Seismic Performance Assessment of Laminated Rubber Bearing on Kadamtaly Flyover

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Abstract

This study is dedicated towards conducting seismic performance assessment is Laminated Rubber Bearing of kadamtali flyover. The flyover isolated by elastomeric rubber bearing subjected to earthquake ground motion records. The isolation system considered in this study consists of a elastomeric rubber bearing, which provides lateral flexibility while supplying high vertical load-carrying capacity. This study describes a technique to estimate the seismic performance on laminated rubber bearing by calculating its strength and deformation from a dynamic time-history analysis using the software Seismostruct. A 3-D model of Kadamtoli Flyover has been constructed and the strength and deformation of rubber bearing has been found. The analytical results show that the seismic responses of rubber bearing are significantly affected by the characteristics of the earthquake ground motion records.

Keywords: Bilinear Model, Dynamic Time History Analysis, Link Hysteretic Curve, Rubber Bearing, Seismic Isolation, Seismic Performance.

1.0. Introduction

1.1. Background

Rubbers are usually considered as incompressible materials. Hence in mechanical testing, the true stress can be readily calculated under the incompressibility assumption to predict the deformed cross section of the specimen. However, there are cases where rubbers under large strains can suffer considerable volumetric change. Although natural rubbers and high damping rubber were used as specimens in this study to display the capability of the device, the device will also be useful in measuring the deformed cross section of other types of highly deformable solids subjected to uniaxial loading (Amin et al., 2003). A study of rubber bearings with thick rubber layers to be used for three-dimensional (3-D) base isolation system is developed. Design parameters of the rubber bearings are determined to effectively reduce both horizontal and vertical seismic loads especially for equipment in the system; horizontal and vertical natural frequencies of the system supported by the rubber bearings are 0.3 Hz and 3 Hz, respectively. Furthermore, primary and secondary shape factors and design vertical pressure of the rubber bearings are determined to give stable mechanical properties. Using scale models of the rubber bearings, static, dynamic and failure tests were carried out to evaluate the mechanical characteristics and the performance of the rubber bearings. From these tests, it is shown that the developed rubber bearings are efficient as 3-D base isolation devices (Yabana et al., 2000). Another study for developing the rubber bearing as 3-D isolators, design targets were reduction of horizontal and vertical seismic loads and good horizontal performances as well as conventional (2-D) rubber bearings. It was determined that horizontal natural frequency and vertical natural frequency of the 3-D base isolation system were about 0.3 Hz and 3 Hz in design to reduce seismic loads. Considering creep of a thick rubber layers, selecting natural rubber and the rubber material was compounded to provide shear modulus of 4.0 kgf/cm^2 (0.39 MPa). From the horizontal tests, it was found that the hysteresis loop was stable and horizontal stiffness relatively agreed with the design value (Ravari et al.).

