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A Comparative Study of the Seismic Behaviour of G+20 Storey Symmetrical Buildings Constructed with Light Weight Concrete and Normal Weight Concrete

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Abstract: Concrete with a density of less than 2000 kg/m^3 is considered lightweight concrete. Structural lightweight concrete (SLWC) is used to reduce the dead load of concrete structures. The purpose of this research is to examine and compare the results of SLWC made with scoria and normal weight concrete (NWC) and normal and light weight concrete(NAL) multistorey buildings. Multistorey buildings are often constructed of ordinary concrete, steel, and other materials. They are subjected to heavy loads, requiring heavy construction that may not be cost-effective. In this paper, a G+20multistorey plan symmetrical building is analysed using the response spectrum method with SLWC and NWC. Bending moment, shear force, storey shear, storey drift, and storey displacement are considered. The results of the NWC and SLWC and NAL buildings are compared . Concluding the research work that when comparing symmetrical plan area cases of normal concrete, light weight concrete and combination of normal and light weight concrete for all the result parameters, light weight concrete seems to be very efficient and most favorable case. Hence should be recommended when this type of construction procedure will be adopted, i.e. always use building with lightweight concrete.
Keywords: Light weight concrete symmetrical plan, response spectrum method, normal weight concrete

I. INTRODUCTION

The demand for tall structures is steadily rising in our modern world. Structural safety remains a top priority, as human lives must never be put at risk. The necessity for multi-storey buildings arises from various crucial factors, such as rapid population growth and economic considerations. Cost-effective solutions like the utilization of lightweight concrete have been sought by developers and city planners due to escalating land prices. This approach allows for optimal space utilization while reducing the overall weight of the structure, thereby facilitating the construction of taller buildings.

II. NORMAL CONCRETE AND LIGHT WEIGHT CONCRETE

Normal concrete, also known as conventional concrete or regular concrete, is the most commonly used type of concrete in construction. It is made with a mix of cement, water, sand, and coarse aggregates (usually gravel or crushed stone). Normal concrete has a typical density, which provides it with standard structural strength and performance.

Lightweight concrete, on the other hand, is a type of concrete with a reduced overall density achieved by combining lightweight aggregates. These lightweight aggregates can be natural materials like expanded clay, shale, scoria ,or slate, or they can be of artificial materials.

By using these lightweight aggregates, adequate structural strength is maintained while the weight of the concrete is significantly reduced. Lightweight concrete offers advantages such as improved thermal insulation, better fire resistance, and reduced dead loads, making it suitable for specific construction applications where weight is a concern. The choice between Normal Concrete and Light Weight Concrete in buildings is made based on several factors, such as the intended use in the structure, budget constraints, seismic considerations, and sustainability goals. Normal Concrete structures are excellent for applications where durability and affordability are of the utmost importance, while Light Weight Concrete buildings are proposed for situations where lightweight, high-strength solutions that reduce dead loads are needed.

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III. PROCEDURE AND 3D MODELING OF THE STRUCTURE

Seismic analysis is carried out on a G+20 storey building by using software approach. The seismic data is taken as per the IS 1893(PART1):2016. The response spectrum analysis method is adopted for analysis of building. Input details and model descriptions are mentioned below:

Table 1: General data used for analysis of structure

Constraint	Data used for all buildings
Floors configuration	G + 20 Residential Apartment
Height of building	70 m
Floor to floor height	3 m
Depth of foundation	4 m
Symmetrical Plan area	4m @6 bays in X direction 4m @6 bays in Y direction 576 sq. m.
RCC Beam size (NC)	450 mm X 300 mm
	550 mm X 350 mm
	650 mm X 550 mm
RCC Column sizes (NC)	650 mm X 500 mm
	850 mm X 800 mm
	1200 mm X 1000 mm
Slab thickness (NC)	140 mm (0.140 m)
Staircase waist slab thickness (NC)	140 mm (0.140 m)
Shear wall thickness (NC)	180 mm (0.180 m)
Footing depth (NC)	500 mm
Material properties	M 30 Concrete Fe 500 grade steel
Weight per unit volume (NC)	24.5167 KN/sq. m.
Modulus of Elasticity E	27386.13 MPa
Poisson's ratio U and Fck	0.2 and 30 MPa

