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SEISMIC RESPONSE OF REINFORCED CONCRETE MONOLITHIC BUILDING PROVIDED WITH BASE ISOLATION

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ABSTRACT

In urban areas, need for new residential accommodation is increasing and supply is insufficient. Housing standards and construction methods are continuously progressing to reflect wide-ranging and inconsistent economic circumstances, societal morals, customs and technical advances. One such advanced technology that has emerged in recent times is the 'cast-in-situ monolithic reinforced concrete construction system'. The numbers of buildings constructed using this technology is increasing and significant number of modern high rise buildings are adopting this technology since it allows faster, more reliable and economical construction options. With the increased use of multi-storey structures in India and around the world, the analysis of such buildings is of considerable significance. In multi storey buildings seismic forces will have a very high impact on any form of the structure. In the event of an earthquake the principle attack on any building is due to transient lateral forces. Elastic strength, inelastic deformability, damping capabilities and their combination results in the seismic resistance offered by any Structure. The base-isolation technique proves to be very effective in enhancing the structural safety and integrity against severe earthquakes. In this paper, a three dimensional response spectrum analysis is carried out in ETABS 16.0.0 to investigate in detail the seismic response of G+7 storey Reinforced Concrete (RC) monolithic building provided with base isolation and fixed base, when subjected to seismic forces. The response parameters like Modal time period, Base Shear, Displacements, Story accelerations are compared between Base Isolated and the fixed base Reinforced Concrete Monolithic building.

Keywords: Base isolation, ETABS, Friction Pendulum Bearing, Monolithic Construction, Response Spectrum Analysis

I.INTRODUCTION

The pace of construction in conventional construction practices is significantly slower due to number of activities such as assembly of formwork, concreting and deshuttering and thereafter plastering and other finishing works. In recent years there has been a tremendous development in the construction industry owing to advancement in technology. The construction industry has started implementing new technologies and methods to enhance the efficiency of a project. Adoption of latest and cost effective technology is essential for facilitating affordable housing to ever increasing population of our country [1, 2].

In-situ-monolithic construction is appropriate for building number of houses in a short duration using formwork for walls and slabs together in one continuous pour. Openings for windows, doors etc., are placed in position before concreting. Pre-fabricated items like Staircase flights, façade panels, chajjas are incorporated into the structure. To enable fast construction, early removal of formwork is accomplished by adopting hot air curing or curing compounds. This is one of the major benefits compared to other contemporary construction techniques.

Strong and sturdy high quality Aluminium Formwork panels for walls and floor slabs together are assembled at site (Fig 1) [3]. The concrete produced in the batching plants with stringent quality control is transported to site in transit mixers and poured in to forms (Fig 2). High quality Aluminium Formwork panels ensure consistency of dimensions. On removal of the formwork mould a high quality concrete finish is achieved to permissible tolerances and verticality. Due to the high quality finish achieved, no plastering is required. Also, there is no requirement for building masonry infill walls and plastering as major part of the structure is cast in one go.

Fig. 1 Erected formwork for walls in monolithic construction

(Source: http://www.hombalegroup.com/monolithic-construction-methology.html)

Fig. 2 View showing pouring of Concrete in to erected forms

(Source: http://www.hombalegroup.com/monolithic-construction-methology.html)

Earthquakes are natural consequences of the incessant evolution of our planet. Civil engineering is continuously improving ways to manage with this natural phenomenon. In response to the destruction by the recent/past tremors in densely inhabited areas, seismic codes have improved with the aim of leading to improved seismic performance on the background of technological development all over the world including India.

Earthquake resistant design of structures has been principally centred on ductility design concept worldwide. Significant damage in buildings under strong ground shaking can be avoided by modifying the structure's features through external interference such that during strong ground shaking the demand is less than the design strength of the Structure. To improve structural safety and integrity of the Structure, effective and reliable methods for aseismic design based on structural control concepts are desired. Seismic base isolation and energy dissipation are some of the approaches adopted to enhance the seismic resistance of the structure. 'Seismic Base Isolation' is one of the most favourable options among the structural concepts available, which is being adopted for new structures and retrofit of existing structures.

1.1 Base Isolation

Base isolation is a technique that offers seismic resistance to the structure. Base isolation cannot claim to make a building "earthquake proof", but it reduces considerably the forces and inter-storey drifts within a building and so limits damage [Charleson & Allaf (4)]. Base isolation alters the response of the structure subjected to earthquake so that the ground can move below the structure without transferring the ground motions into the structure [Kelly (5)].

The Base Isolation system consisting of elastomeric bearings and frictional sliding mechanisms decouple the structure from the lateral ground motions induced by seismic forces and also offer a very stiff vertical component in between the base level of superstructure and substructure (foundation). Base isolation extends the fundamental time period and dissipates the energy in damping. Non-structural components are secured due to reduction in accelerations and acceleration induced damages, leading to protection of the valuables and sensitive content of the structure [Torunbalci & Ozpalanlar (6)]. A base isolation system extensively reduces storey drifts, seismic forces and inelastic deformations, avoiding damages that are expected to occur in a building during an earthquake. This issue is relevant specially for public buildings because of their high prominence [Ribakov and Iskhakov (7)].

