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CRITICAL STUDY ON THE DEVELOPMENT OF FORCES AND DISPLACEMENTS UNDER SEISMIC LOADING IN STRUCTURE WITH OFFSETS

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Abstract - Tall structures are being constructed with offsets in horizontal as well as vertical directions to achieve architectural beauty, architectural complexities have become normal practice leading to development of horizontal and vertical offsets in the structures and making them vulnerable from seismic safety point of view. However creations of these of offset are resulting in uneven increase of forces and displacements in various columns. There is need to evaluate the increase in the forces and displacement in various columns placed at critical locations in the structure. The IS 1893-2002 Part-I is revised with the significant changes in various clauses, especially in relevance the offsets in buildings.

In this project an ideal structure with symmetric plan is considered and offsets are introduced in the structure, this induces various types of irregularities such as vertical geometric irregularity, plan irregularity such as mass irregularity, torsional irregularity. The structures were analysed for forces and displacements and results are compared with regular ideal structure.

It is observed that the introduction of multiple offset ands in symmetric plan may lead to erratic increase of torsional moments and shear forces and displacement in the columns at various column locations, It is advisable to critically evaluate the column forces for columns close to and away from the offsets to make the structures safe under seismic loading.

Offset in structures are unavoidable from aesthetic point of view, however careful analysis with full understanding of consequences is essential from seismic safety point of view.

***Key Words*:**

1.INTRODUCTION

Architects have started giving more emphasis on structural elevation and have started bringing more offsets in the plan as well as in elevation. It is a well-known fact that creation of offsets in elevation may result in improper transfer of inertial force to the ground. These types of structures are normally treated undesirable in areas with severe seismic activities. Proper design considerations and adequate safety measures can result in seismically safe structure with various offsets in plan and elevation. There is great need to critically analyze the development of forces and displacement due to various offsets at various column locations and compare them with regular structures.

Earthquakes are the most unpredictable and devastating of all-natural disasters, which are very difficult to save over engineering properties and life, against it. Hence to overcome these issues we need to identify the seismic performance so that can save as many lives as possible. The behavior of a building during an earthquake depends on several factors, stiffness, adequate lateral strength and ductility, simple and regular configurations. 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. But nowadays need and demand of the latest generation and growing population has made the architects or engineers inevitable towards planning of irregular configurations. Vertical irregularities are one of the major reasons of failures of structures during earthquakes. In IS 1893-2002 define the guidelines related to various types of irregularity.

2. SYSTEM DEVELOPMENT

- Study and understand of relevant IS codes and other specifications related to offsets (vertical irregularity).
- Modelling and Analyse the Different shaped buildings with various shapes such as regular square shape with different in out offsets buildings using Equivalent Static Method.
- All types of Buildings are Analyze and design by using using STAAD Pro software computer program.
- Equivalent Static Method results are obtained considering various parameters.
- Results are compared with the Equivalent Static Method to know the best suited for irregular building
- The torsion produced in irregular buildings is calculated and compared with regular building.

Initially the regular ideal G+11 structure is considered and this structure is analyzed and designed by using STADD PRO. The structure having following details has been analyzed for seismic forces and designed by using STAAD software Column forces and displacement are derived for various positions of structures in Regular ideal structure as well as structure provided with offsets. The Regular ideal structure has following specifications-

- Height of structure = 37.5m
- Story ht= 3m
- Plan size= 32m*32m
- No. Of bays in x-direction= 8 @ 4m c/c
- No. Of bays in y-direction= 8 @ 4m c/c

The structure provided with offset has similar specifications as per Regular Ideal structure, details of offsets are given in subsequent section. The structures are analysed by same software. For comparison of result of both regular structure and structure with offset chosen, same columns are chosen, details are given below:

- ➢Column A – this is the corner column
- ➢Column B – this is the outer peripheral column
- ➢ Column C – this is column just left side of the central column
- ➢Column D – this the Central column
- ➢Column E – this is near the central column
- ➢Column F – this is the outer peripheral intermediate column
- ➢Column G –this is close to the Central column
- ➢Column H – this is the left side of central column.

By considering these column position in all structure comparison of result are made between regular structure and structure provided with offset. Data is analysed and presented in graphical form.

