

#63-F-81

W.P. #251-63

Hwy. #38

ξ FISH CREEK



Mr. A. M. Toye,  
Bridge Engineer,  
Bridge Division.

Attention: Mr. S. McCombie

Mr. A. G. Stermac,  
Principal Foundation Engr.,  
Foundation Section,  
Materials & Research Division.

September 16, 1963

D.H.C. FOUNDATION INVESTIGATION REPORT --  
Realigned Hwy. #38 (Line 'B') and Fish Creek  
Diversion at Parham, Ont. -- District #8.  
W.J. 63-F-81 -- W.P. 251-63

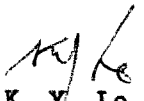
Attached, we are forwarding to you, our detailed  
foundation investigation report on the subsoil conditions  
existing at the above structure site.

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

KYL/MdeF  
Attach.

cc: Messrs. A. M. Toye (2)  
H. A. Tregaskes  
H. D. McMillan  
J. Ford  
E. A. Cash  
J. E. Gruspier  
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Foundations Office  
Gen. Files ✓

  
K. Y. Lo,  
SUPERVISING FOUNDATION ENGR.  
For:  
A. G. Stermac,  
PRINCIPAL FOUNDATION ENGR.

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# FOUNDATION INVESTIGATION

For

Realigned Hwy. #38 (Line 'B') and  
Fish Creek Diversion at Parham, Ont.  
District #8.

W.J. 63-F-81      --      W.P. 251-63.

## 1. INTRODUCTION:

A request dated July 10, 1963, for a foundation investigation at the site of the proposed new bridge at the Fish Creek diversion and relocated Hwy. #38 (Line 'B') crossing, was received from the Bridge Location Section.

In order to determine the soil properties and decide on the type of foundations, an investigation was carried out by this Section. Presented in this report are the results of this investigation, together with the recommendations pertaining to the design of the structure foundations and approach embankments.

## 2. DESCRIPTION OF THE SITE:

The proposed site is about 300 ft. east of existing Hwy. #38 at the south end of the Village of Parham. The existing Hwy. #38 crosses the Fish Creek by means of a concrete culvert founded on bedrock which is well exposed at this location.

The terrain where the investigation was carried out, consists of flat fields surrounded by rock eskers on three sides and open toward the east. It is probably the ancient bed of a dried lake.

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### 3. FIELD AND LABORATORY WORK:

Field work consisted of three boreholes and six dynamic cone penetration tests. In addition, three probings were carried out in order to determine the depth of the overburden on the south bank at the possible alternative crossing. The boring was carried out by means of conventional diamond drilling equipment adapted for soil sampling purposes.

Samples were recovered at required depths by means of a 2" O.D. split-spoon sampler and by 2" I.D. Shelby tube sampler. The dimensions of the split-spoon sampler and the energy used in driving it, conform to the requirements of the Standard Penetration Test. In-situ vane tests were carried out wherever possible, in order to determine the shear strength of the cohesive deposits. Rock core samples were obtained by means of an AXT core barrel.

Detailed logs of each borehole and penetration test are given on the Records of Boreholes at the end of this report. The locations and elevations of all boreholes are shown on Dwg. 63-F-81A appended in this report.

Samples were visually examined and identified in the field as well as laboratory. Tests were carried out in the laboratory on a selection of both disturbed and undisturbed samples to determine:

- i) Natural Moisture Contents
- ii) Bulk Densities
- iii) Grain Size Distributions
- iv) Atterberg Limits
- v) Undrained Shear Strengths

Laboratory and field test results have been summarized and are included under Appendix I of this report.

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4. SUBSOIL CONDITIONS:

4.1) General:

Subsoil at the site generally consists mainly, of fine-grained, granular deposits, followed by sandstone bedrock. A detailed description of various soil types encountered in each boring, is given in Appendix I of this report. The estimated stratigraphy of Dwg. 63-F-81A is based upon this information.

From ground level downwards, the various soil types encountered, are as follows:

4.2) Silty Sand with Organic Matter:

This layer of silty sand with organic matter, was encountered immediately below the topsoil in all the boreholes. It contains traces of organic-silt and decayed wood pieces throughout its entire depth. The thickness of this stratum varied from 9.0 ft. in B.H. #7 to 12.0 ft. in B.H. #6. Standard Penetration resistances or 'N' values of 2 to 6 blows/ft. were obtained in this material. From these values, it is estimated that the relative density varies from very loose to loose.

