Base Isolation of Residential Building using Lead Rubber Bearing Technique

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***Abstract*: -Conventional seismic design practice permits the reduction of forces for designs below the elastic level on the premise, that inelastic action with significant energy dissipation potential in a suitably designed structure should be efficient and able to survive a severe earthquake without collapse. But the base isolation seismic design provides protection technique which in turn allows the structure to function with no damage even after major earthquakes with a negligible increase in expenditure. Basically, the base isolation of structures reduces the storey shear and acceleration and simultaneously increases the time period, storey displacement and storey drift that induces flexibility in rigid structure by dissipating the energy to the foundation. This base isolation study along with seismic analysis is done in equivalent static method using E-TABS software. Analysis of the structures are done using SMRF frame in Zone-II and response of structure like storey displacement, storey drift, storey stiffness, overturning moment, storey shear were observed, plotted in graphs. An overall comparison of G+10 and G+15 structures with isolator and without isolator were observed. Indian standard codes such as IS 456-2000, IS 1893-2002. Design of base isolator was done to find the stiffness and physical dimension of the core of LRB to be given at the base of structures.**

Keywords: - Equivalent Static Analysis, Lateral Force, Overturning Moment, Storey Drift, Storey Displacement, Isolator, Storey Stiffness.

INTRODUCTION: -

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 effects 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, the 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.

Generally, two basic types of isolation systems. In the first approach the isolation system introduces a layer of low lateral stiffness between the structure and the foundation. With this isolation layer the structure has natural period that is much longer than its fixed base natural period. This lengthening of period can reduce the pseudo-acceleration and hence the earthquake-induced forces in structure. This system is being adopted most widely. The second basic type of isolation system is typified by the sliding system. This works by limiting the transfer of shear across the isolation interface.

Through this purpose of extensive study multi-layer elastomeric bearings are used to provide seismic base isolation of the building frame used here. These bearings are very stiff in the vertical direction and can carry the vertical load of the building but are very flexible in horizontally, thereby enabling the building move laterally like a rigid mass under strong ground motion.

The main purpose of our study is to check and compare the behaviour of the buildings and increasing number of stories in seismic zone by using base isolation concept, thereby reduce the story acceleration, story drift and increase the period of oscillation due to earthquake ground excitation, applied to the superstructure of the G+10, G+15 residential building by installing base isolators lead rubber bearing (LRB) at the foundation level then compare the performance between the fixed base condition and base isolated condition by using ETABS 2016 software.

Lead-plug bearings are made up of low-damping elastomers and lead cores with diameters between 15% to 33% of the bonded diameter of the bearing. A laminated-rubber bearing provides the desired displacements for seismic isolation. By combining laminated-rubber bearings with a lead-plug insert, which provides hysteretic energy dissipation, the damping required for a successful seismic isolation system can be incorporated in only a single composite component... The maximum shear strain range for lead- plug bearings varies as a function of manufacturer but is generally between 125% and 20%... LRB isolators have cylindrical rubber bearings, which are reinforced with steel shims.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 7 Issue 05, May-2018

Shims and rubber is placed as alternate layers. Steel plates are also provided at the two ends of the isolator. The steel shims boost the load carrying capacity, thus the structure is stiff under vertical loads and flexible under horizontal loads.

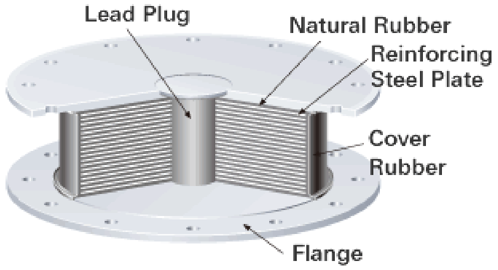

Fig-1. Lead Rubber Bearing

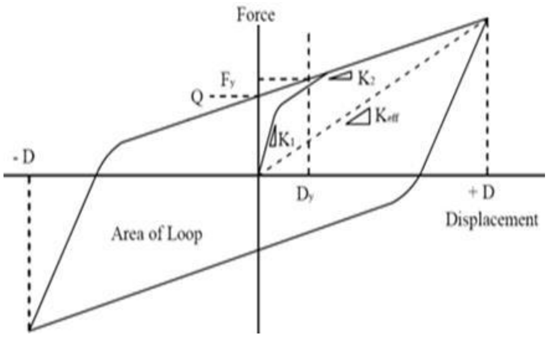

Fig-2. Parameters Basic Hysteresis Loop of lead rubber bearing

The fundamental principal of base isolation system is to rectify the response of the structure so that the ground can move below the structure without transferring these motions into the superstructure. In an ideal system to achieve this flexibility in buildings this separation would be total. But In the existing world there is a need to have some contact between the superstructure and sub structure.

The primary aim of this study is: -

- Design and normal seismic analysis of RCC structure with fixed bases.
- Study types of base isolators, their elements, and effect on structures.
- Using ETABS software, to perform and present a development of theoretical and analytical aspect of the behaviour of base isolated buildings with fixed base buildings and then increasing the number of stories in both cases and accordingly defining the lateral stiffness in isolated conditions. (i.e. with increase in no. of stories; building weight increases and respectively acc. to calculation lateral stiffness increases.)
- Conclusion from the comparisons of results which helps in providing better, safer structure in earthquake zones.

