

GEORECS No.
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Government of Ontario

Ministry of Transportation and Communications

THOROLD TUNNEL

Investigations to Determine the
Cause of Cracking in the Structure

Supplementary Report No.2
East Service Building



December 1972

72-11-096

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1 - INTRODUCTION

1.1 - Terms of Reference

Following submission of the report "Investigations to Determine the Cause of Cracking in the Structure" in March 1972, the Ministry of Transportation and Communications requested Acres to carry out additional stress measurements and continue investigations into loading conditions at the east service building. Based on these results an assessment was made of the structural safety of the east service building.

1.2 - Scope of the Investigations

The investigations have been aimed primarily at obtaining stress levels in the tunnel roof and floor slab at the east service building, and determining the variation of stress with time in the tunnel roof. This has been achieved by means of in situ strain measurements in steel reinforcing bars and in concrete, and continuing strain observations. Cracking patterns in the walls of the structure were also mapped in detail.

2 - CONCLUSIONS AND RECOMMENDATIONS

The investigations at the east service building have resulted in the following conclusions:

- (a) Rock squeeze is not causing a significant load to be applied to the structure at this time, and remedial work will not be required for several years, if at all.
- (b) Further monitoring of the structural behavior is required to establish if rock squeeze is likely to create significant load on the structure in the future.
- (c) Stress levels measured in April 1972 in the tunnel roof and floor are considerably lower than design limits in both the steel and concrete, indicating that the building was not subjected to excessive loading at that time.
- (d) Since June 1972 continuing observations have indicated that the structure has responded to thermal changes as though unrestrained, except for September 1972. During this time an estimated additional compressive stress of 670 psi was developed in the reinforcing steel of the roof beam. This change has been tentatively attributed to limited partial restraint due to rock squeeze, as shown on Plate 6.
- (e) In situ concrete stress measurements in the tunnel roof and floor indicate significantly higher north-south compressive loading at floor level. This may indicate that imposed deformation due to rock squeeze occurs primarily at the level of the shaly limestone layer, identified at the west service building, which is at about floor level in the east service building.
- (f) Cracking in the outer tunnel walls between Stations 73 + 83 and 74 + 33, and below precast ceiling level, elevation 546 feet approximately, is minor, consisting essentially of one or two discontinuous horizontal cracks. This is not considered indicative of a serious structural problem at present. Cracking is more extensive in the outer walls between precast ceiling level, elevation 546 feet approximately, and second floor level, elevation 568 feet. These cracks are vertical and predominantly concentrated in the length of the service building adjacent to the bulkhead, that is, between Stations 73 + 83 and 74 + 33. Inspection of these walls has indicated that further cracking has become evident between May and November 1972.

On the basis of the above conclusions it is recommended that:

- (a) Observations on the performance of the structure be continued for at least 2 years.
- (b) Results of the continuing observations be reviewed in the fall of each year to determine if any significant increase in stress levels is occurring.

3 - FIELD INSTRUMENTATION

The objective of the field instrumentation was to determine present (April 1972) stress levels in the concrete and in the steel reinforcement of the east service building, primarily at tunnel roof level elevation 554.33 feet, and tunnel floor level elevation 529 feet, approximately.

3.1 - Concrete Stress Measurements

Concrete stress levels were determined using the overcoring technique described in the report of March 1972. Stresses were measured in Holes OC-41 to OC-49, located in the tunnel roof structure at elevation 554.33 feet, and in the west wall of the east service building as shown on Plate 1. Holes OC-50 and OC-51 were drilled in the tunnel floor slab from road level and OC-52 in the outer tunnel wall of the south tube. These test locations were selected to enable a comparison to be made between stress levels in the north and south parts of the service building, and to ascertain areas where stresses were expected to be a maximum. It was expected that a concentration of stress would occur in the 2 feet 6 inches by 4 feet 9 inches main north-south roof beam. However, it was considered imprudent to overcore in this member due to the relatively large amount of material which would be removed.

3.2 - Steel Stress Measurements

Stresses in reinforcing steel were determined directly by attaching electrical resistance foil strain gauges to exposed bars. Each bar was cut from the structure and the change of stress was calculated from the strain measured in the bar. This type of test was performed at two locations, one in the top of the main north-south floor beam in the tunnel roof slab, elevation 554.33 feet, and the other in the tunnel floor slab west of the east sump in the ventilation passageway between the north and south tubes, as shown on Plate 1.

The test locations were selected to provide a stress measurement in the main north-south beam where overcoring was not considered advisable, and also in the tunnel floor slab, to enable a comparison of results of the two test procedures to be made.

3.3 - Strain Measurements

To establish the trend in deformation of the structure with time, strain measuring instrumentation was installed. This instrumentation consists of extensometers to monitor the overall dimensional changes at tunnel roof and floor levels; metallic studs on the major north-south roof beam for strain measurements, using an 8-inch Demec mechanical strain gauge; and electrical resistance foil strain gauges on steel reinforcing bars adjacent to those used for the in situ stress measurements. The location of the instrumentation is shown on Plate 2.

4 - FIELD OBSERVATIONS

The results of stress measurements carried out in April 1972 are shown on Plate 1. Continuing observations of deformations and stress changes are given on Plates 3 and 5.

4.1 - Stress Measurements

The stresses determined from strain measurements in both the concrete and reinforcing steel at all locations were considerably lower than design stress levels.

The distribution of compressive concrete stresses in the tunnel roof slab, elevation 554.33 feet, was consistent with that anticipated, with the highest stresses in the area of roof spanning between the north and south bulkheads. Highest concrete stress levels were measured in the area of slab between the ventilation holes, but the readings were not of sufficient magnitude to indicate clearly a stress concentration in this area compared with the adjacent slab. Lower concrete stress levels in the north-south direction were measured in Holes OC-48 and OC-49, located elsewhere in the roof slab.

Concrete stresses in the west wall of the east service building at elevation 557.66 feet indicate a compressive stress predominantly oriented in the vertical direction.

The stresses in the concrete of the road slab in Hole OC-51 were compressive and significantly higher than those at roof level, but were considerably below design values, the orientation being predominantly in a north-south direction.

The stress distribution in the outer wall of the south tube in Hole OC-52 was predominantly compressive in the vertical direction, and did not indicate the presence of excessive bending.

Steel stresses indicated a compressive stress in the major north-south roof beam, elevation 554.33 feet, with a stress level lower than the design limits.

The steel stress determined in the top of the tunnel floor slab in the fresh air duct, as shown on Plate 2, was lower than that in the roof beam. Subsequent strain observations in this area have indicated that restraint by the adjacent internal walls has a significant effect on the observed strains, so that due to unreliability of the in situ steel strain measurements, a meaningful comparison with the concrete stress measurements (OC-50 and OC-51) is not possible.

4.2 - Observed Deformations

The instrumentation for long-term monitoring of the structural behavior shown on Plate 2, was installed in May 1972. There have been insufficient readings yet to confirm any long-term trends with accuracy.

The indications up to November 1972 are that the total deformation of the tunnel at roof level, elevation 554.33 feet, shown on Plate 3, can be correlated well with changes in atmospheric temperature. From the beginning of September onward, however, it appears that the building is being subjected to an increasing compressive deformation in excess of that predicted due to changes in the temperature of the roof slab.

Strain measurements at tunnel floor level in the fresh air passage have indicated a similar trend to that of the roof, with local bending strains superimposed. In October 1972, an additional extensometer to allow assessment of total deformation across the tunnel was installed across the south tube, and located in the south sump of the east service building.

Strain changes measured in the centre of the fresh air duct have been considered representative of the floor slab behavior, and have been correlated with the limited measurements taken across the south tube. Using this correlation, the observations in the fresh air duct have been extrapolated to total tunnel deformation, as shown on Plate 3. Because of the possible influence of the adjacent walls, these deformations are considered only as indicative of the trend of deformational change. As indicated on Plate 3, the trend of deformational change is similar to that of the roof structure.

Crack patterns in the north and south outer wall of the east service building and adjacent tunnel walls have been mapped as shown on Plate 4. No significant changes in the crack pattern have been observed, although a further propagation of cracking above roof level has become evident in the period between April 1972 and November 1972.

Crack widths in the north tunnel wall decreased during the winter and have continued to increase from about April 1972 to September 1972, as shown on Plate 5. The magnitudes observed in September 1971 have been exceeded in September 1972; the maximum increase being of the order of 0.002 inch.

5 - ANALYSIS OF RESULTS

The stress measurements made in April 1972 indicate levels of stress below the design limits. The distribution of stress is consistent with that anticipated from the general structural configuration, subjected to an external loading in a north-south direction. The highest stresses occur in the concrete of the tunnel floor slab, which would appear to indicate that the floor is subjected to a greater deformation than is applied to other members of the structure. This correlates well with the position of the shaly limestone layer in the Gasport Member, referred to in the report "Investigations to Determine the Cause of Cracking in the Structure", March 1972.

At this time there are insufficient observations to confirm that the initial deformation due to rock squeeze is imposed by the shaly limestone layer. If it is, a progressive deformation applied to the tunnel by rock squeeze should become evident as monitoring of the structure continues. The limited observations to date indicate fluctuations of strain, which correlate well with those predicted for temperature changes in the structure with no external restraint. There is some indication that during the month of September 1972 an imposed restraint has been applied by the adjacent rock. This is consistent with the timing for peak rock squeeze, as observed at the west service building. The cyclical nature of rock is illustrated on Plate 6, where a hypothetical rock squeeze curve has been developed, and integrated with estimated structural deformation due to shrinkage of the concrete in the structure, and external hydrostatic and rock-fill loads. The rock squeeze curve was based on observations at the Canadian Niagara wheel pit, and is similar to that described in Supplementary Report No. 3 for the west service building.

From continued strain observations it has been deduced that an imposed compression of approximately 0.020 inch has been applied at tunnel roof level, during September 1972, as shown in Table 1. It is estimated that this caused an increase in compressive stress in the reinforcing steel of 670 psi. During this period the temperature in the structure did not vary significantly.

Although the crack widths in the outer tunnel walls have exceeded the magnitudes of those of September 1971, the observed increase of about 0.002 inch is not considered large enough to indicate a definite trend.