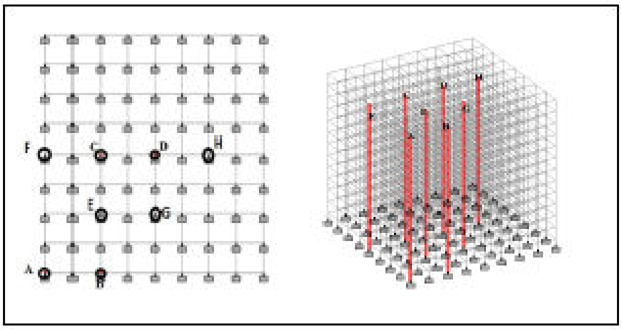

Fig -1: Regular ideal structure

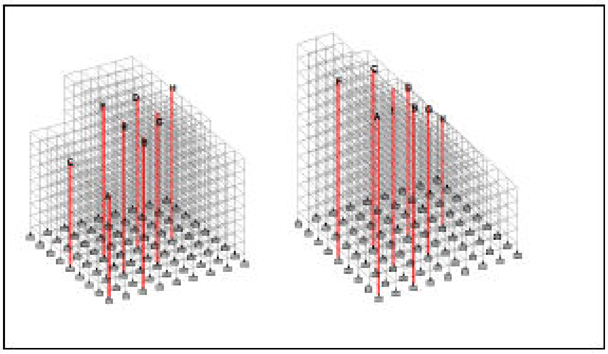

Fig -2: Structure 1 and structure 2

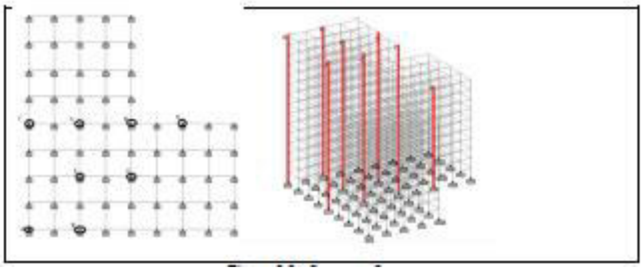

Fig -3: Structure 3

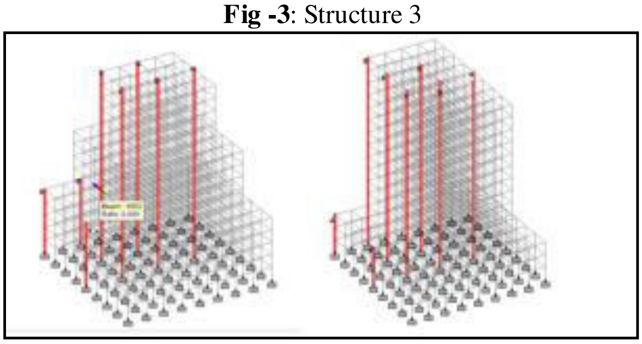

Fig -4: Structure 4 and structure 5

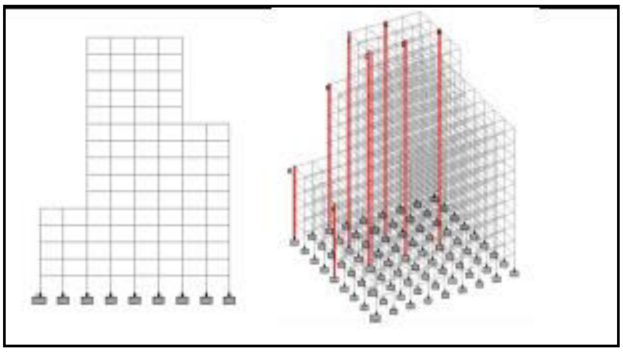

Fig -5: Structure 6

3. RESULT AND DISSCUSSION

These all above structure are analyzed and designed by using Staad pro. And analyzed derived data of forces and displacement for all load combination from which only two load combinations giving higher forces are considered, the cases are

a) 1.5 (DL+EQX),
b) 1.5 (DL-EQX)

Data of forces and displacement observed in selected columns is analyzed and presented in graphical form. All important results and graphs are discussed in this section.

A. ANALYSED DATA OF FORCES PRESENTED IN GRAPHICAL FORM:-

Column A

- **Comparison of Mx and My for 1.5(DL+EQX) in regular structure Vs. structure with offset**

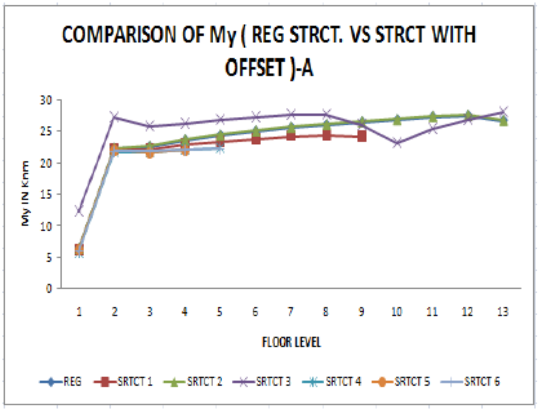

Fig -6:

Fig.6 indicates sudden increasing the moment about y-axis at the first floor level. There after no significant effect due to offset is observed on the corner column under 1.5(DL+EQX) loading.

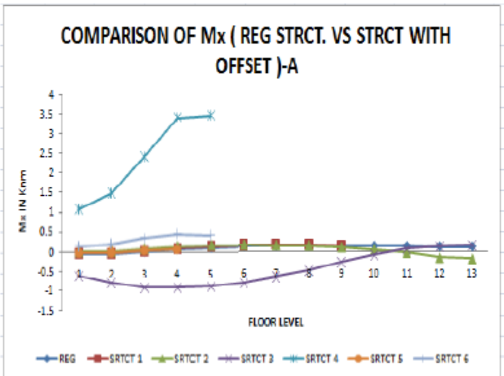

Fig -7

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Fig.7 indicates erratic increase in torsional moment at the corner column if a square plan is reduced to L- shaped plan (structure 3) and also in structure 4 shows more torsional effect on corner column A and this torsional moment increases 135 times in structure 4 with compared regular structure.

- **comparison of Fx for 1.5(DL+EQX) in regular structure Vs. structure with offset**

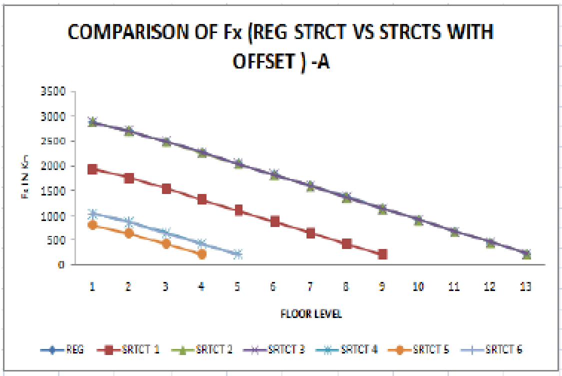

Fig -8

As in fig.8 shows there is marginal difference in axial force in all structure when axial force linked with DL.

- **comparison of Mx and Fy for 1.5(DL-EQX) in regular structure Vs. structure with offset**

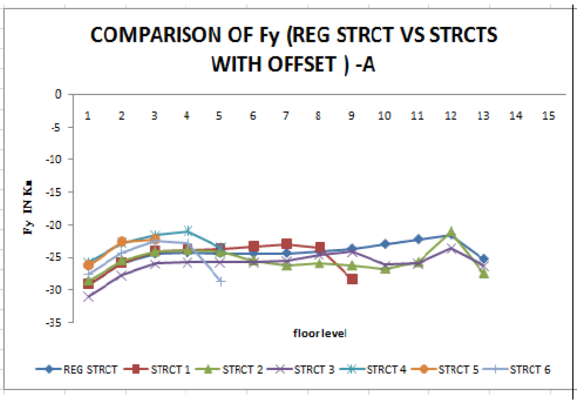

Fig -9

Fig. 9 indicates in structure 5 gives more shear effect on corner column when offset is not provided on that corner column. This shear effect 23.5% more than the regular ideal structure.

