IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Seismic Analysis of Multi-Storey Building with Vertical Irregularities in Stiffness and Mass Under Various Soil Conditions

[1]Muzammil Ahmed, [2]Prof. Tahera

[1]Post Graduate Student (Structural Engineering), [2]Assistant professor

[1,2] Department of Civil Engineering

[1,2] Dayananda Sagar College of Engineering, Bangalore, India

Abstract: Earthquakes are a major problem all around the world as they cause catastrophic damage such as building failure and collapse and most importantly loss of human lives and homes. One of the most common causes of failure during earthquakes is irregular configuration, either in plan or in elevation. As a result, irregular structures, especially in seismic zones, becomes the main cause of concern**.** The current study deals with the performance analysis of a G+6 Storey residential building with Stiffness and Mass irregularity carried out by varying the positions of these irregularities in the building as per IS 1893 (Part 1): 2002 considering seismic zone 4. Response spectrum analysis has been adopted for analyzing the effect of Stiffness and Mass irregularity using ETABS16 software. Parameters such as Storey displacement, Storey drift, Storey stiffness, Storey shear and overturning moment have been considered for its performance study. With the consideration of all the irregular models and their behavior in dynamic earthquake loading, it is evident that the Model H11 gives the most optimal resultsand is recommended to be constructed in the earthquake prone areas that includes least Displacement, least Drift and least Shear force among all the other models**.**

Index Terms **– Irregular structure, Stiffness and Mass Irregularity, Response Spectrum Analysis, Etabs**

I. INTRODUCTION

The term "earthquake" refers to the movement of the Earth's surface. It's a sudden trembling of the Earth's surface. Earthquakes are unquestionably a devastating natural calamity. The severity of an earthquake is determined by its magnitude and the distance from its epicenter. A high-rise structure's performance during significant trembling motions is influenced by its stiffness and mass distribution in both vertical and horizontal directions. A building is classified as irregular if there is a discontinuity in stiffness or mass between adjoining storeys. The presence of a vertical uneven frame that is susceptible to earthquakes is cause for concern. Weak or critical points in structures are areas where stiffness, mass, and strength abruptly change. This flaw causes the structure to deteriorate, eventually leading to structural collapse. One of the primary reasons of earthquake failure has been found as irregular structure forms, either in plan or in elevation.

There are two types of irregularities-

1. Vertical Irregularities
2. Plan Irregularities

Vertical Irregularities are mainly of five types-

i.a) Stiffness Irregularity — Soft Storey-A soft storey is one in which the lateral stiffness is less than 70 percent of the storey above or less than 80 percent of the average lateral stiffness of the three storeys above.

i.b) Stiffness Irregularity — Extreme Soft Storey-An extreme soft storey is one in which the lateral stiffness is less than 60 percent of that in the storey above or less than 70 percent of the average stiffness of the three storeys above.

ii) Mass Irregularity-Mass irregularity shall be considered to exist where the seismic weight of any storey is more than 200 percent of that of its adjacent storeys. In case of roofs irregularity need not be considered.

iii) Vertical Geometric Irregularity- A structure is considered to be Vertical geometric irregular when the horizontal dimension of the lateral force resisting system in any storey is more than 150 percent of that in its adjacent storey.

iv) In-Plane Discontinuity in Vertical Elements Resisting Lateral Force-An in-plane offset of the lateral force resisting elements greater than the length of those elements.

v) Discontinuity in Capacity — Weak Storey-A weak storey is one in which the storey lateral strength is less than 80 percent of that in the storey above.

II. LITERATURE REVIEW

Himanshu Bansal and Gagandeep, 2012 [1], Staad pro was used to perform response spectrum analysis (RSA) and time history analysis (THA) for G+10 structure frames in zone 5 of vertically uneven RC structure frames. Mass irregularity (4th and 8th floors), stiffness irregularity (ground floor), and vertical geometry irregularity are the three types of irregularities considered. The base shear in mass irregular structure frames is shown to be greater than in regular structure frames. The base shear in the stiffness irregular building was smaller, and the inter-storey drifts were larger. And it was discovered that storey shear was highest in the first storey and lowest in the uppermost floor.

Abul Hasnat, and M Rifat Ibtesham Rahim, 2013 [2], The stiffness and vertical irregularities of a 15-story frame are investigated in response to lateral loads. On an asymmetrical frame, the relative distribution of lateral forces progressed through seismic activity and wind load in each storey level due to variations in frame stiffness is investigated. The effects of storey drift and displacement are studied. Conclusion: In an earthquake-prone zone, a frame with stiffness irregularities on a vertically uneven frame is subject to damage. The frame with the least stiffness reflects the worst case scenario since it has been subjected to excessive displacement and is the most likely to be damaged by lateral loads.

Mohammed Rizwan Sultan and D. Gouse Peera, 2015 [3], As a comparison, a 15-story building with four different shapes (rectangular, L-shape, H-shape, and C-shape) was employed. With the help of the ETABS 9.7.1 version, the entire models were examined. Comparative Dynamic Analysis was used to evaluate the deformation of the structure in the current study for all four situations. The most significant goal of this research is to understand how the structure behaves in high seismic zones, as well as to assess Storey overturning moment, Storey Drift, Displacement, and Design lateral forces. Buildings with significant irregularity create greater deformation than those with less irregularity, especially in high seismic zones, according to the findings. In addition, the storey overturning moment changes inversely with storey height. For a typical construction, the storey base shear is the highest in comparison to buildings with irregular shapes.

Dileshwar Rana, and Prof. Juned Raheem 2015 [4], Under the influence of seismic motion, the performance and behavior of regular and vertical geometric irregular RCC framed buildings are investigated. This project uses five different forms of structure geometry: one regular frame and four irregular frames. A comparison study is conducted with respect to height and bay (4bays and 8bays). In the software Staad.Pro V8i, all building frames are modelled and analysed. Several earthquake reactions are investigated, including shear force, bending moment, storey drift, storey displacement, and so on. The seismic analysis is carried out in accordance with part of IS 1893:2002. (1). For all of the situations, seismic zone IV and medium soil layers are used. When compared to setback irregular frames, the steady building frames have a very low shear force. For all structural heights, the critical bending moment of irregular frames is greater than that of regular frames. The seismic performance of both regular and setback buildings improves as the number of bays increases, according to this study.

