ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 3, Issue 2, February 2018

# Frequency and Time Domain Analysis of Irregular and Regular Building

[1] Sneha Rajesahe B Magar, [2] D. H. Tupe, [3] G. R. Gandhe
[1] P.G. student of Structural Engineering, Deogiri Institute of Engineering & Management studies
[2] Assistant Professor of Civil Engineering Department, Deogiri Institute of Engineering &Management studies
[3] HOD of Civil Engineering Department, Deogiri Institute of Engineering &Management studies

***Abstract:* -- The real earthquake characterization is essential for better understanding wave acceleration phenomena and the characterization of the Bhuj and Kobe subject to earthquake excitations. Results of ongoing time-frequency research are presented here with the aim to compare the performance of various state-of-the-art time-frequency distributions when applied to earthquake records to the Irregular and regular building. In a near future, the objective is to adopt this innovative joint time-frequency signal processing technique to earthquake record analysis and parameter estimation. The time-frequency distributions studied are the acceleration, velocity and Displacement. The earthquake records ranging from strong to medium soil condition, where used in this analysis. These accelerogram time series were recorded in the Kobe and Bhuj earthquake time history records applied to medium soil condition for frequency and time domain analysis. Based on our results, is our comparison between two earthquake frequency and time domain applied to Irregular and Regular shape building. The ETAB software is used to analyze the Irregular and regular building for the G+15 storey.**

***Keyword*: Irregular Building, Regular building, Etab Sotware, Bhuj and Kobe time history records, Frequency and Time domain analysis.**

## I. INTRODUCTION

### 1.1 General

Earthquakes are major geological phenomena. Man has been terrified of these phenomena for ages, as little has been known about the causes of earthquakes, but it leaves behind a trail of destruction. There are hundreds of small earthquake around the world every day. Some of them are so minor that humans cannot feel them, but seismographs and other sensitive machines can record them. Every year, earthquakes take the lives of thousands of people, and destroy property worth billions. The 2010 Haiti Earthquake killed over 1, 50,000 people and destroyed entire cities and villages. Designing earthquake resistant structures is indispensable. It is imperative that structures are designed to resist earthquake forces, in order to reduce the loss of life. The science of earthquake engineering and structural design has improved tremendously, and thus, today, we can design safe structures which can safely with stand earthquakes of reasonable magnitude. The most destructive of all earthquakes hazards is caused by seismic waves reaching the ground surface in places where human built structures, such as, buildings and bridges, are located. When seismic waves reach the surface of the earth in such places, they give rise to what is known as strong ground motion. Strong ground motions cause's buildings and other structures to move and shake in a variety of complex ways. Many buildings cannot with stand this movement and suffer damages of various kinds and degrees. Most deaths, injuries, damages and economic losses caused by the earthquake result from ground motion acting on the buildings and other man-made structures not capable of with-standing such movement. Engineers do not attempt to make earthquake proof buildings that will not get damaged even during the rare, but strong earthquake; such buildings will be too robust and also too expensive. Instead the engineering intention is to make buildings earthquake resistant; such buildings resist the effects of ground shaking, although they may get damaged severely but would not collapse during the strong earthquake. Thus, the safety of people and contents is assured in earthquake-resistant buildings, and there by a disaster is avoided. This is a major objective of seismic design codes throughout the world. By analyzing the experiences of past earthquakes, Structural engineer's greatest challenge in today's scenario is constructing seismic resistant structures. Uncertainties involved and behavior studies are vital for all civil engineering structures. The overture to the design of multi-story building should be based mainly on lateral stability and deformation in static analysis. Multi-story buildings are greatly affected by lateral forces to an extent, which plays an important role in the structural design. In this type of buildings, seismic loads play a critical role. Hence better plan configuration for the lateral stability is almost as significant. The case of seismic loadings is not so simple; Even knowing the characteristics of an earthquake movement and interaction with the structure are so complex that the exact values of the forces of earthquake has a degree of uncertainty. As per Bureau of Indian Standard actual forces are much higher than the design forces during an earthquake. Hence it is necessary to design the structural elements by considering their critical responses.