6 - ASSESSMENT OF STRUCTURAL SAFETY

The in situ stress levels, as determined from measured deformations, indicate that the stresses in the structure are below design limits, and are of a similar magnitude to those calculated for this type of reinforced concrete structure under the anticipated design loads.

Continuing observations in 1972 have indicated that the structure was subjected to a total imposed compression of the order of 0.02 inch during September 1972. This caused an increase in the stress in the reinforcing steel in the tunnel roof and floor of approximately 670 psi, creating a peak steel stress of 11,590 psi, as shown in Table 1. This is within the normal design stress level of 12,000 psi, and based on a similar rate of change in stress to that derived from the west service building, it will be some years before stresses are likely to be increased to unacceptable values.

It is not possible at this stage to predict the probable rate of increase in rock squeeze on the structure, but it is deduced that the imposed deformations to date are of a smaller magnitude than those at the west service building. The pattern of restraint is similar to that at the west service building, but at a stage which lags behind that of the west service building by approximately 4 years. This difference may be partly due to the initial rock cut having remained open for approximately 10 months, compared with 7 months at the west service building. The construction sequence for the east service building is detailed in Table 2.

From the higher stresses obtained in the tunnel floor it may be deduced that the floor is subjected at present to a larger deformation due to rock squeeze than other structural members. This may indicate that the rock squeeze originates in the shaly limestone layer, mentioned earlier, which is at floor level at the east service building. The higher stresses may also result from a greater resistance to rock squeeze by the tunnel floor than provided by other structural members.

The crack widths in the outer tunnel walls have increased in 1972, but the magnitudes are small and are not considered significant with respect to structural safety.

It is recommended that the safety of the structure be assessed on an annual basis as more field observations become available.

Table 1

PREDICTION OF STRESSES
OCTOBER 1, 1972

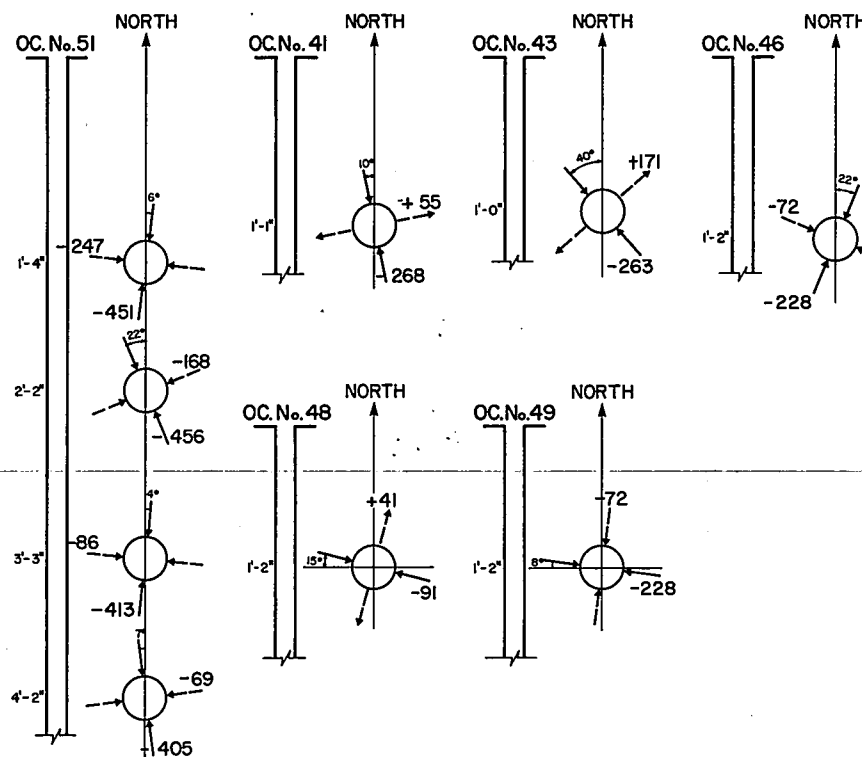
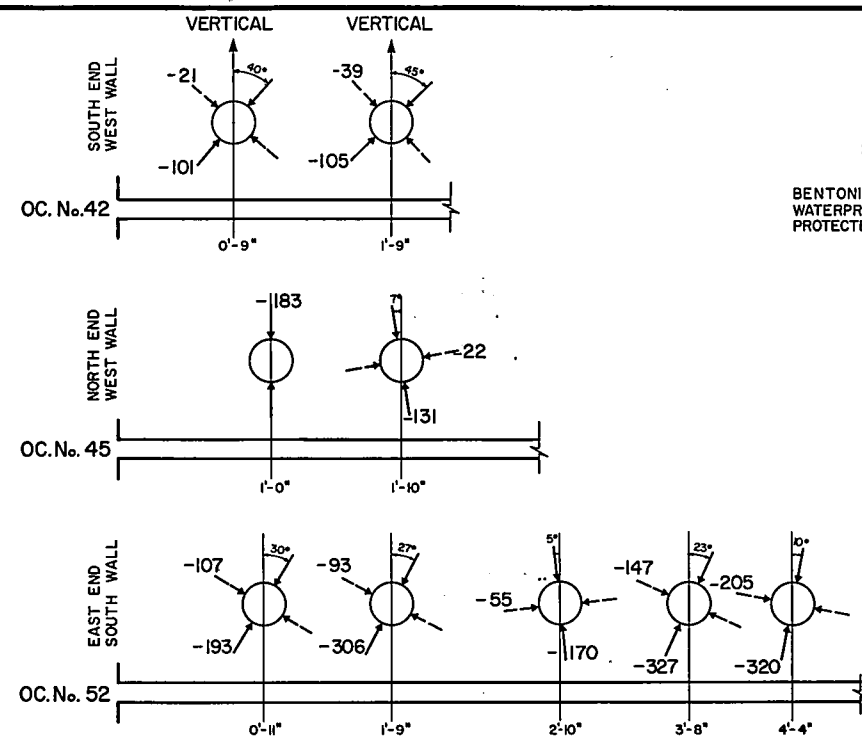
	<u>Tunnel Roof Beam North-South Compressive Stress (psi)</u>
Measured in situ reinforcing steel stress (April 1972) (Attributable to concrete shrinkage and live loading)	10,920
Compression imposed on tunnel observed in September 1972, approximately 0.020 inch	670
Thermal stress change April to September 1972	0
Peak steel stress October 1, 1972	11,590
Peak concrete stress due to applied compression and live loading (Effective modular ratio = 15)	145 to 245 45
	<u>Tunnel Floor Slab North-South Compressive Stress (psi)</u>
Measured in situ concrete stress	420
Increase in compressive stress using same imposed deformation as on roof beam, 0.02 inch in September 1972	45
Thermal stress change April to September 1972	0
Peak concrete stress October 1, 1972	465

Table 2

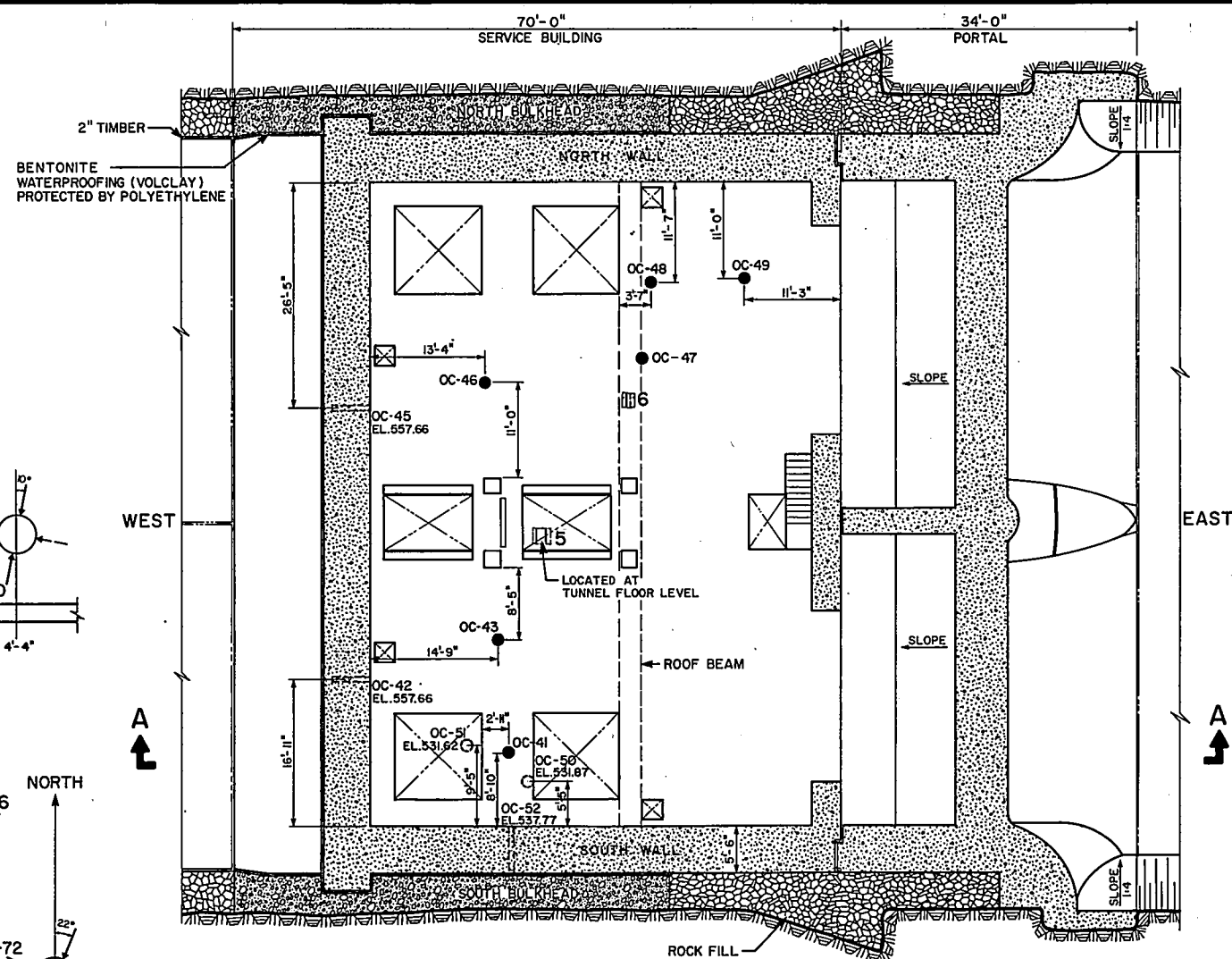
CONSTRUCTION SEQUENCE AT
EAST SERVICE BUILDING