Shaikh Abdul Aijaj Abdul Rahman and Ansari UbaidrrahmanSalik, 2016 [5], Using finite element method-based software, the influence of mass and stiffness irregular construction in zone 5, medium soil is analysed. The reaction of the structure, such as storey shear, storey displacement, and storey drift, was evaluated using linear static and linear dynamic analysis. Conclusion: A sudden change in mass between two storeys of a building (mass irregularity) will result in a sudden change in storey displacement and storey drift. Increased storey drift beyond stipulated limitations is caused by vertical stiffness irregularity at a storey in a building.

S. D. Darshale, and N. L. Shelke. 2016 [6], Response spectrum analysis and time history analysis of fixed base and base isolated vertically irregular RCC structures are used in this work, which follows IS 1893:2002. (Part-1). The researchers looked at three forms of vertical irregularities: mass irregularity, stiffness irregularity, and vertical geometry irregularity with base isolation. Lateral displacement, shear pressures, bending moments, base shear, and inter-storey drift were explored as seismic responses. When compared to a conventional fixed base structure, it was discovered that base isolation minimises lateral displacement, shear forces, bending moments, base shear, and inter storey drift. Base isolation also reduces stiffness, increasing the building's fundamental period.

Oman Sayyed, Suresh Singh Kushwah, and Aruna Raway, 2017 [7], The performance and behaviour of G+10 RC buildings that are subjected to seismic loads, both regular and vertically irregular is studied. Stiffness and setback irregularity are two types of vertical irregularities that have been described. A Different seismic reaction such as storey displacement, storey drift, overturning moment, storey shear force, and storey stiffness are discovered utilising the response spectrum analysis (RSA) approach on a total of eight regular and irregular buildings. A comparison between regular and irregular buildings has been done using these responses. Concluded that, the displacement, overturning moment, and storey shear force are all higher in stiffness irregular buildings than they are in regular buildings. The overturning moment and storey shear force of setback irregular buildings are lower than those of regular buildings. Setback irregular buildings illustrate that the stiffness of the building diminishes as the amount of setback grows.

More Amol R, and Prof. Dr. Kale R.S. 2017 [8], The impact of varied mass and column stiffness irregularities on the seismic response of a structure are the subject of this thesis. The project's goal is to perform Response spectrum analysis (RSA) on irregular RC building frames with vertically varying mass and column stiffness. The results of the irregular structure analysis are compared to the results of the regular structure study. When compared to regular structure, irregular structure exhibits critical responses. Frames with irregular floors and a higher height from the ground are highly critcal. As a result, irregularity should be introduced as close to the ground as possible.

The axial forces in columns and base shear rise as column stiffness increases.

2.1 OBJECTIVES

1) To obtain the response of a regular frame with no irregularities.
2) To study the performance and behaviour of regular and irregular RC buildings having stiffness and mass irregularity.
3) To compare and analyze its responses such as storey displacement, storey drift, storey shear force, storey stiffness and overturning moment for optimum design under consideration.
4) To perform response spectrum analysis considering seismic zone IV in various soil conditions.

III. METHODOLOGY

This segment furnishes an overview of the techniques of modeling and analysis which are being adopted in the present investigation. The following methodology is employed in the present study.

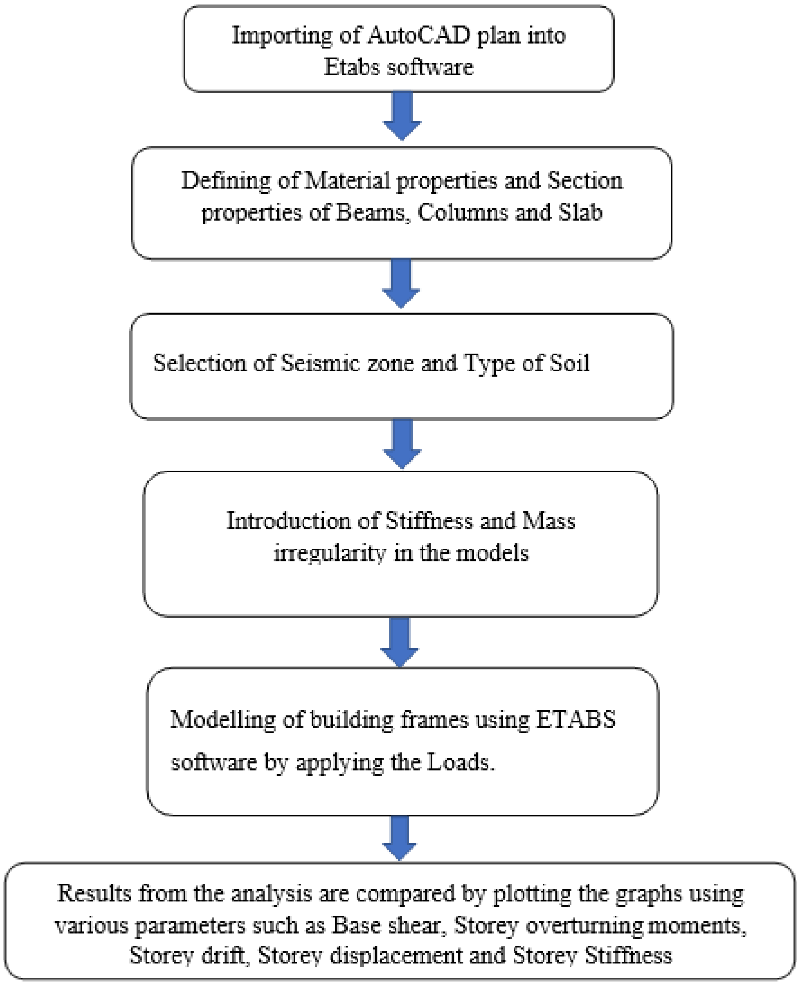

Fig 3.1: Flow Chart of methodology

3.1 STRUCTURAL DETAILS:

Table 3.1 Specification of Structure

Type of Structure	Residential Building	
Plan Area	26m x 21.4m	
No. of stories	G+6	
Height of typical Storey (m)	3.2m	
Height of Irregular Storey (m)	5m	
Slab thickness (mm)	125mm	
Wall thickness (mm)	230mm and 150mm	
Column Size	C1	230X600mm
	C2	230X750mm
	C3	230X900mm
Beam Size	B1	230X450mm
	B2	230x600mm
Grade of Concrete	Column	M30
	Beam	M25
	Slab	M20
Grade of Steel	Fe500	

