HIGHWAY 407 ETR - EXPRESS TOLL ROUTE
GEOENGINEERING MANAGEMENT
INNOVATIVE PROCEDURES

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ABSTRACT

The design and construction of Highway 407 ETR - Express Toll Route in Toronto required innovative geotechnical management to fast track design and construction to meet the tight construction schedule. The Geotechnical Manager and Quality Control Manager had to work in an integrated manner to develop procedures as the design progressed so that approvals could be obtained on time.

The geotechnical management of the project included advance planning and identification of problems, value engineering, innovative applications and constructability reviews. Site specific solutions had to be found to meet limitations of time and budget.

Innovative solutions for various elements of the project including materials, constructability and design from geotechnical perspective are described in this paper. Lack of adequate geotechnical information was compensated by close monitoring of the work during construction. Cooperation between design, construction and QA/QC resulted in timely solutions to difficult situations.

Key Words: highway design; geotechnical; geoenvironmental; quality; innovation; materials; design build; planning.

1.0 INTRODUCTION

Highway 407 ETR - Express Toll Route is a 69 km multilane electronic toll highway being built north of Metropolitan Toronto to serve as a bypass to the existing MacDonald Cartier Freeway (Highway 401) and to serve as the main artery to the growing residential and industrial development north of Toronto.

The route of the highway was identified by the Province of Ontario in the fifties and preliminary soils investigations and preliminary design reports were completed in the seventies. Design and construction was progressing gradually.

Because of severe congestion on existing routes, the Province of Ontario decided to accelerate the project through a integrated public private partnership approach. Canadian Highways International Corporation (CHIC) was awarded the work in May 1994 to design and build the highway under a fixed price, time certain contract. Fast tracking the project required cost effective solutions to numerous design and construction challenges as well as innovative design and construction techniques.

2.0 METHODOLOGY

The geotechnical and geoenvironmental engineering challenges with respect to highway 407 were recognized during the value engineering stage which took place prior to the request for proposals. It was noted that limitations of time did not permit extensive field and laboratory investigations to be completed prior to arriving at precise design recommendations. Available geotechnical data was calibrated with full scale test results from the area and past performance observations. Additional investigations were conducted where data was not available.

In many instances preliminary design reports were prepared based on existing minimum data and later adjusted as additional information became available. It became apparent in the early stages of design that close geotechnical inspection will be required during the
construction stage to amend or modify the design and construction procedures as the work progressed. This minimized the risk to a large extent.

An important aspect of the project was the requirement for an open and dynamic schedule, which could be altered as priorities changed. This was particularly important for areas where earth works required off site fill and for soft areas which required advanced preloading.

With the large scope, it was necessary to standardize design and construction procedures. These procedures were modified to meet site specific requirements.

3.0 INNOVATIVE GEOENGINEERING MANAGEMENT

3.1 General

Design for the project was carried out through a number of specialized firms working under the direction of CHIC’s Central Design Group. The Central Design Group undertook the responsibility of standardizing design procedures and providing direction to designers so as to minimize variations and designer’s discretion. Uniform specifications were prepared for the project. Variations or deviations from the standards were issued in the form of special provisions. Construction personnel were included in the design review process at an early stage so that constructability issues were addressed well in advance and designs amended or altered as required. Environmental and public concerns midway through the design process required taking totally new approaches to problem solving.

Volume purchase of construction materials well in advance was recognized to keep to the schedules which required uniformity in designs.

3.2 Bridge Foundations

Basically three types of foundations were selected for the bridges: spread footings on native soil or rock; spread footings on compacted granular pads; and pile foundations. In some instances a combination of these three types were used in a single structure to meet the geometric requirements of the structure, availability of property and schedule. No restrictions were placed to construct all of the foundation elements at the same time. This provided better flexibility to the construction personnel to prepare economic schedules. In many instances foundation designs were issued for construction prior to the completion of superstructure designs.

For footings on granular pads, a single specification was used for the granular material and the method of placement. Similarly, a single specification was prepared for backfill of bridge abutments. A single steel “H” pile section 310 x 110 was chosen for the entire project. Minor cost savings resulting from using different pile sections or methods of installing deep foundations were offset by supply problems, wastage and schedule constraints.

Integral abutment bridges were used where feasible. These jointless bridges result in cost savings by eliminating expansion joints. However, they have to be used with caution and must meet certain specific foundation requirements. They require a single row of piles and once committed to construction, the design cannot be easily altered or modified. The piles must penetrate a minimum depth into competent soil to achieve required lateral resistance and to achieve a certain minimum design capacity.
The suitability of these types of foundations were evaluated on a site by site basis. At some locations the ground was hard and integral abutments did not appear to be feasible. As an innovative approach, we decided to preaugur with a small diameter (200mm) pilot hole prior to pile driving to achieve the desired penetration. The pilot hole was stopped at a specific predetermined elevation and the pile was driven in the pilot hole filled with sand to the desired tip elevation. Prior to adopting this procedure an experimental pile was pulled out to ensure that the pile driving shoe was not damaged. Adequate leeway in the design was provided if the pile did not reach the required tip elevation below the preaugured level. This procedure was used in dense gravel, hard till and soft shale bedrock.

