Behaviour of Multistoreyed Plan Symmetric and Plan Asymmetric Building Subjected to Seismic Load

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Abstract : Seismic analysis of structures is an important branch of civil engineering which deals with the calculation of the response of a structure subjected to seismic loads. The buildings are mainly classified into two types regular and irregular buildings. Now a days in the urban areas there is a rise in the number of the irregular buildings as the space available for the construction of structures is limited. In the irregular buildings there is a lack of symmetry and they have discontinuity in the geometry, mass and load resisting elements. The irregularities in the structure are broadly classified as plan irregularity and vertical irregularity. In this paper the building with plan irregularities along with the effect of variation in rigidity of diaphragms and effects of orientation of columns on seismic response of a structure is studied. This paper particularly discusses the variation in bending moment and lateral displacement at different positions in the Box and L-shape structural model with a different diaphragm condition under the action of incremental horizontal seismic forces along mutually perpendicular direction. The analysis of the structural model is done by using ETABS 2015 software by considering the static non-linear analysis also called as pushover analysis.

***IndexTerms* – Plan symmetry, Plan Asymmetry, ETABS 2015, Pushover Analysis.**

I. INTRODUCTION

Earthquakes have the possibilities of causing the greatest damage, among all the natural hazards. The earthquake forces are random in nature & unpredictable. During an earthquake, the damage in a structure is generally initiated at the point of the structural weakness present in the building system. The studies conducted on the buildings that are located in high seismic zone, regarding the effect of seismic forces on structures with respect to variations in structural properties like mass regularity, plan regularity, stiffness and strength, etc. along the height of the building shows that there is a large scope for the research in this field. Therefore the structural engineer needs to have a thorough understanding of the seismic response of the irregular structures.

I.1 Irregularity

The irregularity in the building structures may be due to irregular distributions in their mass, strength and stiffness along the height of building. When such buildings are constructed in high seismic zones, the analysis and design becomes more complicated. According IS 1893(Part-1):2002, the criteria for earthquake resistant design of structures, majorly classifies the irregularities found in the structure into 2 types, i.e. plan irregularities and vertical irregularities.

I.2 Plan Irregularities

Irregularities in plan is related to asymmetrical mass, stiffness and strength distributions, causing a substantial increase in the torsional effects when the structure is subjected to lateral forces, on the other hand irregularities in elevation involves the variation of geometrical and structural properties along the height of the building, generally leading to an increase in the seismic demand in specific storey.

There are few types of plan irregularities

I.2.1 Torsion Irregularity

It is to be considered when floor diaphragms are rigid in their own plane in relation to the vertical structural elements that resist the lateral forces. Torsional irregularity is considered to exist when the maximum storey drift, computed with design eccentricity, at one end of the structure transverse to an axis is more than 1.2 times the average of the storey drifts at the two ends of the structure is as shown in fig.01.
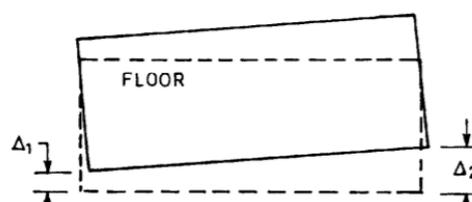

Fig.01: Torsional Irregularity

I.2.2 Re-entrant Corners

Plan configurations of a structure and its lateral force-resisting system contains re-entrant corners, where both projections of the structure beyond the re-entrant corner are greater than 15 per cent of its plan dimension in the given direction is as shown in fig.02.
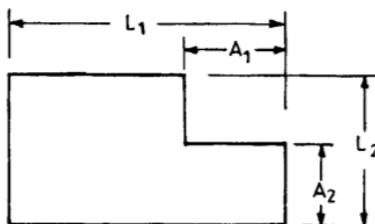

Fig.02: Re-entrant Corner in Plan Irregularity

I.2.3 Diaphragm Discontinuity

Diaphragms with abrupt discontinuities or variations in stiffness, including those having cut-out or open areas greater than 50 per cent of the gross enclosed diaphragm area, or changes in effective diaphragm stiffness of more than 50 per cent from one storey to the next.

