International Association
Bridge Earthquake Engineering

The Third International Bridge Seismic Workshop, 3rd IBSW
Seattle, Washington, USA - October 1st to 4th, 2019

Seismic Risk Analysis and Hybrid Simulation for Function Separation Bridge

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Abstract

The effects and loads on bridges are with great uncertainty and the hazards it liked to be experience are difficult to be predict. In recent years, many bridge structures damaged due to large earthquakes such as Tohoku Earthquakes and Kumamoto Earthquakes. Some of them were designed by the latest performance-based design. It is a wakeup call for engineers to consider the probability of the earthquakes exceeding most considered level in design calculation and the corresponding structural damage. In this study, the concept of Function Separated Bridge is introduced to control the unfunctional time due to damage of key components such as rubber bearings. This study targets Function Separated Bridge and adopts Incremental Dynamic Analysis (IDA) and earthquake risk assessment. It is found out that the main destruction mode of the Function Separated Bridges is that SPD of the abutment break before HDR of the piers break. According to earthquake risk assessment, the risk of Function Separated Bridges is about the half of the traditional isolated bridge. It was also found that Function Separated Bridges is economically and quickly restored by a combination of low cost and easy-to-install bearings considering the earthquake risk, and it contributes to restoration of the damaged area by suppressing loss. On the other hand, to verify its feasibility and evaluate the analysis result, hybrid simulation was also conducted. The whole structure is simulated in numerical model and the only dampers in abutment are loaded in real time.

Keywords: Function Separation, Seismic Response, Incremental Dynamic Analysis, Risk Assessment

1. Introduction

The effects and loads on bridges are with great uncertainty and the hazards liked to be experienced are difficult to be predicted. The complete restoration works of Hanshin Expressway took about 1 year and 8 months after the 1995 Kobe Earthquake. This caused economical loss not only due to damage but also due to blocked facilities. Many damages also have also been found and caused great economical loss in Tohoku Earthquakes and Kumamoto Earthquakes. All these three earthquakes were commonly beyond the design code assigned most considered level at their time. It is a wakeup call for engineers to consider the probability of the earthquakes exceeding most considered level in design calculation and the corresponding structural damage.
Resent year, engineers and scholars realized the importance of considering how to control lost for events that is unlikely to happen though with great consequences. Concepts such as Resilience and Anti-Catastrophe has been one of the most important direction of earthquake engineering.
Taking the resilience of bridge into consideration, a system of multiple energy dissipation and bearing can be considered. In this study, the concept of Function Separated Bridge is introduced to control the unfunctional time due to damage of key components such as rubber bearings. This study targets Function Separated Bridge and adopts Incremental Dynamic Analysis (IDA) and earthquake risk assessment. It is found out that the main destruction mode of the Function Separated Bridges is that SPD of the abutment break before HDR of the piers break.
According to earthquake risk assessment, the risk of Function Separated Bridges is about the half of the traditional isolated bridge. It was also found that Function Separated Bridges is economically and quickly restored by a combination of low cost and easy-to-install bearings considering the earthquake risk, and it contributes to restoration of the damaged area by suppressing loss. On the other hand, to verify its feasibility and evaluate the analysis result, hybrid simulation was also conducted. The whole structure is simulated in numerical model and the only dampers in abutment are loaded in real time.

2. Function Separated Bridge

For Function Separated Bridge, the multiple functions are dispersed into individual damper or bearing due to which even if one device is damaged the whole system will not lose it total functionality. In this study, concept of function decetrolised structure is brought forward with a model consisting of Sliding bearing (to support vertical load), Bingham damper (to absorb deformation such as temperature expansion and contraction and girder), Shear Panel damper (to absorb earthquake energy) and High Damping Rubber(HDR) (to provide horizontal restoring force). All materials and methods that have been used in the work must be stated clearly. Subtitles should be used when necessary.