Table 3.2 Loading According to IS 875 for RCC structure

Live Load	2 kN/m²	
Wall Load	For Regular Storey	6.58 kN/m for 230mm wall
		4.29 kN/m for 150mm wall
	For Irregular Storey	11.13 kN/m for 230mm wall
		7.26 kN/m for 150mm wall
Swimming pool Load	18 kN/m² for Mass Irregularity	
Roof Load	1.5 kN/m²	
Floor Load	1.5 kN/m²	
Density of light weight concrete block	11 kN/m³	

Table 3.3 Seismic Details

Seismic zone	IV
Zone coefficient	0.24
Site type	I, II and III
Damping ratio	5%
Importance co-efficient	1
Response reduction coefficient	5

3.2 MODELLING:

The problem considered for the current study is taken from IS 1893-part 1: 2002 this 6-storey building frame is considered with two different irregularities as mass and stiffness irregularities are taken from IS-1893-part 1: 2002.
A total of 21 models have been modelled of which 3 models are regular models of soft, medium and hard soil and remaining 18 models are Irregular models with 6 models in each soil condition (soft, medium and hard) by varying the positions of Stiffness and Mass Irregularity.

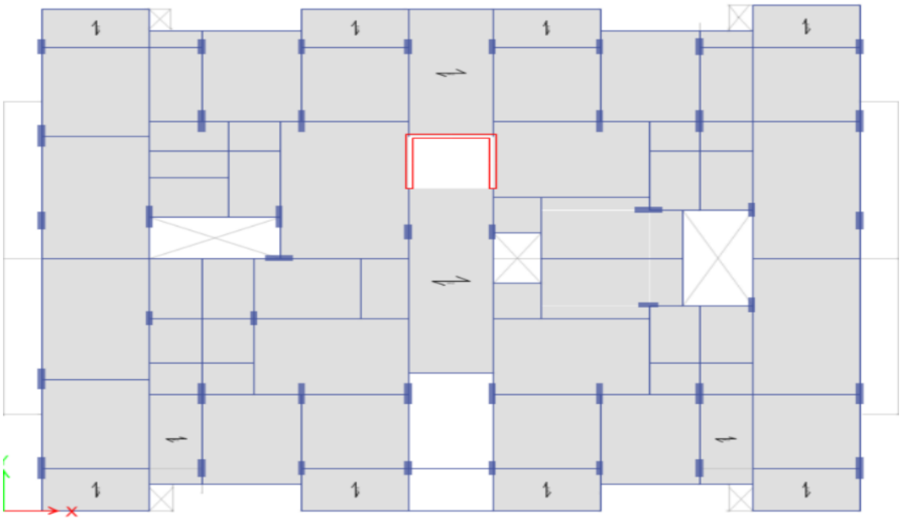

Fig 3.2: Plan

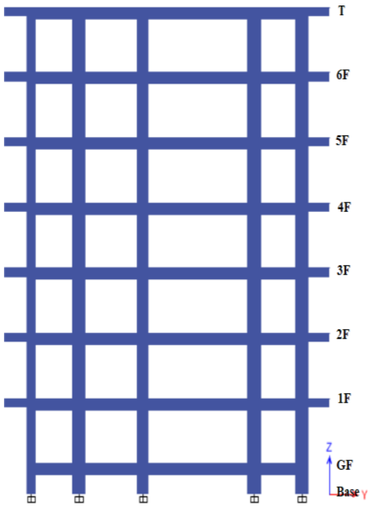

Fig 3.3: Regular Model

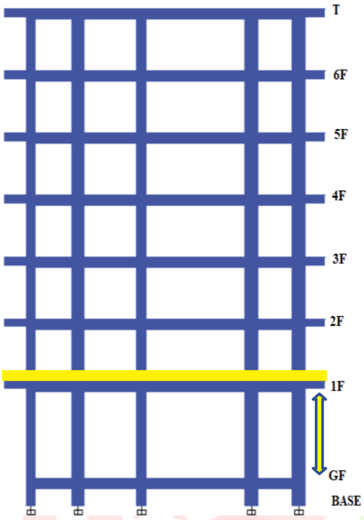

Fig 3.4: Model X11

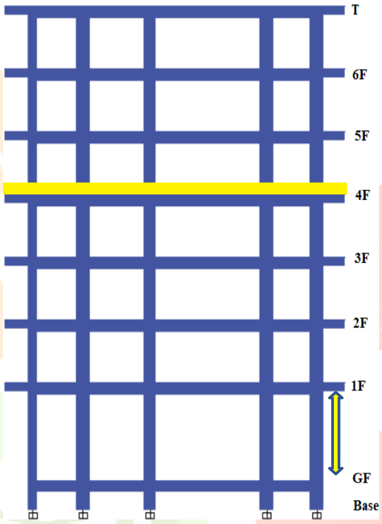

Fig 3.5: Model X12

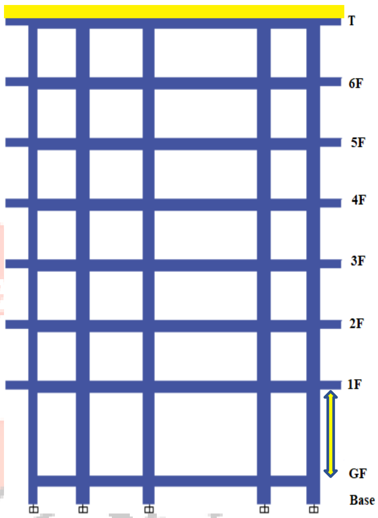

Fig 3.6: Model X13

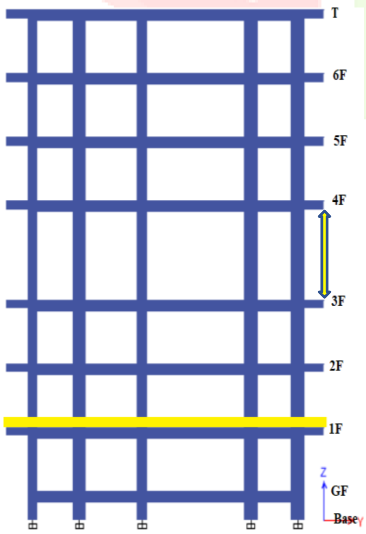

Fig 3.7: Model X21

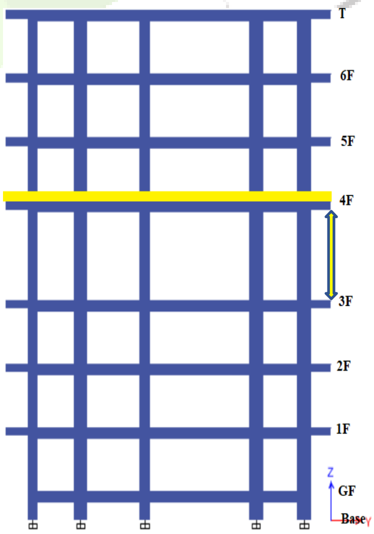

Fig 3.8: Model X22

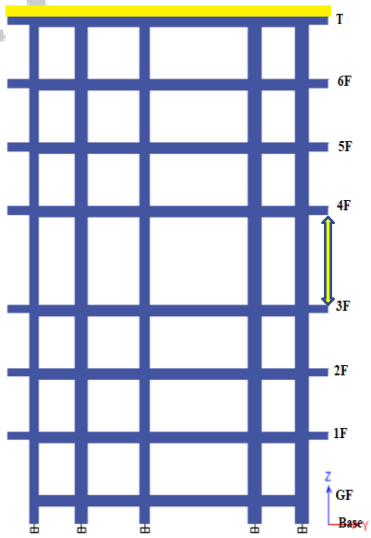

Fig 3.9: Model X23

3.2.1 MODEL DESCRIPTION

