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Seismic Effect of RC Frame with and without Base Isolation for Different Soil Condition using Soil Structure Interaction Effect - A Literature Review

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Abstract—

The seismic response of a structure is greatly influenced by Soil Structure Interaction (SSI). In this study the effect of flexibility of the structure under different soil conditions on the performance of building frame is investigated. Different conditions are considered for the analysis; one is replacing support condition at base by spring of equivalent stiffness and second by considering the base isolation system under same effect. For SSI study three types of soil are generally considered i.e. Hard, Medium Hard and Soft Soil. The study reveals that the SSI significantly affects on the response of the structure. The aim of this study is to observe the behaviour of such system for seismic control for different conditions and soil effect and find its sustainability and is to review technologies for seismic control.

Keywords – Base Isolation System, Soil Structure Interaction, Lead Rubber Bearing, Friction Sliding Isolator, Seismic Analysis, Etabs.

1. Introduction -

In seismic design of building structure, usually, the soil is assumed to be rigid, which is realistic only if the foundation is on solid rock or when soil stiffness is very high. For all other cases, the soil surface interaction (SSI) constitutes of two distinct effects – kinematic and inertial interaction, which is complex. The soil-structure interaction (SSI) refers to the action in which the response of the soil influences, the response of the structure and the response of the structure influence the motion of the soil (Kramer, 1996). The buildings are considered isolated with fixed base while designing for simpler calculations. However, the buildings are not built in isolation in reality. The seismic response of buildings especially when closely spaced, do not act independently and, considering that their foundations are in the same soil, the response is affected by each other. Further, contradictory to the belief that Soil-Foundation-Structure Interaction (SFSI) increases natural time period of structure and is beneficial, as assumed while designing, studies have shown that the increase in natural period of structure due to SFSI can lead to resonance. Additionally, the ductility can also significantly increase with increase in natural period of structure due to SSI. The seismic response of the structure may be further aggravated by the permanent deformation and failure of soil.

1.1 Soil Structure Interaction -

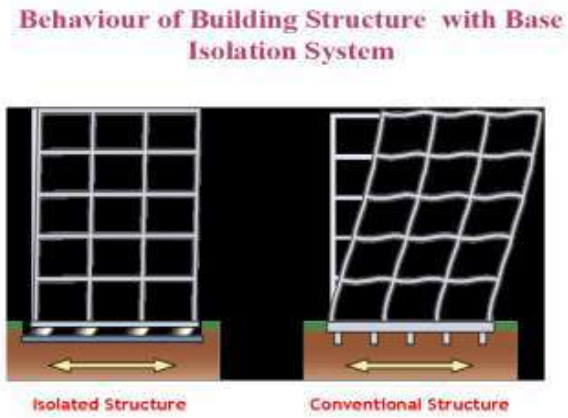
Ground structure interaction (SSI) consists of the interaction between soil (ground) and a structure built upon it. It is primarily an exchange of mutual stress, whereby the movement of the ground-structure system is influenced by both the type of ground and the type of structure. This is especially applicable to areas of seismic activity. Various combinations of soil and structure can either amplify or diminish movement and subsequent damage. A building on stiff ground rather than deformable ground will tend to suffer greater damage. A second interaction effect, tied to mechanical properties of soil, is the sinking of foundations, worsened by a seismic event. This phenomenon is called soil liquefaction.

Most of the civil engineering structures involve some type of structural element with direct contact with ground. When the external forces, such as earthquakes, act on these systems, neither the structural displacements nor the ground displacements, are independent of each other. The process in which the response of the soil influences the motion of the structure and the motion of the structure influences the response of the soil is termed as soil-structure interaction (SSI).

1.2 Base Isolation System –

Base isolation of structures is one of the most desired means to protect it against earthquake forces. It is the fundamental concepts for earthquake engineering which can be defined as separating or decoupling the structure from its foundation. This effect in reduction of inter storey drift and effective

displacement in the floors of base isolated structural system, that ensures the least damage to facilities and also provides safety to life and property. The concept of base isolation had been suggested in last few decades, the technologies are made available, and knowledge of base isolation system are getting used, developed and hence well established. Seismic isolation systems are more effective when applied to high stiffness, low-rise buildings, owing to their abilities to alter the characteristic of the building from rigid to flexible. And the gradual increase in number of structures to be isolated enhances the fact that base isolation system is gradually becoming accepted as a proven technology in earthquake hazard mitigation. Interestingly, base isolation is a passive control system; it does not require any external force or energy for its activation.