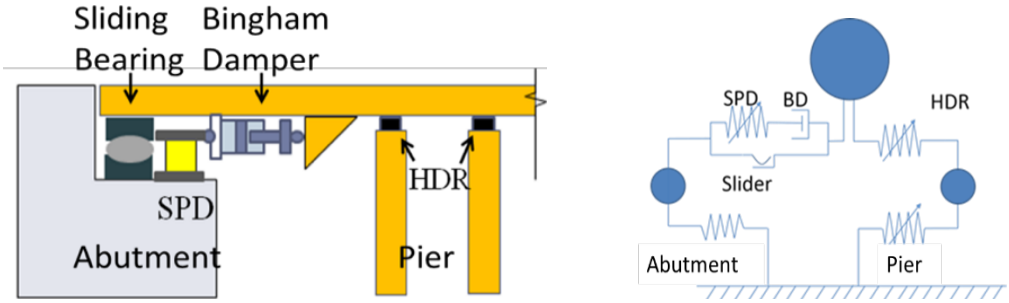

Fig. 1. Function Separated Bridge and its simulation model

3. Recilence Access

The main objective of this study, to evaluate the seismic resilience of function separated bridges, and compare with convenient isolated bridges using HDR only. Here, Incremental Dynamic Analysis were conducted to three structural models and using 100 set of earthquakes. The three structural models are Seismic Bridges, Isolated Bridges and Function Separated Bridges

For each structural model, the earthquake waves were scaled to small Intensity Measure (IM) interval, 10kine in PGV, before being input into the structural models. With the increase of input wave's IM, structural nonlinear response will increase with Damage Measurement (DM) such as response ductility ratio. Until the DM reaching the ultra-limit, such as collapse or facture, the analysis will be continued. The relationship of IM to DM can be summarized as the IDA curves for each earthquake. Using 100 set of earthquakes as input waves, there are total 100 IDA curves can be found.

Finally, the Fragility Curves, showed in Fig.2 can be calculated from those IDA curves. The Fragility Curves from IDA are showing the relationship of damage probability with the increase of IM.

The earthquake risk assessment of Function Separated Bridges was also conducted. The Risk of earthquake damage is shown in Fig.2 quantitatively by the monetary value.

In Fig.2, Function Separated Bridges is compared with other two bridges. The first one is anti-seismic designed bridges without seismic isolation device. The other one is the isolated bridges having HDR. The initial cost of Function Separated Bridges is the same as the one of isolated bridges. But Function Separated Bridges is the lest cost caused by earthquake in each other bridges.

Using inexpensive and easy-to-install devices makes it possible to recover economically and quickly than Isolated bridges. That makes it less the travel time loss and human suffering loss than those of isolated bridges.

According to this research, it was found that Function Separated Bridges is economically and quickly restored by a combination of inexpensive and easy-to-install bearings considering the earthquake risk, and it contributes to restoration of the damaged area by suppressing loss.

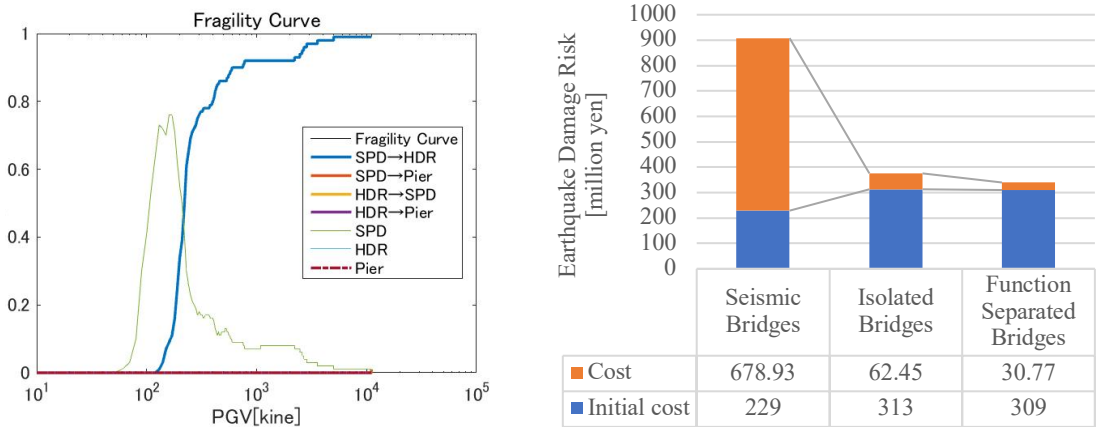

Fig. 2. Fragility Curve and Seismic Risk Assessment

4. Realtime Hybrid Simulation

To verify the analysis model, real hybrid simulation was also conducted in this research. The experiment system was shown in Fig.6.

