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COMPARATIVE STUDY OF CONCEALED BEAM RC BUILDINGS WITH CONVENTIONAL BEAM RC BUILDINGS FOR GRAVITY LOADS & LATERAL LOADS

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***Abstract*— The present investigation deals with the comparative behavior of concealed beams in comparison with conventional beams for different grid sizes to have good aesthetic appearance without compromising the strength and serviceability of the building. The different grid sizes adopted by keeping the aspect ratio of 1, to determine the maximum span upto which concealed beam can be used effectively. Aspect ratios are varied to evaluate the effect of concealed beam as secondary beam in slab by laying the beam in shorter and longer span direction. Also the vulnerability of concealed beam building for seismic load is determined by using E-TABS and SAFE software. It is observed that the concealed beam is more effective when used in shorter span of slab and is more vulnerable to lateral loads therefore they should not be used as main beam in earthquake prone zones..**

***Keywords*—Concealed beam, aspect ratio, conventional beam.**

I. INTRODUCTION

Concealed beam is defined as the beam whose depth is equal to the thickness of the slab. They are also known as "HIDDEN BEAMS". The concept of concealed beam originated from flat slab concept. By providing concealed beam floor height can achieved, clears way for electromechanical duct work, economical and also aesthetic appearance of the building. This is more applicable in commercial buildings.[1]

Stiffness of the slab element is a significant factor, when spanning over longer spans essentially in floors and roofs of a building and carry distributed loads, primarily by flexure. Nowadays modern buildings have many structural constraints. The web of a T- beam or inverted T-beam may pose some problems. In such situations, Concealed beams or Hidden beams may be provided, which performs the function of a conventional beam to a possible extent. This necessitated understanding the behaviour of slab with such non- conventional structural element-Concealed beam.

The small effective depth in comparison with conventional beam sections, The diminishing of ductility due to the excessive reinforcement at interior supports, The shallow section renders the beam weaker in strut compressive force resistance, Shallow beams are normally narrower than the columns on which they connect, Therefore torsion action is amplified. The present study intends to address numerically the behavior of such shallow elements from the perspective of performance and behavior.

An attempt is made in this work to evaluate and compare the performance of concealed beam for gravity loading for different aspect ratio and its vulnerability to seismic loads a G+7 story made with normal beams and concealed beams to evalvate it. ETAB and SAFE software are used for this purpose. Models are analyzed separately for gravity loading to understand the effect of concealed beam on slabs and G+7 storey models are analyzed by selecting region of zone III on a medium soil. Response spectrum method is used for analysis. Displacement, Base shear and axial force are considered as parameters to evaluate concealed beam vulnerability to seismic load.

II. OBJECTIVES

1. To evaluate the maximum span upto which concealed beam can be used as main beam for gravity loading by keeping slab aspect ratio as 1.
2. To evaluate the effect of concealed beam on slab (deflection, bending moment, area of steel) when concealed beam is used as main beam and secondary beam for gravity loading only, when compared with conventional beam.
3. To evaluate best direction of providing concealed beam as a secondary beam for gravity loading only.
4. To understand concealed beam effect on overall building for lateral and gravity load (base shear, story drift, time period, stiffness).

LITERATURE REVIEW

1. Mr. V.S.Jagadeesh, Dr.D.S.Prakash "ANALYSIS OF CONCEALED BEAMS"

Author studied on slab with concealed beam having different aspect ratios of slab with short span, orthogonal and diagonal concealed beams. A linear static analysis is carried out for slab with and without Concealed beam using the finite element software NISA and found that "Slabs with diagonal Concealed beams show higher reduction in deflection and greater reduction in slab moments at mid span and at corner in both short and longer directions than other two type mentioned earlier, shear force, twisting moment and bending moment at mid span and at support of edge beams reduce for slab with diagonal Concealed beams.

2. Ziad N. Taqieddin "Deflection of Wide Hidden Beams in One-Way SlabSystems: A Nonlinear Finite Element Study"

The effectiveness of compression reinforcement in controlling the deflection of a wide-hidden continuous reinforced concrete beam is studied using nonlinear finite element (FE) simulations. Concrete Damaged-Plasticity and reinforcing steel Elasto-Plasticity are used in the nonlinear FE simulations of ABAQUS. Results are compared to Elastic FE simulations as well as to conventional code procedures.

The maximum deflection values are calculated using three different methods: initially according to the provisions of Section 9.5 of the ACI Code, followed by two types of finite element simulations; Elastic and Inelastic.

Test was carried out by varying the percentage of compression steel and behaviour of beam is studied. As the compression steel is increased deflection of the beam reduces.

3. Samir H. Helou, Riyad Awad "Performance based analysis of hidden beams in reinforced concrete structures"

The primary intention of the present study is to numerically investigate vernacular moment resisting structures in Palestine from the perspective of performance during strong seismic events. The selected topology for the present undertaking is arbitrarily comprised of five levels i.e. G+4 structure with each floor level having 3.50 meter height. The structure, shown in Figures 1 and 2, has 2 equal spans in one direction and 3 spans in the orthogonal direction. The span lengths are all equal; they are of 7 meters length in one direction and 6 meters in the other. The building is acted upon by equally distributed Live Load of 4.0 KN per square meter in addition to a Dead Load of 3.0 KN per square meter. The numerical models are constructed using SAP

2000. The slab thickness in all models is set to 20 cm. The periphery ledger beams have a 30x80 cm cross section while the hidden beams have a 25x80 cm cross section. All columns are square of 50x50 cm sections.

Case 1: no shear wall provided.

Case 2: building with shear walls.

Case 3: hidden beams replaced by drop beams.

4. Ziad N. Taqieddin "Deflection of Wide Hidden Beams in One-Way Slab

Systems: A Nonlinear Finite Element Study"

The effectiveness of compression reinforcement in controlling the deflection of a wide-hidden continuous reinforced concrete beam is studied using nonlinear finite element (FE) simulations. Concrete Damaged-Plasticity and reinforcing steel Elasto-Plasticity are used in the nonlinear FE simulations of ABAQUS. Results are compared to Elastic FE simulations as well as to conventional code procedures.