II RESEARCH METHODOLOGY

Pushover analysis is a method in which the structure is subjected to increasing lateral forces with an invariant height-wise distribution until a target displacement is reached. Pushover analysis consists of a series of sequential elastic analysis, superimposed to approximate a force-displacement curve of the overall structure. The pushover analysis of box and L-shaped building is done in this paper. The modeling and analysis of the building is done using ETABS 2015 software.

The software utilized in this exploration is ETABS-2015 and the procedure used for seismic evaluation is Non-linear Static Analysis also called as Pushover Analysis. ETABS is a designing and programming tool that can be utilized in planning and analysis of multi storeyed structures. Both box and L-shape models consist of 4 floors (G+4) with floor height being 3.2m each. The dimensions of the columns and beams are fixed as 230X450mm and 230X450mm respectively as per IS 456:2000. The thickness of the slab is 150mm for both models as shown in table 1. The column positions are fixed in such a way that the spans of all the beams in both X and Y directions are kept same and equal to 5m is shown in fig.03 and fig.04. The roof modeling is considered as rigid diaphragm and semi rigid diaphragm respectively (The slab is assigned as membrane and shell thin). The loading conditions for both plan symmetric models and plan asymmetric models are similar. The model is subjected to dead load and live load as per Indian codes. If all the members pass the design check, then the next part of analysis i.e. seismic analysis is carried out or else the member sizes are revised and the procedure is continued. The static non-linear load patterns and load cases required for carrying out pushover analysis are defined in both X and Y directions. Once the member sizes are fixed, all the columns and beams (frame members) are assigned hinges based on the hinge properties from tables given in ASCE 41-13. After this the model is checked for errors and then finally it is analyzed under the action of lateral pushover loads applied under displacement control method. After the analysis is complete, the push over results are plotted. Also both the symmetric model and the asymmetric models have been analyzed for membrane and shell-thin of rigid and semi rigid diaphragm conditions. In this study the bending moment and lateral displacement values between the columns at the corner of the building projection (C1) and the re-entrant corner (C2) have been made.
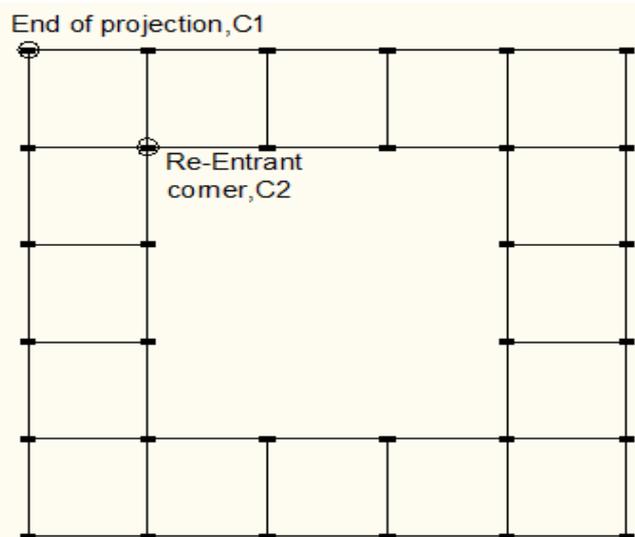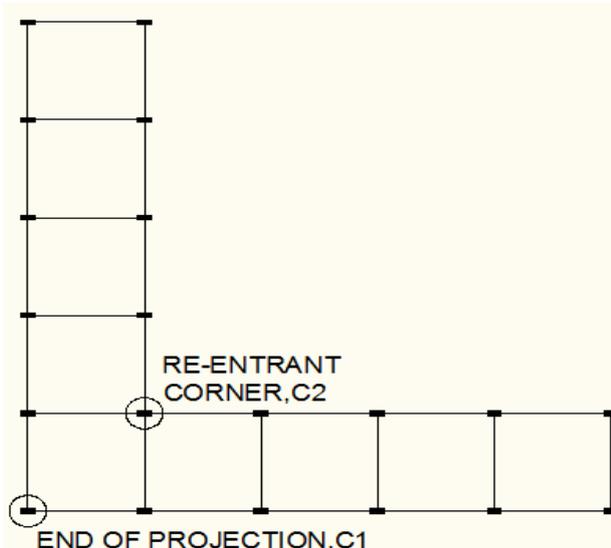
Fig.03: Box Shaped Model   Fig.04: L Shaped Model

