International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 08 Issue: 03 | Mar 2021 www.irjet.net p-ISSN: 2395-0072

SEISMIC PERFORMANCE OF SOLID AND HOLLOW RC MEMBERS IN RCC FRAMED BUILDING USING ETABS

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Abstract: *In this case study of this paper were mainly emphasizes on behaviour of reinforced cement concrete framed building having hollow (Box-type) and solid reinforcing concrete members, with shear wall along periphery, on sloping ground and progressive collapse behaviour using ETABS 2015 ultimate v 15.2.0. By using the hollow (Box-type) reinforced concrete beams and columns will help in decrease in superstructure weight and so the seismic mass is minimized as compared to the conventional solid reinforced concrete beams and columns. The modelling is done as per the requirements for the hollow (Box-type) and solid reinforcing concrete members, with shear wall along periphery and on sloping ground, a response spectrum analysis is carried out for the structures and Progressive Collapse behaviour is carried out to study the behaviour of RC structure under gravity loading by linear static analysis, the storey shears, overturning moments, storey displacement etc. of analysis results are dropped in the cases of hollow members as compared with the solid members in reinforced cement concrete framed building.*

INTRODUCTION

The conventional concrete superstructure weight and seismic mass can be minimized by introducing the Hollow (Box-type) reinforced concrete beams and columns and by the use of hollow reinforced concrete members the economical convenience can be achieved due to the cost saving afforded by reduced sectional area.

For example the hollow concrete rectangular concrete piers have been used in San Francisco-Oakland Bay Bridge, Benicia Martinez Bridge and Carquinez Strait Bridge. By introducing the hollow reduces the mass and decreases the seismic burdens on the extension, empty center guarantees the more prominent quality control amid development by decreasing the warmth of hydration on the inside of the segment and minimizes breaks brought on by temperature contrasts inside the curing wharf.

Objectives

The study consists of

- Comparison of solid and hollow (Box-type).
- Comparison of solid and hollow (Box-type) with shear wall along the periphery of the building.
- Comparison of solid and hollow (Box-type) on sloping ground which has taken randomly.
- Comparison of solid and hollow (Box-type) on Progressive Collapse behaviour by removing the column of an unsymmetrical building.

REVIEW OF LITERATURE

The following literature reviews are carried out for the comparisons of seismic analysis of solid and hollow (Box-type) beams and columns in RCC framed building for with shear walls, on sloping ground and progressive collapse analysis using ETABS software.

Abhaycarried out work on 'Comparisons of Seismic Performance of Solid and Hollow Reinforced Concrete Members in RCC Frame Building Using ETABS Software' in which the main emphasizes of this case study is the structural behaviour of RCC framed building having hollow and solid reinforced concrete members.

He considered a 3storey RCC framed building of 12m x 12m in plan with columns spaced at 4m from centre to centre and a floor to floor height of 3.5m. The beam and column dimensions are 450mm x 450mm and 500mm x 500mm respectively and slab thickness is 100mm. The support conditions are fixed. The live load is 3 KN/m^2, seismic zone; soil type, I, R and damping are V, 2, 1, 5 and 5% respectively for earthquake load to both directions. The static analysis is carried out.

After analysis the comparison taken for storey overturning moments due EQX load, storey shear due to EQY load, storey drifts due to EQX load, column forces, and maximum node displacement of members, maximum stress diagram due to 1.5(DEAD-EQY) load, weight of members, and axial forces for columns of 1st storey.

The given conclusion is that, 8-9.5% reduction in maximum node displacement, 20-27% reduction in storey overturning moment, 8-9% reduction in storey drift, storey shears decreases with the increase in storey height and 74.1687 Ton of M30 concrete is saved by using hollow members in RCC framed building so it leads to economical design without the failure of the structure against seismic loads.

Thanuja H P, E Ramesh Babu, Dr. N S Kumarcarried out the work on 'A Study on Behaviour of Circular Stiffened Hollow Steel Column Filled with Self Compacting Concrete under Monotonic Loading' in which to observe the behaviour and buckling load of variable lengths and D/T ratios

The given conclusion is that, as length increased the load carrying capacity decreases, as diameter increases load carrying capacity increased, the capacity of loading carrying is higher in the steel tubes filled with SCC and the stiffened steel tube is stronger and load carrying capacity is also higher.