The laminated rubber bearings (LRB) should be protected from failure or instability because the instability of rubber bearings may result in serious damage to superstructure. Predicting of behavior of LBR usually are obtained from Haringx's theory and have been developed by many researchers and they have proposed nonlinear mechanical model for multilayer elastomeric bearings. Comparisons of theoretical and experimental results show that the present analysis model has good accuracy for analyzing LBR. Examples are presented to demonstrate the validity of the develop method in predicting the horizontal stiffness of laminated elastomeric bearings with different geometric parameters. It has been found that the horizontal stiffness of laminated rubber bearing will increase or decrease according different boundary conditions. An analytical model of multilayer elastomeric isolation bearings has been developed based on the Haringx's theory. By using the initial rotations of bearing as new boundary condition, the movement and rotation equations of bearings have been formulated and the variations of horizontal stiffness of LBR have been investigated. A series of cyclic loading tests under seismic conditions (i.e., axial loading) and worn conditions (i.e., 300 cycles) were conducted to clarify the effect of tensile axial loading on plastic shear deformation of a LBR. Each LRB specimen was subjected to three cycles of lateral deformation that was gradually varied from a global shear strain of 50% to 250%. Hysteretic loops between lateral force and lateral displacement were evaluated to compare hysteretic energy dissipation and equivalent stiffness between an LRB under tensile axial loading and under compressive loading (Shoji et al., 2004). Another study is devoted towards evaluating the seismic responses of a base-isolated highway bridge with different isolators. The mechanical behavior of the bearings as observed is characterized by nonlinear elasto-plastic, strain-rate dependence and strain-hardening features at high strain levels as documented in published papers of the authors. However, the equivalent linear and the bilinear models are used in the analysis for idealizing the mechanical behavior without considering the strain-rate dependence of the bearings. The mechanical behavior of the bridge pier is approximated using the Takeda tri-linear model and the remaining parts of the bridge are idealized using simple elastic model. Two design earthquake ground motions as recommended by codes and specifications, applied in the longitudinal direction, are used in the analysis. The seismic responses of the bridge are evaluated by solving the equations of motion of the bridge system using a standard direct integration method. The parametric studies are conducted for different system configurations and isolation systems. The seismic response of base-isolated bridge is seen to be considerably altered due to the dissimilarity in the isolator properties. Finally, a comparative assessment of the bridge responses shows the sensitivity of isolation bearings" mechanical properties in evaluating seismic responses of the bridge (Haque et al.). The LBR, which provides lateral flexibility while supplying high vertical load-carrying capacity and an auxiliary device made of multiple loops of SMA wires. The SMA device offers additional energy dissipating and re-centering capability. Numerical simulations of abridge are conducted for various near-field ground motions that are spectrally matched to a target design spectrum. The normalized forward transformation strength, forward transformation displacement and pre-strain level of the SMA device, ambient temperature and the lateral stiffness of the rubber bearings are selected as parameters of the sensitivity study. The variation of the seismic response of the bridge with the considered parameters is assessed. Also, the performance of the SRB isolation system with optimal design parameters is compared with an SMA based sliding isolation system (Ozbulut et al. 2010). Moreover, a study is analyzed for two suites near and far field earthquake ground acceleration records. The nonlinearity of the bridge pier is considered by employing a bilinear force-displacement relationship, whereas a visco-elasto-plastic rheology model is employed to evaluate the mechanical behavior of LRB under seismic excitations. The numerical results have revealed that the seismic responses of the bridge system are significantly affected by the characteristics of the earthquakes ground motion records (Bhuiyan et al.).

2.0. Bridge Bearings

2.1. Kadamtaly Flyover

Chittagong Development Authority has undertaken the 940-meter-long and 15-meter-wide project at the cost of Tk 499.787 million to ease traffic congestion at Kadamtali area. The area faces severe traffic jam because of haphazard parking of the inter district buses including the Dhaka-bound coaches. It will be the 3rd flyover of the port city. With construction of the around one kilometerlong and four-lane flyover to be connected between city's old Railway. Station and Dhaniala para over Kadamtali level crossing, it would perform as the alternative of Dewanhat Over Bridge which life-time has already expired and need to be re-constructed. the construction of the flyover will take 15 months to complete.

2. 2. Elastomeric Bearings

Laminated bearings are either fabricated as plain bearing pads (consisting of elastomer only) or as laminated (steel reinforced) bearings (consisting of alternate layers of steel reinforcement and elastomer bonded together). These bearings are designed to transmit loads and accommodate movements between a bridge and its supporting structure. Performance information indicates that elastomeric bearings are functional and reliable when designed within the structural limits of the material. For several years plain elastomeric bearing pads have performed well on prestressed girder structures. Prestressed girders using this detail are fixed into the concrete diaphragms at the supports and the girders are set on 1/2" (13 mm) thick plain elastomeric bearing pads .The design is based on service loads without impact.

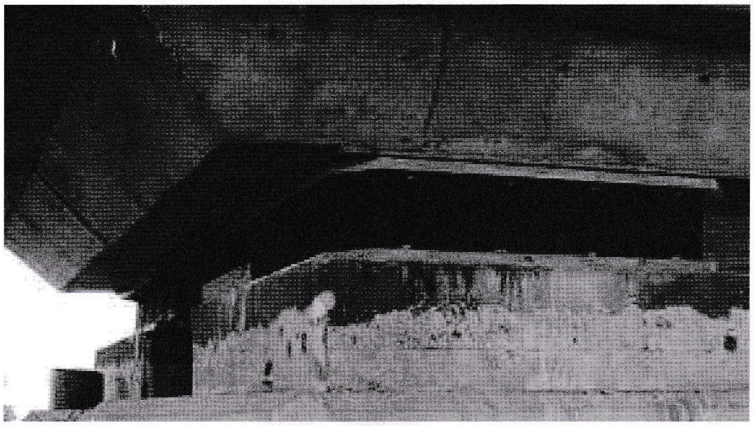


Fig. 1. Laminated rubber bearing.

3.0. Methodology

3.1. Modelling Software (SeismoStruct)

SeismoStruct is an award-winning Finite Element package capable of predicting the large displacement behavior of space frames under static or dynamic loading, taking into account both geometric nonlinearities and material inelasticity. Concrete, steel, frp and sma material models are available, together with a large library of 3D elements that may be used with a wide variety of pre-defined steel, concrete and composite section configurations. The program has been extensively quality-checked and validated, as described in its verification report.