COLUMN B

- **comparison of Fy and Mx for 1.5(DL+EQX) in regular structure Vs. structure with offset**

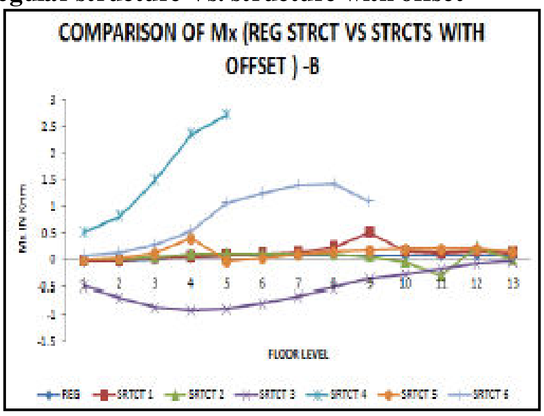

Fig -10

Provision of offset can increase torsion in side column this can be seen from fig.10. as structure 4 and also shows significant increase torsion in structure 3 and structure 6 also indicates similar increase in torsion though as relatively lower scale. In structure 4 torsional effect shows 100 times more than regular structure.

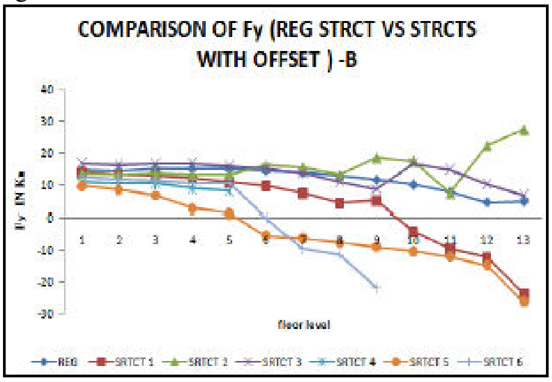

Fig -11

Various offset can induced shear in transverse direction of the earthquake forces, especially at high floor as indicated in fig. 11. This shear effect in offset structures is more up to 6 times of regular ideal structure.

- **Comparison of My for 1.5(DL+EQX) in regular structure Vs. structure with offset**

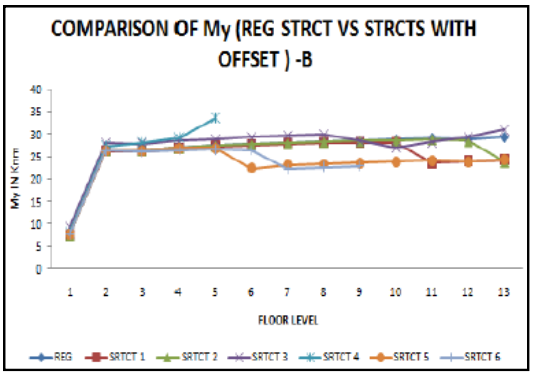

Fig -12

Fig. 12. indicate that the column B is peripheral column on that effect of moment in x direction there is marginal difference up to floor 2 and it will be sudden increase in floor 2.the effect of moment on top floor is 28% more than regular structure.

COLUMN C

- **Comparison of Mx for 1.5(DL+EQX) in regular structure Vs. structure with offset**

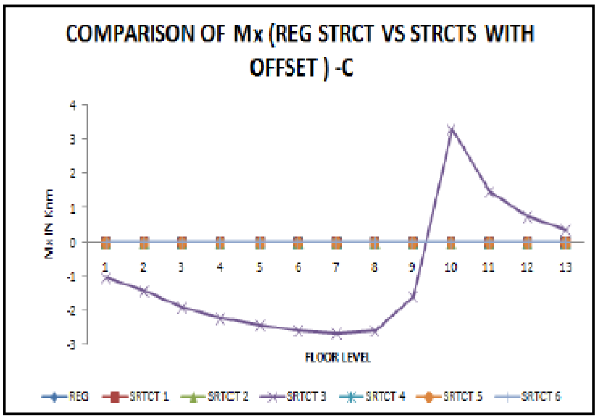

Fig -13

There can be sudden increase in torsion moment in middle column if a symmetric structure is converted into L-shaped structure as indicated structure 3.

- **comparison of Fy for 1.5(DL-EQX) in regular structure Vs. structure with offset**

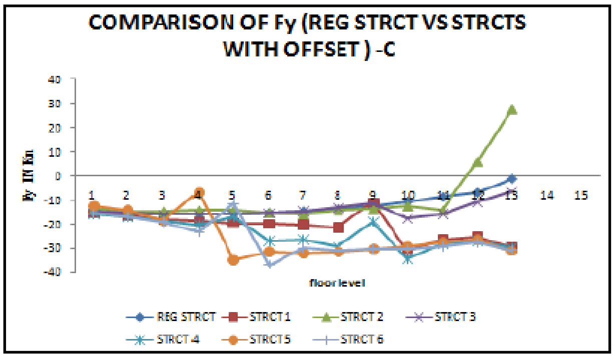

Fig -14

In all structure effect of shear force is more critical in intermediate floor of just near the central column it will suddenly increase and decrease in all structure due to introducing offset on structure as indicated fig.14.

