A Comparative Study of RCC Pre-Cast and Composite Structure Using Delta Beams

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ABSTRACT

Composite structures are gaining greater recognition these days in production regions. Composite beams like concrete filled metal tube are components with precise performance because of the confinement impact of metal with concrete and layout versatility. The composite shape has extra advantage over RCC body structure. The study about the behaviour and the characteristics of a composite over RCC is the high need. In India, concrete is a very famous material of production, particularly in the case of high-raised building, medium-raised and low-raised buildings. where in structural steel is typically used, the composite production isn't that popular, but it's miles possible that composite creation can be extra useful in the case of medium and high-raised buildings. steel concrete composite creation may be constructed in region of RCC systems to get maximum benefit of steel and concrete, to produce green and low-budget systems. it's miles the selection of the contractor or owner which kind of properties they require within the area and in line with those properties, the sort of material can be selected. This paper is in particular based totally at the assessment of the RCC frame structure with the Composite beam structure by using the delta beam. It is largely focused on the structural behaviour and results are tabulated within the form of comparison.

Keywords: Composite structure, RCC, Steel structure, Story Drift, Base Shear.

CHAPTER 1

Introduction

Structural factors that are made from 2-different kind of materials, bonded together with steel and concrete and are used as beams and columns in a structure are referred to as composite systems. Delta beam is a superior composite beam permitting slim floors for multi-storied buildings of any type of low raised building or high raised building. Its composite action between steel and concrete allows for innovative systems with massive open spaces. Delta beams have grate fire resistance with non-additional fire protection. Its shallow layout decreases the constructing's floor to floor height. This paper mainly based on evaluating the RCC frame structure with composite beam structure by using the delta beam of a (G+7) storey building.

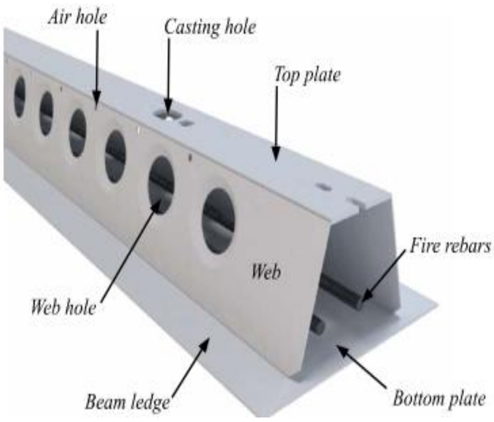


Figure 1: Delta Beam Parts

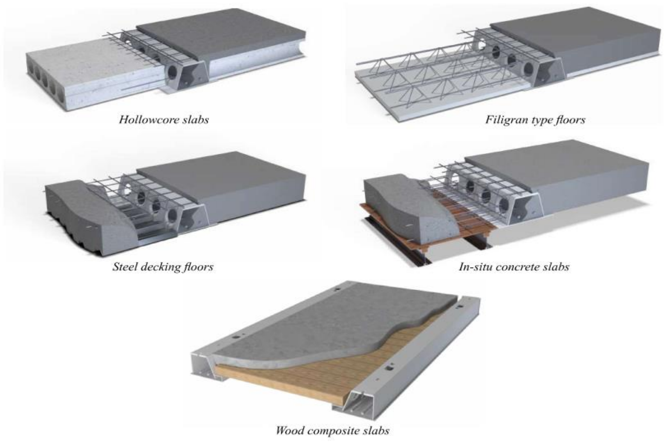
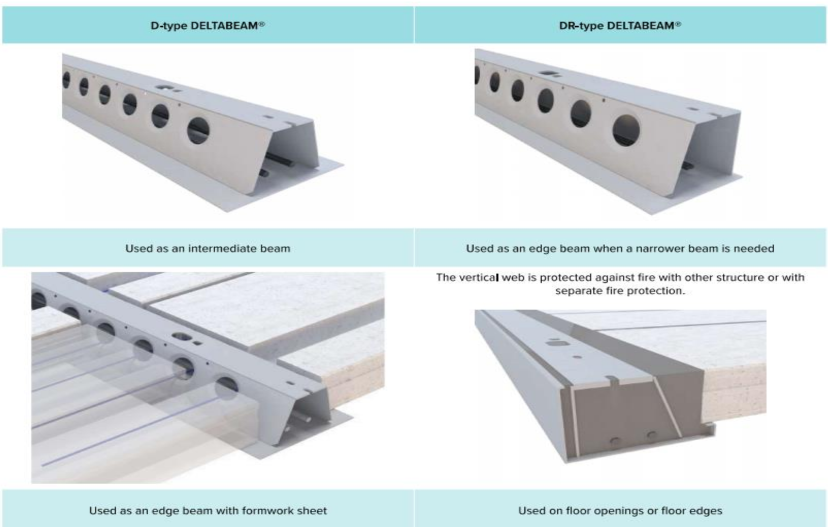


Figure 2: Ideal Floor types with Delta Beam

There are two forms of Delta beam. The D-kind Delta beam has ledges on each side of the beam. This beam type can bring floor on both sides of the beam. The DR-kind Delta beam has one vertical web and a ledge on only one side. each forms of Delta beam may be used as edge beams to carry floor load to only one side of the beam. Curved floor edges can be made by using combining D-type beams with curved formwork.



1.1 Types of Delta Beam

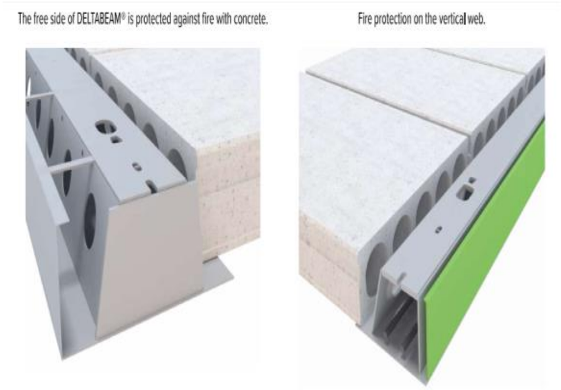


Figure 3: Delta Beam Types

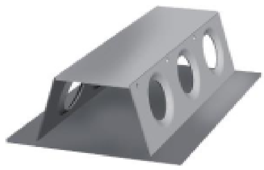
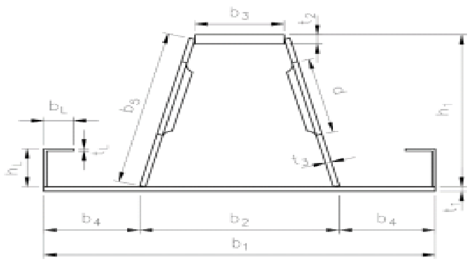


Figure No.4:D-Types of Delta Beam

Figure No.5: DR-Types of Delta Beam

D-Types of Delta Beam:



Section Diagram-1 with web holes and with downstands

1.2 Objective of the study

Slim floor steel beam has been introduced as a new structural beam system in the last 5 years. This project considers delta beams plus precast HCS as floor units with precast RCC columns for the structure.

1. To find the section properties of the delta beam, i.e., moment of inertia, percentage of steel, section modulus, radius of gyration, torsional constant.
2. To know the performance of the G+7 building models in seismic Zone-II of India under the same soil conditions.
3. To know the behaviour of a structure subjected to lateral loads, i.e. Wind loads and earthquake loads to compare the results of storey stiffness, storey drifts, base shear and storey displacements..

4. To compare the bending moment, shear force and deflection of the RCC beam with the Delta beam.

1.3 Problem Statement:

A G+7 storey office building having a planned area of 50mx50m, selected for comparison of slim floor beams using a precast system using suitable IS codes. This study investigates the compatibility of slim floor beams with RCC columns and precast slab, also comparing the analysis results in terms of lateral displacement, storey drift, storey displacement and base shear. Tabulate the difference between bending moment, shear force and deflection.

CHAPTER 2
METHODOLOGY

2.1 General

This study mainly focuses on the behaviour of G+7 buildings using slim-floor beams by utilizing ETABS software, it creates an 8-storey model for RCC precast structure and Composite beam (Delta beam) structure. Loads on a structure are considered as per IS 875:1987 part-1, IS 875:1987 part-2. analyse the structure subjected to gravity and lateral loads with the help of IS 875:2015 part 3, IS 456:2000, IS1893:2016 and IS13920:2016. The observations from the analysis comparing the two types of structures will be tabulated and conclusions will be reported.

2.2 Methods of Analysis of Structure

There are two types of analysis of structure

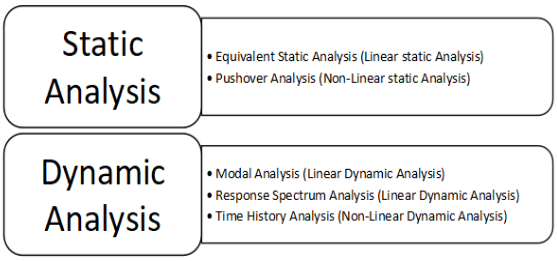


Figure 6: Methods of Analysis

As per IS 1893 (part 1):2016 Cl 7.7.3

Here, dynamic analysis is to be performed by using Response spectrum analysis. The main reason is fundamental time period is less than 0.4 sec and total height of building is more than 15m.