## II. LITERATURE REVIEW

F. Venancio Filho, A.M. Claret b, F.S. Barbosa [1] The dynamic analysis of structural systems can be performed by time-domain (TD) and by frequency domain (FD) methods. TD methods stem from the unit impulse transfer function and the convolution integral while FD methods stem from the complex frequency response function through Fourier transforms (FTs). The strict relation between both methods is a consequence that the unit-impulse transfer function and the complex-frequency response function constitute a pair of FTs. Matrix formulation for FD and TD dynamic analysis SDOF structural systems were presented. The strict correspondence between the two types of analysis was discussed. The convergence analysis of the response obtained by the FD method indicated that, when N is even, there is a complex term in the response whose imaginary part oscillates and that, with increasing N, the response finds to the exact one. The causality of the response was proven and a possible source of non-causality related to the insufficient extension of the period was pointed out. The given examples support the conclusions of the convergence and causality analyses. FD domain methods are superposition methods like mode superposition ones. These methods have the advantage over TD methods as they prevent the analysis of vibration frequencies and mode shapes. On the other hand the frequency truncation in FD methods corresponds to the mode truncation in TD methods. From the computational point of view one cannot be dogmatic whether one or other method is superior. The computational efficiency depends very much upon the problem and the preference of the analyst. Numerical solutions in the FD through the ImFT concept are competitive with TD ones with regard to accuracy and computational efficiency, as indicated by the examples in. In conclusion, FD methods are theoretically consistent and mandatory for rigorous analysis of systems with hysteretic damping and frequency-dependent properties.

**Matjaz Mrsnik, Janko Slavic, Miha Boltezar [3]**
This theoretical and experimental research on the frequency-domain methods for vibration-fatigue estimation focuses on the questions typical for the structural dynamics (i.e., close modes, noise background, mode numbers and spectral width) in the automotive accelerated test. In the theoretical background the well-established and also recent methods are presented and discussed: Dir-lik, Tovo-Benasciutti (2 versions), Wirsching-Light, Zhao-Baker (2 versions), Petrucci-Zuccarello, empirical _0:75 and the Gao-Moan method. Some of the methods have been compared with each other, while this research compares all the methods (including very recent ones) side by side. Furthermore, this research focuses on the real experimental data obtained with an electro-dynamical shaker experiment. The vibration profiles typical in structural dynamics and in an automotive-industry accelerated test are analyzed. Thus a group of best performing methods is selected, which can be applied to general broad-band spectra. At the same time, an estimate of the error one can expect is provided. The frequency-based methods are compared to the time-domain rainow method. Twenty-eight different fatigue loads (5 different groups of loads) were experimentally compared. If all 28 loads are evaluated, then the improved Tovo-Benasciutti is found to be the best method, followed by the improved Zhao-Baker and Dirlik methods. These findings are in contrast to the findings of Benasciutti and Tovo, who obtained better results with the Dirlik method. Overall, the Dirlik, Zhao-Baker and Tovo-Benasciutti frequency-domain methods are all very consistent when the material fatigue parameter k (S-N slope) is relatively low (k 3). With steeper slopes the error increases. Similar conclusions were already made by Bouyssy et al. and Benasciutti and Tovo By analyzing selected load groups it was found that the improved Tovo-Benasciutti method gives the most accurate results if the increased background noise spectrum is increased or if the spectral width is increased. For the close modes group and for the multi-mode group the improved Tovo-Benasciutti method was found to give non-conservative damage estimation, while the Dirlik method always gave a conservative estimation; however, for the higher values of the material fatigue parameter k the Dirlik estimation error (compared to the rainow time-domain method) is up to 50%. The improved Zhao-Baker method was found to be the most accurate (giving a conservative fatigue-damage estimation) for the typical automotive-industry accelerated test profiles. This research showed that the improved Tovo-Benasciutti and the improved Zhao-Baker methods should also be

considered together with the Dirlik method. In general, the improved Tovo-Benasciutti method gives best results, while the improved Zhao-Baker method gives the best results for the tested vibration profiles typical in the automotive industry.

## III. SYESTEM DEVELOPMENT

Literature review presented in the preview chapter has provided the information about the interaction of various features of seismic analysis and their effects on multi-story building. On the basis of literature, objectives of the present work are finalized as below,

1. To analyze two G+15 storey Regular and Irregular reinforced concrete building with moment resisting frame. One set with both building using equivalent static analysis.
2. To analyze two G+15 storey Regular and Irregular reinforced concrete building with moment resisting frame. One set with both building using Nonlinear dynamic analysis i.e. Time history analysis.
3. To evaluate and compare the results obtained by static and Nonlinear dynamic analysis for two different earthquake acceleration records.
4. To analyze two G+15 storey Regular and Irregular reinforced concrete building with moment resisting frame. One set with both building using Frequency and Time domain analysis for Bhuj and Kobe earthquake records.
5. To examine the result and investigate the better critical analysis methods for the analysis of RCC frames.

