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Comparative Study of the Seismic Behaviour of G+20 Storey Building for Unsymmetrical Plan Area Using Light Weight Concrete and Normal Weight Concrete

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Abstract: This research examines and compares the performance of structural lightweight concrete (SLWC) made with scoria and normal weight concrete (NWC), and normal and light weight concrete (NAL) in multi-storey buildings. A G+20 multi-storey unsymmetrical plan building is analysed using the response spectrum method with SLWC and NWC. Bending moment, shear force, storey shear, axial force, storey drift, and storey displacement are considered. The results show that SLWC can be used to reduce the weight of buildings without sacrificing strength or performance. This can lead to significant cost savings on construction and materials.
Keywords: Structural lightweight concrete unsymmetrical plan, response spectrum method, normal and light weight concrete

I. INTRODUCTION

The construction of tall buildings is a complex and challenging task. It requires careful consideration of a number of factors, including structural safety, cost, and sustainability. In recent years, there has been a growing demand for tall buildings, driven by factors such as rapid population growth and economic development. One way to address the challenges of tall building construction is to use lightweight concrete. Lightweight concrete is a type of concrete that has a lower density than traditional concrete. This is achieved by using lightweight aggregates, such as expanded shale, scoria, clay, or slate. Lightweight concrete can weigh up to 35% less than traditional concrete, while still maintaining good strength and other desirable properties.

II. NORMAL CONCRETE AND LIGHT WEIGHT CONCRETE

1) Lightweight concrete is a type of concrete with a reduced density, typically achieved by using lightweight aggregates. This makes it lighter than normal concrete, but with comparable structural strength. Lightweight concrete offers several advantages over normal concrete, including:
   a) Improved thermal insulation: Lightweight concrete has a higher porosity than normal concrete, which gives it better thermal insulation properties. This can help to reduce energy costs and improve the comfort of buildings.
   b) Better fire resistance: Lightweight concrete has a lower thermal conductivity than normal concrete, which means that it takes longer to heat up in a fire. This gives lightweight concrete structures better fire resistance.
   c) Reduced dead loads: Lightweight concrete is lighter than normal concrete, which reduces the dead load on a structure. This can lead to smaller foundation sizes and other structural components, which can save money on construction costs.
2) Normal concrete is the most common type of concrete used in construction. It is made with a mixture of cement, sand, gravel, and water. Normal concrete is strong and durable, but it is also heavy.

The choice between lightweight concrete and normal concrete for a particular building project depends on a number of factors, including:

a) Intended use of the structure: Lightweight concrete is often used for buildings where weight is a concern, such as high-rise buildings, bridges, and offshore structures. Normal concrete is typically used for buildings where durability and affordability are of the utmost importance.
b) Budget constraints: Lightweight concrete can be more expensive than normal concrete, but the cost savings on foundation size and other structural components can offset the higher cost of the concrete itself.

c) Seismic considerations: Lightweight concrete can be a good choice for buildings in seismic zones, as it can reduce the overall weight of the structure and make it less susceptible to damage during an earthquake.
d) Sustainability goals: Lightweight concrete can help to reduce the environmental impact of a building project by reducing the amount of material needed and the energy required to transport it.

In general, lightweight concrete is a good choice for buildings where weight is a concern, such as high-rise buildings, bridges, and offshore structures. It is also a good choice for buildings in seismic zones and buildings where sustainability goals are important. Normal concrete is a good choice for buildings where durability and affordability are of the utmost importance.