Where, as per IS 1893 (part 1): 2016 Cl 7.6.2

$$T_a = \frac{0.09h}{\sqrt{d}}$$

Ta= Fundamental Time Period

h= Total height of building

d= width of building

CHAPTER 3

Structural Behavior of Delta Beam

3.1 Load Transfer Mechanism

The behavior of Delta beam depends on the building conditions that is described below:

1. Temporary Condition: Delta beam acts like a steel beam before the infill concrete has hardened.
2. Final Condition: Delta beam acts like a composite structure.
3. Fire Condition:

For this research a Delta beam After load applying on members is to be considered and section properties calculated as a composite beam structure.

3.1.1 Temporary Condition:

DELTABEAM acts as a steel beam before the infill concrete has reached the required strength. During the erection stage. all loads are transferred to DELTABEAM" through the beam ledges (see Figure 7). It is important to position the Hollow-core slab end correctly onto the beam ledge because this affects the DELTABEAM's design. The erection stage design is carried out in accordance with elastic design principles, with the loads acting in the erection stage. The precamber of DELTABEAM compensates for the deflection in the erection stage.

The amount of precamber depends on the length of the DELTABEAM, on the loads in the end on the selected static system of delta beams and RCC columns.

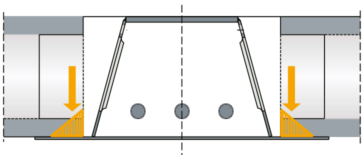


Figure No.7: Load Transfer in the Temporary Condition

3.1.2 Final Condition

The infill concrete and DELTABEAM form a composite structure after the concrete has reached the required strength. In the final condition, the loads are transferred to DELTABEAM through a compression arc against an inclined web (see Figure:8). The load transfer is proven by lad tests, where DELTABEAM was tested without the beam ledges. Transverse reinforcement, which is assembled through the DELTABEAM Composite Beam's web holes. secures load transfer.

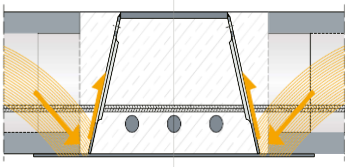


Figure No.8: Load Transfer in the Final Condition

The shear connection between the infill concrete and DELTABEAM is formed by the dowel action of the web holes. Static loading tests have proven that the composite interaction is full.

3.1.3 Fire Situation:

The evaluation of the fire resistance of DELTABEAM is based on standard fire tests and design guidelines obtained from tests. DELTABEAM can have a fire rating as high as R180 depending on local approvals. DELTABEAM is dimensioned in compliance with the fire rating requirements of the project.

when needed, the designed number of fires rebars is Installed inside DELTABEAM at the factory (see Figure). High fire resistance is achieved by fire rebars and infill concrete. The DELTABEAM Composite Beam's fire rebars and the webs act as tensile reinforcement in the event of a fire. The rebars compensate for the strength that the bottom plate loses, meaning that additional fire protection is not normally needed.

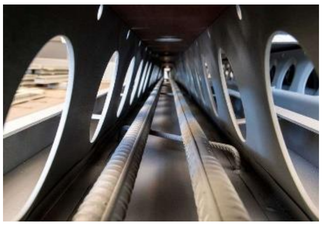


Figure 9: Fire Rebars Inside Deltabeam

The vertical web of the DR-type of DELTABEAM must be protected against fire by other structures or by protective materials/finishes. Separate fire protection is needed when there is no other structure protecting the vertical web. The material and thickness of the separate fire protection are determined on a case-by-case basis by the responsible structural engineer of the project.

The load transfer in the fire situation behaves similarly as in ambient conditions, see Figure. due to the heated bottom plate (reduced stiffness) the resultant is shifted towards the web, however the remaining stiff corner can carry the full reaction. To secure the load transfer transverse horizontal reinforcement is needed to tie the floor slab and the DELTABEAM together. Also, a special design procedure for the hollow core unit is required.

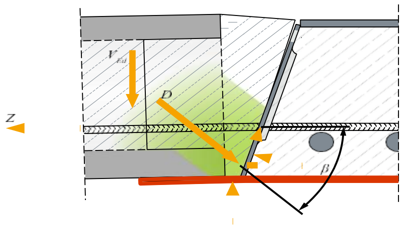
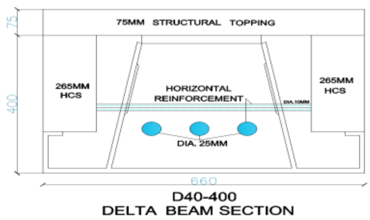


Figure 10: Load Transfer in fire situation

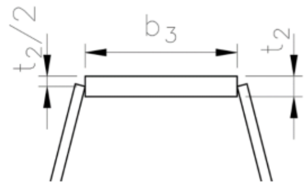
3.1.4 In Accidental Situation:

Buildings should be designed to carry the extent of localized failure from an unspecified cause without a disproportionate collapse. The transverse and parallel reinforcement should be therefore designed for a design tensile load defined according to EN 1991-1-7 and its National Annex in the accidental situation.

CHAPTER 4
Calculation Of Delta Beam



Section Diagram-2 Delta Beam Section with HCS and 75mm Structural Topping



Section Diagram -3 Fastening of webs to top plate

4.1 Calculation of section properties of D40-400 type of delta beam:

4.1.1 Assumptions for calculations are listed below:

1. Fastening of web is carried out at the middle of top plate
2. Projection of web thickness t'_3 is equivalent to web thickness t_3.
3. Distance between the center of inclined web and the center of cross section, is equal to distance between the center of vertical web and the center of cross-section $Z_{V.}$
4. Webs without holes are not significantly affecting the distance between the geometry center of cross section and the mass center.

Given Data

t2=Thickness of top plate=30mm.

b3=Width of top plate=245mm.

Bottom Plate:

t1=Thickness of Bottom Plate=15mm.

b1=Total Width of Delta Beam Section=660mm.

b2=Distance Between Two Inclined Web Plates=400mm.

b4= Distance between Downstands and Inclined Web Plate=130mm

Web Plate:

t3= Thickness of Inclined Web Plates=10mm.

d= Diameter of Web Holes=150mm.

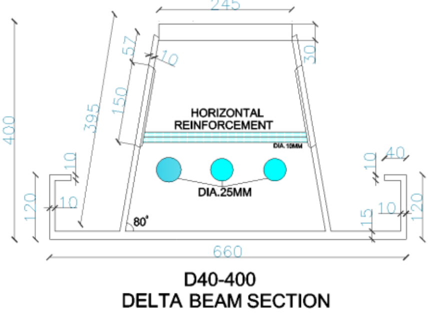
h1= Total Height of Delta Beam =400mm.

Downstands:

h_L= Height of Downstands=135mm.

b_L=Width of Downstands=40mm.

t_L =Thickness of Downstands=10mm.

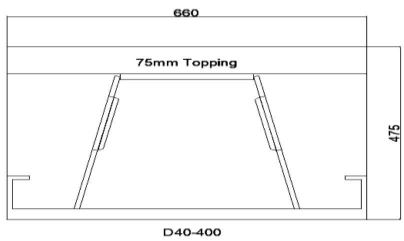


Section Diagram -4 Delta Beam Section Used in Etabs Model

4.1.2 Calculation of Moment of Inertia of Composite Delta Beam Steel Section With downstands and web holes:

$$I_{yComposite\ beam} = \frac{b_1(h_1+75)^3}{12} - 2 \times \frac{110 \times (h_1+75-135)^3}{12}$$
$$= 5173879791.67\ mm^4$$

$$I_{zComposite\ beam} = \frac{(h_1+75)(b_1)^3}{12} - 2 \times \frac{(h_1+75-135) \times 110^3}{12}$$
$$= 11304626666.65\ mm^4$$



Section Diagram -5 Geometric layout of cross section of composite beam

4.1.3 Calculation of Section Modulus (Z) of Composite Delta Beam With downstands and web holes:

Section Modulus of Composite Delta Beam about Y-axis:

$$y_{max} = z_{bpl} + \frac{t_1}{2} = 200mm$$

$$z_y = \frac{I_{yComposite\ beam}}{y_{ymax}} = \frac{5173879791.67}{200} = 25869398.95mm^4$$

Section Modulus of Composite Delta Beam about Z-axis:

$$y_{max} = y_{L1} + \frac{t_L}{2} = 400mm$$

$$z_z = \frac{I_{ZComposite\ beam}}{y_{Zmax}} = \frac{11304626666.67}{400} = 28261566.67mm^4$$

4.1.4 Calculation of Area of Composite Delta Beam With downstands and web holes:

Calculation of Gross Area of Composite Delta Beam

$A_G = 2A_{Downstands} + ((b_1 - 220) \times ((h_1 + 75) - h_L)$

Here, 75mm Topping is considered.