4.3) Sandy Silt to Silty Sand:

A deposit of sandy silt to silty sand was observed in all the boreholes. The percentage of silt and sand varied somewhat throughout the stratum but, in general, the deposit may be described as sandy silt to silty sand, except at B.H. #1 where the sand content was predominant. The thickness of the stratum ranges from 12.5 ft. to 16.0 ft., and its denseness based on 'N' values of 4 to 11 blows/ft., is loose to compact.

cont'd. /4 ...

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

4.4) Silt with Occasional Layers of Clayey Silt & Silty Clay:

Underlying the deposit of sandy silt to silty sand is a stratum of silt with occasional layers of clayey silt and silty clay. This was observed in all the boreholes between elev. 563.5 and elev. 551.5. The silt is predominantly non-cohesive with 'N' values ranging from 2 to 7 blows/ft. Wherever possible in the cohesive layers of silty clay and clayey silt, Atterberg limits and undrained shear strength tests were carried out. These tests indicate the following results:

|                                |             |
|--------------------------------|-------------|
| Liquid Limit .....             | 32% - 54%   |
| Plastic Limit .....            | 12% - 28%   |
| Moisture Content .....         | 29% - 31%   |
| Undrained Shear Strength ..... | 1400 p.s.f. |

4.5) Silty Sand:

A further deposit of silty sand underlies the stratum of silt with occasional layers of silty clay and clayey silt. The lower boundary varies from elev. 540.0 to elev. 528.4, where the bedrock was contacted. The thickness of the stratum ranges from 12 ft. in B.H. #7 to 23 ft. in B.H. #1. Occasional traces of gravel were also observed in samples from this stratum. Standard penetration resistances in this deposit ranged from 32 to in excess of 100 blows/ft., generally increasing with depth. From these values, it is estimated that the relative density varies from dense to very dense.

cont'd. /5 ...



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

4.6) Bedrock:

Sound sandstone bedrock was recovered by drilling 5 ft. of rock core in B.H. #1, where as in B.H. #7, the bedrock contact was established by driving BX casing to refusal. The contact with bedrock was established between elev. 540.0 and elev. 528.4.

5. GROUND WATER CONDITIONS:

No attempt was made to establish an accurate ground water level by means of piezometers. Observations carried out during the time of the field investigation, indicated that the ground water level was approximately 3.5 ft. below the natural ground. The exact water levels observed at the time of investigation, are shown in the borehole logs (Appendix I).

The water level in the creek during the time of investigation, was at elev. 586.0.

6. DISCUSSION & RECOMMENDATIONS:

It is proposed to construct a single-span structure where the relocated Hwy. #38 (Line 'B') crosses the proposed Fish Creek diversion.

Subsoil at the site consists mainly of 49 ft. to 60 ft. of loose to very dense fine-grained granular deposits followed by bedrock.

6.1) Structure Foundations:

The strength and compressibility of the very loose to compact sandy silt to silty sand is such that very low safe bearing

cont'd. /6 ...

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

6.1) Structure Foundations: (cont'd.) ...

loads will have to be used. Therefore, it is recommended that the structure be supported on end-bearing piles driven to practical refusal to bedrock. For example, for a 12 BP 73 steel 'H' piles driven to bedrock, a safe design load of 70 tons/pile may be used for design purposes.

6.2) Approaches:

At the proposed structure location, the finished grade of the approach fills will be at approx. elev. 597.0. This requires construction of 8.0 ft. high fills. Because of the sandy nature of the subsoil, no approach fill stability problems are anticipated for the standard 2:1 side slopes.

6.3) Creek Diversion:

In order to establish whether bedrock exists above elevation 575.0, three dynamic cone penetration tests (B.H.'s #3, #4, #5) were carried out at the proposed creek diversion. These revealed that the bedrock is well below elev. 575.0 and therefore, no rock excavation will be required for channel excavation for the stream diversion.

No stability problems are anticipated for any excavation using standard 2:1 side slopes for the proposed creek diversion.

6.4) Alternative Scheme:

During the investigation, bedrock outcrops were observed to be present on the north bank of the river at several places between the existing structure and the proposed line. A site visit was

cont'd. /7 ...