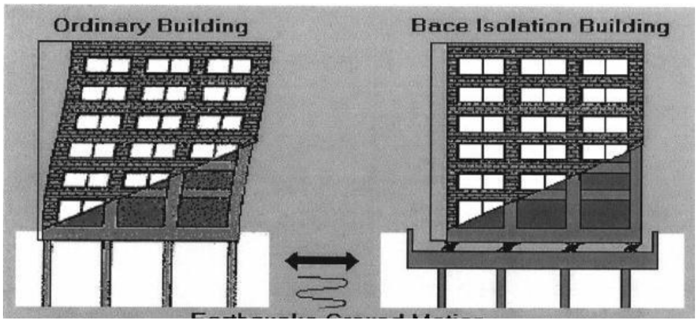

Fig-3:- Effect of Earthquake forces on building in fixed base and isolated base.

THEORETICAL CONTENT CONCEPT OF BASE ISOLATION: -

The concept of base isolation represents a radical departure from the current seismic design practice. In this technique of base isolation, the building is detached or isolated from the ground in such a way that only a very small portion of seismic ground motions is transmitted up through the building. In other words, although the ground underneath it may vibrate violently, the building itself would remain relatively stable. This results in significant reduction in floor accelerations and inter-storey drifts, thereby providing protection to the building components and contents. The system decouples the structure from horizontal components of the ground motion by interpose structural elements with low horizontal stiffness between the structure and the foundation. Base Isolation falls into general category of Passive Energy Dissipation.

PURPOSE OF BASE ISOLATION: -

In designing a building, designer will design it for earthquake resistance & not for the earthquake proof. It is designed for an inertia force which is a product of building mass & earthquake ground acceleration caused during an earthquake. Therefore, it is necessary that the building should have sufficient strength to resist the earthquake. It is not practical and not feasible to continue to increase the strength of the building indefinitely. In high seismic zones the accelerations causing forces in the building may exceed one or even two times the acceleration due to gravity. In this case, base isolation technique is used to mitigate the damages and effects in an earthquake to minimal extent.

PRINCIPLE OF BASE ISOLATION: -

In practice, isolation is limited to a consideration of the horizontal forces to which buildings are most sensitive. Vertical isolation is less needed and much more difficult to implement. Although each earthquake is unique, it can be stated in general that earthquake ground motions result in a greater acceleration response in a structure at shorter periods than at longer periods. A seismic isolation system exploits this phenomenon by shifting the fundamental period of the building from the more force-vulnerable shorter periods to the less force-vulnerable longer periods. The principle of seismic isolation is to introduce flexibility in the basic structure in the horizontal plane, while at the same time adding damping elements to restrict the resulting motion.

In an ideal system, the isolation would be total. In the real world, there needs to be some contact between the structure and the ground. A building that is perfectly rigid will have a zero period. When the ground moves, the acceleration induced in the structure will be equal to the ground acceleration and there will be zero relative displacement between the structure and the ground. Thus, the structure and ground move by same amount.

ELEMENTS OF BASE ISOALTOR: -

1. Isolation system- The various isolators, which reduce the time period shift of the structure to a period, range of 2 to 3 secs, with the isolation system. In base isolation structure, only isolation system show non-linear behaviour, while structure and soil system are shows linear behaviour.
2. Structural system- This system consists of structural component of superstructure as well as foundation. The inter storey drift for isolated structure is very low so, that the super structure can conveniently be assume to behave like linear elastic manner.
3. Soil system- The sub soil system exhibits its own stiffness and damping properties which may or may not affect the response of the structure which is situated upon it. This influence of the interaction between the soil and structure becomes significant in case of loose subsoil strata.

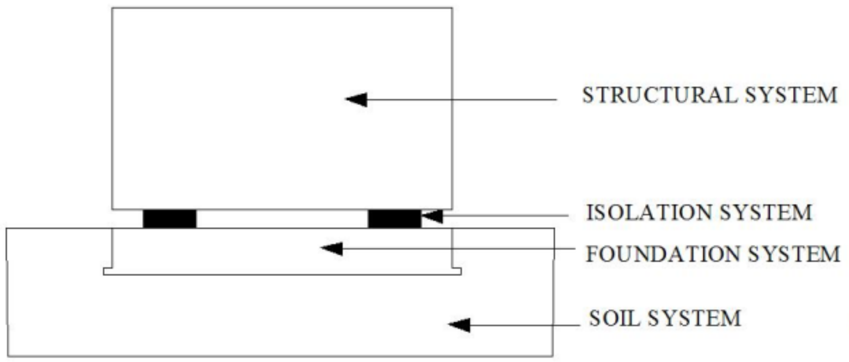

Fig-4: - Components of a base isolation system

LEAD RUBBER BEARING: -

The second type of elastomeric bearings is lead-rubber bearings (LRB). This base isolation system provides the combined features of vertical load support, horizontal flexibility, restoring force, and damping in a single unit.

A lead-rubber bearing is formed of a lead plug force-fitted into a pre-formed hole in an elastomeric bearing. The lead core provides rigidity under service loads and energy dissipation under high lateral loads. When subjected to low lateral loads such as minor earthquake the lead-rubber bearing is stiff both laterally and vertically. The lateral stiffness results from the high elastic stiffness of the lead plug and the vertical rigidity.

A major advantage of the lead-rubber bearing is that it combines the functions of rigidity at service load levels flexibility at earthquake load levels and damping into a single compact unit.