$A_G = 2(120 \times 110) + ((660 - 220) \times (475 - 120))$

$A_G = 182600mm^2$

Calculation of Area of Steel in Delta Beam:

$A_{top\ plate} = b_3 \times t_2 = 245 \times 15 = 3675\ mm^2$

$A_{bottom\ plate} = b_1 \times t_1 = 660 \times 30 = 19800\ mm^2$

$A_{web\ plates} = b_5 \times t_3 = 389.27 \times 10 = 3892.7\ mm^2$

$A_{downstands\ plates} = A_{D1} + A_{D2}$

$A_{D1} = h_L t_L = (120 \times 10) = 1200\ mm^2$

$A_{D2} = (b_L - t_L) \times t_L = (40 - 10) \times 10 = 300\ mm^2$

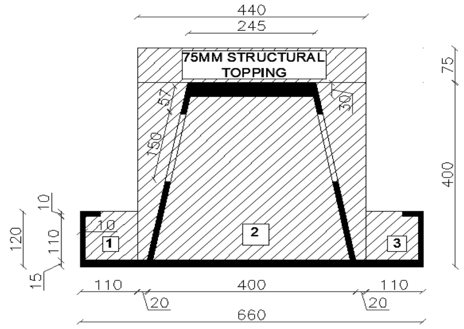
$A_{downstands\ plates} = 1200 + 300 = 1500mm^2$

$A_{steel} = A_{top\ plate} + 2 \times A_{bottom\ plate} + 2 \times A_{downstands\ plates}$

$A_{steel} = 3675 + 19800 + (2 \times 23892.7) + (2 \times 1500) = 34260.58\ mm^2$

$A_{concrete} = A_{Gross} - A_{steel}$

$A_{concrete} = 182600 - 34260.58 = 148339.42\ mm^2$



Section Diagram -6 Geometric layout for calculation of area of composite beam for with web holes and with downstands

4.2 Calculation of Radius of gyration of Composite Delta Beam With downstands and web holes:

Calculation of Radius of gyration of Composite Delta Beam along Y-axis:

$$R_y = \sqrt{\frac{I_y}{A_g}} = \sqrt{\frac{5173879791.67}{182600}} = 168.32MM$$

Calculation of Radius of gyration of Composite Delta Beam along Z-axis:

$$R_Z = \sqrt{\frac{I_Z}{A_g}} = \sqrt{\frac{11304626666.67}{182600}} = 248.82\text{mm}$$

4.3 Calculation of Shear Area of Composite Delta Beam With downstands and web holes:

Shear Area of composite Beam = $A_{concrete} + m \times A_{steel}$

Here, m=83.3 %

Shear Area of composite Beam $= 148339.42 + 0.833 \times 34260.58$

$$\text{Shear Area of composite Beam} = 176878.48mm^2$$

4.4 Calculation of Plastic Modulus of Composite Delta Beam With downstands and web holes:

Area of Tension Zone = Area of Compression Zone

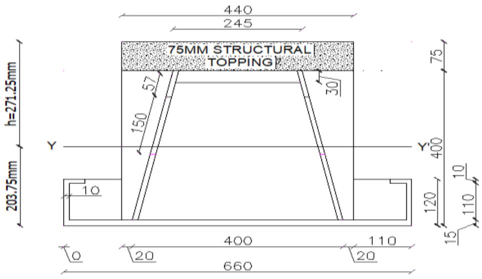
A_t=A_c

Plastic modulus of Y-Direction

(b_1-h) =(2×110×(t_1+120)) + (b_2+40) ×(h_1+75-h)

h=271.25

Z_{py} =A_{top}+ A_{bottom} = (b2+400) × h×0.5h=29366562.5mm^3



Section Diagram -7 Plastic modulus of Y-Direction

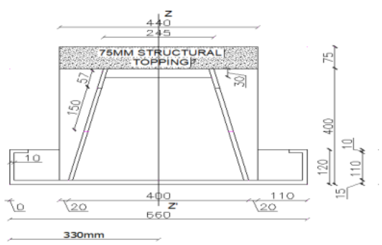
Plastic modulus of Z-Direction

$$h = \frac{b_1}{2} = \frac{660}{2} = 330mm$$

Zpz=2×Aleft section

$$Zpz = 2(((hL + 15) \times 110) \times \left(\frac{b1}{2} - \frac{110}{2}\right)) + (\frac{(b2 + 40) \times (h1 + 75)}{2} \times \frac{(b2 + 40)}{2}))$$

$$P_{zy} = 15578750mm^3$$



Section Diagram -8 Plastic modulus of Z-Direction

4.5 Calculation of Torsional Constant (J_T) of Composite Delta Beam With downstands and web holes:

$$J = \frac{b1 \times (h1 + 75)}{12}[b1^2 + (h1 + 75)^2] - 2 \times (\frac{110 \times (h1 + 75 - 135)}{12}[110^2 + (h1 + 75 - 135)^2])$$

$$J(Composite\ Delta\ Beam) = 17312030313mm^4$$

Table No.1: Section Properties of Delta Beam

CHAPTER 5
Hollow Core Slab

A HCS (hollow core slab) is a precast, or a prestressed concrete component having holes that spread along the span of the slab, in conditions that decrease weight management, thus cost and such a lateral of advantage, can work in electrical or mechanical management. Mainly operated as surface or else roof deck systems, HCS also has usage as members, partition sections, and bridge deck elements. The span of the HCS reaches equal (18m) without support. Elements pre-stressed HCS purpose designed for various applications needing floor or roof systems. This method can be preferably used in residential, commercial or car garage projects. Precast and prestressed HCS offer major structural member success through the operation of HSC, but all together demand little material consumption.

Gross Area of Composite beam	**182600 mm^2**
Shear Area of composite Beam X-axis	**176878.48 mm^2**
Shear Area of composite Beam Y-axis	**176878.48 mm^2**
Moment of inertia about X-axis	**5173879791.67 mm^4**
Moment of inertia about Y-axis	**11304626666.65 mm^4**
Section Modulus about X-axis	**25869398.95 mm^4**
Section Modulus about Y-axis	**28261566.67 mm^4**
Radius of gyration about X-axis	**168.32 mm**
Radius of gyration about Y-axis	**248.82 mm**
Plastic Modulus about X-axis	**29366562.5 mm^3**
Plastic Modulus about Y-axis	**15578750 mm^3**
Torsional Constant (J_T)	**17312030313 mm^4**

5.1 Advantages of hollow core slabs:

- The main advantages of the slab system with hollow cores can be summarized as follows:
- It reduces the total dead load of the building.
- It reduces construction cost and time.
- Immediate un-propped working platform.
- Extra-long spans.
- The factory is produced to rigorous quality standards.

Figure No.: 11 Hollow Core Slab Unit

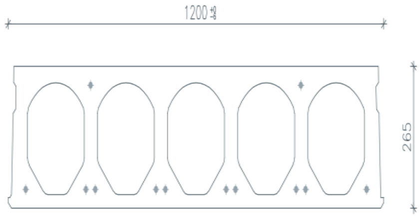


Figure 12: Section of Hollow Core Slab.

CHAPTER 6
Analysis and Modeling and Structural Configuration of Structure

6.1 General

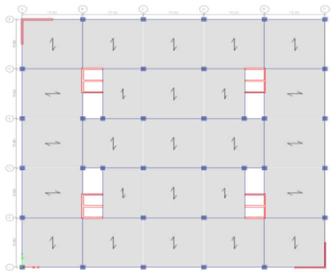


Figure 13: Plane View

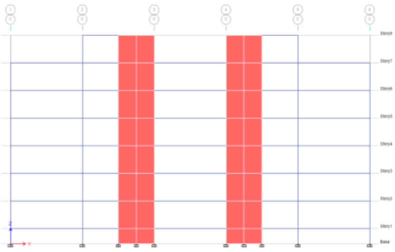


Figure 14: Elevation View

Seismic Data (As per IS 1893:2016 (part 1))	
Location	HYDERABAD
Zone	II
Zone factor	0.1
Response reduction factor	3
Rock and soil site factor	2.5
Importance factor	1.2
Damping ratio	0.05 (For Concrete)

Rock / soil type	Medium
General	
Number of stories	G+7 (8 Stories)
Plan size	50 × 50 m
Typical storey height	3.6 m
Bottom storey height	2 m
Total height	27.2 m
Material Property	
Grade of concrete	M45
Grade of Steel	
For Longitudinal Bars	HYSD500
For Confinement Bars	HYSD415
Structural steel	S345