III. MODELS AND RESULTS.

A. INPUT DATA.

Model number	Description
G+2 Storey building	
1	3mx3m Panelled Conventional beam slab model (Etabs and safe)
2	3mx3m Panelled Concealed beam slab model (Etabs and safe)
3	4mx4m Panelled Conventional beam slab model (Etabs and safe).
4	4mx4m Panelled Concealed beam slab model (Etabs and safe)
5	5mx5m Panelled Conventional beam slab model (Etabs and safe).
6	5mx5m Panelled Concealed beam slab model (Etabs and safe)
7	4mx6m Conventional beam slab model with Concealed beam as secondary beam
8	5mx6m Conventional beam slab model with Concealed beam as secondary beam.
G+7 Storey building	
10	Conventional beam slab with shear walls (Etabs)
11	Concealed beam slab with shear walls (Etabs)

Table 1 : Panels detail

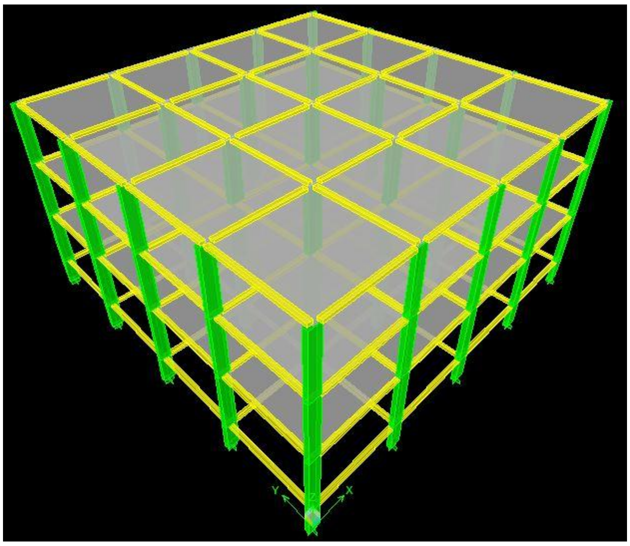


Fig.1 3D model of 5m x 5m Grid Panel

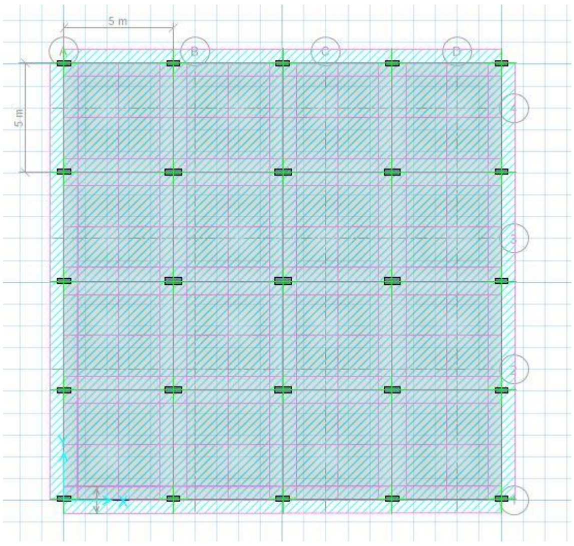


Fig.2 Plan of 5m x 5m Grid Panel

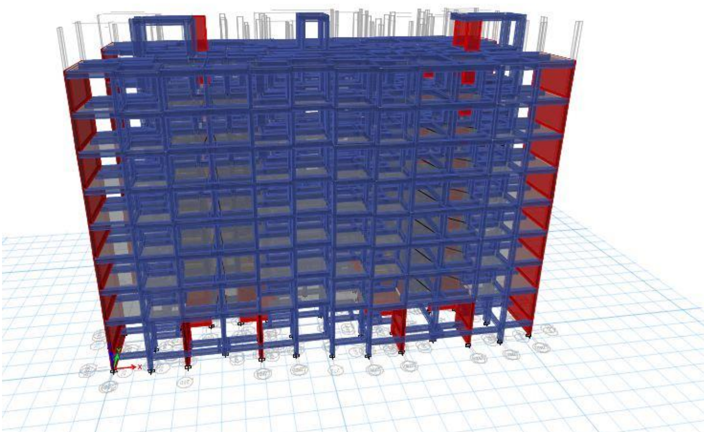


Fig.3 3D model with normal beam and shear wall

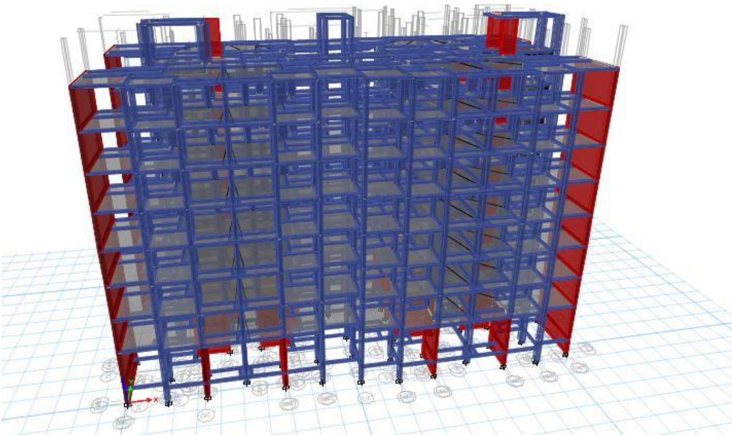


Fig.4 3D model with concealed beam and shear wall

	Gravity loading		Seismic loading	
Type of building	**Conventional beam slab building**	**Concealed beam slab building**	**Conventional beam slab building**	**Concealed beam slab building**
No of stories	2 stories	2 stories	7 stories	7 stories
Storey height	3.35m	3.35m	3.35m	3.35m
Live load +Floor finish	3kN/m2 +1.25kN/m2	3kN/m2+ 1.25kN/m2	3kN/m2 + 1.25kN/m2	3kN/m2+ 1.25kN/m2
Grade of Concrete	M25	M25	M25	M25
Grade of reinforcing Steel	Fe500	Fe500	Fe500	Fe500
Thickness of masonry wall	18kN/m2	18kN/m2	18kN/m2	18kN/m2
Thickness of slab	150mm	150mm	150mm	150mm
Sizes of beams	230 X varies as per span of beam	230X150mm	230 X varies as per span of beam	230X150mm
Zone			III	III
Soil type			II	II
Importance factor			1.2	1.2
Response reduction factor			5	5

Table 2 : loading detail

1. PANELS OF 3X3, 4X4, 5X5, 4X5, 4X6, 5X6, 6X7.(FOR GRAVITY LOADING)
2. LIVE LOAD ON SLAB 3kN/m^2
3. FLOOR FINISH ON SLAB 1.25 kN/m^2.
4. FLOOR HEIGHT 3.35m.
5. CONCEALED BEAM SIZE 230mm X 150mm.
6. NORMAL BEAM DEPTH VARIED AS PER SPAN.
7. A RESIDENTIAL APARTMENT OF G+7 IS USED IN ANALYSIS SITUATED IN ZONE III.