The LRB also provides energy absorbing capacity through additional hysteretic damping in yielding of the lead core that reduces the lateral displacements of the isolator, especially under ambient vibrations. The force deformation behaviour of the LRB is generally represented by nonlinear characteristics following a hysteretic nature. The characteristics of the lead material have been considered in the production of LRB systems. In general, lead has a low yield point when its shear stress reaches 10Mpa and it exhibits elasto-plastic behaviour. Lead is also resistant Lead rubber bearing isolator to repeated loads and can renew itself over time following deformation. The system has a high initial stiffness against minor horizontal forces that may affect the structure, caused by either wind or mild earthquakes. The most important disadvantage of this system is that when the system is exposed to strong ground motion, it is impossible to determine whether damage to the lead core in the centre has occurred.

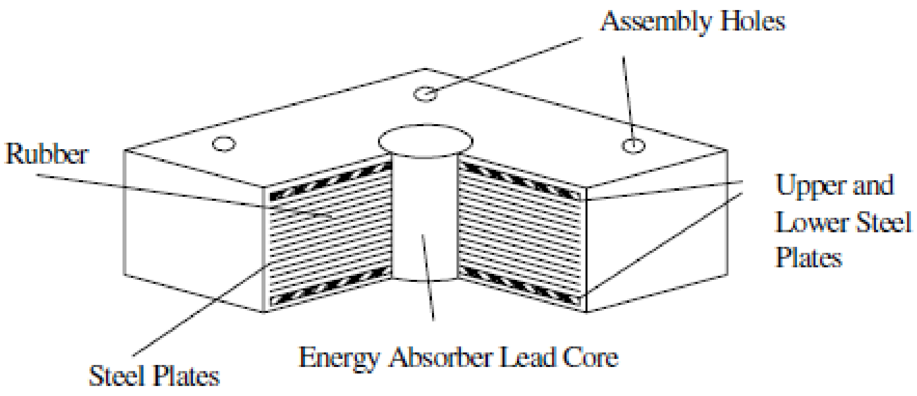

Fig-5:- Lead Rubber bearing

METHODOLOGY OF WORK

Step - 1: Initial setup of Standard Codes and Country codes.

The standard codes to be used in design were entered accordingly.

Step - 2: Creation of Grid points & Generation of structure

After getting opened with ETABS we select a new model and a window appears where we had entered the grid dimensions and story dimensions of our building.

Step - 3: Defining of property

Here we had first defined the material property by selecting define menu material properties. We add new material for our structural components (beams, columns, slabs) by giving the specified details in defining. After that we define section size by selecting frame sections & added the required section for beams, columns etc.

Step - 4: Assigning of Property

After defining the property, we draw the structural components using command menu. Draw line for beam for beams and create columns in region for columns by which property assigning is completed for beams and columns.

Step - 5: Assigning of Supports

By keeping the selection at the base of the structure and selecting all the columns we assigned supports by going to assign menu joint\frame Restraints (supports) fixed.

Step - 6: Defining of loads

In ETABS all the load considerations are first defined and then assigned. The loads in ETABS are defined as using static load cases command in define menu.

Step - 7: Assigning of Dead loads

After defining all the loads. Dead loads are assigned for external walls, internal walls in E-Tabs automatically taken care by software.

Step - 8: Assigning of Live loads

Live loads for roof and floor are assigned separately for the entire structure.

Step - 9: Assigning of wind loads

Wind loads are defined and assigned as per IS 875 1987 PART 3 by giving wind speed and wind angle.

Step - 10: Assigning of Seismic loads

Seismic loads are defined and assigned as per IS 1893: 2002 by giving zone, soil type and
response reduction factor in X and Y directions.

Step - 11: Assigning of load combinations

Using load combinations command in define menu automatically produces load combinations as per codes chosen.

Step - 12: Analysis

After the completion of all the above steps we have performed the analysis and checked for errors. Correcting the errors the comparison graphs are formed.

Step-13: Give Base isolation parameters of LRB.

After analysis with fixed base, the base is isolated by LRB technique to make structure earthquake resistant.
Hence its LRB parameters are found from isolation design procedure and assigned in required field of LRB formulation.

. ANALYTICAL WORK

Through the process of analysis we study comparatively the effect of earthquake forces with increase in stories in building with fixed base and isolated base. Here RC buildings of G+10, G+15 are compared combining their effects on different parameters such as storey drift, Displacement, storey shear, moment, time period, stiffness and deformed shape due to earthquake load on various plots.

ANALYTICAL INPUTS OF BUILDING-

- Load on floor: 4.0 KN/Sq.m
- Live load on roof: 1.5 KN/Sq.m
- Roof finish: 1 KN/Sq.m
- Water proofing: 2 KN/Sq.m
- Floor finish: 1KN/Sq.m
- External Wall Load: 0.23*20*3.5= 16.1 KN/Sq.m
- Internal Wall Load: 0.13*20*3.5= 9.1 KN/Sq.m
- Thickness of slab: 200 mm