Mohammed umar farooque Patel, A.V. kulkarni, nayeemullaInamdar carried out work on 'A performance study and seismic evaluation of RC frame buildings on sloping ground' in which the impact of shifting stature of sections in ground storey because of inclining ground and the impact of Shear wall at various positions amid seismic tremor is concentrated on.

The given conclusion is that the parallel relocations and storey floats are extensively lessened while commitment of Shear wall, Shear wall at outside corners is subjected to less dislodging contrasted with different cases, otherworldly removal and rooftop uprooting is diminishing impressively to build models on plain ground when contrasted with building models on inclining ground. Plastic pivots are more if there should be an occurrence of structures laying on inclining ground when contrasted with structures laying on plain ground. The quantities of plastic pivot arrangement in structures on inclining ground are more in longitudinal heading due to the impact of asymmetry along longitudinal bearing and the execution of the structures on slanting ground proposes an expanded helplessness of the structure with development of segment pivots at base level and bar pivots at every storey level at execution point.

Ram Shankar Singh, Yusuf Jamal, Meraj A. Khancarried out work 'Progressive Collapse Analysis of Reinforced Concrete Symmetrical and Unsymmetrical Framed Structures by ETABS' in which to look at the potential capacity of seismically composed working against progressive behaviour is concentrated on.

The given conclusion is that the loads, beams design forces and beam forces of DCR values are less than 2 in all the cases, it recommends that the segments are protected according to GSA rules for dynamic investigation consequently seismically composed building sections have inalienable capacity to oppose progressive behaviour. The DCR estimations of pillars are inside the acknowledgment criteria according to GSA rules it is sheltered and satisfactory support is required to confine the DCR with in the acknowledgment criteria to evade the dynamic disappointment of bars and sections created by disappointment of specific segment. Basic architect can achieve by applying the GSA criteria to forestall progressive behaviour for solid structures by utilizing promptly accessible programming and for minimal extra development cost.

METHODOLOGY

The most critical segment of exertion required for this examination was growing full scale diagnostic models of the model reinforced concrete beams and columns of solid & hollow (Box-type) buildings with ETABS 2015 and the goal is to compared with the storey drift, storey displacement, storey shears etc.

Modelling Cases and Procedure for Preparing the Models

Case 1: Comparison of solid and hollow (Box-type) RC framed models

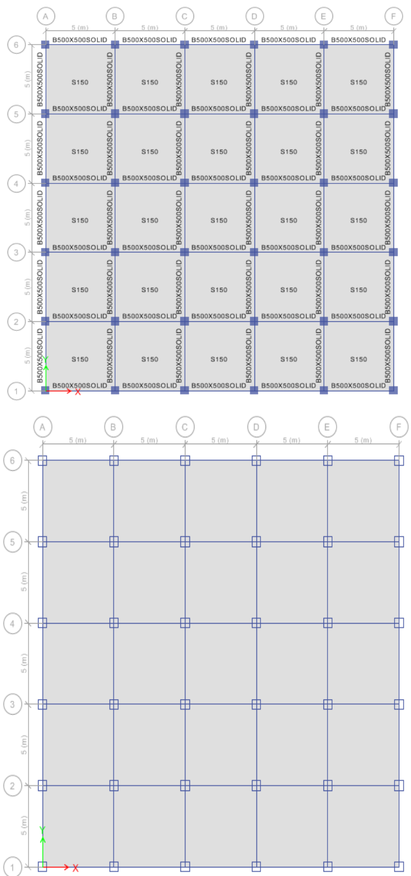


Fig 1 Plan of 5 Bay 5 Storey of Solid and Hollow (Box-type) RC Frame Building

Case 2: Comparison of solid and hollow (Box-type) RC framed with shear walls.

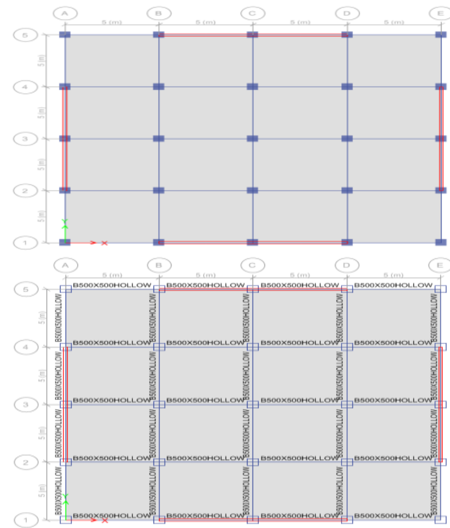


Fig 2 Plan of 4 Bay 5 Storey of Solid and Hollow (Box-type) RC Frame Building with Shear Wall along the Periphery.