- **Comparison of Mz for 1.5(DL-EQX) in regular structure Vs. structure with offset**

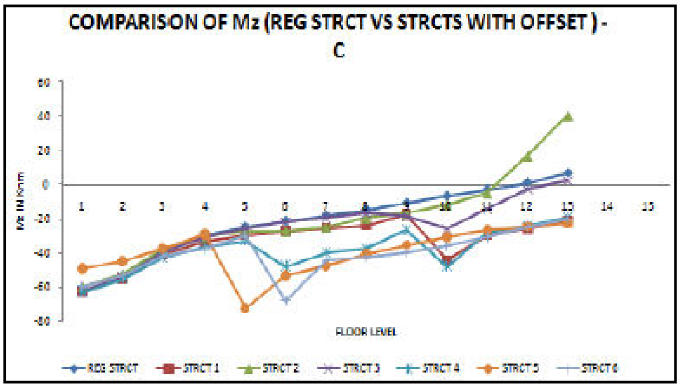

Fig -15

Fig.15 indicates effect of moment in all structure is more in just behind the centre column, moment is suddenly increase and decrease in all structure in intermediate floor column c.

COLUMN D

- **comparison of Fy and Mx for 1.5(DL+EQX) in regular structure Vs. structure with offset**

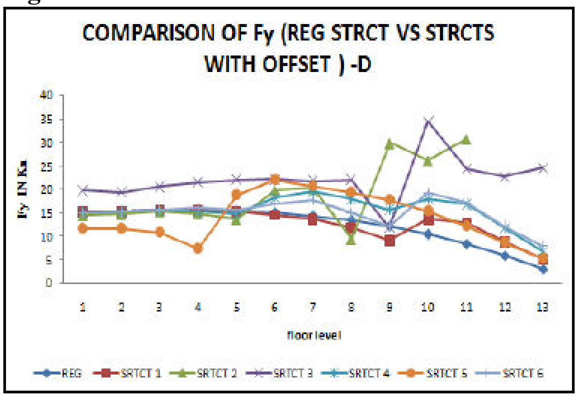

Fig -16

There can be sudden increase in shear force in the direction of earthquake force as indicated in structure 2 at floor 10 on centre column due to providing offset on it and this shear effect may lead up to 4 times more than regular structure.(fig.16)

As indicated in fig.16 the shear force effect in L-shaped structure (structure 3) is more on the centre column (in structure 3 column D is the peripheral column).

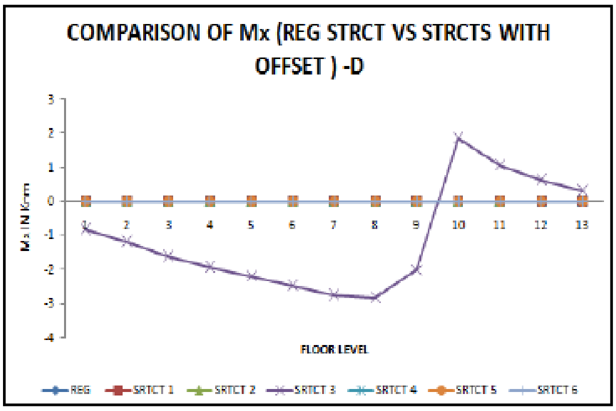

Fig -17

There can be more torsional moment in centre column D of L-shaped structure (structure 3) but in all other structure torsional moment is null.

- **comparison of Fz and Mx for 1.5(DL-EQX) in regular structure Vs. structure with offset**

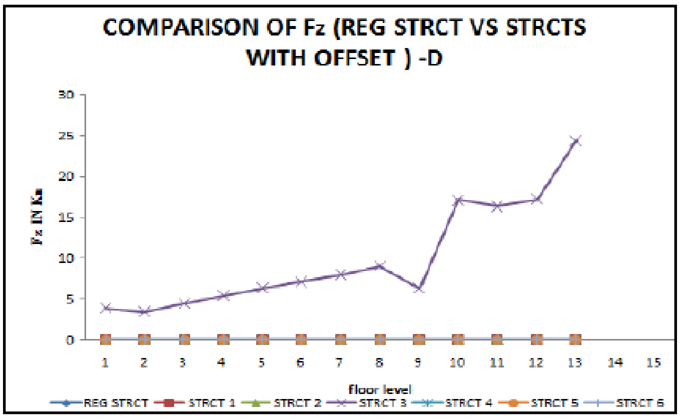

Fig -18

There can be sudden increase shear force in z direction in all structure is having null effect but in L-shaped structure (structure 3) is having more shear effect and it gives maximum value at floor 9 on that central peripheral column.

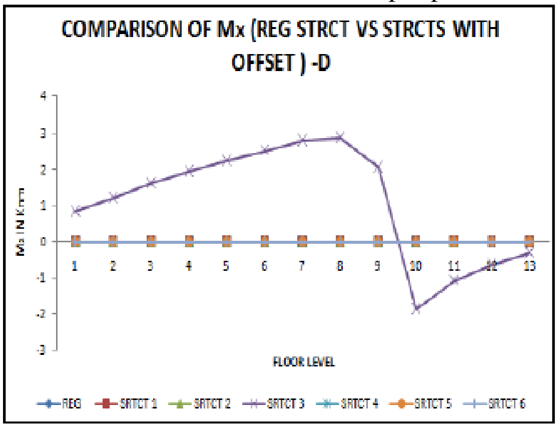

Fig -19

This graph shows torsional moment in all structure is having null effect but in L-shaped structure is giving more torsional effect and its value change from negative to positive side as indicated in fig.19

- **comparison of My for 1.5(DL+EQX) in regular structure Vs. structure with offset**

Due to introducing the vertically geometric irregularity in structure 3 and structure 6 shows sudden fluctuation in the moment in the direction of earthquake force as indicated in fig.20.