International Journal of Engineering Research & Technology (IJERT)
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- Location of the site: Bhubaneswar in Seismic Zone-II, Z=0.16
- Type of Soil: Medium Soil, (Type-II as per IS: 1893 (Part-1))
- Response Reduction Factor: 5
- Special Moment Resisting Frame(SMRF)
- Importance Factor: 1
- Allowable bearing pressure: 150 KN/Sqm
- Each Storey Height: 3.5m
- No of Floors: G+9, G+14, G+19
- External Wall Thickness: 230 mm
- Internal Wall Thickness: 130 mm
- Column Size: 300x600 Sqmm
- Beam Size: 450x500 Sqmm
- Wind Load: As per IS: 875-1987 (Part-3)
- Earthquake Load: As Per IS: 1893-2002 (Part-1)
- Density of concrete: 25KN/m^3
- Density of Brick: 20 KN/m^3
- Modulus of elasticity of concrete: 25000n/m^3
- fck : 25N/mm^2
- fy : 415N/mm^2

DESIGN OF ISOLATORS (LEAD RUBBER BASE):
LRB is generally made by introducing the lead in the ordinary rubber bearing, thereby making its design parameters are common with ordinary rubber bearing such as bearing plane size, the rubber layer thickness. But the use of lead joining, LRB gave some unique design parameters. The diameter and height of lead change have a direct impact on the function of absorbing and dissipating energy by the LRB. In addition, the initial elastic stiffness and yield stiffness of bearing and their ratio, are also the main parameters affecting the seismic design of buildings and bridges.
The design steps are as follows: -

- Consider vertical load on isolator after gravity load analysis (Dead+ Live+ SIDL) and Let consider it as R KN.
- Fixed base time period of frame is T, a time separation of 3 is considered for base isolated structure consider it as Tb sec., Tb= 3*T
- From the vertical reaction R and Tb calculate,
- The effective stiffness of isolator = Keff = ((R*4*π2) / (g*Tb2))
- From the given response spectra for 10% damping as per IS 1893(Part-I):2002, calculate
- The maximum displacement of isolator, Sd = ((Sa*Tb2) / (4*π2))
- From above two calculated quantity calculate Energy dissipation per cycle, i.e. WD,
  WD= 2*π*Keff*Sd2*Ɛeff
- From the given data, calculate QD which is first approximation for the short term yield force
  QD = Wd / (4×Sd)
- The post yield horizontal stiffness (Kd) can be obtained as,
  Kd= Keff – (QD / Sd)
- Using the expression for Dy (Displacement) can be calculated as:-
  Dy= QD / (9*Kd)
  Correcting the first estimate of QD for Dy, gives Yield Force = Q = WD / (4*(Sd – Dy)
- Geometric Design for isolator,
- The lead plug area, Ap = Q / fpy
- Yield strength of lead core fpy; dp= √ ((4*Ap)/(π))
- Total height of the rubber layers, H= (Sd / γmax) ,
- Where γmax= Design shear strain = 50%
- The compression modulus of rubber-steel composite; Ec= E (1+2Ks2), where
- k = modification factor = 0.57, S Shape factor = 10 (assumed),
- The effective area A0 of the bearing based on the allowable normal stress under the vertical load case: - A0= R/σc,
- σc= Allowable normal stress
- Effective area A1 from the shear strain condition for the vertical load case: -
  A1= ((18*S*R)/ (Ec*Ɛb)); where Ɛb= Damping constant= 500%
- Kr= Stiffness of rubber; Kr is related to Kd (Final stiffness)
- Kr = Kd / (1+12(Ap/A0));
- From the above data, A = (KrH/G) and calculate d,
- B = 2*Cos^{-1}β Sd/d
- Area= ((d2)/4(β-sin 〖β)〗)
- Area of single rubber layer, A = max (A0, A1, Are) calculate A, and d
- Single layer thickness: t= (d/4*S)
- Number of layers= N = (H/t)
- Assume thickness of steel plate, ts= 2.5 mm
- Total height of isolator, h = H+N×ts + 2× (cover plate thickness)
- Assume cover plate thickness of as 25mm and diameter of cover plate must be greater than diameter of rubber core.

COMPARISION OF RESULTS
Through the comparative analysis of various RC framed structure with fixed base and isolated base were studied. Moreover, the effect of increasing number of storeys equivalently in both the cases (i.e. in fixed and isolated base) were also compared and recorded in reference with maximum storey displacement, maximum storey drift, storey shears, overturning moments, storey stiffness and time period.

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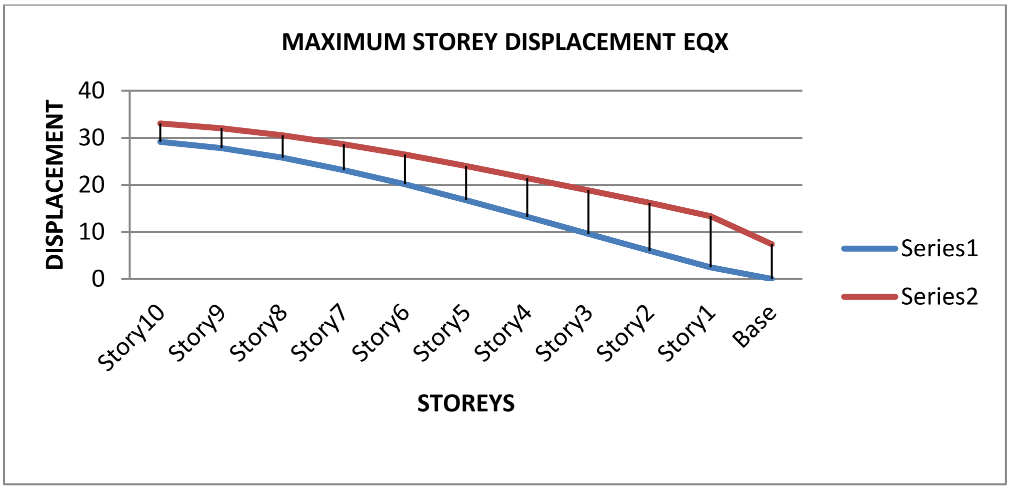
TIME PERIOD: -