At locations where boulders were anticipated in the native tills based on geology and field investigations integral abutments were not used due to the risk of piles meeting refusal to driving at unacceptable higher tip elevations.

At some river crossings, geotechnical investigations revealed the presence of artesian ground water conditions at depth. Earlier construction at these locations by others encountered unstable ground conditions causing delay, redesign and additional cost. Value engineering resulted in using pile foundations with reduced design loads at higher tip elevations without reaching the artesian water stratum. Instead of relying on additional field investigations to study the problem, it was found to be more economical using conservative design approach together with full time field inspection. Monitoring of pile driving operations in the field and additional analysis resulted in accepting higher than theoretical pile tip elevations giving rise to further savings.

3.3 Abutments, Wing walls and Other Structures

Constructabilty reviews carried throughout the design process resulted in innovative applications for retaining structures associated with bridges. Retained Soil System walls were extensively used for retaining structures associated with bridges as false abutments. In several cases the use of these types of retaining structures resulted in reduced spans for the bridges resulting in standard designs. This in turn minimized the variations in depths for precast prestressed concrete girders.

Because of a provincial restriction on the maximum length of girder that could be transported on highways, the spans of standard bridges were limited to fall within the acceptable range. Retained Soil System walls were used in combination with spread footings on native ground, compacted granular pads and both conventional pile foundations and integral abutments.

Approaches to high level ramp structures at freeway to freeway interchange structures presented special problems. Limitations imposed by height, available space and permissible slopes and berms precluded conventional approaches. Retained Soil Systems were engineered in combination with conventional methods of compacted earth and granular fills to achieve the desired results. Slope stability and erosion potential assumed importance in deciding the geometry for the approaches.

During early stages of construction it became apparent that long working hours and night work was required to meet the schedule. This required advancing the highmast lighting construction. Extensive soil investigations were not carried out to determine the subsurface conditions at pole locations for foundation design due to time limitations. Instead, available information at structure locations and along the roadway was interpolated or extrapolated to arrive at the recommended geotechnical design parameters. Any minor adjustments required were made in the field during construction. Three standard foundation caisson diameters were selected for design and construction to enable simplicity in design and construction.
Similar procedures were used for the design and construction of foundations for tolling structures and overhead sign structures.

3.4 Slope Stability

Limitations imposed by property limits, hydro towers, water bodies, the presence of other ramps or roads required some embankment slopes to be steepened. Conventional cantilever retaining walls, gabion walls, Retained Soil System walls were used as appropriate and in combination to contain the slopes as determined by value engineering. Modular toe walls were used in the combination with the above where other alternatives proved to be less economic.

Slope protection consisted of hydro seeding, erosion control blankets, bioengineering and rock rip-rap over geotextile. Where tree planting and landscaping requirements precluded the use of geotextile, composite sand and gravel filter materials were used instead of geotextile. The selection of a particular slope protection covering was based on soil characteristics and environmental considerations.

For stream erosion and scour protection use of broken concrete and small size concrete pavement slabs were permitted to be used in combination with stone. Close liaison was maintained with hydraulic design and environmental personnel.

3.5 Roadway Construction

With an accelerated schedule the earthwork schedule had to be flexible. Climatic conditions imposed restrictions and winter working was inevitable. The working season at stream crossings was restricted by fisheries regulations. Availability of offsite fill was erratic and required the opening of multiple fronts for the placement of fills. Soft ground conditions had to be recognized well in advance of construction to facilitate preloading. During winter months, advance filling was carried out working round the clock to utilize the available offsite fill material and minimize problems associated with frozen fill. Sometimes it became necessary to stockpile fill and to rework the material by spreading and drying it to bring the moisture to within a workable range.

To improve workability of wet soils, Soil Stabilizing Agent (SSA) was used. This byproduct from cement manufacturing was determined to be environmentally acceptable for the specified use. Application of this product for the required purpose was tested ahead and necessary approvals obtained. The use of this product was confined to fill in the lower and intermediate stages of high embankments in areas where borrow soils were extremely wet and earthworks were required to be carried out under inclement weather. The SSA was worked into the fill and left to cure for a minimum of one day. Next day placement and compaction was carried out with ease. As an alternative, borrow areas which were identified to be wet were treated ahead with SSA. This facilitated excavation and transportation of wet soil material. This is the first time SSA was used on a large project to improve workability of wet soils. Further work is presently in progress to establish the suitability of this material for use at the pavement subgrade level.

The availability of large quantities of shale from offsite sources became apparent during construction. The shale bedrock in the Greater Toronto Area contained limestone in thick bands. Excavated shale contained generally large slabs of limestone which required to be broken into smaller pieces prior to delivery or onsite during placement and compaction. Heavy vibratory rollers were used under strict quality control protocol. Mixing with other
soil material was not permitted. The use of shale was limited to preapproved areas. Shale was not permitted to be used within the frost zone to minimize deterioration under climatic conditions. Exposed shale fill slopes were provided with soil cover to facilitate the growth of vegetation.