<u>Date</u>	<u>Operation</u>
October 22, 1965	Overburden excavation commenced Stations 67 + 53 to 74 + 87
November 13, 1965	Rock excavation commenced Stations 68 + 50 to 74 + 87
December 4, 1965	Overburden excavation Stations 67 + 53 to 74 + 87, 98 per cent complete
February 11, 1966	Rock excavation Stations 67 + 53 to 74 + 87, 90 per cent complete
March 28, 1966	Rock excavation Stations 67 + 53 to 74 + 87, complete
July 12, 1966	Tunnel floor slab Stations 67 + 53 to 74 + 87 complete
October 11, 1966	Tunnel roof slab complete
November 9, 1966	Lower half of bulkheads north and south of building placed
November 16, 1966	Upper walls of service building concreted and backfilling commenced

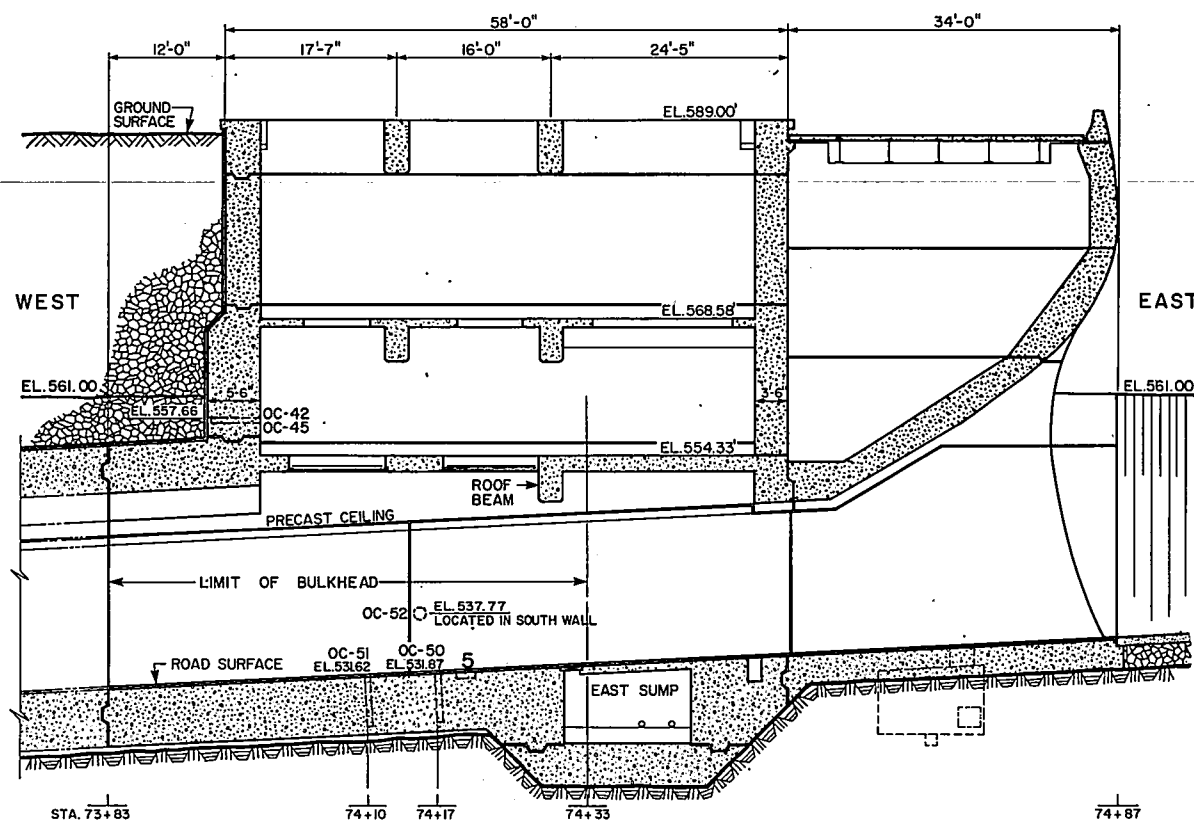
PLATES



- NOTES**
- ALL RESULTS PLOTTED LOOKING INTO HOLE FROM SURFACE OF CONCRETE
 - σ_1 → MAJOR PRINCIPAL STRESS
 σ_2 → MINOR PRINCIPAL STRESS
 - POSITIVE DENOTES TENSION
 - ALL STRESSES IN PSI
 - ALL READINGS TAKEN BETWEEN APRIL 17/72 AND APRIL 26/72



PLAN AT EL. 554.33



SECTION A-A

REINFORCING BAR STRESSES - PSI

POSITION NUMBER	NORTH-SOUTH STRESS (TEMPERATURE)
5	-2 200 (42 °F)
6	-10 920 (42 °F)

NOTE
A POSITIVE SIGN DENOTES TENSION IN THE STEEL

LEGEND

- OC.No. 43 LOCATION OF OVERCORING STRESS MEASUREMENT APRIL 1972
- 5 LOCATION OF REINFORCING BAR STRESS MEASUREMENT AND DESCRIPTION OF CUT BARS

SCALE IN FEET
0 20 40

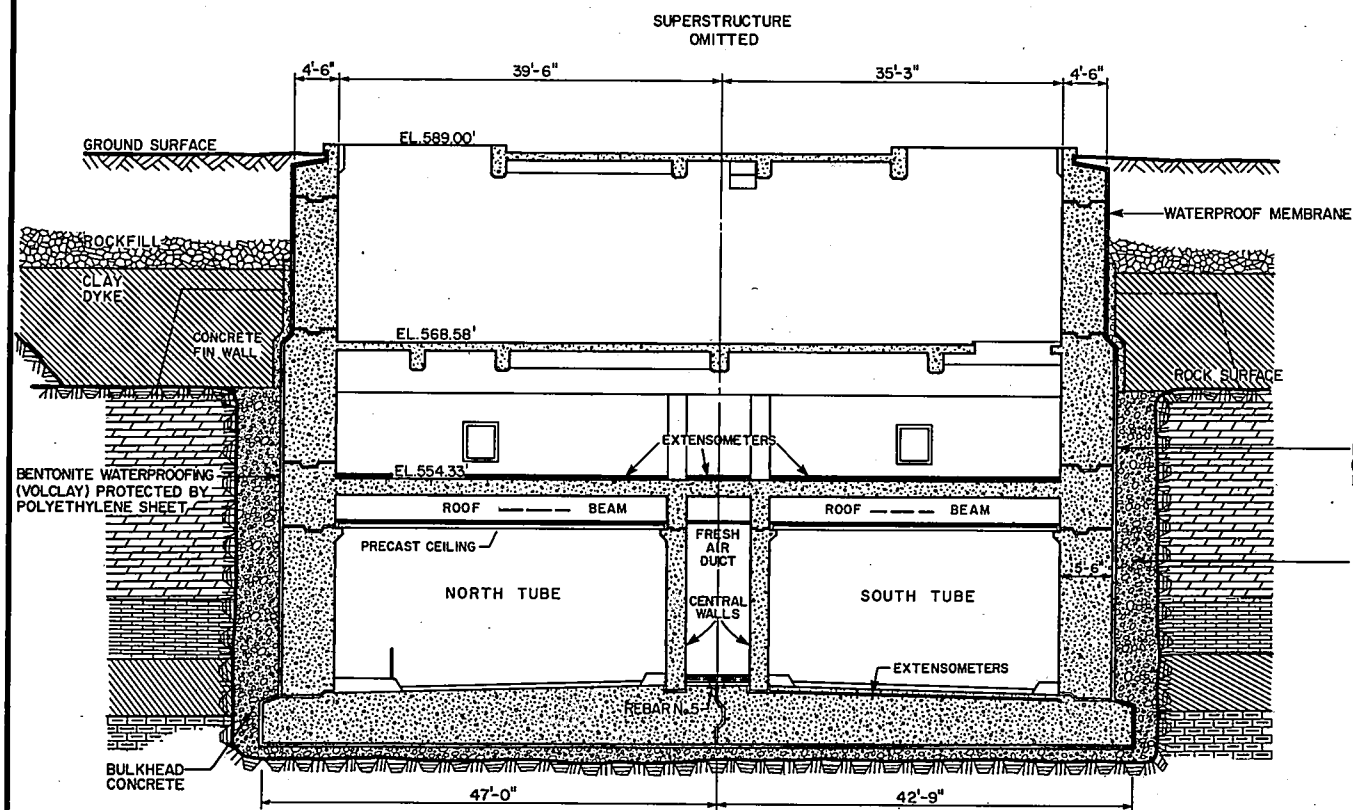
ACRES MINISTRY OF TRANSPORTATION AND COMMUNICATIONS
 THOROLD TUNNEL STRUCTURAL INVESTIGATIONS