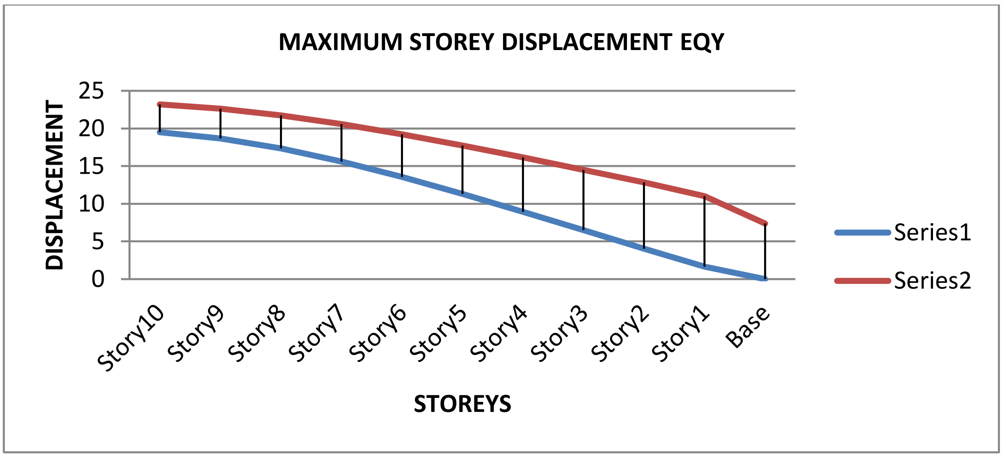
In course of our study comparison of time period between fixed base and base isolated structure is one of the most important and fundamental study. Moreover, in our case we can observe the effect on time period with increase in number of storeys. In base isolated structure time period increases. Due to this increase in time period, structure experiences less amount of seismic forces.

STOREYS	TIME PERIOD IN FIXED BASE	TIME PERIOD IN ISOLATED BASE
G+10	2.622	3.723
G+15	4.087	5.074

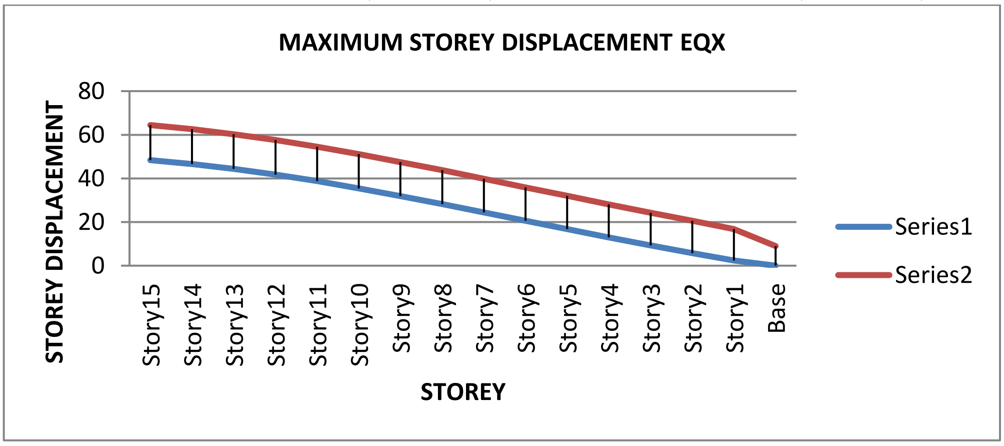
MAXIMUM SROREY DISPLACEMENT:-

COMPARISION OF G+10 WITH FIXED BASE (SERIES-1) AND ISOLATED BASE (SERIES-2).





COMPARISION OF G+15 WITH FIXED BASE (SERIES-1) AND ISOLATED BASE (SERIES-2).