### 3.1 Method of Analysis

Earthquake shaking is random and time variant. But, most design codes represent the earthquake induced inertia forces as the net effect of such random shaking in the form of design equivalent static lateral force. This force is called as Seismic Design Base Shear VB and remains the primary quantity involved in force based earthquake resistant design of buildings. This force depends on the seismic hazard at the site of the building represented by the Seismic Zone Factor Z. Also, in keeping with the philosophy of increasing design forces to increase the elastic range of the building and thereby reduce the damage in it, codes tend to adopt the Importance Factor I for effecting such decisions. Further, the net shaking of a building is a combined effect of the energy carried by the earthquake at different frequencies and the natural periods of the building. Codes reflect this by the introduction of a Structural Flexibility Factor Sa/g. To make normal buildings, economical, design codes allow some damage for reducing cost of construction. This philosophy is introduced with the help of Response Reduction Factor R, which is larger for ductile buildings and smaller for brittle ones. Each of these factors is discussed in subsequent chapters. In view of the uncertainties involved in parameters, like Z and Sa/g, the upper limit of imposed deformation demand on the building is not known as a deterministic upper bound value. Thus, design of earthquake effects is not termed as earthquake proof design. Instead, the earthquake demand is estimated only based on concepts probability of exceedence, and the design of earthquake effects is termed as earthquake resistant design against the probable value of demand.

**Parametric Details of Model**

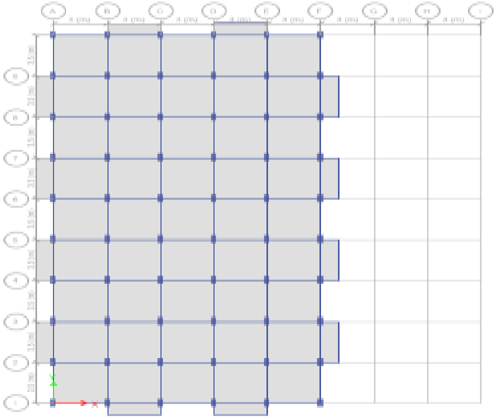


*Figure No. 3.1: Regular Shaped Structure*

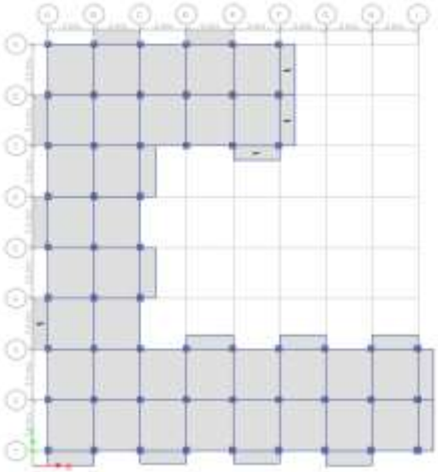


*Figure No. 3.2: Irregular Shaped Structure*

### 3.2 Loading Calculations

The loads will include the following

Dead Load: These includes the weight of all the components at each level, i.e., roof including parapets, roof finishes, slabs, beams, head room including plasters and surface cladding, etc., at each floor level including fixed masonry or other partition walls, infill walls, columns, slabs and beams,

weight of the stairs, cantilever balconies, parapets and plastering or cladding wherever used. The dead loads may be calculated on the basis unit weights of materials given in IS 875 Part-I 1987. Unless more accurate calculations are warranted, the unit weights of plain concrete and reinforced concrete made with sand and gravel or crushed natural stone aggregate may be taken as 24 kN/m3 and 25 kN/m3 respectively.
Slab Thickness = 150mm,
Self-Weight of Slab = 0.150 x 25 = 3.75 kN/m2 ,
Floor Finishing Load = 1 kN/m2 ,
Total Dead Load = 4.75 kN/m2
Member Load: Unit Weight of Brick Work = 20 kN/m3 , External Wall Thickness = 230mm, internal Wall Thickness = 115mm, Floor to Floor Height = 3.1 m, Parapet Wall Height = 1m, Load of External Wall = 0.23 x 3.1 x 20 = 13.8 kN/m, Load of Internal Wall = 0.115 x 3.1 x 20 = 6.9 , Load of Parapet Wall = 0.23 x 1 x 20 = 5.75 kN/m
Imposed Floor Loads or Live Load: There is a provision for reduction in the imposed loads for certain situations, example: for large span beams and number of stories above the columns of a story. The earthquake code IS 1893 Part I 2002 permits general reduction in roof and floor imposed load when considering the combination with the earthquake loading. Let the live load is assumed as 3 kN/m$^2$
Earthquake Load: For working out the earthquake loading on a building frame, the dead load and imposed load and weights are to be lumped at each column top on the basis of contributory areas. The imposed load is to be reduced as specified in IS 1893 Part I 2002 for seismic load determination.

