Different Techniques for the Modeling of Concrete Box Girder Bridges

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ABSTRACT:

This paper presents a comparison between response of post-tensioned concrete box-girder bridges analyzed by using different modeling techniques. Each type of modeling technique requires a certain set of assumptions to simplify the problem and thus results obtained from these techniques vary according to the assumptions made. In this study, a typical concrete box-girder bridge is analyzed using commercially available finite element software for two analysis cases, static and modal. Static analysis is used to study the responses of the bridges for dead load, moving load and post-tensioning load cases whereas modal analysis is used to study modal dynamic responses of the bridge. Finally, response of the bridge is compared in terms of natural time periods, mode shapes, support reactions, deformations, and internal forces. This study shows that with proper assumptions, similar results can be achieved from different modeling techniques.

KEYWORDS: Post-Tensioned, Box-Girder Bridge, Finite Element Modeling, Bridge Response.

Nowadays, the use of computer models to perform structural analysis in the field of bridge engineering has become a common practice. Engineers are supposed to use proper model in order to accurately predict the response of the bridge model for design purposes. In recent years, researchers have been developing many modeling techniques that can be used to model a bridge. Each type of modeling techniques requires some set of assumptions to simplify the problem and thus results obtained from these techniques vary according to the assumptions made. Moreover, each type of modeling techniques has its own advantages and disadvantages. Therefore, sometimes engineers use several modeling techniques to model complex bridge structures in order to compare the results and to use them for various purposes.

The modeling techniques being used by engineers to model a bridge range from the simplest one to the highly complex one. The simplest model (spine model) usually comprises of only one single girder to model the bridge deck and hinge or roller supports to model the bearing and abutment. Even though this model is very simple, it is able to give reasonable prediction of the bridge responses under dead load such as maximum displacement and moment at the mid span and support reactions. However, there are many limitations of this model such as transverse analysis of moving load in bridge deck cannot be performed, inaccurate prediction of modal analysis, etc. Therefore, nowadays most of engineers use this model only to do preliminary analysis or sizing of a bridge's components. To overcome some limitations in spine model, a frame/grid model was developed. In this model, the bridge deck is modeled using frames and these frames are connected each other using the diaphragms at supports. In this model, transverse analysis of moving load in bridge deck can be performed. Furthermore, this model gives more accurate prediction of modal responses as compared to spine model. Nevertheless, slab behavior cannot be modeled properly in this model, especially the two-way response including twisting. Frame shell model can be used to improve the accuracy of frame/grid model. In this model, the slab is modeled using shell elements, which means the effects of the slab (both for out-of-plane loads and in-plane stresses) are included explicitly in the model for analyzing purposes. Thus, it can improve the accuracy of analysis results under several load cases. Full shell

model is considered as complex modeling technique for bridge. In this model, all elements are modeled using shell elements. Due to its complexity, sometimes it is difficult to extract information from analysis results for design purposes. However, with the help of powerful analysis software and computers that are available nowadays, this problem can be overcome. Therefore, many engineers have started to use this model in order to get accurate prediction of bridge responses under many load cases.

In this study, a typical concrete box-girder bridge is modeled and analyzed. The bridge has total length of 80 m. The box-girder bridge has two spans of 40 m each and 10 m wide. The clearance of the bridge above the ground level is 7 m. Here, the concrete compressive strength (fc') for the box-girder is 41 MPa and modulus of elasticity of the concrete is 30442 MPa. In this study, the selected bridge has only two lanes for the vehicles. The connection between the deck and pier I restricts the displacement of the deck in X, Y, and Z direction and permits the rotation about X, Y, and Z direction (i.e. hinge support). The connections between the deck and pier II and III permit the displacement along X direction and rotation about X, Y, and Z direction but restrict the displacement along Y and Z direction (i.e. roller support).

In this study, the bridge is analyzed and reviewed for static and modal analysis cases. Static analysis is used to study the responses of the bridge for dead load, moving load and post-tensioning load cases whereas modal analysis is used to study the mode shapes of the bridge. The standard truck HSn-44 (AASHTO) is used for moving load cases. The moving truck loads are applied in both two lanes in opposite direction. For post-tensioning load cases, tendon elements are used as a load pattern on the bridge. The post-tensioning is estimated in such a way that moments produced by the post-tensioning effect should be able to balance most of the moment from dead load.

It is found that all models give first and second mode as longitudinal mode. However, for third mode, spine model show transverse mode, frame model show longitudinal mode, and the other models show torsional mode. The natural periods for first and second mode obtained from all model in average (excluding frame shell model natural periods for calculating average) is around 0.45s and 0.44s. Other than frame shell model, all the model predicts first and second natural period lower than full shell model. Furthermore, it should be noted that in all three modes, frame shell model without any modifications always gives higher natural period which means the structure is more flexible. This happens due to incorrect girder location which in this model, the girder centroid is located at the same elevation as the slab centroid. Thus, it reduces the moment of inertia of the whole section of the bridge and reduces the bridge stiffness. For maximum displacements and moments at middle span, almost all models give approximately same values. The major difference can be found in frame shell model without any modifications. As explained before, incorrect modeling of the girder location causes reduction in the bridge stiffness. Therefore, in this model, the displacement values are higher as compared to other models in all load cases (dead, live, and post-tensioned). Similar results are found for both external and internal reactions from all modeling techniques except spine model. Besides accuracy of analysis results from different technique, it is equally important to account the computational time for each technique. It is found that full shell model takes higher computational time as compared to other modeling techniques.

From the two analysis cases (static and modal) which can be classified as longitudinal analysis, the responses are quite similar between different modeling techniques, except for some cases. It should be noted that proper assumptions are needed to achieve these similar results. Indeed, this is an advantage for engineers who want to do a preliminary design or analysis with a simple model and they can achieve reasonable results. This can save computational effort, cost, and time. However, it may not be the case for transverse analysis which is quite complicated and is not considered in this study. Therefore, it is recommended for future research to investigate the effect of different modeling techniques in the response of post-tensioned concrete Box-girder bridge for the transverse analysis case.