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Effect of Mass Irregularity on High Rise RCC Structure

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Abstract— In construction of buildings irregularities are not avoidable; how the structures behaves with these irregularities during earthquake needs to be studied. A study of buildings with irregularities is essential for structural behavior of their design. Civil engineering structures are specially designed to take static load. Normally dynamic loads acting on structure and their effect of are not considered. This feature of ignoring dynamic forces are sometimes becomes the cause of disaster, Over the last three decades, seismic engineering has increasingly focused on the high rise structures, since there will be a lot of damage and financial loss associated with these buildings and also huge loss is encountered by these high rise buildings. As some of these models and engineering data filters into the design codes and standards. As we see, more rapid increase in population along the world with a generally unacceptably low standard of new building construction inspection. It does not seem quite likely that loss of life, as well as insured and uninsured property losses will continue in the future. In this present work analysis for G+10 Reinforced cement concrete building having mass irregularity in 3rd, 6th and 9th floors and building without mass irregularity are analyzed. This paper highlights the effects on floor which structures has different mass irregularity in multistory building.

Keywords- *Mass irregularity, Seismic analysis, Drift.*

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I. INTRODUCTION

The component of the structural building, which use to resists the seismic forces, is known as lateral force resisting system (L.F.R.S). The lateral force resisting system of the structural building may be of various types. The most usual type of these systems in a structure are special moment resisting frames, shear walls and frame-shear wall dual systems. There were structural weak planes present in the building systems the damage in such a structure generally initiates at these locations. These weaknesses were likely to generate further structural deterioration which leads to the structural collapse. These weaknesses were likely to occur due to presence of the structural irregularities in strength, stiffness and mass in a building system. The structural irregularity can be broadly classified as plan and vertical irregularities.

A structure may be classified as vertically irregular if it contains irregular distribution of mass, strength and stiffness along the building height. As per IS 1893:2002, a storey in a building is said to be of mass irregularity if its mass exceeds 200% than that of the adjacent storey. If storey stiffness is less than 60% of the adjacent storey stiffness, then a storey is termed to be as “weak storey”. If storey stiffness is less than 70% or more as compared to the adjacent storey, then the storey is said to be a “soft store”. Many existing buildings contain mass irregularity, and some of them have been designed irregular initially to fulfill the different functions e.g. for commercial and basements purposes created by eliminating the central columns. Also, there is reduction of size of beams and a column in the upper storey’s to fulfill the functional requirements. For commercial purposes like storing heavy mechanical appliances etc. This difference in usage of specific floor with respect to the adjacent floors which results in irregular distributions of strength, mass and stiffness along the building height.

The detailed classification of structural irregularity is shown in Figure 1.1 Irregular buildings are preferred for their functional and aesthetic considerations from some of the realistic buildings as shown in Figures 1.2 to 1.4 examples. The different types of irregularities are presented from Figures 1.5 to 1.8.

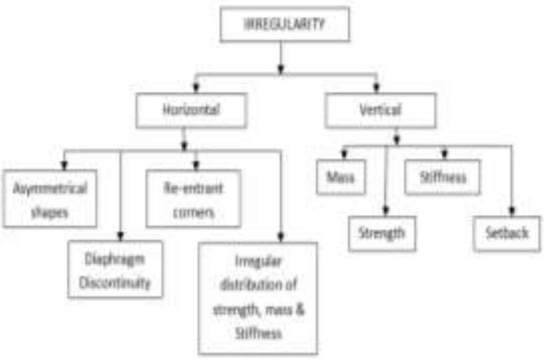


Fig 1 Classification of structural Irregularities

Fig 2 New Yorker hotel, USA

Fig 3 Manhattan city showing different irregularities

Fig 4 Setback building, New Delhi (India)