Case 3: Comparison of solid and hollow (Box-type) RC framed in sloping ground

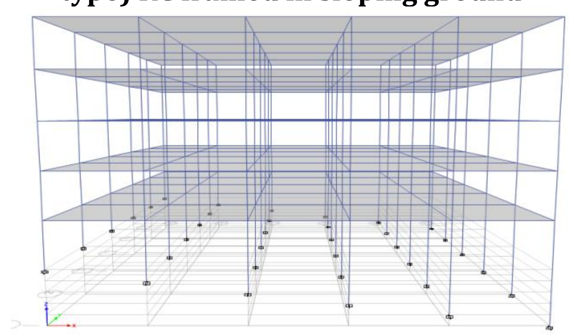


Fig 3 3D View of a Building on Sloping Ground (5bay 5storey).

Case 4: Comparison of solid and hollow (Box-type) RC framed in Progressive Collapse Behaviour.

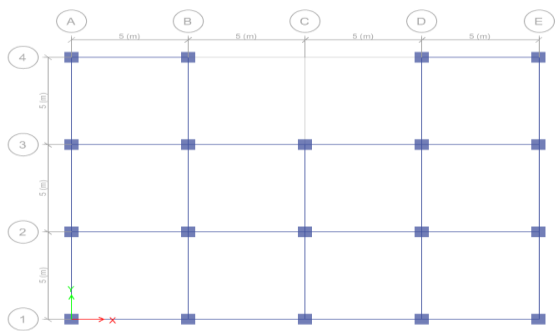


Fig 4 Plan of Unsymmetrical Building

Table 1 Material Properties

Density of RCC	25 KN/m³
Density of Masonry	19.2 KN/m³
Compressive Strength, f_{ck}	25 N/mm² (Beam) 30 N/mm² (Column)
Steel, f_y	500 N/mm²& 415 N/mm²
Modulus of Elasticity, E_c	$5000*(f_{ck})^{0.5}$

Table 2 Data / Parameters for the analysis of Problem

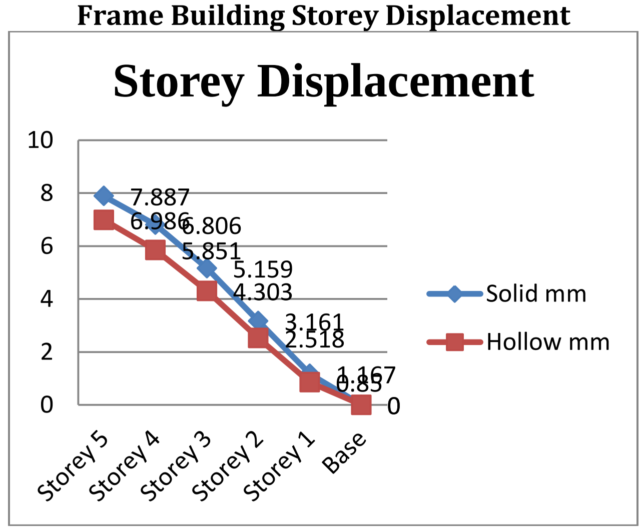
Each Storey Height	3m
Wall & Shear wall Thickness	200 mm
Thickness of Slabs	150 mm
Size of Beams	500 x 500 mm
Size of Columns	600 x 600 mm
For Hollow (Box-Type)	120 mm thick
Building Frame System	Ordinary RC Moment Resisting Frame
Parapet Height	600 mm
Supports	Fixed

Table 3 Loading Conditions

SLAB	**SDL** Assuming, Floor Finish = 1.5KN/m **LIVE** Considered as per IS 875 (part 2)-1987 i.e., Live Load = 3 KN/m³
WALL	For 200 mm thick Wall load = (3-0.5) * 0.2 * 19.2 = 9.6 KN/m Parapet wall load = 0.6 * 0.2 * 19.2 = 2.3 KN/m
EARTHQUAKE LOADS	All the building frames are analysed for one seismic Zone-2,the seismic parameters for building frames are Response Reduction Factor = 2, Importance Factor = 1. Damping = 5 %, Soil Type is Medium and the fundamental natural period is 0.09h/√d. Where 'h' is height and'd' is base dimension (Plinth level).