4.1 MODEL 1 & 2

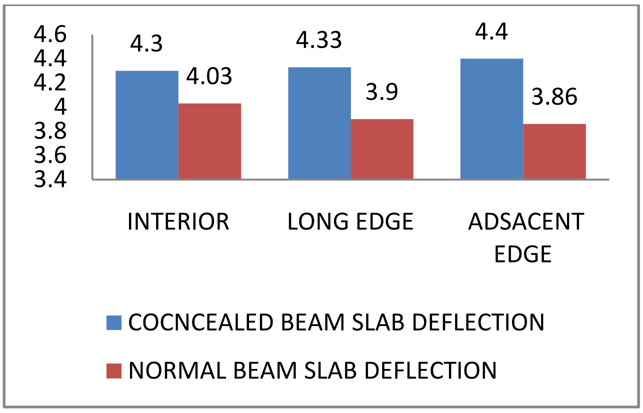
3x3 GRID PANEL

Sl no.	Panel location	Slab deflection (mm) with		Slab bending moments (KN-m)				Area of steel in slab (mm^2)			
				+ve BM		-ve BM		Normal beam slab		Concealed beam slab	
		Concealed beam	Normal beam	Normal beam	Concealed beam	Normal beam	Concealed beam	Mid span bottom reinf.	Support top reinf.	Mid span bottom reinf.	Support top reinf.
1	Interior panel	4.3	4.03	2.7	9	3.6	12.3	180	180	197	185
2	One long edge discontinuous	4.33	3.9	4	10.2	5	14.85	180	180	206	280
3	Two adjacent edge discontinuous	4.4	3.86	4	13.2	6	14.78	180	180	245	280

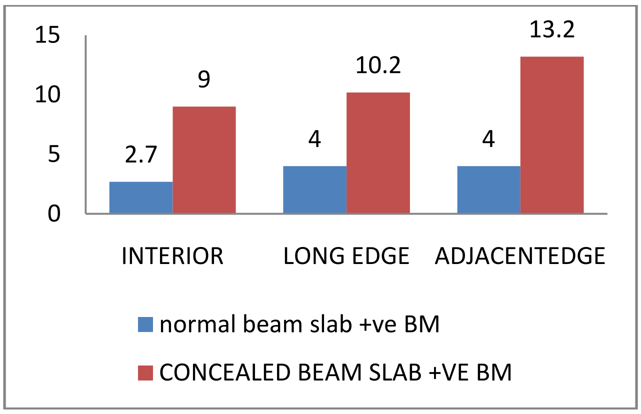
Beam bending moment and max SF

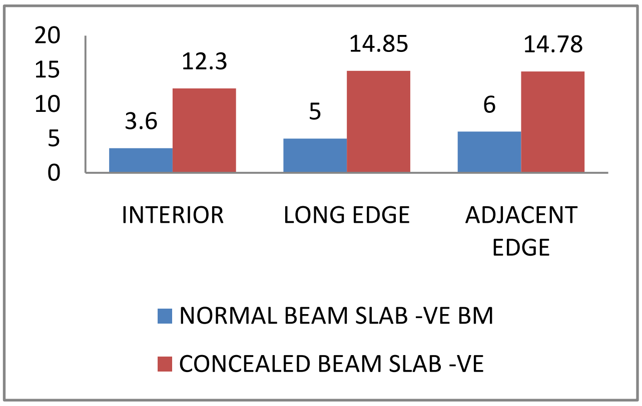
Sl no.	Type	Bm mid span (KN-m)	Bm supports (KN-m)	Max sf (KN)	Max deflection (mm)
1	Normal beam with wall loads	19	35	65	8.66
2	Concealed beam with wall loads	19	35	65	11.33
3	Normal beam without wall loads	12	20	35	8
4	Concealed beam without wall loads	10	18	30	10

Table:3 3m x 3m Grid panel results



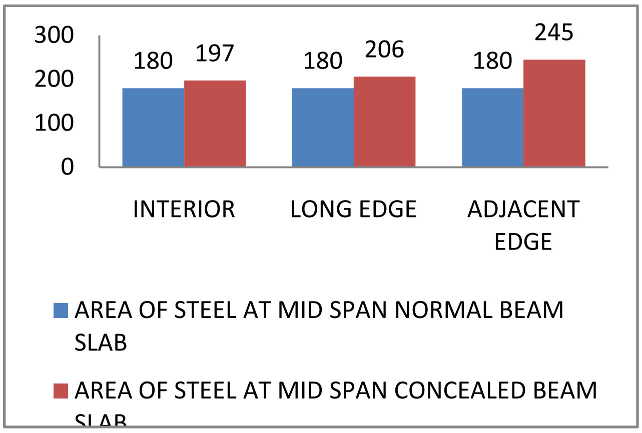
Model 1 & 2 Slab Deflection



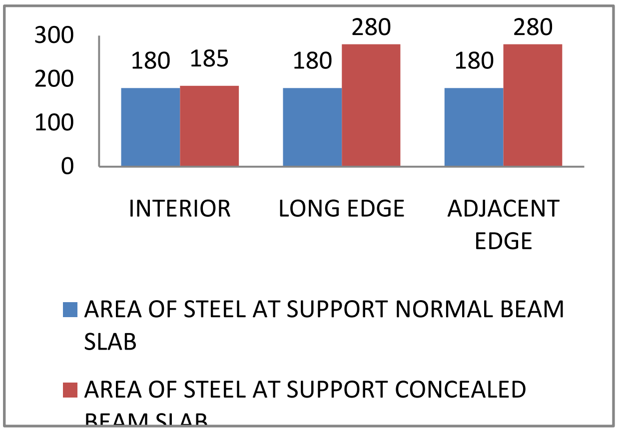


Model 1 &2 +ve Bending Moments of slabs

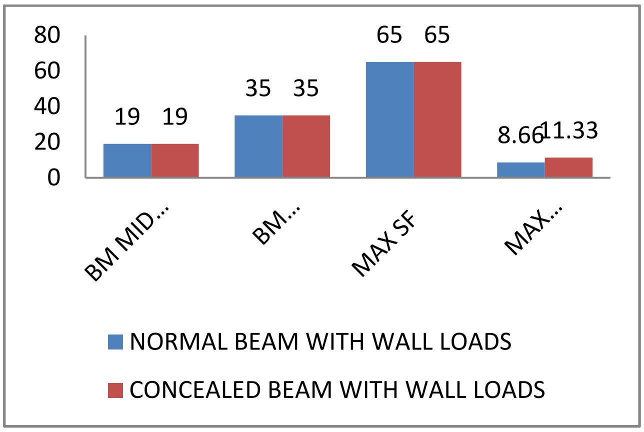
Model 1 & 2 Slab –ve Bending Moment of slabs