Seismic base isolation for structures is provided to protect the structural integrity and to avoid the destruction by decreasing the seismic-induced forces and deformations in the structure. The base isolators shield the structures from strong earthquakes by limiting the stiffness and enhancing the damping, Kelly [8]. On the other hand, the flexibility of the super-structure in a base isolated building is generally less than the non-isolated building which can cause the reduction of construction costs [Monfared et. al, 9]. Analytically it has been shown by Kabeer & Kumar [10] that isolators can bring about 20% savings in the reinforcement used due to base isolation, since the building does not undergo any deformation but only gets displaced. Till date, there are lot of buildings in Japan, New Zealand, USA, and very few in India which use seismic isolation principles and technology for their seismic design. Earthquake response assessment, parametric analysis and seismic parameter optimisation of base-isolated buildings are some serious issues for design of base-isolated structures [Huang, Ren & Mao (11)].

Most of the previous studies concerned to Base Isolation have been carried out on response of beam-column framed structure provided with Base Isolation systems for earthquake resistance [12, 13]. The present paper evaluates the response of a G+7 storey reinforced concrete monolithic residential building subjected to seismic forces using response spectrum method in ETABS Software with fixed base and isolated base. The building is same as that considered in previous study, in which the seismic behaviour of fixed base monolithic building was compared with that of conventional beam-column building with fixed base [14]. Response spectrum analysis is a linear dynamic statistical analysis method which measures the effect from each mode of vibration to specify the likely maximum seismic response of an essentially elastic structure.

II.OJECTIVE

The main objective of this work is to evaluate the response of a R C monolithic residential building, base isolated with friction pendulum bearings in comparison to that with fixed base when subjected to different loadings including seismic loads in all four zones as given in Table 1 considering soil type I (hard soil) as per IS 1893-2002[14].

Table-1: Classification of seismic zones as per IS code

Zone	II	III	IV	V
Intensity	Low	Moderate	Severe	Very severe
Zone Factor	0.10	0.16	0.24	0.36

III.METHODOLOGY

An attempt is made to analyze a realistic multi-storey apartment, modelled as a three dimensional structure in ETABS 2016 software[15]. This is to ensure that the building represents a typical realistic construction in modern India. Reinforced Concrete monolithic residential building with G+ 7 storeys is considered to study the seismic responses with fixed and base isolated condition. Typical architectural floor plan is shown in Fig 3. The building details and properties are given in Table 2 and 3. A comparative study is proposed between the response of fixed and isolated base using friction pendulum bearings under seismic loads. To achieve this objective, response spectrum method is considered. The response parameters like Modal time period, Base shear, Displacement, Story accelerations are compared between fixed base building and the Base isolated Reinforced Concrete monolithic building.

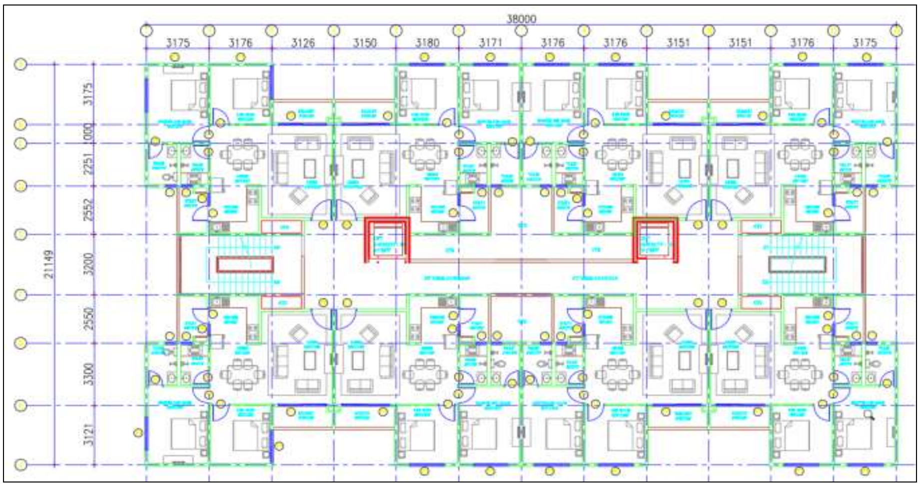

Fig. 3 Architectural Floor Plan of the residential building

3.1 Loads

Dead Loads and Live loads are considered as per the provisions in IS 875-1987[16,17, 18].

3.1.1 Dead loads

Floor Finish: 1.5 kN/m^2

Sunken areas : 1 X (0.45 – 0.15) X 7.85 = 2.35 kN/m^2

3.1.2 Live loads (Residential building)

Load on all rooms : 2 kN/m^2

Load on Balconies, Staircases, Corridors and Store rooms : 3 kN/m^2

Load on the Roof Slab: 1.5 kN/m^2

3.1.3 Seismic Loads

The seismic loads in equivalent static method and response spectrum method of analysis are applied to the structural models as per IS code.

IV. MODELING AND ANALYSIS

The Reinforced Concrete Monolithic building modeled as a three-dimensional structure is analysed by response spectrum method using FEM based computer software ETABS 2016. The structural material is assumed to be isotropic and homogeneous. The floors/slabs are modeled as membrane elements and considered as rigid diaphragms. All walls including those containing openings meant for doors/windows at respective locations are modeled as shell elements. The typical floor plan of model, 3D view and elevation of the building modeled in ETABS are shown in Fig 4, 5 & 6 respectively.