Table 2: Light Weight Concrete data used for analysis of structure

Constraint	Data used for all buildings
Light weight aggregate used	Scoria lightweight aggregate
Density	1800 kg/m3
Poisson's ratio U and Fck	0.2 and 30 MPa
Modulus of Elasticity E (LWC)	$E = 0.043 \times \omega 1.5 \times \sqrt{fc}$ ....Eq. 3.1 17986.13 MPa
Shear strength reduction factor	0.75
RCC Beam size (LWC)	450 mm X 300 mm
	550 mm X 350 mm
	650 mm X 550 mm
RCC Column sizes (LWC)	650 mm X 500 mm
	850 mm X 800 mm
	1200 mm X 1000 mm
Slab thickness (LWC)	140 mm (0.140 m)
Shear wall thickness (LWC)	180 mm (0.180 m)
Staircase waist slab thickness (LWC)	140 mm (0.140 m)
Footing depth (LWC)	500 mm
NAL Concrete application configuration	up to G+6 (NC) Shear wall – NC (Complete) Footing – NC (Complete) G+7 above (LWC)

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Table 3: Seismic data used for analysis of structure

Constraint	**Data used for all buildings**
Fundamental natural period of vibration (Ta)	0.09*h/(d)0.5...........Eq. 3.2
Fundamental natural period (Tax) in X direction for symmetrical plan area	1.286 seconds
Fundamental natural period (Taz) in Z direction for symmetrical plan area	1.286 seconds
Importance factor I	1.5
Response reduction factor R	4
Damping ratio	5%
Zone factor	0.16
Zone	III
Soil type	Medium Soil

Table 4: Loading data used for analysis of structure

Constraint	Data used for all buildings
Floor finished load	2.8 KN/ sq. m
Water proofing load	0.508 KN/ sq. m
External wall load	14.04 KN/m
Internal wall load	7.74 KN/m
Parapet wall load	2.58 KN/m
Live load on floors	3 KN/ sq. m
Live load on roof	0.8 KN/ sq. m
Live load on staircase	3 KN/ sq. m

Table 5: Model Description

S. No.	Abbreviation	Description of structure
1.	NC 1	Residential apartment with symmetrical plan area 576 sq. m. using normal concrete
2.	LWC 1	Residential apartment with symmetrical plan area 576 sq. m. using light weight concrete
3.	NAL 1	Residential apartment with symmetrical plan area 576 sq. m. using normal and light weight concrete

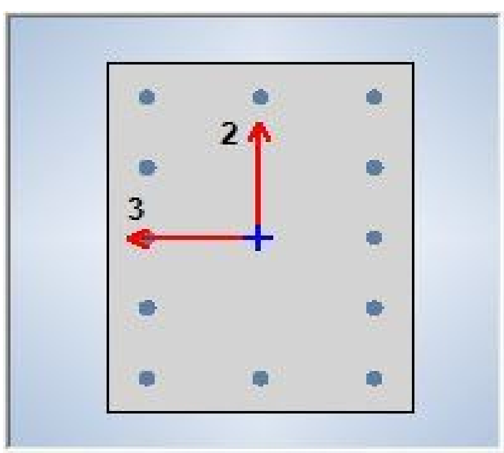

Fig. 1: Cross section of beam member

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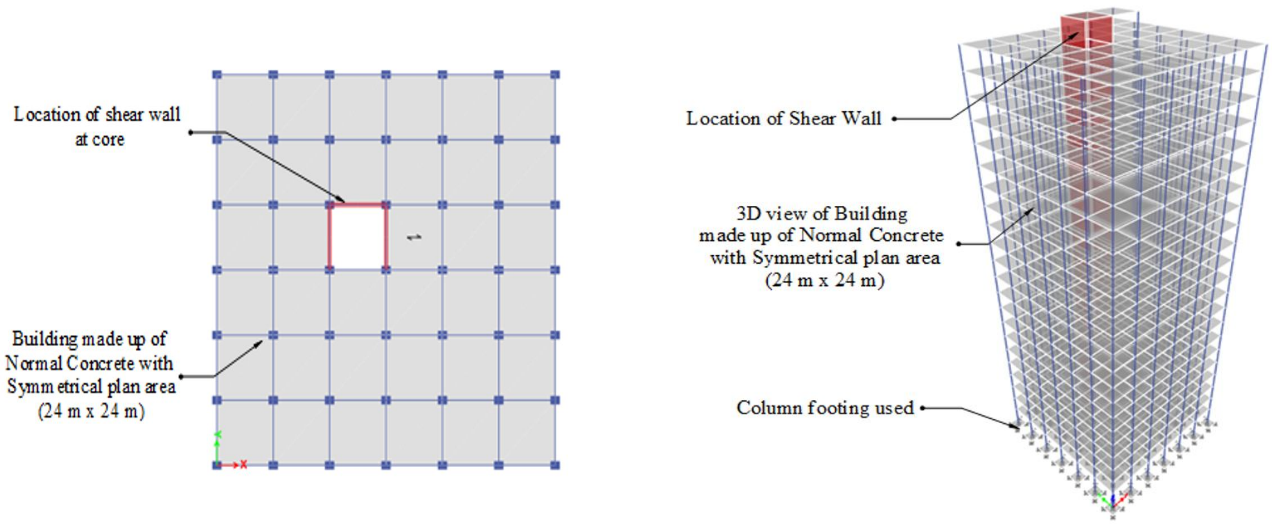