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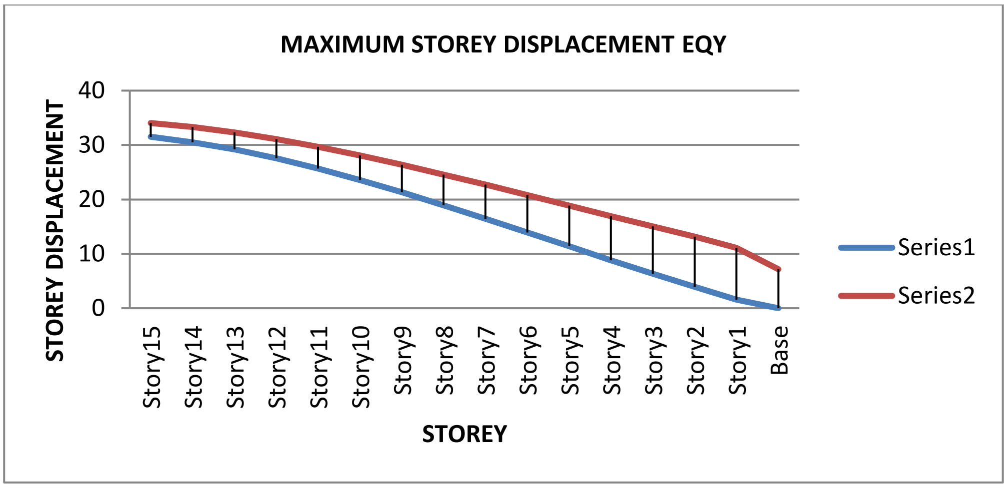
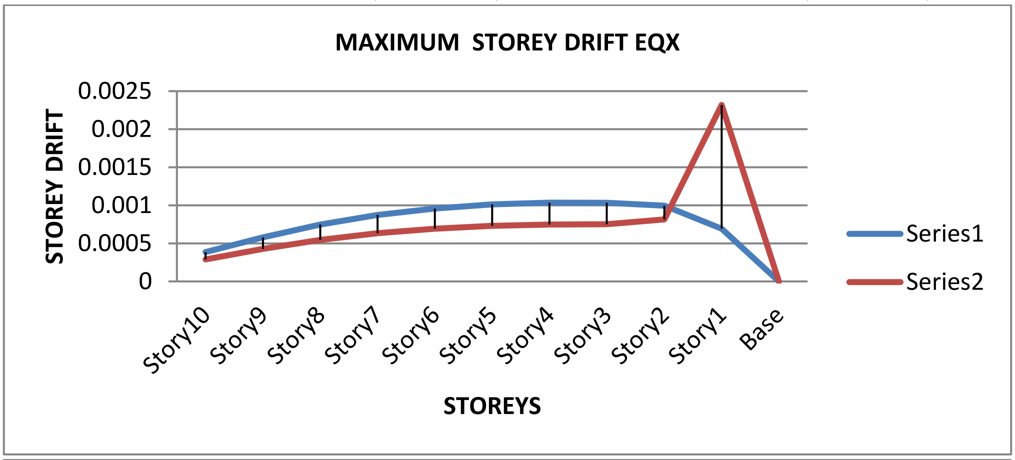
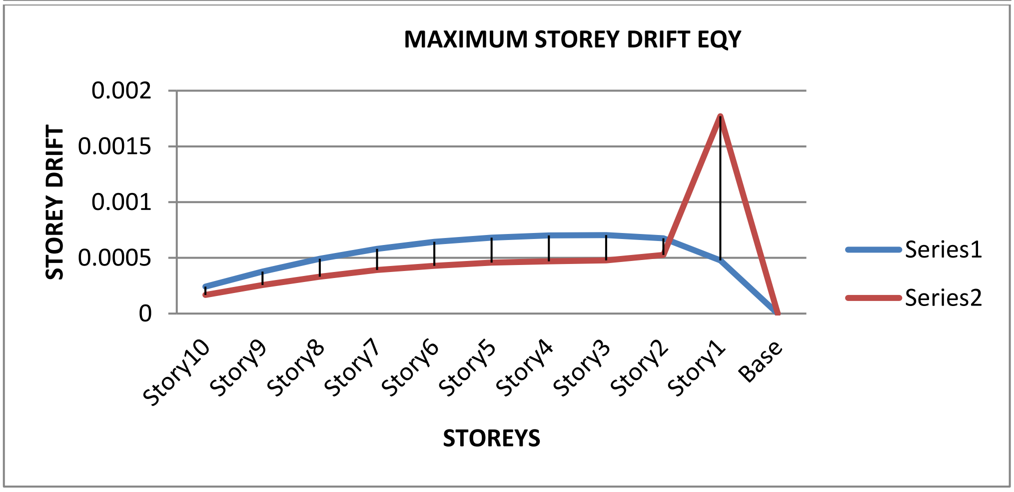


