This memorandum provides designers with seismic analysis and retrofit requirements for bridge rehabilitation projects.

**Implementation**

This memorandum is effective as of the date of issue.

**Background**

Design for seismic loading has undergone significant changes since the first edition of the Ontario Highway Bridge Design Code (OHBDC). Seismic loading began as a simple fraction of the structural mass, depending on the structure type, called the Equivalent Static Design (ESD) method. An improved design concept, Force Based Design (FBD), was later introduced to try and capture the dynamic characteristics of the structure and foundation to ensure prescribed ductility and provide capacity protection. However, FBD does not consider post elastic performance of a structure which is a core component of modern seismic design procedures. Therefore, the results and conclusions derived from the FBD method are not entirely reliable (and discussed in a paper by Priestly (1993)).

The Canadian Highway Bridge Design Code (CHBDC) introduced the concept of Performance Based Design (PBD) in 2014. This considers the post-elastic non-linear response of the structural system and produces more reasonable results. PBD and FBD are both applicable in the 2019 version of CHBDC, with FBD still allowed for simpler structures.

The CHBDC has been calibrated for a 75-year design life, although the earthquake frequencies are related to the probability of exceedance in 50 years to match Geological Survey of Canada data. The CHBDC provides some discretion to owners on seismic rehabilitation of existing bridges. It's understood that a full seismic retrofit may not be warranted when pre-existing conditions cannot readily be improved, or where the remaining service life is short.

Similar to the concepts of CHBDC Section 14 on Evaluation (where a reduced Target Reliability Index is tolerated to reflect existing conditions), this memo provides reduced seismic loadings for existing bridges undergoing rehabilitation. The magnitude of seismic event is reduced such that the probability of exceedance of the reduced seismic event throughout the remaining service life is equal to the probability of exceedance of the code specified seismic events for a new bridge throughout it’s full 75-year design life.
Over the past several decades, several groups have provided guidance to building and bridge engineers on evaluating existing structures for seismic loadings. Guidance for bridges were generally produced by the Federal Highway Administration (FHWA), Applied Technology Council (specifically ATC-18 and ATC-40) or Federal Emergency Management Agency (FEMA). When using methods prepared by these agencies, the engineer must understand these methods and use the most appropriate one (with modification when necessary) to satisfy the CHBDC minimum performance levels and performance criteria.

**Policy**

Structural Sections shall determine the Seismic performance Category (SPC) as per this memo and attached Appendix A prior to starting a rehabilitation design assignment.

Seismic analysis requirements for bridge rehabilitations shall be determined as follows:

1. Isolated minor repairs to specific components and holding strategies with an expected remaining service life of 15 years or less do not require any seismic considerations.

2. For all other instances, the Earthquakes with 10%, 5%, and 2% probabilities of exceedance in 50 years described in CHBDC Section 4.4.3.1 shall be replaced by X, Y, and Z respectively depending on the expected remaining service life, as given in Table 1.

<table>
<thead>
<tr>
<th>Remaining Service Life</th>
<th>X%</th>
<th>Y%</th>
<th>Z%</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;60-75+</td>
<td>10.0% (475)</td>
<td>5.0% (975)</td>
<td>2.0% (2475)</td>
</tr>
<tr>
<td>&gt;40-60</td>
<td>15.0% (300)</td>
<td>7.5% (650)</td>
<td>3.5% (1400)</td>
</tr>
<tr>
<td>&gt;30-40</td>
<td>20.0% (225)</td>
<td>10.0% (500)</td>
<td>5.0% (1000)</td>
</tr>
<tr>
<td>&gt;15-30</td>
<td>30.0% (150)</td>
<td>20.0% (225)</td>
<td>7.5% (650)</td>
</tr>
</tbody>
</table>

*In lieu of a more refined analysis, seismic parameters for intermediate seismic events may be taken by linear interpolation (using percentages) of the parameters provided by Geological Survey of Canada. (Approximate Return Period in brackets)*

3. The procedures of CHBDC Section 4 shall be followed to determine the Seismic Performance Category (SPC) and all other requirements using the modified seismic events.

4. Seismic evaluation and retrofit design shall be done according to CHBDC requirements and the associated calculations shall clearly demonstrate the fulfillment of the code requirements. The theoretical validity and compatibility with CHBDC must be established and reported in sufficient detail where the evaluators/designers will use guidelines or manuals other than the CHBDC.
5. When the minimum performance levels of CHBDC Table 4.15 cannot be met due to cost, low remaining expected service life, or other factors, the Structural Section, in consultation with Bridge Office, may specify a higher probability of exceedance seismic hazard (i.e. lower magnitude earthquake) from Table 1 above.

6. When the required scope of rehabilitation is excessive based on CHBDC Section 4 using seismic events outlined in this memo, the Structural Section, in consultation with Bridge Office, may waive or alter certain rehabilitation needs depending on the degree of deficiency, the remaining service life, and other site-specific conditions.

Manager (A), Bridge Office                                 Highway Standards Branch

c: Distribution List (see attached)

APPENDIX A: Seismic Performance Category (SPC) and Seismic Analysis Requirement Calculation Procedure.

Reference:

Distribution List

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Appendix A

Seismic Performance Category (SPC) and Seismic Analysis Requirement
Calculation Procedure.

The following steps shall be taken to determine the SPC and seismic analysis requirements in accordance with the CHBDC.

1. Determine Seismic Importance as per Clause 4.4.2 and MTO Policy Memo 2016-03.

2. Determine response spectrum values for Sa(0.2), Sa(0.5), Sa(1.0), and PGA for the Z% in 50 years earthquake, from Geological Survey of Canada, as per Clause 4.4.3.1.

3. Determine Soil Class based on soil conditions as per Clauses 4.4.3.2 and 4.11.5.2. This can be done using existing soil information, obtained from Bridge files or MTO Foundation Library (http://www.mto.gov.on.ca/FoundationLibrary/index.shtml), and/or consultation with MTO Foundation Section. As a first iteration, a conservative assumption can be made of the soil and the upper bound value determined. For soil Class E or F, it may be advisable to determine the site specific sprecta, as described in Clause 4.4.3.1.

4. Determine PGA_{REF}, based on ratio of Sa(0.2) and PGA, as per Clause 4.4.3.3.

5. Determine the site coefficients, F(0.2), F(0.5) and F(1.0), based on Soil Class and PGA_{REF}, as per Clause 4.4.3.3.

6. Determine design spectral acceleration values, S(T) for a fundamental period of 0.2 and 1.0 seconds, i.e. S(0.2) and S(1.0), as per Clause 4.4.3.4.

7. Determine Seismic Performance Category (SPC) base on design spectral acceleration value, S(T), and bridge fundamental period, T, as per Table 4.10 of Clause 4.4.4.

8. Determine the seismic analysis requirements as per CHBDC Tables 4.11, 4.12, and 4.13.