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

6.4) Alternative Scheme: (cont'd.) ...

arranged by this Section at which were present Messrs. A. Watt, Bridge Location Section, J. E. Gruspier, Soils Section, L. Shore, Functional Planning Section, and M. Devata, Foundation Section. At this time, a tentative geometrically acceptable line was established 92 ft. west of the existing bridge. This (shown on Dwg. 63-F-81A), passes through the rock outcrops on the north bank, and where it intersects the south bank, three probes showed the bedrock to be quite shallow (4.5' - 12'). In view of the foregoing, it is suggested that a more economical structure can be built with the footings founded directly on bedrock. This latter possibility should be explored further.

7. SUMMARY:

Subsoil at the site consists mainly of fine-grained granular deposits having a very loose to very dense relative density, followed by sandstone bedrock. Maximum and minimum depths to bedrock were observed to be 49 ft. and 60 ft., respectively.

A single-span structure is proposed where the relocated Hwy. #38 (Line 'B') crosses the proposed Fish Creek diversion.

The structure can be supported on end-bearing steel 'H' piles driven to bedrock. A safe design load of 70 tons/pile may be used for design purposes for 12 BP 73 steel 'H' piles.

Approach fill stability problems are not anticipated for the standard 2:1 side slopes.

cont'd. /8 ...

7. SUMMARY: (cont'd.) ...

No stability problems are anticipated for the proposed creek diversion provided the standard 2:1 side slopes are adopted for cut sections.

An alternative line where the footings can be founded directly on bedrock, resulting in a more economical structure, is discussed under Section 6.4.

8. MISCELLANEOUS:

The field work, performed during the period from July 16/63 to July 23/63, together with the preparation of this report, was undertaken by Mr. V. Korlu, Project Foundation Engineer. The investigation was carried out under the general supervision of Mr. M. Devata who reviewed this report.

Equipment was owned by Dominion Soil Investigation, Ltd.

September 1963

APPENDIX I.

| SOIL PROFILE   |  |            | SAMPLES     |      |              | DYNAMIC PENETRATION RESISTANCE<br>BLOWS / FOOT | LIQUID LIMIT — %L<br>PLASTIC LIMIT — %P<br>WATER CONTENT — %w | BULK DENSITY<br>P.C.F. | REMARKS |
|----------------|--|------------|-------------|------|--------------|--|---|------------------------|---------|
| ELEV.<br>DEPTH | DESCRIPTION  | STRAT PLOT | NUMBER      | TYPE | BLOWS / FOOT | SHEAR STRENGTH P.S.F.                          | %<br>10 20 30   |                        |         |
| 588.5          | Groundlevel  |            |             |      |              |  |   |                        |         |
| C.O            | Topsoil  |            |             |      |              |  |   |                        |         |
| 585.0          | G.W.   |            |             |      |              |  |   |                        |         |
| 3.5            | Silty sand with organic matter.                            |            | 1           | SS   | 6            |  |   |                        |         |
| 577.0          | Loose  |            | 2           | SS   | 5            |  |   |                        |         |
| 11.5           | Silty sand loose to compact.                               |            | 3           | SS   | 7            |  |   |                        |         |
|                |  |            | 4           | SS   | 11           |  |   |                        |         |
| 563.5          |  |            | 5 TO Pushed |      |              |  |   |                        |         |
| 25.0           | Silt wit. occasional layers of clayey silt and silty clay. |            | 5A          | SS   | 8            |  |   | 119.0                  |         |
|                |  |            | 6           | SS   | 7            |  |   |                        |         |
| 551.5          |  |            |             |      |              |  |   |                        |         |
| 37.0           | Silty sand.  |            |             |      |              |  |   |                        |         |
|                | Dense to very dense.                                       |            | 7           | SS   | 32           |  |   |                        |         |
|                |  |            | 8           | SS   | 37           |  |   |                        |         |
|                |  |            | 9           | SS   | 57           |  |   |                        |         |
| 528.4          |  |            |             |      |              |  |   |                        |         |
| 60.0           | Bedrock  |            | 10          | SS   | >100         |  |   |                        |         |
| 523.4          | (Sandstone)  |            |             |      |              |  |   |                        |         |
| )              | End of borehole.   |            |             |      |              |  |   |                        |         |

