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DISPLACEMENT-BASED APPROACH FOR SEISMIC DESIGN OF HIGHWAY BRIDGES ACCORDING TO NEW AASHTO GUIDE SPECIFICATIONS

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Following the San Fernando earthquake (1971), significant effort was expended to develop comprehensive design guidelines for the seismic design of bridges in the United States. That effort led to updates of both the AASHTO and Caltrans design provisions and ultimately resulted in the development of ATC-6, *Seismic Design Guidelines for Highway Bridges*, which was published in 1981. That document was subsequently adopted by AASHTO as a Guide Specification in 1983; the guidelines were formally adopted into the *Standard Specifications for Highway Bridges* in 1991, then revised and reformatted as Division I-A. Later, Division I-A became the basis for the seismic provisions included in the *AASHTO LRFD Bridge Design Specifications*. *Iranian Road and Railway Bridges Seismic Resistant Design Code* (Publication No. 463) has been published according to AASHTO Division I-A and most of modern bridges in Iran, has been designed according to that provisions with 475-yr return period earthquake ground motion and 50-year design life.

The new AASHTO guideline was founded on *displacement-based design principles*, recommended a 1000-year return period earthquake, and comprised a new set of guidelines for seismic design of bridges. The title of the guideline reflects the fact that the Guide Specifications are approved as an alternate to the seismic provisions in the *AASHTO LRFD Bridge Design Specifications* which its 8th edition has been published in 2017. New Guide Specifications differ from the current procedures in the LRFD Specifications in the use of displacement-based design procedures, instead of the traditional, force-based "R-Factor" method. This new approach is split into a simplified implicit displacement check procedure and a more rigorous pushover assessment of displacement capacity. The selection of which procedure to use is based on Seismic Design Categories (SDC), similar to the seismic zone approach used in the *AASHTO LRFD Bridge Design Specifications*, Also included is detailed guidance and commentary on earthquake-resisting elements (ERE) and systems (ERS), global design strategies (GDS), demand modeling, capacity calculation, and liquefaction effects. Similar to the LRFD force-based method, capacity design procedures underpin the Guide Specifications' methodology, and these procedures include prescriptive detailing for plastic hinging regions and design requirements for capacity protection of those elements that should not experience damage. The stages for seismic design of highway bridges with this new approach are discribed in flowchart of Figure 1. The first edition of the new Guide Specifications was published in 2009 and the second edition has been released in 2011. Some of computer programs such as SAP2000 and CSi Bridge uses the provisions of the new Guide Specifications for automatic seismic design of bridge structures.

In this study, a typical bridge is modeled and both methods of design (force-based & displacement-based procedures) are applied for seismic design. Demand analysis was performed using response spectrum with 1000-yr return period ground motion. For capacity assessment of bridge piers, pushover analysis was used, because the bridge site has high seismisity (SDC=D). 3D model and pushover curve are shown in Figure 2. If the bridge site is classified to SDC B or C (low to moderate seismisity), designer may use Implicit Procedure to capacity assessment of bridge piers and pushover analysis is not required. Implicit capacity is determined using formulas as follows for SI units:

$$\Delta_C^L = 0.01H_0(-1.27\ln(x) - 0.32) \geq 0.01H_0 \quad \textit{for} \quad \textit{SDC B}, \quad x = \frac{\Lambda B_0}{H_0} \qquad (1)$$

$$\Delta_C^L = 0.01H_0(-2.32\ln(x) - 1.22) \geq 0.01H_0 \qquad \textit{SDC C} \qquad (2)$$

H_0 : clear height of column (mm)

B_0 : column diameter measured parallel to the direction of displacement under consideration (mm)

Λ : factor for column end restraint condition equal to 1 for fixed-free and 2 for fixed top and bottom

D/C ratios for lateral displacement of bridge pier are calculaed and they are fewer than one. The results show that, in the new approach, owner may choose performance level (such as fully operational level) and would assess the lateral displacements of bridge piers in longitudinal and transverse directions but in conventional procedure (force-based method), designer could not predict the performance level in an specified seismic hazard level. The new approach, may be replaced the force-based "R-factor" conventional procedure in future versions of AASHTO and other codes in all around the world. Therefore, bridge designers should learn provisions of the displacement-based design procedures. As a result, bridge designers can choose the new approach for seismic design of bridges and some of programs such as CSi Bridge or SAP2000 may be used for this purpose. Similar approach suggested by FHWA for retrofitting of existing bridge structures which called D2 method.

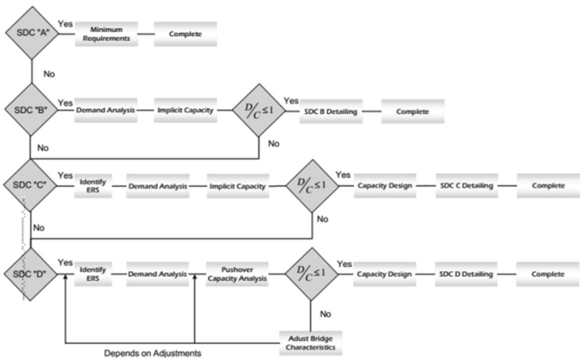

Figure 1. Flowchart for seismic design of highway bridges in each SDC according to the guide specifications.

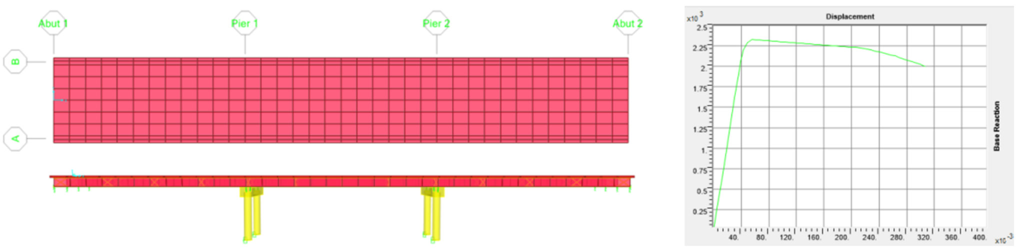

Figure 2. 3D Model of Bridge for Performance-Based Seismic Design (Left Side), Pushover Curve (Right Side).

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