**Load Combination**

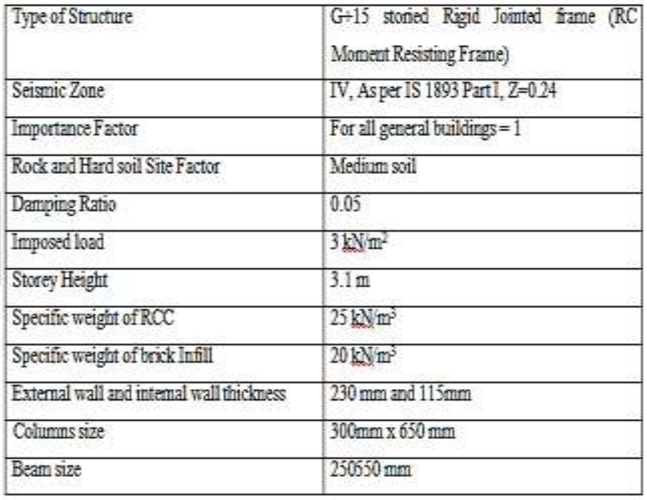
DL for Dead Load, LL for Live Load, EQX for Seismic Force in X direction, EQY for Seismic Force in Z direction and DYL for Dynamic Load The load combination as per IS 1893 Part I 2002 Clause 6.3.2.1 for analysis and design will be taken as follows:
1.5 x (DL + LL), b. 1.2 x (DL + LL + EQY), 1.2 x (DL + LL + EQY), 1.2 x (DL + LL - EQX), 1.2 x (DL + LL - EQY), 1.5 x (DL + EQX), 1.5 x (DL + EQY), 1.5 x (DL - EQX), 1.5 x (DL - EQY), 0.9DL + 1.5EQX, 0.9DL + 1.5EQY, 0.9DL - 1.5EQX, 0.9DL - 1.5EQY

### 3.3 Details of Earthquake:-

The 2001 Gujarat earthquake, also known as the Bhuj earthquake, occurred on 26 January, India's 51st Republic Day, at 08:46 AM IST and lasted for over 2 minutes. The epicentre was about 9 km south southwest of the village of Chobari in Bhachau Taluka of Kutch District of Gujarat, India.
The intraplate earthquake reached 7.7 on the moment magnitude scale and had a maximum felt intensity of X (Extreme) on the Mercalli intensity scale. The earthquake killed between 13,805 and 20,023 people (including 18 in southeastern Pakistan), injured another 167,000 and destroyed nearly 400,000 homes.

Date of Earthquake: 26th January 1967
Magnitude: 7.7
Epicenter: 23o419'N 70o232'E
Areas Affected: India, Casualties: 13805-20023 dead, 166800 injured.

***Table No. 3.5: Specification of Models***



| | |
|---|---|
| Type of Structure | G+15 storied Rigid Jointed frame (RC Moment Resisting Frame) |
| Seismic Zone | IV, As per IS 1893 Part I, Z=0.24 |
| Importance Factor | For all general buildings = 1 |
| Rock and Hard soil Site Factor | Medium soil |
| Damping Ratio | 0.05 |
| Imposed load | 3 kN/m$^2$ |
| Storey Height | 3.1 m |
| Specific weight of RCC | 25 kN/m$^3$ |
| Specific weight of brick Infill | 20 kN/m$^3$ |
| External wall and internal wall thickness | 230 mm and 115mm |
| Columns size | 300mm x 650 mm |
| Beam size | 250650 mm |

**3.11 Time history analysis**:- It is an analysis of the dynamic response of the structure at each increment of time, when its base is subjected to a specific ground motion time history. Alternatively, recorded ground motions database from past natural events can be a reliable source for time histories but they are not recorded in any given site to include all seismological characteristics suitable for that site. Recorded ground motions are randomly selected from analogous magnitude, distance and soil condition category (bin); three main parameters in time history generation. Adding more constraints to characteristics of each bin makes it to be more definite and similar to site characteristic. However, it may be put serious availability limit for real records in the bin. Selected ground motions response spectrum around fundamental period of the structure can be different than target response spectrum determined from seismic hazard analysis. Therefore, records are scaled by single-factor scales to have their mean spectral accelerations complied with target spectrum. Nevertheless, not much close agreement between the response spectrum of the record and target will be achieved with simply a single factor scaling of the record.