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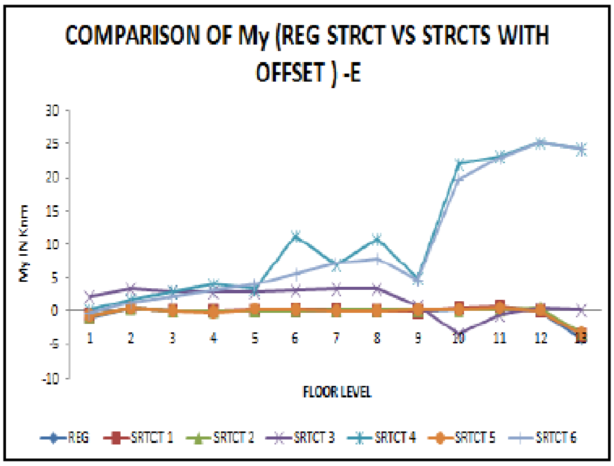

Fig -20

- **comparison of Mx for 1.5(DL-EQX) in regular structure Vs. structure with offset**

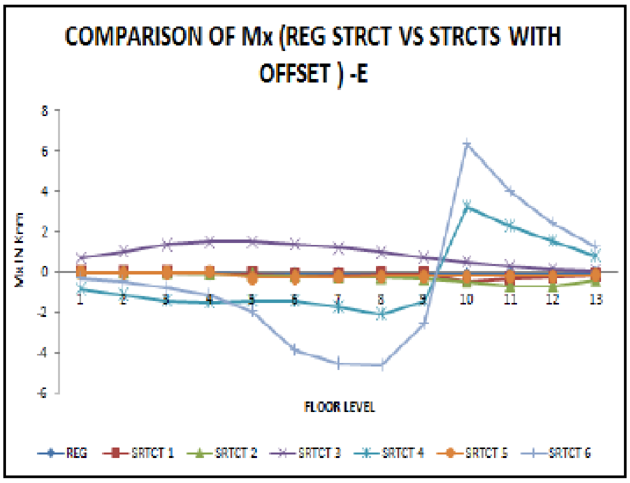

Fig -21

Fig.21 indicate the same kind of result (as fig.21) only by changing the reversing direction

COLUMN F

- **comparison of Fy and Mz for 1.5(DL+EQX) in regular structure Vs. structure with offset**

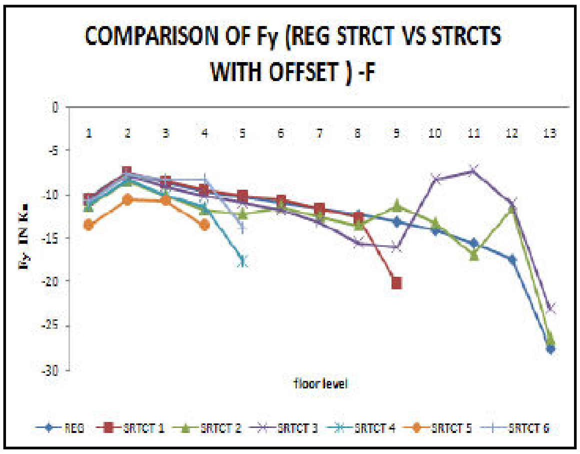

Fig -22

Fig.22 indicate that effect of shear force in the direction of earthquake force is more in structure 6 of middle peripheral column when on that column offset is not introduce.

By provisioning offset on all structure in that structure 6 of middle peripheral column shows critically moment effect as indicated fig.23

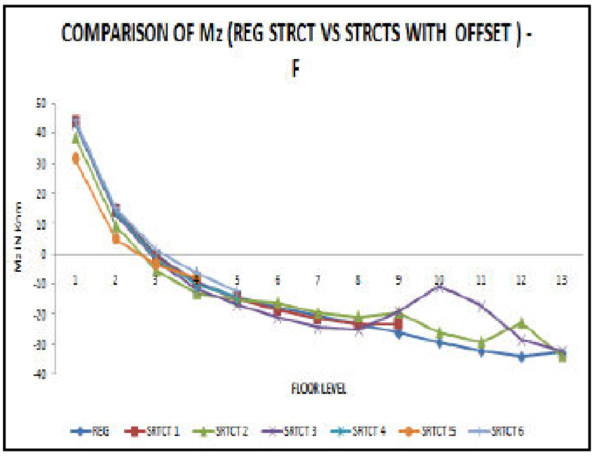

Fig -23

- **comparison of Fy for 1.5(DL-EQX) in regular structure Vs. structure with offset**

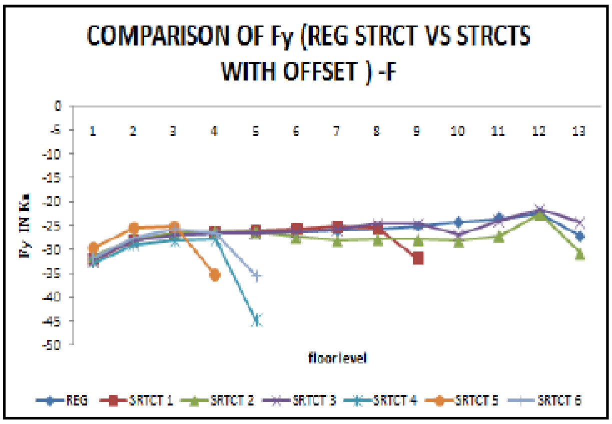

Fig -24

There can be sudden increase in shear force in the direction of the earthquake force at top level of middle peripheral column in all structure except L-shaped structure (structure 3), from that all structure, structure 6 is seriously affected as indicated in fig.24.

COLUMN G

- **comparison of Fy and Fz for 1.5(DL+EQX) in regular structure Vs. structure with offset**

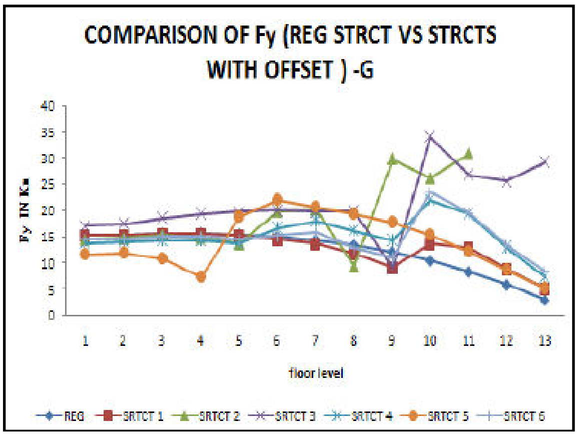

Fig -25

Provision of offset on the all structure gives more shear effect in the direction of the earthquake force, in structure 2 gives maximum shear force effect at floor 8 on just near the centre column.(fig.25)

There can be sudden increase and decrease of shear force in z direction as indicated structure 4 due to providing offset on that column and also structure 6 shows same kind of result and all other structure gives negligible effect.