Table 2. Building details and Loads

Building	Monolithic(RCC)
Number of floors	Ground +7 floors
Height of each floor	3.15 m
RC Wall	160 mm thick
Slab	150 mm thick
Depth of foundation	1.5 m
Number of lift cores	2
Size of the lift core	2.05 m X 2.15 m
Thickness of the lift core wall	160 mm
Concrete	M25
Reinforcement	Fe 500
Soil type	I(Hard Soil)

Table 3. Properties of FPS bearings

Linear Effective Stiffness U1	15000000 kN/m
Non-Linear Effective Stiffness U1	15000000 kN/m
Linear Stiffness U2 and U3	750 kN/m
Non-Linear Stiffness U2 and U3	15000 kN/m
Friction Coefficient, Slow U2 and U3	0.03
Friction Coefficient, Fast U2 and U3	0.05
Rate Parameter U2 and U3	0.04
Radius of Sliding Surface U2 and U3	2.23m

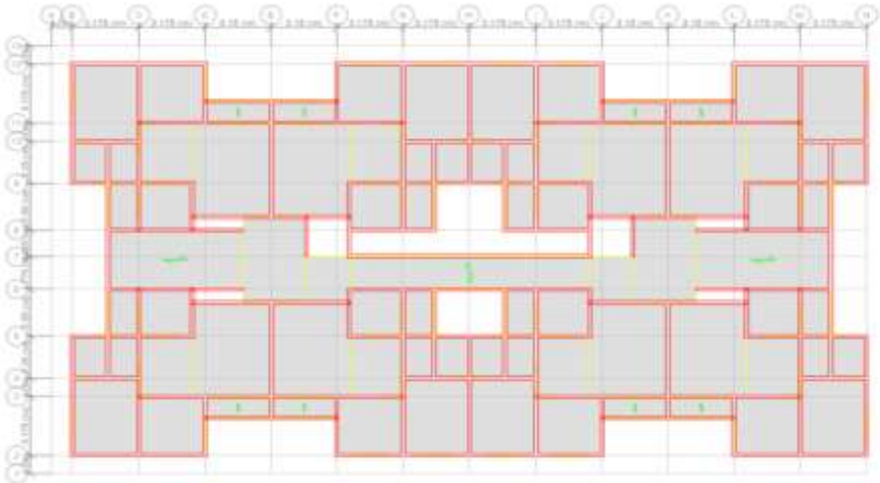

Fig 4. Floor Plan (typical) of the RC monolithic building in model

Fig 5. Three dimensional view of the RC monolithic Building model

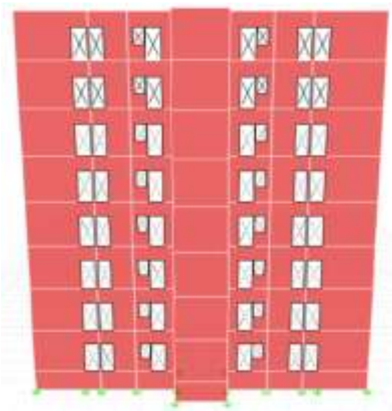

Fig.6. Elevation of the RC monolithic building model

4.1 RC Monolithic Building -Fixed Base

For the analysis of the RC Monolithic building with Fixed base, the structural models are generated for the seismic zones as given in Table 1 for soil type 1(hard soil)

4.2 RC Monolithic Building -Isolated Base

For the models generated, isolated base is modeled as a link property friction isolator in ETABS. The properties of the isolators are adopted from a journal paper published by Torunbalci and Ozpalanlar [6].The details of the properties of the Friction Pendulum bearings considered are given in Table 3.

The building under consideration has a very large area. In order to decide on the number of isolators, a study was made by varying the number and the position of the isolators. Five models were generated by varying

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number and position of the isolators. Numbers of the isolators considered were 14, 26, 44, 68 and 92. To get the optimum number of isolators, from the analysis results of each model the Base shear v/s number of isolators graph was plotted and presented in Fig. 7.

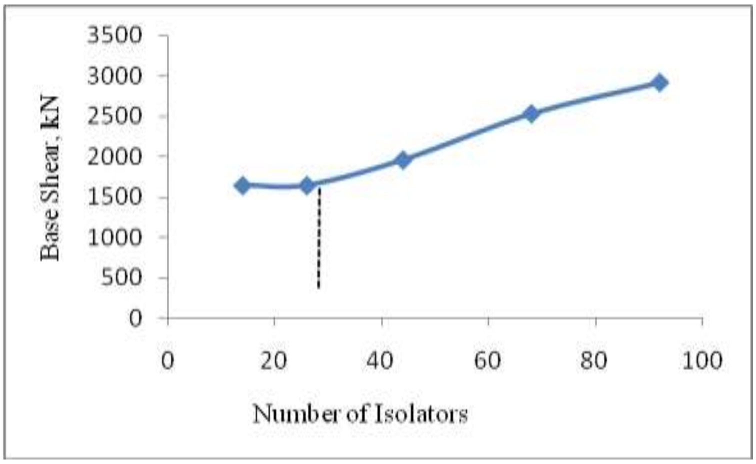

Fig.7. Variation of Base Shear v/s Number of isolators

In Fig.7, the x – axis represents the number of isolators and y – axis represents the base shear values for the corresponding number of isolators. From the above graph, it can be witnessed that the base shear value, gradually reduces with reduction in number of isolators and gets saturated from 26 numbers of isolators. This indication is considered as the optimum number of isolators that can be provided as 26 numbers. The location of 26 numbers of isolators considered in the ETABS model is shown Fig 8.

