Golder Associates
CONSULTING GEOTECHNICAL ENGINEERS

REPORT

TO

CANADA CENTRE FOR INLAND WATERS
EFFECT OF PROPOSED MTC TUNNEL

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INTRODUCTION

The hydraulics laboratory of the Canada Centre for Inland Waters is located on filled land in Hamilton Harbour alongside the Burlington Skyway bridge. (Figure 1).

The Ontario Ministry of Transportation & Communications proposes to increase the capacity of the road which the bridge carries and one of the schemes proposed to do this involves the construction of a road tunnel under the entrance to Hamilton harbour. The tunnel would be a concrete box section floated into position and sunk into a previously dredged hole. The inclined approaches to the tunnel would have sloping earth sides and the top of one of them would come within 20 to 30 ft. of the end wall of the hydraulics laboratory.

The question to be answered is "would such an excavation cause any damage to the laboratory?"

Soil and water conditions

The soil and water conditions are known accurately enough from existing information from boreholes made to design the foundation of the CCIW laboratory and the boreholes made at the time of the construction of the existing bridge. The soil conditions are adequately described in the report no. V8159 by Geocon on which the summary given below is based.

The groundwater level is approximately lake level i.e. Elevation 245 to 248. The ground level in the filled area is about 254 O.D.

The fill consists of medium to fine sand with some gravel and is some 15 to 20 feet thick. There is some dense sand and gravel below the fill, and below this is a stratum of compact to dense reddish brown fine to medium sand extending to elevation 110.

This stratum changes gradually into a compact sandy to clayey silt, below which is a stiff grey silty clay. Shale bedrock lies below this. Figure 2.

Laboratory Structure

The laboratory contains a number of concrete tanks, flumes and pipes, and equipment for precise measurement of water levels. The tanks which are below floor level are supported on piles founded at elevations 220 to 230 in the compact to dense sand. The floors are founded on compacted fill.

The remaining portion of the floor slab and the below-slab duct system for the return and distribution of water between the tanks are directly supported on the subsoil. At the present time, there is no evidence of cracking of the concrete walls in the water distribution ducts.

For the efficient operation of the laboratory it is essential that the tanks and ducts do not go out of level and that they do not develop leaks. This means that no cracking of the tanks can be allowed.

Proposed Excavation

It is proposed to make an excavation some 70 ft. deep adjacent to the end of the hydraulics laboratory, the top of the unsupported 1.75 to 1 slope being 20 to 30 feet from the wall of the laboratory. The exact dimensions are not yet known. (Figure 2.)

It is further proposed to put down a wall of flexible concrete cast insitu in a slurry filled trench and extending to about elevation 140 at the tunnel portal i.e. well into the silty part of the dense sand stratum. The purpose of this wall is to cut-off seepage of water into the excavation from the upper more pervious region and so reduce the amount of water to be pumped and increase the stability of the base of the excavation.

Effect of excavation on laboratory structure

During excavation the foundation conditions are changed in two ways:

a) the groundwater level below the structure will be lowered to some extent

b) the stresses in the ground will be changed due to the removal of the weight of excavated soil.

a) Water-lowering

The cut-off wall will reduce the drawdown of the groundwater level below the laboratory, however some lowering will occur. The effect of this lowering is to increase the weight of the soil which lies between the original and the lowered water levels. In compressible soils this causes settlement due to consolidation. In the compact frictional soils at this site movements will be extremely small. The tanks are founded on piles bearing in dense sand and the floors are on pre-loaded fill. We would not expect damage to the structure from this cause.

b) Excavation

The amount of soil to be removed is considerable as will be the change in stresses in the soil which remains adjacent to the excavation. These stress changes will certainly extend below the hydraulic laboratory and below the toes of the piles supporting the tanks.

Since the soil has a finite modulus of deformation the stress changes will çause deformations of the foundation soil. These can be considered for our purposes to be of two types, vertical and horizontal.

The vertical movements will be greatest at the top of the slope and diminish in a direction at right angles to and away from the slope. At a certain distance from the slope the vertical movements will be virtually zero. There is a danger that a hinge may form in the floor system at this point causing rupture of the duct system.

