

MEMORANDUM

To: Mr. F. G. Allen,
District Engineer,
District No. 6 (Toronto),
Central Bldg., Downsview.

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

ATTENTION: Mr. K. Livingstone,
Maintenance Engineer
OUR FILE REF.

DATE: August 27, 1969

IN REPLY TO

SEP - 4 1969

SUBJECT:

-- FOUNDATION INVESTIGATION --
To

Determine Causes of Subsidence in
Vicinity of Toronto International
Airport Expressway - Indian Line Road
Complex, Co. of Peel, Twp. of Toronto
District No. 6 (Toronto)

W.J. 69-F-59 -- Contract 62-267

Attached, we are forwarding to you, our foundation investigation report on the subsoil conditions existing at the above mentioned site. We believe that the factual data, together with our assessment of the problem, are adequate for your immediate requirements. In addition, possible remedial measures are outlined and are presented in this report.

Should you find it necessary or desirable to discuss with us, the report, or any part of it, please feel free to call on this Office.

MD/MacF
Attach.

cc: Messrs. F. G. Allen (2)
H. A. Tregaskes
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Foundations Files (4)✓
Gen. Files

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

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-- FOUNDATION INVESTIGATION --
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1. INTRODUCTION:

Subsidence, within the plan limits of the Indian Line Rd. - Toronto International Airport Expressway complex, has occurred in the vicinity of Sta. 62+00 (Indian Line chainage) - i.e., some 850 feet south of the existing Dixon Road structure. This subsidence also extends both east and west of this highway complex.

In a memo dated July 30, 1969, Mr. J. K. Livingstone, Maintenance Engineer, District #6 (Toronto), requested that this Section carry out an investigation to determine the causes of this subsidence, as well as make recommendations with regard to any remedial measures required. Subsequently an investigation was carried out by this Section to determine the subsoil and groundwater conditions at this site, as well as the accumulation of all data pertaining to the causes of the subsidence.

This report will present information on all the factual data obtained during this study, together with our assessment of the causes of the subsidence, as well as recommended remedial measures.

2. DESCRIPTION OF THE SITE AND GEOLOGY:

The site in question is located in the vicinity of the Indian Line Rd. - Airport Expressway complex, approximately 850 feet south of the existing Dixon Rd., Indian Line Rd. structure; it is immediately east of the Airport. In this area

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

Indian Line Rd. has 2 concrete paved lanes in both the North and Southbound directions, separated by a median, which is anywhere from 6 to 45 feet in width. At the location of the structure the grade of Indian Line Rd. is at elevation 565 - i.e., the approach fills have a maximum height of between 24 to 26 feet. The Northbound and Southbound lanes are flanked on either side by the single-lane expressway ramps to and from the airport. In addition, a two-lane service road is located approximately 135 feet west of this highway complex.

The surrounding terrain is flat to gently undulating in relief between about elevations 540 and 544.

Physiographically, the site is situated in the section known as the "Peel Plain". In the vicinity of the site the "Plain" is basically a smoothed ground moraine. The glacial deposit is primarily composed of a silty clay with a trace of sand, locally known as "Malton Clay Till". In some areas the till is overlain by up to 10 feet of plastic lacustrine deposited stratified clay. The overburden is, in turn, underlain by shale and limestone bedrock of the Neaford - Dundas formation, Ordovician Period. Available information indicates that, in the area the surface of the bedrock is at about elevation 470 - i.e., some 70 to 75 feet below existing ground surface.

3. DATA PERTAINING TO AFFECTED AREA:

a) Visual Observations:

The subsidence extends in an east to west direction along a line which crosses the highway complex at a skew angle of approximately 45° . In the affected area the width of this dish-shaped strip varies from 53 to 60 feet in width.

The magnitude of the subsidence was exemplified at a manhole located 450 feet east of the highway complex (manhole #4); here up to 2 feet of settlement has occurred in an area where no fill material has been placed.

3. DATA PERTAINING TO AFFECTED AREA: (cont'd.) ...

a) Visual Observations: (cont'd.) ...

Within the limits of the highway complex, the subsidence can easily be discerned by the slumping of the pavement profile and the distinctive cracking noticed at the junction between the affected and unaffected areas. It should be noted that the Southbound lane of Indian Line Rd. has undergone more subsidence than the Northbound lane. The dishing along either lane adversely affects vehicular traffic.