2. OBJECTIVES OF THE STUDY

Structural stability is a useful parameter which is responsible to co-relate the seismic elastic response of RC structures. The objective of the present study is to evaluate the previous researches carried out determine the SSI effect on various dynamic properties of R.C. frame. Effect of various soil and structural parameters are also studied to identify their effect on seismic performance of building frames. The study is carried out by two SSI methods i.e. discrete support (using spring) and Elastic Continuum (using FEM). An attempt is also made to understand the effectiveness and utility of this study and its effect on the structure.

3. Literature Review –

There were various studies which have been conducted on the static and dynamic analysis and design of such structures with different types of soil effects and base isolation. The studies also suggests about the difficulties arise for the seismic design of high rise building where such situation occurs. Few of the data from previous studies have been discussed here along with the methodology adopted and conclusions. Many research investigations have been carried out regarding the use of base isolation system in the multi-storey structures.

Soil Structure Interaction -

Constantinou and Kneifati (1986) Kinematic soil-structure interaction from strong motion recordings. Journal of Geo-technical & Geo-environmental Engineering. 129(4): 323-335. DOI: 10.1061/(ASCE)1090-0241(2003)129:4(323) proposed an energy strategy to gauge the damping of seismically confined structure, considering the energy dispersal of the bearing and the radiation damping in the dirt.

Novak and Henderson (1989) Effect of soil stiffness on seismic response of reinforced concrete buildings with shear walls. Innovative Infrastructure Solutions . 1(2). DOI: https://doi.org/10.1007/s41062-016-0004-0 explored the modular properties of base-disconnected structures furthermore presumed that, when the adaptability of soil and isolators are equivalent, the commitment of SSI ought not to be overlooked.

Kelly (1991) Seismic soil-structure interaction: new evidence and emerging issues", Proc. 3rd Conf. Geotechnical Earthquake Engineering and Soil Dynamics, Seattle, USA. completed an exploratory review concerning base-secluded atomic offices established on delicate destinations, prompted the end that the isolator configuration ought to be taken into the record for huge dislodging requests.

Spyrakos and Vlassis (2002) Effect of Soil Structure Interaction on Seismic Response of Framed Structure. International Research Journal of Engineering and Technology. 08(3):317-323. surveyed the impacts of SSI on the reaction of base-confined spans by a parametric report. They inferred logical articulations to show the meaning of SSI peculiarities in impacting the reaction of the disengaged framework.

Tsai et al. (2004) Equivalent linear model for existing soil-structure systems. International Journal of. Structural Stability and Dynamics. 16, 1450099. DOI: https://doi.org/10.1142/S0219455414500990. fostered a period area method to research the productivity of isolators to lessen the energy imported in a FPS-disengaged working for seismic tremor movement. Both radiation damping and establishment adaptability were viewed as fundamental in the precision of reaction forecast and wellbeing of the disengaged structure.

B.R. Jayalekshmi, Katta. Venkataramana, R. Shivashankar, (2009) "Earthquake response of multi storeyed R.C. frames with soil structure interaction effects." NITK Research Bulletin Vol. 16. No.1, June 2009, pp 14 to 18 Studied the seismic response of space frames with disconnected balance on layered soil. In this paper, Seismic reaction of multi-story RC space outline working with detached balance laying on shallow layered soil. Different firmness layered soil from exceptionally delicate to solid reach is thought of. The examination of construction exposed to is code configuration utilizing programming ANSYS. Structure is introduced the impact of layer soil on regular period and base shear. The impact of SSI expands the seismic base shear.

Mr Magade S B, Prof. Patankar J P (2009) Assessing lateral period of building frames incorporating soil flexibility", Journal of sound and vibration, 269 (2009), pp.795-821concentrated on the influence of soil structure interaction on dynamic behaviour of the buildings. In this paper for the examination reason the structure model is fixed at their base. Because of the general development of soil medium influence the structure to twist for some degree. This diminishes the general solidness of primary framework and these build the normal time frame. The reaction of the structure is adjusted by the incomplete fixity of the establishment because of soil adaptability. The primary target of this paper is to concentrate on the impact of soil structure association on infill outline and uncovered outline with shear dividers considered for various soil conditions utilizing STAAD-PRO 2008 programming bundle. The relocation, base shear, regular recurrence is assessed in examination and these are contrasted and the different soil profiles.