It is recognized that the isolation bearing has generally nonlinear inelastic hysteretic property. Some specifications have specified guidelines for using the bilinear model in order to represent the nonlinear inelastic hysteretic property of elastomeric rubber bearing. In this case, three parameters are required to represent the hysteresis loop of the bearing, initial stiffness k1, post yield stiffness k2 and the yield strength of the bearings.

Table 1. Parameters of the Bilinear model for Laminated Rubber Bearing.

Initial Stiffness, K1(N/mm)	Post yield ratio	Yield Strength(N)
20000	0.005	1000

3.2 Seismic Performance Analysis

Engineers need to know the quantified level of the actual or anticipated seismic performance associated with the direct damage to an individual building subject to a specified ground shaking. Such an assessment may be performed either experimentally or analytically. Experimental evaluations are expensive tests that are typically done by placing a (scaled) model of the structure on a shake-table that simulates the earth shaking and observing its behavior. Such kinds of experiments were first performed more than a 7 century ago. Only recently has it become possible to perform 1:1 scale testing on full structures. Due to the costly nature of such tests, they tend to be used mainly for understanding the seismic behavior of structures, validating models and verifying analysis methods.

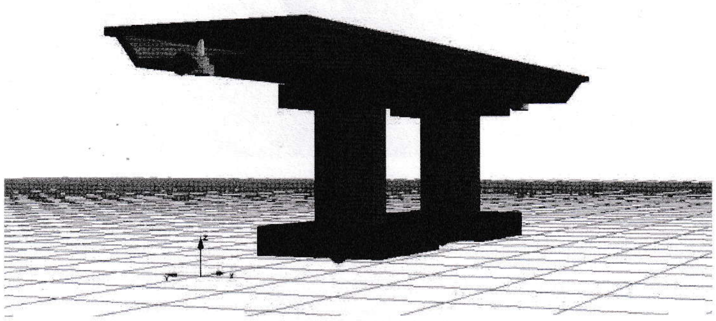
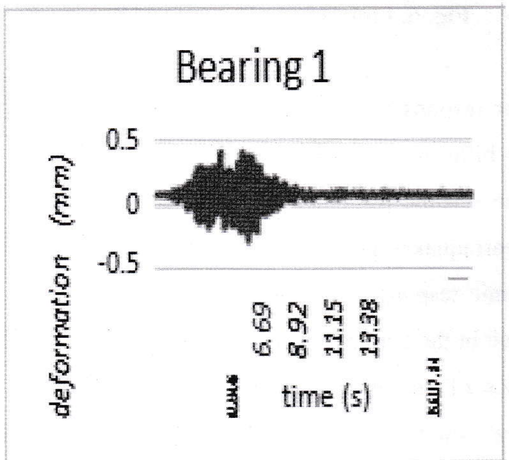


Fig. 2. A 3-D model of Kadamtaly flyover.

The dynamic time history response analysis is conducted on the bridge with elastomeric pads subjected to the ground motions. At each end, a massless rigid link preserves the skewed geometry of the bridge and serves as the connecting element between the bridge deck and the end. In the model, the damping of the bridge deck, pier, pier cap and footing is approximated with the Rayleigh damping approximation, where the parameters are computed by assuming a 4% modal damping ratio in the first and the second modes. In the bearing, it is taken as stiffness proportional damping approximation, where the parameters are computed by assuming a 4% modal damping ratio in the first and the second modes.

4.0. Numerical Result

The time vs deformation curve of bearing 1 is presented in Fig. 3. A bilinear symmetric model for describing the mechanical behavior of rubber bearing is employed with an initial stiffness of 20000N/mm, yield force of 1000N, post yield hardening ratio of 0.005. Damping is not taken into consideration. Here the peak deformation of the bearing is 0.425 mm at the time of 4.10 sec.



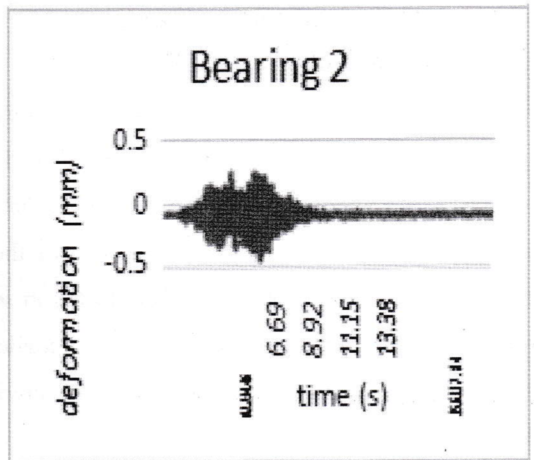


Fig. 3. Time Deformation Curve of Bearing 1. **Fig. 4.** Time Deformation Curve of Bearing 2.