Table No. 2: Structural Configuration

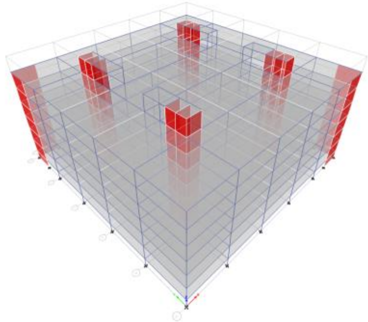


Figure 15: 3D View

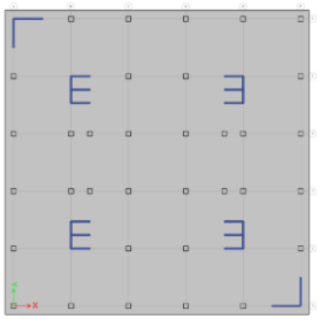


Figure 16: Plan view of Mat Footing

Structural Element	Modifiers (As per IS 1893 part-1 Cl 6.4.3.1)
Column	0.7 × Ig (Gross area)
RCC Beam	0.35 × Ig
Delta Beam	Ig
Slab	0.25 × Ig
Shear Wall	0.7 × Ig

Table No. 3: Stiffness Modifiers

CHAPTER 7
Design of Mat Footing

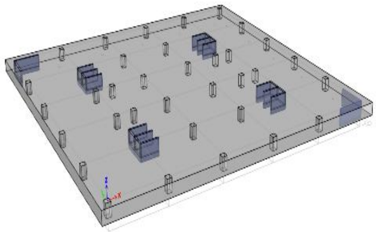


Figure 17:3-D View of Mat Footing

Mat Footing Data

Mat Footing Data	
Grade of Concrete	M45
Grade of Steel	Fe500
Soil Subgrade Property	250kN/M^2
Suitable Depth of Footing for RCC Frame Structure	1.5 M
Suitable Depth of Footing for Delta beam Structure	1.1 M
Design Code	IS456-2000
Young's Modulus for Concrete	33541.02 N/M^2
Young's Modulus for Steel	210000 N/M^2

Table No. 4: Mat Footing Data

CHAPTER 8
RESULTS AND DISCUSSIONS

A 10m span internal beam in RCC structure and Delta structure are to be selected for comparison of Bending moment, Shear force and Deflection results.

8.1 Bending Moment Difference in Delta Beam Structure and RCC Beam Structure in one internal continuous span of 10m.

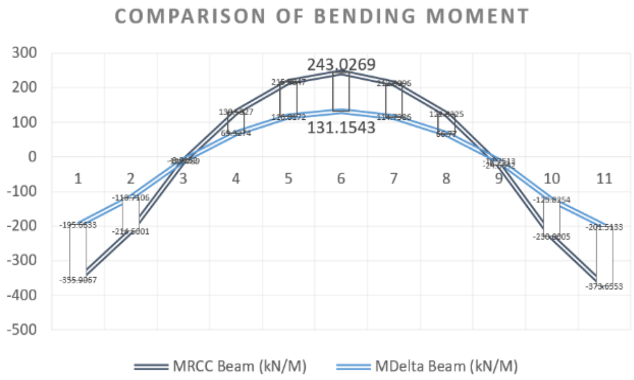


Figure No. 18: Bending Moment Diagram

Bending Moment		
Length(M)	**$M_{RCC\ Beam}$ (kN/M)**	**$M_{Delta\ Beam}$ (kN/M)**
0	-355.9067	-195.6633
1	-214.5001	-118.7106
2	-12.8789	-8.9152
3	130.5827	69.3274
4	215.8847	116.0172
5	243.0269	131.1543
6	212.0096	114.7386
7	122.8325	66.77
8	-24.5042	-12.7513
9	-230.0005	-123.8254
10	-373.6553	-201.5133

Table No. 5: Bending Moment Values

Observations:

In the above figure No.18, the black colour curve indicates the bending moment obtained from the RCC beam and blue colour indicates the bending moment obtained from the Delta beam. The maximum bending moment occurred at mid span of the beam. In RCC beam, we got the bending moment at mid span is 243.0269kN/M where, in Delta beam, we got 131.1543 kN/m.i.e. The RCC beam shows 111.9147kN/M times more bending moment than that of the Delta beam. In RCC beam the self-weight is more compared to the delta beam. Therefore, it shows more bending moments at midspan.

8.2 Shear Force Diagram Difference in Delta Beam Structure and RCC Beam Structure in one internal continuous span of 10m.

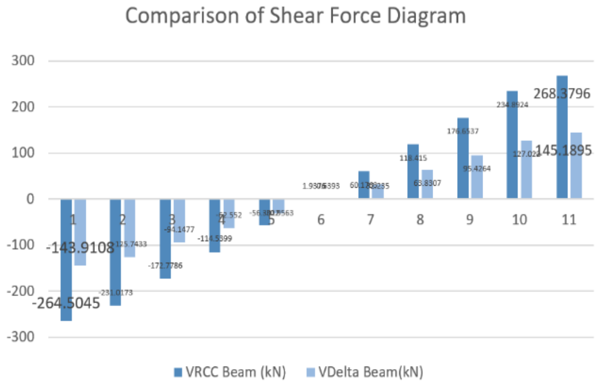


Figure No.19: Shear Force Diagram

Shear Force		
Length(M)	**$V_{RCC\ Beam}$ (kN)**	**$V_{Delta\ Beam}$(kN)**
0	-264.5045	-143.9108
1	-231.0173	-125.7433
2	-172.7786	-94.1477
3	-114.5399	-62.552
4	-56.3012	-30.9563
5	1.9376	0.6393
6	60.1763	32.235
7	118.415	63.8307
8	176.6537	95.4264
9	234.8924	127.022
10	268.3796	145.1895

Table No. 6: Shear Force Values

Observation:

In the above figure No.19 Dark blue colour indicates the value of shear force obtained from RCC beam and a faint blue colour indicates the shear force value obtained from the Delta beam. The maximum shear force occurred at the end supports of the beam. The shear force value is zero where at the maximum bending moment occurs. Hence, the shear force value is zero at mid span of the beam. In figure no.19, it is observed that on the left support shear force value in RCC is 264.5045 kN, where in delta beam is 143.9108 kN. The shear force value is more in RCC beam by 120.637kN than that of the Delta beam. Similarly, on the right support shear force value in RCC beam is 268.3796 kN. Where, in delta beam is 145.1895 kN. The shear force value is more in RCC beam by 123.1901kN than that of the Delta beam

8.3 Deflection Diagram Difference in Delta Beam Structure and RCC Beam Structure in one internal space of continuous beam of span 10m.

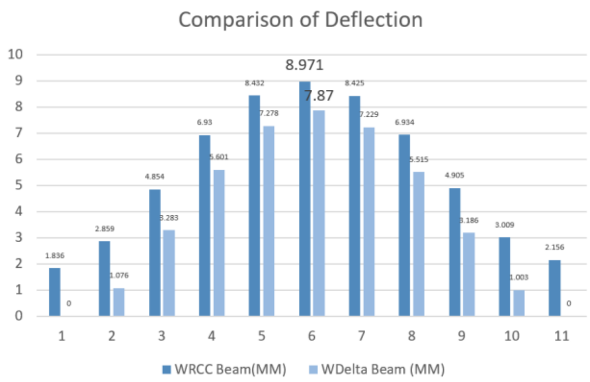


Figure No. 20: Deflection Diagram

Deflection		
Length(M)	**$W_{RCC\ Beam}$ (MM)**	**$W_{Delta\ Beam}$ (MM)**
0	1.836	0
1	2.859	1.076
2	4.854	3.283
3	6.93	5.601
4	8.432	7.278
5	8.971	7.87
6	8.425	7.229
7	6.934	5.515
8	4.905	3.186
9	3.009	1.003
10	2.156	0

Table No. 7: Deflection Value

Observations:

In the above figure No.20, dark blue colour indicates the deflection value obtained from the RCC beam and a faint blue colour indicates the deflection value obtained from the Delta beam. The maximum deflection occurs where the shear force value becomes zero, i.e., at mid span. As observed in the above figure, the RCC beam shows a deflection value of 8.971mm, where the delta beam shows 7.87mm. The deflection value in the RCC beam is 1.1mm more than that of the delta beam because of the structural steel used in the delta beam.

8.4 Modal Analysis

		RCC Beam Frame		Delta Beam Structure	Difference
Translation	UX	58.58%		58.22%	0.38%
	UY	59.97%		59.74%	0.23%
Rotation	(Rz)	70%		65.6%	4.4%
Time Period	Mode-1	0.935	17.64%	1.015	20.88%
	Mode-2	0.77		0.803	

Table No. 8: Analysis Results of Modal Mass Participation Ratio of RCC Frame Structure and Delta Beam structure.