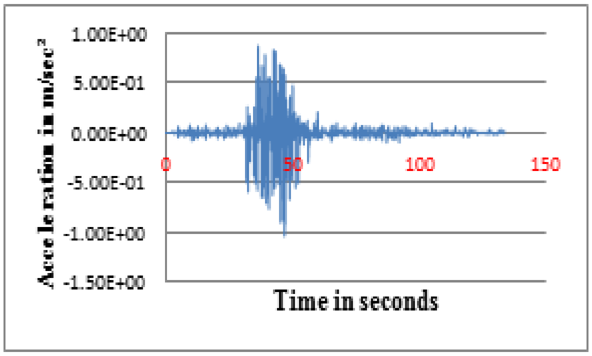


*Figure No. 3.3 Bhuj grounds acceleration records*

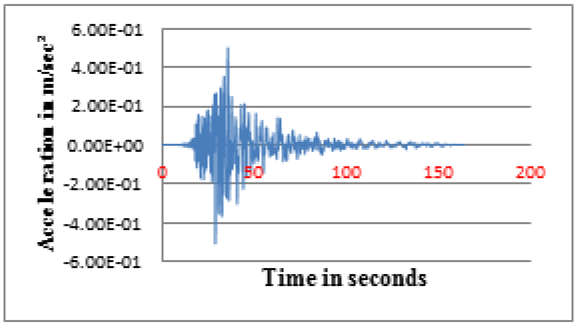


*Figure No. 3.4 Kobe ground acceleration record*

Frequency and Time domain analysis: Reinforced concrete (RC) frame buildings are the most common type of constructions in urban India, which are subjected to several types of forces during their lifetime, such as static forces due to dead and live loads and dynamic forces due to wind and earthquakes. Unlike static forces, amplitude, direction and location of dynamic forces, especially due to earthquakes, vary significantly with time, causing considerable inertia effects on buildings. Behavior of buildings under dynamic forces depends upon the dynamic characteristics of buildings which are controlled by both their mass and stiffness properties, whereas the static behavior is solely dependent upon the stiffness characteristics. Performance of buildings largely depends on the strength and deformability of constituent members, which is further linked to the internal design forces for the members. The internal design forces in turn depend upon the accuracy of the method employed in their analytical determination. Analyzing and designing buildings for static forces is a routine affair these days because of availability of affordable computers and specialized programs which can be used for the analysis. On the other hand, dynamic analysis is a time-consuming process and requires additional input related to mass of structure, and an understanding of structural dynamics for interpretation of analytical results.