III. PROCEDURE AND 3D MODELING OF THE STRUCTURE

Seismic analysis of a G+20 storey building was performed using a software approach, in accordance with IS 1893(PART1):2016, using the response spectrum analysis method. 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
Unsymmetrical Plan area	4m @6 bays in X direction 4m @12 bays in Y direction 1152 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	0.2
Fck	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
Compressive strength	30 MPa
Modulus of Elasticity E (LWC)	$E = 0.043 \times \omega 1.5 \times \sqrt{fc}$ ....Eq. 3.1 17986.13 MPa
Poisson’s ratio	0.20

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)

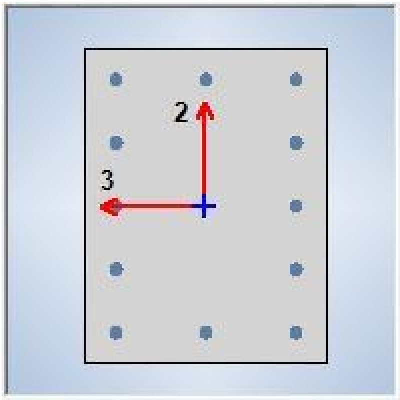

Fig. 1: Cross section of beam member

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 unsymmetrical plan area	1.286 seconds
Fundamental natural period (Taz) in Z direction for unsymmetrical 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 2	Residential apartment with unsymmetrical plan area 1152 sq. m. using normal concrete
2.	LWC 2	Residential apartment with unsymmetrical plan area 1152 sq. m. using light weight concrete
3.	NAL 2	Residential apartment with unsymmetrical plan area 1152 sq. m. using normal and light weight concrete

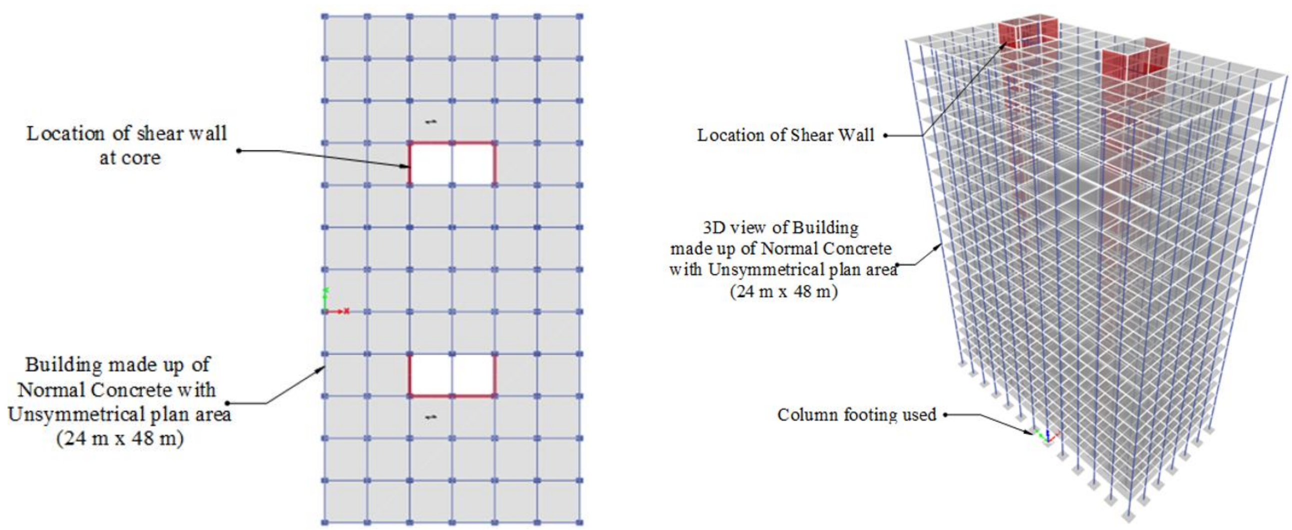

Fig. 2: Plan and 3D view of unsymmetrical plan using Normal Concrete (NC2)