1. Regular Model: Building model with No Irregularities
2. Model X11: Stiffness irregularity in GF and Mass Irregularity in 1F (Where X = Soft soil (S), Medium soil (M) and Hard soil (H))
3. Model X12: Stiffness irregularity in GF and Mass Irregularity in 4F
4. Model X13: Stiffness irregularity in GF and Mass Irregularity in Top Floor
5. Model X21: Stiffness irregularity in 3F and Mass Irregularity in 1F
6. Model X22: Stiffness irregularity in 3F and Mass Irregularity in 4F
7. Model X23: Stiffness irregularity in 3F and Mass Irregularity in Top Floor

IV. RESULT AND DISCUSSION

4.1 HARD SOIL

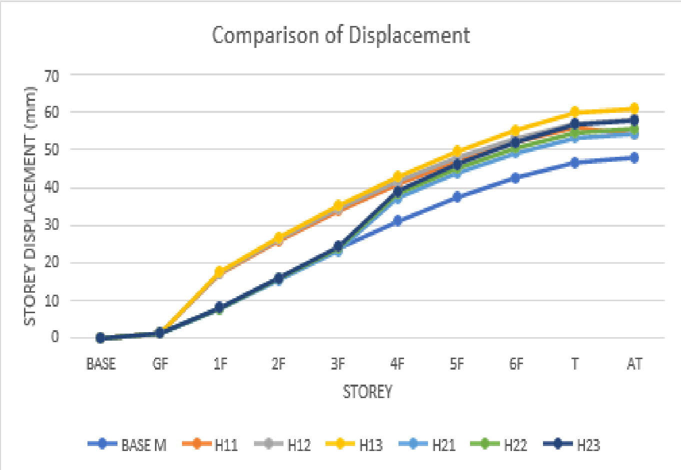

Fig 4.1: Storey Displacement

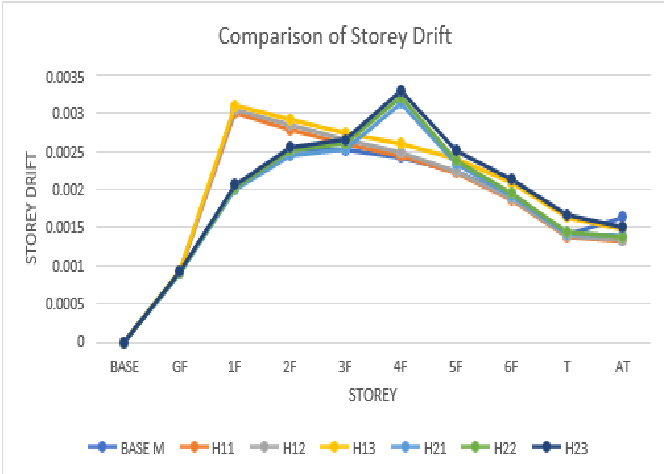

Fig 4.2: Storey Drift

From the fig 4.2 it can be observed that the Displacement increases as the height of the structure increases. Maximum displacement is observed at the top of the building in the Model H13 i.e., 60.94mm which is 26.86% more than the regular building having 48.03mm. All the building models are within the permissible limit, except Model H13 which is beyond the permissible limit. Out of all the irregular building, model H11 has the least Displacement with a value of 54.09mm and from the fig 4.2 it can be observed that Storey Drift keeps increasing with height up to certain floors and gradually decreases. Maximum Drift is observed at the 4th floor of the building in the model H23 i.e., 0.0033 which is 35.80% higher than the regular building having value of 0.00243. Out of all the irregular building, Model H11 has the least Drift of 0.00301.