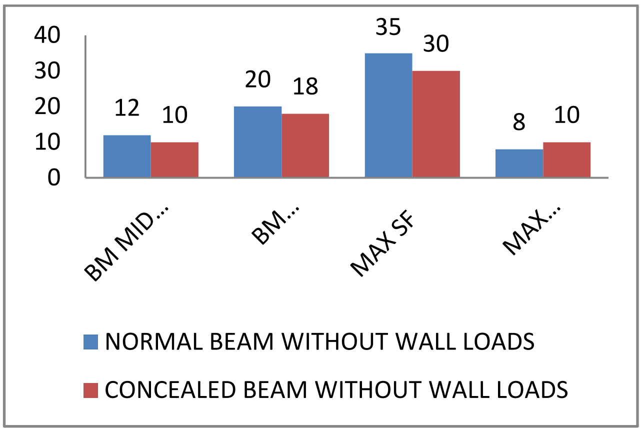
Model 1 & 2 Area of steel at Mid span



Model 1 & 2 Area of steel at Support



Model 1 & 2 Bending Moments, SF and Deflections With Wall Loads



Model 1 & 2 Bending Moments, SF and Deflections Without Wall Loads

Discussions

- A 6.69% of deflection increase is observed in concealed beam slab model at the interior panel when compared with normal beam slab.
- A 11% of deflection increase is observed in concealed beam slab model at the one edge discontinuous edge panel when compared with normal beam slab.
- A 13.98% of deflection increase is observed in concealed beam slab model at the two adjacent edge discontinuous panel when compared with normal beam slab.
- It is observed that there is a increse in bm by 2-3 times in concealed beam slab when compared to normal beam slab
- 36% of steel increse is observed in two adjacent edge discontineous case for concealed beam slab at mid span.
- 55.5% of steel increse is observed in one edge discontineous, two adjacent edge discontineous case for concealed beam slab at supports.
- It is obseved that there in variation in bm and max sf in both type of beams with wall loads.
- 30% increse in deflection when compared to normal beam with wall loads.
- A small amount of bm and sf decrese is found in concealed beam without wall load due to reduction in self wt. Of beam.

4.2 MODEL 3 & 4

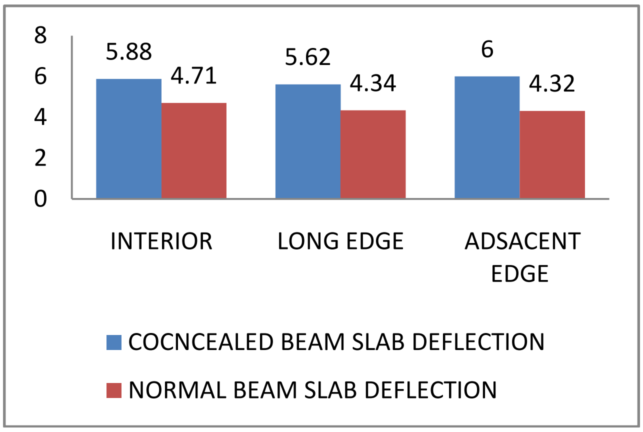
4x4 GRID PANEL

Sl no.	Panel location	Slab deflection (mm) with		Slab bending moments (KN-m)				Area of steel in slab (mm^2)			
		Concealed beam	Normal beam	+ve BM		-ve BM		Normal beam slab		Concealed beam slab	
				Normal beam	Concealed beam	Normal beam	Concealed beam	Mid span bottom reinf.	Support top reinf.	Mid span bottom reinf.	Support top reinf.
1	Interior panel	5.88	4.71	4.75	8.6	6.72	17.67	180	180	260	270
2	One long edge discontinuous	5.62	4.34	5.55	9.42	8	21.22	180	180	275	320
3	Two adjacent edge discontinuous	6	4.32	7	12.86	9.32	23.63	180	230	308	370

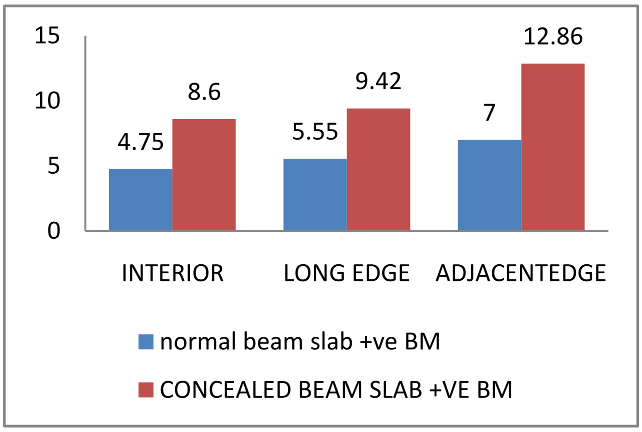
Beam bending moment and max SF

Sl no	Type	Bm mid span (KN-m)	Bm supports (KN-m)	Max sf (KN)	Max deflection (mm)
1	Normal beam with wall loads	40	75	98	10
2	Concealed beam with wall loads	38	72	95	23.33
3	Normal beam without wall loads	26.5	45	56	9.88
4	Concealed beam without wall loads	25	42	52	18

