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Seismic Behavior Evaluation of Base – Isolated Structure with Different Isolators

Rohit Laxman Gaikwad, Prof. Shriganesh S Kadam

M. E Student, Department of Civil Engineering, S. K. N. Sinhgad College of Engineering Korti, Pandharpur.

Solapur University, Solapur, India

Department of Civil Engineering, S. K. N. Sinhgad College of Engineering Korti, Pandharpur, Solapur University,
Solapur, India

ABSTRACT: In existing system the seismic response of base-isolated bridge is seen to be considerably altered due to the dissimilarity in the isolator properties. The eccentricity arose due to the isolation stiffness affects more than that due to the isolator yields forces. The effectiveness of isolation reduces at higher eccentricities and the torsionally coupled response diminishes with the increase of uncoupled torsional to lateral frequency ratio. The research and numerous applications in the field of seismic base isolation have undoubtedly proved that this system of alternative seismic protection is extremely effective in minimizing the damage of certain type of buildings during seismic action. The technical development of rubber bearings and dampers in recent years has reduced their price and such systems have become an important alternative for construction of building structures in seismic areas, even for ordinary multi-storey buildings such as offices, residential housing, industrial buildings and others. It is also a fact that the architectural design is based on completely different values compared with those favored by earthquake engineering and that the recognizable complex irregular buildings usually win the first prizes in competitions led by the architects and the investors. Such structures are very often asymmetric in plan or/and in elevation and thus completely irregular from a structural point of view. We do believe that the correct usage of base isolation systems with respect to certain structural rules, limitations and rational technological limits, can substantially reduce the negative torsional effects produced by structural asymmetry and thus contribute to general structural safety in seismic areas.

KEYWORDS: Base isolator, theoretical, Base-isolated bridges, isolation system, seismic protection.

I. INTRODUCTION

1. Background

The research and numerous applications in the field of seismic base isolation have undoubtedly proved that this system of alternative seismic protection is extremely effective in minimizing the damage of certain type of buildings during seismic action. The technical development of rubber bearings and dampers in recent years has reduced their price and such systems have become an important alternative for construction of building structures in seismic areas, even for ordinary multi-storey buildings such as offices, residential housing, industrial buildings and others [1_3]. It is also a fact that the architectural design is based on completely different values compared with those favored by earthquake engineering and that the recognizable complex irregular buildings usually win the first prizes in competitions led by the architects and the investors. Such structures are very often asymmetric in plan or/and in elevation and thus completely irregular from a structural point of view. We do believe that the correct usage of base isolation systems with respect to certain structural rules, limitations and rational technological limits, can substantially reduce the negative torsional effects produced by structural asymmetry and thus contribute to general structural safety in seismic areas. Our research,

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summarized in the paper, is focused on the study of the seismic behaviour of the in plan asymmetric multi-storey base isolated structures. The literature survey showed that the response of base isolated asymmetric buildings is still an ongoing research topic with relatively few works available. Some of the first reported research studies on rigid superstructure models could be found in [4,5] and on multi-storey models in [6]. They have concluded that a base isolation system with zero or a small amount of eccentricity (e.g. CI - CM) significantly reduces torsion in base isolation systems caused by superstructure asymmetry, of the superstructure has a minimal effect on the displacement of the base isolation system. Contrarily Nagarajaiah et al. [7], using multi-storey models, concluded that the isolation system eccentricity as well as asymmetry and dynamic characteristics of the superstructure are both important generators of torsion in base isolated structures, nevertheless, that the torsional amplifications are reduced due to the isolation system. Similarly Jangid and Datta [8] concluded that the base isolation system becomes less effective for greater eccentricities, since the displacements of the base isolation system are increased due to a larger contribution of torsion.