Fig. 2: Plan and 3D view of symmetrical plan using Normal Concrete (NC1)

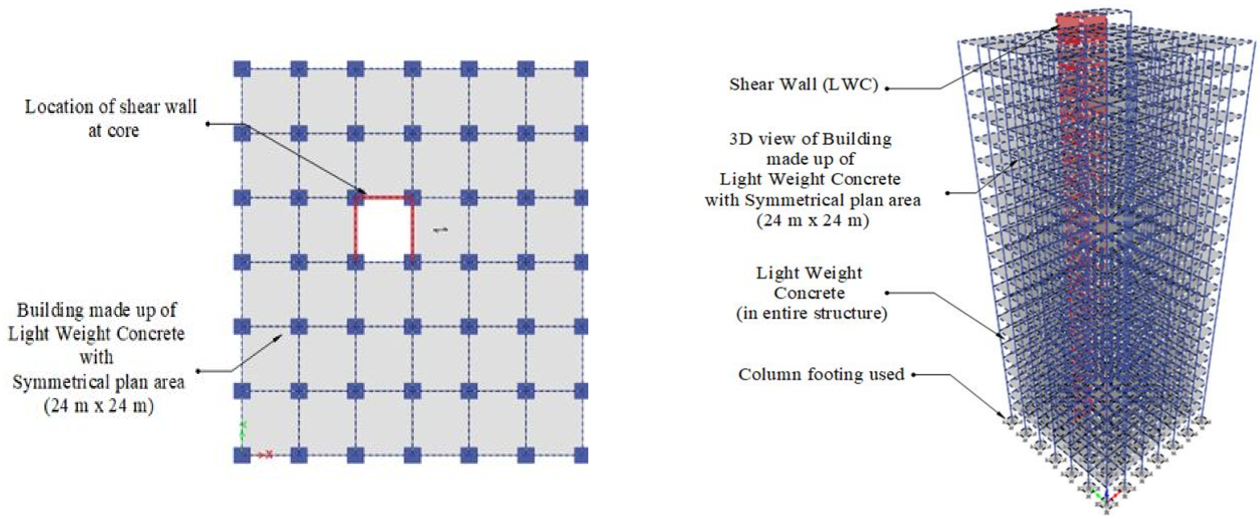

Fig. 3: Plan and 3D view of symmetrical plan using Light Weight Concrete (LWC1)

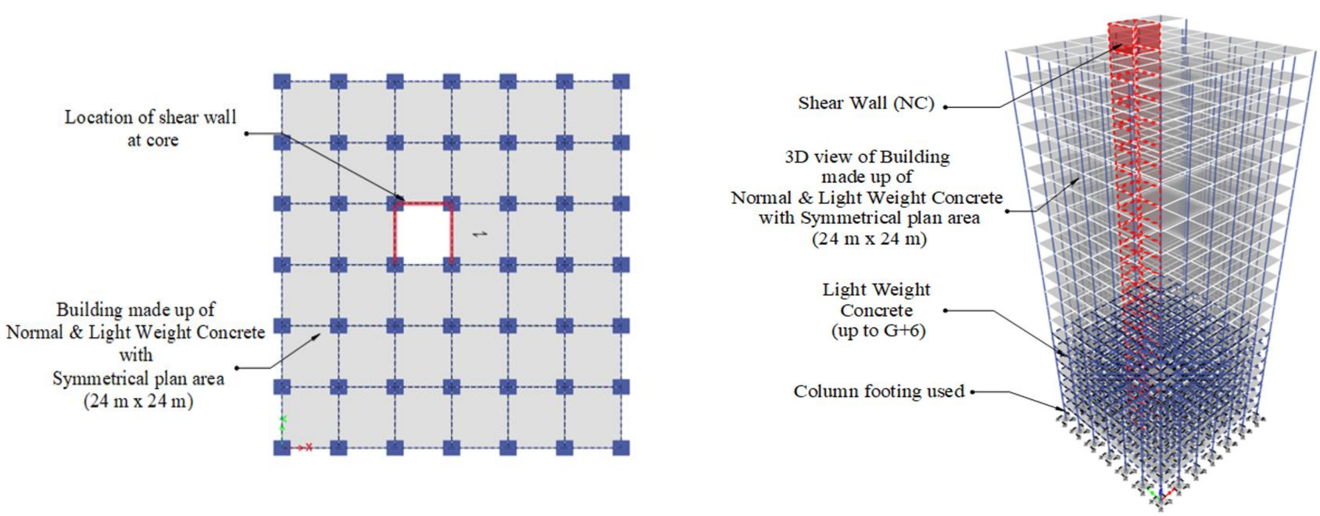

Fig. 4: Plan and 3D view of symmetrical plan using Normal and Light Weight Concrete (NAL1)