Table -1: Parameters considered in the present study

Type of building	Mass regular
Structure type	Ordinary moment resisting frame
No. of stories	G+3
Typical storey height	3.2m
Type of building use	Public cum office
Foundation type	Isolated footing
Seismic zone	V
Material properties	
Grade of concrete	M20
Grade steel	Fe500
Density concrete	25 kN/m^3
Member properties	
Slab thickness	150 mm
Beam size	230X450 mm
Column size	230X450 mm
Wall size	230 mm
Dead load intensity	
Floor finish	1 kN/m^2
Live load intensities	
Roof	2.5 kN/m^2
Floor	3.5 kN/m^2
Earthquake live load on slab as per clause 7.3.1 and 7.3.2 of IS:1893(part 1)2002	
Roof	0.25X2.5=0.625 kN/m^2
Floor	0.5X3.5=1.75 kN/m^2

III. RESULTS AND DISCUSSION

The following section discusses the results obtained from the analysis with regards to bending moment with respect to the storey number. The fig.05 and fig.06 shows the 3-D view of a box shaped and L-shaped building considered in the study. The roof modeling is considered as rigid diaphragm and semi rigid diaphragm respectively (The slab is assigned as membrane and shell thin) for the column at the end of projection (C1) & at the re-entrant corner (C2).
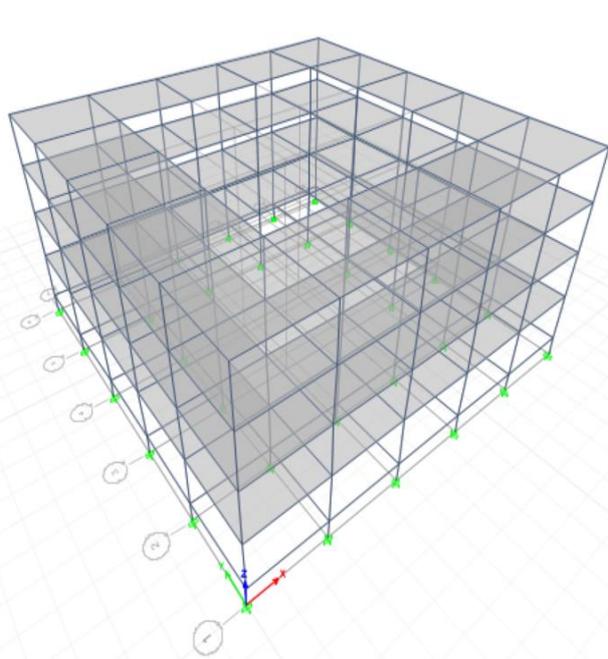
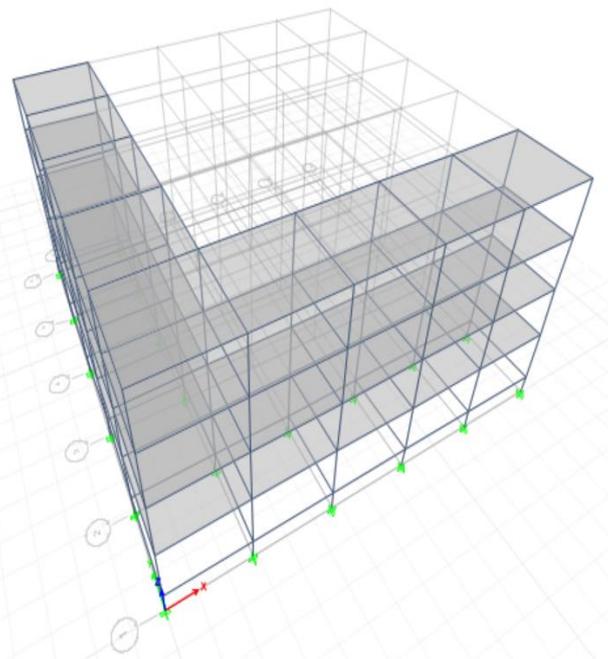Fig.05: 3D view of Box shape model   Fig.06: 3D view of L-shape model