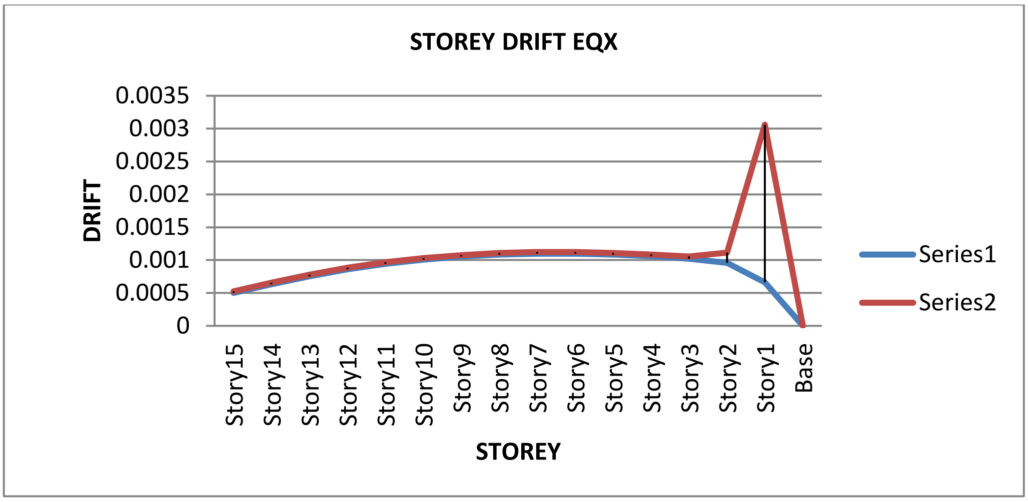
MAXIMUM STOREY DRIFTS: -

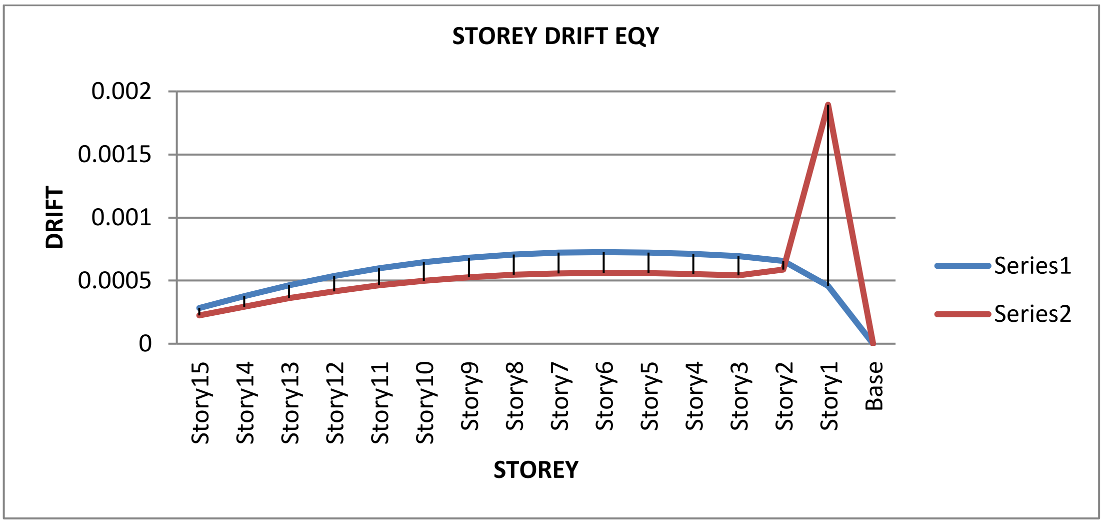
COMPARISION OF G+10 WITH FIXED BASE (SERIES-1) AND ISOLATED BASE (SERIES-2)





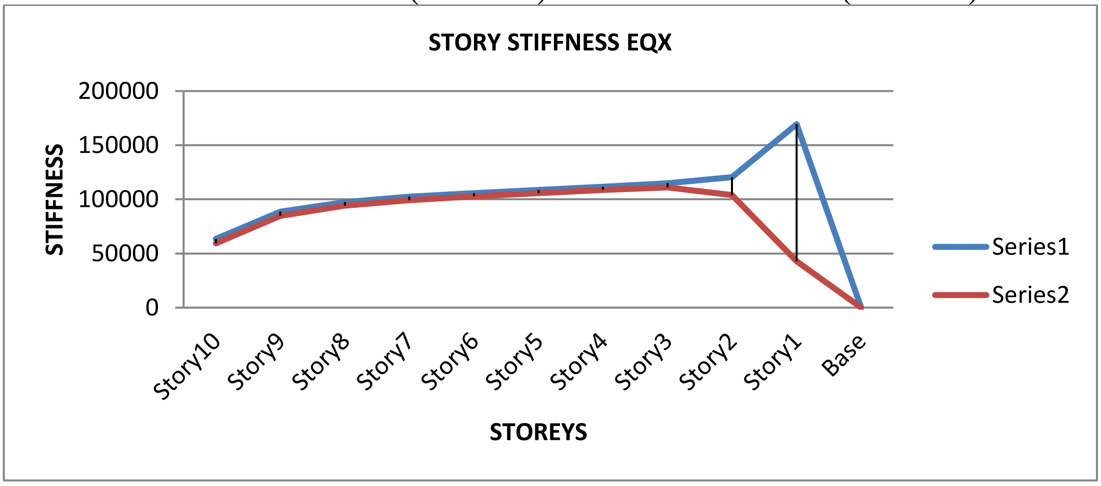
COMPARISION OF G+15 WITH FIXED BASE (SERIES-1) AND ISOLATED BASE (SERIES-2)





STOREY STIFFNESS

COMPARISION OF G+10 WITH FIXED BASE (SERIES-1) AND ISOLATED BASE (SERIES-2).