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IV. RESEARCH OBJECTIVES

On keeping in mind the above problem statement outlined for new research work for box culvert are given below :-

1) To create and study various cases of residential apartment building (G+20) configuration with Normal Concrete with Light Weight Concrete configurations. Also, it is essential to conduct a study with usage of both types of concrete within building structures that will help to understand the behaviour of mix behaviour.
2) To check behaviour in the analysis, it is recommended to create symmetrical plan areas.
3) To create and study various cases of NC, LWC and NAL over medium soil and comparing them by using Response Spectrum Method of dynamic analysis.
4) To determine and compare maximum displacement in X and Y direction for NC, LWC and NAL symmetrical building structure.
5) To study the variation in base shear in both X and Y direction for NC, LWC and NAL symmetrical building structure.
6) To determine maximum axial forces in columns at base level for various cases.
7) To study and relate the maximum shear forces and bending moment in beam member for NC, LWC and NAL symmetrical building structure.
8) To evaluate and relate storey drift in both X and Y direction for NC, LWC and NAL symmetrical building structure.

V. RESULTS ANALYSIS

The application of loads and their combinations on different cases as per the Indian Standard 1893:2016 code of practice yield result parameters under normal weight concrete , light weight concrete and normal and light weight concrete.
Result of each parameter has discussed with its representation in graphical form below:-

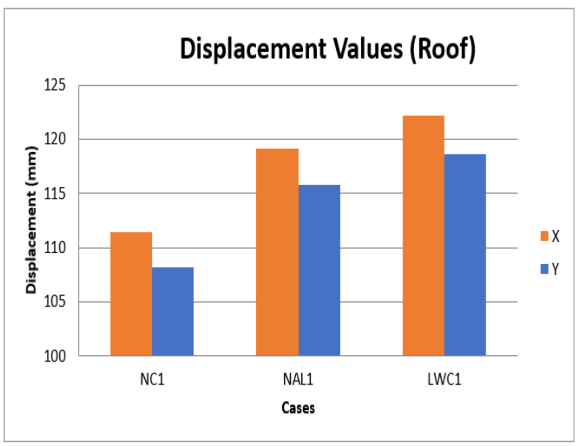

Fig. 5: Maximum Displacement (Roof level)

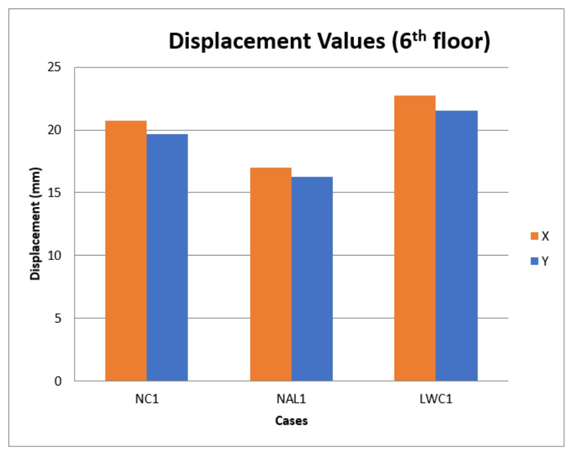

Fig. 6: Maximum Displacement (6th floor level)

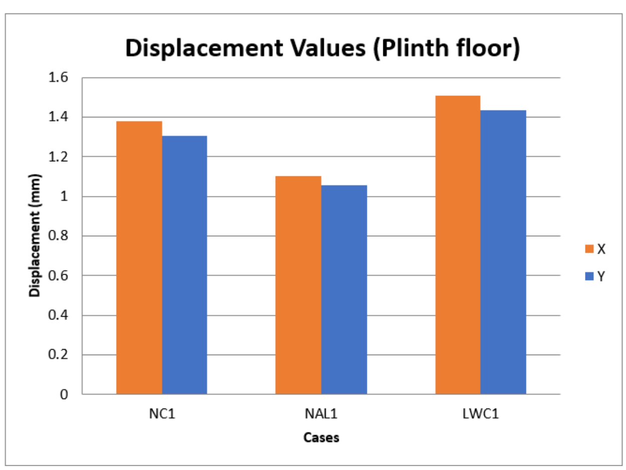

Fig. 7: Maximum Displacement for symmetrical plan area (plinth floor level)