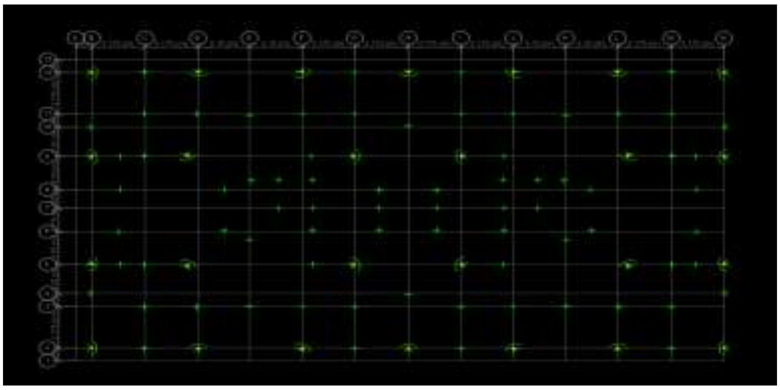

Fig. 8 Position of 26 numbers isolators considered in Model.

V.RESULTS AND DISCUSSIONS

The fixed base and the Base Isolated RC monolithic models are analyzed for four seismic zones and soil type I. The response parameters like Modal time period, Base Shear, maximum displacements, maximum storey accelerations are compared between Base Isolated building and fixed base building in all four zones. The results are presented in Table 4 and Fig 9 to 12.

5.1 Modal Time Period and Frequency

The time period of the first mode of vibration is Fundamental period. The comparison of modal time period and frequencies between Base isolated structure (BIS) and Fixed Base (FB), RC monolithic building is given in Table 4. Reduction in fundamental frequency results in lengthening the fundamental time period of the structure. This is the most important aim and effect of base isolation practices, which can eliminate the devastating first shocks of the earthquake. The predominant period of the structure is lengthened for the base-isolated building as expected.

Table 4. Comparison of Modal time period between Base Isolated Structure (BIS) and Fixed Base (FB) RC monolithic building

Mode	Base isolated Structure		Fixed Base Structure	
	Period, Sec	Frequency, Cycles/sec	Period, Sec	Frequency, Cycles/sec
1	4.281	0.234	0.165	6.07
2	4.279	0.234	0.112	8.92
3	3.593	0.278	0.111	9.01
4	0.093	10.72	0.048	20.84
5	0.058	17.23	0.037	27.07
6	0.058	17.33	0.036	27.76
7	0.043	23.40	0.028	36.17
8	0.043	23.46	0.028	36.19
9	0.035	28.72	0.025	40.25
10	0.035	28.78	0.022	46.45

The first mode time period for fixed base condition is 0.165sec and 4.281sec for isolated base condition. The modal time periods are constant in all the four seismic zones for both fixed and isolated base building respectively, because, Time period is dependent on the mass and stiffness of the structure which remain the same in all the four seismic zones.

5.2 Base Shear

Seismic base shear (V_B) is the product of sum of seismic masses at different floor levels multiplied by seismic coefficient. As seen in Table 5, for the RC monolithic building with base isolation system, the base shear reduces significantly.

When compared to zone II, the base shear increases by 1.6 times for Zone III, 2.4 times for Zone IV and 3.6 times for Zone V in both isolated base and fixed base models. When compared between isolated base and fixed base models, the reduction in base shear is 91% for isolated base models, thus averting damages that could be caused to the building during an earthquake.

Table 5. Comparison of Base Shear

Zone	Base Isolated building, kN	Fixed Base building kN
II	339	3625
III	542	5800
IV	813	8699
V	1219	13048

5.3 Maximum Storey Displacement

Lateral displacement is the deformation caused in the structure due to application of lateral forces. For the comparative study maximum storey displacements along lateral directions are chosen. For base isolated building, appreciable amount of lateral displacement is observed at the base as depicted in Fig-9 to 14. Fixed base models have zero displacement at base. For base isolated buildings the lateral displacement variation is negligible at higher elevations, whereas the lateral displacement increased significantly in case of fixed base building. When compared between ground floor level and roof level of the building, for isolated base models displacement is constant in both x and y directions. Whereas, in fixed base models the increase is about 19 times for x direction and 28 times for y direction respectively, resulting in negligible interstorey drift. The maximum drift is 0.000058 for isolated base and 0.000096 for fixed base building.