The horizontal movements towards the excavation are also potentially dangerous. Since these decrease in a direction away from the excavation their effect is to stretch the concrete of the tanks and ducts. Small differential extensions can crack concrete. If it is essential to ensure that the concrete will not crack there are two possible approaches to the problem:

a) Estimating Movements

Make a careful estimate of the amount of movement which will occur and the amount which can be tolerated.

b) Pre-stressing

Devise a solution which will maintain the present state of stress in the ground during and after excavation.

Possible Solutions

a) Estimating movements

Theoretically the movements of the soil of the slope, and beneath the laboratory, which will occur when the excavation is made, can be calculated. However there are several practical difficulties.

These are:

a) the calculation is for an elastic material and sands do not behave elastically,

b) values of deformation modulus and Poisson's ratio for the soil must be measured or estimated

c) the result depends on the method of excavation since the soil to be removed cannot be taken out instantaneously as one block.

The theoretical answer may be close to reality for some clays in which Poisson's Ratio is close to 0.5, and there is a reasonable chance of measuring the deformation modulus by laboratory or in-situ tests. For sands the problem is more difficult. Sands do not behave elastically in general. It is extremely difficult to take and test undisturbed samples, and although insitu methods of test, such as the pressuremeter, exist, the relationship of the value of modulus obtained to the true value is unknown because the act of making a hole into which to insert the measuring instrument in itself changes the value of the property to be measured in the volume tested.

The other side of this problem is the estimation of the "stretch" that can occur across a tank before failure of the concrete in tension occurs. This is outside our field of expertise. We do not know if the answer exists.

A system of monitoring vertical and horizontal movements which occur in the normal loading and unloading operations of the tanks should be set up. The accuracy to be aimed at should be 1/2 mm or better.

The results will be of help in interpreting the theoretical analysis.

In spite of the difficulties this approach should be pursued. It is possible that the movements will be small enough over the likely range of values for the modulus of deformation not to crack the tanks.

a) Pre-stressing

The problem is essentially to prevent any change in the existing state of stress in the ground below the building when the excavation is made.

This can be done by transferring the ground stresses at a chosen vertical section, from the soil to a structural unit. This is not a theoretical concept, it has been done before.

Geocon in their report describe an alternative to the unsupported slope comprising a vertical cast in-situ reinforced concrete wall tied back by drilled-in ground anchors. This scheme would not be an acceptable solution to our problem because the anchors would have to be drilled at about 45^{o} in sand underwater and to a considerable depth below both the floor slab and the piles supporting the building and the tanks. Loss of ground in drilling, which could hardly be avoided, could be severely damaging. This was not so in the Geocon scheme which was well away from the building. Even so Geocon rejected the scheme because of uncertainties about anchor loads and construction difficulties. This solution should not be considered.

We give below the principles of a possible solution using an insitu concrete wall pre-stressed against buttresses. Details of strength and depth of wall, length of panels, size and spacing of buttresses, pit excavation and jacking procedure remain to be worked out as does cost. But the method will work.

Principle of Pre-stressed Wall Solution

All of the construction steps described below will be carried out before any water-lowering or excavation takes place on the tunnel scheme. Dredging of the canal bottom and floating in of a tunnel section will have no harmful effect and may go ahead at any time.

Step 1

Construct a reinforced concrete cast insitu wall around that end of the laboratory near the proposed excavation. The depth of the wall to be determined later but certainly not below elevation 140. The wall to be at the closest possible working distance from the laboratory wall. Thickness of wall probably 24 inches.

Step 2

On the outside of this wall, construct, opposite the centre of each panel another such short wall at right angles to the main wall to form a buttress. The buttress to be one panel (say 10 ft.) in length, and about 6 or 8 ft. from the main wall and of maximum thickness compatible with method of construction (say 4 ft.). See figure 3.

Step 3

Sink a timbered pit between each buttress and the adjacent section of wall to a depth to be determined, probably about 50 ft.