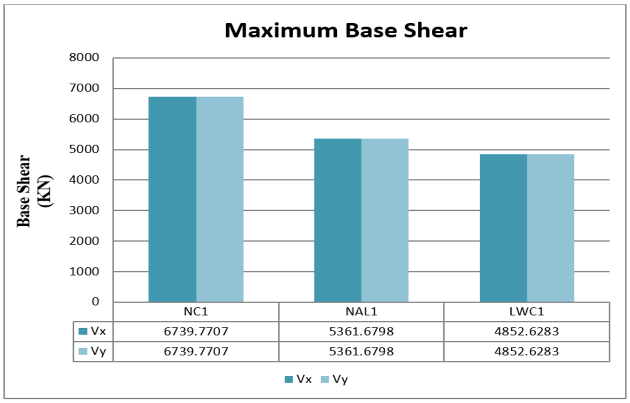

Fig. 8: Maximum Base Shear

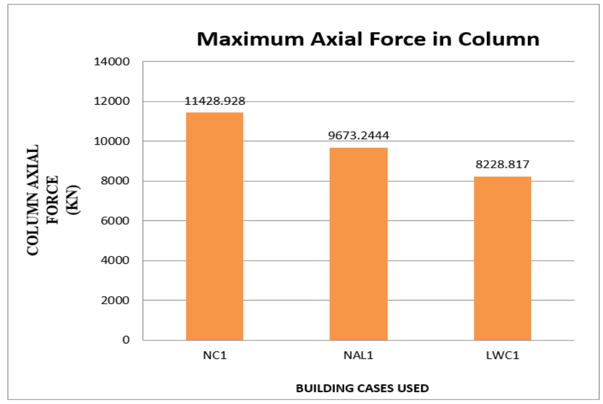

Fig. 9: Maximum Axial Forces

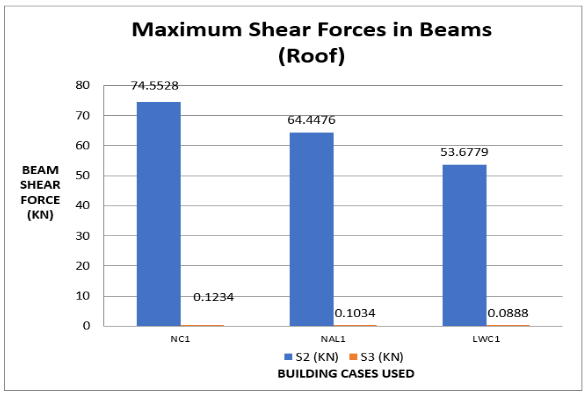

Fig. 10: Maximum Shear Forces in beams (Roof level)

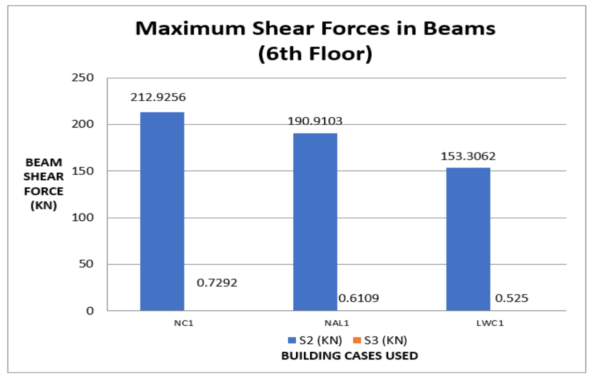

Fig. 11: Maximum Shear Forces in beams (6th floor level)

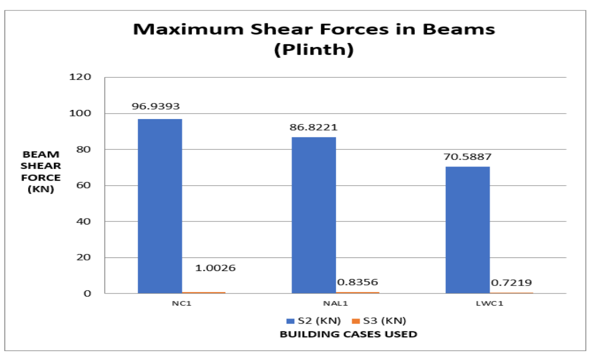

Fig. 12: Maximum Shear Forces in beams (plinth floor level)

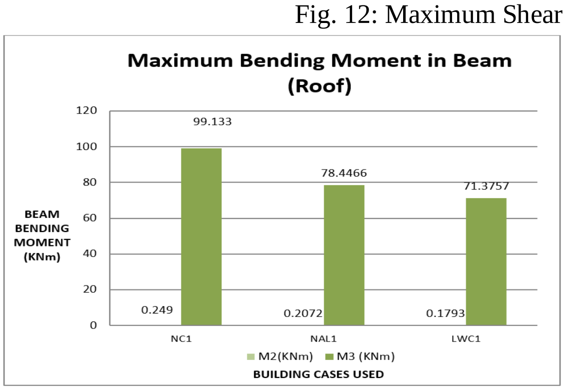

Fig. 13: Maximum Bending Moment in beams (Roof level)