FOUNDATION SECTION

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DEPARTMENT OF HIGHWAYS - ONTARIO  
MATERIALS & RESEARCH DIVISION

## RECORD OF BOREHOLE NO. 4

## FOUNDATION SECTION

JOB 63-F-81 LOCATION Hwy. 38 crossing Fish Creek at Parham 529/23 (13' Rt.) ORIGINATED BY V.K.  
W.P. 251-63 BORING DATE July 18, 1963 COMPILED BY V.K.  
DATUM Geodetic BOREHOLE TYPE Dynamic Cone Penetration Test. CHECKED BY M.D.

| SOIL PROFILE   |                          |             | SAMPLES |      | DYNAMIC PENETRATION RESISTANCE |            | LIQUID LIMIT — $w_L$  |  | BULK<br>DENSITY<br>$\gamma$<br>P.C.F. | REMARKS |                       |  |
|----------------|--------------------------|-------------|---------|------|--------------------------------|------------|-----------------------|--|---------------------------------------|---------|-----------------------|--|
| ELEV.<br>DEPTH | DESCRIPTION              | STRAT. PLOT | NUMBER  | TYPE | BLOWS / FOOT                   | ELEV SCALE | BLOWS / FOOT          |  |                                       |         | PLASTIC LIMIT — $w_p$ |  |
|                |                          |             |         |      |                                |            | SHEAR STRENGTH P.S.F. |  |                                       |         | WATER CONTENT — $w$   |  |
|                |                          |             |         |      |                                |            |                       |  |                                       |         | WATER CONTENT %       |  |
| 588.5          | Groundlevel              |             |         |      |                                | 590        |                       |  |                                       |         |                       |  |
| 0.0            |                          |             |         |      |                                | 580        |                       |  |                                       |         |                       |  |
|                |                          |             |         |      |                                | 570        |                       |  |                                       |         |                       |  |
|                |                          |             |         |      |                                | 560        |                       |  |                                       |         |                       |  |
| 558.5          | End of cone Penetration. |             |         |      |                                | 550        |                       |  |                                       |         |                       |  |
| 30.0           |                          |             |         |      |                                | 540        |                       |  |                                       |         |                       |  |

RECORD OF BOREHOLE NO. 5

JOB 63-F-81 LOCATION Hwy. 38 crossing Fish Creek at Parham 528+95 (45' Lt.) ORIGINATED BY V.K.  
W P 251-63 BORING DATE July 22, 1963 COMPILED BY V.K.  
DATUM Geodetic BOREHOLE TYPE Dynamic Cone Penetration Test. CHECKED BY M.D.

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DEPARTMENT OF HIGHWAYS - ONTARIO  
MATERIALS & RESEARCH DIVISION

## RECORD OF BOREHOLE NO. 6

FOUNDATION SECTION

JOB 63-F-81 LOCATION Hwy. 38 crossing Fish Creek at Parham 528+50 (14' Rt.) ORIGINATED BY V.E.  
 W.P. 251-63 BORING DATE July 22, 1963 COMPILED BY V.K.  
 DATUM Geodetic BOREHOLE TYPE Wash boring using NX or BX Casing CHECKED BY H.D.



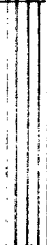


| SOIL PROFILE |  | SAMPLES    |        | DYNAMIC PENETRATION RESISTANCE |                       | LIQUID LIMIT — WL |                 | BULK DENSITY<br>P.C.F. | REMARKS |
|--------------|--|------------|--------|--------------------------------|-----------------------|-------------------|-----------------|------------------------|---------|
| ELEV. DEPTH  | DESCRIPTION  | STRAT. PLT | NUMBER | TYPE                           | BLOWS / FOOT          | ELEV. SCALE       | BLOWS / FOOT    |                        |         |
|              |  |            |        |                                | SHEAR STRENGTH P.S.F. |                   | WATER CONTENT % |                        |         |
|              |  |            |        |                                |                       |                   |                 |                        |         |
| 589.0        | Groundlevel  |            |        |                                |                       | 590               |                 |                        |         |
| 0.0          | Topsoil  |            |        |                                |                       |                   |                 |                        |         |
| 585.5        | G.W.   |            |        |                                |                       |                   |                 |                        |         |
| 3.5          | Silty sand with organic matter (Loose)                     |            | 1      | SS                             | 2                     |                   |                 |                        |         |
|              |  |            | 2      | SS                             | 5                     | 530               |                 |                        |         |
| 577.0        | Sandy Silt (Loose)   |            | 3      | SS                             | 4                     |                   |                 |                        |         |
| 12.0         |  |            | 4      | SS                             | 4                     | 570               |                 |                        |         |
| 564.5        | Silt with occasional layers of clayey silt and silty clay. |            | 5      | T.O.                           | Pushed                |                   |                 |                        |         |
| 24.5         |  |            | 6      | T.O.                           | Pushed                | 560               |                 |                        |         |
|              |  |            | 6A     | SS                             | 2                     |                   |                 |                        |         |
| 554.0        | End of borehole due to breaking of the casing.             |            |        |                                |                       | 550               |                 |                        |         |
| 35.0         |  |            |        |                                |                       |                   |                 |                        |         |
| 544.0        |  |            |        |                                |                       | 540               |                 |                        |         |
| 45.0         |  |            |        |                                |                       | 530               |                 |                        |         |