The values of bending moment for various storey along push x and push y loads for membrane and shell thin of rigid and semi rigid condition of box and L-shaped building at end of projection and re – entrant corner is as shown in Table -2, Table- 3, Table-4 and Table-5. From the table 2 to table 5 and fig.07 to fig. 14, it can be seen that the bending moment goes on increases from the top storey to bottom story. Also bending moment is more for rigid diaphragm condition compare with semi rigid diaphragm condition in both plan symmetric and plan asymmetric building. Shell thin Semi-rigid roof modelling gives better results, when compared to membrane rigid and semi rigid and shell thin rigid roof modelling.

Table-2: Bending moment of Box shape buildings at End of Projection (C1 Column)

Model type	Storey No.	Rigid				Semi rigid			
		Push X		Push Y		Push X		Push Y	
		M2	M3	M2	M3	M2	M3	M2	M3
Membrane	5	0.00	72.36	466.54	2.87	0.00	72.25	13.34	0.00
	4	0.00	125.10	686.14	3.87	0.00	125.41	33.10	0.00
	3	0.00	81.75	1024.50	9.40	0.00	90.2	45.55	0.00
	2	0.00	267.18	1403.20	28.9	0.00	270.70	88.24	0.00
	1	0.00	278.30	1528.60	70.22	0.00	273.90	119.25	0.00
Shell thin	5	1.24	35.83	15.95	1.00	1.15	33.37	18.73	1.00
	4	2.20	71.00	36.90	1.26	2.10	66.96	42.31	1.70
	3	3.74	90.00	54.50	2.75	3.40	84.90	60.56	3.50
	2	2.30	164.53	81.23	1.75	2.11	162.77	100.27	2.50
	1	0.00	264.47	109.18	0.00	0.00	224.42	133.0	0.00

Table-3: Bending moment of Box shape buildings at End of Projection (C2 Column)

Model type	Storey No.	Rigid				Semi rigid			
		Push X		Push Y		Push X		Push Y	
		M2	M3	M2	M3	M2	M3	M2	M3
Membrane	5	0.00	126.31	298.71	30.95	0.00	126.20	21.00	0.00
	4	0.00	144.70	441.78	33.00	0.00	144.90	45.90	0.00
	3	0.00	110.80	705.67	36.68	0.00	118.66	71.76	0.00
	2	0.00	264.00	1121.14	162.10	0.00	265.87	114.57	0.00
	1	0.00	275.40	1234.60	260.23	0.00	273.80	156.10	0.00
Shell thin	5	1.70	57.32	26.51	1.62	1.57	53.51	31.02	2.00
	4	2.10	108.92	55.81	1.52	2.00	102.28	65.79	1.80
	3	2.56	174.85	87.13	1.55	2.34	165.12	103.50	2.47
	2	1.42	218.10	109.87	1.00	1.33	207.80	119.00	0.00
	1	0.00	252.34	136.80	0.00	0.00	241.61	158.35	0.00

Table-4: Bending moment of L shape buildings at End of Projection (C1 Column)