The subsidence along the highway complex has been of a continuing nature and, as such, has required periodic maintenance. This has involved:

i) adding lifts of asphalt periodically. The patched areas are quite visible; and

ii) elevating the profile grade by mud jacking beneath the concrete paved lanes.

b) Relationship of Sewer Location to Subsidence:

It is pertinent to note that the direction and extent of the affected area coincides with the alignment of the existing storm sewer leading from the airport. It is inferred, therefore, that this sewer installation may be the major cause of the subsidence. This being the case, it was considered that a study of the case history of this sewer installation may in fact provide both an insight into and an explanation of the subsidence. The results of this study are presented in Section 4 to follow.

4. HISTORY OF THE SEWER INSTALLATION:

a) Sewer Construction:

In the summer of 1958 a 66-inch diameter (C.S.P. with reinforced steel rings) storm sewer was installed, by the Dundas Construction Company on behalf of the Federal Department of Transport,

4. HISTORY OF THE SEWER INSTALLATION: (cont'd.) ...

a) Sewer Construction: (cont'd.) ...

in the area under investigation. The purpose of this sewer was to improve the drainage regime within the airport area.

In the vicinity of the highway complex, the invert elevation of the storm sewer varies from 500.5 to 507, increasing in a westerly direction; this corresponds to depths below original ground level of 37.5 and 37 feet, respectively. A cut-and-cover operation was employed on this project. It is understood that the construction side slopes of the open excavations were maintained at a slope slightly steeper than 1:1. The sewer excavation so formed, was then backfilled with material similar in composition to the parent cohesive subsoil on site.

Based on verbal information provided, it is understood that:

1) the backfill was placed in a haphazard fashion, rather than in uniform lifts, and that it was not properly compacted; and

ii) the backfilled sewer trench settled up to 6 inches during the construction period alone. The observed settlement was dish-shaped, being greater in the centre of the excavation.

b) Improvement - Alignment of Highway Complex:

In 1963 Indian Line Rd. was relocated to its present alignment. At this time the Dixon Road structure was constructed and the expressway ramps to the airport added.

The south approach fill superimposes a surcharge loading on the sewer backfill. Because of the super-elevation along this approach, the magnitude of this surcharge varies from 1 foot at the Northbound lane to 10 feet at the Southbound lane of Indian Line Rd. This may explain why the subsidence noted along the latter lane is more severe (refer to Section 3. a)).

5. FIELD INVESTIGATION:

a) General:

The composition, consistency, and related engineering properties of the subsoil, within the affected and unaffected areas, were determined by putting down 14 detailed sampled boreholes with a power auger (Penndrill). In addition, 9 dynamic cone penetration tests were put down to supplement the information provided by the borings. The groundwater level conditions across the site were determined by recording the water level in the open auger holes following completion of the drilling operations.

In order to monitor the magnitude and the time rate of settlement taking place within the affected area, the existing Southbound lane approach embankment fill was instrumented. This instrumentation included the installation of a settlement plate and auger.

The locations and elevations of all borings and cone penetration tests, as well as all surveying of pertinent cross-sections, etc., were provided by personnel from District #6.

b) Subsoil Conditions:

The predominant overburden stratum across the site is composed of Malton clay till, which is basically a silty clay with a trace of sand and gravel. In general, the deposit extends down to a depth of more than 55 feet below existing ground surface. The borings, put down within the limits of the affected area, indicate that the subsoil is similar in composition to the parent Malton clay till. There are, however, localized zones throughout the area which contain a trace of organic matter. The boring programme made it possible to define the limits of the affected area, as will be discussed in the paragraphs to follow. This programme revealed that, at ground surface, the width of the problem area varies between 53 and 60 feet. This was substantiated by visual observations.

5. FIELD INVESTIGATION: (cont'd.) ...

b) Subsoil Conditions: (cont'd.) ...

Standard penetration tests were carried out. The results of this testing indicated that the 'N' values, within the affected area, randomly vary from 4 to 20 blows/ft., being on the average, about 8 blows/ft., while in the unaffected subsoil, the 'N' values range from 20 to 103 blows/ft., being on the average, approximately 45 blows/ft. A figure showing the relationship between the 'N' values recorded in the affected and unaffected areas, is shown in the Appendix of this report. Based on these results, it is estimated that the consistency of the subsoil, within the plan limits of the subsidence, varies from soft to firm, while outside this area, it is in the very stiff to hard range. Further, inspection of the samples obtained, indicates that the moisture content of the former material is, generally, considerably higher than that of the parent material - i.e., it is in a much wetter state.