H. Matinmanesh and M.Sales Asheghababi (2011) "A critical review on idealization and modelling for interaction among soil-foundation structure system", Computers and Structures 80 (2011), pp.1579_1594 discuss the seismic analysis on soil-structure interaction of buildings over sandy soil. In this current paper 2D plane strain FEM component seismic SSI investigation considering 3 ground movement records in low, moderate and high seismic movements for recurrence, enhancement, speed increase reaction and stress engendering content of the quakes with various dirt, structures stature. The impact of SSI in both sandy soils enhances seismic waves on the SSI.

Vivek Garg and M.S.Hora, (2012) "A review on interaction behaviour of structure foundation soil system.", International Journal of Engineering Research and Applications, Vol. 2, Issue 6, November - December 2012, pp.639-644 dissected An audit Interaction Behaviour of Structure-Foundation-Soil System. In this current review the structure and soil is displayed by limited component technique and by the traditional non-straight investigation, the segments in the structure outlines are expected to be lay on the non yielding help. The conduct of the construction because of static stacking and seismic stacking is examined by the limited component investigation. The current review is to assess the impact of SSI on the structure outlines. The distinctions in stacking examples, aggregate and differential settlements in non-straight examination are contemplated.

Ayman Ismail (2014) "Effect of Soil Structure Interaction in Seismic Loads of Framed Structures"; International Journal of Scientific & Engineering Research Volume 4, Issue 5, May-2014 ISSN 2229-5518 concentrated on the effect of soil flexibility on seismic performance of three dimensional Frames. In this paper the impact of soil firmness on the seismic execution of seismic reaction unbending underlying structure outlines laying on separated balance. The adaptability of the dirt reasons the horizontal normal time of the primary framework decline in parallel firmness. The investigation has been done using Sap2000. The impact of soil –structure communication on parallel regular period as the equivalent even a pontoon establishment is given other than separated balance.

D. K. Jain & M.S. hora (2014) ***Seismic design aids for buildings incorporating soil-flexibility effect, J. Asian Archit. Build., 5(2), 2006, 341-348*** focused on a analysis of space frame - Shear Wall-Soil System interaction to investigate Foundation Forces under Seismic stacking. In this paper the dirt construction investigation of G+5 RC shear divider multi story outlined structures laid on disconnected segment footings. The model investigation is completed by utilizing the ANSYS programming. With respect to the Is code 1893-2000 the seismic deposit blend is thought of. The impact of SSI investigation completed shear divider with and without on the footings for differential settlement of soil mass. The SSI impacts altogether the powers and minutes in the footings to the differential settlement. In the in a large portion of section footings lessens bowing minutes.

Base Isolation System –

Donato Cancellara, ET al (2016) "Effects of soil–structure interaction on seismic base isolation, ELSEVIER, Soil Dynamics and Earthquake Engineering 66, pp167–177, (2016) has studied the dynamic nonlinear analysis of different base isolation systems for a multi-storey RC building irregular in plan. Two base isolation systems were analyzed and their seismic behaviour is compared with reference to a multi-storey reinforced concrete building. A comparative analysis is presented for evaluating the behaviour of a base isolated irregular building subject to seismic events. Two base isolation systems have been considered, the High Damping Rubber Bearing (HDRB) actuated in parallel with a Friction Slider (FS) and the Lead Rubber Bearing (LRB) was actuated in parallel with a Friction Slider (FS). A dynamic nonlinear analysis is performed for the three-dimensional base isolated structure. A comparative study is conducted on behaviour of the structure isolated by the two considered base isolation systems and the corresponding behaviour of the traditional fixed base structure.

Dr Manjunath N Hegde et al (2016) Seismic analysis of multi story buildings resting on normal and sloping grounds in different seismic zones with and without base isolator, Imanager's Journal on Structural Engineering, Vol. 4 l No. 1, (2016), In this research an attempt is made to study the results for building with fixed base, base isolator (rubber isolator), and damper and shear wall. Here irregular plan building of (G+7) floor is taken for analysis. For seismic zone IV by considering type II (medium) soil using ETABS Software. Analysis is carried out by both equivalent static method and response spectrum method. Results like time period, displacement, storey drift and base shear are compared for building with base isolator and shear wall with fixed base building. Building provided with base isolator has more displacement than compared to fixed and shear wall. When compared to fixed base building base shear is reduced in base isolated building, thus seismic response of building with base isolator is better than fixed base.

