upon to provide adequate passive resistance.

6.2 FILL/TILL CONTACT

The more relevant findings of the subsurface investigation in relation to this study are as follows:

The investigation has shown, below some fill, the presence of a major deposit of glacial till. In most places, the till is overlain a thin layer of upper silty clay. Top portions of the silty clay and/or the silty clay till generally have a slight to high organic content. The test pits,

however, indicated that the wall footing was placed below this organic zone (at least at the two test pit locations). At these two test pit locations, further substantiated by borehole findings, the footing was constructed on the silty clay till. For the purposes of this study, from a geotechnical foundation engineering point of view, the most important consideration is the condition of the soil at the base of the footing and within the major stress zone of the footing (i.e. to about 1 m below the base of the footing).

The test pits and borehole results show that the silty clay till is firm to stiff immediately below the footing, but becomes more competent very rapidly with increasing depth (i.e. within 0.1 to 0.2 m of the founding elevation). These findings indicate that the footing is founded on the firm to very stiff till, becoming very stiff to hard with increasing depth, within the major stress influence zone of the footing. A failure mode due to inadequate soil resistance (i.e. bearing capacity failure, or excessive settlements due to weak soils) can therefore be ruled out. An exception to this is an approximately 50 mm thick layer of very wet silty very fine sand layer found immediately underneath the footing in Test Pit B. This is unlikely to cause tilting movements of the magnitudes noted. Furthermore, the layer was not encountered in Test Pit A location where movements of similar magnitude were noted. The bearing resistances at the base (bottom) of the existing footing ranges from 50 kPa (within the upper several centimeters) to about 300 kPa for the SLS and approximately 1.5 times of these values for ULS. For analysis purposes, the following values can be assigned for the existing footings:

SLS = 150 kPa

ULS = 250 kPa

For new footing construction, a uniform geotechnical resistance of 200 kPa and 320 kPa can be used for SLS and ULS respectively, at a depth of 0.20 m below the existing footing bottom elevation (i.e. to utilize these values the new footing should be placed at a depth of not less than 0.20 m below the existing footing (bottom) elevation.

6.3 CONSTRUCTION ISSUES

During the construction, the base of the footing excavations should be inspected and evaluated prior to pouring the concrete by a geotechnical (foundation) engineer who is familiar with the findings of this project. If the excavation is to be left open for a period of time of more than about four hours or construction foot traffic is anticipated, there may be a requirement for the placement of a 100 mm thick mud (skim) coat of concrete, to prevent disturbance.

No major problems due to groundwater ingress into the footing excavations are anticipated during the construction but allowance should be made to intercept and discharge surface water or water due to a perched groundwater condition. This can be achieved by gravity drainage and pumping from open sump(s).

All excavations, shoring and backfilling should be carried out in conformance with the safety regulations of the Province, as well as the following specifications.

SP 539 01 – Protection Schemes

SP 902 01 – Excavation and Backfilling to Structures

The natural silty clay and silty clay till deposits can be classified as Type 2 soil, while the fills, including the granular road fill materials can be classified as Type 3 soil above groundwater or perched water level and Type 4 soil below (this will largely depend on the weather events at the time of construction). For the fills, depending on the duration of construction and weather conditions, a temporary slope of 1 $\frac{3}{4}$ H:1V may be satisfactory, but this may have to be flattened where conditions warrant. This can be decided by visual inspection. Below the water table or where seepage occurs, the site will have to be dewatered and slopes may be flatter than 2H:1V.

Temporary support may be required to retain the ramp during the construction of the new wall. Since the grade differential is only about 2.5 to 3 m, the contractor may choose to slope the ground rather than shore it for the duration of the construction. If, however, support is necessary, the shoring should be designed so that the lateral movement of any portion of the roadway protection system will not exceed the established criterion for the performance level. In this case, the Performance Level should be 2.

6.4 ENGINEERING CONSIDERATIONS

Panel 16 shows that the movement at the top of the panel is in the direction of the low side of the wall. Reference to Photos 1 and 2 indicate a rotational mode of failure rather than a settlement failure. Field information confirms adequate frost cover, and the test pits indicate that the panel, for the most part is founded on firm to hard silty clay till. With this in mind, the wall was examined for overturning.