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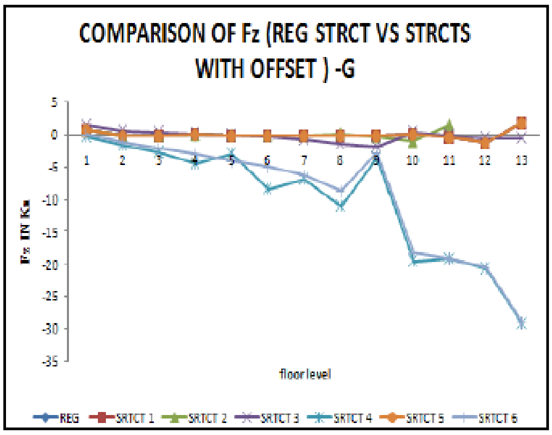

Fig -26

- **comparison of Mx for 1.5(DL-EQX) in regular structure Vs. structure with offset**

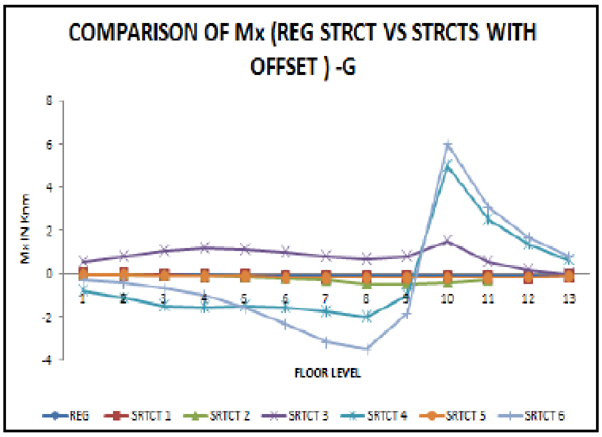

Fig -27

Fig.27 indicate the same kind of result only by changing the reversing direction of torsional moment.

COLUMN H

- **comparison of Fy for 1.5(DL+EQX) in regular structure Vs. structure with offset**

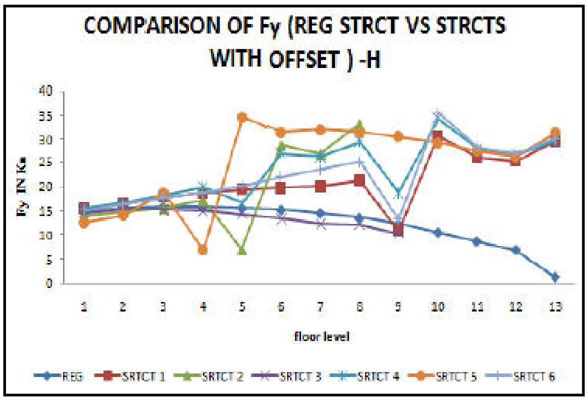

Fig -28

Fig.28 indicate there can be sudden increase in shear force in the direction of earthquake force at the middle floor level as indicated in all structure except L-shaped structure (structure 3).

- **comparison of Mz for 1.5(DL+EQX) in regular structure Vs. structure with offset**

Fig.29 indicate that effect of moment in z direction gives more effect in the middle floor due to providing vertical geometric irregularity in all structure except L-shaped structure (structure 3)

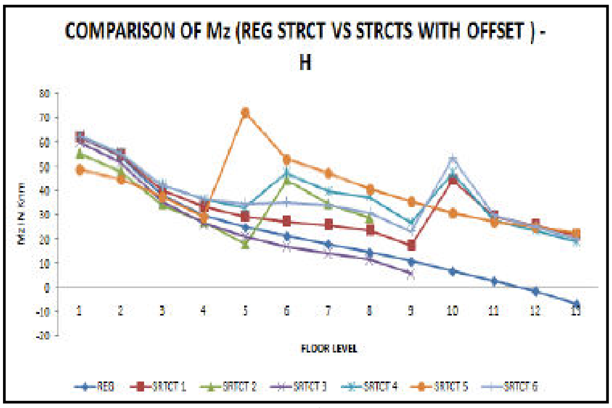

Fig -29

- **comparison of Fy and Fz for 1.5(DL-EQX) in regular structure Vs. structure with offset**

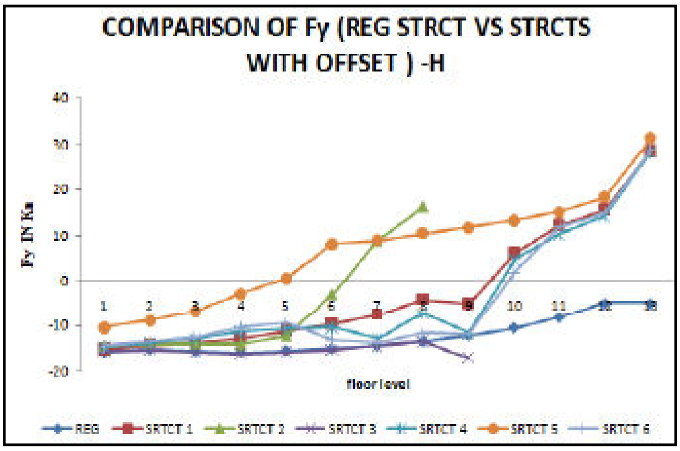

Fig -30

Fig.30 indicate that the shear force effect in the direction of earthquake forces is maximum at the upper floor of column just near the centre column in all structure except structure 3

B. ANALYSED DATA OF DISPLACEMENT PRESENTED IN GRAPHICAL FORM

COLUMN A

- **Comparison of displ. In x and y direction for 1.5(DL+EQX) in regular structure Vs. structure with offset**