2. Motivation

In recent years a series of new studies have been carried out on multi-storey building models. A large amount of research was carried out by Tena-Colunga and his co-authors. In [9] the displacement response amplifications of the base isolation system of an asymmetric structure are compared with the response of a symmetric structure. It was shown that the base displacement demand amplifications are bigger for larger eccentricities of the superstructure, and that they also depend on the period of the isolated structure. It was again concluded that asymmetry reduces the effectiveness of base isolation systems, since the more exposed isolators tend to deform plastically, while the others still remain elastic. It was also observed that the maximal base displacement is recorded for unidirectional eccentricity and not for bidirectional eccentricity as might be a priori expected. In [10] the effect of the base isolation system eccentricity is studied even more in detail. It is concluded that a greater eccentricity of the base isolation system (>15%) has an even more negative base displacements effect than the superstructure eccentricity and that an eccentric base isolation system therefore should not be used in structural practice. In [11] it is pointed out that bigger torsional amplifications can be expected in the case of a mass eccentric structure than in the case of stiffness eccentric structures. It is also concluded that the maximal torsional base displacement amplifications are not necessarily obtained for the greatest eccentricities of the superstructure. One of the most recent studies of lateral-torsional coupling in base isolated multistorey structures contrarily concludes that the eccentricity of the superstructure does not have a significant effect on the torsional amplifications of the base displacements for a wide range of investigated base eccentricities and the torsional to lateral frequencies ratio of the superstructure. It also concluded that for the torsionally flexible base isolation systems and smaller base eccentricities, the maximum amplification of the response occurs at the stiff edge. Otherwise, for torsionally stiff isolation systems, the maximum amplifications occur at the flexible edge. In the presented paper, special attention is given to the level of protection of the superstructure that can be achieved by different positions of CI of the base isolation system. Our standing point was that the eccentricity of the superstructure, which is our major object of protection, is not completely in the hands of a structural designer as is the eccentricity of the base isolation system. The main difference to all presented studies is a complete 3D nonlinear modelling of the base isolated superstructure that enables to track the development of damage induced by asymmetry of the superstructure and position of the centre of isolators CI. For the isolators of the base isolation system we have intentionally selected the stiffness that brings the symmetric variant of the superstructure exactly to the limit of elastic range. Such a case would probably not be used in safe practice, but in this way all additional damage gained in parametric studies could be contributed only to the studied effects of asymmetry. For the parametric study three levels of mass asymmetry, three levels of torsional rigidity of the superstructure and six various distributions of bearings in the isolation system have been applied on a selected realistic RC frame building structure designed according to Eurocodes 2 and 8. The comparison of the results is presented in terms of relative top displacements, interstorey drifts, base displacements and ductility factors for stiff and flexible sides of the buildings as well as in terms of top and base rotations of the plan.

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3. Problem Statement

In existing approach the same building structure with various reinforcement distributions had already been used in several previous research reports by the first author and his co-authors, which addressed the problems of non-linear torsional response of fixed base buildings. More detailed descriptions of the selected structure can also be found in [2] as well with some modifications in [5].

4. Objective

- (i) To develop and study asymmetries in base isolated bridge due to yielding forces and stiffness.
- (ii) To analyses various parameter affecting response of the base-isolated bridges.
- (iii) To study system parameter affecting the lateral-torsional response as well as to study existing and proposed system.
- (iv) To study performance different isolation system used for bridge and study the effect of effect of eccentricities in restoring force provided by isolation

II. LITERATURE REVIEW

Vasant A. Matsagar[1], has presented seismic response of simply supported base-isolated bridge with different isolators. He said that the isolated bridge deck is idealized using simplified model of simply supported rigid deck with three degrees of freedom, two lateral translational, mutually orthogonal and rotational. The rotational degrees of freedom of the bridge deck may arise because of the dissimilarity in properties of different seismic isolation devices such as elastomeric and sliding system supporting the bridge deck. An isolation stiffness and yield force considered as source of dissimilarities in the isolators. Also the flexibility of abutments and bridge deck is ignored and two horizontal components of earthquake ground motion are applied and also considering Bi-directional interaction of coupled bridge are derived solved and conducted for different system configuration .supported on base isolation system is investigated under real earthquake motion. The superstructure is idealized as a shear type flexible building with lateral degree-of-freedom at each floor.