EAST SERVICE BUILDING IN SITU STRESS MEASUREMENTS - APRIL 1972

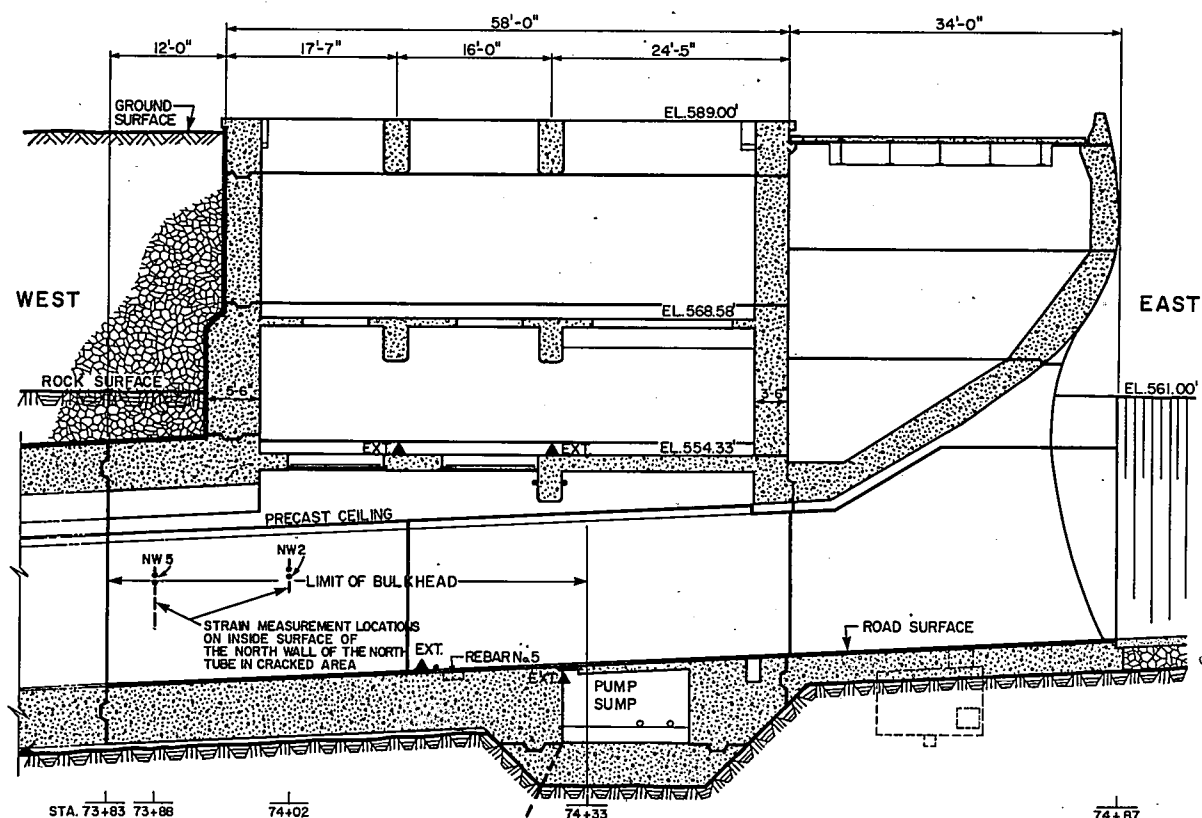
DECEMBER 1972

ACRES CONSULTING SERVICES LIMITED

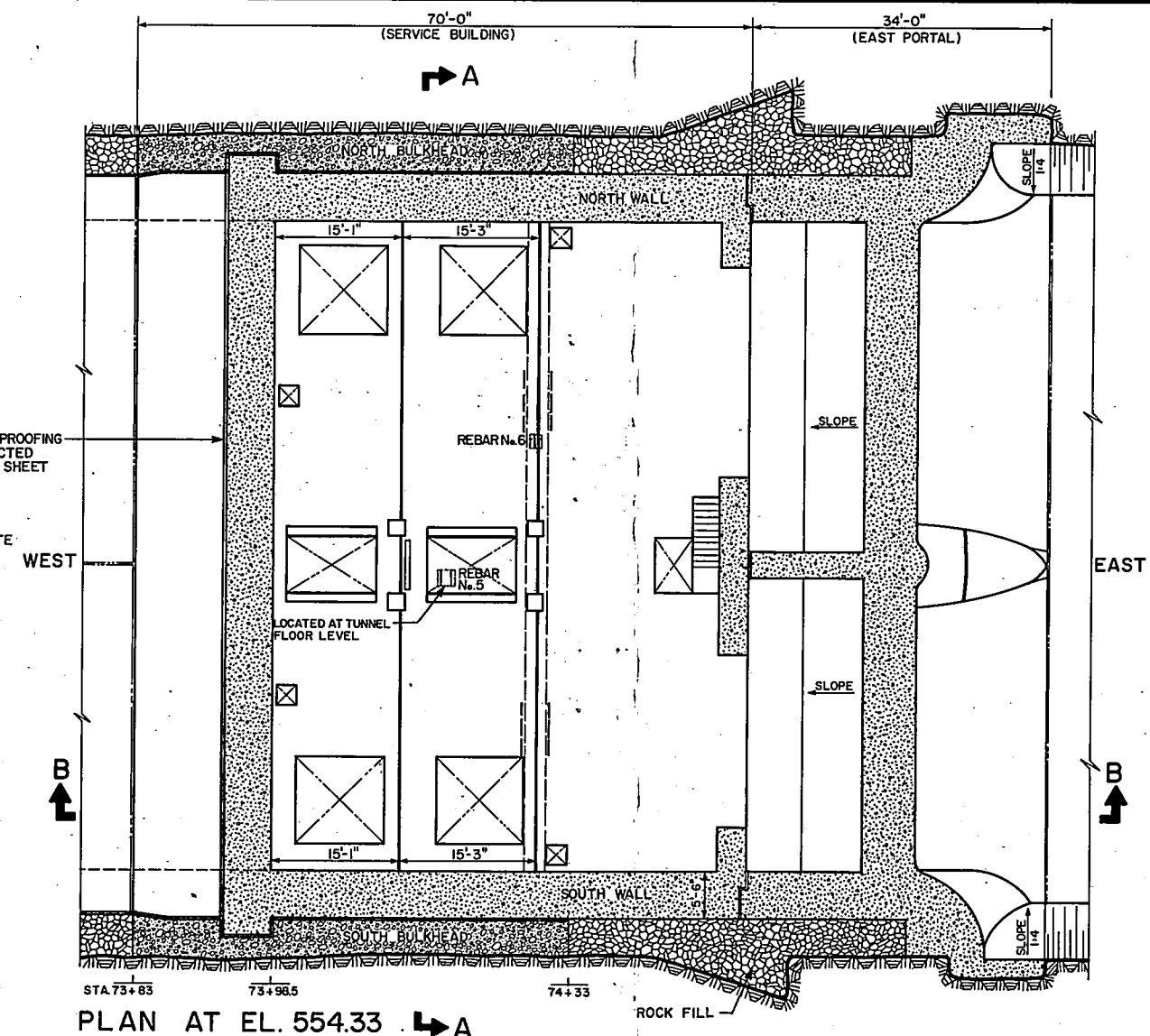
PLATE 1



SECTION A-A



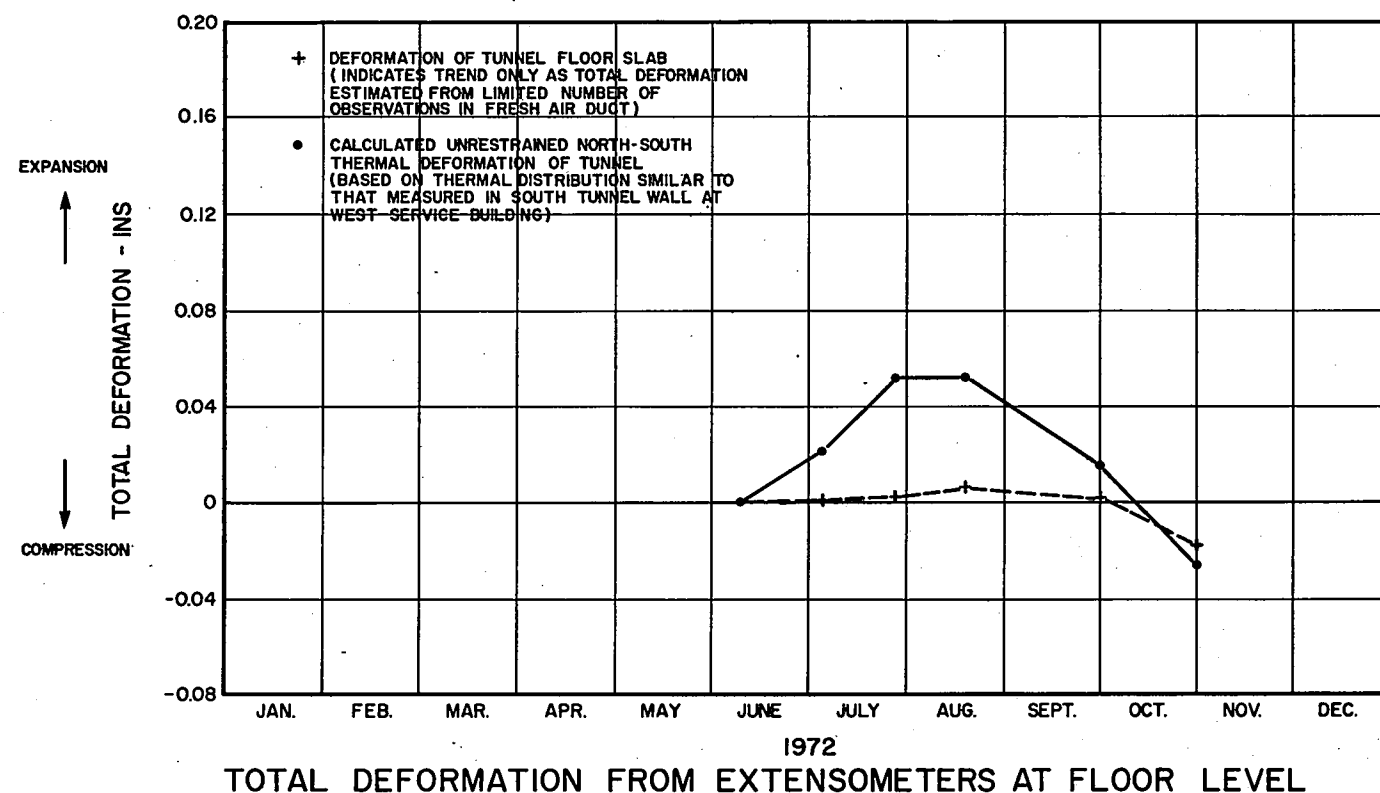
SECTION B-B



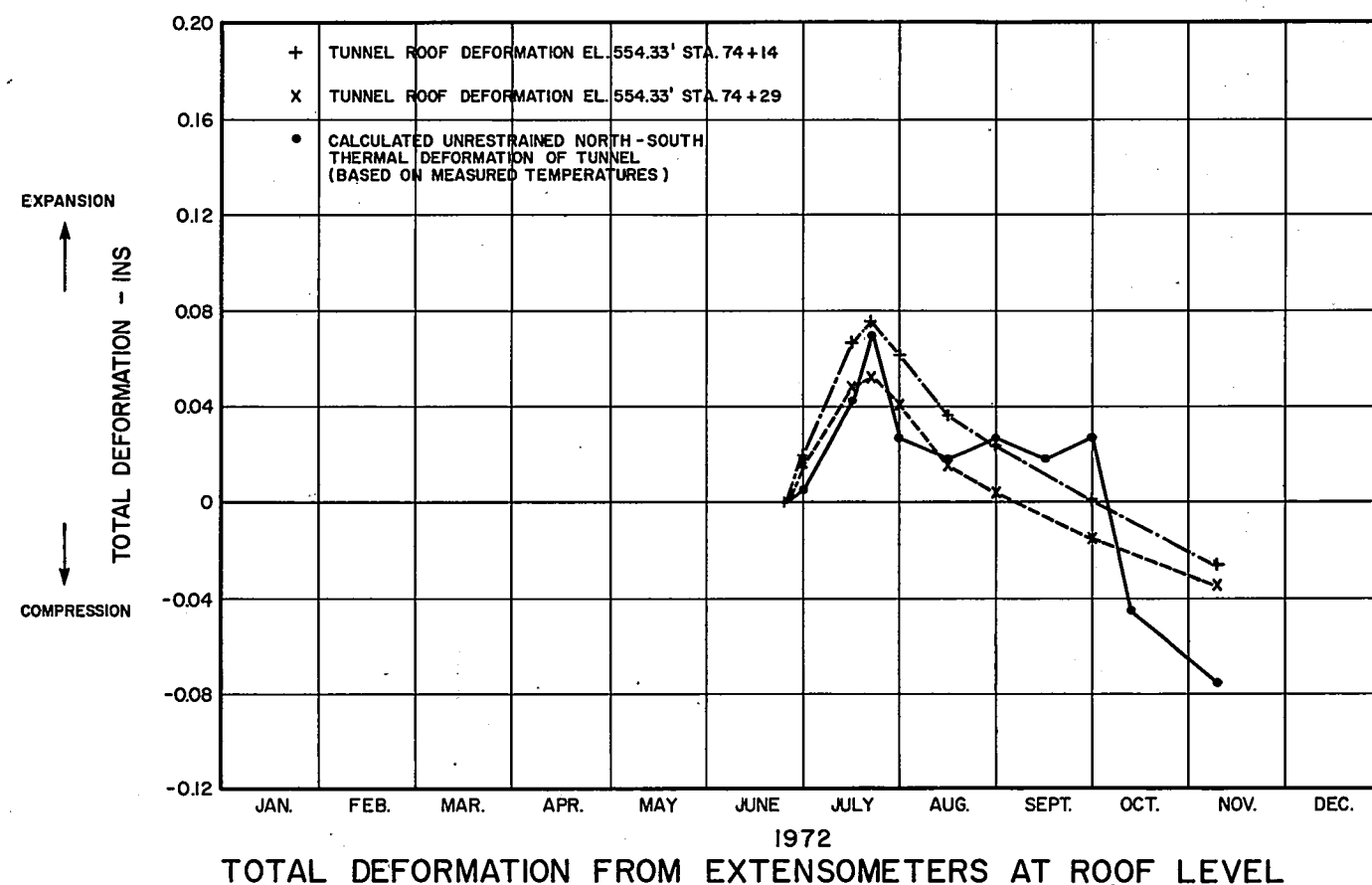
