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City of Victoria
#1 Centennial Square
Victoria, BC V8W 1P6

Attention: **Mike Lai, P.Eng.**

Dear Sir:

Reference: **Johnson Street Bridge Project – Options, Peer Review**

Introduction

The City of Victoria has retained Stantec Consulting Ltd. to perform a technical peer review of the replacement and rehabilitation options, currently being considered for the Johnson Street Bridge Project.

The replacement and rehabilitation options have been configured to provide similar operational characteristics. Analysis and design for both options has proceeded, but is still at a preliminary level, approximately 20% complete.

Stantec's assignment is to review both options with respect to:

- Design assumptions
- Structural configuration
- Mechanical / electrical aspects
- Price estimate assumptions

We have engaged Beacon Construction Consultants to act as the price estimate reviewer.

The Peer Review is meant to comment on the existing options (rehabilitation and replacement) and will not propose any alternative designs. Due to the early stage of design, it is entirely likely that technical questions raised in this review will be resolved going forward. Therefore, the key finding will be to identify aspects that may not have been explored fully and to ensure that adequate funding to account for these is included in any estimate.

REPLACEMENT OPTION

New Structure

The type of bascule bridge selected for the site is considered appropriate.

The conceptual architectural drawings were in the early stages of structural evaluation. If this option were to proceed we anticipate that the structural design and other requirements will modify the concept in a number of areas:

- Adjustment of the deck level to conform to the existing railway grade.
- Adjustment of the south side walkway elevation to meet navigational headroom requirements from high water level.
- Adjustment in the proportioning of the counterweight lobes to balance the lift span.
- Adjustments in the proportioning of the 'wheel' and mechanical system as required to support the moving span weight.

REHABILITATION OPTION

Electrical & Mechanical Upgrade

The last electrical upgrading of any consequence was done in about 1978, which primarily involved rewinding of the electric motors and rewiring circuits. The mechanical bearings were also checked for wear.

The current design recommends replacement of the existing electrical and mechanical systems. We concur with this recommendation. The main bearings are also identified as being worn and in some cases overstressed and replacement is recommended.

Replacement of the main bearings/bushings is not a simple operation as it requires the temporary support of the movable parts, i.e.

- Main trunnion bearings – these support one end of the lift span. When the lift span is in the down position, the bearings carry high horizontal loads and half the weight of the lift span. If the work is undertaken with the bridge in the vertical position, the horizontal load is reduced but the vertical load is doubled. In either case, temporary works will have to be designed and installed to carry these forces as the bearing shafts are changed. The temporary works for either operation will be complex and costly.
- Bearings at each end of the link member that joins the top of the lift span to the counterweight truss. The force in these bearings is that of the counterweight mass acting to balance the mass of the lift span. With the bridge in the down position, a probable solution would be to temporarily support the mass of the counterweight off a new structure or install some temporary ties on the same alignment as the linking truss. Neither will be a simple operation.

- The main bearings that support the counterweight truss (at the top of the 'A' frame towers) carry a vertical load greater than double the weight of the counterweight. Therefore, the jacking force required for the highway bridge will be at least 1500 tons and for the railway bridge of about 1100 tons. (Note also that this has a horizontal component.) The operation would be less hazardous if the structure was relieved of the counterweight mass while undertaking these operations. We therefore recommend that consideration be given to demolition and recasting of the counterweights as part of the bearing replacement operation. The uncertainty regarding the counterweight condition is also a factor in making this recommendation as follows:

<u>Counterweights Repair/Replacement Issues</u>

The designer should consider the costs and benefits of replacing the counterweights at the time of rehabilitation.

The counterweights are made from both normal weight concrete (the upper-most sections) and a denser concrete at the bottom. It is believed that this concrete was made denser by the addition of rivet punchings into the aggregate. Rivet punchings were also used in the manufacture of 1 ft. cube balancing blocks used to adjust the counterweights mass (these are located within the pockets in the counterweight sides and top). When inspected about 1980, rusting of the punchings was resulting in the disintegration of the cubes.

The counterweights suffer from penetration of water through cracks, hatchways and at structural steel interfaces. Repairs to the counterweights surfaces, necessary because of corrosion activity of steelwork and concrete reinforcement, was undertaken in 2001/2002 and similar work, possibly increasing in magnitude, can be anticipated on about a 10 year cycle.

The cost effectiveness of counterweight demolition and later recasting, phased with the work involved in replacement of the bearings requires evaluation. Bearing replacement with the counterweight mass removed would be considerably easier than bearing replacement with the counterweight in place.

<u>Seismic Rehabilitation – An Explanation of the Issues</u>

Good seismic design accepts that damage to superstructures will occur (where it can be readily inspected and repaired) but that foundations should have overstrength capacity and not be damaged. The existing bridge has been estimated to have a 35% chance of collapsing in the next 50 years, and that could be tomorrow. Seismic upgrading is therefore recommended.

A design criteria for upgrading has been specified for two events of increasing magnitude:

a) 10% chance of occurring in 50 years – the 1 in 478 year event (approximate magnitude 6.5).

b) 3% chance in 75 years; approximately 1 in 2500 year event (approximate magnitude 8.5).

This criteria has also been applied to the analysis and design of the replacement option.

A bridge of this complexity has to be analyzed dynamically, i.e., a computer model that reveals its behavior at varying time periods. Sophisticated programs show how failures develop through a structure (that has redundancy) until collapse occurs. This is also referred to as a 'push-over' analysis. Note that the Johnson

Street Bridge has no redundancies, i.e., when one member fails (and this could be a simple bracing member) collapse will quickly follow.