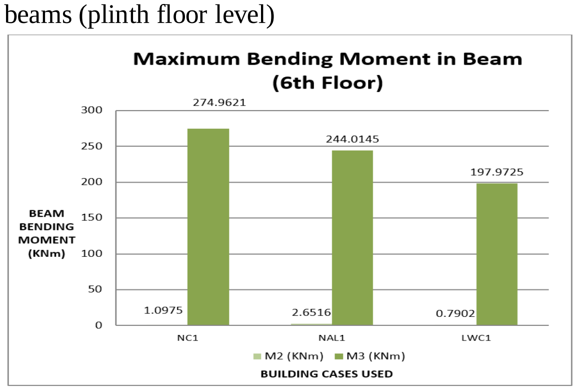

Fig. 14: Maximum Bending Moment in beams (6th floor level)

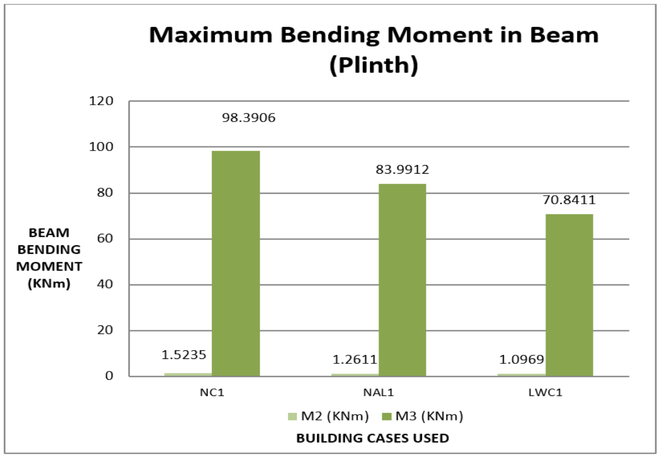

Fig. 15: Maximum Bending Moment in beams (plinth floor level)

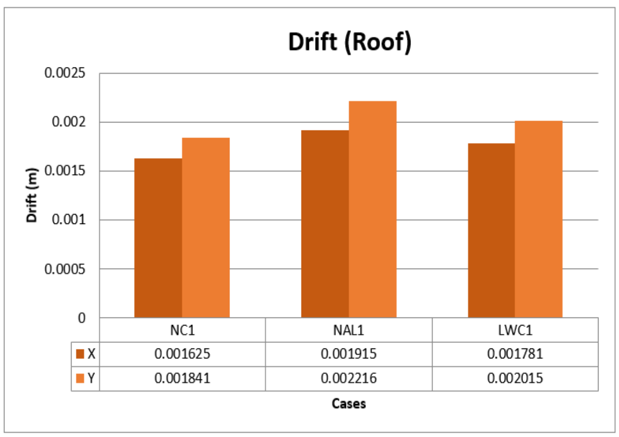

Fig. 16: Maximum Storey Drift (Roof level)6

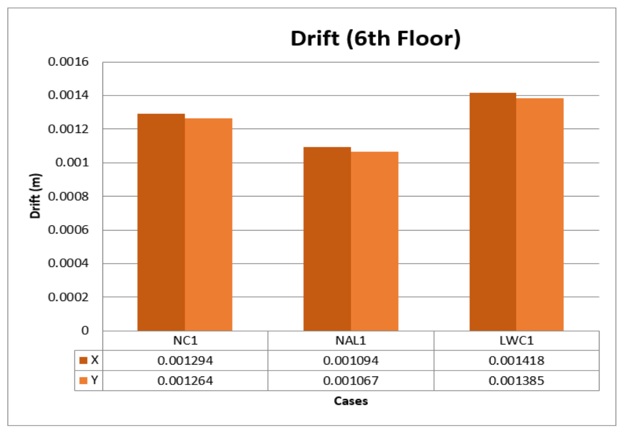

Fig. 17: Maximum Storey Drift (6^{th} floor level)

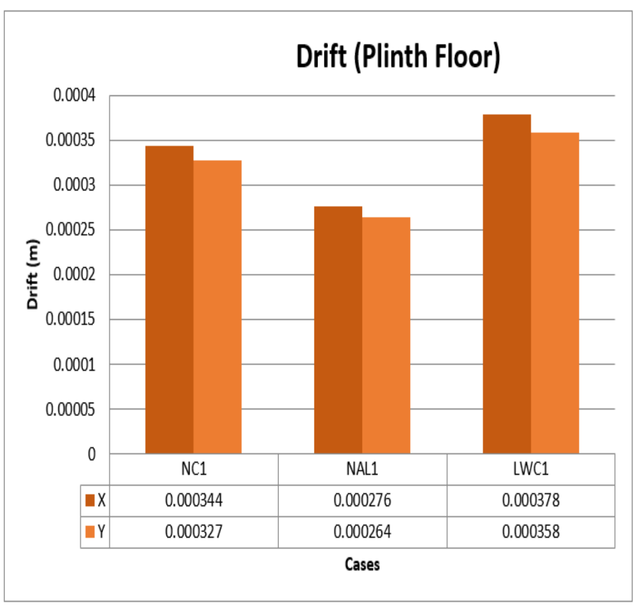

Fig. 18: Maximum Storey Drift (plinth floor level)

