Lead Rubber Bearings as Base Isolating Devices for the Construction of Earthquake Resistant Structures-A Review

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Abstract-

Base isolation, also identified as seismic base isolation or base isolation system, is one of the utmost means of shielding a structure against earthquake forces. A laminated rubber bearing (LRB) can be used as a base isolator. It consist of steel shims between rubber layers, the LRB practices its flexibility to bend seismic waves and, through plastic deformation absorbs the energy from the vibrations. Furthermore its lead core assists in supplementary dissipating the energy. LRB is a type of base isolation employing a heavy damping. It was invented by William Robinson, a New Zealander.

Keywords- *Earthquake, Ground Motion, Isolator, Lead Core, Lead Rubber Bearing.*

I. INTRODUCTION

Concept of base isolation appears to have an irresistible attraction to inventors, and many new and different systems of isolators are proposed and patented each year. Many of which might prove to be impractical, but the number continues to increase year by year. Most of the practical systems today incorporate either elastomeric bearings, with the elastomer being either natural rubber or neoprene, or sliding bearings, with the sliding surface generally being Teflon and stainless steel. Rubber bearings offer the simplest method of isolation and are relatively easy to manufacture. The bearings are made of vulcanization bonding of sheets of rubber to thin steel reinforced plates. The bearings are stiff in vertical direction and very flexible in horizontal direction. High vertical stiffness of these bearings is achieved through the laminated construction of the bearing using steel plates. The ratio of vertical stiffness and horizontal stiffness should be high and the desired value is in the range of 200 to 500. The damping achieved from natural rubber is low, of the order of 2 to 4 percent and therefore these bearings are called as “low damping rubber bearings”. It is unusual to utilize it without some other element able to provide some increased damping. Thus for energy dissipation often passive mass dampers are incorporated along with these bearings. However, development of a natural rubber compound with enough inherent damping to eliminate the need for supplementary damping elements was achieved in 1982 by Malaysian Rubber Producers Research Association of the United Kingdom.

Lead Core Rubber Bearings(LRB) consist of a laminated rubber and steel bearing with steel flange plates for mounting to the structure. Ninety percent of our isolators have an energy dissipating lead core. The rubber in the isolator act as a spring. It is very soft laterally but very stiff vertically. The high vertical stiffness is achieved by having thin layers of rubber reinforced by steel shims. These two characteristics allow the isolator to move laterally with relatively low stiffness. The lead core provide damping by deforming plastically when the isolator are cut to exacting tolerances by laser. The steel mounting plates are machined by computer controlled milling machines that give high production throughout and accurately. Molding each bearing takes 8 to 48 hours depending on the size of the bearing. The curing phase is continuously monitored to ensure that the rubber is uniformly cured throughout the bearing. Lead rubber hysteretic bearings provide in a single unit the combined features of vertical load support, horizontal flexibility and energy absorbing capacity required for the base isolation of structures from earthquake attack. Since the invention of the lead rubber bearing, a total of eleven bearings upto a diameter of 650 mm, with lead plugs ranging from 50 to 170 mm in diameter, have been tested under various conditions including vertical loads to 3.15 MN, strokes to +-110 mm, rates from 1 mm/h to 100 mm/s, and temperatures of -35 deg C to +45 deg C.

II. SCOPE AND OBJECTIVES

The lead-plug rubber bearing was invented in New Zealand in 1975 and has been used extensively in New Zealand, Japan and United states. Lead Rubber bearing consists of a laminated elastomeric rubber bearing equipped with lead cylinder at the centre of the bearing. The function of the rubber steel laminated portion of the bearing is to carry the weight of the structure. This bearing consists of alternate horizontal layers of steel and rubber, same as in case of elastomeric bearings. Steel provides the vertical stiffness to isolation system and is rigid under service loads. Whereas, lead core provides energy dissipation and resists excessive displacement under high lateral loads. The lead cylinder extends throughout the full depth of the bearing. Lead plug must fit tightly in the elastomeric bearings, and this is achieved by making the lead plug slightly larger than the hole and forcing it in. The lead core is designed to deform plastically, thereby providing energy dissipation and to increase damping. However, addition of damping may increase the contribution of secondary modes on the structure response. This may decrease the efficiency of the isolation system. Hence, lead-plug rubber isolators are used with enough number of elastomeric or low damping natural rubber bearings to achieve the required superstructure response. Buildings isolated with these bearings performed well during some major earthquakes. One of the most recent examples involved the USC university Hospital, Isolated by Lead Rubber Bearing in 1991. In the 1994 Northridge earthquake, the hospital suffered no damage and remained operational while an adjacent hospital complex without isolators sustained about $400 million in damages.

