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BRIDGE BEARINGS – A REVIEW

Arun Mohan C M [1], Sowmya V Krishnankutty.[2]

[1]PG Student, Department of Civil Engineering, FISAT, Angamaly, India
[2]Assistant Professor, Department of Civil Engineering, FISAT, Angamaly, India

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Abstract - *Earthquakes can create serious damage to bridges. Structures already built are vulnerable to future earthquakes. Damage to the structures can cause deaths, injuries, economic losses etc. Earthquake risk is associated with the seismic hazard, vulnerability of the structure and its exposure. Bridges designed earlier where deficient to withstand the effect of future earthquake. The super structure of the bridges were deficient to withstand the effect of future earthquakes. Bearings are the most vulnerable component in resisting earthquakes. Bridge bearings are the components of a bridge which typically provides a resting surface between bridge piers and bridge deck. Purpose of bearing is to allow controlled movement and thereby reduce the stress involved. Various types of bridge bearings are studied in this paper.*

Key Words: Bearings, vulnerability, seismic hazard.

1 INTRODUCTION

Bridge is a structure and its function is to provide passage over an obstacle without closing the way beneath. The required passage may be for a road, a railway, pedestrians, a canal or a pipeline. The obstacle to be crossed may be a river, a road, railway or a valley. There are different types of bridges such as Slab bridge, Beam bridge, Truss bridge, Arch bridge, Cable stayed (or) suspended bridge, Timber bridge, Concrete bridge, Stone bridge, R.C.C bridge, Steel bridge, P.C.C bridge, Composite bridge, Aluminum bridge etc. Bridge is a structure that spans horizontally between the supports, whose function is to carry vertical loads. The prototypical bridge is quite simple consisting of a beam supported by two supports. The supports must be strong enough to hold the structure up, and the span between the supports must be strong enough to carry the loads on the bridge.

Seismic activity is described by geologists as the elastic wave traveling through the Earth followed by an earthquake or geological disturbance. Seismic activity encompasses the frequency, size and type of earthquake. Seismic activity results not only from earthquakes, but from volcanoes and from human activities, such as explosions. Seismologists use Richter scale to measure the magnitude of earthquakes, volcanoes and other seismic activity throughout the world.

Earthquakes can create serious damages to bridges. Bridges which are already built are also vulnerable to future earthquakes. Damages to the bridge can cause deaths, injuries, economic losses etc. Bridges designed earlier were deficient to withstand the effect of future earthquake. The super structure of the bridges were vulnerable to falling down in the absence of restraining devices. Bearings are the most vulnerable component in resisting earthquakes. Bridge bearings are the components of a bridge which typically provides a resting surface between bridge piers and bridge deck. Purpose of bearing is to allow controlled movement and thereby reduce the stress involved. The movement could be thermal expansion, contraction or movement from other sources such as seismic activity. The oldest form of bearing is simply two plates resting on top of each other.

Bridge decks supported by piers are susceptible to damage due to movement of the vehicle and heat expansion. The primary function of the Elastomeric Bearing Pad is to provide a connection to control the interactions of loading and movements between parts of the structure, usually between the superstructure and sub structure. Bearing pads provide a uniform transfer of load from beam to sub-structure allowing the following types of movements of the super structure, Translation movements are the displacements in vertical and horizontal directions due to in-plane or out-of-plane forces like wind and self-weight. Rotational movements can cause due to moments. The main objective of this paper is to study the various types of bridge bearings as these bearings are more efficient in reducing the forces and moments on the bridge.

2 BEARINGS

Bridges supported by abutments and piers require bearings to transfer girder reactions without overstressing the supports, ensuring that the bridge functions as intended. Bridges need bearings that are more elaborate than those required for building girders, columns and trusses. Bridge bearings require greater consideration in minimizing the forces caused by temperature change, friction and restraint against the elastic deformation. A more detailed analysis in bridge bearing design considers the following:

- Bridges are supported by reinforced concrete substructure units, and the magnitude of horizontal thrust determines the size of the substructure units. The coefficient of friction on the bridge bearings should be as low as possible.
- The dynamic forces and the resulting vibrations must be transferred through bridge bearings without causing eventual wear and destruction of the substructure units.

• Bridges are exposed to the elements of nature. Bridge bearings are usually subjected to greater total expansion and contraction movement due to changes in temperature. Since bridge bearings are exposed to weather, they are designed as maintenance-free as possible.

2.1 Bearing types

Bearings may be classified into 4 main categories

- Elastomeric pads.
- Pot bearings.
- Sliding surfaces
- Curved sliding surfaces.

Elastomeric Pads: Elastomeric bearing pads and steel-reinforced elastomeric bearings use elastomers. Elastomeric bearing pads and steel reinforced elastomeric bearings have several advantages. They require low cost and require minimal maintenance. Further, the components can sustain higher values than the design loads, which is useful in case of extreme events which are having low probability of occurrence (earthquakes, for example). Natural rubber or neoprene may be used in the bearings. Elastomers are visco-elastic nonlinear materials and their properties varies with strain level, rate of loading and temperature. Elastomers are flexible under shear and uniaxial deformation, but are very stiff against volume changes. This feature allows for the design of bearings that are stiff in compression but flexible in shear. The shear stiffness of the bearing is the most important property, since it affects the forces transmitted between the super structure and substructure.