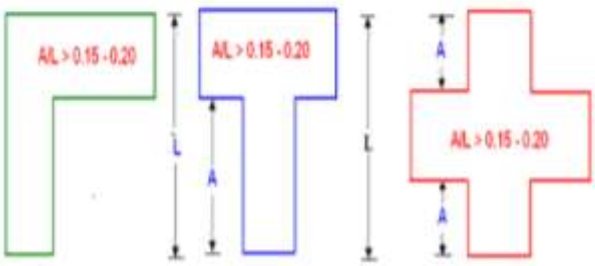


Fig 5 Re-entrant corner irregularity

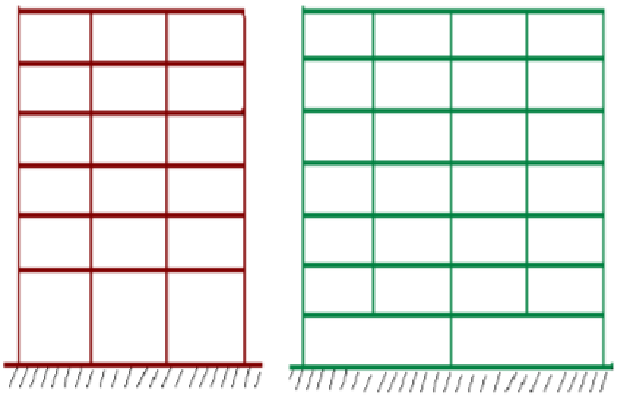


Fig 6 Irregular distribution of stiffness in structure

II. LITERATURE REVIEW

1. **Poncet, L. and Tremblay, R**. The influence of mass irregularity is examined for eight-storey concentrically braced steel frame with different setback configurations. Three height locations of mass discontinuity and two ratios of seismic weight were considered. A regular structure was also studied for comparison. Both the equivalent static load method and the response spectrum analysis method were used in design. Mass irregularity was found to have limited impact on collapse prevention when static analysis was used. For irregular structures exhibiting lower performance than the regular frame, the response was improved by adopting dynamic analysis but not to the level achieved with the regular structure.
2. **N.Anvesh , Dr. Shaik Yajdani, K. Pavan kumar.** A detailed study of structural behavior of the buildings with irregularities is essential for design and behavior. Civil engineering structures are mainly designed to resist static load. Generally the effect of dynamic loads acting on structure is not considered.. As some of these model- and full – scale wind engineering data filters into the design codes and standards, one may expect to see reduced hurricane/cyclone damage. However, when one combines the more rapid increase in population along the world's tropical coasts with a generally unacceptably low standard of new building construction inspection, it seems quite likely that loss of life, as well as insured and uninsured property losses will continue to be the norm in the foreseeable future. The wind engineering community needs to be more responsible in forcefully transferring our technical knowledge to the designer and builder. In this present work analysis for G+10 Reinforced cement concrete building having mass irregularity in 3rd and 6th floors and building without mass irregularity are analyzed. This paper highlights the effects on floor which has different loads (mass irregularity) in multistory building.
3. **S.Varadharajan**, In this study, limitations are addressed and a new index has been proposed to

represent the effects of structural irregularity and cracking. The proposed approach has been compared with code approaches and previous research studies to evaluate the efficiency of the proposed index. The proposed equation showed close agreement with results of dynamic analysis with a high correlation coefficient. Thus, the author proposed index can be effectively used for assessment of seismic damage. The seismic vulnerability assessment of irregular buildings estimated by five methods has been compared.