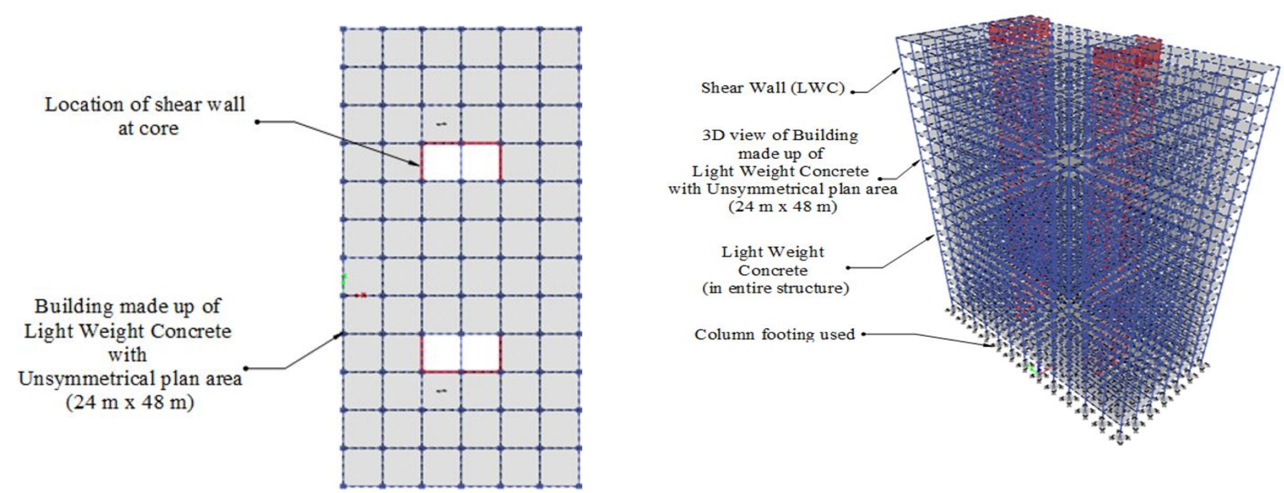

Fig. 3: Plan and 3D view of unsymmetrical plan using Light Weight Concrete (LWC2)

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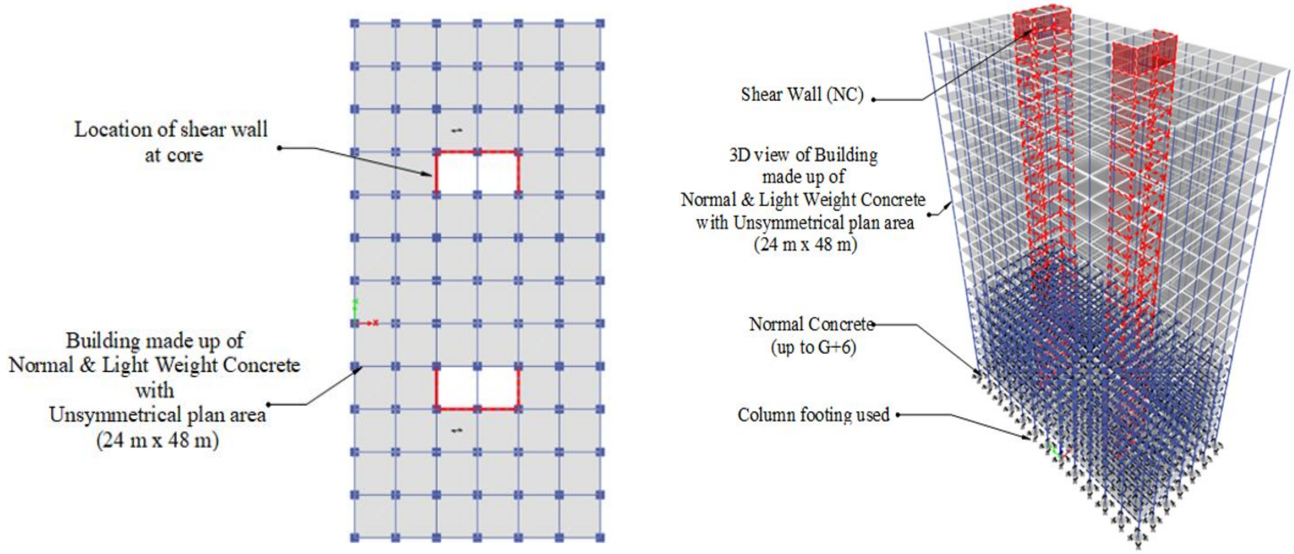