Athanasios et al (2016) Non-linear analysis of multistory g + 4 building by time history method using newmark's linear and average acceleration method, international journal of engineering sciences & research technology, issn: 2277-9655, (2016) have conducted a study on response simulation of hybrid base isolation systems under earthquake excitation .Investigated the response of a hybrid base isolation system under earthquake excitation. The base isolation system consists of high damping rubber bearings and low friction sliding bearings. Two separate models are employed for the numerical simulation of the high damping rubber bearing component, namely a bilinear and a tri-linear system, both in parallel with a linear viscous damper. A series of numerical simulations are carried out to study the behaviour of the considered hybrid base isolation system under different excitation and site conditions.

Fabio De Angelis et al (2016) System identification of base isolated building using seismic response data. J Eng. Mech-ASCE, 2016, 131: 268–275 conducted a study on nonlinear dynamic analysis for RC structures with hybrid base isolation systems in presence of bi-directional ground motions. The work analyzed three different hybrid base isolation systems in order to protect reinforced concrete structures with regards to bidirectional ground motions. The Elastomeric Spring Dampers operated in parallel with Friction Sliders, the Lead Rubber Bearings operated along with Friction Sliders and the High Damping Rubber Bearings operated in parallel with Friction Sliders are the three hybrid base isolation systems considered. A comparative analysis is made for the three base isolated composite structures by reporting the base acceleration, the base shear, base displacements and of the inter-storey drifts and the peak values of the base shear. Finally a comparative analysis is presented between the base isolated structure with the three considered base isolation systems and the fixed base structure.

N Murali Krishna et al (2016) seismic Response Control of R.C.C. Structure using Base Isolation", International Journal of research in Engineering science and Technology, vol.2, No.1, (2016) studied the nonlinear time History Analysis of Building with Seismic Control Systems. Asymmetric buildings have been taken for the study to control the seismic response of the structure. The study was on the nonlinear time history analysis, considering the effect of use of shear wall and base isolation system. The RCC moment resisting frame is subjected to nonlinear time history analysis (NLTHA). The storey drifts, base shear, torsion-al moment and storey displacement of the structure were studied. The results indicate that significant effect of the base isolation was observed on the storey drift, storey shear, storey displacement and torsion-al moment of low rise asymmetric buildings and significant effect of the shear wall was observed on the same responses of high rise asymmetric buildings.

Minal Ashok Somwanshi (2015) Effects of Soil-Structure Interaction on the Seismic Response of Base Isolated in High-Rise Buildings, International Journal of Structural and Civil Engineering Research Vol. 4, No. 3, (2015) et al carried out a study on Seismic Analysis of Fixed Based and Base Isolated Building Structures. The work deals with modelling and analysis of 13-storey rigid jointed plane frame for two cases. First case is fixed base and second case is base isolated. Modelling and analysis is done using E-TABS software for Bhuj earthquake ground motion records. Maximum vertical reaction is obtained from analysis in E-TABS software. Using this vertical reaction and total mass of structure lead rubber bearings are designed manually. Time-history analysis is carried out in order to evaluate floor response, accelerations and displacements during a ground motion. This paper intends to demonstrate how an isolation system can be efficient, evaluating its effectiveness for the building in terms of maximum shear force, maximum bending moment, base shear, storey drift and storey displacement reductions. From analytical results, it is observed that base isolation technique is very significant in order to reduce the seismic response of both symmetric as well as asymmetric models as compared to fixed base building and control the damages in building during strong ground shaking.

Radmila B. Salic et al (2008) "Performance of sliding resilient-friction base-Isolation system", ASCE, Journal of Structural Engineering, vol 11 Issue No 7 PP 56 – 69 (2008), in this paper the authors have demonstrated the effect of dynamic response of the seven-story residential building under the earthquake ground motions. Mode shapes, natural frequencies and damping ratios of the existing fixed-base building are obtained by ARTAMIS (Ambient Response Testing and Modal Identification Software). The fixed base model represents the dynamic behaviour of the structure and seismic isolated model representing the dynamic behaviour of the structure isolated by lead rubber bearing seismic isolation system. Dynamic analysis of both models has been performed by ETABS (Nonlinear version 9.0.4). The finite element model was chosen to satisfy the needs of this analysis. The Dynamic responses of fixed base and seismic isolated models have been calculated for four types of real earthquake time histories of different frequency characteristics whose value is determined based on the detailed site response analysis. The authors have showed that increase of natural period of structure increases flexibility of the same structure. In seismic isolated model, base shear force is highly reduced. Increased flexibility of the system led to increase of the total displacements due to the elasticity of the existing isolation. Implementation of the isolation system resulted into the reduction of the inter-story drifts. Analysis of seismic isolated model has shown significant reduction of the story accelerations**.**