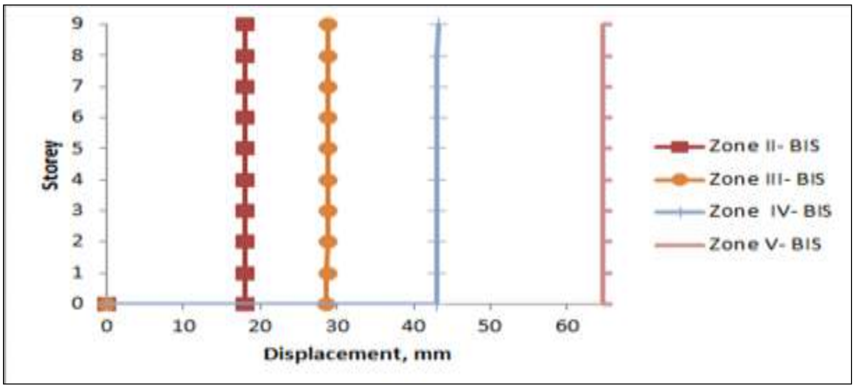

Fig 9. Variation of maximum storey displacement in X direction base isolated building

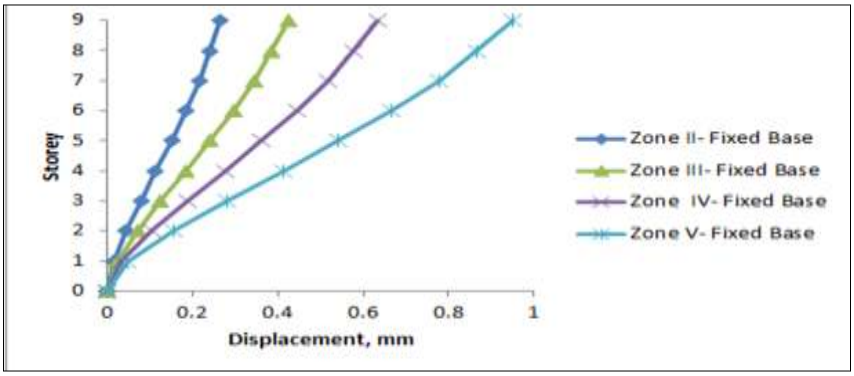

Fig 10. Variation of maximum storey displacement in X direction fixed base building

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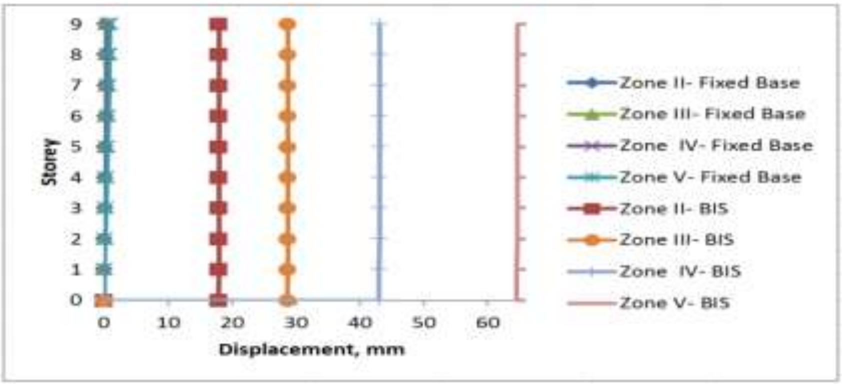

Fig 11. Variation of maximum storey displacement in X direction for both base isolated building and fixed base building

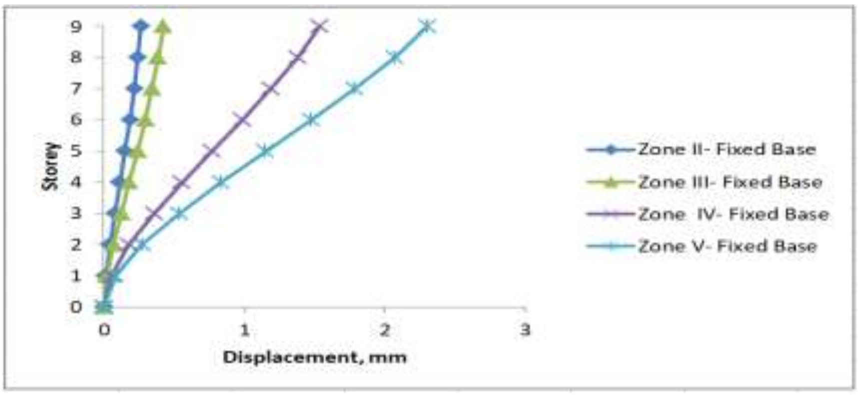

Fig 12. Variation of maximum storey displacement in Y direction base isolated building

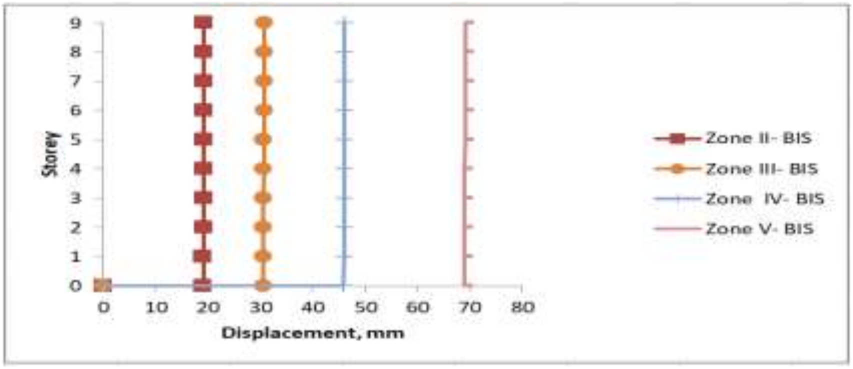

Fig 13. Variation of maximum storey displacement in Y direction fixed base building