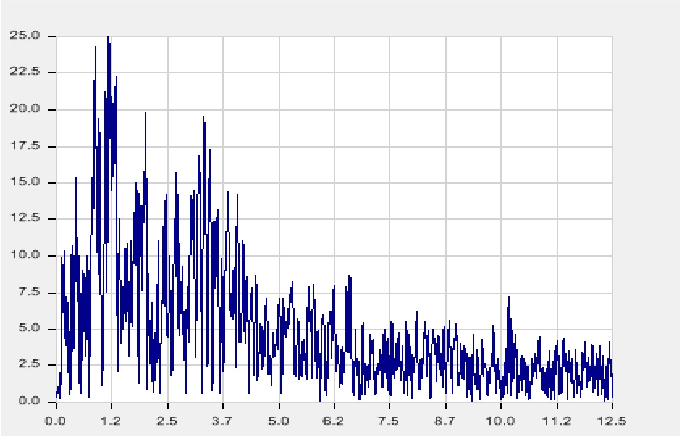


*Figure No. 3.5 Bhuj frequency content of time history*

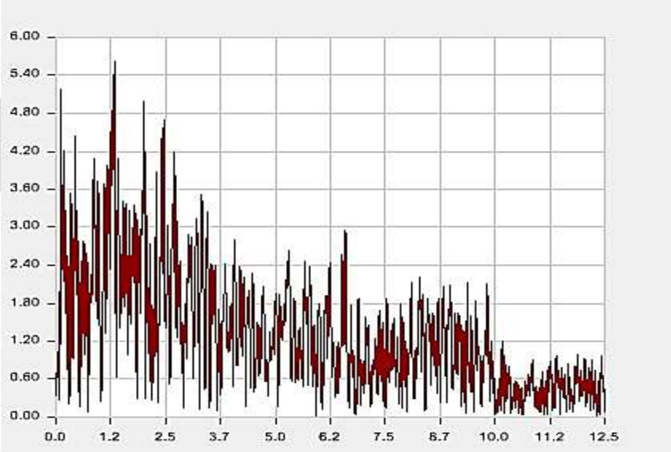


*Figure No. 3.6 Bhuj frequency content of matched time history*

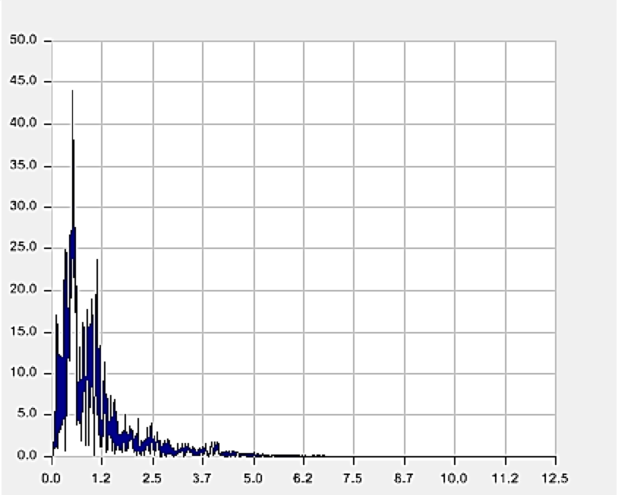


*Figure No. 3.7 Kobe frequency content of time history*

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 3, Issue 2, February 2018

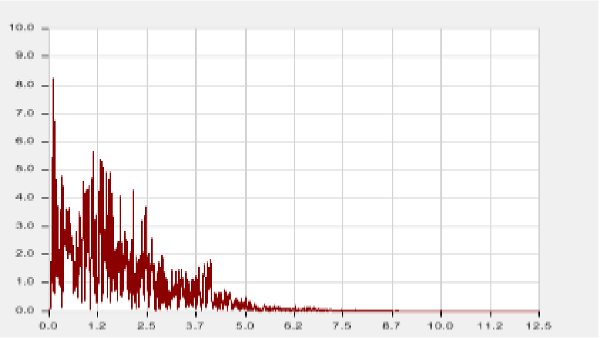


*Figure No. 3.8 Kobe frequency content of matched time history*

## IV. PERFORMANCE ANALYSIS

4.1 General The main objective of the analysis is to study the seismic behavior of Irregular building and Regular building under equivalent static and nonlinear dynamic analysis i.e. time history analysis and frequency and domain analysis for two different earthquakes. The analysis is carried out using E-TABS software.

4.2 Modeling of Building for the study, two types of RCC buildings are considered, one is Regular building and Irregular building. The Equivalent static analysis of a structure is an IS 1893:2002 (Part 1) procedure. It depends on the soil condition as seismic zone. This makes the analysis procedure iterative. Difficulty in the solution is faced near the ultimate load, as the stiffness matrix at this point becomes negative definite due to instability of the structure becoming a mechanism. Extended Three Dimensional Buildings Systems (E-TABS) are used to analyse the RCC G+15 storey structure for better comparative analysis.