Juan C. Ramallo, et al (2008) System identification of base isolated building using seismic response data. J Eng. Mech-ASCE, 2008, 131: 268–275 . In this paper authors have investigated the effects of using controllable semi-active dampers, such as magneto-rheological fluid dampers, in a base isolation system. A two degree of freedom model of a base isolated building is used. The fundamental concept is to isolate a structure from ground, especially in the frequency range where the building is most affected. The goal is to reduction in inter-storey drifts and floor accelerations to limit damage to the structure and its contents in a cost-effective manner. This paper investigates the improvements that may be achieved by replacing supplemental linear viscous damping devices in base isolation with semi-active dampers. A linear, two degree of freedom (2DOF), lumped mass model of a base-isolated building is used as the test bed for this study. The system model is used in this test is a single degree-of freedom model that has mass and fundamental modal frequency and damping ratio. In this study passive linear viscous damper, active damper and semi-active damper have been used. Generalized semi-active as well as magneto-rheological fluid dampers were used in seismic protection system. Authors have concluded that the semi-active damper was able to accomplish nearly as much as the fully active damper. With the semi-active damper, the peak base drifts were decreased as compared to the optimal passive linear damper. This study suggests that semi-active dampers, such as magneto-rheological fluid dampers, show significant promise for use in base isolation applications with greatly reduced power requirements as compared to the active systems.

J. C. Ramallo1, et al (2008) Identification of hysteretic model of rubber-bearing based on sequential nonlinear least-square estimation. Earth. Eng. Eng.9: 375–383, (2008) have presented an innovative base isolation strategy and shows how it can effectively protect the structures against extreme earthquakes without sacrificing performance during the more frequent, moderate seismic events. This innovative concept includes base isolation system with semi-active or controllable passive dampers for seismic response mitigation. In this method the structure is modelled as a single degree-of-freedom system representing the fundamental mode. When the isolation layer is added, the augmented model is a two degree-of-freedom system. Test has been shown experimentally that the linear behaviour of low-damping rubber bearings can extend to shear strains above 100%. Lead-rubber bearings are considered as the baseline against which the smart damping strategies are compared. The rubber isolation in these two systems is identical. The various ground excitations are used for modal excitation. A family of controllers that decreases base drift and absolute accelerations (compared to the LRB) is obtained for a controllable smart damper. The base isolation system, comprised of low-damping elastomeric bearings, and controllable semi-active dampers, was shown to have superior performance compared to several passive base isolation designs using lead-rubber bearings.

4. Conclusion –

Idealization of supporting soil by spring is an approximate approach. This doesn't reflect the flexibility with high precision. Thus it yields the less accurate results. However the realistic idealization of supporting soil is possible by FEM. It is possible to incorporate variation in the soil properties, layered soil and boundary conditions etc. This will produce the precise data than spring model. The study also reveals that there is difference in the results of both. The spring model underestimates the values.

Difference in spring model and FEM model is less up to medium hard soil. For soft soils this difference is high. Therefore one can employ Spring models for hard soil and FEM models for soft soil. Finite Element Method has proved to be a very useful method for studying the effect of SSI. However to reduce the complexity for practical purpose, at least Winkler hypothesis should be employed to consider SSI instead of fixed base.

From the above literatures of base isolation system, it is find out that the use of base isolation considerably reduces the response of the structure due to earthquake loading. Base isolation is very promising technology to protect different structures like buildings, bridges, airport terminals and nuclear power plants etc. from seismic excitation.

The significant characteristic of base isolation a system affect the superstructure to have a rigid movement and as a result shows the relative story displacement & story drift of structural element will decrease and consequently the internal forces of beams and columns will be reduced.

Due to decrease in lateral loads to stories, the accelerations of the stories are reduced. This results in the reduction of inertia forces. Story overturning moment and story shear are also reduced in base isolated building.

From the above points, it is concluded that the performance of isolated structure is efficient in the Earthquake prone areas.

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