Observations:

From table no. 8, the translation of building in UX-direction in mode-1 is 0.38% more in the RCC beam than that of the delta beam. Similarly, the translation of building in UY-direction at mode-2 is 0.23% more in the RCC beam as compared to the delta beam. But the rotation in the delta beam is observed to be less by 4.4% than that of the RCC beam. The time period difference between mode-1 and mode-2 is 17.64% in RCC beam and 20.889% in delta beam. The total mass participated in modal analysis is greater than 90% in UX-direction, UY-direction and RZ-direction. The time period frequency at last mode is less than 33Hz.

8.5 Earthquake Analysis:

8.5.1 Lateral Displacement

Storey displacement is the lateral displacement of the storey relative to the base.

The lateral force resisting system can limit the excessive lateral displacement of building up to H/500.

A) X-Direction

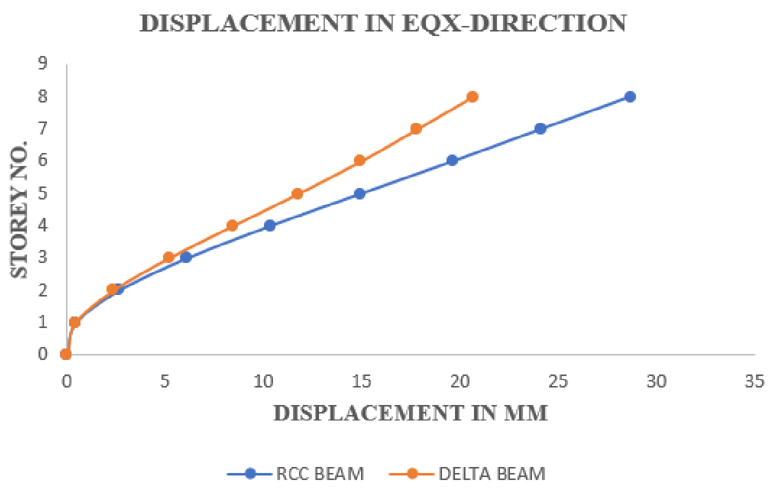


Figure No. 21: Lateral Displacement in EQX- Direction RCC Beam Model and Delta Beam Model

- For RCC Frame Structure H/500 = 27200/500 = 54.4mm > 28.679mm
- For Delta Beam Structure H/500 = 27200/500 = 54.4mm > 20.672mm

Observations:

In figure no.21 shows the lateral displacement occurring in the delta beam structure and RCC frame structure in EQX-direction. The blue colour curve shows the lateral displacement in the RCC frame structure and orange colour shows the lateral displacement in the Delta beam structure. The lateral displacement in the RCC structure is 8.007mm more than that of a delta beam structure.

B) Y-Direction

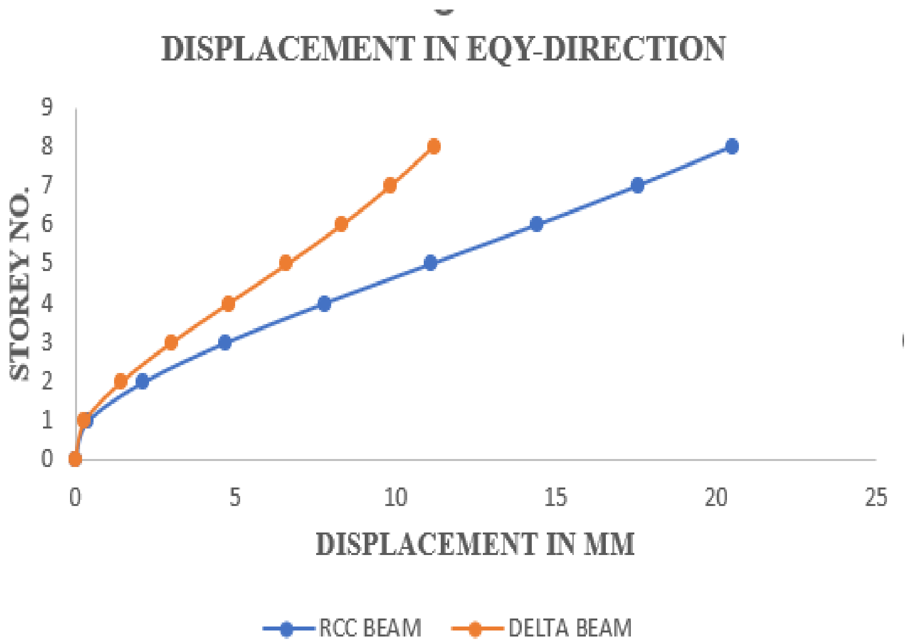


Figure No.22: Lateral Displacement in EQY- Direction RCC Beam Model and Delta Beam Model

- For RCC Frame Structure H/500 = 27200/500 = 54.4mm > 20.512mm
- For Delta Beam Structure H/500 = 27200/500 = 54.4mm > 11.202mm

Observations:

In figure no.22 shows the lateral displacement occurring in the delta beam structure and RCC frame structure in EQY-direction. The blue colour curve shows the lateral displacement in the RCC frame structure and orange colour shows the lateral displacement in the Delta beam structure. The lateral displacement in the RCC structure is 9.31mm more than that of the delta beam structure.

8.5.2 Storey Drift:

Storey drift is the lateral displacement of a floor relative to the floor below.

As per IS 1893 (Part-1) 2016 Cl. 7.11.1 the storey drift in any storey shall not exceed 0.004 times the storey height i.e., H/250.

A) X- Direction:

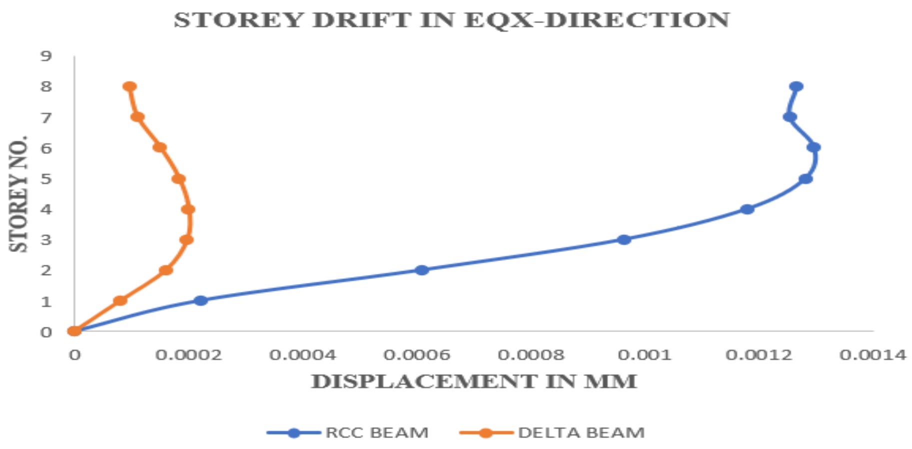


Figure No. 23: Lateral Drift in EQX- Direction RCC Beam Model and Delta Beam Model

- For RCC Frame Structure H/250 = 3600/250 = 14.4 > 0.00128
- For Delta Beam Structure H/250 = 3600/250 = 14.4 > 0.000199

Observations:

The figure no.23 shows the storey drift occurring in the delta beam structure and RCC frame structure in EQX-direction. The blue colour curve shows the storey drift in the RCC frame structure and orange colour shows the storey drift in the Delta beam structure. The storey drift value is more in the RCC structure than that of a delta beam structure.

B) Y- Direction:

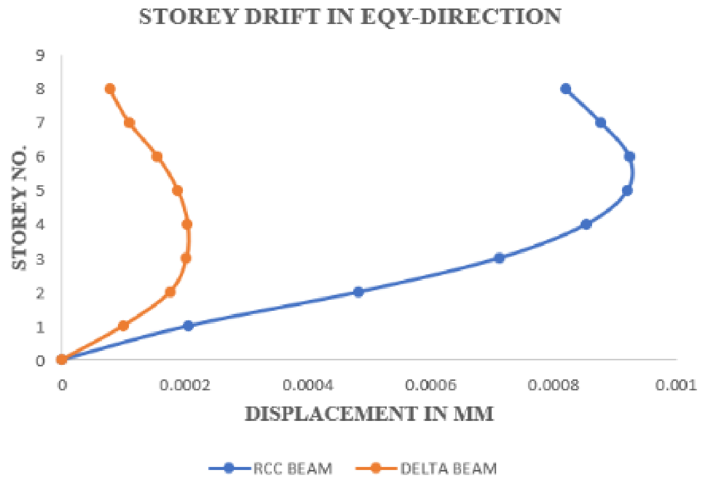


Figure No. 24: Lateral Drift in EQY- Direction RCC Beam Model and Delta Beam Model

For RCC Frame Structure H/250 = 3600/250 = 14.4 > 0.00092

For Delta Beam Structure H/250 = 3600/250 = 14.4 > 0.000204

Observations:

The figure no.24 shows the storey drift occurring in the delta beam structure and RCC frame structure in EQY-direction. The blue colour curve shows the storey drift in the RCC frame structure and orange colour shows the storey drift in the Delta beam structure. The storey drift value is more in the RCC structure than that of a delta beam.

