Seismic retrofitting of bridges based on indirect strategies

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Summary

An indirect retrofitting scheme for bridges is analytically studied and evaluated. The scheme is based on the reduction in seismic actions of the bridge, namely the displacements of the deck and the bending moments of the piers by utilizing external key walls (barrettes) that participate in the earthquake resisting system (ERS) of the bridge as external supports. Simultaneously, the deck of the bridge is made partially continuous by replacing part of the existing sidewalks by new connecting slabs that are fixed on the existing ones. No strengthening of the existing members of the ERS of the bridge was attempted. The new sidewalk slabs respond as RC structural struts connecting the subsequent simply supported spans of the deck, while sliding on the rest of their lengths. The end spans of the deck are connected with the new key walls (barrettes) constructed behind the abutment. During the bridge service, the part of the RC struts, which are supported by the existing sidewalks, i.e. the unrestraint part of the struts, respond as concrete struts (during expansion of the deck) or ties (during the contraction of the deck). The role of these structural struts is to receive safely the deck constraint movements through their constraint shortening (struts) or lengthening (ties). During an earthquake the movements of the deck are effectively restrained by the external supports namely the key walls (barrettes). Hence, the displacements of the deck and the resulting loading of the existing piers, bearings and foundations are reduced. The effectiveness of the above retrofitting scheme has been assessed on an existing bridge of Aliakmon River, actually built in the early ‘90s. The study revealed that this low cost retrofitting scheme can effectively reduce the seismic demand of the bridge.

Keywords: bridge; retrofit; indirect strategies; reduction of actions.

1. Description of the retrofitting measures

The retrofitting measures included the following two primary interventions. Firstly, part of the lengths of the sidewalks was removed above the piers. The part of the pavement that was replaced covered 3m of the deck on both sides of the piers in the longitudinal direction of the bridge. Two more meters were provided at the ends of these new sidewalks for the connection of the new elements to the existing sidewalks through dowels as shown in Figure 1. This replacement and re-construction of the new pavements was repeated for all the four pier supports of the deck. The described replacement and re-construction technique partially restored the continuity of the deck slab of the MSSS bridge. It is reminded that MSSS bridge systems provide gaps (i.e. expansion joints) above all pier supports. Hence, the simply supported spans are colliding during earthquake causing high pounding forces to the deck. This contact interaction effect can trigger potential unseating mechanisms. This potential can be avoided by the use of cable restrainers in existing bridges that were designed without consideration of seismic forces. As for the connection of the

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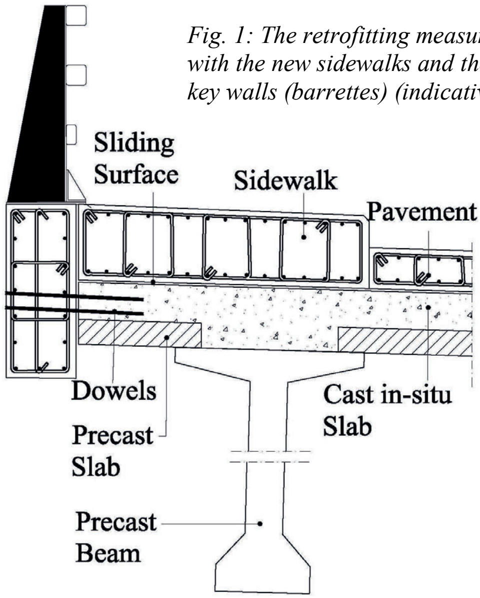

Fig. 1: The retrofitting measures with the new sidewalks and the key walls (barrettes) (indicative)

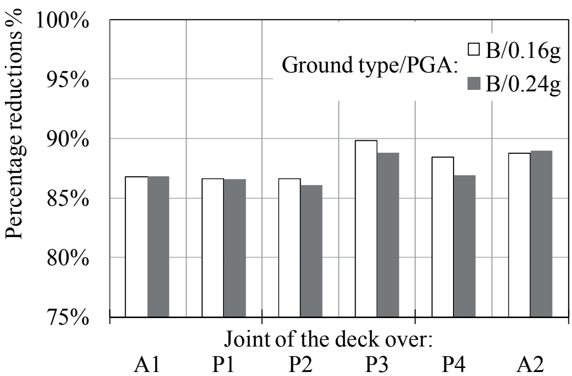

Fig. 2: The percentage movement reductions of the retrofitted bridge

deck with the external key walls this was also achieved by using the same technique. In this case one side of the new sidewalk slabs was connected to the existing deck slab, while the other side of the new sidewalks is restrained by the key walls.

1.1 Conclusions

An indirect retrofitting scheme for existing MSSS bridges was analytically studied. The proposed retrofitting measures were analytically evaluated on the basis of deck's movements and piers' bending moments comparisons between the existing and the retrofitted bridge systems. The study came up with the following conclusions:

The serviceability requirements of the retrofitted bridge can be accommodated by utilizing the allowable cracking of the new sidewalk parts. The new sidewalk slabs, that make the deck slab partially continuous, respond as either struts or ties during the bridge expansion or contraction respectively. During an earthquake the sidewalks transmit a large portion of the seismic action to externally installed key walls.

The analytical investigation showed that the proposed retrofitting scheme reduces effectively the longitudinal and transverse seismic movements of the deck by almost 90% and 58% correspondingly, see Fig. 2. The actions of the piers were also found to be effectively reduced in the retrofitted bridge system. A comparison of piers' bending moments between the existing and the retrofitted bridge revealed that the piers' bending is reduced by almost 68% and 61% under the longitudinal and the transverse seismic motion respectively. The check of the piers and their foundations showed that the foundations of the existing bridge were seismically deficient to receive the current code seismic actions in the transverse direction. The utilization of the proposed retrofitting scheme was found to be adequate to cover the current seismic action requirements. The retrofitting measures are considered to have low cost, as both the materials and the construction do not require specialized work, while communications and traffic are not obstructed, as the construction occupies only the sidewalks area of the deck.