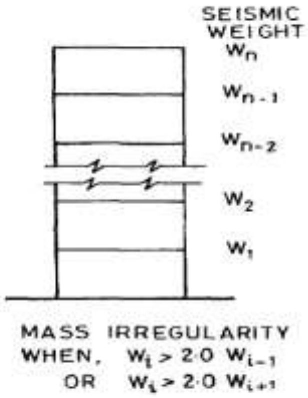
4. **S.Varadharajan, V.K. Sehgal and B.Saini.** The study summarizes the research works done in the past regarding different types of structural irregularities i.e. Plan and vertical irregularities. Criteria and limits specifi ed for these irregularities as defi ned by different codes of practice (IS1893:2002, EC8:2004 etc.) have been discussed briefl y. It was observed that the limits of both Plan and vertical irregularities prescribed by these codes were comparable. Different types of modeling approaches used have also been discussed briefl y. The review of previous research works regarding different types of plan irregularities justifi ed the preference of multistorey building models over single storey building models and concept of balanced CV (Center of strength) – CR (Center of rigidity) location was found to be useful in controlling the seismic response parameters. Regarding the vertical irregularities it was found that strength irregularity had the maximum impact and mass irregularity had the minimum impact on seismic response. Regarding the analysis method MPA (Modal pushover analysis) method even after much improvement was found to be less accurate as compared to dynamic analysis.
5. **Vinod K. Sadashiva, Gregory A. MacRae & Bruce L. Deam**. This paper describes a simple and efficient method for quantifying irregularity limits. They were designed in accordance with the Equivalent Static Method of NZS 1170.5. Regular structures were defined to have constant mass at every floor level and were either designed to produce constant interstorey drift ratio at all the floors simultaneously or to have a uniform stiffness distribution over their height. Design structural ductility factors of 1, 2, 4 and 6, and target (design) interstorey drift ratios ranging between 0.5% and 3% were used in this study. Inelastic dynamic time-history analysis was carried out by subjecting these structures to a suite of code design level earthquake records. Irregular structures were created with floor masses of magnitude 1.5, 2.5, 3.5 and 5 times the regular floor mass. These increased masses were considered separately at the first floor level, mid-height and at the roof. The irregular structures were designed for the same drifts as the regular structures. The effect of increased mass at the top or bottom of the structure tended to increase the median peak drift demands compared to regular structures for the record suite considered. When the increased mass was present at the mid-height, the structures generally tended to produce lesser drift demands than the corresponding regular structures. A simple equation was developed to estimate the increase in interstorey drift due to mass irregularity.
6. **Ashvin G. Soni, Prof. D. G. Agrawal, Dr. A. M. Pande** In case, it is necessary to identify the performance of the structures to withstand against disaster for both new and existing one. Structures experience lateral deflections under earthquake loads. Magnitude of these lateral deflections is related to many variables such as structural system, mass of the structure and mechanical properties of the structural materials. Reinforced concrete multi-storied buildings are very complex to model as structural systems for analysis. The paper discusses the performance evaluation of RC (Reinforced Concrete) Buildings with irregularity. Structural irregularities are important factors which decrease the seismic performance of the structures. The study as a whole makes an effort to evaluate the effect of vertical irregularity on RC buildings, in terms of dynamic characteristics and the influencing parameters which can regulate the effect on Story Displacement, Drifts of adjacent stories, Excessive Torsion, Base Shear, etc.
7. **Umesh Salunkhe, J.S. Kanase.** The behavior of a building during an earthquake depends on several factors, stiffness, and adequate lateral strength, and ductility, simple and regular configuration. The buildings with regular geometry and uniformly distributed mass and stiffness in plan as well as in elevation suffer much less damage compared to irregular configurations. Mass irregularity has different definition in different codes. According to IBC 2003, NZS (New Zealand Standard) and NBCC (National Building Code of Canada) criteria for structural irregularity Mass Irregularity shall be considered to exist where the effective mass of any storey is more than 150 percent of the effective mass of an adjacent storey. A roof that is lighter than the floor below need not to consider. Discontinuity due to mass irregularity causes weakness in structure. Response of mass irregular structure needs to be study for the earthquake scenario. This dissertation deals with RCC framed structure in both regular and mass irregular manner with different analysis methods.

III. MODELING AND ANALYSIS

In this present study the Four RCC frame of G+10 building is analyzed. each building consist of irregular mass at different floor level. one bare frame model is first analyzed under the effect of earthquake. the results of bare frame model is compared with models having irregular mass at different level. the brae frame model is used as benchmark frame model i.e. No mass irregularity in structure.

The irregular model have mass irregularities at different levels. As it is clearly known that the in mass irregular structure dead load is irregularly placed at any level.

This acting dead load can be 100%, 200% , 300% etc. more than the acting dead load. In this analysis 300% more dead load is used as a irregular mass in different floor. This 300% irregular mass placed at 3rd, 6th and 9th floor in different model. The basic plan are of model 15 x 12 meter. The floor to floor height of building is 3.5 meter. Column spacing is 3 meter in X and Z - direction. The STAAD PRO software is used for analysis, prevailing IS 1893:2002 standard of seismic effect on building (ZONE III).



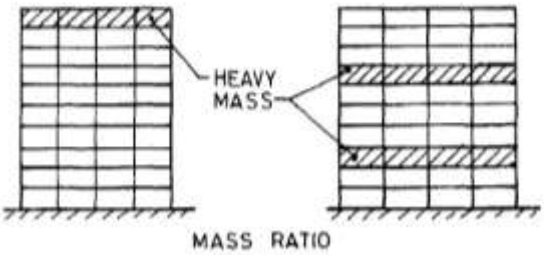


Fig. 7

Fig. 8 Mass Irregularity (IS 1893:2002)

The basic model of G+10 is created in STAAD PRO software and earthquake analysis is performed, the Codal provision method is used. Similarly different models are built and model consist irregular mass at 3rd, 6th and 9th floor. The results of different column is studied in different places in structure. The axial force, moment and torsion is compared with bare frame model. The drift of different models with irregularity is compared with bare frame model. The models having irregularity and basic bare frame model is also compared for Base shear. the total height of structure is 39.5 meters i.e 38.5 total floor height + 1 meter plinth height. the depth of foundation is 3.5 meters.