DEPARTMENT OF HIGHWAYS - ONTARIO  
MATERIALS & RESEARCH DIVISION

# RECORD OF BOREHOLE NO. 7

FOUNDATION SECTION

JOB 63-F-81 LOCATION Hwy. 38 crossing Fish Creek at Parham 528<sup>th</sup> 14' Rt.) ORIGINATED BY V.K.  
W.P. 251-63 BORING DATE July 23, 1963 COMPILED BY V.K.  
DATUM Geodetic BOREHOLE TYPE Wash boring using BX or NX Casing. CHECKED BY M.D.

| SOIL PROFILE   |  |   | SAMPLES |      |              | DYNAMIC PENETRATION RESISTANCE |                       |  | LIQUID LIMIT — WL<br>PLASTIC LIMIT — WP<br>WATER CONTENT — W |                                |  | BULK<br>DENSITY<br>P.C.F. | REMARKS |
|----------------|--|---|---------|------|--------------|--------------------------------|-----------------------|--|--|--------------------------------|--|---------------------------|---------|
| ELEV.<br>DEPTH | DESCRIPTION  | STRAT. PLOT   | NUMBER  | TYPE | BLOWS / FOOT | ELEV. SCALE                    | SHEAR STRENGTH P.S.F. |  |  | Wp — W — WL<br>WATER CONTENT % |  |                           |         |
| 589.0          | Groundlevel  |   |         |      |              | 590                            |                       |  |  |                                |  |                           |         |
| 0.0            | Topsoil  |    |         |      |              |                                |                       |  |  |                                |  |                           |         |
| 585.5          | G.W.   |   |         |      |              |                                |                       |  |  |                                |  |                           |         |
| 3.5            | Silty sand with organic matter.                            |    |         |      |              |                                |                       |  |  |                                |  |                           |         |
| 580.0          |  |   |         |      |              | 580                            |                       |  |  |                                |  |                           |         |
| 9.0            | Sandy silt.  |   |         |      |              |                                |                       |  |  |                                |  |                           |         |
| 564.0          |  |   |         |      |              |                                |                       |  |  |                                |  |                           |         |
| 25.0           | Silt with occasional layers of clayey silt and silty clay. |  |         |      |              | 560                            |                       |  |  |                                |  |                           |         |
| 552.0          |  |   |         |      |              |                                |                       |  |  |                                |  |                           |         |
| 37.0           | Silty sand.  |  |         |      |              | 550                            |                       |  |  |                                |  |                           |         |
| 540.0          |  |   |         |      |              | 540                            |                       |  |  |                                |  |                           |         |
| 49.0           | End of borehole<br>Probable Bedrock.                       |   |         |      |              | 530                            |                       |  |  |                                |  |                           |         |