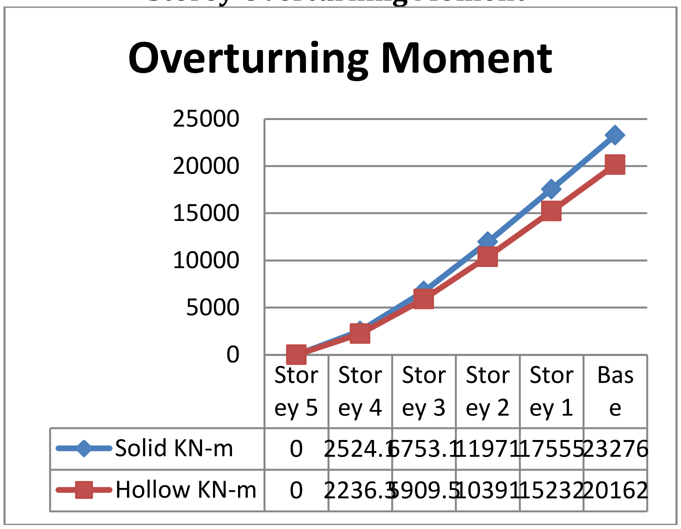
RESULTS AND DISCUSSIONS

Comparison of Solid and Hollow (Box-type) RC Frame Building Storey Displacement



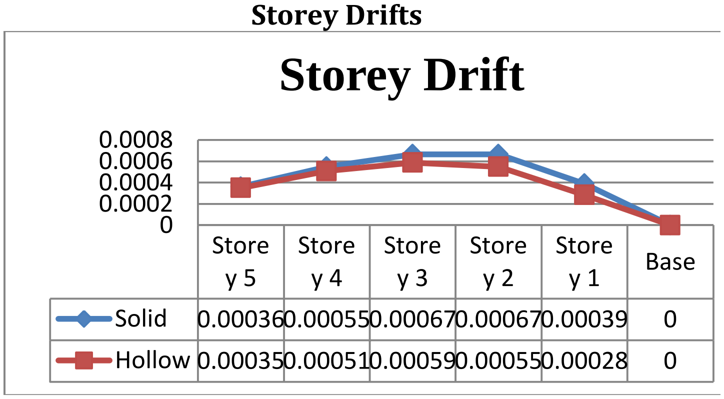
From the above figure, it has been concluded that the by increasing with the storey height the maximum displacement increases and there is 11.42% reduction in the maximum displacement due to the Hollow (Box-type) members in RCC framed building as compared to the Solid members with the wall load consideration.

Storey Overturning Moment



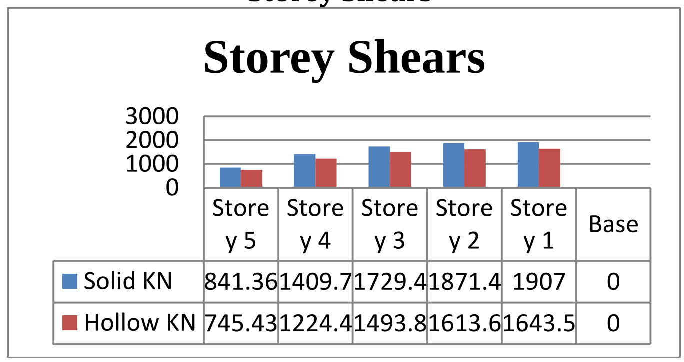
The RCC framed building having solid members having the higher values of overturning moment as compared to the Hollow (Box-type) member, where the hollow members of beams and columns helps in reducing the storey overturning moment as compared to solid beams and columns. Where from 12% to 13% difference will come from base to the top storey for when we use the hollow (Box-type) member with the wall load consideration but however the storey overturning moment decreases with increase in storey height for both the solid and hollow (Box-type) RC frame buildings

Storey Drifts



From the above figure it is observed that the by using the hollow (Box-type) RC members in RCC framed buildings will help in reducing the storey drift as compared to the solid beams and columns and where 11% to 18% reduction occurs in the storey one and two.

Storey Shears



In the above figure there is 8% to 13.81% reduction in the storey shears from storey five to storey one when we use the hollow (Box-type) beams and columns in the RCC framed buildings instead of the solid RCC framed buildings with the wall load consideration.