The Fig. 9 and 10 shows plan area with different position of columns with and without swimming pool.

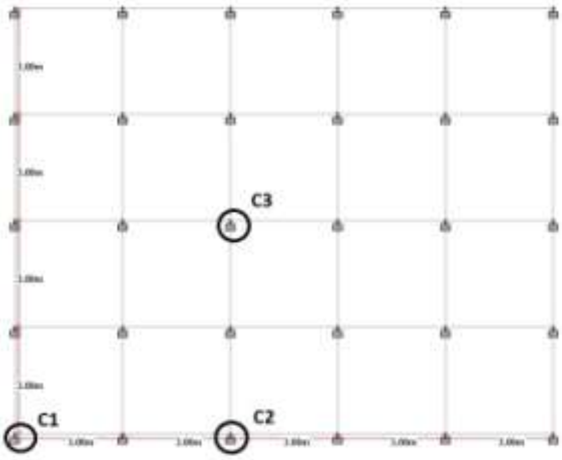


Fig. 9 plan area with swimming pool and column position

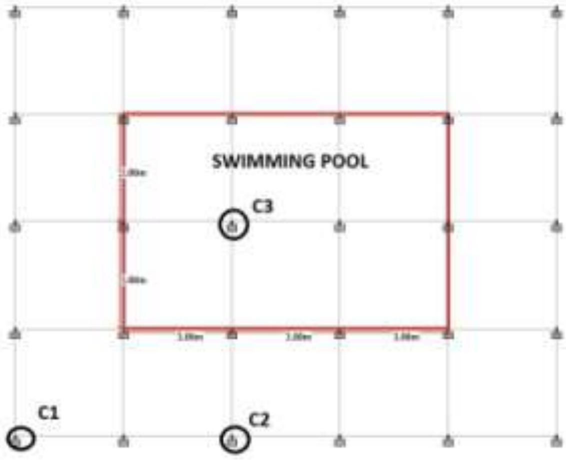


Fig. 10 plan area with swimming pool and column position

following table no.1 consist of parameter used in the analysis as,

PARAMETERS	DIMENSIONS
SIZE OF COLUMN	800 X 600 MM
SIZE OF BEAM	450 X 300 MM
LIVE LOAD	4 KN/M^2
SLAB	125 MM
BAY ALONG X-DIR.	5
BAY ALONG Z - DIR	4
FLOOR FINISH	1.5 KN/M^2
PLINTH HT.	1M
STOREY HT.	3.5 M
SPACING OF COL.	3M
DEPTH OF FOUNDATION	3.5 M
DENSITHY OF CONCRETE	25 KN/M^2
DENSITY OF BRICK	20 KN/M^2
THICKNESS OF INTERNAL WALL	115MM
THICKNESS OF EX. WALL	230 MM
PARA. WALL HT.	1M
SWIMMING POOL	15 KN/M^2
ZONE	ALL
SOIL TYPE	MEDIUM SOIL
IMPORTANCE FACTOR	1.5
STRUCTURE TYPE	CONCRETE STRUCTURE

LOAD COMBINATION	1.5 (DL+LL) 1.2(DL+LL+_ EQ) 1.5(DL+_EQ) 0.9DL+_1.5EQ
SUPPORT TYPE	FIXED TYPE
SIZE OF SWIMMING POOL	6 X 9 M
SIZE OF BUILDING	15 X 12 M

Table no.1 Parameters of structure

As per IS 1893:2002 the zone of earthquake in India is divided in four zones as follows, (Clause 6. 4. 2, Table 2, Pg. 16)