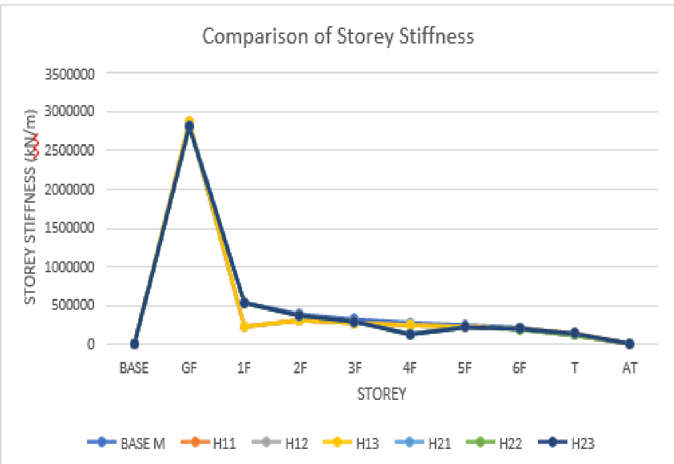

Fig 4.3: Storey Stiffness

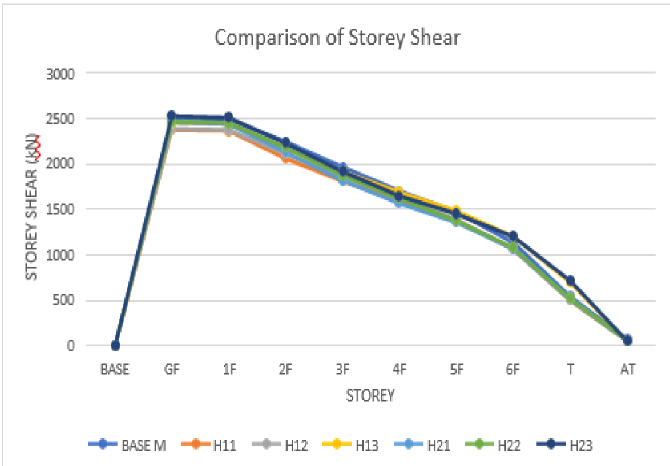

Fig 4.4: Storey Shear

Fig 4.3 indicates that the Storey Stiffness decreases as the height of the building increases. Storey Stiffness is almost similar for all the Models and fig 4.4 indicates that storey Shear decreases as the height of the building increases. The storey shear of Model H23 is similar as Base model. Out of all the irregular structure, Model H11 has the least Storey Shear of value 2.378x10³ kN.

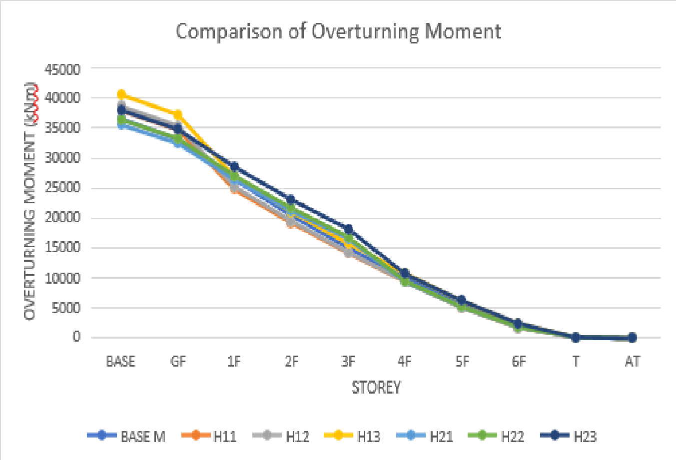

Fig 4.5 Overturning moment

Overturning moment decreases as the height of the building increases. Overturning moment of Irregular building is slightly more than the regular building and Out of all the irregular building, model H21 has the least overturning moment with a value of 35.55x10³ kN-m is observed from fig 4.5.

4.2 MEDIUM SOIL

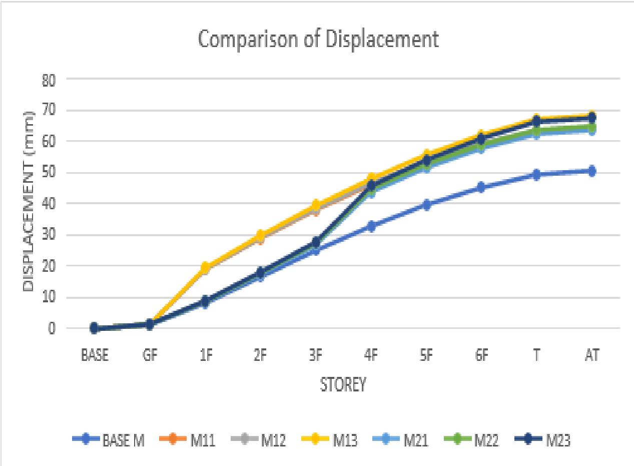

Fig 4.6: Storey Displacement

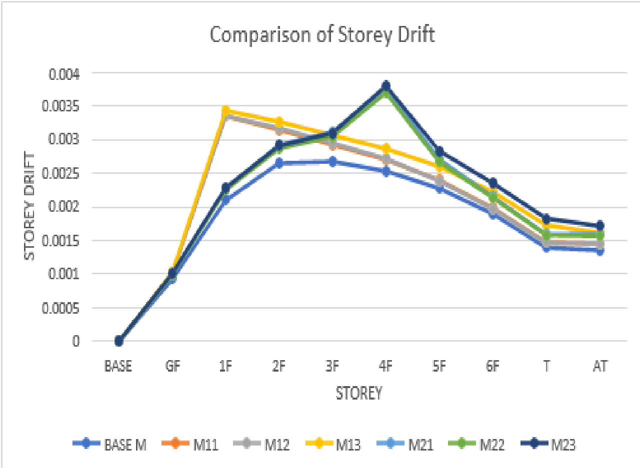

Fig 4.7: Storey Drift

From the fig 4.6 it can be observed that the Displacement increases as the height of the structure increases. Maximum displacement is observed at the top of the building in the Model M13 i.e., 68.25mm that is 34.64% more than the regular building having 50.69mm. Except Regular building, the displacement of all other buildings exceeds the permissible limit i.e., 57.8mm.

fig 4.7 indicated that Storey Drift keeps increasing with height up to certain floors then gradually decreases. Maximum Drift is observed at the 4th floor of the building in the Model M23 i.e., 0.00380 which is 49.60% higher than the regular building having a value of 0.00254. Out of all the irregular building, Model M11 has the least Drift of 0.00335.