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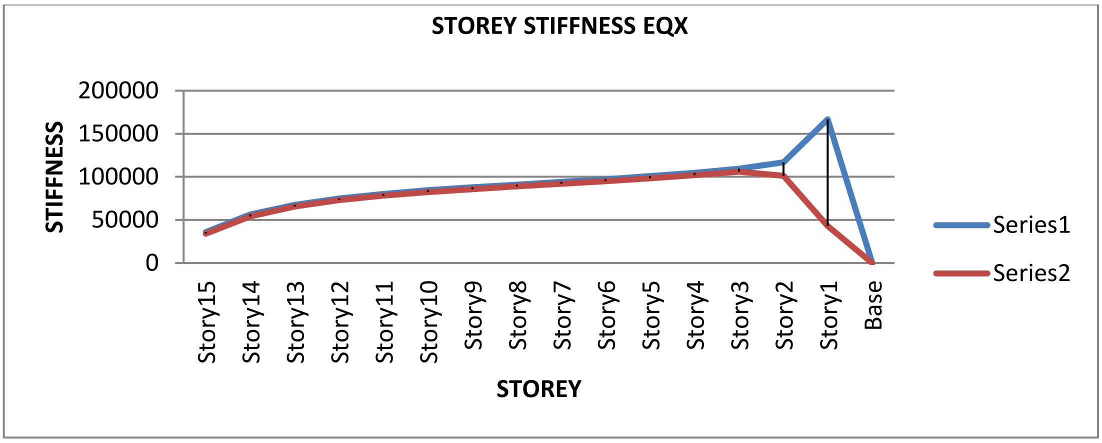
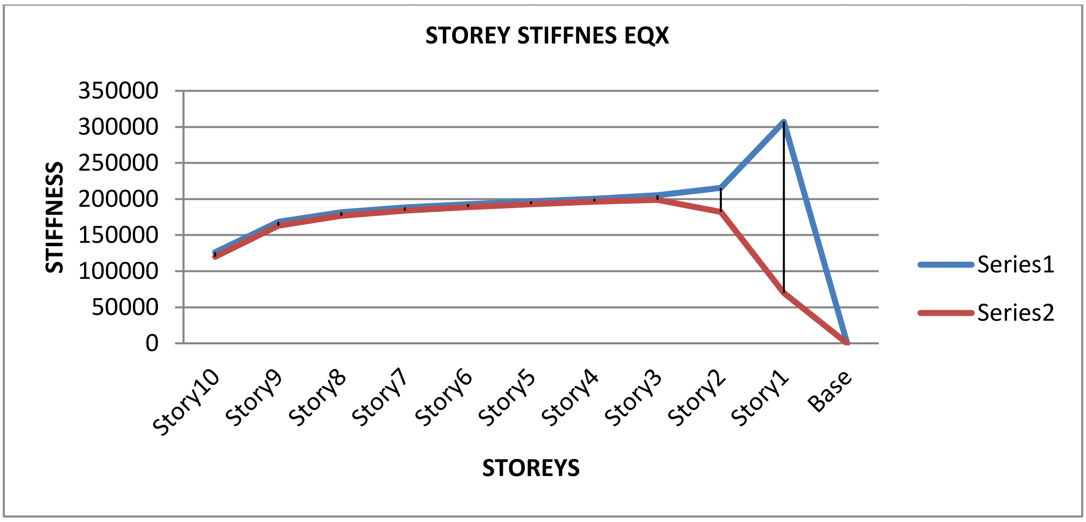
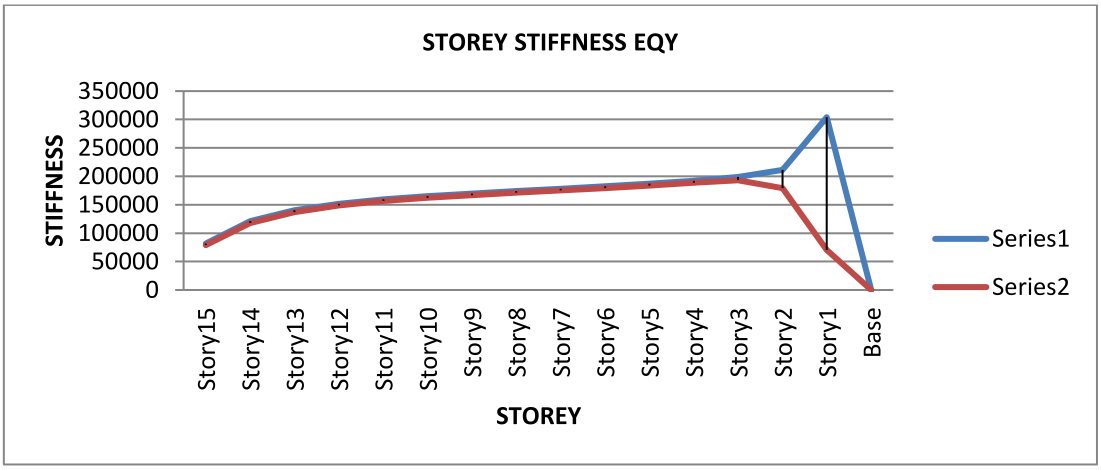


COMPARISION OF G+15 WITH FIXED BASE (SERIES-1) AND ISOLATED BASE (SERIES-2)





CONCLUSION

The aim of present study was to analyse building at seismic zone i.e. in zone-II without and with base isolator and to assess the seismic behaviour of structure. The main purpose of this study is to investigate the effectiveness of base isolator which acts as energy dissipater. Moreover, this study provides an overall comparative result analysis of structure with increase of number of storeys.

Simultaneously, with analysis of both the building structures, the design of Base isolator was made according to loads of structures and parameters of base isolators were found respectively for G+10, G+15. Following conclusions can be drawn after analyzing the results of 3-D analysis of G+ 10, G+ 15 storeys building in seismic zone II using ETABS software.

- The time period of structure increases approximately 2 times after providing the base isolator to fixed base structure. Due to this increase in time period, structure experiences less amount of seismic forces.

- The lateral earthquake Load, storey shear, column forces and moment are reduced to significant amount due to use of base isolator to the structure.
- The maximum storey displacement in base isolated structure increases.
- The maximum storey stiffness of structure decreases in base isolated structure.
- The storey drift in base isolated structure increases.
- From the above data, the damage to the base isolated structure will be less as compared to fixed base structure. Thus, structure can be immediately occupied after the actual earthquake.
- If important machinery is installed in structure, due to isolator it is safer and suffers less damage than fixed base building.

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