ZONE	II	III	IV	V
INTENSITY	0.10	0.16	0.24	0.36

Table no. 2 Intensity of Zones

As per Clause 6. 4. 2, the design horizontal seismic coefficient (A_h)

$$A_h = \frac{Z}{2} \frac{I}{R} \frac{Sa}{g}$$

The Response Reduction Factor (R) as Per IS1893:2002 Clause 6. 4. 2, Table No.7

SYSTEM	R
SMRF	3
OMRF	5

Table no. 3 Response reduction factor

NAME	DESIGN MODEL
BARE FRAME MODEL (BF)	MODEL WITH NO MASS IRREGULARITIES
MODEL 1.1	MODEL WITH HEAVY MASS AT 3RD FLOOR LEVEL
MODEL 2.1	MODEL WITH HEAVY MASS AT 6TH FLOOR LEVEL
MODEL 3.1	MODEL WITH HEAVY MASS AT 9TH FLOOR LEVEL

Table no. 4 Modeling names

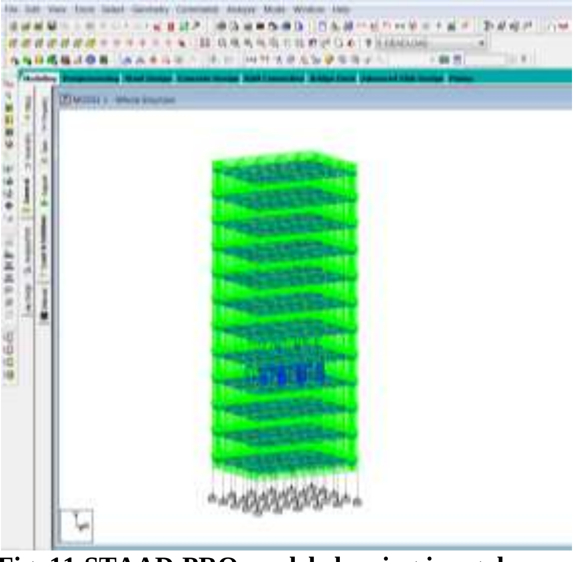
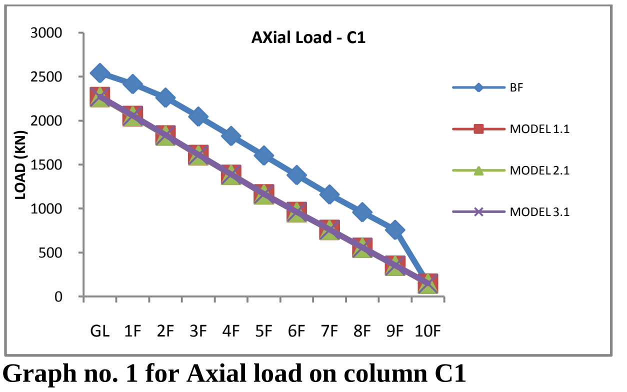
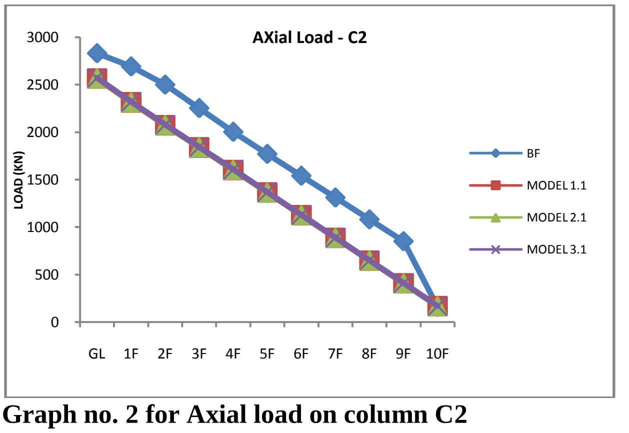


Fig. 11 STAAD PRO model showing irregular mass at 3rd floor(MODEL 1.1)

The columns are mainly design for compressive forces. The structure always have the axial force acting on the column. The column are the vertical member which carries load from slab and transfer to foundation. The analyzed structure shows the column with axial and moment @ both direction on them, hence the columns are called as biaxial column.