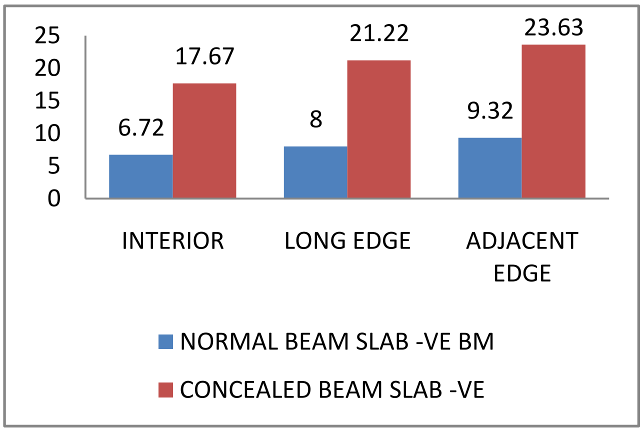
Table:4 4m x 4m Grid panel results



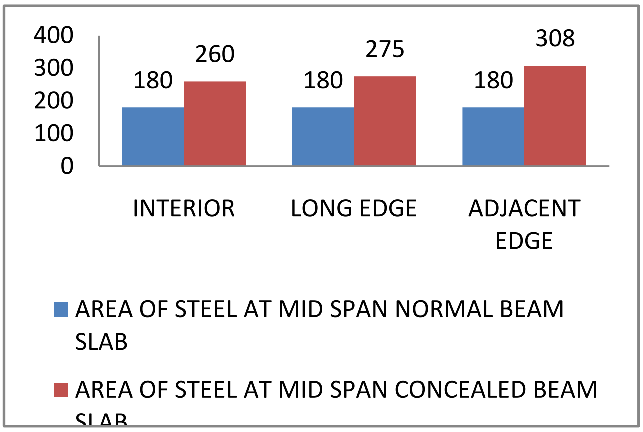
Model 3 & 4 Slab Deflection



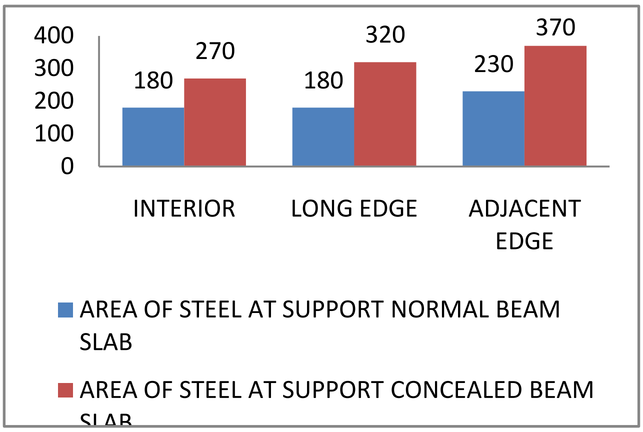
Model 3 & 4 +ve Bending Moments of slabs



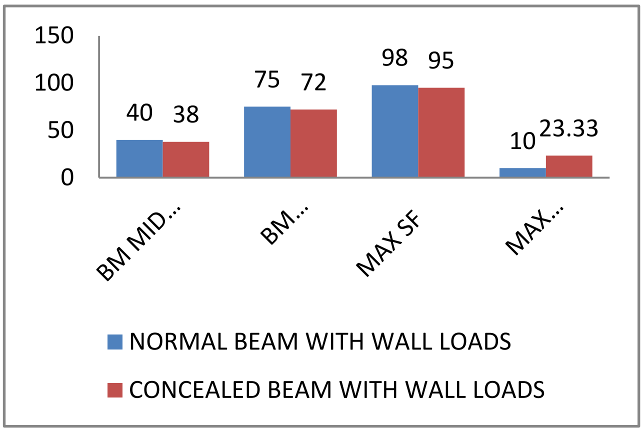
Model 3 & 4 Slab –ve Bending Moment of slabs



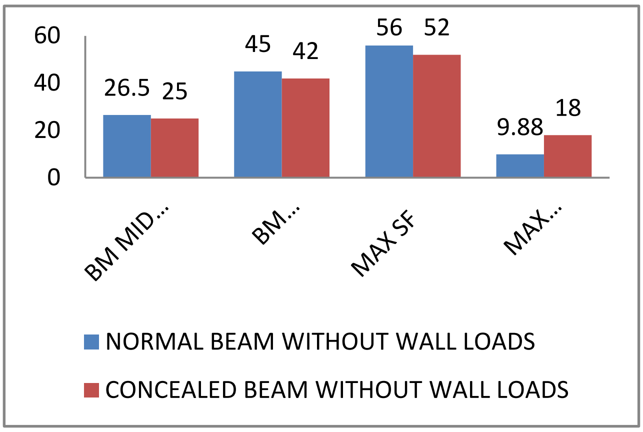
Model 3 & 4 Area of steel at Mid span



Model 3 & 4 Area of steel at Support



Model 3 & 4 Bending Moments, SF and Deflections With Wall Loads



Model 3 & 4 Bending Moments, SF and Deflections Without Wall Loads

- A 24.84% of deflection increas is observed in concealed beam slab model at the interiro panel when compared with normal beam slab.
- A 29.49% of deflection increas is observed in concealed beam slab model at the one edge discontineous edge panel when compared with normal beam slab.
- A 38.88% of deflection increas is observed in concealed beam slab model at the two adjacent edge discontineous panel when compared with normal beam slab.
- It obsereved that there is 1.5-2 times increse in deflection of concealed beam slabs 4x4 panels when compared to 3x3 panels
- It is observed that there is a increse in bm by 2-3 times in concealed beam slab when compared to normal beam slab
- 2.33 times increse in deflection when compared to normal beam with wall loads.
- 1.82 times increse in deflection when compared to normal beam without wall loads

4.3 MODEL 5 & 6

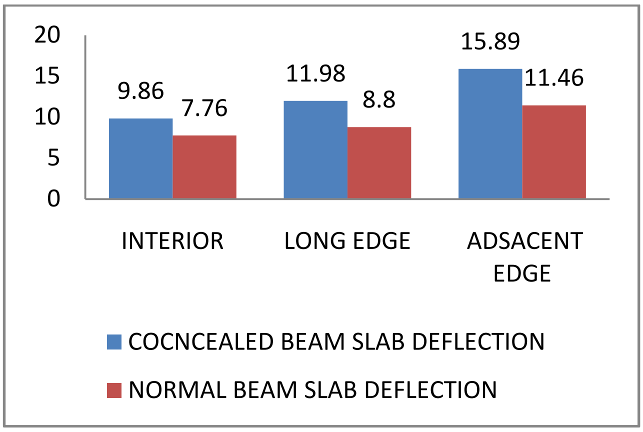
5x5 GRID PANEL

Sl no.	**Panel location**	**Slab deflection (mm) with**		**Slab bending moments (KN-m)**				**Area of steel in slab (mm^2)**			
				+ve BM		**-ve BM**		**Normal beam slab**		**Concealed beam slab**	
		Conc ealed beam	**Norma l beam**	**Norma l beam**	**Conce aled beam**	**Norma l beam**	**Concea led beam**	**Mid span botto m reinf.**	**Suppor t top reinf.**	**Mid span botto m reinf.**	**Supp ort top reinf.**
1	Interior panel	9.86	7.76	9.96	12.15	10.58	20.29	180	240	205.63	420
2	One long edge discontinuous	11.98	8.8	10.89	13.055 1	11.3	20.844	211.25	322	231	435
3	Two adjacent edge discontinuous	15.89	11.46	14.14	17.47	15.27	28.056	220	463	260	480

