Seismic Performance Verification of the Akashi-Kaikyo Bridge

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Summary

Seismic retrofit work for the Honshu-Shikoku Bridges has recently been launched because there is a concern that seismic risk for the bridges increases. This paper presents a seismic performance verification of the Akashi-Kaikyo Bridge, the world's longest suspension bridge, against large-scale earthquakes that are predicted at the bridge location. In the verification, an analytical model incorporated nonlinear behaviors was used for dynamic analyses. As a result, although some accessory members such as expansion joints or bearings are damaged partially, it was found that taking some minor countermeasures ensured the target seismic performance.

Keywords: seismic performance; dynamic analysis; seismic retrofit; suspension bridge.

1. Introduction

The Honshu-Shikoku Bridges are located in seismic-prone area, where plate boundaries and several inland active faults exist nearby. The bridges were designed based on specific design codes developed for this bridge. In the original seismic design, although site-specific design seismic force was determined in consideration of the information regarding earthquake histories, earthquakes occurring in plate-boundaries and geotechnical conditions around the bridge site, an inland near-field earthquake, such as the 1995 Great Kobe Earthquake, was not considered in the design seismic force. Occurrence of a large-scale earthquake exceeding the design seismic force has recently been predicted by the government, and there is concern that seismic risk for the bridges increases. Besides, the bridges undertake a role as emergency transportation routes in case of a large-scale earthquake since there is no alternative routes. Under those circumstances, Honshu-Shikoku Bridge Expressway Company Limited (HSBE) has been executing seismic performance verification and seismic upgrading works against large-scle earthquakes for the long span bridges.

The Akashi-Kaikyo Bridge is the world's longest suspension bridge with a center span of 1,991 m, and was completed in 1998 overcoming the 1995 Great Kobe Earthquake which occurred during its construction. When the earthquake occurred, all the cable strands were erected and cable squeezing work was in progress. Although the center span length was widened by about 1m due to the movement of ground, the Akashi-Kaikyo Bridge did not receive a serious damage by the earthquake. According to the latest seismic information, seismic performance verification of the Akashi-Kaikyo Bridge has been conducted.

2. SEISMIC PERFORMANCE VERIFICATION

In the verification, after defining seismic performance criteria and site-specific large-scale earthquakes, several analyses which could simulate the nonlinear seismic behavior accurately were performed in order to assess the performance reasonably.

Seismic ground motions of site-specific large-scale earthquakes for the verification, which are larger than the original design one by and large, were estimated by a hybrid method using fault

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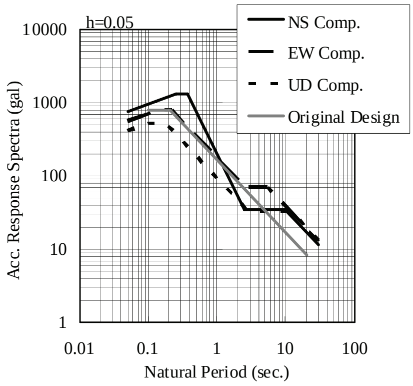
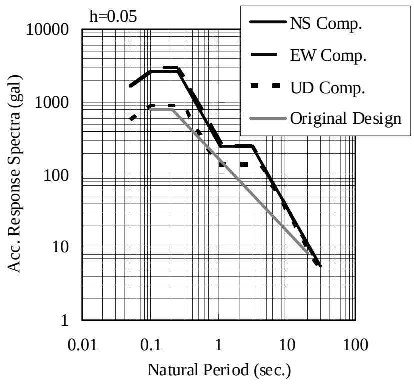
models based on the recent information from government agencies (see Fig.1). After performing nonlinear dynamic analyses with a 3D full bridge model, as shown Fig.2, and FEM analyses with shell models.

As a result, responses of the tower exceeded its buckling strength at the base of tower shafts and the lower horizontal beam, whereas responses of other main structural elements, such as the main cable, suspenders and the girder were within elastic range. In addition, some damages at sub structural elements, such as stoppers at the girder ends, bearings of the steel deck, expansion joints, and oil dampers, were generated.

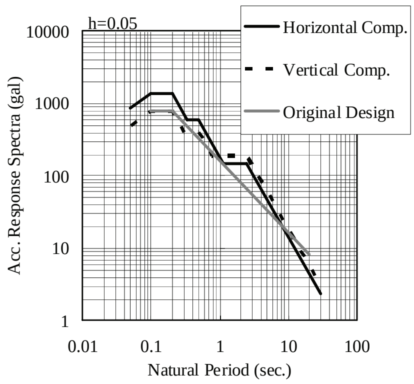
For the damage evaluation of the tower, detailed studies were performed by FEM analyses, which were pushover analyses using shell elements. As the results, it was found that the structure has redundancy beyond the maximum moment of dynamic analyses and the degree of local buckling is small enough to repair it. Besides, there is concern that strengthening of the horizontal beam might lead to the damage of the tower shaft, which is not desirable for the seismic performance of the entire bridge system. Therefore, the damage was assessed to be acceptable. In addition, the damages of other sub structural elements, such as stoppers at the girder ends, bearings of the steel deck and oil dampers, were also assessed to be acceptable since the damages of those elements do not have much influence on operations and functions of the bridge and are repairable under traffic condition. On the other hand, the damage of expansion joints was assessed to be not acceptable. Since expansion joints of the bridge are huge ones, those failures might result in large holes, approximately 2.5-meter-long in the longitudinal direction, on the road surface. Accordingly, there is a fatal possibility that a vehicle might fall from a 60-meter-height during an earthquake. Therefore, a countermeasure for the damage of expansion joint was planned.



(a) Tounankai-Nankai EQ.



(b) Rokko-Awaji Fault EQ.



(c) Unknown Inland Active Fault EQ.

Fig.1:Site-specific Large-scale Earthquake

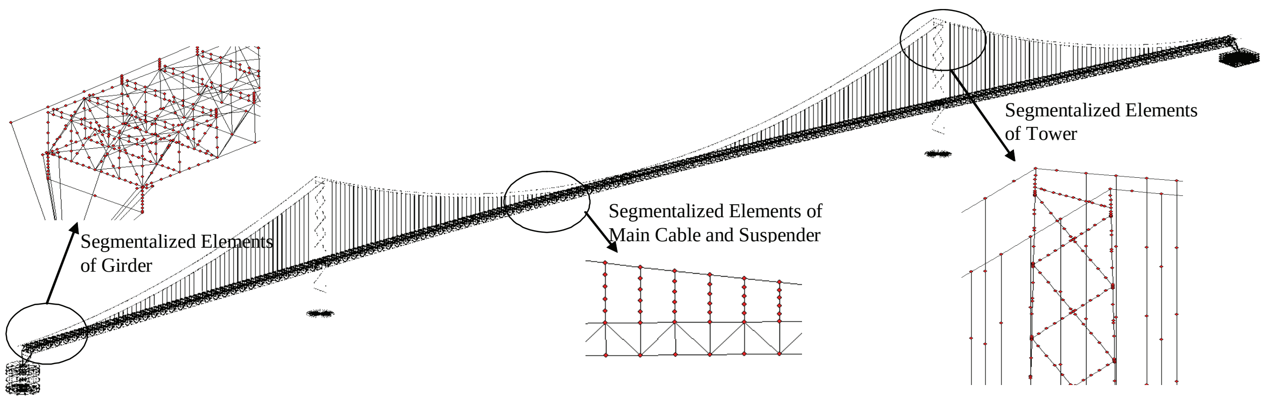


Fig.2:3D Full Bridge Model