Elastomeric bearings: Elastomeric bearing pads include plain elastomeric pads (PEP), cotton duck reinforced pads (CDP), and layered fiberglass reinforced bearing pads (FGP). Elastomeric bearings can easily accommodate small to moderate compressive loads with limited or no rotation and translation, so they are best suited for bridges with small lengths. Translations less than 25 mm and rotations of a degree or less may be accommodated with GFP, whereas smaller values are possible with PEP, and no significant movements are practical with CDP.

Steel reinforced elastomeric bearings: The behavior of steel reinforcement with in elastomeric pads are quite different from plain elastomeric pads. This type of bearings are having uniformly spaced layers of steel and elastomer. The bearing accommodates translation and rotation by deformation of elastomer. Under uniaxial compression, the flexible elastomer would shorten significantly and sustain large increase in its plan dimension, but this lateral expansion is restrained by the stiff steel layers. This restraint induces bulging pattern and provides large increase in stiffness under the compressive loads. This permits steel reinforced elastomeric bearing to support relatively high compressive loads and can accommodate large translations and rotations. The elastomer thickness and the shape factor of the bearing controls the stress in the steel plate and strain in the elastomer. Large rotations and translations require taller bearings.

Pot bearings: The basic components of pot bearings are a shallow cylinder, a pot, an elastomeric pad, a set of sealing rings and a piston. Pot bearings are fixed against translation in all directions unless they are used with a polytetrafluorethylene (PTFE) sliding surface. The pot and piston are made of structural carbon steel, whereas the sealing ring is usually made of a single circular brass ring or a set of two or three flat brass rings. The brass rings are placed on the top of the elastomeric pad.

Vertical load is carried through the piston and is resisted by the compressive stress in the elastomeric pad. The pad is deformable but is almost incompressible and is often idealized as behaving hydrostatically. In practice the elastomer has some shear stiffness. Deformation of the pot wall is a concern, as this deformation changes the clearance between the pot and the piston. This may lead to binding of the bearing or to elastomer leakage. Rotation about any axis is accommodated by deformation of the elastomeric pad. These bearings are designed for a maximum compressive strain of 15% in the elastomer due to rotation. The elastomeric pad compresses on one side and expands on the other during rotation, so the elastomer is in contact with the pot wall and slips against it. This may cause elastomer abrasion and contributes to elastomer leakage. Lateral load is transferred from piston to the pot of the bearing by contact between rim of the piston and wall of the pot. The contact stress may be high because the piston rim may be relatively thin to avoid binding as the piston rotates and the rim slides against the pot. The pot wall must transfer the load to the base plate. The load is then transferred to the substructure through friction action under the base of the bearing and shear in the anchor bolts.

Sliding surfaces: Lubricated bronze and polytetrafluroethylene (PTFE) are the commonly used components of bridge bearings. Sliding surfaces develops frictional force that acts on the superstructure, substructure, and bearing. Lubricated bronze sliding surfaces are used to accommodate very large translation, and the load capacity is also big as it is only limited by the surface area. The coefficient of friction is 0.07 under initial lubricated conditions. However, it increases to 0.1 as the surface dissipates with time and movement. Coefficient of friction in the order of 0.4 may be expected after the lubrication has completely dissipated.

PTFE sliding surfaces are used to accommodate large translations, when combined with spherical or cylindrical bearings, large rotations. They develop substantially smaller friction forces than the lubricated bronze bearings. However, they require greater care in design and greater quality control in the construction and installation. PTFE is used with mating surfaces made of smooth stainless steel or anodized aluminum. The stainless steel is larger than the PTFE surface to achieve full movement without exposing the PTFE. The steel plate is typically placed on the top of PTFE to prevent contamination with dust or dirt. They are used in combination with a wide range of other bearing systems. PTFE requires replacement after a period of time as it wears under service conditions. Low temperatures, fast sliding speeds, rough mating surface, lack of lubrication, and contamination of the sliding interface increase the wear rate.

Curved sliding surfaces: Bearings with curved sliding surfaces consists of spherical and cylindrical bearings. They are a special case of lubricated bronze or PTFE sliding surfaces. They are used primarily to sustain large rotations about one or more axes, and are fixed against the translational motion. The rotation occurs about the centre of radius of the curved surface. The maximum rotation is limited by the geometry and clearances of the bearing. These bearings develop horizontal resistance by virtue of the geometry. The lateral load capacity is limited and large lateral loads require an external resisting system. The centre of rotation of the bearing and the neutral axis of the beam seldom coincide, and this eccentricity introduces additional translation and girder end moment. An additional flat sliding surface must be added if the bearing is to accommodate displacements or to reduce the girder end moment. The inside and outside radii of the spherical and cylindrical bearings must be controlled accurately and machined to assure good performance. When using PTFE, a small tolerance between the two radii and a smooth surface finish is required to prevent wear, creep, or cold flow damage due to non-uniform contact and to ensure a low coefficient of friction.