VI. CONCLUSIONS

The conclusion can be pointed out for symmetrical plan areas are as follows:-

1) On comparing maximum displacement values with symmetrical plan area,

For roof level,

a) The displacement values increases by 6.86% in X direction and decreases by 7.05% in Y direction when comparing normal concrete (NC) with normal & light weight concrete (NAL).
b) The displacement values increases by 9.63% in X direction and increases by 9.63% in Y direction when comparing normal concrete (NC) with light weight concrete (LWC).

For 6th floor level,

a) The displacement values decreases by 7.97% in X direction and decreases by 17.18% in Y direction when comparing normal concrete (NC) with normal & light weight concrete (NAL).
b) The displacement values increases by 9.63% in X direction and increases by 9.63% in Y direction when comparing normal concrete (NC) with light weight concrete (LWC).

For plinth level,

a) The displacement values decreases by 19.88% in X direction and decreases by19.20% in Y direction when comparing normal concrete (NC) with normal & light weight concrete (NAL).
b) The displacement values increases by 9.58% in X direction and increases by 9.64% in Y direction when comparing normal concrete (NC) with light weight concrete (LWC).

2) Observing base shear values, since the plan area is symmetrical in both X and Y plane, comparing with normal concrete (NC), the base shear decreases by 20.45% for normal & light weight concrete (NAL)and decreases by 28% for light weight concrete (LWC) respectively.
3) Comparing maximum axial forces in column with symmetrical plan area, with normal concrete (NC) the values decreases by 15.36%comparing with normal & light weight concrete (NAL) and decreases by 28% comparing with light weight concrete(LWC) respectively.

4) On comparing **maximum shear force** values with symmetrical plan area.

For roof level,

a) The shear force values decreases by 13.55% in V2 direction and decreases by 16.21% in V3 direction when comparing normal concrete (NC) with normal & light weight concrete (NAL).
b) The shear force values decreases by 28% in V2 direction and decreases by 28.04% in V3 direction when comparing normal concrete (NC) with light weight concrete (LWC).

For 6th floor level,

a) The shear force values decreases by 10.34% in V2 direction and decreases by 16.22% in V3 direction when comparing normal concrete (NC) with normal & light weight concrete (NAL).
b) The shear force values decreases by 28% in V2 direction and decreases by 28% in V3 direction when comparing normal concrete (NC) with light weight concrete (LWC).

For plinth level,

a) The shear force values decreases by 10.44% in V2 direction and decreases by 16.66% in V3 direction when comparing normal concrete (NC) with normal & light weight concrete (NAL).
b) The shear force values decreases by 27.18% in V2 direction and decreases by 28% in V3 direction when comparing normal concrete (NC) with light weight concrete (LWC).

5) On comparing maximum bending moment values with symmetrical plan area,

For roof level,

a) The bending moment values decreases by 16.79% in M2 direction and decreases by 20.87% in M3 direction when comparing normal concrete (NC) with normal & light weight concrete (NAL).

b) The bending moment values decreases by 28% in M2 direction and decreases by 28% in M3 direction when comparing normal concrete (NC) with light weight concrete (LWC).

For 6th floor level,

a) The bending moment values increases by 141.60% in M2 direction and decreases by 11.26% in M3 direction when comparing normal concrete (NC) with normal & light weight concrete (NAL).

b) The bending moment values decreases by 28% in M2 direction and decreases by 28% in M3 direction when comparing normal concrete (NC) with light weight concrete (LWC).

For plinth level,

a) The bending moment values decreases by 17.22% in M2 direction and decreases by 14.63% in M3 direction when comparing normal concrete (NC) with normal & light weight concrete (NAL).

b) The bending moment values decreases by 28% in M2 direction and decreases by 28% in M3 direction when comparing normal concrete (NC) with light weight concrete (LWC).

6) On comparing storey drift values with symmetrical plan area,

For roof level,

a) The storey drift values increases by 17.85% in X direction and increases by 20.37% in Y direction when comparing normal concrete (NC) with normal & light weight concrete(NAL).

b) The storey drift values increases by 9.60% in X direction and increases by 9.45% in Y direction when comparing normal concrete (NC) with light weight concrete (LWC).

For 6th floor level,

a) The storey drift values decreases by 15.46% in X direction and decreases by 15.59% in Y direction when comparing normal concrete (NC) with normal & light weight concrete (NAL).

b) The storey drift values increases by 9.58% in X direction and increases by 9.57% in Y direction when comparing normal concrete (NC) with light weight concrete (LWC).