The groundwater level in the area is about 6 to 9 feet below ground surface - i.e., between about elevations 534 and 539.

6. DISCUSSION:

a) Reasons for the Subsidence:

Based on the observations and facts presented in Sections 3, 4 and 5 of this report, it is concluded that the subsidence has occurred within the confines of the backfill to the sewer excavation.

The random pattern of low 'N' values observed, within the backfill area, implies that: i) the fill was placed in a haphazard fashion, rather than in uniform lifts, and ii) that the fill was not properly compacted. Under these conditions the fill would, therefore, tend to have a high percentage of open voids, which would, in turn, create favourable conditions for infiltration of free water into the voids, such as would occur during periods of heavy precipitation. This, of course, would

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

a) Reasons for the Subsidence: (cont'd.) ...

tend to soften the surrounding soil and increase the in situ moisture content. This was substantiated by the boring programme, which indicates that the subsoil in the affected area (sewer backfill) is in a wet state and soft condition, when compared to the parent cohesive subsoil. This resulted in the backfill being subjected to settlement under its own weight. It is pertinent to note that the fill, placed over the improperly compacted sewer backfill material, would add an additional surcharge loading; this loading would increase the magnitude of the settlement within the backfill. As discussed previously, the height of the approach fill is higher along the Southbound lane of Indian Line Rd. than along the Northbound lane; this explains why the observed settlement, in the vicinity of the former, was more severe.

Due to the fact that the backfill is basically cohesive in nature, this settlement would be of a consolidation nature. This being the case, it would be time dependent - i.e., take place over a number of years.

b) Suggested Remedial Measures:

The only satisfactory way to completely eliminate the continual settlement in the affected area, would be to subexcavate the existing embankment and storm sewer backfill. The excavation so formed, should be reconstructed to the required grade by placing acceptable earth material. Placement and compaction of fill material should be carried out as per current D.H.C. Specifications - (refer to Form #406). This operation may be costly and thus may not be warranted, unless of course, the life expectancy of this existing highway complex is reasonably long.

It is understood that the present Airport expressway will be expanded and incorporated into proposed Hwy. #27 North. For the reconstruction of the new expressway, in the vicinity of

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

b) Suggested Remedial Measures: (cont'd.) ...

the area under investigation, it will be necessary to remove all the softened backfill material located within the plan limits of the new roadway alignment.

As an alternative, the affected area could be bridged by constructing a reinforced concrete slab across the affected area. The length of the span required would have to be something of the order of 60 feet in the longitudinal direction. Further details of this scheme could be obtained from the Bridge Design Section.

In order to determine the present and future time-rate of settlement of the backfill in the problem area, an instrumentation programme has been initiated. The details of the instrumentation are discussed in Section 7).

7. INSTRUMENTATION:

The instrumentation installed within the west shoulder of the Southbound lane, in the vicinity of the storm sewer, consists of the following:

- i) a settlement plate (2.5 feet square) installed at a depth of 1.5 feet below the shoulder of the roadway; and
- ii) a settlement auger installed immediately below the roadway fill - i.e., at a depth of 13 feet below the shoulder.

Initial readings have already been taken on these instruments. In order to establish the settlement pattern, it is essential that future readings be taken every 2 weeks for approximately 2 months, then monthly from then onwards. Depending on the magnitude and rate of the settlements observed, the frequency of the readings may be modified at a later date.

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

Borelog sheets for each boring put down, as well as a detailed drawing showing the subsoil stratigraphy and the limits of the affected area, will be submitted in due course.

8. MISCELLANEOUS:

The field work for this project was carried out during the periods of July 23rd and August 7th, 1969, under the supervision of Mr. D. Phelps, Project Foundation Engineer.

This report was written by Mr. B. T. Darch, Senior Foundation Engineer.

The project was carried out under the supervision of Mr. M. Devata, Supervising Foundation Engineer, who also reviewed this report.