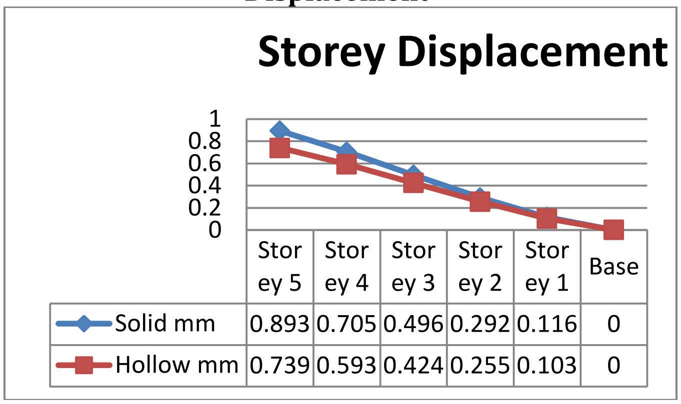
Total Base Reactions

RC Frame Building	Reactions KN	Moment KN-m
Solid	79925.87	999073.46
Hollow (Box-type)	69759.2404	871990.5047
Forces C6	**Solid Member**	**Hollow Member**
Axial Force P, KN	-1172.75	-1056.91
Shear Force V_2,KN	-17.60	-14.45
Bending Moment M_3,KN-m	27.41	22.47

there is a reduction in the total base reactions that is reaction and the moment is reduced by 12.72% for both by using the hollow (Box-type) RC frames in the buildings and also from the C6 column of Storey 1, the axial force, shear force and bending moment is reduced by 9.87%, 17.89% & 18.02% respectively which will leads to economical design of the building

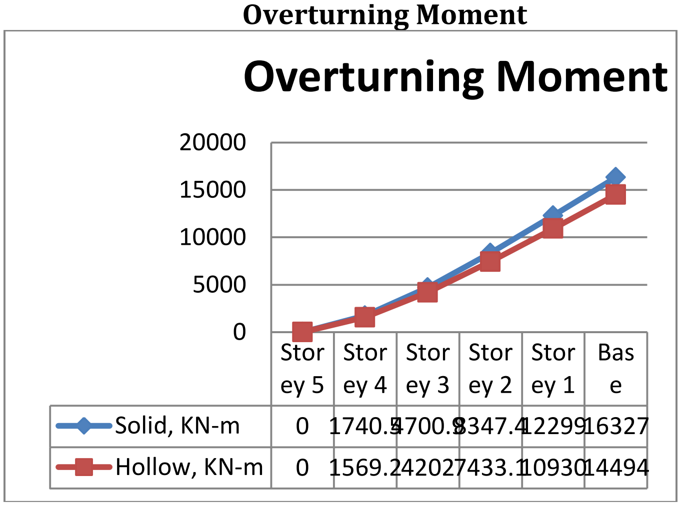
With Shear Wall along the Periphery

Displacement



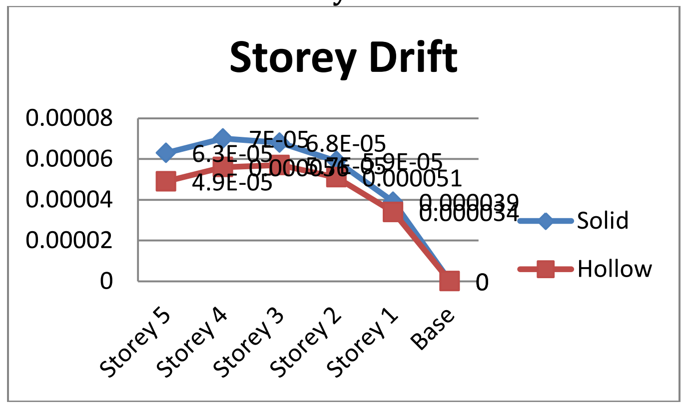
After analysing the solid and hollow (Box-type) beams and columns in a building there is reduction in the storey displacement for a hollow (Box-type) beams and columns that is 17.24% reduction in the top storey& 11.2% to 16% reduction in storey 4 to storey 1 as compared to the solid RC frame building.