8.5.3 Base Shear:

Base shear is the estimation of maximum expected lateral force which will occur at the base of a structure due ground motion during the earthquake. Due to seismic activities, the ground start moving. Due to the movement of ground, lateral force is developed in opposite direction of motion.

A) X-Direction:

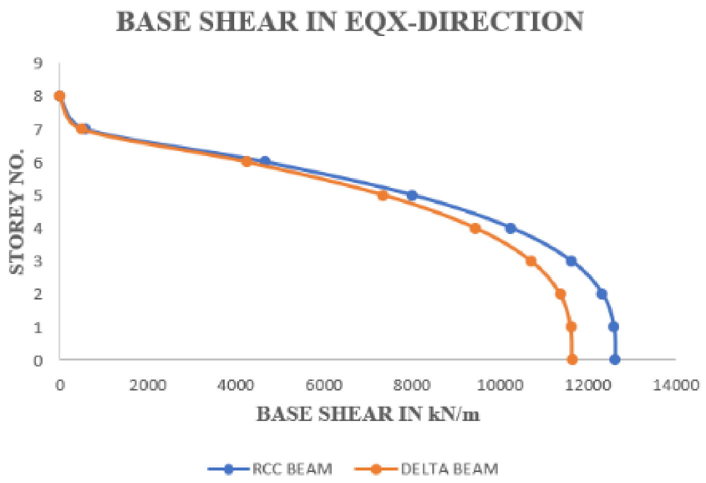


Figure No.25: Base Shear in EQX- Direction RCC Beam Model and Delta Beam Model

For RCC Frame Structure Base Shear = 12610.8055kN/M

For Delta Beam Structure Base Shear =11639.854kN/M

Observations:

In figure no.25 shows the storey shear occurring in the delta beam structure and RCC frame structure in EQX-direction. Where the blue colour curve shows the storey shear in the RCC frame structure and orange colour shows the storey shear in Delta beam structure. The total base of the RCC beam structure is 970.9515kN/M more than that of a delta beam structure.

8.5.4 Storey Stiffness:

The stiffness of a building is its ability to resist deformation induced by applied loads.

A) X-Direction:

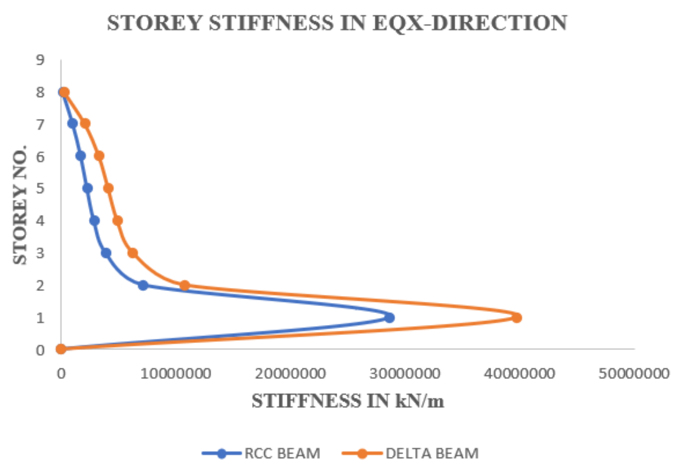


Figure No. 26: Storey Stiffness in EQX- Direction RCC Beam Model and Delta Beam Model

For RCC Frame Structure Stiffness= 28619348.219
For Delta Beam Structure Stiffness = 39722123.67

Observations:

The figure no.26 shows the storey stiffness occurring in the delta beam structure and RCC frame structure in EQX-direction. Where the blue colour curve shows the storey stiffness in the RCC frame structure the orange colour shows the storey stiffness in the Delta beam structure. Storey stiffness is more in delta structure as compared to the RCC frame structure.

B) Y-Direction:

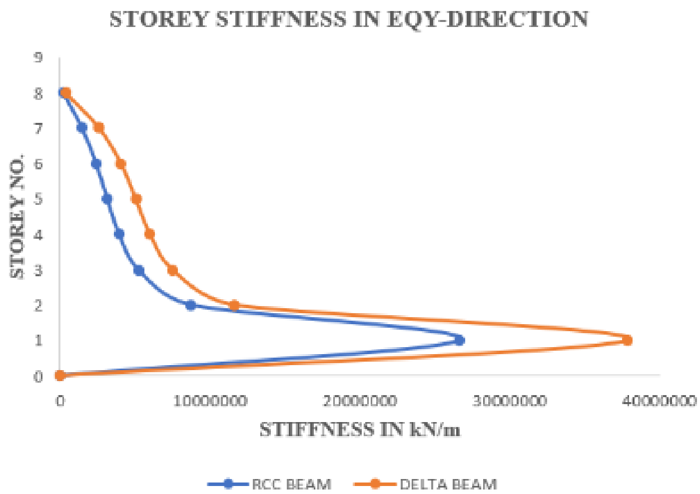


Figure No. 27: Storey Stiffness in EQX- D RCC Beam Model and Delta Beam Model

For RCC Frame Structure Stiffness= 30643187.866
For Delta Beam Structure Stiffness= 37832293.272

Observations:

In figure no.27 shows the storey stiffness occurring in the delta beam structure and RCC frame structure in EQY-direction. Where the blue colour curve shows the storey stiffness in the RCC frame structure and orange colour shows the storey stiffness in the Delta beam structure. Storey stiffness is more in the delta structure as compared to the RCC frame structure.

8.6 Response Spectrum Analysis

8.6.1 Storey Shear

A) X-Direction:

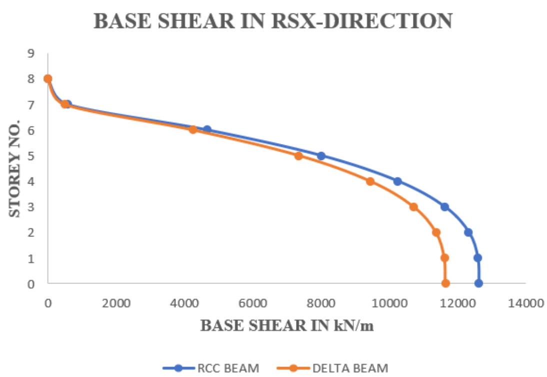


Figure No.28: Base Shear in RSX- Direction RCC Beam Model and Delta Beam Model

For RCC Frame Structure Base Shear = 12610.8055kN/M
For Delta Beam Structure Base Shear =11639.854kN/M

Observations:

In figure no.28 shows the storey shear occurring in the delta beam structure and RCC frame structure at RSX-direction. Where the blue colour curve shows the storey shear in the RCC frame structure and orange colour shows the storey shear in the Delta beam structure. The total base of the RCC beam structure is 970.9515kN/M more than that of a delta beam structure.

8.6.2 Storey Displacement

A) X-Direction:

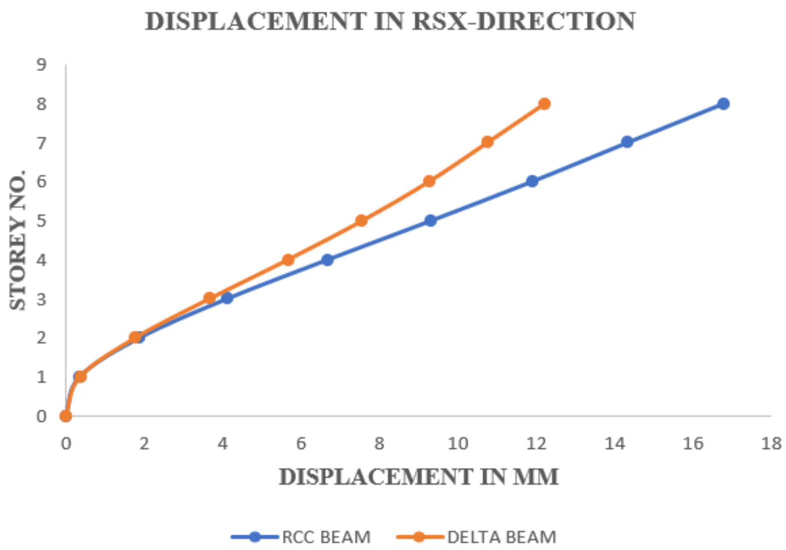


Figure 29: Lateral Displacement in RSX- Direction RCC Beam Model and Delta Beam Model

H/500 = 27200/500 = 54.4mm > 16.785mm
H/500 = 27200/500 = 54.4mm > 12.202mm

Observations:

In figure no.29, it shows the lateral displacement occurring in the delta beam structure and RCC frame structure in the RSX-direction. The blue colour curve shows the lateral displacement in the RCC frame structure and orange colour shows the lateral displacement in the Delta beam structure. The lateral displacement in the RCC structure is 4.583mm more than that of the delta beam structure.

