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Sensitivity Analysis of Response of a Cable Bridge with Base Isolation to Material Variation under Near Earthquake

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ABSTRACT: Several factors can influence the response of structures under seismic loading. The specifications of the materials used may differ from the parameters required in the design of structures. This difference can affect the response of structures. In this study, we have tried to investigate the sensitivity analysis of the effects of changing the properties of materials on the seismic response of a suspended cable bridge equipped with RNC isolator. A cable bridge with and without the RNC isolation has been dynamically analyzed after initial modeling under a Sanfernado earthquake record. Then, the effect of random variables on the response of these structures is investigated using Monte Carlo and first order second moment sensitivity methods. Finally, the accuracy of FOSM analysis compared to Monte Carlo method. Two parameters of base shear and maximum deck displacement are considered as structural responses. The results show that among the material characteristics, final strength properties of concrete, reinforcement yield stress and modulus of elasticity of cables have the most influence on the seismic response of these structures. Also, the sensitivity of these parameters in the isolated bridge is lower than that of the non-separated bridge.

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1. INTRODUCTION

Bridges are one of the essential structures in the transportation system [1]. Today, a variety of structural systems of bridges are designed and implemented. One of the most popular systems for bridge construction is the use of a suspended cable bridge system [2]. The construction of bridges in earthquake-prone areas should be carefully considered [3]. Materials specifications, damping, flexibility, span size and such are factors that should be taken into consideration when designing and analyzing these structures [4]. Reducing the effects of seismic load is one of the most important ways to deal with these loads. There are various tools available today to reduce these effects on different structures. One of these methods is the use of energy absorbers such as isolation and dampers [5].

2. RNC ISOLATION

The RNC isolation is one of the recently proposed seismic controllers. The operating mechanism of this isolation is based on the roller movement to convey the minimum movement of the substructure above it. Like most isolators, this isolator is designed for horizontal motion control. The unique rolling configuration is made of a linear gravity-based reflection mechanism and an energy-absorbing (brake) mechanical brake mechanism with the back pedals that cover the inner plates of the upper and lower plates. The horizontal damping in this isolator is caused by a series of hysteretic metal dampers embedded around the roller. Metal surrender dampers are chosen so as to provide sufficient length for expansion motion, reduce the central stress in bending mode and keep the roller motions away from the main body so that they never touch each other. Due to their precise design, these separators do not produce vertical acceleration due to their horizontal movement and acceleration [6]. The schematic figure of this separator is shown in Figure 1.

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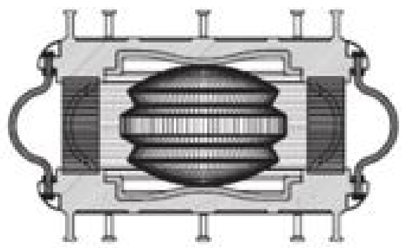

Fig 1. Detail of RNC Isolator

3. METHODOLOGY

There are various methods for evaluating the structural sensitivity to the desired engineering parameters. Three methods: Monte Carlo (MCS), Tornado Diagram, and

FOSM are the most commonly used methods for evaluating the sensitivity of structures. MCS is one of the most precise approaches to the problems of uncertainty analysis and probabilistic analysis. In this method, the random variable is defined as a set of specified values. This input data set produces a set of outputs. Due to its high accuracy, the MCS method is commonly used to validate other probabilistic methods [7]. The MCS method is very time consuming.

In FOSM method, only mean and standard deviation (SD) of random variables are assumed based on their distribution. Mean and SD responses are measured. The standard deviation of this method can be a measure of sensitivity. The main advantage of the FOSM method is that, although simpler in its analysis process than in other methods, the probabilistic characteristics of the structural responses can be obtained [7]

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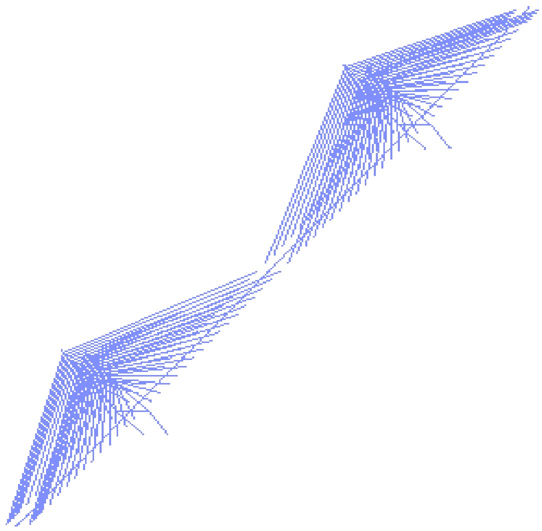