Graph no. 1 for Axial load on column C1



Graph no. 2 for Axial load on column C2

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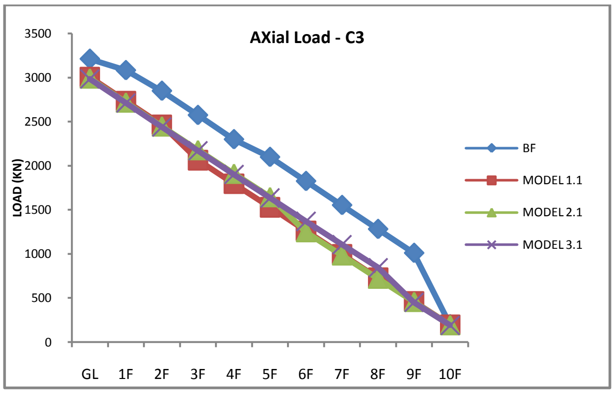
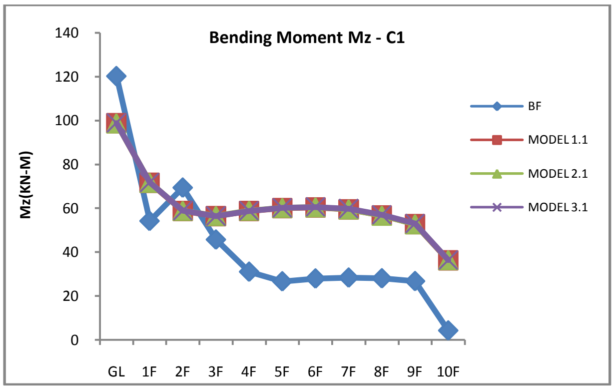
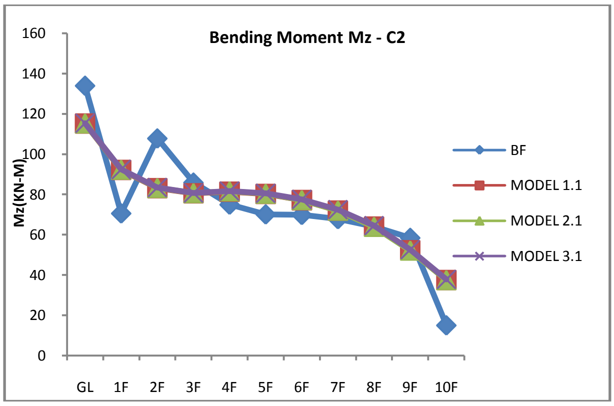