Although Panel 16 has moved, it remains stable for most of the time. The analysis for overturning, therefore, considered the most worse possible scenario assuming that only under these circumstances would movement occur, and only as a rare occasion.

6.5 THE ASSUMPTIONS USED IN OVERTURNING CALCULATIONS

6.5.1 THE GROUNDWATER LEVEL

During heavy rainfall, it is assumed that the water level can rise to the road level. This may occur because of surface infiltration, leakage from service lines or groundwater seepage. This rise is assumed to be of very short duration and only occurring during the heaviest of rainfall. The groundwater level is assumed to drop rapidly after the rainfall stops. The weep holes in each panel show signs of water discharge.

The level of the groundwater in the overturning analysis is the most critical of all assumptions.

6.5.2 THE EARTH PRESSURE COEFFICIENT

An earth pressure coefficient $K=0.5$ has been used when assessing the overturning of this panel. A lower value is not warranted based upon the traffic vibrations that continue to increase the value of K from an active, to an at rest condition.

6.5.3 PASSIVE RESISTANCE

The passive resistance on the low side of the wall has been ignored. This fill is loose and will offer little or no resistance for the degree of movement under consideration.

6.5.4 SURCHARGE

Surcharges of 12 kPa for traffic have been included in the calculation, along with values for the curb and roadway.

6.5.5 THE ESTIMATED SAFETY FACTOR AGAINST OVERTURNING

The estimated safety factor against overturning assuming all the most adverse conditions act together is approximately 1.0. The safety factor increases to 1.3 when the groundwater level drops below the retained earth level.

A safety factor of 2.0 can be obtained under the most adverse conditions if the footing width on the low side is increased by 0.5 m.

7. CONCLUSIONS

Our investigation and analyses indicate that the cause of tilting of this segment of the wall is overturning. The movement only occurs sporadically probably during or shortly after very heavy rainfall. There may be a broken service line in the area.

It is recommended that the footing on the toe (low) side of the wall be increased in width by not less than 0.5 m. As mentioned before, the new footing should be founded at least 0.2 m below the existing footing (bottom) level. The following resistances can be utilized for design purposes for footing placed at this elevation.

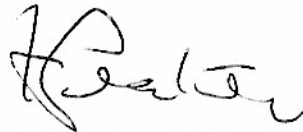
Serviceability Limit States (SLS) = 200 kPa

Ultimate Limit States (ULS) = 320 kPa

8. CLOSURE

The Limitations of Report, as quoted in Appendix F, are an integral part of this report.