Model type	Storey No.	Rigid				Semi rigid			
		Push X		Push Y		Push X		Push Y	
		M2	M3	M2	M3	M2	M3	M2	M3
Membrane	5	9.80	66.77	11.83	1.10	9.24	67.42	12.24	1.00
	4	6.10	113.90	26.00	3.85	7.00	117.10	26.10	3.94
	3	5.20	72.36	41.38	6.36	5.17	73.55	41.42	5.65
	2	3.42	225.65	76.15	5.10	5.00	235.53	78.41	7.16
	1	7.70	249.72	103.88	9.74	5.27	260.93	105.67	5.90
Shell thin	5	3.13	32.64	17.52	1.33	2.70	29.62	15.44	1.20
	4	4.63	67.73	38.44	2.10	4.37	65.43	36.76	2.10
	3	6.40	86.15	53.73	4.21	5.55	84.35	52.10	3.10
	2	3.21	161.10	85.00	3.73	3.87	159.72	85.48	5.10
	1	3.10	232.55	108.10	8.92	1.23	218.21	115.61	4.20

Table-5: Bending moment of L shape buildings at End of Projection (C2 Column)

| Model type	Storey No.	Rigid				Semi rigid			
		Push X		Push Y		Push X		Push Y	
		M2	M3	M2	M3	M2	M3	M2	M3
Membrane	5	4.32	118.63	19.15	1.10	2.43	119.37	19.78	1.00
	4	2.65	130.77	45.52	1.20	3.10	133.82	45.41	1.00
	3	2.32	103.99	68.42	2.50	2.53	104.55	68.30	1.67
	2	1.54	258.97	104.31	2.15	2.37	262.33	107.00	3.00
	1	3.56	262.60	132.30	3.73	2.34	253.42	138.32	2.36
Shell thin	5	0.00	55.65	29.10	1.51	0.00	50.56	26.17	0.00
	4	0.00	105.89	61.52	1.30	0.00	101.21	58.18	0.00
	3	1.00	172.00	96.48	1.45	1.20	164.87	92.71	0.00
	2	1.00	212.00	116.56	1.00	1.00	207.34	116.31	0.00
	1	1.50	244.75	141.23	3.66	1.25	237.58	146.44	0.00
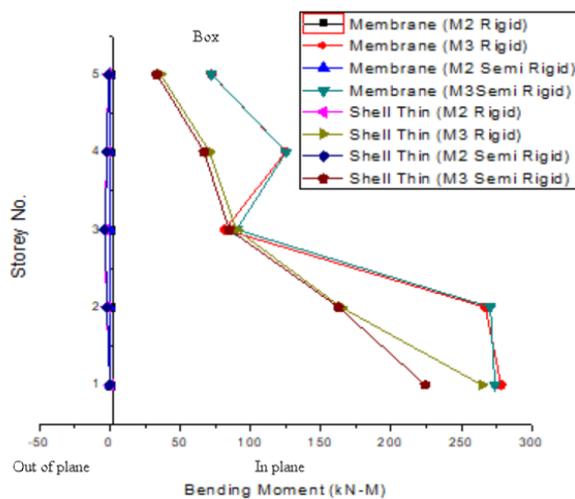
Fig.07. Variation of bending moment (M2 and M3) at the end of projection (C1) due to push X (BOX Shape)
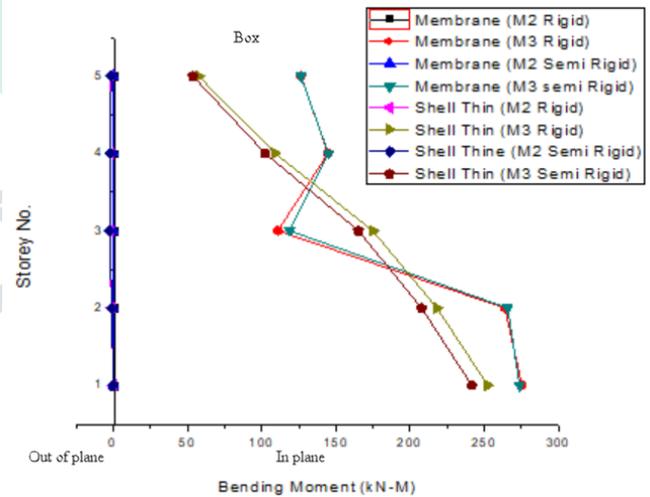