The time vs deformation curve of bearing 2 is presented in Fig. 4. A bilinear symmetric model for describing the mechanical behavior of rubber bearing is employed with an initial stiffness of 20000N/mm, yield force of 1000, post yield hardening ratio of 0. 005.damping is not taken into consideration. Here the peak deformation of the bearing is .425 mm at the time of 4.10 sec.

Constitutive force-displacement response plots are provided in Fig 4 and Fig. 5. Bearing 1 and 2 exhibited stable hysteretic response at high shear strains, with modest degradation of slip force levels upon increasing numbers of slip cycles.

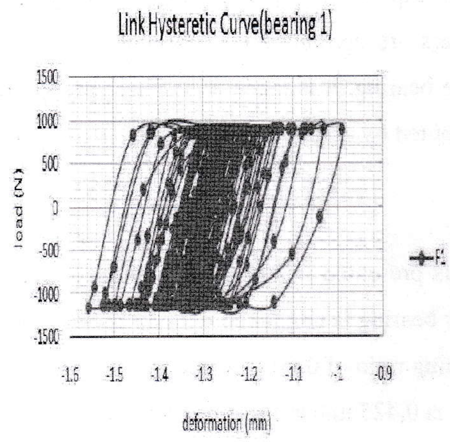


Fig. 5. Link Hysteretic curve of Bearing 1.

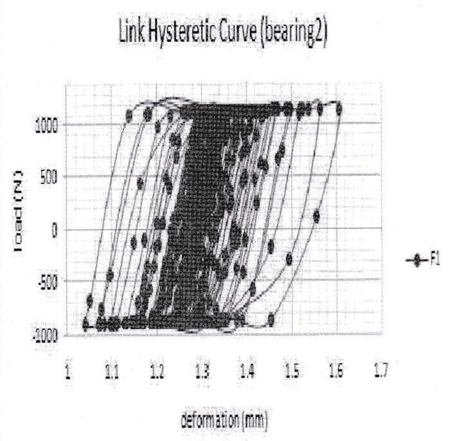


Fig. 6. Link Hysteretic curve of Bearing 2.

5.0. Conclusions and Discussions

Effect of modeling of bearings on the seismic responses of the isolated bridge is evaluated by conducting dynamic time history analyses. The bilinear model is employed for elastomeric bearing. The numerical results have revealed that the seismic responses of the bridge system are significantly affected by the characteristics of the earthquakes ground motion. The consequence effect of this phenomenon has been reflected in seismic responses considered in the current study motion records. From the numerical analysis conducted in the current study it can be concluded that not only the magnitude but the other characteristics of earthquake ground motions also have significant effect on the seismic responses of the bridge which should be carefully considered in the design phase of bridge system. It should be also noted that the selection of the type and modeling approach of isolation bearings may have a remarkable effect on the seismic performance evaluation of highway bridges, which should be carefully considered in the analysis and design steps of any bridge project. The elastomeric bearings satisfactorily restrained the deck displacement and the relative displacement between the deck and the pier for strong ground motion. From the present study, the conclusions may be drawn are (i) The Elastromeric bearing provides stiff connection between the pier and the deck for small external loading, (ii) The Elastromeric bearing satisfactorily restrained the deck displacement and the relative displacement between deck and pier for strong ground motions. (iii) The response quantities of the seismically isolated bridge by the isolator are found to be quite satisfactory. The influence of seismic isolation on the reduction in pier shear in the bridge was impressive for the isolator, (iv) A little isolation can go a long way in reducing seismic forces in simple span bridges. Generally, there was a substantial reduction in deck accelerations and displacement for isolated bridge (compared to the non-isolated case). Within the range of the parametric study of this paper, it is observed that a careful selection of the models of isolation bearings is very important for seismic design of an isolated bridge system.

6.0. Acknowledgement

This paper is a part of research supported by Department of Civil Engineering, Chittagong University of Engineering & Technology, Chittagong. On the other hand, Prof. Dr. Md. Abdur Rahman Bhuiyan, Department of Civil Engineering, CUET, Chittagong, supplied related documents and gave suggestions. The authors acknowledge all the support provided.

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