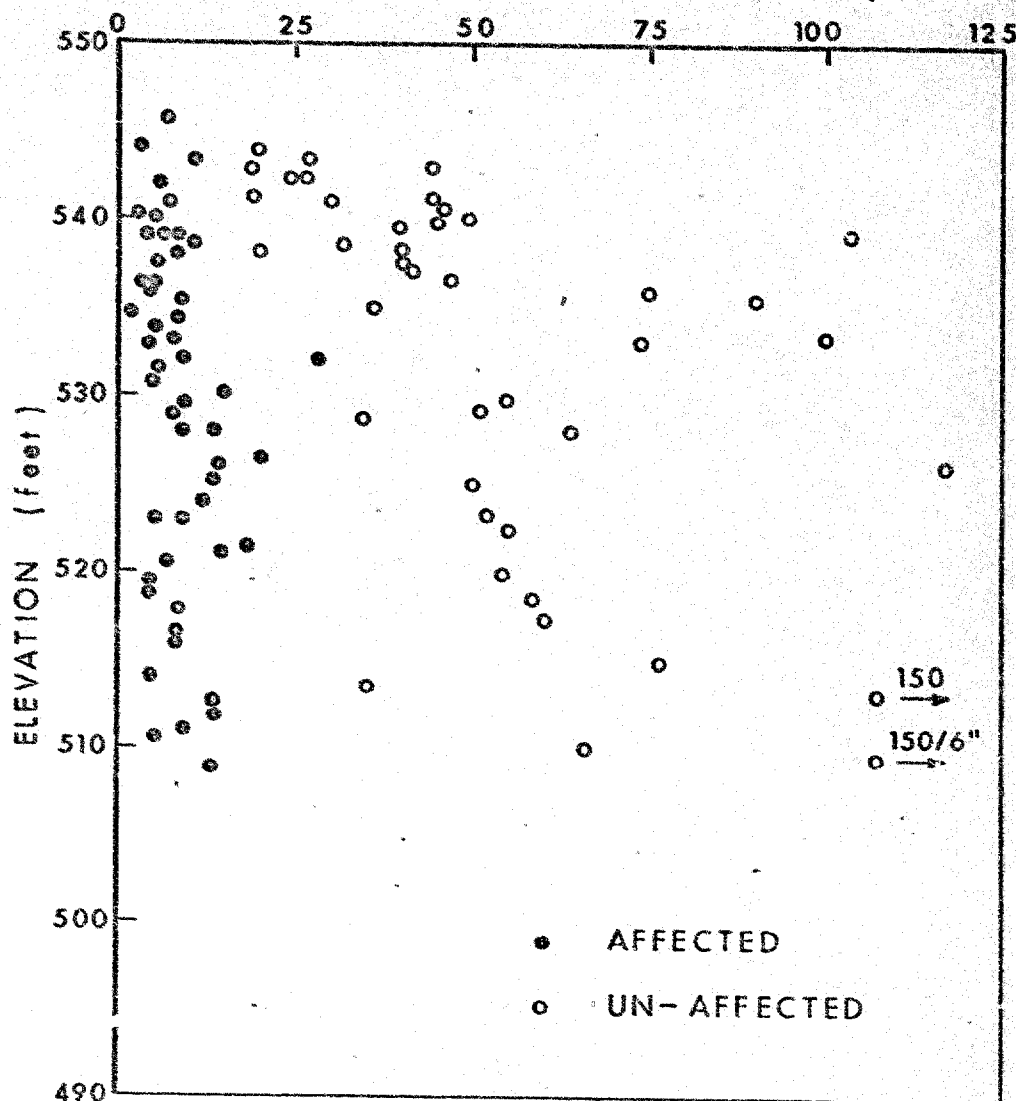
The equipment used was owned and operated by Master Soil Investigation Limited.

August 1969.

APPENDIX I.

SUMMARY PLOT OF STANDARD PENETRATION RESISTANCE VALUES (Affected and Un-Affected Areas)

STANDARD PENETRATION RESISTANCE VALUE 'N' (BLOWS/FT.)



69 - F - 59

FIG. 1

ABBREVIATIONS USED IN THIS REPORT

PENETRATION RESISTANCE

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

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

DESCRIPTION OF SOIL

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

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

TYPE OF SAMPLE

S.S	SPLIT SPOON	T.W	THINWALL OPEN
WS	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

Q _u	UNCONFINED COMPRESSION	L.V	LABORATORY VANE
Q	UNDRAINED TRIAXIAL	F.V	FIELD VANE
Q _{cu}	CONSOLIDATED UNDRAINED TRIAXIAL	C	CONSOLIDATION
Q _u	UNDRAINED TRIAXIAL	S	SENSITIVITY

ABBREVIATIONS USED IN THIS REPORT

SOIL PROPERTIES

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

GENERAL

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

STRESS AND STRAIN

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

EARTH PRESSURE

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