The force-deformation behavior of the isolation system is modeled by the bilinear behavior which can be effectively used to model all isolation systems in practice. Here derived governing equations of motion of the isolated structural system. The response of the system is obtained numerically by step-by-step method under three real recorded earthquake motions and pulse motions associated in the near-fault earthquake motion. The variation of the top floor acceleration, under story drift, base shear and bearing displacement of the isolated building is studied under different initial stiffness of the bi-linear isolation system. It was observed that the high initial stiffness of the isolation system excites higher modes in base-isolated structure and generate floor accelerations and story drift. Such behavior of the base-isolated building especially supported on sliding type of isolation systems can be detrimental to sensitive equipment installed in the building. On the other hand, the bearing displacement and base shear found to reduce marginally with the increase of the initial stiffness of the initial stiffness of the isolation system. Further, the above behaviour of the base-isolated building was observed for different parameters of the bearing and earthquake motions Vancouver, B.C[3], This research work gives an effective way to common seismic design for improving the seismic performance of structures by using Seismic isolation and energy dissipating systems. That techniques reduce the seismic forces by changing the stiffness and/or damping in the structures, whereas conventional seismic design is required for an additional strength and ductility to resist seismic forces. The research and development works of passive, active and hybrid devices are ongoing intensively. This paper presents a brief history of isolation techniques and introduces these systems from passive devices to sophisticated ones and completely active systems. From this paper they conclude that recommended provisions from codes for new buildings and other structures is reviewed. On the other hand, this paper reviews the situation of earthquake protective systems used in Turkey. This technique is not yet very common, but a number of research activities is going on in order to investigate the behavior of the isolated buildings. Civil engineers, architects, constructors and owners have great responsibilities concerning applications of these systems, but especially the users have sanction, therefore widely use of the earthquake protective systems will be

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provided by the users' awareness. Sumana C V. [4] works on Building frames on sloping ground (hilly areas) one of the factors which reduces the capacity of the structure due to the fact that the column in the ground storey are of different heights which leads to combination of short column and long column. Along with this if building has an open ground storey, it is often induced into structures either due to client requirement or improper planning.

If this structure is subjected to earthquake which becomes more vulnerable in severe zones. Srijit Bandyopadhyay [5], studied the performance of a well-designed layer of sand, geogrid, geo-textiles and composites like layer of sand mixed with shredded tyre (rubber) as low-cost base isolators is studied in shake table tests in the laboratory. The selected base isolator is placed between the block and the sand foundation. Accelerometers are placed on top of the footing and foundation sand layer. The displacement of the footing is also measured by transducers. The whole set-up is mounted on the shake table and subjected to sinusoidal motion with varying amplitude and frequency. Sand is found to be effective only at very high amplitude (>0.65 g) of motion. Among all the different materials tested, the performance of a composite consisting of sand and 50% shredded rubber tyre placed under the footing is found to be the most promising as a low-cost, effective base isolator.

S. M. Dhawade et al. [6], compared the seismic effect of fixed base structure with respect to isolated structure of the G+14 storied frame structure. The (G+14) storied frame structure is design with base isolation by using the ETAB software. High Damping Rubber Bearing (HDRB) is used as an isolator having efficient results for frame structure over the fixed base structure than any other isolation system. The report concluded that the very less values come for lateral loads by using High Damping Rubber Bearing. It has high flexibility and energy absorbing capacity, so that during an earthquake, when the ground vibrates strongly only moderate motions are induced within the structure itself.

S. M. Dhawade [7], has been examined the seismic behavior of base isolated structures with friction pendulum slide bearing devices subjected to near fault events characterized by significant vertical ground motion components. In particular, in order to evaluate the effects of the mass eccentricity, of the ratio between the superstructure mass and the overall mass system, of the bearing radius of curvature and of the friction on the seismic response, nonlinear dynamic analysis, carried out by using MDOF numerical model, have been performed by considering two near-fault seismic events, L'Aquila 2009 and Emilia Romagna 2012. The results obtained show that mass eccentricity do not influence significantly the main seismic response parameters, while the mass ratio, the friction coefficient and the radius strongly affect the seismic behavior of the base isolated structures. asymmetric building to random ground excitation using the state space formulation.