B) Y-Direction:

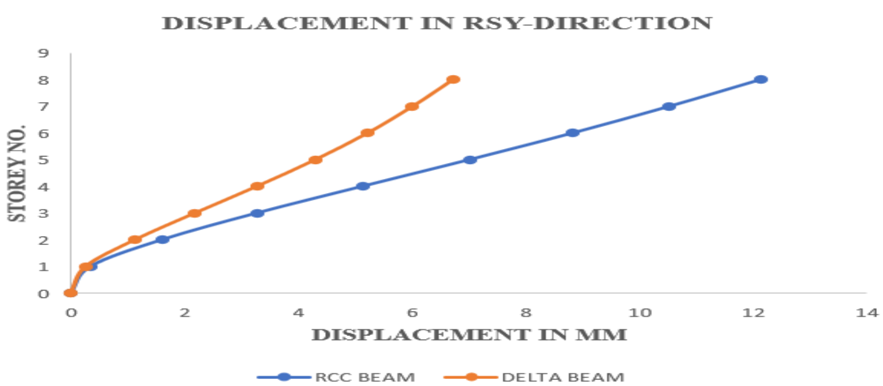


Figure 30: Lateral Displacement in RSY- Direction RCC Beam Model and Delta Beam Model

H/500 = 27200/500 = 54.4mm > 12.124mm

H/500 = 27200/500 = 54.4mm > 6.705mm

Observations:

In figure no.30 shows the lateral displacement occurring in the delta beam structure and RCC frame structure in the RSY-direction. The blue colour curve shows the lateral displacement in the RCC frame structure and orange colour shows the lateral displacement in the Delta beam structure. The lateral displacement in the RCC structure is 5.419mm more than that of a delta beam structure.

8.7 Wind Load Analysis

8.7.1 Storey Displacement

A) X-Direction

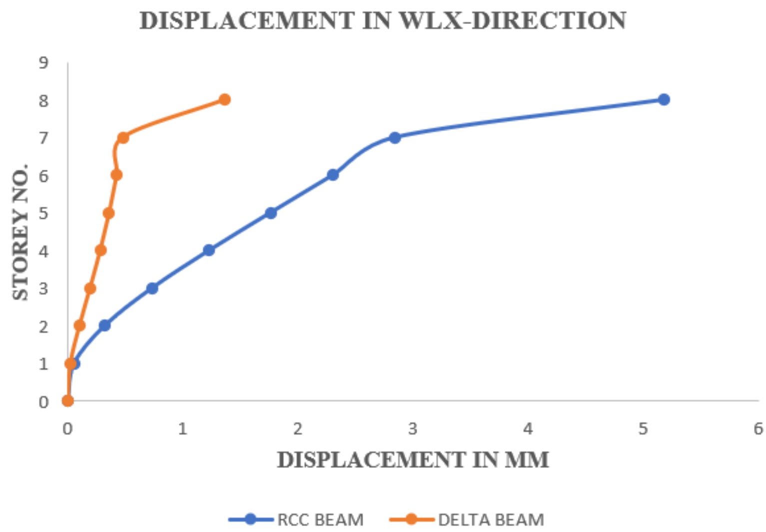


Figure 31: Lateral Displacement in WLX- Direction RCC Beam Model and Delta Beam Model

H/500 = 27200/500 = 54.4mm > 5.179mm

H/500 = 27200/500 = 54.4mm > 1.367mm

Observations:

In figure no.31 shows the lateral displacement occurring in the delta beam structure and RCC frame structure in the WLX-direction. The blue colour curve shows the lateral displacement in the RCC frame structure and orange colour shows the lateral displacement in the Delta beam structure. The lateral displacement in the RCC structure is 3.812mm more than that of delta beam.

B) Y-Direction

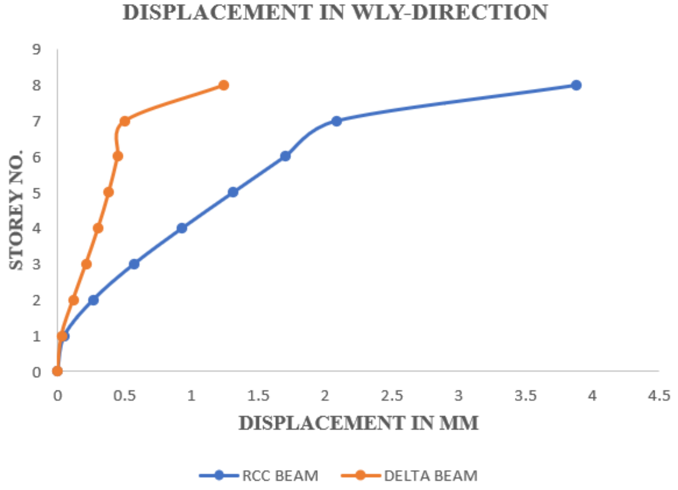


Figure 32: Lateral Displacement in WLY- Direction RCC Beam Model and Delta Beam Model

H/500 = 27200/500 = 54.4mm > 3.876mm

H/500 = 27200/500 = 54.4mm > 1.243mm

Observations:

In figure no.32, shows the lateral displacement occurring in the delta beam structure and RCC frame structure in the WLY-direction. The blue colour curve shows the lateral displacement in the RCC frame structure and orange colour shows the lateral displacement in the Delta beam structure. The lateral displacement in the RCC structure is 2.633mm more than that of the delta beam structure.

8.8 Mat Footing Results

8.8.1 Allowable Upward Soil Pressure

The allowable soil pressure for soil may be either gross or net pressure permitted on the soil directly under the base of the footing. The gross pressure represents the total stress in the soil created by all the loads above the base of the footing.

In this project SBC of soil is 250 kN/M^2 i.e., the allowable upward soil pressure is 250kN/M^2.

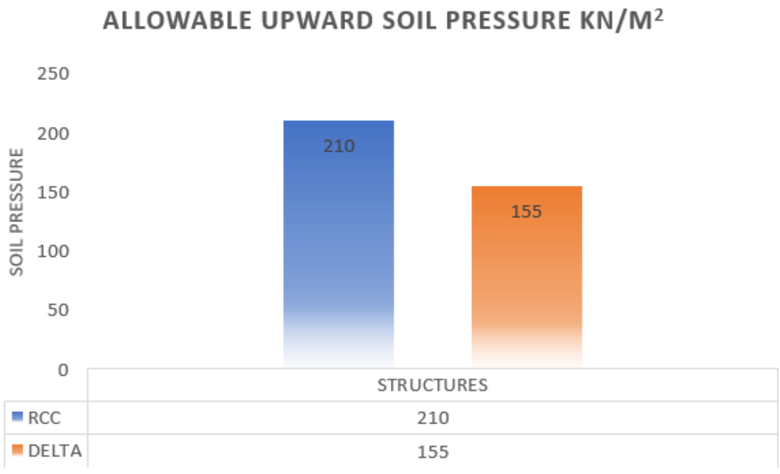


Figure 33: Allowable upward soil pressure of Delta Beam Structure and RCC Beam Structure

Here, allowable upward soil pressure of Delta Beam Structure 155kN/M^2 < 250 kN/M^2

Allowable upward soil pressure of RCC Frame Structure 210 kN/M^2 < 250 kN/M^2

Observations:

In Figure no.33 shows the allowable upward soil pressure in the delta beam structure footing and RCC frame structure footing. The upward soil pressure limit is up to the self-bearing capacity of soil, which is 250kN/M. The allowable upward soil pressure of the RCC frame structure is more by 55kN/M than that of a delta beam structure.

8.8.2 Allowable Downward Soil Settlement:

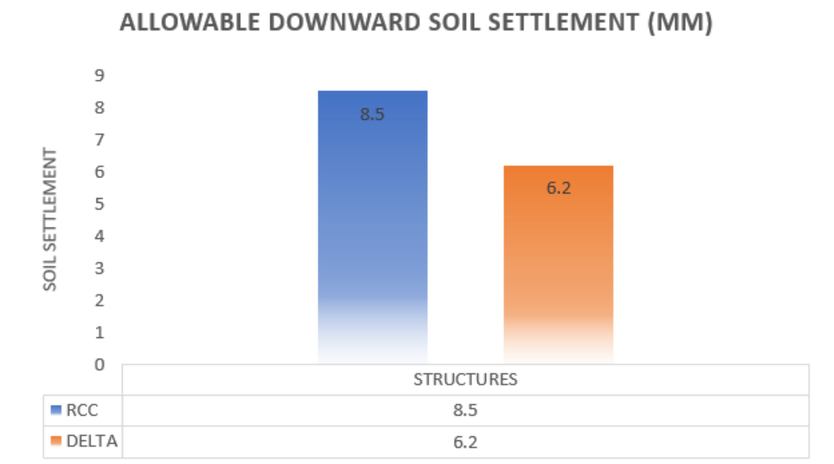


Figure 34: Allowable Downward Settlement for Delta Beam Structure

Here, allowable downward settlement of Delta Beam Structure 6.2 mm < 50mm.
Allowable downward settlement of RCC frame structure 8.5 mm < 50mm.