LEGEND

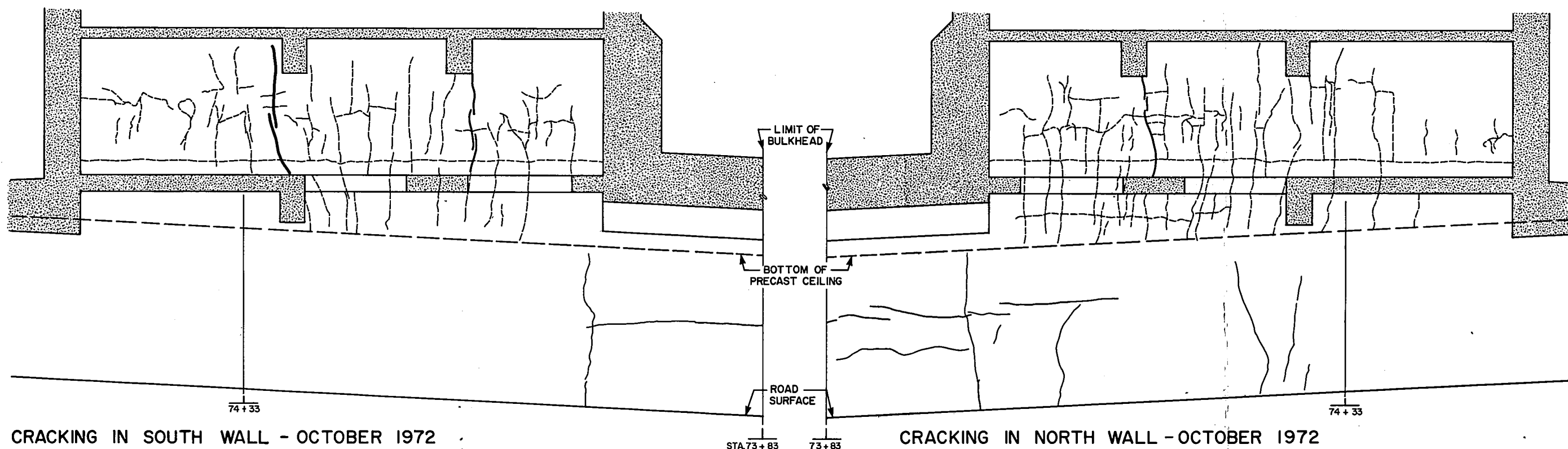
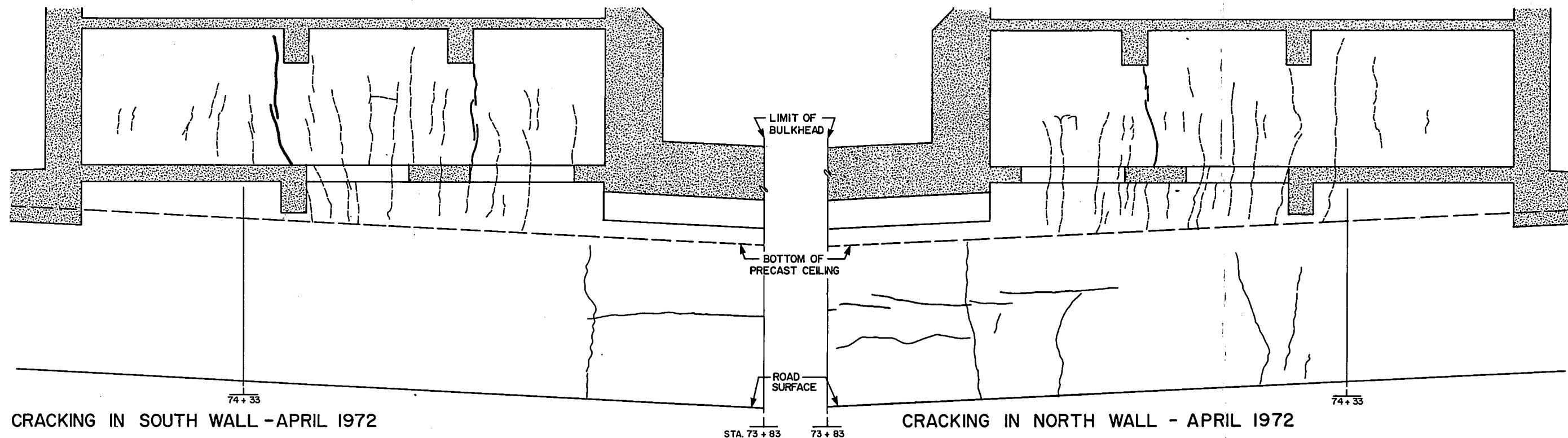
- REBAR No. 5 LOCATION OF STRESS MEASUREMENTS ON NORTH-SOUTH ORIENTATED REINFORCING STEEL
- 8" 'DEMEC' MECHANICAL STRAIN GAUGE MEASUREMENT LOCATIONS ON STRUCTURAL CONCRETE
- LOCATION OF EXTENSOMETERS