Three types of base isolation devices are considered: the laminated rubber bearing (LRB); the New Zealand system (NZ); and the resilient-friction base isolator (R-FBI). For the NZ and R-FBI systems, for which force-deformation behavior is nonlinear, an equivalent linearization technique is applied to obtain an approximate response. The effect of linearization on the response is investigated by comparing the responses of the linearized solution with those obtained from simulation analysis. The RMS responses of the system are obtained under different parametric variations in order to investigate the effectiveness of different base isolation devices for stationary random ground motion. The study shows that the stochastic response of the asymmetric building isolated by an R-FBI system is less sensitive to the parametric variations.

Luigi Petti [9] determined the seismic behavior of base isolated structures with friction pendulum slide bearing devices subjected to near fault events characterized by significant vertical ground motion components. In particular, in order to evaluate the effects of the mass eccentricity, of the ratio between the superstructure mass and the overall mass system, of the bearing radius of curvature and of the friction on the seismic response, non-linear dynamic analysis, carried out by using MDOF numerical model, have been performed by considering two near-fault seismic events, L'Aquila 2009 and Emilia Romagna 2012. The results obtained show that mass eccentricity do not influence significantly the main seismic response parameters, while the mass ratio, the friction coefficient and the radius strongly affect the seismic behaviour of the base isolated structures.

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AmitPurohit et.al. [10] studied various base isolation systems using for structural nonlinear vibration control and seismic control of structures. From the past little year base isolation has become one of the most popular tool for earthquake resistant design of structure. The concept of decoupling of building with the help of base isolation is being invented from a century. Many researchers has been worked on base isolation system that it is become acceptable as a whole in engineering field. However so many types of isolation systems are being invented but amongst them few has become accepted thoroughly. Now a days full scale testing is being performed on shake table to test the various characteristics of different isolators. Present review summarizes literature and theoretical aspect available on base isolation system. Some of the papers also deals with the effectiveness of different available isolator and their applicability.

Omar Salomo et.al. [11] developed a finite element formulation modelling hyperelasticquasi-incompressible rubber-like materials (elastomers) which takes into account large displacements and large elastic strains as well as inelastic effects. The capacity of laminated rubber-like materials to support high loads in compression and large displacements in shear is the principal reason for their use in devices for seismic base isolation of structures. The energy- dissipation capacity of these devices is increased by using high damping rubber, which is an elastomer incorporating carbon black particles, or having lead-plug insertion. Daniele Losanno et.al. [12] worked on a numerical investigation on the seismic performance of a benchmark bridge with different optimal isolation systems under near fault ground motion. Usually, very large displacements make seismic isolation an unfeasible solution due to boundary conditions, especially in case of existing bridges or high risk seismic regions. Hence, near-fault ground motions are most likely to affect either structures with long natural period range like isolated structures or structures sensitive to velocity content such as viscously damped structures. The work is aimed at analyzing the seismic performance of a three-span continuous bridge designed with different isolation systems having different levels of damping.

Gordon P. Warn et.al. [13] summarize current practices, describe widely used seismic isolation hardware, chronicle the history and development of modern seismic isolation through shake table testing of isolated buildings, and reviews past efforts to achieve three-dimensional seismic isolation. The review of current practices and past research are synthesized with recent developments from full-scale shake table testing to highlight areas where research is needed to achieve full seismic damage protection of buildings. The emphasis of this paper is on the application of passive seismic isolation for buildings primarily as practiced in the United States, though systems used in other countries will be discussed.