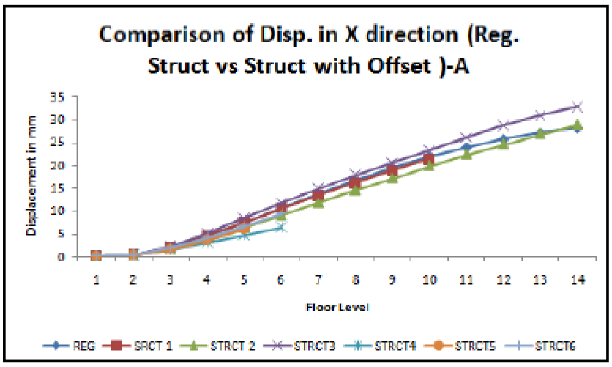

Fig -31

This graph shows in all structure having displacement in the direction of earthquake force gives marginal difference.(fig.31)

Fig.32 indicate the displacement along the direction of earthquake force in maximum in all structure except structure 1 and structure 4.

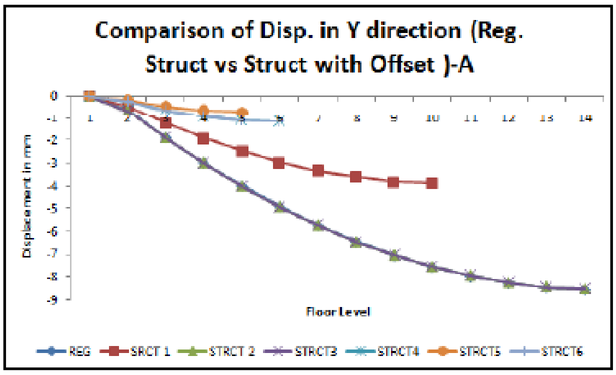

Fig -32

- **Comparison of displ. In z-direction for 1.5(DL+EQX) in regular structure Vs. structure with offset.**

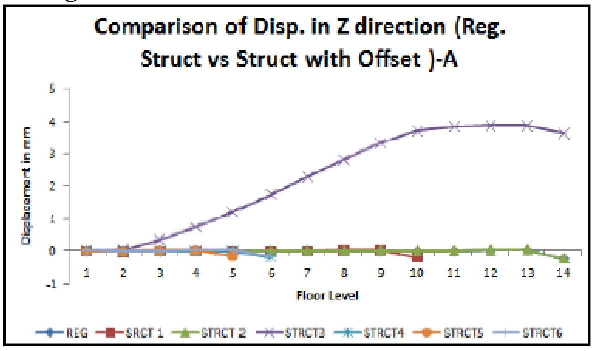

Fig -33

Fig.33 indicates displacement in along the transverse direction in L-shaped structure (structure 3) shows maximum displacement and all other structure having negligible displacement.

- **Comparison of displacement in x and y direction for 1.5(DL-EQX) in regular structure Vs. structure**

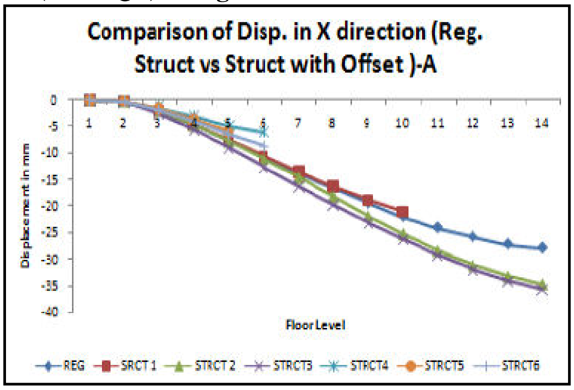

Fig -34

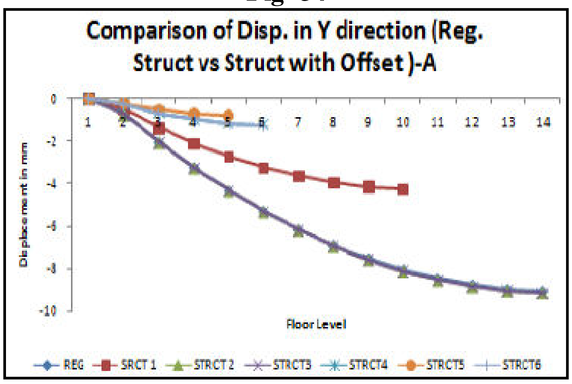

Fig -35

- **Comparison of resultant displ. And In z-direction for 1.5(DL-EQX) in regular structure Vs. structure with offset**

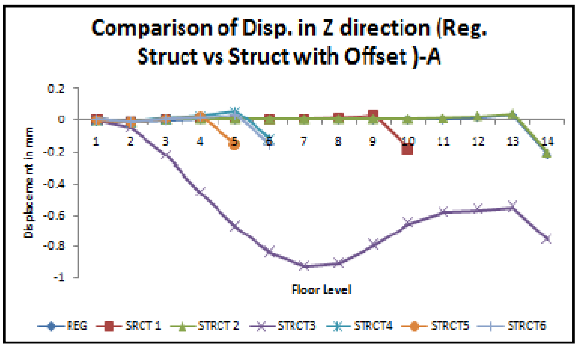

Fig -36

There can be maximum displacement shows in the transverse direction of earthquake force in L-shaped structure (structure 3) of corner column A as indicated in fig.36

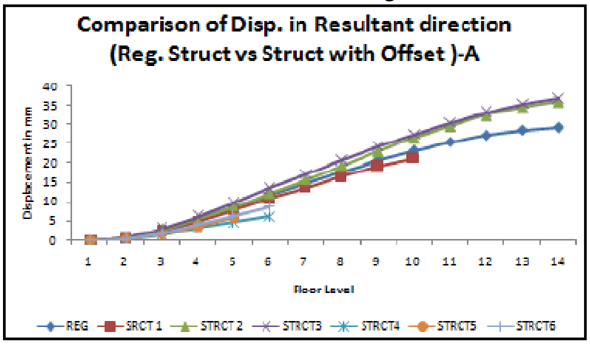

Fig -37

Fig indicate resultant displacement in all structure shows marginal difference at the top floor due to introducing offset