3 LITERATURE REVIEW

Various literatures reviewed on bearings are presented in this section. A number of works have been performed on seismic assessment. A review of literatures is presented in brief summarizing the work done by different scholars and researchers.

Nikolay Kravchuk, Ryan Colquhoun & Ali Porbaha(2008), The objective of the study was to model the concept of base isolation systems and verify the reduction in the lateral response due to seismic event. The difference in responses was measured by comparing two identical model structures, one with Friction Pendulum Bearing base isolation system and other without any base isolation. After extensive testing on a Shake Table, the structure with Friction Pendulum Bearing base isolation showed a significant decrease in the lateral acceleration due to varying lateral forces. The maximum lateral acceleration observed for base isolated structure was 0.23g which was less than half of the non-base isolated structure that experienced a maximum lateral acceleration of 0.57g. The calculated damping of each structure showed a similar trend with base isolated structure having a damping of 0.085 which was more than five times greater than the non-base isolated structure with a damping of 0.016. Overall the Friction Pendulum Bearing base isolated system showed significant improvement in the dynamic response of the model structure by reducing the lateral acceleration and increasing the damping of the system.

M. N. Haque, A. R. Bhuiyan& M. J. Alam (2010) In this paper the response of a five-span continuous deck girder bridge seismically isolated with laminated rubber bearings acted upon by unidirectional earthquake ground motion is presented. Three different types of isolation bearings are used to investigate the effect of isolation over bridge system. These bearings are modeled using the design model as specified in the manual for highway bridges (JRA 2004): the bilinear model is employed for modeling Lead Rubber Bearing (LRB) and High Damping Rubber Bearing (HDRB), and the equivalent linear model for Rubber Bearing (RB).It should be noted that a set of parameters corresponding to the design models are estimated using the design equations as specified in JRA (2004). In this paper, bridge responses are discussed in terms of the base shear of the pier, deck acceleration, displacement of deck & pier top force, since these responses are predominant for the seismic design of bridge systems. The effect of laminated rubber bearings is significantly observed in the responses indicating that the isolation reduces the response of stiff bridge system significantly and can be used effectively to design a safe bridge system.

Ankit Gupta, DiwakarprakashVerma, Jagdish Singh Dasouni and GirijaShanker(2014) Design of POT-PTFE bearing is governed by minimum average stress on the PTFE disc, elastomer pad and the plate at which the system is fixed. It is evident that the maximum stress developed in PTFE disc, elastomer pad and top plate is considerable as a safe design. It is also evident that the stresses developed in the POT- PTFE bearing is also under critical stress as per the design consideration. This work concludes that the POT PTFE bearing is useful where heavy load is under consideration. It is also mentioned that POT-PTFE bearing is the best replacement of roller bearings which is widely used in the bridges.

Vijay Krishna Pandey&VikashSrivastav (2015)

Conducted study on the response of an isolated and non-isolated bridge . Two types of isolation bearings viz. Lead Rubber Bearing (LRB) and Friction Pendulum System (FPS) have been considered. It is found that the isolated bearings reduce the seismic response of non-isolated bridge. They concluded that for a given time period and damping the LRB is more efficient in reducing the pier force and moment than FPS, Also FPS bearings are more effective in reducing deck displacement than LRB.

J. Lopez Gimenez, T.Himeno, H. Shinmyo & T. Hayashikawa(2015)

The seismic response of the curved viaduct models isolated with elastomeric-type and sliding-type isolation bearings subjected to great earthquake ground motions has been analysed. The overall seismic performance of the isolated viaducts has been analyzed focusing on their fundamental periods, mode shapes, bearing displacements, deck accelerations, and piers response, and considering two different cases depending on the configuration of the isolators. The obtained results the following conclusions are made. Allowing isolation bearings to move in both horizontal directions increases the effects of the seismic isolation, improving the seismic response of the viaduct regardless of the type of isolator. When compared to viaducts equipped with Spring Confined Pb High Rubber Bearings(SPR-S) supports, FPS viaducts present larger periods of vibrations. In the event of near-fault earthquakes characterized by high peak accelerations and large predominant periods, these viaducts present larger displacements but lower deck accelerations. The lower restoring forces of the FPS supports imply lower energy dissipation capacity but, at the same time, reduce the forces transmitted to the piers of the viaduct. Bridge models equipped with SPR-S supports showed lower bearing displacements, but larger deck accelerations in majority of cases. SPR-S isolators present remarkably high energy dissipation capacity. When allowed to move in both horizontal directions, protect the piers from seismic damage under the action of the strong earthquake ground motions taken into account in the current study.

4 SUMMARY AND CONCLUSION

A brief review of several literatures presented shows that bearings proves to be efficient for reducing the effects of the damage caused by the bridge by seismic activities. These bearings are more efficient in reducing the forces and moments on the bridge. They are also effective in reducing the deck displacement. Seismic behavior of various bearings are different. There is future scope for further study in this area to find the most efficient bearing.

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