The timbering will not be difficult since there is a complete concrete section on one side and a partial concrete section on the other side. The size of the pit is such that the jacking operation described in step 4 is possible.

Water will be met with in this operation. This can be dealt with in a small pit such as this by pumping from a sump in a corner of the pit or, better, by sinking a deep well alongside of and below the pit before digging commences.

As this step proceeds from one buttress to the next the water lowering technique becomes extremely simple, each pit serving as a sump for the next pit in turn.

Step 4

Starting at ground level, the buttress is jacked away from the panel wall to a predetermined load. A strut is then inserted and the jack moved to a lower level and the procedure is repeated. In this manner the force on the outside of the wall is made equivalent to $k_o = 1$ and the reaction is supplied by the buttresses.

It is desirable that the reaction comes from the base of the buttress. This can be assured by boring behind the buttress and filling with a clay concrete of low strength. This is a detail of construction procedure to be worked out on the site.

Step 5

Step 5 is a monitoring step during excavation. It is expected that nothing will happen but movements of the top of the wall and the buttresses must be measured during excavation. Adequate jacking facilities must be available to maintain the force in the buttresses if they yield during excavation. Any yield means that some support up to that time came from lateral soil support and this must be transferred to support from the base. We have made no calculations of base support at this stage but we are confident that a proper design can produce adequate base support.

Step 6

Backfill the pits with concrete leaving the prestressed struts in position.

Conclusions and Recommendations

1. The movements of the laboratory structure caused by the excavation will be small but measurable.

   We recommend that a series of measurements be started forthwith on the vertical and horizontal movements of those parts of the hydraulics laboratory structure and hydraulics installations situated within 100 ft. of the top of the proposed excavation. The accuracy aimed at should be 1/2 mm or 1/50 inch.

The records should include, in addition to movements, date, time of day, temperature, barometric pressure, weather and groundwater level measured in a borehole.

These measurements should record the effect of the normal operation of the laboratory including loading and unloading procedures such as filling and emptying the tanks.

2. There is no danger of collapse of the laboratory structure provided all of the construction operations of the tunnel and approaches are properly carried out.

3. The excavation poses a possible danger of damage to the hydraulic installations which could put them out of action for a considerable time.

4. An estimate of movements based on theoretical concepts should be made but the results should be viewed with reserve because of differences between the assumption made and the actual conditions.

5. A positive preventive measure by pre-stressing the ground below the structure will eliminate horizontal movement and damage to the laboratory. Such a measure is described in principle. An estimate of the cost of such an operation and the time it would take to carry out should be made.