Overturning Moment



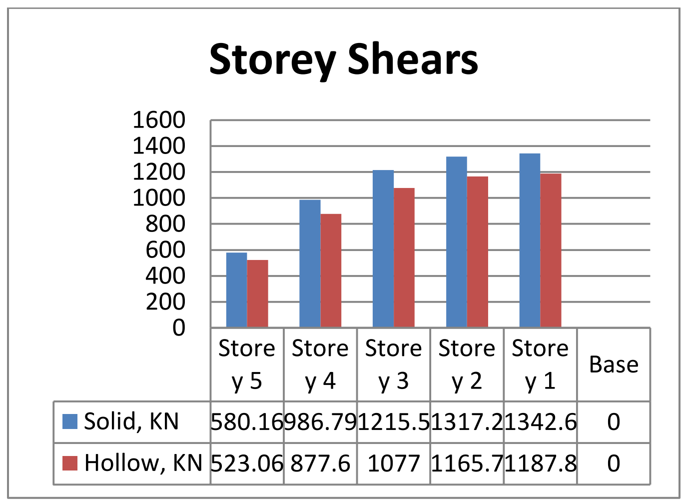
From the above figure there is reduction in the storey overturning moment when we are using the hollow (Box-type) RC frames in the building that is 9% to 12% reduction when compared to the solid RC framed building with the wall load consideration

Storey Drift



There is 12% to 22.22% reduction in the storey drift while using the hollow (Box-type) RC frame in the building as compared to the solid RC frames.

Storey Shears



In the above figure there is reduction in the storey drift by using the hollow (Box-type) RC frames when compared to the solid frames that are 9% to 12% and storey shears increases with the storey height in both the cases

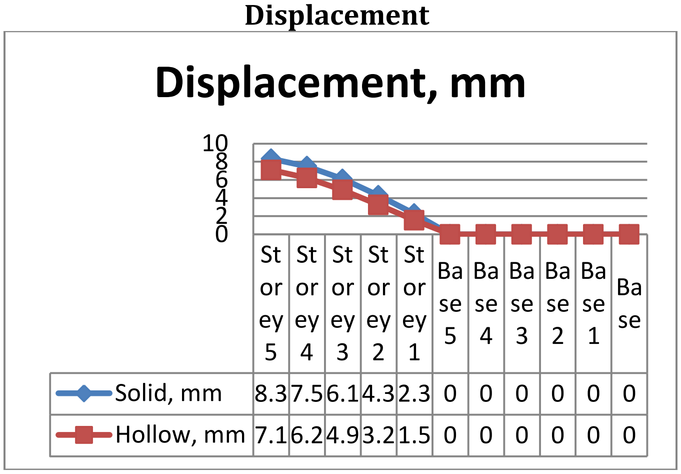
Total Base Reactions

RC Frame Building	Reactions KN	Moment KN-m
Solid	55932.7572	559237.8442
Hollow (Box-type)	50001.1797	500156.7405

ForcesC6	Solid Member	Hollow Member
Axial Force P, KN	-1019.72	-563.07
Shear Force V_2,KN	-8.75	-6.56
Bending Moment M_3, KN-m	13.46	10.56

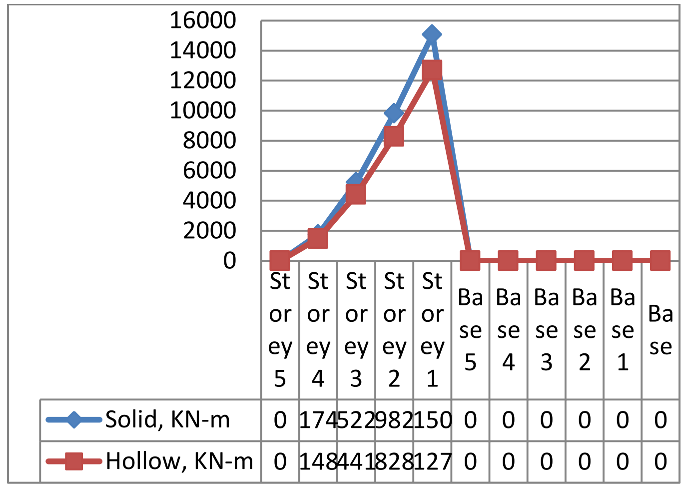
From the above tables there is 11% reduction in the total base reactions in the hollow (Box-type) RC frames when compared to the solid RC frames and also for a C6 column the axial force reduction is 50% reduction, Shear Force is 25% reduction and Bending Moment is 21.54% reduction respectively which helps in the economical design of the building.