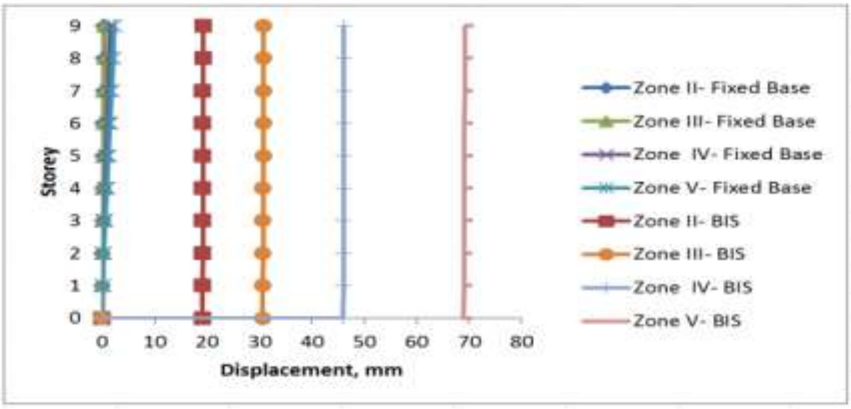

Fig14. Variation of maximum storey displacement in Y direction for both base isolated building and fixed base building

When compared to zone II, the displacements in x and y directions increases by 1.6 times for Zone III, 2.4 times for Zone IV and 3.6 times for Zone V in both isolated base and fixed base models.

5.5 Storey Accelerations

The objective of seismic base isolation is to lessen earthquake damage, which includes structural system and non-structural items like building parts, components and contents. The reduction of floor accelerations results in reduction of non-structural damage. Due to acceleration induced on the structure by earthquake motion, the structure also gets accelerated at an amplified rate of input ground motion acceleration. Inertia forces due to floor accelerations will results in damage to components like ceilings and also contents on the floor. A building can be designed stiffer to reduce drifts and damage costs, due to which the floor accelerations have a tendency to be higher in stiffer buildings hence, acceleration-related damage, will intensify.

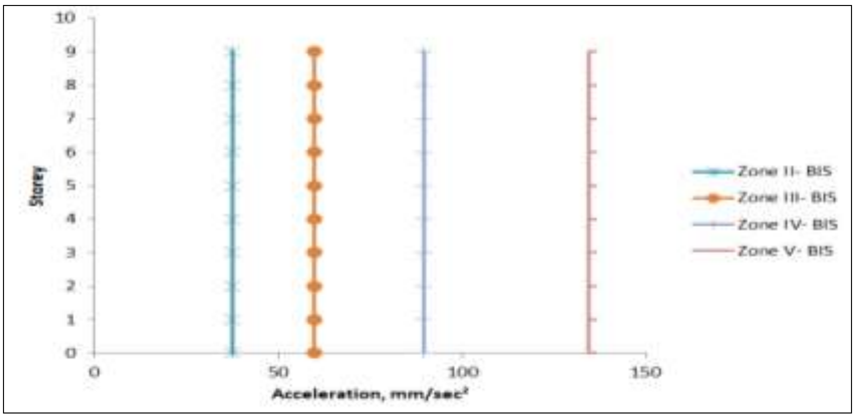

Fig15.Variation of maximum storey acceleration in X direction for base isolated building

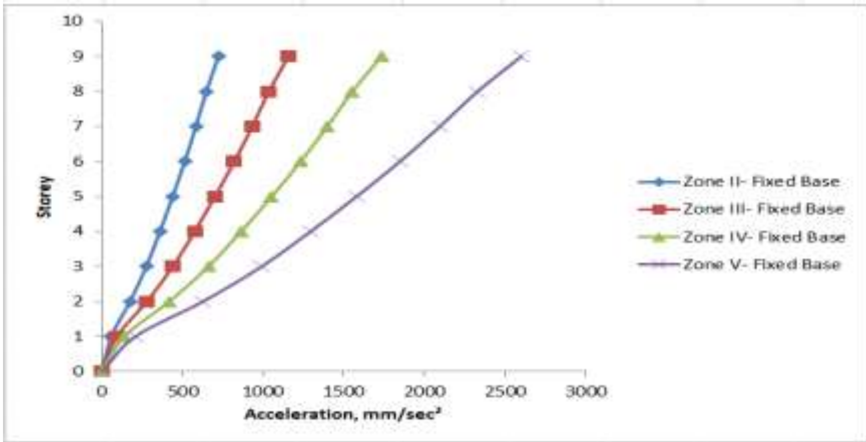

Fig16.Variation of maximum storey acceleration in X direction for fixed base building