0 20 40
SCALE IN FEET



NOTE
FOR LOCATION OF MEASUREMENTS SEE PLATE 2





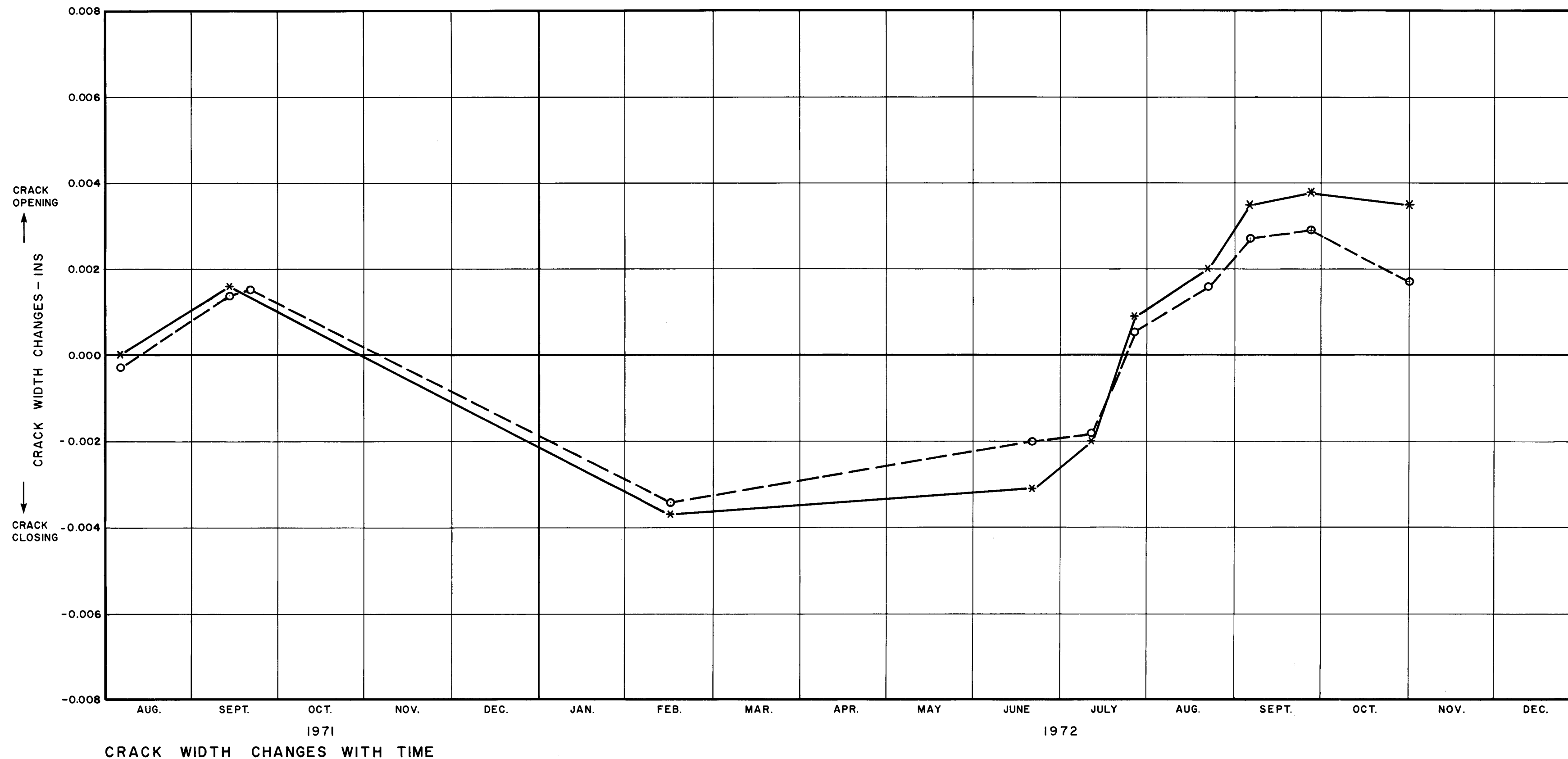
LEGEND

- 1-5
- 5-10
- 10-15
- 15-20
- 20-25

APPROXIMATE CRACK WIDTHS
IN THOUSANDS OF AN INCH

0 10 20
SCALE IN FEET

AGRES	MINISTRY OF TRANSPORTATION AND COMMUNICATIONS	
	THOROLD TUNNEL STRUCTURAL INVESTIGATIONS	
EAST SERVICE BUILDING PATTERN OF CRACKING NORTH AND SOUTH WALLS		
<i>[Signature]</i> AGRES CONSULTING SERVICES LIMITED	DECEMBER 1972	PLATE 4

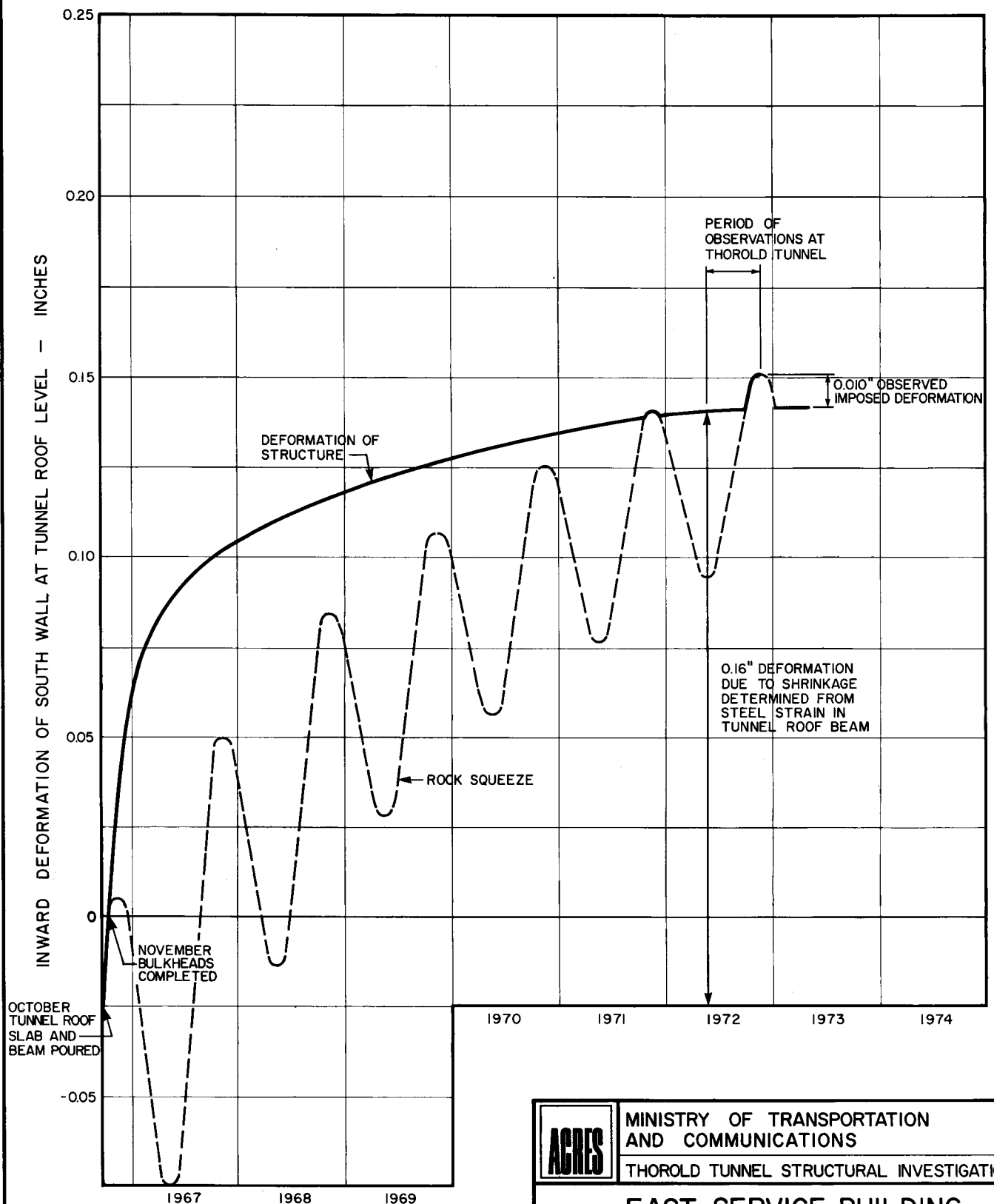


LEGEND

* NW 2 } TYPICAL CRACK MEASUREMENTS

O NW 5 }

FOR LOCATION OF MEASUREMENTS SEE SECTION B-B ON PLATE 2



NOTES

HYPOTHETICAL CURVE OF DEFORMATIONS DEVELOPED FROM MEASUREMENTS OF WHEEL PIT MOVEMENTS MADE BY ONTARIO HYDRO AND 1971-72 FIELD OBSERVATIONS AT THOROLD

CHANGES IN STRUCTURAL DEFORMATIONS DUE TO TEMPERATURE FLUCTUATIONS HAVE BEEN EXCLUDED



MINISTRY OF TRANSPORTATION
AND COMMUNICATIONS

THOROLD TUNNEL STRUCTURAL INVESTIGATIONS

EAST SERVICE BUILDING
IMPOSED DEFORMATION
DUE TO ROCK SQUEEZE
HYPOTHETICAL CURVE

W. T. Tanner
ACRES CONSULTING SERVICES LIMITED

DECEMBER 1972

PLATE
6

APPENDIX A

H. G. ACRES LIMITED — CONSULTING ENGINEERS
NIAGARA FALLS, CANADA

DRILLING REPORT

CLIENT Ministry of Transportation and Communications JOB No. P2499.02
 PROJECT Thorold Tunnel Field Investigations HOLE No. OC42
 SITE East Service Building SHEET No. 1 OF 1

CONTRACTOR: Canadian Longyear STARTED a.m. April 18 19 72
Limited FINISHED a.m. April 18 19 72
 METHOD OF DRILLING: SOIL Concrete Diamond Drill CASING DIAM. 6.0 inches
ROCK CORE DIAM. 5.778 inches

LOCATION: LATITUDE Third Level ELEVATIONS: 557.66 feet
DEPARTURE West Wall DRILL PLATFORM
BEARING South End GROUND SURFACE
Bearing West ROCK SURFACE
OTHER DIPS Horizontal BOTTOM OF HOLE
WATER TABLE

DEPTH	Concrete ROCK TYPE	DESCRIPTION: COLOUR, TEXTURE, FOLIATION, JOINTING, FRACTURING, FAULTING, ALTERATION, WATER LOSS OR GAIN, CAVING, LOST CORE, CEMENTING, ETC.	% CORE
0'0" to 3'0"	Structural Concrete	0'0" - Ex-hole offset approximately 0.5 inch downward from centre line of core.	
	Concrete Appears Compact and Sound	0'0" to 0'3" - Six-inch diameter core on north side has been indented approximately 0.5 inch in a southerly direction. The south side of core is flush.	
		0'3.25" Horizontal Steel - Runs above centre line of core.	
		1'2" Core Broken Manually by Drillers - Break is approximately 90 degrees to axis of core. - Ex-hole off centre 0.5 inch downward.	
		3'0" End of Hole - Core broken manually at approximately 90 degrees to axis of core. - Ex-hole off centre, downward by approximately 1/2 inch.	

INSPECTOR W. P. Pratt

APPROVED *W. P. Pratt*

LOGGED BY W. P. Pratt

DATE August 11, 1972

H. G. ACRES LIMITED — CONSULTING ENGINEERS
NIAGARA FALLS, CANADA

DRILLING REPORT

CLIENT Ministry of Transportation and Communications JOB No. P2499.02

PROJECT Thorold Tunnel Field Investigations HOLE No. OC43

SITE East Service Building SHEET No. 1 OF 1

CONTRACTOR: Canadian Longyear Limited STARTED a.m. April 18, 19 72
 FINISHED a.m. April 18, 19 72

METHOD OF DRILLING: SOIL Concrete Diamond Drill CASING DIAM. 6.0 inches
 ROCK CORE DIAM. 5.778 inches

LOCATION: DATUM Third Level ELEVATIONS: DATUM Floor El. 554.33 feet
 DEPARTURE Floor DRILL PLATFORM
 BEARING Southwest Area GROUND SURFACE
 INITIAL DIR Vertical ROCK SURFACE
 OTHER DATA BOTTOM OF HOLE
 WATER TABLE

DEPTH	Concrete —ROCK TYPE	DESCRIPTION: COLOUR, TEXTURE, FOLIATION, JOINTING, FRACTURING, FAULTING, ALTERATION, WATER LOSS OR GAIN, CAVING, LOST CORE, CEMENTING, ETC.	% CORE
0'0" to 0'3"	Industrial Topping	0'3" Core Break - Core split during drilling at interface between industrial topping and concrete slab.	
0'3" to 1'3"	Structural Concrete	0'8" - Sliver of east/west steel on extreme edge of core.	
	Concrete Appears Sound and Compact	0'9" North/South Steel - Running through centre line of core.	
		1'3" End of Hole - Core broken manually by drillers at approximately 90 degrees to axis of core.	