COLUMN B

- **comparison displacement in y and z-direction for 1.5(DL+EQX) in regular structure Vs. structures**

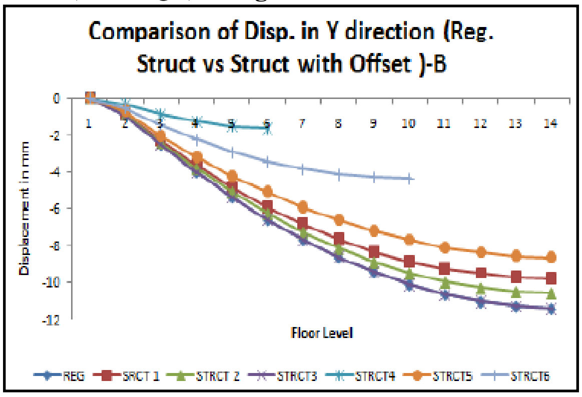

Fig -38

Due to action of dead load on all structure provided with offset shows minimum displacement in y-direction as compared to regular ideal structure as indicated.

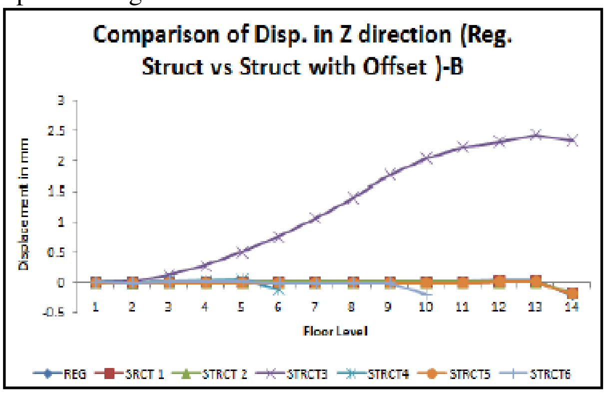

Fig -39

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Below Fig.40 indicate the displacement in the transverse direction of earthquake force in L-shaped structure shows maximum displacement and except that all structure shows marginal difference of displacement at the top floor.

- **comparison displacement in x and y-direction for 1.5(DL-EQX) in regular structure Vs. structures with**

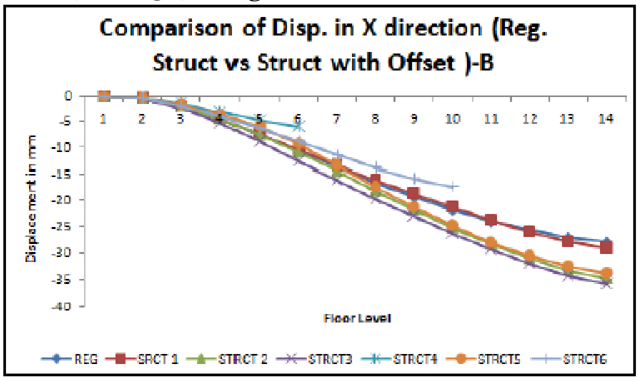

Fig -41

Fig.42 indicate displacement in the direction of earthquake force shows same kind of result only by changing reversing direction.

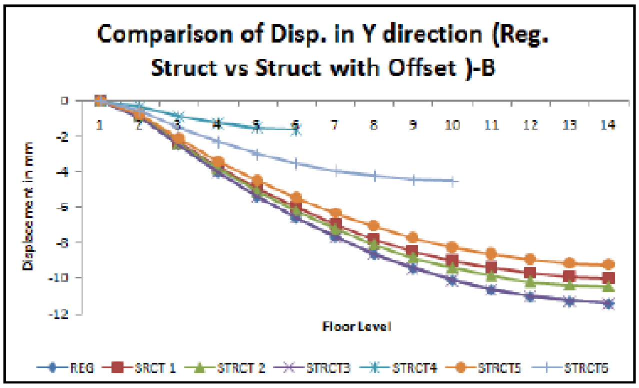

Fig -42

- **comparison displacement in z-direction for 1.5(DL-EQX) in regular structure Vs. structures**

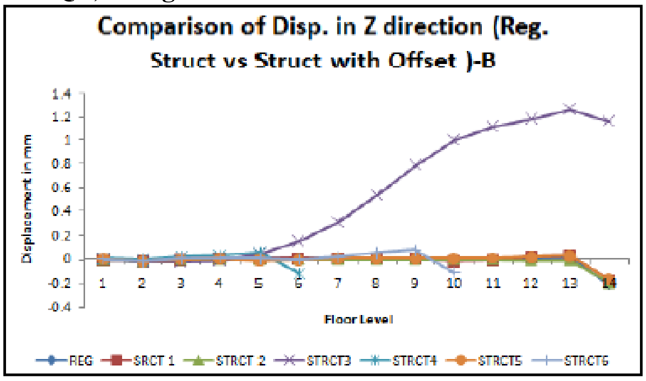

Fig -43

4.CONCLUSION

The seismic design approach, in both the versions, is based on designing a strong and ductile structure, which can take care of the inertial forces generated by earthquake shaking. Unlike previous version of 2002, the latest 2016 version clearly reflects that design seismic force is much lower than what can be expected during strong shaking. In the calculation of design horizontal seismic coefficients, the latest versions gives some modification regarding Importance factor also the graph of spectral acceleration coefficients vs natural period modified.

The effect of shear force and moment in the direction of earthquake force is more critical due to provision multiple offsets, especially in intermediate columns. Provision of offsets may lead to rise in moments and torsion in corner columns, if no floors are provided above corner columns, but provided away from the corner column, there can be significant rise in moments and torsion. While In Structure-2 as per the results shown in software maximum bending moment as 40.387 kNm in column E.

In case of Displacement following results found, For column C,D,E,G in case of regular structure compare to irregular structure is less. Among the all above consider cases, the maximum percentage increase in displacement is seen in column C of Structure-4 i.e. 25.83%.

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