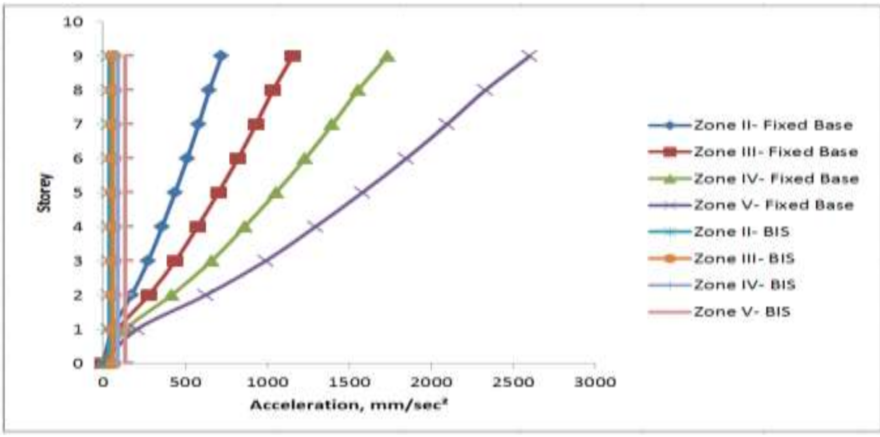

Fig 17.Variation of maximum storey acceleration in X direction for both base isolated and fixed base building

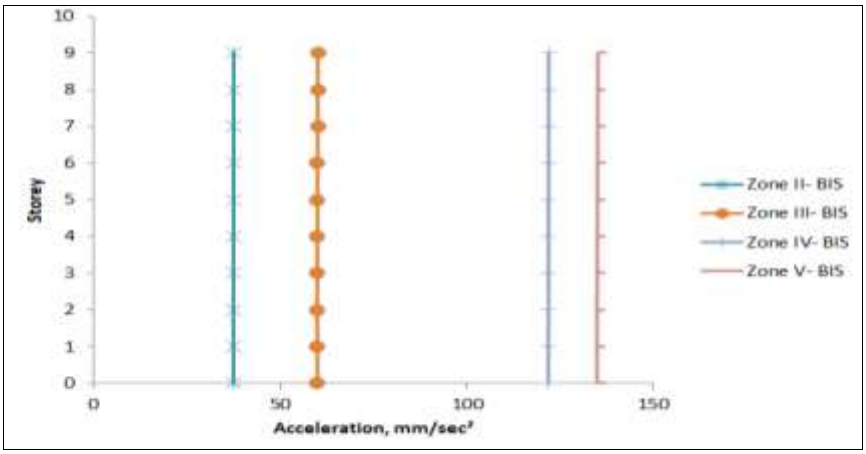

Fig18.Variation of maximum storey acceleration in Y direction for base isolated building

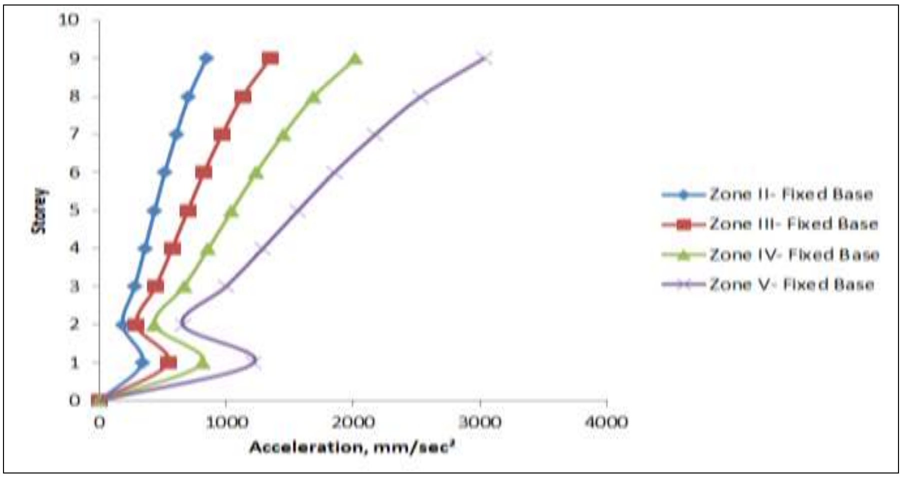

Fig19.Variation of maximum storey acceleration in Y direction for fixed base building

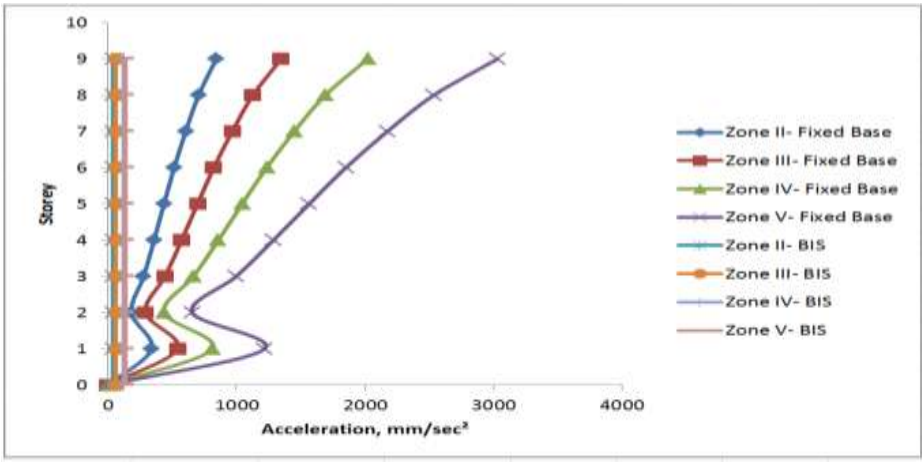

Fig 20.Variation of maximum storey acceleration in Y direction for both base isolated and fixed base building

When the floor accelerations are examined, it is observed that substantial reduction in storey accelerations is achieved with base isolation for the RC monolithic building. The variation of storey acceleration in x and y direction in all the four zones are shown in Fig 15 and 20. When compared between isolated base and fixed base models, there is a reduction in storey acceleration of about 95% in base isolated models.