For plinth level,

a) The storey drift values decreases by 19.77% in X direction and decreases by 19.27% in Y direction when comparing normal concrete (NC) with normal & light weight concrete (NAL).

b) The storey drift values increases by 9.88% in X direction and increases by 9.48% in Y direction when comparing normal concrete (NC) with light weight concrete (LWC).

This project concluded that The use of lightweight concrete in a multi-storey building with a symmetrical plan area significantly reduced the base shear, axial forces in columns, and shear and bending moments in beams and columns at all levels, while slightly increasing story drift at the roof level and decreasing it slightly at the plinth level. Overall, lightweight concrete can be an effective way to reduce the seismic load on a building without sacrificing its structural performance.

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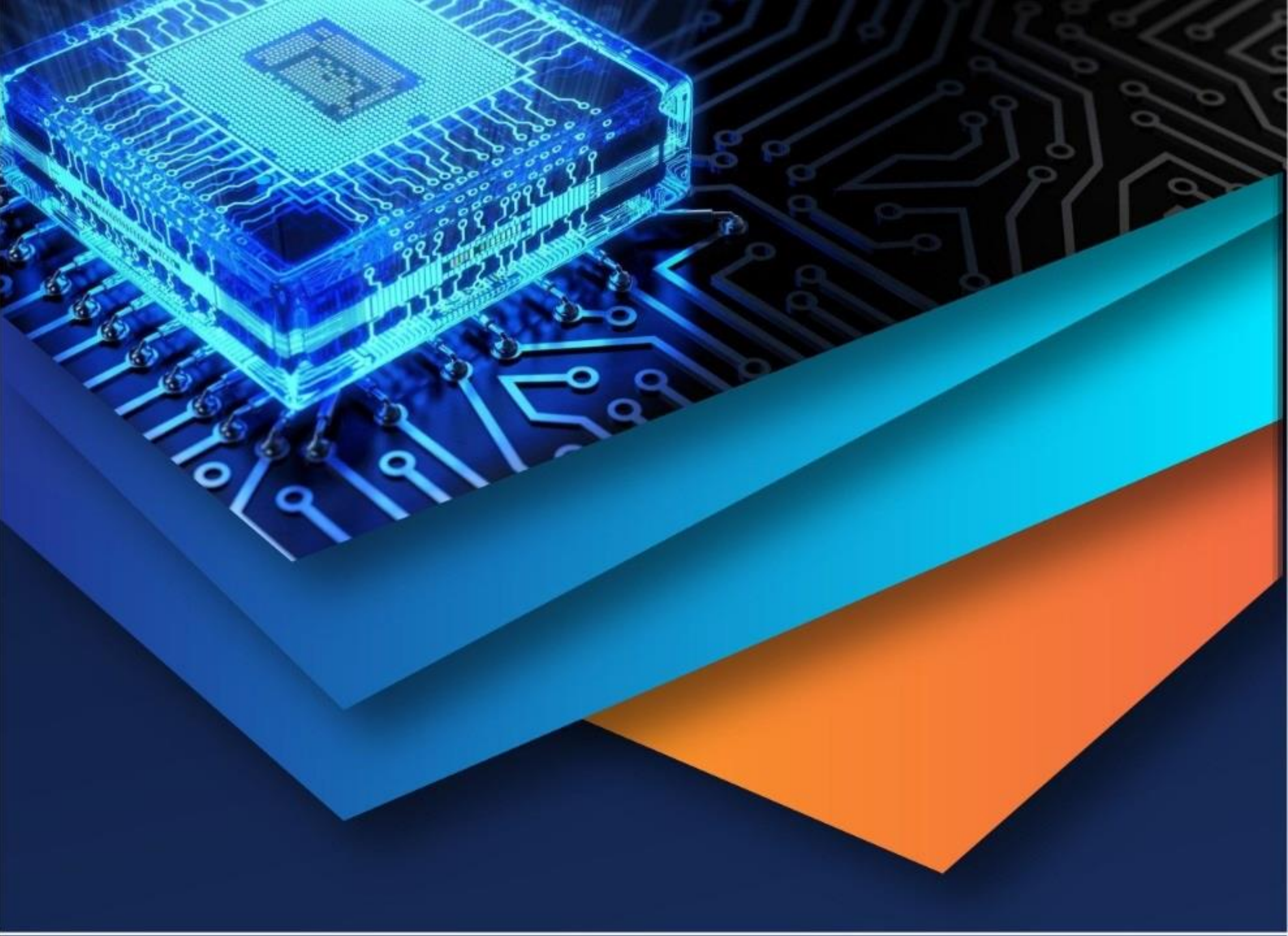

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