The full dynamic analysis, not only models the superstructure members, but also includes a 'model' of the restraints imposed on the foundations by the ground. This ground/foundation interaction cannot be produced with the same level of certainty that can be derived for a superstructure of known dimensions and properties that will typically behave elastically. A range of foundation parameters therefore needs to be input and the corresponding effects on the superstructure, from the required range of seismic motions, determined.

If the analysis reveals a weakness in the foundations as well as the superstructure, revised parameters for improved foundations and strengthened superstructure would be inputted and the analysis repeated iteratively until a solution is found that meets the required seismic capacity designs.

However, a rehabilitation concept has been conceived and the preliminary analysis received is commented on as follows:

Review of the Seismic Rehabilitation Scheme

The rehabilitation concept seeks to resolve two issues:

- **Prevent failure of the foundations by anchoring the abutments and rest pier to rock and perform a major upgrade to the main trunnion and counterweight piers.**

- **Upgrade the main trunnion and counterweight pier foundations in a configuration so that its dynamic behavior under seismic excitation minimizes the amount of structural upgrading in the superstructure. Minimizing the amount of intervention in the historic superstructure is in accordance with accepted heritage principles.**

The rehabilitation scheme proposed is based on a dynamic analysis undertaken by Delcan in their Condition Assessment Report. Their finding is that the bridges are most vulnerable to an earthquake acting in the north south direction transversely to the bridge centerlines. This is because the design loads on the original structure were only wind loads. Earthquake loads, acting for instance on the heavy counterweights, were not considered at the time of original design. Indeed, if seismic loads had formed part of the original design criteria, a bridge of the Strauss Trunnion Bascule Bridge type would have been at an economic disadvantage to the rival contender designed by Scherzer. The proposed replacement bridge has its ancestry in the Scherzer design.

The Delcan analysis modeled the pier foundation supported on a large number of piles of variable length due to change in the bedrock profile. It was found by Delcan that the shortest piles failed first and then failure progressed through the others. It appears therefore that analysis considered the piles to fail in bending (as opposed to shear) as the piles are fixed ended into the base of the piers and restrained at the bedrock surface. The stress at which this bending failure would occur was assumed to be 10MPa adjusted further by a short duration load factor of 2.8.

The CHBDC clause used for pile design gives 20.1 MPa for bending and 17 MPa for compression stress. The compression stress in the top of the piles from the dead weight of the piers and steelwork is currently about 2.7 MPa. It can therefore be seen that the net effect of compression capacity being used is small and therefore the capacity in bending (if that is the type of failure assumed) will govern. Using 20 MPa as the limiting stress (and then adjusted for short duration loads) the foundation capacity against failure, for this mode, is therefore probably double over what was assumed.

As foundation failure is probable, the proposed rehabilitation therefore focused on a foundation upgrade and developed a concept of installing 8 steel and concrete shafts into bedrock that would be set into a concrete cap that embraces the tops of the Main Trunnion and Counterweight piers, effectively bracing them in both the North/South and East/West directions. The dimensions of these shafts have been “tuned” to result in a time period (for seismic excitation) of 2 seconds. At this time period the level of forces indicated in the steel superstructure are significantly reduced over what is generated at shorter time periods and correspondingly reduces the amount of intervention required for rehabilitation. The steelwork and bearings upgrade proposed is that needed to meet the magnitude of these induced forces at the 2 second time period.

The normal lateral resistance capacity of a pile (or pile group) is that of a passive soil pressure block acting in the top of the pile zone and not of bending within the pile. One bound of foundation failure is therefore the passive failure of the soils over a block equivalent to the embedded part of the pier concrete and extending some distance down the pile length (the piles are embedded some 1.5m into the concrete piers thus providing some fixing at this point). As the evaluation engineers felt that the soils were too soft for the passive soil resistance to govern, this bound was not examined. We are of the opinion this condition should be evaluated as the detailed design progresses.

As described earlier, the proposed rehabilitation comprises 8 steel and concrete shafts socketted into bedrock that would be set into a concrete cap that embraces the tops of the main trunnion and counterweight piers.

As the combination of a new foundation acting together with the existing piled foundation will be stiffer (in terms of its embedment in the ground restraining it from behaving dynamically compared to the 8 shafts alone) the effect of this combined stiffness needs to be evaluated and the greater amount of upgrading to the superstructure that would be needed evaluated in terms of feasibility and cost. If a structural upgrade to this higher force level proves impractical, then the fall back position would be that the base of the existing piers would need to be severed from the new 8 shaft system. Seismically upgrading a bridge of the Strauss Bascule type is a challenge.

Price Estimate Review

The designer should consider increasing the contingency for the replacement bridge from the 15% provided in the documentation , to 20%.

This review utilized data supplied by the project team and assumed that these quantities are a reasonable representation of the work that will be required. In general terms, on the assumption that the quantities for the materials are correct, then the rates applied to the estimate produce a reasonable assessment of the total cost of carrying out the work.

However, there are some items that are worthy of comment:

- The assumption was made that the new pedestrian/bike bridge will be constructed simultaneously with the rehabilitation work of the existing bridges; should this not be the case, the contractors overhead element of the estimate would need to be increased. It is probable, however, that the foundation upgrading could be undertaken at the same time as the construction of the multipurpose bridge.

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- The percentage addition to allow for contingencies for the rehabilitation option is 25%. The contingency used for the replacement bridge is 15%. While the estimation of new works carries a lower risk, the differential between the percentages is greater than considered advisable, as the present development is very preliminary. An allowance of 20% for contingencies for the replacement is a more reasonable assessment of the risk.

Conclusion

Given the inherent risks that can be expected in the rehabilitation, cost estimates for that option should be set accordingly.

Sincerely,

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