INSPECTOR W. P. Pratt

APPROVED

LOGGED BY W. P. Pratt

DATE

August 11, 1972

H. G. ACRES LIMITED — CONSULTING ENGINEERS
NIAGARA FALLS, CANADA

DRILLING REPORT

CLIENT Ministry of Transportation and Communications JOB No. P2499.02
 PROJECT Thorold Tunnel Field Investigations HOLE No. OC44
 SITE East Service Building SHEET No. 1 OF 1

CONTRACTOR: Canadian Longyear Limited STARTED a.m. April 19, 1972
 FINISHED a.m. April 19, 1972
 METHOD OF DRILLING: ~~SOIL~~ Concrete Diamond Drill CASING DIAM. 6.0 inches
~~ROCK~~ CORE DIAM. 5.778 inches
 LOCATION: ~~EXTITUDE~~ Third Level ELEVATIONS: DATUM Floor El. 554.33 ft
~~DEPARTURE~~ Floor
~~BEARING~~ North Strut
~~INITIAL DIRECTION~~ Vertical
~~OTHER DATA~~
 DRILL PLATFORM
 GROUND SURFACE
 ROCK SURFACE
 BOTTOM OF HOLE
 WATER TABLE

DEPTH	Concrete ROCK TYPE	DESCRIPTION: COLOUR, TEXTURE, FOLIATION, JOINTING, FRACTURING, FAULTING, ALTERATION, WATER LOSS OR GAIN, CAVING, LOST CORE, CEMENTING, ETC.	% CORE
0'0" to 0'4"	Industrial Topping	0'4" Core Break - Core split during drilling at interface between industrial topping and concrete slab. - Ex-hole well centred.	
0'4" to 1'5"	Structural Concrete	0'8" East/West Bars Intersected - Run slightly off centre.	
	Concrete Appears Sound and Compact	0'9" - Sliver of north/south steel on extreme edge of core.	
		1'5" End of Hole - Core broken by drillers at approximately 90 degrees to cores axis. - Ex-hole well centred.	

INSPECTOR W. P. Pratt
 LOGGED BY W. P. Pratt

APPROVED *[Signature]*
 DATE August 11, 1972

H. G. ACRES LIMITED — CONSULTING ENGINEERS
NIAGARA FALLS, CANADA

DRILLING REPORT

CLIENT Ministry of Transportation and Communications JOB No. P2499.02
 PROJECT Thorold Tunnel Field Investigations HOLE No. OC45
 SITE East Service Building SHEET No. 1 OF 1

CONTRACTOR: Canadian Longyear STARTED p.m. April 19, 1972
Limited FINISHED p.m. April 20, 1972
 METHOD OF DRILLING: ~~SOIL~~ Concrete Diamond Drill CASING DIAM. 6.0 inches
~~ROCK~~ CORE DIAM. 5.778 inches
 LOCATION: ~~DATUM~~ Third Level ELEVATIONS: ~~DATUM~~ El. 557.66 feet
~~DEPARTURE~~ West Wall DRILL PLATFORM
~~BEARING~~ North End GROUND SURFACE
~~INITIAL DIR~~ West ROCK SURFACE
~~OTHER DIPS~~ BOTTOM OF HOLE
 WATER TABLE

DEPTH	Concrete ROCK TYPE	DESCRIPTION: COLOUR, TEXTURE, FOLIATION, JOINTING, FRACTURING, FAULTING, ALTERATION, WATER LOSS OR GAIN, CAVING, LOST CORE, CEMENTING, ETC.	% CORE
0'0" to 2'7"	Structural Concrete	0'0" to 0'10" - Core battered badly by drillers while attempting to remove core from barrel.	
	Concrete Appears Compact and Sound	0'3" Vertical Bars - Run south of core centre line.	
		0'4" - Sliver of horizontal steel on upper surface of core.	
		0'10" - Sliver of vertical steel on north side of core (believe this is sliver of steel that jammed core in barrel).	
		- Ex-hole good.	
		2'7" End of Hole - Core broken manually by drillers at approximately 90 degrees to core axis.	

INSPECTOR W. P. Pratt
 LOGGED BY W. P. Pratt

APPROVED

DATE

W. P. Pratt
 August 11, 1972

H. G. ACRES LIMITED — CONSULTING ENGINEERS
NIAGARA FALLS, CANADA

DRILLING REPORT

CLIENT Ministry of Transportation and Communications JOB No. P2499.02
 PROJECT Thorold Tunnel Field Investigations HOLE No. OC46
 SITE East Service Building SHEET No. 1 OF 1

CONTRACTOR: Canadian Longyear Limited STARTED p.m. April 21, 1972
 FINISHED p.m. April 21, 1972
 METHOD OF DRILLING: ~~SOX~~ Concrete Diamond Drill CASING DIAM. 6.0 inches
~~ROCK~~ CORE DIAM. 5.778 inches

LOCATION: ~~WATITUDE~~ Third Level ELEVATIONS: ~~DATUM~~ Floor El. 554.33 feet
~~DEPARTURE~~ Floor DRILL PLATFORM
~~BEARING~~ Northwest Area GROUND SURFACE
~~WIND DIRECTION~~ Vertical ROCK SURFACE
~~OTHER DATA~~ BOTTOM OF HOLE
 WATER TABLE

DEPTH	Concrete ROCK TYPE	DESCRIPTION: COLOUR, TEXTURE, FOLIATION, JOINTING, FRACTURING, FAULTING, ALTERATION, WATER LOSS OR GAIN, CAVING, LOST CORE, CEMENTING, ETC.	% CORE
0'0" to 0'4"	Industrial Topping	0'4" Core Break - Core split during drilling at interface between industrial topping and concrete slab. - Ex-hole well centred.	
0'4" to 1'8"	Structural Concrete Concrete Appears Compact and Sound	0'9" North/South Steel Inter- cepted - Runs east side of centre line. - Core is badly cracked between bars and around east side of circumference. 1'8" End of Hole - Core broken manually by drillers at approximately 90 degrees to core axis. - Ex-hole well centred.	

INSPECTOR W. P. Pratt

APPROVED

LOGGED BY W. P. Pratt

DATE

August 11, 1972

H. G. ACRES LIMITED — CONSULTING ENGINEERS
 NIAGARA FALLS, CANADA

DRILLING REPORT

CLIENT Ministry of Transportation and Communications JOB No. P2499.02
 PROJECT Thorold Tunnel Field Investigations HOLE No. OC47
 SITE East Service Building SHEET No. 1 OF 1

CONTRACTOR: Canadian Longyear LIMITED STARTED p.m. April 21, 1972
 FINISHED p.m. April 21, 1972
 METHOD OF DRILLING: ~~SOIL~~ Concrete Diamond Drill CASING DIAM. 6.0 inches
~~ROCK~~ CORE DIAM. 5.778 inches
 LOCATION: ~~LATITUDE~~ Third Level ELEVATIONS: ~~EASTING~~ Floor El. 554.33 feet
~~DEPARTURE~~ Floor DRILL PLATFORM
~~BEARING~~ Northeast Area GROUND SURFACE
~~WIND DIRECTION~~ Vertical ROCK SURFACE
~~OTHER DATA~~ BOTTOM OF HOLE
 WATER TABLE

DEPTH	Concrete ROCK-TYPE	DESCRIPTION: COLOUR, TEXTURE, FOLIATION, JOINTING, FRACTURING, FAULTING, ALTERATION, WATER LOSS OR GAIN, CAVING, LOST CORE, CEMENTING, ETC.	% CORE
		Hole abandoned due to presence of too much steel in core.	

INSPECTOR W. P. Pratt

LOGGED BY W. P. Pratt

APPROVED

DATE

August 11, 1972

H. G. ACRES LIMITED — CONSULTING ENGINEERS
NIAGARA FALLS, CANADA

DRILLING REPORT

CLIENT Ministry of Transportation and Communications JOB No. P2499.02

PROJECT Thorold Tunnel Field Investigations HOLE No. OC48

SITE East Service Building SHEET No. 1 OF 1

CONTRACTOR: Canadian Longyear Limited STARTED a.m. April 24, 1972
 FINISHED a.m. April 24, 1972

METHOD OF DRILLING: ~~SOIL~~ Concrete: Diamond Drill CASING DIAM. 6.0 inches
~~ROCK~~ CORE DIAM. 5.770 inches

LOCATION: ~~ENTRANCE~~ Third Level ELEVATIONS: ~~DATUM~~ Floor El. 554.33 feet
~~DEPARTURE~~ Northeast Area DRILL PLATFORM
~~BEARING~~ Just East of GROUND SURFACE
~~INITIAL DIP~~ 2'6" x 9'9" beam ROCK SURFACE
~~OTHER DIPS~~ Vertical BOTTOM OF HOLE
 WATER TABLE

DEPTH	Concrete ROCK TYPE	DESCRIPTION: COLOUR, TEXTURE, FOLIATION, JOINTING, FRACTURING, FAULTING, ALTERATION, WATER LOSS OR GAIN, CAVING, LOST CORE, CEMENTING, ETC.	% CORE
0'0" to 0'3.5"	Industrial Topping	0'3.5" Core Break - Core split during drilling at interface between industrial topping and concrete slab. - Ex-hole well centred.	
0'3.5" to 1'7"	Structural Concrete Concrete Appears Compact and Sound	1'7" - No steel intercepted. - Ex-hole well centred. - Core broken manually by drillers at approximately 90 degrees to axis of core.	