In isolated base models, the storey acceleration is constant and almost equal in both x and y directions. In fixed base models, when compared between ground and roof floor of the building, the storey acceleration increases by 12.6 times in x direction and 2.5 times in y direction.

When compared to zone II, the storey accelerations in x and y directions increase by 1.6 times for Zone III, 2.4 times for Zone IV and 3.6 times for Zone V in both isolated base and fixed base models.

VI.CONCLUSIONS

An attempt is made to investigate a Reinforced Concrete monolithic G+7 storey residential building modeled as three dimensional structure in ETABS Software to study the seismic response with base isolated and fixed base condition situated in all four seismic zones with soil type I (hard soil).

1. Lengthening of the fundamental period of base isolation system results in reduction of the maximum acceleration and hence the reduction in earthquake-induced forces in the structure.
2. For the RC monolithic building with base isolation system, the base shear reduces significantly. The reduction is 91% for soil type I compared to the fixed base RC monolithic building in all the zones.
3. For isolated base models the displacement between ground floor level and roof level is constant in both x and y directions. In fixed base models, the displacement between ground floor level and roof level increases by about 19 times in x direction and 28 times in y direction respectively.
4. There is a reduction of about 95% in the peak storey acceleration in the base isolated building when compared to the fixed base building.
5. When compared to zone II, the base shear, displacements and storey accelerations increases by 1.6 times for Zone III, 2.4 times for Zone IV and 3.6 times for Zone V in both fixed base and isolated base models in soil type I.

The results show that the Base Isolation is very effective at lessening the seismic response of the structure.

REFERENCES

[1] http://www.builtconstruction.in/fasttrackconstruction/industryinteraction/monolithicconstructiontechnology/

[2] http://www.masterbuilder.co.in/monolithic-constuction-technology-booster/

[3] http://www.hombalegroup.com/monolithic-construction-methology.html

[4] A W Charleson & N J Allaf (2012) *"Cost of Base-isolation and Earthquake insurance in New Zealand" New Zealand Society for Earthquake Engineering (NZSEE) Conference, Paper no.-41*

[5] T E Kelly *"Base isolation of Structures - Design guidelines" Holmes Consulting Group Ltd (200 1).*

[6] N Torunbalci & G Ozpalanlar *"Earthquake response analysis of mid-story buildings isolated with various seismic isolation techniques" The 14th World Conference on Earthquake Engineering, October 12-17, 2008, Beijing, China (2008)*

[7] Y Ribakov & I Iskhakov *"Experimental Methods for Selecting Base Isolation Parameters for Public Buildings" The Open Construction and Building Technology Journal, 2008, 2, (2008) 1-61*

[8] J M Kelly *"Earthquake-resistant design with rubber" 2nd edition, London: Springer-Verlag(1997).*

[9] H Monfared, A Shirvani & S Nwaubani *"An investigation into the seismic base isolation from practical perspective" International Journal of Civil and Structural Engineering, Vol-3, Issue-3(2013).*

[10] S A Kabeer & K S Kumar (2014) *"Comparison of Two Similar Buildings with and without Base Isolation" International Journal of Advance research Ideas and Innovations in technology,Volume-1, Issue-1*

[11] D M Huang, W X Ren & Y Mao (2013*) "Modified complex mode superposition design response spectrum method and parameters optimization for linear seismic base-isolation structures" Techno Press-Earthquake and structures, Vol-4, PP: 341-363.*

[12] S. K. Jain & S. K,(Thakkar 2004) *"Application of Base Isolation for Flexible Buildings", 13th World Conference on Earthquake Engineering Vancouver, B.C.,Canada, August 1-6, 2004 Paper No. 1924*

[13] H Sharada Bai , P Chaithra, Ancy Mathew & G Ambrish *" Correlation Analysis on Seismic Response of Base-Isolated Multi-Storey Structures", International Journal of Earth Sciences and Engineering ISSN 0974-5904, Vol. 09, No. 05, October, 2016, pp. 1938-1946*

[14] B Pradeep, KS Shiva Kumar & G Ambrish *"Study of Seismic behavior of Conventional and RC Wall building", International Journal of Research in Engineering and Technology eISSN: 2319-1163, pISSN: 2321-7308(2016).*

[15] IS: 1893 (2002) *"Indian Standard code of practice for criteria for Earthquake resistant design of structures, Part-1: General provisions and buildings" Bureau of Indian Standards, New Delhi*

[16] CSI (2016). *Computer Program ETABS, Computers and Structures, Inc., Berkeley,CA.*

[17] IS 875:1987*, "Code of Practice for Design Loads (other than Earthquake)for Buildings and Structures: Part I Dead Loads- Unit Weight of building Materials and Stored Materials" (Second Revision) , Bureau of Indian Standards, New Delhi, August 2001.*

[18] IS 875:1987*, "Code of Practice for Design Loads (other than Earthquake)for Buildings and Structures: Part II Imposed Loads (Second Revision) , Bureau of Indian Standards, New Delhi, August 2001.*