Sloping Ground Displacement



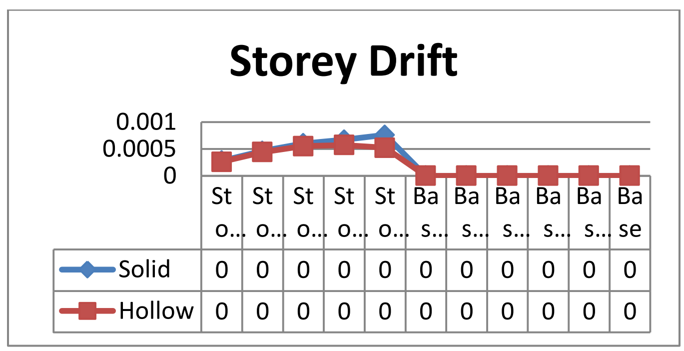
From the above figure it is shown that the, there is 14.77% reduction in the top storey displacement by using the hollow (Box-type) RC framed building as compared to the solid framed building.

Storey Overturning Moment



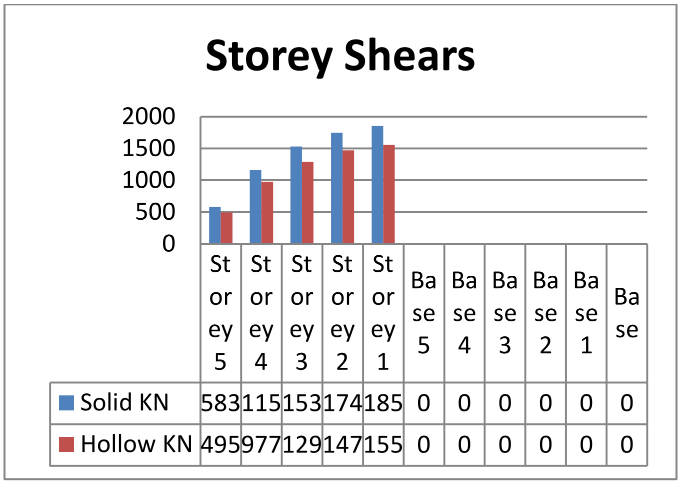
there is 17% reduction in the storey overturning moment in the Storey 1 which is maximum at that point when we use the hollow (Box-type) reinforced concrete frames in the building as compared to the solid reinforced concrete frames in the building and there is decrease in the storey overturning moment when the storey increases in both the cases.

Storey Drift



there is a reduction in storey drift by using the hollow (Box-type) RC frames in the building that is 31.58% in storey 1 and 14.92% reduction in storey 2 where the maximum drift occurred compared to the solid RC frame building

Storey Shear



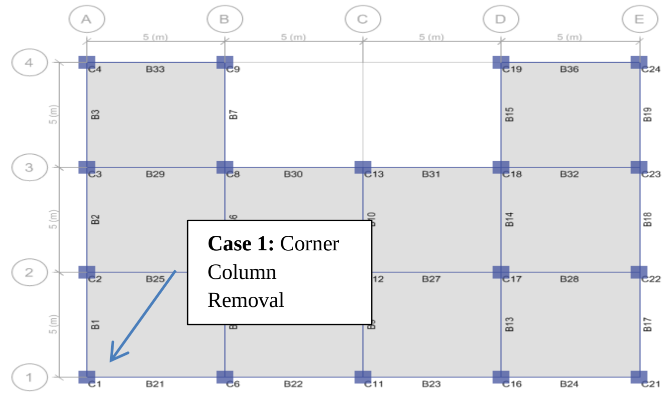
it is observed that, there is 15% to 16% reduction in the storey shears when the hollow (Box-type) RC frames is used when compared to the solid RC frames.

Total Base Reactions

RC Frame Building	Reactions KN	Moment KN-m
Solid	77522.8921	969433.0955
Hollow (Box-type)	66590.4628	833153.2723
Forces C6	**Solid Member**	**Hollow Member**
Axial Force P, KN	-1118.1	-959.01
Shear Force V_2, KN	-10.30	-6.02
Bending Moment M_3, KN-m	23.86	17.15

there is reduction in base reactions and the forces in the C6 column in storey 1 by using the hollow (Box-type) RC frames in the building that is 14.10% in the reaction and 14% in the moment compared to the solid RC frames. In C6 columns of storey 1 there is reduction in the axial forces, shear force and moment that is 14.22%, 41.55% and 28.12% respectively. These reductions will help in the economical design of the members.