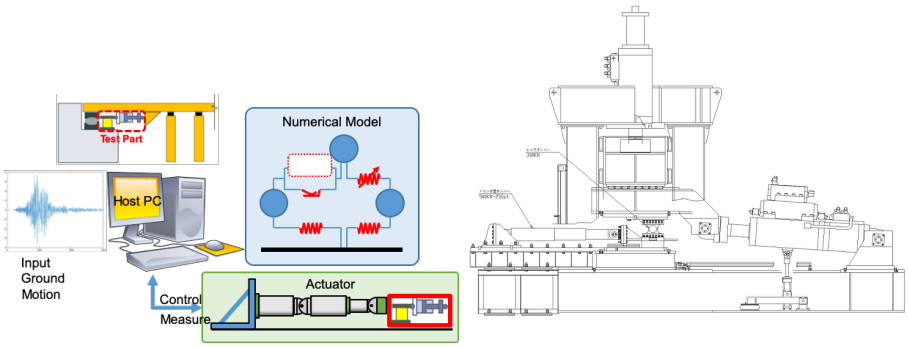

Fig. 3. Hybrid Simulation and Dynamic Loading Device

Hybrid simulation system, as shown in the figure, conducts nonlinear simulation in the host PC, and loading some target members in physical space by loading actuators. Force and displacement measurement feedback were sending back after one step loading and the simulation will correct the step using Predictor-Corrector method in this study. As the Viscos Damper is rate depending member, the loading speed should be real-time.

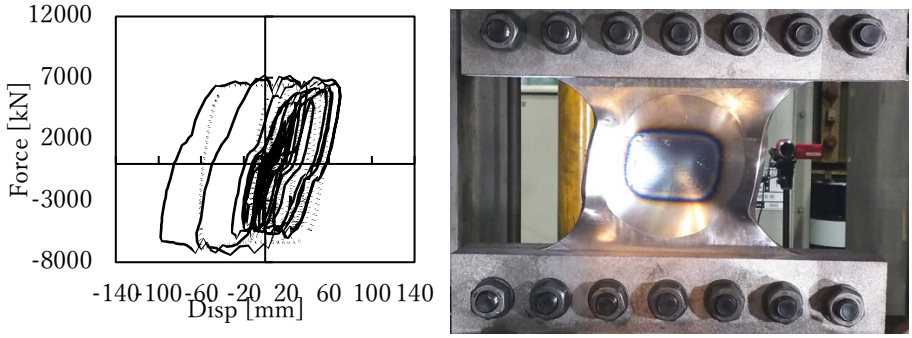

Fig. 3. Hysteresis Curve and specimen after Realtime loading

Real-time hybrid test was conducted using the up-mentioned specimen and loading system. The hysteresis curves from the real-time loading are shown in Fig.9. In the figure, test result was plotted by solid line and numerical simulation by proposed method was plotted in dashed line.

It can be seen that the real loading's response is larger than the simulation. This implies that further experiments were necessary. And the simulation model for the dampers should be updated by more hysteresis rules to consider the hardening effect Low yield point (LYP) steel.

5. Conclusions

In this study, Incremental Dynamic Analysis (IDA) and earthquake risk assessment were conducted for the Function Separated Bridge to evaluate its seismic resilience performance in future large earthquake. It is found out that the main destruction mode of the Function Separated Bridges is that SPD of the abutment break before HDR of the piers break.

According to earthquake risk assessment, the risk of Function Separated Bridges is about the half of the traditional isolated bridge. It was also found that Function Separated Bridges is economically and quickly restored by a combination of low cost and easy-to-install bearings considering the earthquake risk, and it contributes to restoration of the damaged area by suppressing loss.

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