## ABBREVIATIONS USED IN THIS REPORT

### PENETRATION RESISTANCE

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

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

### DESCRIPTION OF SOIL

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

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

### TYPE OF SAMPLE

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

### SOIL TESTS

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

# ABBREVIATIONS USED IN THIS REPORT

## SOIL PROPERTIES

|            |   |
|------------|---|
| $\gamma$   | UNIT WEIGHT OF SOIL (BULK DENSITY)                                    |
| $\gamma_s$ | UNIT WEIGHT OF SOLID PARTICLES  |
| $\gamma_w$ | UNIT WEIGHT OF WATER  |
| $\gamma_d$ | UNIT DRY WEIGHT OF SOIL (DRY DENSITY)                                 |
| $\gamma'$  | UNIT WEIGHT OF SUBMERGED SOIL   |
| G          | SPECIFIC GRAVITY OF SOLID PARTICLES $G = \frac{\gamma_s}{\gamma_w}$   |
| e          | VOID RATIO  |
| n          | POROSITY  |
| w          | WATER CONTENT   |
| $S_r$      | DEGREE OF SATURATION  |
| $w_L$      | LIQUID LIMIT  |
| $w_p$      | PLASTIC LIMIT   |
| $I_p$      | PLASTICITY INDEX  |
| s          | SHRINKAGE LIMIT   |
| $I_L$      | LIQUIDITY INDEX $= \frac{w - w_p}{I_p}$                               |
| $I_C$      | CONSISTENCY INDEX $= \frac{w_L - w}{I_p}$                             |
| $e_{max}$  | VOID RATIO IN LOOSEST STATE   |
| $e_{min}$  | VOID RATIO IN DENSEST STATE   |
| $I_D$      | DENSITY INDEX $= \frac{e_{max} - e}{e_{max} - e_{min}}$               |
|            | RELATIVE DENSITY $D_r$ IS ALSO USED                                   |
| h          | HYDRAULIC HEAD OR POTENTIAL   |
| q          | RATE OF DISCHARGE   |
| v          | VELOCITY OF FLOW  |
| i          | HYDRAULIC GRADIENT  |
| k          | COEFFICIENT OF PERMEABILITY   |
| j          | SEEPAGE FORCE PER UNIT VOLUME   |
| $m_v$      | COEFFICIENT OF VOLUME CHANGE $= \frac{-\Delta e}{(1+e)\Delta \sigma}$ |
| $c_v$      | COEFFICIENT OF CONSOLIDATION  |
| $C_a$      | COMPRESSION INDEX $= \frac{\Delta e}{\Delta \log_{10} \sigma}$        |
| $T_v$      | TIME FACTOR $= \frac{c_v t}{d^2}$ (d, DRAINAGE PATH)                  |
| U          | DEGREE OF CONSOLIDATION   |
| $\tau_f$   | SHEAR STRENGTH  |
| $c'$       | EFFECTIVE COHESION  |
| $\phi'$    | EFFECTIVE ANGLE OF SHEARING RESISTANCE, OR FRICTION                   |
| $c_u$      | APPARENT COHESION   |
| $\phi_u$   | APPARENT ANGLE OF SHEARING RESISTANCE, OR FRICTION                    |
| $\mu$      | COEFFICIENT OF FRICTION   |
| $S_t$      | SENSITIVITY   |

## GENERAL

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

## STRESS AND STRAIN

|                |  |
|----------------|--|
| u              | PORE PRESSURE  |
| $\sigma$       | NORMAL STRESS  |
| $\bar{\sigma}$ | NORMAL EFFECTIVE STRESS ( $\bar{\sigma}$ IS ALSO USED) |
| $\tau$         | SHEAR STRESS   |
| $\epsilon$     | LINEAR STRAIN  |
| $\gamma$       | SHEAR STRAIN   |
| $\nu$          | POISSON'S RATIO ( $\mu$ IS ALSO USED)                  |
| E              | MODULUS OF LINEAR DEFORMATION (YOUNG'S MODULUS)        |
| G              | MODULUS OF SHEAR DEFORMATION                           |
| K              | MODULUS OF COMPRESSIBILITY                             |
| $\eta$         | COEFFICIENT OF VISCOSITY                               |

## EARTH PRESSURE

|          |   |
|----------|---|
| d        | DISTANCE FROM TOP OF WALL TO POINT OF APPLICATION OF PRESSURE   |
| $\delta$ | ANGLE OF WALL FRICTION  |
| K        | DIMENSIONLESS COEFFICIENT TO BE USED WITH VARIOUS SUFFIXES IN EXPRESSIONS REFERRING TO NORMAL STRESS ON WALLS |
| $K_0$    | COEFFICIENT OF EARTH PRESSURE AT REST   |

## FOUNDATIONS

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

## SLOPES

|         |  |
|---------|--|
| H       | VERTICAL HEIGHT OF SLOPE                 |
| D       | DEPTH BELOW TOE OF SLOPE TO HARD STRATUM |
| $\beta$ | ANGLE OF SLOPE TO HORIZONTAL             |