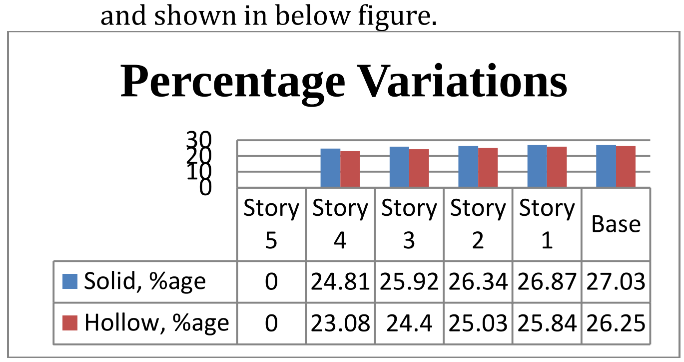
Progressive Collapse Behaviour



Comparison Solid and Hollow (Box-type) RC Framed Building.

Before Removal of Column (Storey 1)

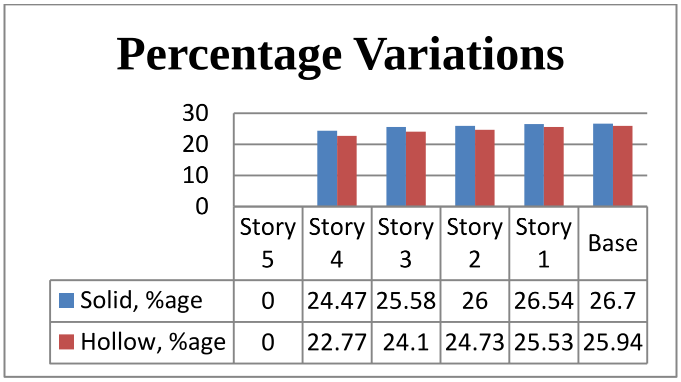
- it is observed that there is decrease in the bending moment by using the hollow (Box-type) beams and columns in a building of 10% by comparing the solid framed building.
- it is concluded that, there is 23.18% reduction in the axial force by using the hollow (Box-type) RC frames as compared to the solid RC frames in the building.
- There is reduction in the percentage of variations in axial forces also as it is tabulated and shown in below figure.



B. After Removal of Column (Storey 1)

- There is 18.11% reduction in the bending moment by using the hollow (Box-type) RC beams and columns compared to the solid RC beams and columns in a building

- And there is 20% reduction in the axial force by using the hollow (Box-type) RC beams and columns compared to the solid RC beams and columnsin a building.
- There is reduction in the percentage of variations in axial forces also as it is tabulated and shown in below figure.



	Story 5	Story 4	Story 3	Story 2	Story 1	Base
Solid, %age	0	24.47	25.58	26	26.54	26.7
Hollow, %age	0	22.77	24.1	24.73	25.53	25.94

CONCLUSION

In the present examination an endeavour (attempt) has been made to assess the execution of 5 storey structure for comparison of solid and hollow (Box-type) RC frame building with the wall load, with shear wall along periphery and on sloping ground using response spectrum analysis in zone II and a progressive collapse behaviour is also studied by linear static analysis with the corner column removed.

- The quantity of concrete required for the construction of a building is saved than required by the conventional concrete building by using hollow (Box-type) RC framed building.
- In comparison of solid and hollow (Box-type) RC frames there is reduction of 11.42%, 12% to 13%, 11%to 18% and 8% to 13.81% in displacement, overturning moment, drift and shears respectively by using the hollow members and also there is 12.72% reduction in the total base reactions where the economical sections can be achieved.
- When the shear wall is provided along the periphery of a building in a hollow (Box-type) RC framed buildingthere is a reduction of 17.24%, 9% to 12%, 12% to 22.22% and 9% to 12% reduction in the displacement, overturning moment, drift and shears respectively than the solid RC framed members.
- On a sloping ground, there is 14.27%, 17%, 31.58% and 15% to 16% reduction in the displacement, overturning moment, drift and shears respectively when we use the hollow (Box-type) RC members in a building.
- In the above three cases there is reduction in column forces which have taken C6 column at storey 1 that is in axial force, shear and moment respectively.
- In Progressive Collapse Behaviour of an unsymmetrical building there is reduction in the moment and axial forcesat the point when the section is evacuated (removed) at the corner. The percentage variations is also reduced in the C6 & C2 columns when Hollow (Box-type) members used in building.

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BIOGRAPHIES

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