Fig.08. Variation of bending moment (M2 and M3) at the re-entrant corner (C2) due to push X (BOX Shape)
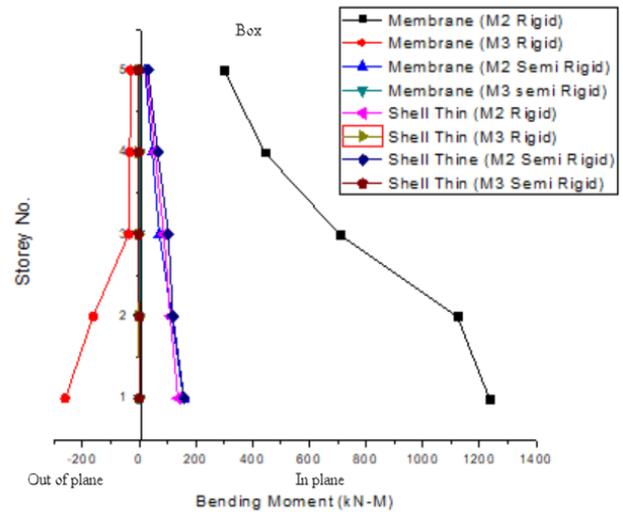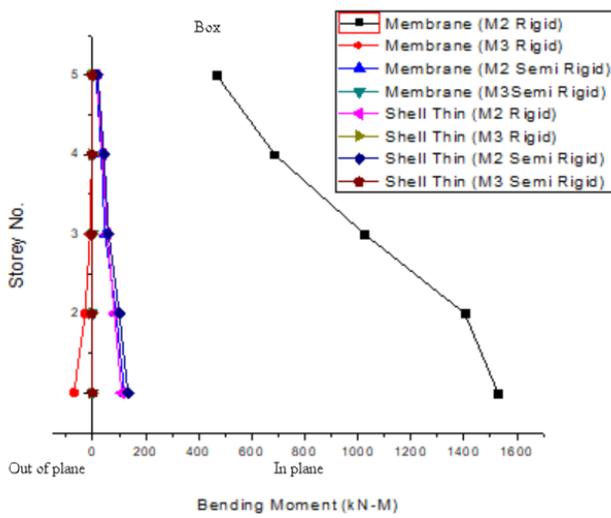
Fig.09. Variation of bending moment (M2 and M3) at the end of projection (C1) due to push Y (BOX Shape)

Fig.10. Variation of bending moment (M2 and M3) at the re-entrant corner (C2) due to push Y (BOX Shape)
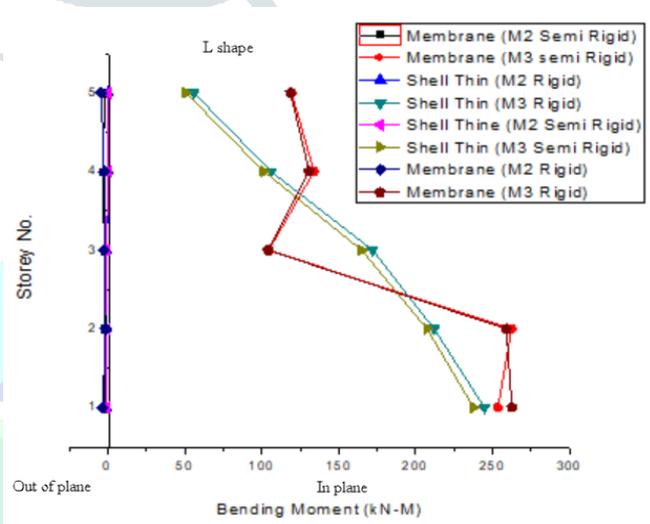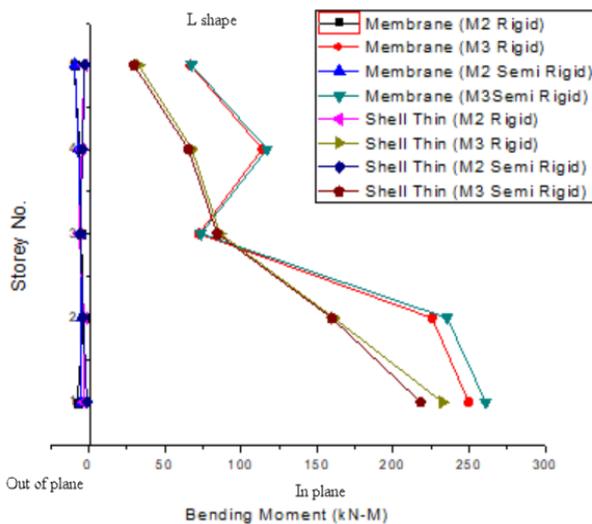