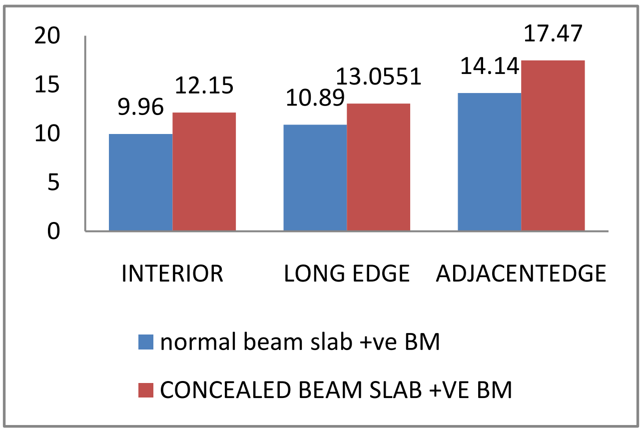
Beam bending moment and max SF

Sl no	**Type**	**Bm mid span (KN-m)**	**Bm supports (KN-m)**	**Max sf (KN)**	**Max deflection (mm)**
1	Normal beam with wall loads	71	130	137	4
2	Concealed beam with wall loads	68.96	126	132	64
3	Normal beam without wall loads	50	88	85.5	3
4	Concealed beam without wall loads	48	83	80	43

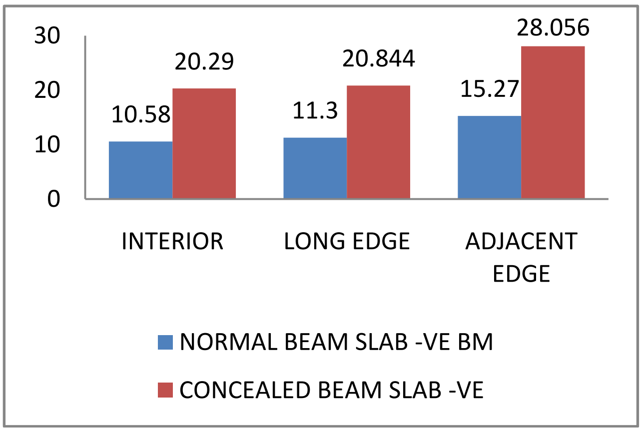
Table:5 5m x 5m Grid panel results



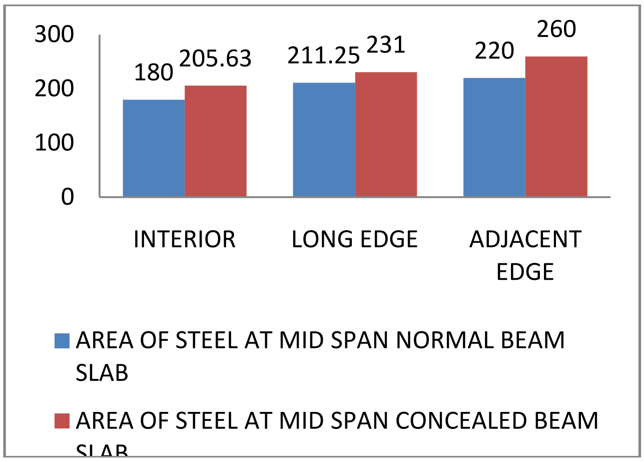
Model 5 & 6 Slab Deflection



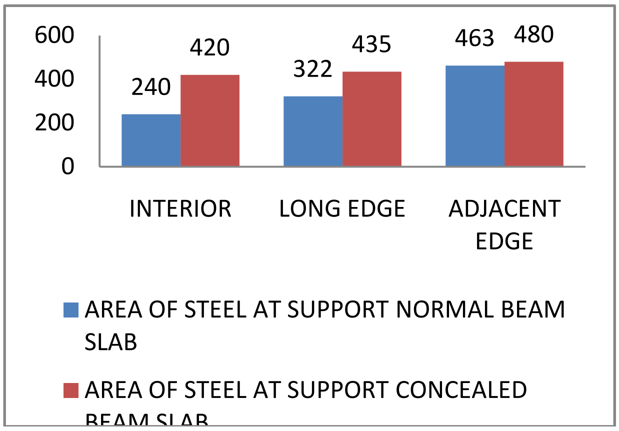
Model 5 & 6 +ve Bending Moments of slabs



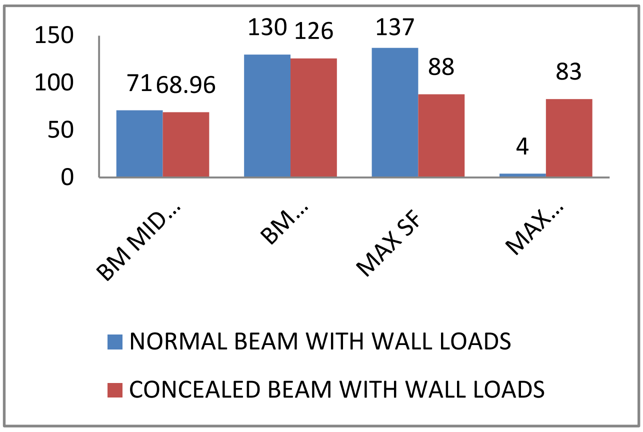
Model 5 & 6 Slab –ve Bending Moment of slabs