3.6 Pavements

Early in the design stage it was recognized that surficial soils in the Greater Toronto Area are predominantly glacial tills with minor locations. Therefore, it was not necessary to revisit the pavement design for every intersecting road, ramp and detour. Though the present and projected volume and composition of traffic varied from one intersecting road to the other it was decided to adopt uniform pavement designs generally and allow variations based on site specific local conditions.

Pavement design for detours was standardized with the exception of detours for existing multi-lane freeways and for obviously well developed industrial areas with heavy truck traffic. In all cases the approval of the appropriate local authority was obtained prior to finalization of design.

3.7 Granular Materials

It was noted, in the early stages of construction, that it would be difficult to procure, the required quantities of acceptable quality subbase and basecourse granular material for meeting schedule requirements. Crusher run limestone and pit-run sand and gravel of varying quality were available from different sources. After considerable review, it was concluded that a single crusher run material would meet the requirements of both pavement base and subbase course granular material and as structure backfill. As an innovation we decided to proceed with this approach. Specifications were prepared and extensive testing and calibration was carried out at the crusher, in the laboratory and in the field prior to the submission of revised specifications for approval. Basically the specification exceeded the requirements of subbase granular material but was slightly on the coarser side of the base course material with the maximum size passing 100 percent being 37.5 mm sieve opening. Production samples gave well graded material matching the maximum density chart. This material was designated as modified granular “A” specifically developed for this project. It was exclusively used in mainline pavement and freeway to freeway ramps.

As the production quantity of modified granular “A” material fell short of the total requirements of granular material for the project, other sources of both crusher run and pit-run sand and gravel were identified and used on the project as required. Modified granular “A” material was not exclusively used for connecting roads, sewer backfill, structural backfill or as foundation backfill. Sub-contractors to the project also did not have access to modified granular “A”. They used granular materials from local nearby approved sources were used. The designs accommodated any required changes.

3.8 GeoEnvironmental Considerations

At several locations along the route, soil contamination was found from previous urban and industrial operations. A detailed audit of these areas was carried out by the environment group to classify these materials as acceptable or unacceptable from environmental considerations. The geotechnical group was consulted regarding the utilization of these materials in the project. A similar examination was also carried out for all offsite fill to be delivered to the project.
Environmentally acceptable materials were examined from geotechnical considerations, which included the presence of topsoil, wood and organic materials, large boulders, asphalt, concrete, metals, plastics and other foreign substances. Percentage of foreign material in the soil matrix, in-situ moisture content, compactability and stability characteristics often determined the acceptability of the materials for incorporation into the work.

In one particular instance environmentally acceptable deep fill containing foreign material from domestic sources recognized under the proposed roadway was preloaded in advance so that settlements took place prior to construction of the pavement. In another instance where the onsite fill contained unacceptable quantity of foreign material, it was sorted and reused.

In some instances, the materials were removed from the roadway platform and put in either landscape berms or low fill areas within the right-of-way. Highly toxic and hazardous materials were disposed offsite in accordance with environmental regulations and statutory requirements.

### 3.8 Recycling of Materials

Reuse of granular materials was well planned in advance. Granular materials used for the preparation of false work support were used in bridge abutment backfill. Granular materials used for the preparation of detours were reused as granular bedding for culverts and utility trenches.

Granular materials of poor quality recovered from existing roadways not incorporated into the project were used as fill in earth works.

Recycled asphalt and crushed concrete pavement were used extensively for haul roads and detours. Broken concrete pavement slabs were used for stream bank erosion protection.

Stone recovered from temporary rock check dams and from silt fences were used in slope and stream protection. Clayey material which could not be used in embankment construction was utilized for lining of water management ponds as impervious material. Excess top soil and otherwise unsuitable material were used for slope flattening and berm building.

### 4.0 QUALITY CONTROL

Because of the accelerated schedule, design and construction had to proceed simultaneously. Rules and procedures were established based on value engineering. Strict quality control procedures and protocol to liaise with the design team were established. The importance of geotechnical input at every stage of the project was recognized and the Geotechnical Manager provided consulting services to Construction and QA/QC teams.

To ensure that the requirements of design are met during construction, the level of inspection was specified jointly by the geotechnical and QA/QC teams in advance. Where information was not exhaustive or variations in ground conditions were anticipated, full time inspection by experienced inspectors was specified. The cost saving was apparent in the case of pile driving operations. Temporary protection works were monitored while working close to existing utilities and sensitive heritage houses.

Critical stages of construction were subject to full-time on-site supervision, quality control and coordination with the designers, so that modifications to the procedures and/or materials could be made. Several instances of unanticipated ground conditions were encountered.
during construction. The associated problems were managed using innovative often unconventional geotechnical procedures. The risk associated with the accelerated schedule was managed using close supervision and co-ordination between construction and design with the help of QA/QC team.