Fig.11. Variation of bending moment (M2 and M3) at the end of projection (C1) due to push X (L Shape)

Fig.12. Variation of bending moment (M2 and M3) at the re-entrant corner (C2) due to push X (L Shape)
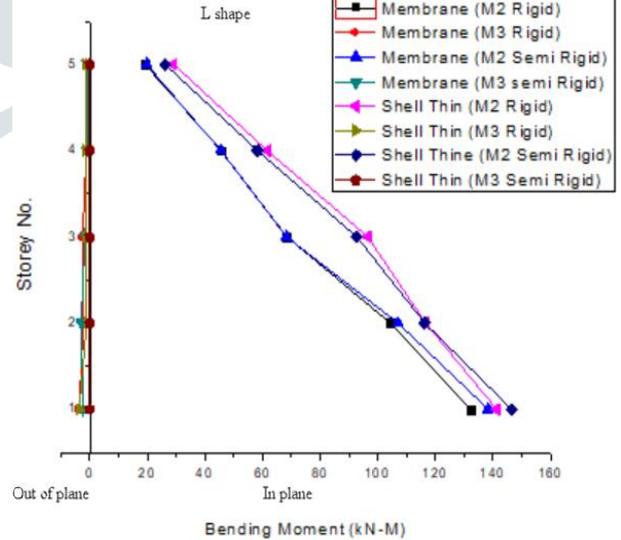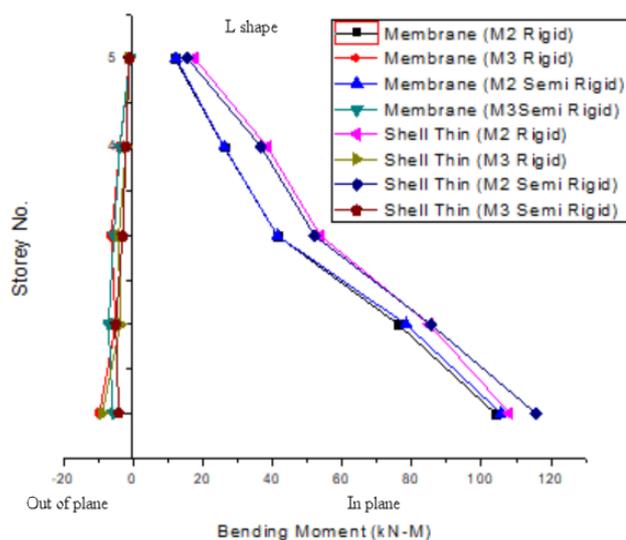

Fig.13. Variation of bending moment (M2 and M3) at the end of projection (C1) due to push Y (L Shape)

Fig.14. Variation of bending moment (M2 and M3) at the re-entrant corner (C2) due to push Y (L Shape)

IV CONCLUSION

From the present study it can be concluded that, the bending moment of the Plan asymmetric building is more when compared to plan symmetric building. Also, the bending moment value is more for rigid diaphragm when compare to semirigid diaphragm. The bending moment value for all models goes on increases towards the bottom storey. So that, it proves that plan asymmetric buildings are harmful and it leads the structure to vulnerable condition in seismic zones. Therefore, as far as possible irregularities in a building must be avoided. If irregularities have to be introduced for any reason such buildings should be designed properly as per IS codes.

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