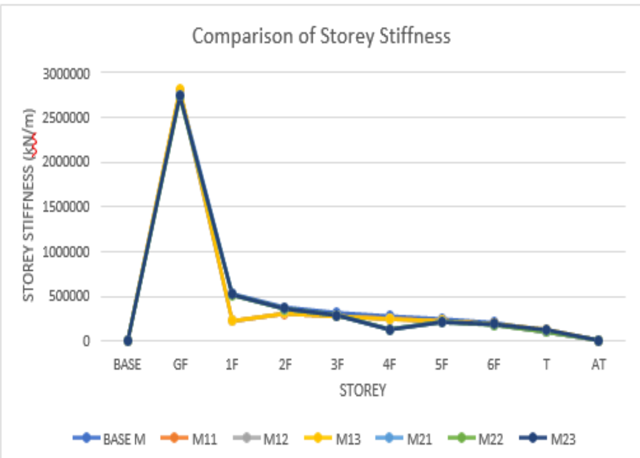

Fig 4.8: Storey Stiffness

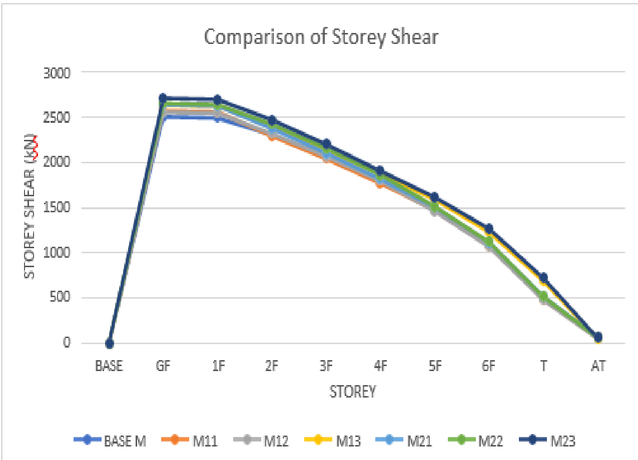

Fig 4.9: Storey Shear

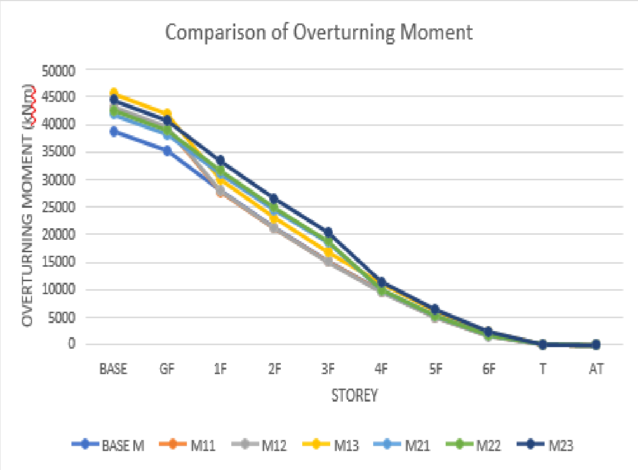

Fig 4.10 Overturning moment

From fig 4.8 it is observed that Storey Stiffness decreases as the height of the building increases. Storey Shear decreases as the height of the building increases. Model M12 has the least Storey Shear of value 2.558×10^3 kNm is observed from fig 4.9. A sudden decrease of overturning moment from GF to 1F among the model M11, M12 and M13 are observed due to the stiffness irregularity present in the GF. Out of all the irregular building, model M21 has the least overturning moment with a value of 41.78×10^3 kNm is observed from fig 4.10.