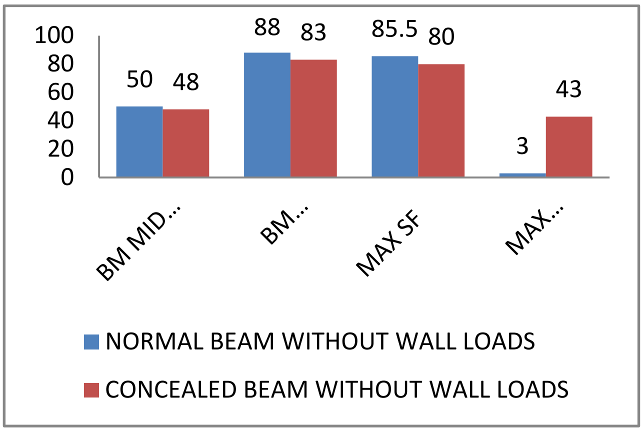
Model 5 & 6 Area of steel at Mid span



Model 5 & 6 Area of steel at Support



Model 5 & 6 Bending Moments, SF and Deflections of beam With Wall Loads



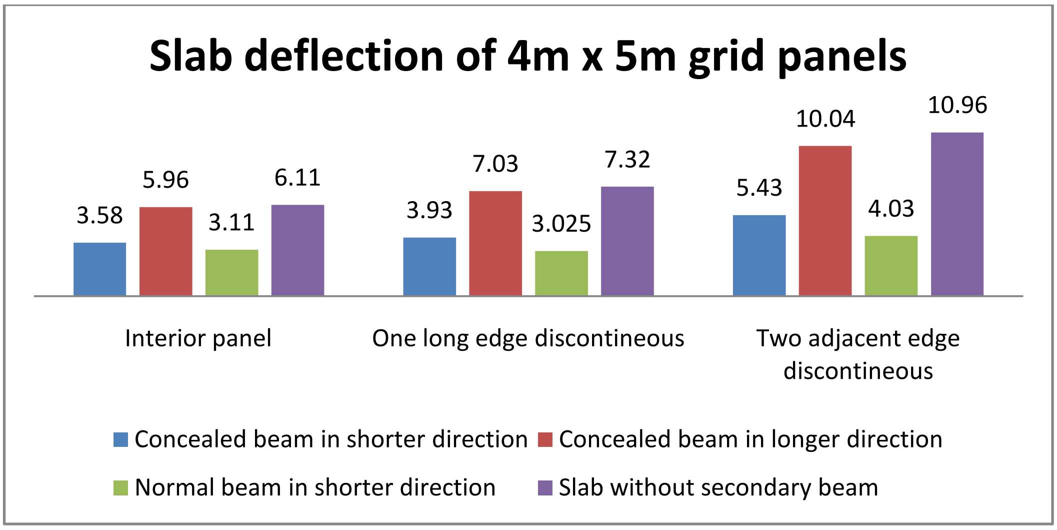
Model 5 & 6 Bending Moments, SF and Deflections of beams Without Wall Loads

- Deflection of concealed beam is greater than 20mm which violates the serviceability criteria of IS 456:2000.
- $k = M_u/(bd^2)$ value exceeds that in SP 16 which indicates beam is designed as over reinforced or can not take upcoming loads.

4.4 MODEL 7

4x5 GRID PANEL					
Sl no.	Panel location	Slab deflection with and without concealed beam (mm)			
		Slab with Secondary beam			Slab without secondary beam
		Concealed beam in Shorter Direction	Concealed beam Longer Direction	Normal beam in shorter direction	
1	Interior panel	3.58	5.96	3.11	6.11
2	One long edge discontineous	3.93	7.03	3.025	7.32
3	Two adjacent edge discontineous	5.43	10.04	4.03	10.96

Table:6 4m x 5m Grid panel results



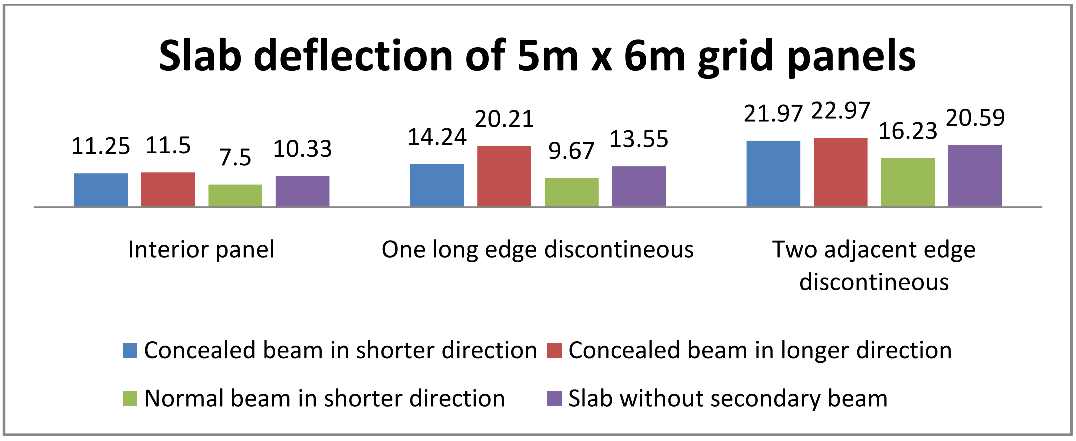
Slab deflections for 4m x 5m grid panel

1. it is observed that 41.41% reduction in deflection of slab when concealed beam is used as secondary beam in shorter span of the slab.
2. A marginal variation of 2.5% reduction in deflection of slab found when concealed beam is given in longer span.

4.5 MODEL 8

5mx6m GRID PANEL						
Sl no.	**Panel location**	**Slab deflection with and without concealed beam (mm)**				
		Slab with Secondary beam			**Slab without secondary beam**	
		Concealed beam in Shorter Direction	**Concealed beam Longer Direction**	**Normal beam in shorter direction**		
1	Interior panel	11.25	11.5	7.5	10.33	
2	One long edge discontineous	14.24	20.21	9.67	13.55	
3	Two adjacent edge discontineous	21.97	22.97	16.23	20.59	

Table:7 5m x 6m Grid panel results



Slab deflections for 4m x 5m grid panel

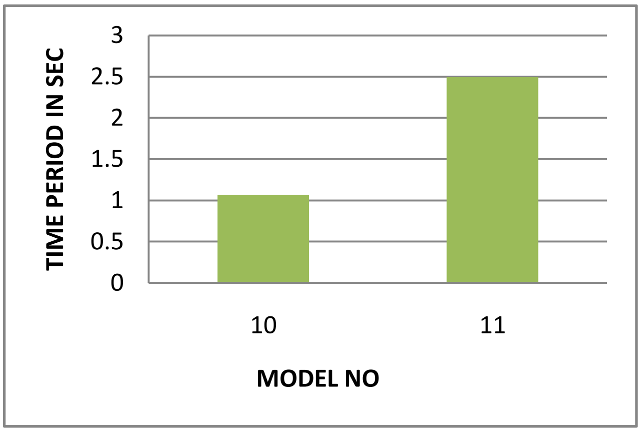
1. It is observed that when the concealed beam is provided in the longer direction deflection of the slab is increasing as the self deflection of concealed beam increases abruptly as seen in model5 and model6 this is the reason for increase in slab deflection.