INSPECTOR W. P. Pratt

APPROVED

W. P. Pratt

LOGGED BY W. P. Pratt

DATE

August 11, 1972

H. G. ACRES LIMITED — CONSULTING ENGINEERS
NIAGARA FALLS, CANADA

DRILLING REPORT

CLIENT Ministry of Transportation and Communications JOB No. P2499.02
 PROJECT Thorold Tunnel Field Investigations HOLE No. OC49
 SITE East Service Building SHEET No. 1 OF 1

CONTRACTOR: Canadian Longyear STARTED a .M. April 24, 1972
Limited FINISHED a .M. April 24, 1972
 METHOD SON CASING DIAM. 6.0 inches
 OF Concrete.....Diamond Drill
 DRILLING: ROCK CORE DIAM. 5.778 inches

LOCATION: ~~EXTITUDE~~ Third Level ELEVATIONS: ~~RATHM~~ Floor El. 554.33 feet
~~DEPARTURE~~ Floor DRILL PLATFORM
~~BEARING~~ Northeast Area GROUND SURFACE
~~INITIAL DIP~~ Vertical ROCK SURFACE
~~OTHER DIPS~~ BOTTOM OF HOLE
WATER TABLE

DEPTH	Concrete ROCK TYPE	DESCRIPTION: COLOUR, TEXTURE, FOLIATION, JOINTING, FRACTURING, FAULTING, ALTERATION, WATER LOSS OR GAIN, CAVING, LOST CORE, CEMENTING, ETC.	% CORE
0'0" to 0'4.25"	Industrial Topping	0'4.25" Core Break - Industrial topping separated from concrete slab at interface during drilling.	
0'4.25" to 1'7"	Structural Concrete		
	Concrete Appears Compact and Sound	0'10" - Bars run through centre line of core. 0'11" - Bars run through centre line of core.	
		1'7" End of Hole - Core broken manually by drillers at approximately 90 degrees to axis of core.	

INSPECTOR W. P. Pratt
 LOGGED BY W. P. Pratt

APPROVED *W. P. Pratt*
 DATE August 11, 1972

H. G. ACRES LIMITED — CONSULTING ENGINEERS
NIAGARA FALLS, CANADA

DRILLING REPORT

CLIENT Ministry of Transportation and Communications JOB No. P2499.02
 PROJECT Thorold Tunnel Field Investigations HOLE No. OC50
 SITE Tunnel South Tube, East Portal SHEET No. 1 OF 2

CONTRACTOR: Canadian Longyear STARTED p.m. April 24, 1972
Limited FINISHED p.m. April 25, 1972
 METHOD OF DRILLING: SOIL CASING DIAM. 6.0 inches
Concrete Diamond Drill
ROCK CORE DIAM. 5.778 inches
 LOCATION: LATITUDE Roadway ELEVATIONS: DATUM El. 531.87 feet
DEPARTURE Sta. 74 + 17 DRILL PLATFORM
BEARING 5'5" North of GROUND SURFACE
INITIAL DIPS South Wall ROCK SURFACE
OTHER DIPS Hole Normal to BOTTOM OF HOLE
Road Surface WATER TABLE

DEPTH	Concrete ROCK TYPE	DESCRIPTION: COLOUR, TEXTURE, FOLIATION, JOINTING, FRACTURING, FAULTING, ALTERATION, WATER LOSS OR GAIN, CAVING, LOST CORE, CEMENTING, ETC.	% CORE
0'0" to 0'4.5"	Asphalt Topping	0'4.5" Core Break - Core broke during drilling at interface between asphalt topping and concrete slab. - Ex-hole well centred.	
0'4.5" to 4'11"	Structural Concrete	0'4.5" to 0'7" - Vertical crack on west side of core runs down to intersect north/south steel. 0'7" - First layer of north/south steel runs just east of centre line of core. 0'11.5" - Second layer of north/south steel runs through centre line of core.	
	Concrete Generally Sound and Compact. Areas of Voids Apparent	1'0" to 1'5" - Area of voids in north/west quadrant of core. 2'6" to 3'1" - Impression of 12-inch water pipe on north side of core. Maximum indentation of impression is 1.0-inch piece of pipe (portion of south wall of pipe was in fact retrieved).	

INSPECTOR W. P. Pratt
 LOGGED BY W. P. Pratt

APPROVED *W. P. Pratt*
 DATE August 11, 1972

H. G. ACRES LIMITED - CONSULTING ENGINEERS

NIAGARA FALLS, CANADA

DRILLING REPORT

CLIENT Ministry of Transportation and Communications JOB No. P2499.02

PROJECT Thorold Tunnel Field Investigations HOLE No. OC50

SITE Tunnel South Tube, East Portal SHEET No.2 OF 2

DEPTH	Concrete ROCK TYPE	DESCRIPTION: COLOUR, TEXTURE, FOLIATION, JOINTING, FRACTURING, FAULTING, ALTERATION, WATER LOSS OR GAIN, CAVING, LOST CORE, CEMENTING, ETC.	% CORE
		3'2" <ul style="list-style-type: none">- Core broken manually by drillers at approximately 90 degrees to axis of core.- Ex-hole off centre approximately 1/4 inch north of centre line.	
		4'11" End of Hole <ul style="list-style-type: none">- Core broken manually by drillers at approximately 90 degrees to axis of core.- Ex-hole off centre approximately 1/4-inch north of centre line.	

H. G. ACRES LIMITED — CONSULTING ENGINEERS
NIAGARA FALLS, CANADA

DRILLING REPORT

CLIENT Ministry of Transportation and Communications JOB No. P2499.02

PROJECT Thorold Tunnel Field Investigations HOLE No. OC51

SITE Tunnel, South Tube, East Portal SHEET No. 1 OF 2

CONTRACTOR: Canadian Longyear Limited STARTED a.M. April 25, 1972
 FINISHED p.M. April 25, 1972

METHOD OF DRILLING: SOIL Concrete Diamond Drill CASING DIAM. 6.0 inches
ROCK CORE DIAM. 5.778 inches

LOCATION: Roadway Sta. 74 + 10 ELEVATIONS: DATUM El. 531.62 feet
9.5 feet north of DRILL PLATFORM
south wall. Vertical GROUND SURFACE
in north/south plane ROCK SURFACE
Normal to road surface BOTTOM OF HOLE
in east/west plane. WATER TABLE

DEPTH	Concrete ROCK TYPE	DESCRIPTION: COLOUR, TEXTURE, FOLIATION, JOINTING, FRACTURING, FAULTING, ALTERATION, WATER LOSS OR GAIN, CAVING, LOST CORE, CEMENTING, ETC.	% CORE
0'0" to 0'4"	Asphalt Topping	0'4" Core Break - Asphalt topping separated from concrete slab during drilling. - Ex-hole well centred.	
0'4" to 4'8"	Structural Concrete Concrete Appears Compact and Sound Slight Indication of Voids	0'4" to 0'6" - Vertical crack intersects top reinforcing bars. Crack extends across total diameter of core. 0'6" to 0'9" - Conglomeration of reinforcing bars. 0'6" - North/south steel running through centre line of core. 0'8" - Two east/west bars running just north of centre line of core. Bars are in same horizontal plane and are nearly touching. 0'9" - Second layer of north/south steel running through centre line of core.	

INSPECTOR W. P. Pratt

APPROVED

[Signature]

LOGGED BY W. P. Pratt

DATE

August 11, 1972

H. G. ACRES LIMITED - CONSULTING ENGINEERS

NIAGARA FALLS, CANADA

DRILLING REPORT

CLIENT Ministry of Transportation and Communications JOB No. P2499.02

PROJECT Thorold Tunnel Field Investigations HOLE No. OC51

SITE Tunnel, South Tube, East Portal SHEET No. 2 OF 2

DEPTH	Concrete ROCK TYPE	DESCRIPTION: COLOUR, TEXTURE, FOLIATION, JOINTING, FRACTURING, FAULTING, ALTERATION, WATER LOSS OR GAIN, CAVING, LOST CORE, CEMENTING, ETC.	% CORE
		2'6" - Core broken manually by drillers at approximately 90 degrees to axis of core. - Ex-hole well centred.	
		2'6" to 4'8" - Corrugation rings indicating "chattering" drill.	
		4'8" End of Hole - Core broken manually by drillers at approximately 90 degrees to axis of core. - Ex-hole well centred.	

H. G. ACRES LIMITED — CONSULTING ENGINEERS
NIAGARA FALLS, CANADA

DRILLING REPORT

CLIENT Ministry of Transportation and Communications JOB No. P2499.02

PROJECT Thorold Tunnel Field Investigations HOLE No. OC52

SITE Tunnel, South Tube SHEET No. 1 OF 1

CONTRACTOR: Canadian Longyear Limited STARTED .M. April 25, 1972
 FINISHED .M. April 25, 1972

METHOD OF DRILLING: ~~SOIL~~ Concrete Diamond Drill CASING DIAM. 6.0 inches
~~ROCK~~ CORE DIAM. 5.778 inches

LOCATION: ~~DATUM~~ South Wall ELEVATIONS: DATUM El. 537.77 feet
~~DEPARTURE~~ Sta. 74 + 17 DRILL PLATFORM
~~BEARING~~ South GROUND SURFACE
~~ROTARY DRILL~~ ROCK SURFACE
~~OTHER DATA~~ BOTTOM OF HOLE
Water Table

DEPTH	Concrete ROCK TYPE	DESCRIPTION: COLOUR, TEXTURE, FOLIATION, JOINTING, FRACTURING, FAULTING, ALTERATION, WATER LOSS OR GAIN, CAVING, LOST CORE, CEMENTING, ETC.	% CORE
0'0" to 4'8"	Structural Concrete Concrete Appears Compact and Sound	0'3" Vertical Steel - Runs through centre line of core. 0'4.25" Horizontal Steel - Runs through extreme upper portion of core. 0'3.5" to 0'7.5" - Core broken during handling. - Break runs from 3.5 inches. 2'1" - Core broken manually by drillers at approximately 90 degrees to its axis. - Ex-hole off centre by approximately 1/4 inch towards top of core. 2'1" to 3'0" - Corrugation rings indicate "chattering" drill. 4'8" End of Hole - Core broken manually by drillers at approximately 90 degrees to its axis. - Ex-hole off centre approximately 1/4 inch towards top of core.	

INSPECTOR W. P. Pratt

APPROVED *W. P. Pratt*

LOGGED BY W. P. Pratt

DATE August 11, 1972