### 4.2.1 Models of Regular and Irregular building:

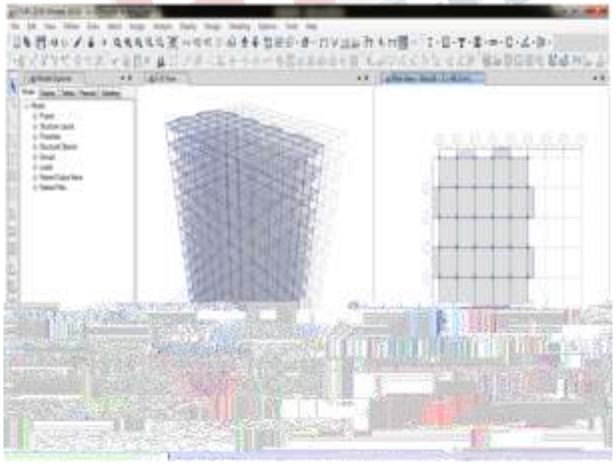


*Figure 4.1 Regular building*

*Figure 4.2 Irregular building*

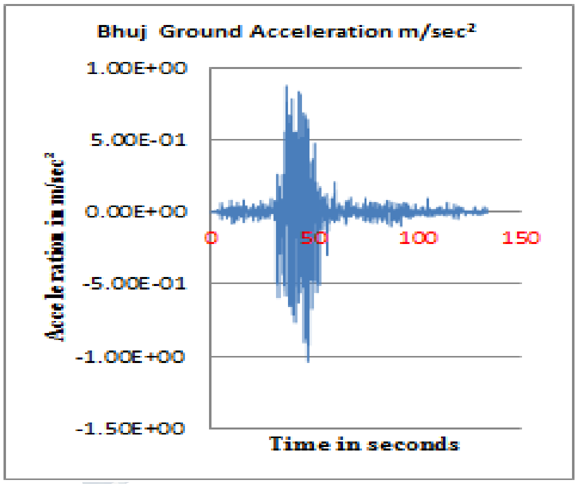


*Figure 4.3 Time history records of Bhuj earthquake acceleration*

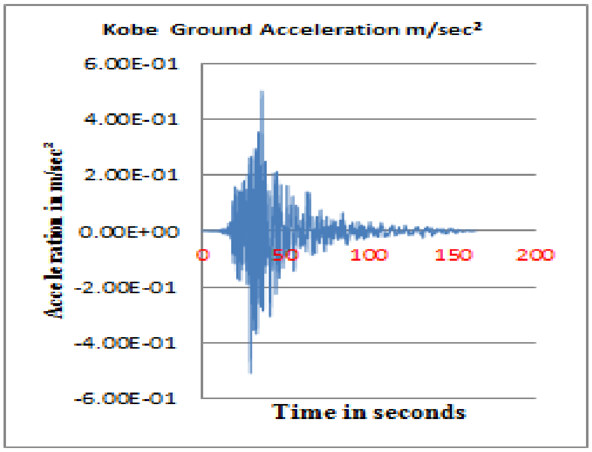


*Figure 4.4 Time history records of Kobe earthquake acceleration*

### 4.3.2 Frequency and Time domain analysis of Irregular building with G+15 storey for Acceleration in mm/sec2, velocity in mm/sec and displacement in mm for Bhuj and Kobe earthquake

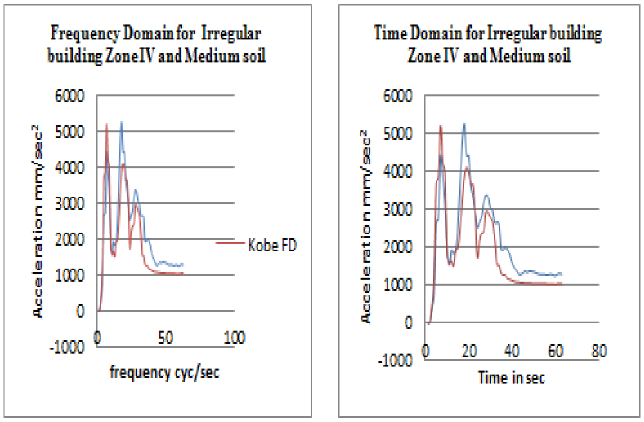


*Fig 4.5: Frequency domain and Time domain of acceleration of Bhuj and kobe*

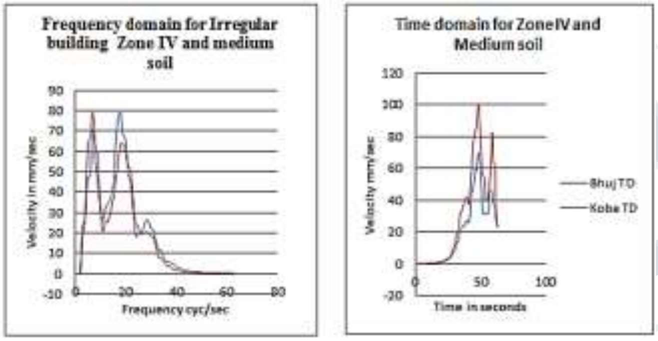


*Fig 4.6: Frequency domain and Time domain of Velocity of Bhuj and kobe*

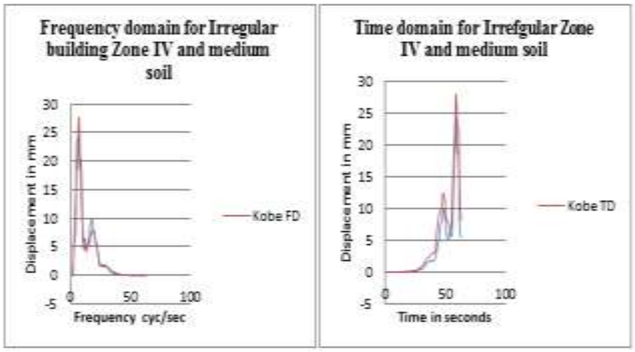


*Fig 4.7: Frequency domain and Time domain of Displacement in mm of Bhuj and kobe*

### 4.6.3 Frequency and Time domain analysis of Regular building with G+15 storey for Acceleration in mm/sec2, velocity in mm/sec and displacement in mm for bhuj and Kobe earthquakes

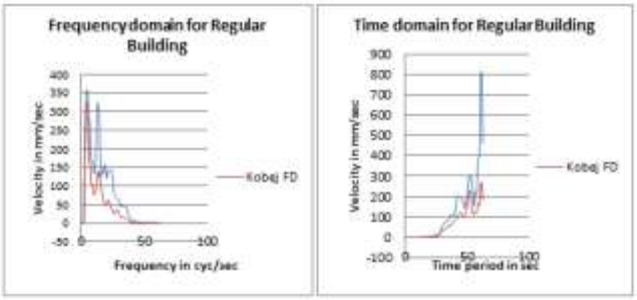


*Fig 4.8: Frequency domain and Time domain of Displacement in mm of Bhuj and kobe*