Zaoui D, Djermanet.al. [14] studied behavior of cylindrical metal silos composed of horizontally corrugated sheets strengthened by vertical open-sectional thin-walled columns. The aim of three-dimensional finite element analysis taking into account the complexity of the whole structure (corrugated form, open-sectional thin-walled stiffeners, conical form for the roof and the hopper) and the use of lead-plug bearings device for the base isolation was to evaluate the feasibility of the bearings isolator to ensure an adequate performance of the studied silo structure namely to avoid the buckling risk of the vertical open-sectional stiffeners. The response frequency and thereductions of the global base shear and overturning moment, the energy dissipation provided by the lead rubber bearings isolator has assured the bearing capacity recommended by the Eurocode rules and avoid the buckling failures observed in the thin-walled stiffeners.

Rasna.P. et.al. [15] compared asymmetric structures with plan irregularity. For creating theasymmetry in the structures, eccentricity from 0% to 30% is provided in centre of mass of the structure. To assess the effect of LRB isolators on the response of structures, for the present study 4 types of structures having same outer perimeter area are considered. Both fixed base and base isolated models are created and analyzed in ETABS-2016 software. Comparison based on eccentricity is also carried out by varying the height of the structure from low-rise to high rise building.

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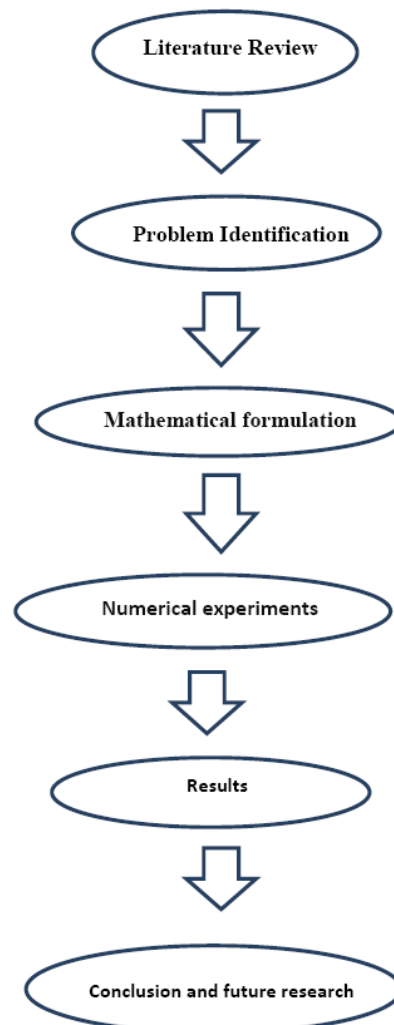
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III. METHODOLOGY

To illustrate Response analysis of Base – Isolated Bridge , Past Earthquake ground motion Data (upto 5 places) are selected . The data includes different parameters like Different System Configuration, Isolation System , Frequency Ratio etc.



IV. CONCLUSION

From the consideration of all the above points we conclude that our study concerns with the seismic response comparison of a fixed base building with a base isolated building and parametric study of a base isolated building. The structural system considered for analysis is a three storey reinforced concrete building, which is idealized as a shear type building with one lateral degree of freedom at each floor level. In existing system the seismic response of base-isolated bridge is seen to be considerably altered due to the dissimilarity in the isolator properties. The eccentricity arose due to the isolation stiffness affects more than that due to the isolator yields forces.

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The torsional coupling arising due to the mismatch of isolation stiffness and/ or yield forces of the seismic isolators in the simply supported base-isolated bridges is formulated and discussed here. Following conclusions are arrived at from the study of seismic response of torsionally coupled base-isolated bridge subjected to bi-directional earthquake ground motions.

1. The eccentricities arising due to the dissimilar isolator properties (isolation stiffness and/ or yield forces) in the base-isolated bridge affects its seismic response considerably.
2. The effectiveness of isolation reduces at higher eccentricities due to the asymmetries in the isolator properties, and the effectiveness of isolation will be over-predicted if these eccentricities are ignored. Inclusion of the isolation eccentricities in the analysis leads to correct estimation of the effectiveness of isolation and appropriate provision of the isolation gaps to avoid seismic pounding.
3. The eccentricity arose due to the variation in isolation stiffness affects the seismic response more severely than that due to the isolator yield forces.
4. The torsionally coupled seismic response diminishes with increasing torsional to lateral frequency ratio.

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