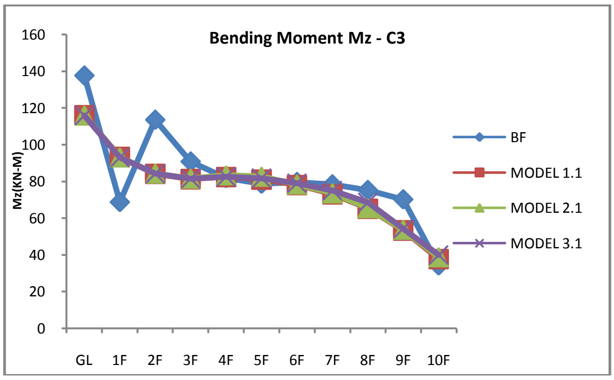
Graph no. 3 for Axial load on column C3



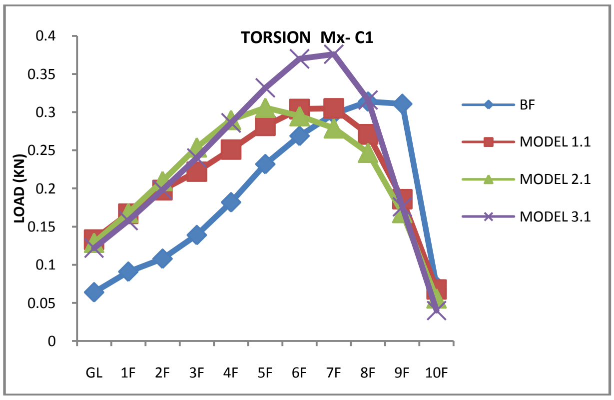
Graph no. 4 for moment Mz on column C1



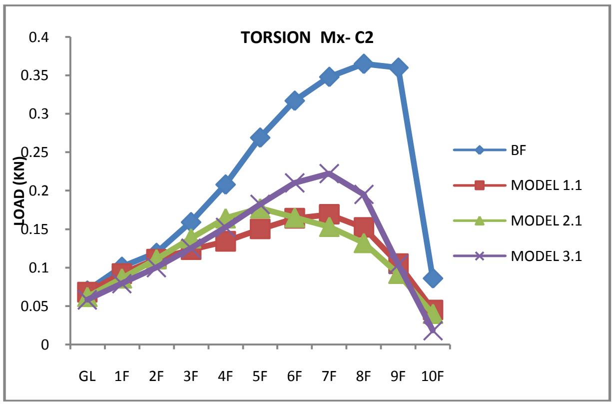
Graph no. 5 for moment Mz on column C2



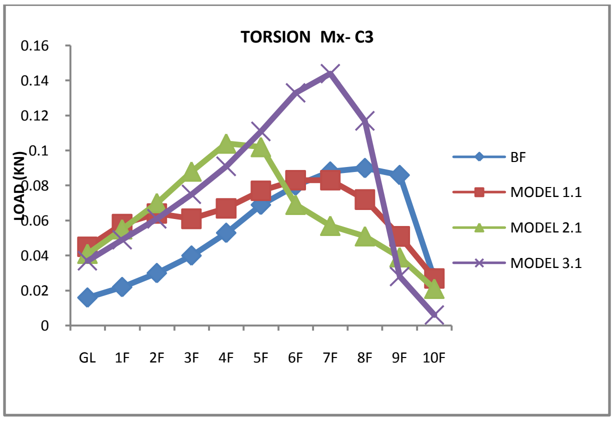
Graph no. 6 for moment Mz on column C3



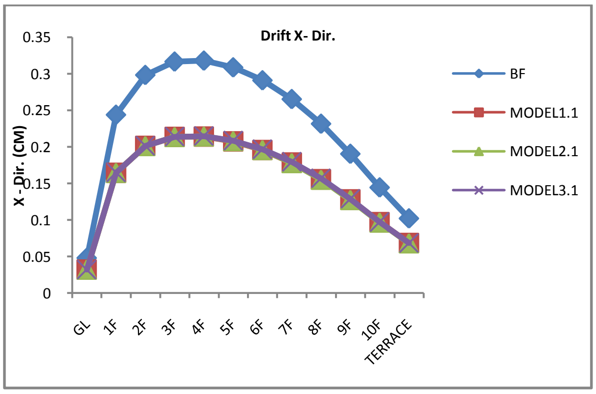
Graph no. 7 for moment Mx on column C1



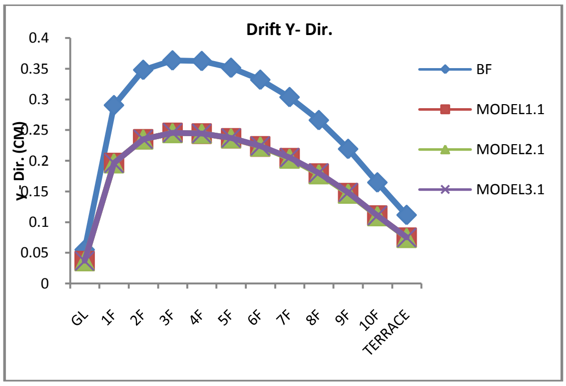
Graph no. 8 for moment Mx on column C2



Graph no. 9 for moment Mx on column C3



Graph no. 10 for Drift X- Direction



Graph no. 11 for Drift Y- Direction

IV. Conclusion

The building model is analyzed, the results of bare frame model is compared with MOEDL 1.1, MODEL 2.1 and MODEL 3.1. The details of each model is mentioned in the **Table No. 4**.

1. The axial load at column C1 and C2 of MODEL1.1, MODEL 2.1 and MODEL 3.1 is less when compared BF model.
2. The axial load of column C3 show slight change in load carrying capacity, the MODEL 1.1 and MODEL 2.1 when compared with BF model. But the MODEL 3.1 is slightly higher when compared with other models (MODEL1.1 & MODEL 2.1).
3. The bending moment on Column C1 and C2 of MODEL 1.1, MODEL 2.1 & MODEL 3.1 is much higher when Compared with BF model.
4. The bending model on C3 column is slightly higher when compared with BF model. The column C3 is located just below the heavy mass.
5. The moment Mx on Column C1 is higher of every model when compared with BF model.
6. The column C2 shows the very less Mx moment on column when the MODEL 1.1, MODEL 2.1 & MODEL 3.1 compared with BF model.
7. The Mx moment on Column C3 is less for model above 3rd floor for MODEL 1.1 but moment is less when compared with BF model.
8. The moment Mx for MODEL 2.1 is higher for 6th floor and less rest of the floor.
9. The drift of the structure is also carried out and it is been studied that the irregular mass model shows very less drift when compared with BF model.

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