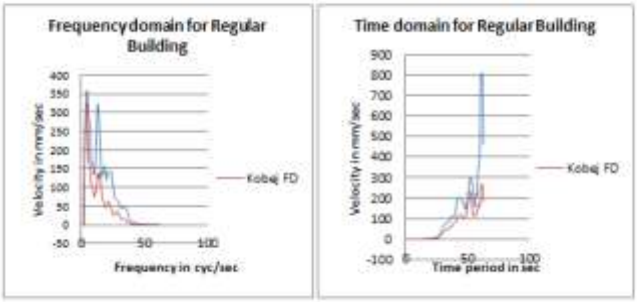


*Fig 4.9: Frequency domain and Time domain of velocity in mm/sec of Bhuj and kobe*

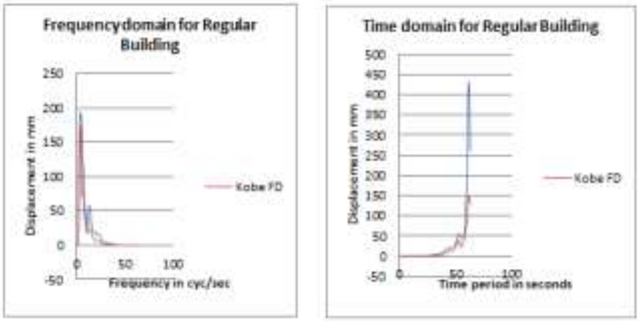


*Fig 4.10: Frequency domain and time domain of Displacement in mm of Bhuj and kobe*

### 4.9 Result and Discussion:

#### 4.9.1 Result and Discussion of Frequency and Time domain analysis of Irregular and regular building are drawn into following points

1. The comparison of frequency and time domain analysis of acceleration for 5% damping are considered and less acceleration in Kobe as compare with Bhuj for Irregular building.

2. The comparison of frequency and time domain analysis of velocity for 5% damping are considered and less acceleration in Kobe as compare with Bhuj For Irregular building.
3. The comparison of frequency and time domain analysis of Displacement in mm for 5% damping are considered and less acceleration in Kobe as compare with Bhuj Irregular building.
4. The comparison of frequency and time domain analysis of acceleration for 5% damping are considered and less acceleration in Kobe as compare with Bhuj for Regular building.
5. The comparison of frequency and time domain analysis of velocity for 5% damping are considered and less acceleration in Kobe as compare with Bhuj For Regular building.
6. The comparison of frequency and time domain analysis of Displacement in mm for 5% damping are considered and less acceleration in Kobe as compare with Bhuj Regular building.

## V.CONCLUSION

In this work a comparative study of Regular and Irregular building of G+15 storey height is carried out using frequency domain and Time domain analysis in E-TABS. The main objective of study is to understand the behavior of building using different shapes. Based on this analytical study following conclusion can be drawn:

1. In Frequency and time domain analysis.

a. The frequency domain analysis of Bhuj and Kobe earthquake records with considering acceleration, velocity and displacement are less in Regular building as compared with Irregular building.

b. The Bhuj earthquake for frequency and time domain are less as compare with Kobe earthquake.

## REFERENCES

1. F. Venancio Filho, A.M. Claret b, F.S. Barbosa, “Frequency and time domain dynamic structural analysis: convergence and causality”, Computers and Structures 80 (2002).

2. Kevin A. Goodell, “Dynamic Analysis of Multi-Degree-Of-Freedom Systems Using a Pole-Residue Method”, University of Rhode Island, 2016

3. Matjaz Mrsnik, Janko Slavic, Miha Boltezar, “Frequency-domain methods for a vibration-fatigue-life estimation - Application to real data”, International Journal of Fatigue, Vol. 47, 2013.

4. Ney Augusto Dumont and Ricardo A. P. Chaves, “General time-dependent analysis with the frequency-domain hybrid boundary element method”, Civil Engineering Department
Pontificia Universidade Catolica do Rio de Janeiro (PUC (Rio))

5. James Guo, Brian Johanek and Doug Patterson, “Fatigue life estimation of a non-linear system due to random vibration”, Robert Bosch LLC, Chassis Systems Control Division

6. Karl Sweitzer, “Random vibration response statistics for fatigue analysis of nonlinear structures”, faculty of engineering, science and mathematics, Institute of Sound and Vibration Research, 2006

7. Reza Taghipour, Torgeir Moan, “Efficient Frequency-Domain Analysis of Dynamic Response for the Multi-Body Wave Energy Converter in Multi-Directional Wave”s, the International Society of offshore and Polar Engineers (ISOPE) ISBN 978-1-880653-70-8 (Set); ISBN 1-880653-68-0 (Set)

8. Tristan Perez, Thor I. Fossen, “Identification of Dynamic Models of Marine Structures from Frequency-domain Data Enforcing Model Structure and Parameter Constraints”, ARC Centre of Excellence for Complex Dynamic Systems and Control, Sept 2009