4.3 SOFT SOIL

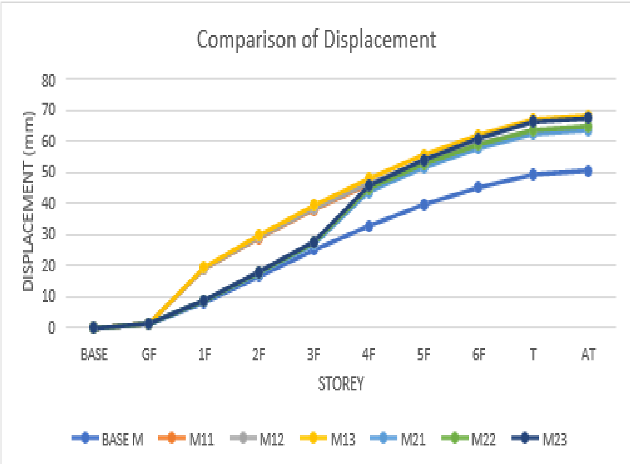

Fig 4.11: Storey Displacement

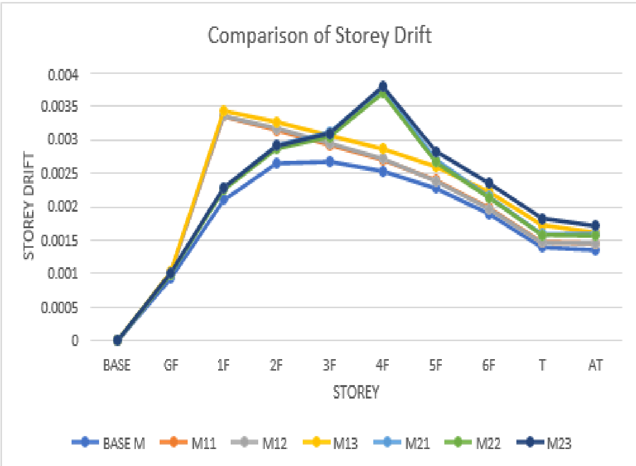

Fig 4.12: Storey Drift

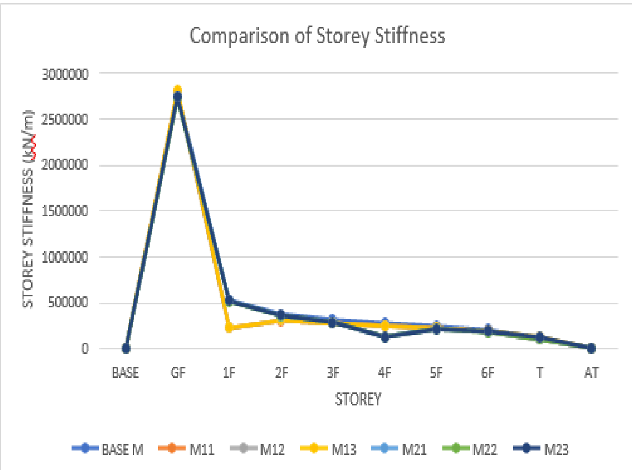

Fig 4.12: Storey Stiffness

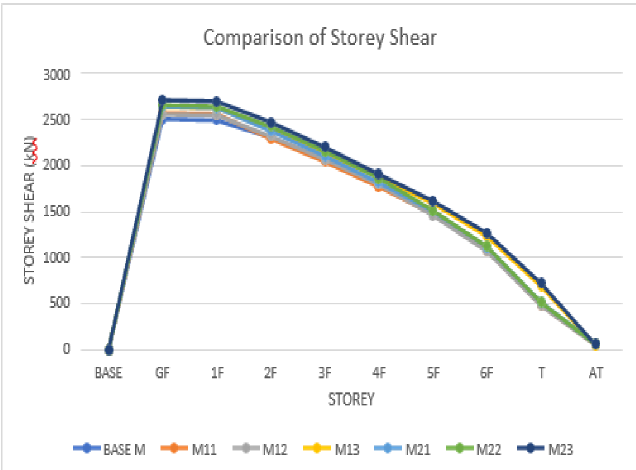

Fig 4.14: Overturning moment

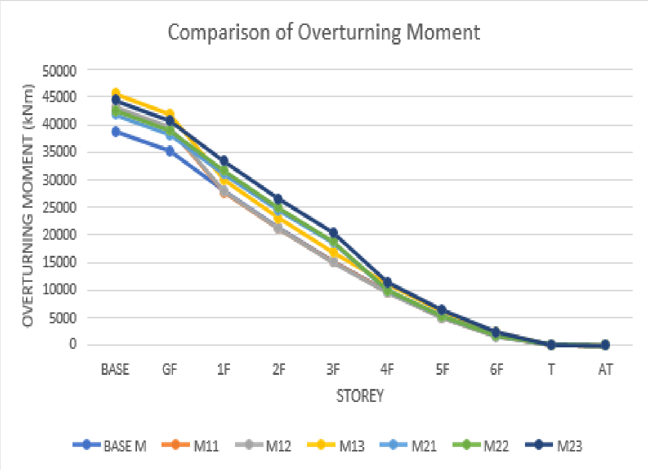

Fig 4.15: Overturning moment

From table 4.11 it is observed that a sudden increase of displacement in 1st floor among the models S11, S12, and S13 are observed due to the stiffness irregularity present in Ground floor. Also, due to the Stiffness Irregularity present in the 3rd floor, a sudden increase of the displacement in the 4th floor of the models S21, S22 and S23 are observed. Except Regular building, the displacement of all other buildings exceeds the permissible limit i.e., 57.8mm (H/500 = 28900mm/500 = 57.8mm), Fig 4.12 indicates Model S23 is very close to the permissible limit. Out of all the irregular building, Model S11 has the least Drift of 0.00340. and Fig 4.15 indicates a sudden decrease of overturning moment from GF to 1F among the models S11, S12 and S13 are observed due to stiffness irregularity present in the ground floor.

4.4 COMPARISON OF SOILS

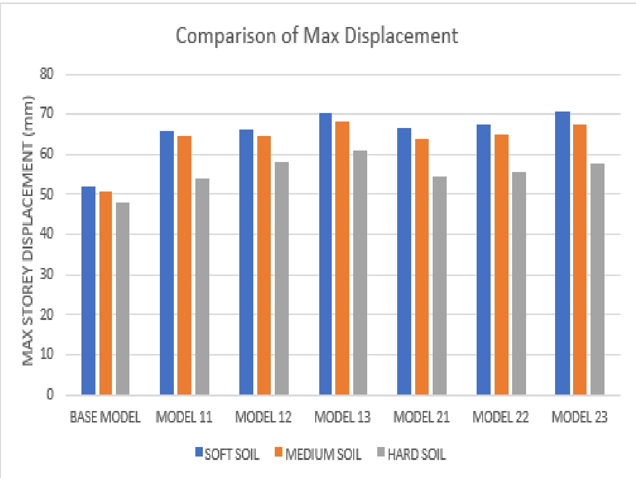

Fig 4.16: Max Displacement

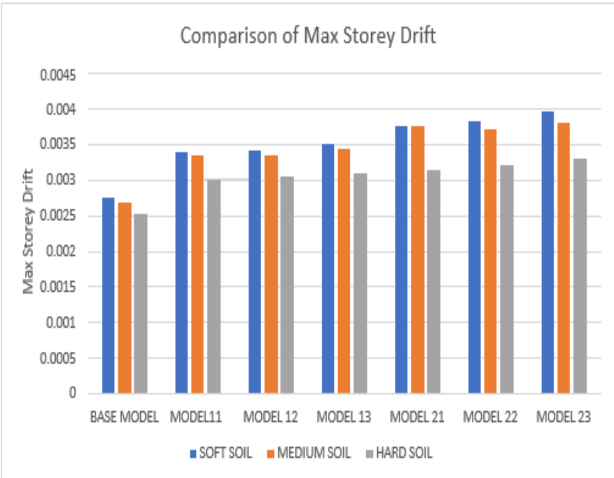

Fig 4.17: Max Drift

From Fig 4.16 it is observed that the soft soil model has a higher maximum displacement than Medium and Hard soil. All the irregular models of soft soil and medium soil exceeds the permissible limit and Hard soil models are within the allowed range, with the irregular model H11 exhibiting the least displacement. Fig 4.17 indicates that the as we progress from the Base model to the Model X23, the amount of drift increases. Soft soil has more drift values than medium soil and Hard soil. All the models are well within the allowed limit, with the exception of model S23, which is quite close to the allowed limit. The model H11 has the least drift of all the irregular models.

Fig 4.18 shows that the Hard soil model has more Stiffness than the soft soil and medium soil model. Out of all the models, model S22 has the least Stiffness. From fig 4.19 it is observed that the soft soil models have more Shear than the Medium and Hard soil models. All the regular models have the almost similar Storey Shear. Hard soil models have the least amount of shear and Model H11 has the least Storey Shear of all the irregular models. Fig 4.20 shows Overturning moment in soft soil model is more than the medium and hard soil models. Hard soil has the lesser overturning moment than the other soils. Out of all the irregular models, Model H21 has the least the Overturning moment which is almost similar to regular model.