Fig 2. Finite element model of cable bridge

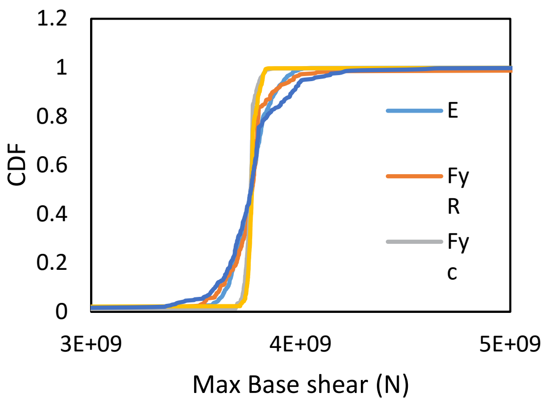

Fig.3 Result of Mont carlo analysis for Maximum base shear of isolated bridge

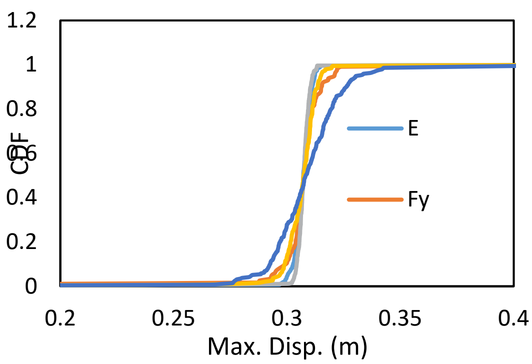

Fig.4 Result of Mont carlo analysis for Maximum deck displacement of isolated bridge

4. RESULTS AND DISCUSSION

Bill Emerson Cable Bridge in Missouri, USA, was used to select the structural model and to conduct the analysis and achieve the research objectives. The finite element model of this bridge in the opensees software is shown in Figure 2.

Concrete ultimate strength, reinforcement yield stress, reinforcement elastic modulus, cable elastic modulus, and cable yield stress were considered as uncertainties in the bridge as random variables in the sensitivity analyzes. For the ultimate strength of concrete, a normal distribution with a mean of 2.8 e + 6 N / m2 and a coefficient of variation of 10% (standard deviation 2.8 e + 5) was used. A lognormal distribution with a mean of 2.4 e + 7 N / m2 and a coefficient of variation of 10% (standard deviation 2.4 e + 6) was used for the reinforcement stress and ect… Figures 1 and 2 show the results of Monte Carlo analysis in the form of CDF curves for seismic separation bridges.

This curve shows how much the maximum displacement of the deck can be reduced by a given earthquake. This curve shows how much of a parameter affects the response of the structures if one considers its probability distribution. A Monte Carlo analysis was performed to evaluate the impact of each parameter on the structural response. In fact, to investigate the impact of each random variable on the seismic response of the structure, a separate analysis was performed using the Monte Carlo method. In each analysis the parameter is considered with its distribution in the analysis and the other parameters are considered in their mean value. The width of the CDF curve can be considered a criterion for sensitivity. The wider the CDF curve, the greater the dispersion of the responses, and the corresponding parameter has been able to create more dispersion in the responses.

5. CONCLUSIONS

The results showed that the bridge with RNC separator was able to reduce the deck displacement and had good control over the horizontal direction of the deck so that the maximum horizontal displacement in the bridge with RNC isolator was 34% less than the bridge without isolator. The results of sensitivity analysis by Monte Carlo method on maximum horizontal displacement of deck show that the sensitivity coefficient for reinforcement modulus of elasticity, reinforcement yield stress, cable yield stress, cable modulus of elasticity and concrete strength in structures with separator 0.059, 0.092, 0.058, 0.082 and 0.1

respectively. The sensitivity coefficient of these parameters in the bridge without isolation is 0.1, 0.2, 0.06, 0.12 and 0.23, respectively. The sensitivity coefficient of these parameters for the maximum base shear for the separated bridge is 0.03, 0.07, 0.045, 0.044 and 0.1 and for the non-isolated bridge is 0.11, 0.17, 0.07, 0.12 and 0.19, respectively. Comparison of the coefficient of sensitivity of the isolated and non-isolated bridges to the random variables shows that the isolated structure is less sensitive to the random variables.

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