Shaheen & Peaker Limited



K. R. Peaker, Ph.D., P.Eng.



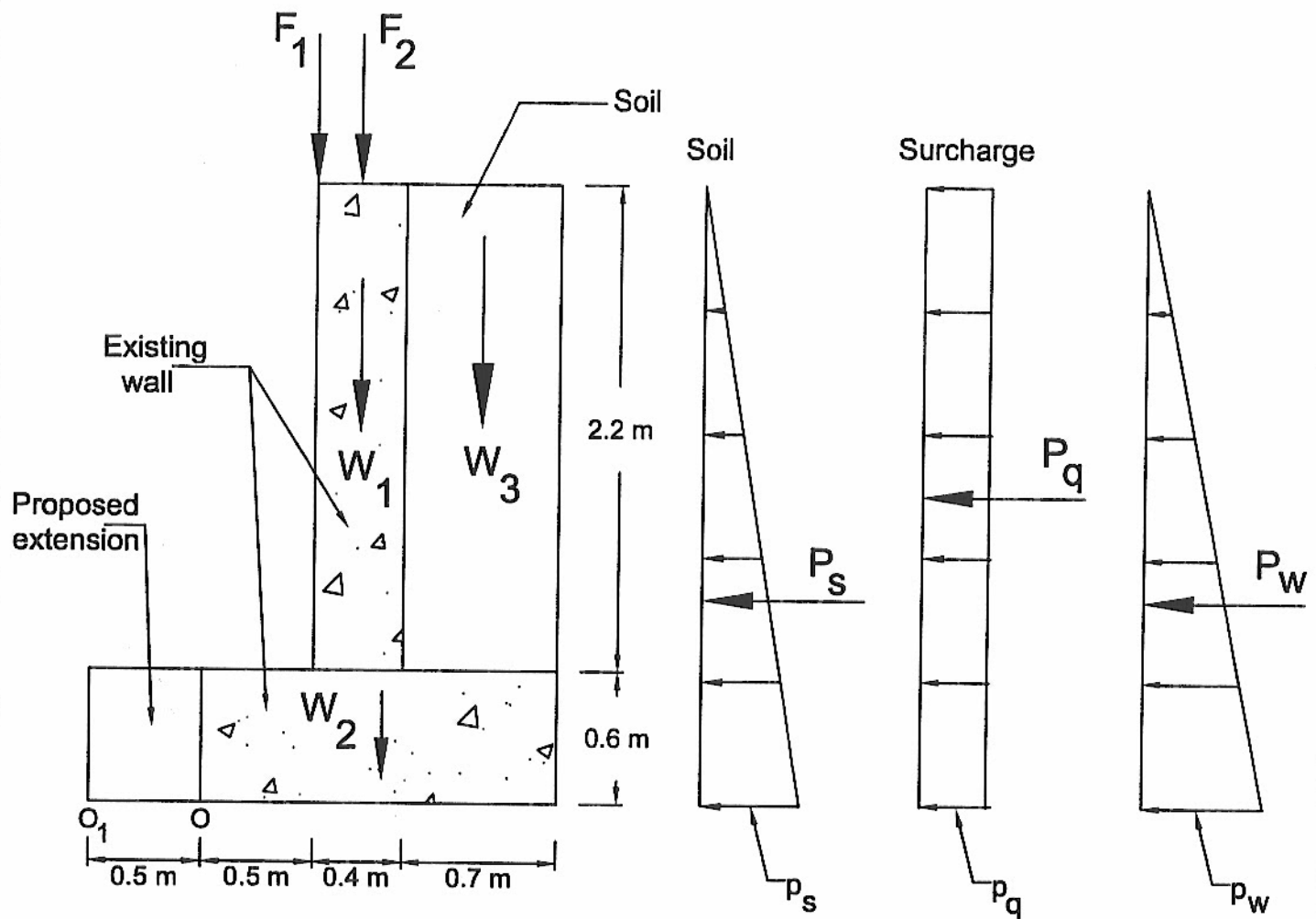
Z.S. Ozden, P.Eng.



KRP:tr/hd

Appendix E

Overturning Considerations



SHAHEEN AND PEAKER LIMITED

CONSULTING GEO-ENVIRONMENTAL ENGINEERS

20 Meteor Drive, Toronto

ONTARIO, M9W 1A4

TEL: (416) 213-1255

FAX: (416) 213-1260

SCALE: NTS

DATE: July/2002

DRAWN BY: GT

APPROVED BY:

TILTED RETAINING WALL

401 & YONGE STREET

Toronto, Ontario

PROJECT NO. SPT 1071

DRAWING NUMBER: E1

SPT1071 – RETAINING WALL STABILITY

1. INTRODUCTION

Analyses of the retaining wall against overturning are carried out. As shown in Drawing E1, the retaining wall is 2.8 m high and the wall footing is 1.6 m wide. The unit weights of wall and soil were 24 and 20 kN/m³, respectively. Lateral earth pressure is assumed to be 0.5 times vertical effective stress ($K=0.5$). A surcharge of $q=12$ kPa is used in the analysis.

2. WALL STABILTY WITH SUBMERGED SOIL

2.1 Existing Wall

Overturning Moment, M:

Water pressure at bottom:	$p_w = 27.5$ kPa
Lateral earth pressure at bottom	$p_s = 14.3$ kPa
Lateral earth pressure due to surcharge:	$p_q = 6$ kPa
Total water pressure:	$P_w = 38.5$ kN
Total lateral earth pressure:	$P_s = 20.0$ kN
Total lateral force due to surcharge:	$P_q = 16.8$ kN

Overturning moment at point O:

$$M = 38.5 \times 2.8/3 + 16.8 \times 2.8/2 + 20.0 \times 2.8/3 = 78.1 \text{ kN-m}$$

Moment of Resistance, Mr:

Wall part 1 weight:	$W1 = 0.4 \times 2.2 \times 24 = 21.1$ kN
Wall footing weight:	$W2 = 1.6 \times 0.6 \times 24 = 23.0$ kN
Soil weight:	$W3 = 0.7 \times 2.2 \times 20 = 30.8$ kN
Weight 1 at wall top:	$F1 = 5.8$ kN
Weight 2 at wall top:	$F2 = 4.8$ kN

Moment of Resistance at point O:

$$\begin{aligned} Mr &= 21.1 \times 0.7 + 23.0 \times 0.8 + 30.8 \times 1.25 + 5.8 \times 0.5 + 4.8 \times 0.7 \\ &= 14.8 + 18.4 + 38.5 + 2.9 + 3.4 \\ &= 78.0 \text{ kN-m} \end{aligned}$$

Factor of Safety against Overturning, FS:

$$FS = Mr/M = 1.00$$

2.2 Extended Wall

If the wall footing is extended 0.5 m outside as shown in Drawing E1, the stability against overturning will be increased.

Overturning Moment at point O_1 , M :

Same as Section 2.1, $M = 78.1 \text{ kN-m}$

Moment of Resistance at point O_1 , M_r :

The values of W_1 , W_2 , W_3 , F_1 and F_2 are not changed.

$$\begin{aligned} M_r &= 21.1 \times (0.5 + 0.7) + 23.0 \times (0.5 + 0.8) + 30.8 \times (0.5 + 1.25) \\ &\quad + 5.8 \times (0.5 + 0.5) + 4.8 \times (0.5 + 0.7) \\ &= 25.3 + 29.9 + 53.9 + 5.8 + 5.8 \\ &= 120.7 \text{ kN-m} \end{aligned}$$

Factor of Safety against Overturning, FS :

$$FS = M_r/M = 1.55$$

3. WALL STABILITY WITHOUT WATER

3.1 Existing Wall

Overturning Moment, M :

Water pressure at bottom:	$p_w = 0$
Lateral earth pressure at bottom	$p_s = 28.0 \text{ kPa}$
Lateral earth pressure due to surcharge:	$p_q = 6 \text{ kPa}$

Total water pressure:	$P_w = 0$
Total lateral earth pressure:	$P_s = 39.2 \text{ kN}$
Total lateral force due to surcharge:	$P_q = 16.8 \text{ kN}$

Overturning moment at point O :

$$M = 16.8 \times 2.8/2 + 39.2 \times 2.8/3 = 60.1 \text{ kN-m}$$

Moment of Resistance, M_r :

Same as in Section 2.1, $M_r = 78.0 \text{ kN-m}$

Factor of Safety against Overturning, FS :

$$FS = M_r/M = 1.30$$

3.2 Extended Wall

If the wall footing is extended 0.5 m outside as shown in Drawing E1, the stability against overturning will be increased.

Overturning Moment at point O_1 :, M :

Same as Section 3.1, $M = 60.1 \text{ kN-m}$

Moment of Resistance at point O_1 :, M_r :

Same as Section 2.2, $M_r = 120.7 \text{ kN-m}$

Factor of Safety against Overturing, FS :

$$FS = M_r/M = 2.01$$

Appendix F

Limitations of Report

LIMITATIONS OF REPORT

The conclusions and recommendations given in this report are based on information determined at the testhole locations. The information contained herein in no way reflects on the environment aspects of the project, unless otherwise stated. Subsurface and groundwater conditions between and beyond the testholes may differ from those encountered at the testhole locations, and conditions may become apparent during construction, which could not be detected or anticipated at the time of the site investigation. The benchmark and elevations used in this report are primarily to establish relative elevation differences between the testhole locations and should not be used for other purposes, such as grading, excavating, planning, development, etc.

The design recommendations given in this report are applicable only to the project described in the text and then only if constructed substantially in accordance with the details stated in this report.

The comments made in this report on potential construction problems and possible methods are intended only for the guidance of the designer. The number of testholes may not be sufficient to determine all the factors that may affect construction methods and costs. For example, the thickness of surficial topsoil or fill layers may vary markedly and unpredictably. The contractors bidding on this project or undertaking the construction should, therefore, make their own interpretation of the factual information presented and draw their own conclusions as to how the subsurface conditions may affect their work. This work has been undertaken in accordance with normally accepted geotechnical engineering practices.

Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. Shaheen & Peaker Limited accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.