Observations:

In Figure no.34 shows the allowable downward soil settlement in the delta beam structure footing and RCC frame structure footing. The downward soil settlement limit is 50mm. The allowable downward soil settlement of the RCC frame structure is more by 2.3 than that of a delta beam structure.

8.8.3 Punching Shear Result

The punching shear is a failure mechanism in structural members like slabs and foundation by shear under the action of concentrated loads. The action of concentrated loads is on a smaller area in the structural members. In most cases, this reaction is the one from the column acting against the bottom slab.

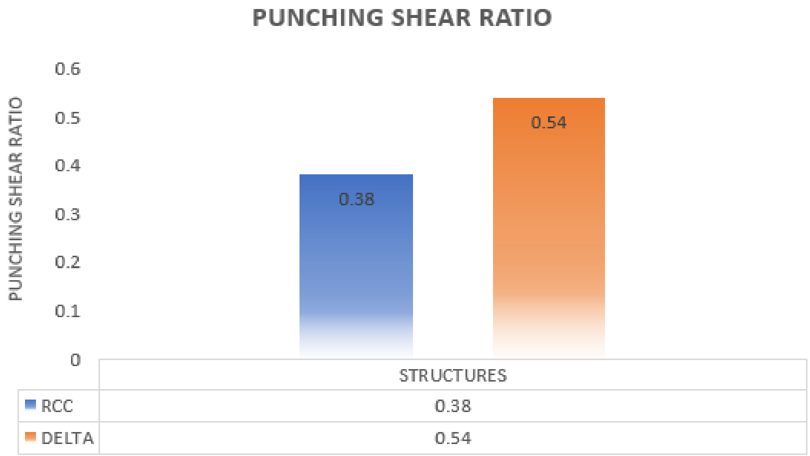


Figure 35: Punching Shear Report of Delta Beam Structure and RCC Frame Structure.

Observations:

In Figure no.35 shows the punching shear results in delta beam structure footing and RCC frame structure footing. The punching shear ratio is more in delta beam structure footing as compared to RCC beam structure footing.

CHAPTER 9
INFERENCES

9.1 General

1) The RCC beam size required is 650mm wide X 700mm deep in RCC frame structure. The corresponding delta beam section required is of 660mm wide X 475mm deep. By opting for Delta structure, a height of 225mm will be saved in the floor height.

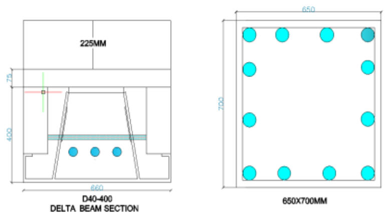


Figure 36: Depth Comparison Between RCC Beam and Delta Beam

2) Delta beam provides a similar load carrying capacity to that of the RCC beam.
3) The flexural rigidity of Delta Beam is more than the flexural rigidity of RCC beams i.e., the strength of the Delta beam to resist bending is greater than that of the RCC beam.

9.2 Modal Analysis:

- It is seen that Delta beam structure shows same translation in both directions (i.e., UX and UY) as that of RCC frame structure.
- Delta beam structure shows less rotation as that of RCC frame structure.
- In Delta beam structure the time period difference between mode-1 and mode-2 is 18% and 21% at RCC frame structure.

9.3 Earthquake Analysis:

		RCC Frame Structure	Delta Beam Structure	Difference
Lateral Displacement (mm)	EQX	28.67	20.672	7.998
	EQY	20.51	11.202	9.308
Lateral Drift	EQX	0.000923	0.000204	0.000719
	EQY	0.001296	0.000199	0.001097
Stiffness (By Etabs)	EQX	28619348.22	39722123.67	11102775.45
	EQY	30643187.87	37832293.3	7189105.43
Base Shear (kN)	12610.8		11587.9	1022.9
Seismic Weight (kN)	252216.11		231758	1468.11

Table No. 9: Earthquake Analysis Comparison

From the above table following are the observations:

- Lateral Displacement and Lateral Drift in both directions (EQX and EQY) is slightly more in RCC frame structure as compared to Delta Beam Structure.
- Stiffness is less in RCC frame structure to that of Delta beam structure.
- Due to less self-weight delta beam structure attract fewer lateral forces hence the total base shear in delta beam structure is less as compared to RCC beam structure as well as the total seismic weight in delta beam structure is less as compared to RCC beam structure.

9.4 Response spectrum Analysis:

		RCC Frame Structure	Delta Beam Structure	Difference
Lateral Displacement (mm)	EQX	16.785	12.202	4.583
	EQY	12.124	6.705	5.419
Base Shear (kN)		12610.8	11587.9	1022.9

Table No. 10: Response Spectrum Analysis Comparison

In dynamic analysis lateral displacement and base shear is more in RCC frame structure compared to delta beam structure.

9.5 Wind load Analysis:

		RCC Frame Structure	Delta beam Structure	Difference
Lateral Displacement (mm)	EQX	5.179	1.367	3.812
	EQY	3.876	1.243	2.617

Table No. 11: Wind Load Analysis Comparison

The lateral displacement in wind load analysis is more in RCC frame structure as that of delta beam structure.

9.6 Mat Foundation:

	RCC Frame Structure	Delta beam Structure	Difference
Depth of Footing (mm)	1500	1000	500
Settlement (mm)	8.5	6.2	2.3
Allowable upward soil pressure kN/m^2	210	155	55
Punching Shear Ratio	0.38	0.54	0.16

Table No. 12: Mat Foundation Comparison

From the above table it is clear that

1. Depth of mat foundation is more in RCC frame structure than that of Delta beam structure.
2. Settlement is slightly less in Delta beam structure than that of RCC frame structure.
3. At foundation level the base pressure provided in Delta beam structure is less compared to RCC frame structure.
4. The punching shear ratio (ratio of maximum design shear stress to that of conc. Shear stress capacity) is more in Delta beam structure as compared to RCC beam structure because the maximum design shear stress is more in Delta beam structure.

9.7 Bending Moment, Shear Force and Deflection comparison of RCC beam and Delta beam.

	RCC Beam	Delta Beam	Difference
Maximum Bending Moment at mid span	243.0269 kN/M	131.1543 kN/M	111.8726
Maximum shear force	In(kN)		
At 0m	-264.5045 kN	-143.9108 kN	120.5937
At 10m	268.3796 kN	145.1895 kN	123.1901
Maximum Deflection at mid span	8.971mm	7.87mm	1.101

Table No. 13: Bending Moment, Shear Force and Deflection comparison of RCC beam and Delta beam.

From the above table it is clear that:

1. The bending moment occurred at mid span is more in RCC beam and less in Delta beam.
2. The shear force at end support is more in RCC beam as compared to Delta beam.

3. The maximum deflection at mid span is less in Delta beam and more in RCC beam.

CHAPTER 10
CONCLUSIONS

1. By replacing the delta beam with the RCC beam at each floor, 225mm floor height get saved.
2. Delta beam with its web having holes although concrete is to be filled into the web portion, thus providing a composite section with a fire resisting component.
3. In the RCC beam, the moment of inertia is more than that of the delta beam but, young's modulus of steel is more as compared to young's modulus of concrete, hence the flexural rigidity in delta beam should be more than that of the RCC beam is more.
4. In modal analysis, translation in UX and UY direction at mode-1 and mode-2 is similar, but at mode-3 rotation in RZ direction is reduced by 4.4%. By replacing the RCC beam with a delta beam, the time period difference between mode-1 and mode-2 has increased from 17.64% to 20.88%.
5. In earthquake analysis, the Lateral displacement and Storey drift values are less in the delta beam structure and more in the RCC beam structure.
6. In earthquake analysis, the stiffness of the delta beam structure in both directions is more than that of the RCC frame structure.
7. The base shear of the delta beam structure in the equivalent static method and response spectrum method is less compared to the RCC frame structure.
8. The Lateral displacement in the dynamic method (response spectrum method) and wind analysis method is less in the delta beam structure than that of the RCC frame structure.
9. The composite option is better than RCC for high rise buildings. The weight of a composite structure is low as compared to the RCC structure, which helps in reducing the amounts of forces at foundation level induced due to an earthquake. As a result, the depth of footing, settlement of footing and upward soil pressure induced is less in the delta beam structure than that of the RCC frame structure.
10. Due to the effect of self-weight and load carrying capacity of delta beams, the bending moment, shear force and deflection values are seen to be less than those of RCC beams.
11. From all of the above results the Delta beam structure is more economical and efficient for large column free structure, as it reduces the floor height predominantly compared to RCC frame structure.

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