4.6 MODEL 10 & 11

TIME PERIOD:

COMPARSION OF TIME PERIOD MODEL 10 VS MODEL 11

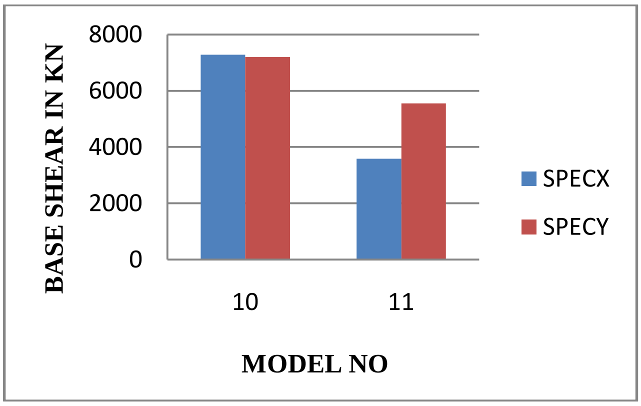
MODEL NO	TIME PERIOD IN SEC
10	1.064
11	2.493



From the chart it is seen that, the Fundamental Time Period is highest for the model 11 and less for the model 10. The percentage increase in Time period for model 11 is 57.32% when compared to model 10. Hence building is more susceptible to lateral loads.

COMPARSION OF BASE SHEAR BETWEEN MODEL 10 & MODEL 11

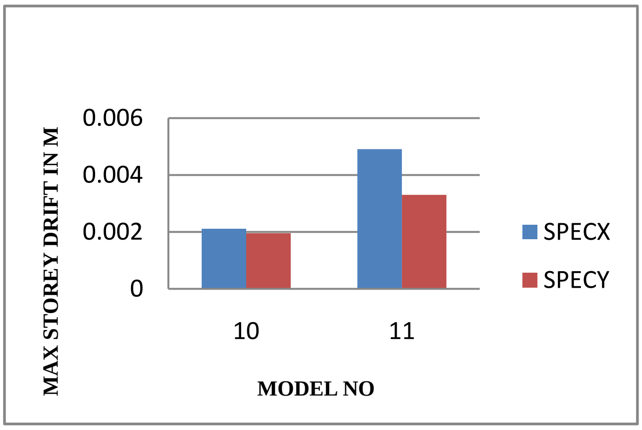
MODEL NO	BASE SHEAR IN KN	
	SPECX	SPECY
10	7278.0516	7204.7182
11	3590.232	5554.0942



From the chart it is seen that, the base shear value is minimum for model 11 and maximum for model 10 for spec-x and spec-y directions respectively. The percentage decrease in Base shear for model 11 in Spec-X Spec- y direction is 50.67% and 22.91% respectively for RSA when compared to model 10. This reduction in base shear is due to reduction of self weight of building due to use of concealed beam.

COMPARSION OF STOREY DRIFT BETWEEN MODEL 10 & MODEL 11 FOR RESPONSE SPECTRUM ANALYSIS (RSA) ALONG LONGITUDINAL AND TRANSVERSE DIRECTION (SPEC-X AND SPEC-Y)

	MAX STORY DRIFT IN M	
MODEL NO	SPECX	SPECY
3	0.002114	0.001957
4	0.004908	0.003303

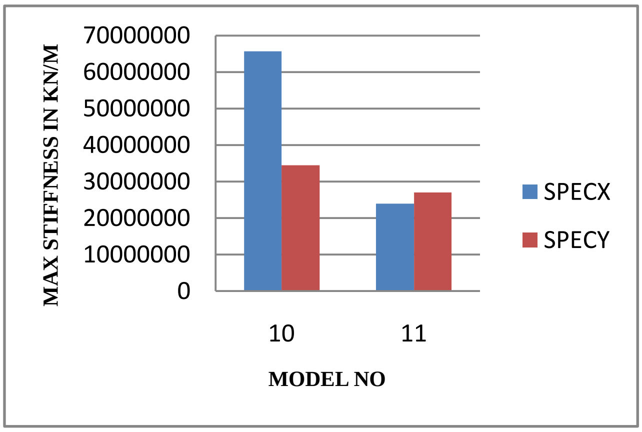


From the charts it is seen that ,the storey drift is maximum for model 11 and minimum for model 10. All the story drift values are within the permissible limits i.e., 0.004times the height of each story 0.004x3.35=0.0134m=13.4mm.

The percentage increase in storey drift for model 11 is 56.92% and 40.75% For RSA in X and Y directions respectively when compared to model 10.

COMPARSION OF MAX STOREY STIFFNESS BETWEEN MODEL 10 & MODEL 11

MODEL NO	MAX STORY STIFFNESS IN KN/M	
	SPECX	SPECY
10	65684277	34496002
11	23921013	27036381



From the charts it is seen that, the story stiffness is maximum for model 10 and minimum for model 11.

The percentage decrease in storey stiffness value for model 11 is 63.58% and 21.62% For RSA in X and Y directions respectively when compared to model 10. As the beam depth reduces results in the increase of effective length of column which inturn reduces the stiffness.

IV. CONCLUSIONS

1. Deflection of slab increases if the concealed beams are used as main beams instead of conventional beams.
2. For an aspect ratio 1 and slab thickness 150mm concealed beam is more effective upto a clear span of 4m as a main beam beyond which deflection of beam increases abruptly as seen in model5 and model6.
3. High reinforcement ratio diminishes the ductility of slab.
4. Concealed beam as secondary beam is more effective when provided in shorter direction as in model7.
5. Concealed beam as secondary beam is less effective in case of slabs spanning over 5 in any both direction as the deflection of concealed beam itself more when compared to slab as in model8 in such cases it is advisable to use conventional beams as secondary beams.
6. As the storey stiffness is decreased, time period is increased storey drift is increased in case of concealed beam slab building under gravity and lateral loads it is justifiable conclude that the overall seismic strength and the stiffness of the building are compromised thus lowering the fundamental frequencies and thus rendering the structure deficient under the action of any strong motion ground excitation.

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