H. Q. Golder, P.Eng.

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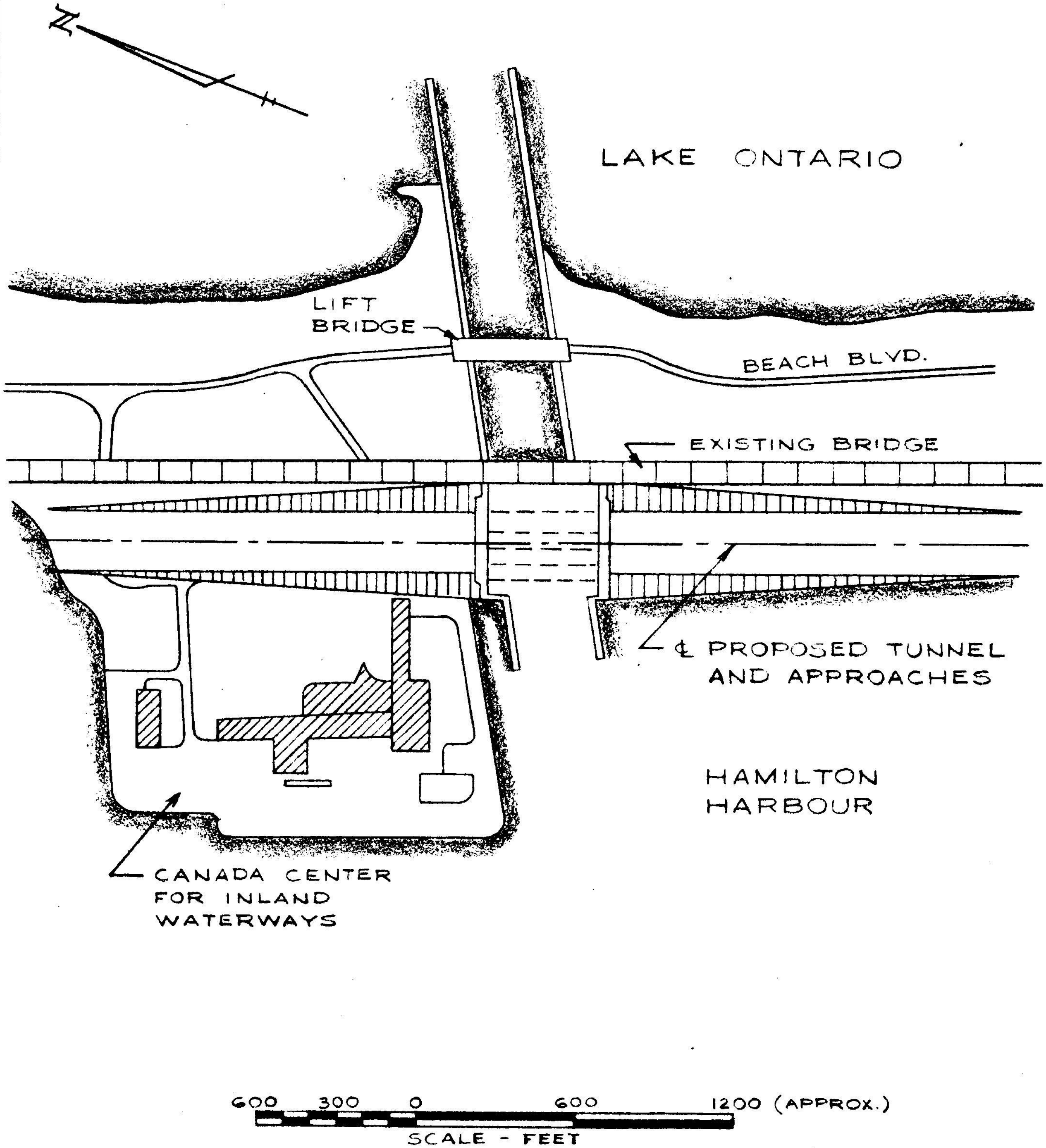
April 22nd, 1974

KEY PLAN

FIGURE 1



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SOIL CONDITIONS AND PROPOSED EXCAVATION