III. LITERATURE REVIEW

A. B. M. Saiful Islam1*, M. Jameel1, M. A. Uddin1 and Syed Ishtiaq Ahmad (2011) observes in this work that seismic base isolation is now a days moving towards a very efficient tool in seismic design of structure. Increasing flexibility of structure is well achieved by the insertion of these additional elements between upper structure and foundation as they absorb larger part of seismic energy. However in Bangladesh, this research is still young for building structures. Therefore, this is a burning question to design isolation device in context of Bangladesh. Effort has been made in this study to establish an innovative simplified design procedure for isolators incorporated in multi-storey building structures. Isolation systems namely lead rubber bearing (LRB) and high damping rubber bearing (HDRB) have been selected for the present schoolwork. Numerical formulation and limiting criteria for design of each element have been engendered. The suitability to incorporate isolation device for seismic control has been sight seen in details. The study reveals simplified design procedures for LRB and HDRB for multi-storey buildings in Bangladesh. The detail design progression has been proposed to be included in Bangladesh National Building Code (BNBC).

V. Kilaret al In thispaper four-storey RCC building is designed according to Euro Code 8 for seismic analysis and dynamic performance evaluation. Different sets of base isolation devices are studied for investigation. First case is the use of simple rubber bearing and second one is the use of lead rubber bearing as a base isolation system. For the investigation of each system a soft, normal and hard rubber stiffness with different damping values were used. Non-linear pushover analysis was performed with the recent version of computer analysis software SAP 2000. From this study it is concluded that the stiffer isolators with higher damping gives smaller target base displacements as compared to softer one with lower damping. It can also be seen that the relative displacement of the superstructure are smaller if the softer isolators are used. The smallest relative displacement can be expected with the use of softer isolators with higher damping. If the used isolators are too stiff it cannot protect the superstructure.

A. B. M. Saiful Islam et al In this paper a soft storey building is analyzed for seismic loading by creating a building model having lot of open spaces. The soft storey creates the major weak point in earthquake which means that during the event when soft storey collapses, it can make the whole building down. It causes very severe structural damage and building becomes unusable. This research includes the placement of two types of isolators, first is lead rubber bearing (LRB) and second one is high damping lead rubber bearing (HDRB). Each storey is provided by isolators and its consequences were studied for different damping values. Finally the study reveals that use of isolators is most beneficial tool to protect soft storey buildings under strong earthquake ground motions. Provision of lead rubber bearing is more efficient than high damping rubber bearing because as time period increases in high damping rubber bearing, acceleration also increases which is undesirable to protect building during earthquake. This condition is exactly reverse in case of lead rubber bearing. It has been also shown the response of base isolated building and arrangement of bearing in the building. As damping provides sufficient resistance to structure against service loading, various damping values are taken into account for this investigation. This study also deals with the main requirement for installation of isolators. Finally, it has concluded that the flexibility, damping and resistance to service loads are the main parameters which affects for practical isolation system to be incorporated in building structures. Additional requirements such as durability, cost, ease of installation and specific project requirements influences device selection; but all practical systems should contain these essential elements.

Pradeep Kumar T. V. et al has shown force-deformation behavior of isolation bearings. In this paper the isolation bearing consists of an isolator which increases the natural period of the structure away from the high-energy periods of the earthquake and a damper to absorb energy in order to reduce the seismic force. The most common isolation bearing used was the lead–rubber bearing. It has been observed that lead–rubber bearings have little strain-rate dependence for a wide frequency range which contains typical earthquake frequencies. Authors have designed the isolated bearing. The isolation bearings are modeled by a bilinear model based on the three parameters: initial stiffness, lower stiffness, and characteristic strength. It has given new relationship to find out the yield displacement and yield force for an equivalent bilinear isolation bearing system. Compared to the conventional method the newly derived equations give accurate results and are less time consuming.

IV. RESULTS

A deep review has been carried out accompanied by a through study of the base isolation concept using Lead Rubber Bearings(LRB) as insulators for earthquake resistant structures. This study presents theoretical investigation for buildings subjected to earthquake induced load with fixed base and with base-isolation method using rubber bearing. The aim of this work is to contribute to the efficient design of base-isolated structure subjected to seismic ground motion.

V. CONCLUSION

The lead-rubber bearings represent an economic solution for the seismic isolation problems because it combines the functions of vertical support, of rigidity at service load levels, and of horizontal flexibility at earthquake load. Lead yields at low stress, around 10MPa, and behaves like an elastic-plastic solid. Lead is also “hot-worked” when plastically deformed at ambient temperature and the mechanical properties of the lead are being continuously restored by the simultaneous interrelated processes of recovery, recrystallization and grain growth. As a matter of fact, deforming lead at 20°C is like deforming steel at temperatures higher than 400°C. Lead has good fatigue properties during cycling at plastic strains. The hole for the lead-plug can be machined through the bearing after manufacture, or the hole can be made in the steel plates and rubber sheets before they are joined together. The lead, in any case, must fit tightly in the elastomeric bearing and this is achieved by making the lead plug a little larger (1%) than the hole and forcing it into it. In this way, when the bearing is deformed horizontally, the led insert is forced by the interlocking steel plates to deform in shear throughout its whole volume. The yield force of the lead insert can be easily determined from the yield stress of the lead in the bearing.

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