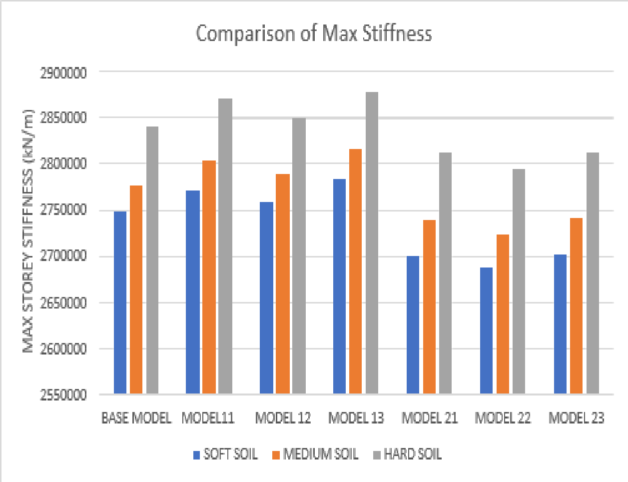

Fig 4.18 Max Stiffness

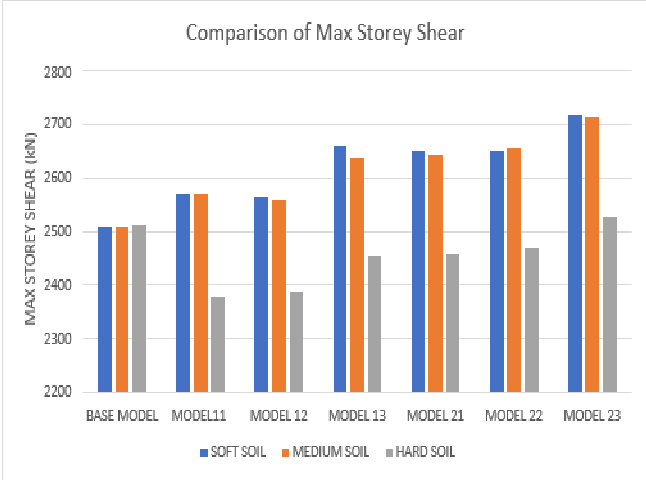

Fig 4.19 Max Storey Shear

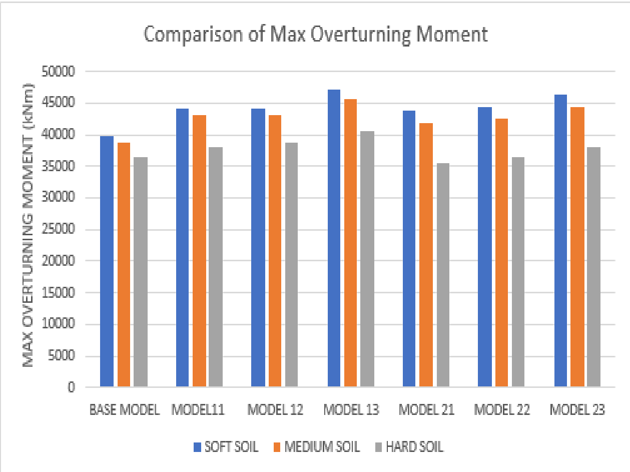

Fig 4.20 Max Overturning moment

V. CONCLUSION

Following conclusions are drawn based on the data obtained after analyzing the performance and behavior of regular and vertical irregular G+6 reinforced concrete buildings under seismic loading for different soil conditions:

1. With increase in height of the structure, the Storey Displacement is observed to be increased simultaneously, and the Storey Displacement of a vertical irregular structure is found to be greater than that of a regular structure.
2. A sudden increase in Storey Drift is observed when Stiffness irregularity is present in any floor.
3. The Storey Shear force has been found to be highest on the first floor and lowest on the top Storey among all the cases.
4. Overturning moment has decreased gradually with increase in the height of the building.
5. Among all the models analyzed under consideration, Model H11 has the least Displacement of 23.41% less than the Model S23 having the highest. Also, the Drift of 24% and Storey shear of 12.40% are less as compared to Model S23.
6. With the consideration of all the irregular models and their behavior in dynamic earthquake loading, it is evident that the Model H11 gives the most optimal resultsand is recommended to be constructed in the earthquake prone areas that includes least Displacement, least Drift and least Shear force among all the other models.

REFERENCES

[1] Himanshu Bansal, Gagandeep. 2012. Seismic Analysis and Design of Vertically Irregular RC Building Frames. International Journal of Science and Research (IJSR), ISSN (Online): 2319-7064.

[2] Abul Hasnat, M Rifat Ibtesham Rahim. 2013. Response of Building Frames with Vertical and Stiffness Irregularity due to Lateral Loads. International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181Vol. 2 Issue 12.

[3] Mohammed Rizwan Sultan and D. Gouse Peera. 2015. Dynamic Analysis Of Multi-Storey Building For Different Shapes. International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2163 Issue 8, Volume 2.

[4] Dileshwar Rana, Prof. Juned Raheem. 2015. Seismic Analysis of Regular & Vertical Geometric Irregular RCC Framed Building. International Research Journal of Engineering and Technology (IRJET), e-ISSN: 2395-0056, p-ISSN: 2395-0072, Volume: 02 Issue: 04.

[5] Shaikh Abdul Aijaj Abdul Rahman and Ansari UbaidrrahmanSalik. 2016. Seismic analysis of vertically irregular buildings. Current Science, VOL. 111, NO. 10, 25 November 2016.

[6] S. D. Darshale, N. L. Shelke. 2016. Seismic Response Control of Vertically Irregular R.C.C. Structure using Base Isolation. International Journal of Engineering Research, ISSN:2319-6890) (online),2347-5013(print), Volume No.5 Issue: Special 2, pp: 683-689.

[7] Oman Sayyed, Suresh Singh Kushwah, Aruna Rawa. 2017. Seismic Analysis of Vertical Irregular RC Building with Stiffness and Setback Irregularities. IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), e-ISSN: 2278-1684, pISSN: 2320-334X, Volume 14, Issue 1.

[8] More Amol R, Prof. Dr. Kale R.S. 2017. Study Of Seismic Responses Of Multi-Storied RCC Building With Mass Irregularity & Column Stiffness Variation. International Journal of Engineering and Techniques - Volume 3, Issue 6.

[9] Rohith R Shenoy, Dr. Sridhar R, Karthik B.S. (2018). Effect of Mass and Stiffness of Vertically Irregular RC Structure. International Research Journal of Engineering and Technology (IRJET), e-ISSN: 2395-0056, p-ISSN: 2395-0072, Volume: 05 Issue: 05

[10] B G Nareshkumar, Arun Kumar, Punith N, T M Prakash. (2018). Comparative Study on Stiffness Regular and Stiffness Irregular Building Subjected to Seismic Load using Pushover Analysis. International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181, Vol. 7 Issue 05

[11] Suchita Hirde, Rahul Aher. (2016). Seismic Evaluation of Irregular Structures. International Journal of Engineering Research, ISSN:2319-6890) (online),23475013(print), Volume No.5 Issue: Special 3, pp: 750-755