FIGURE 2

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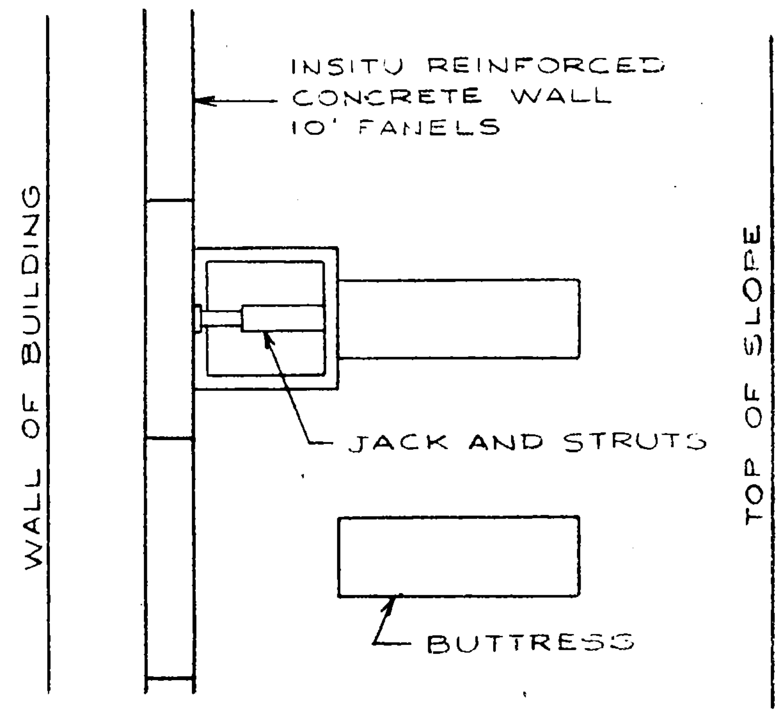
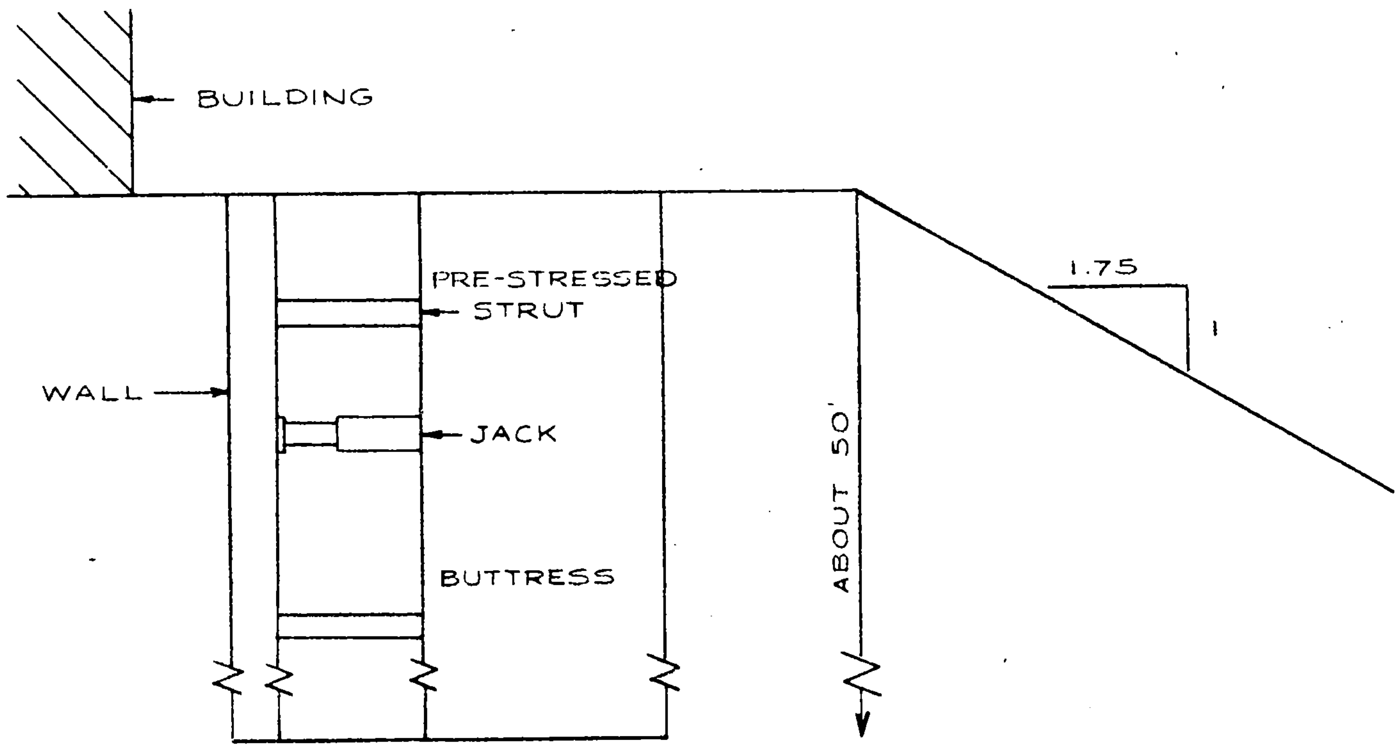
DIAGRAM OF PRE-STRESSING OPERATION

FIGURE 3



PLAN

SCALE: 1" To 8'



ELEVATION

SCALE: 1" To 8'

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