Fig. 4: Plan and 3D view of unsymmetrical plan using Normal and Light Weight Concrete (NAL2)

IV. RESEARCH OBJECTIVES

On keeping in mind the above problem statement outlined for new research work is proposed in the form of conclusive outcomes 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 unsymmetrical 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 unsymmetrical building structure.
5) To study the variation in base shear in both X and Y direction for NC, LWC and NAL unsymmetrical 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 unsymmetrical building structure.
8) To evaluate and relate storey drift in both X and Y direction for NC, LWC and NAL unsymmetrical 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:-

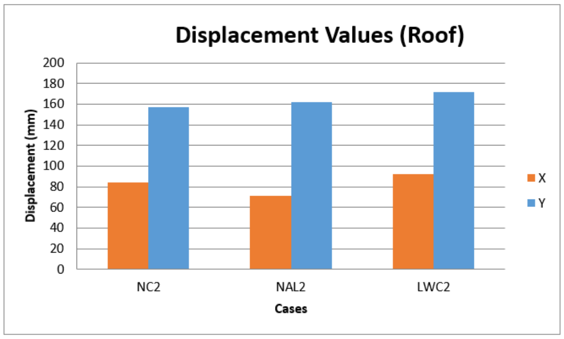

Fig. 5: Maximum Displacement (Roof level)

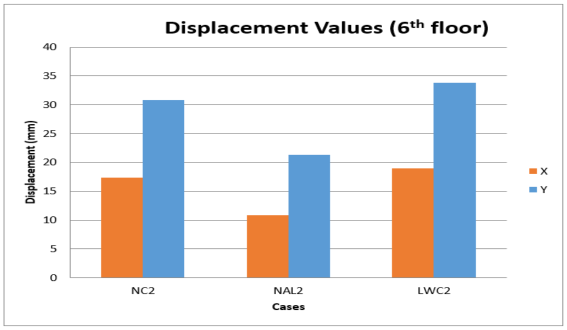

Fig. 6: Maximum Displacement (6^{th} floor level)

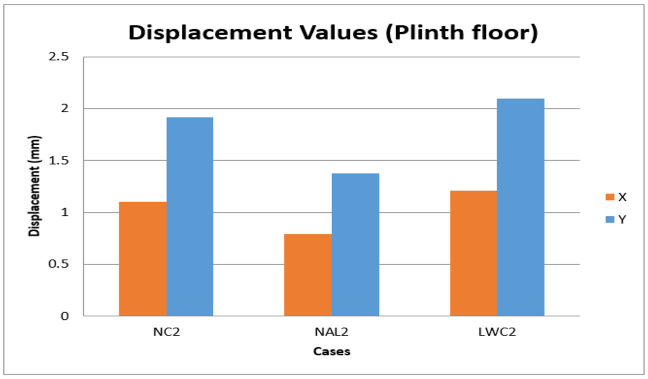

Fig. 7: Maximum Displacement (plinth floor level)

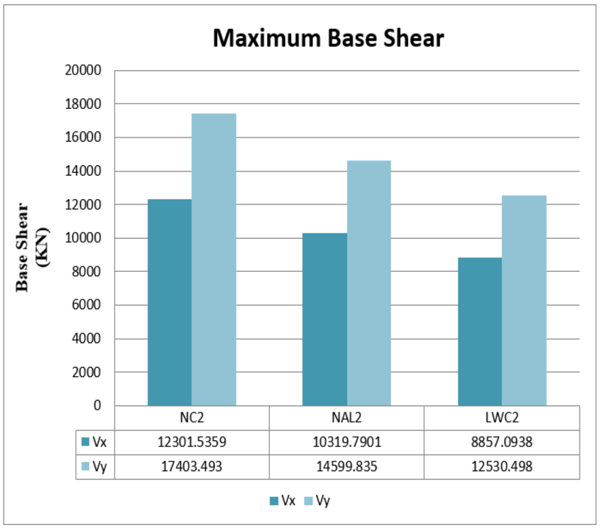

Fig. 8: Maximum Base Shear

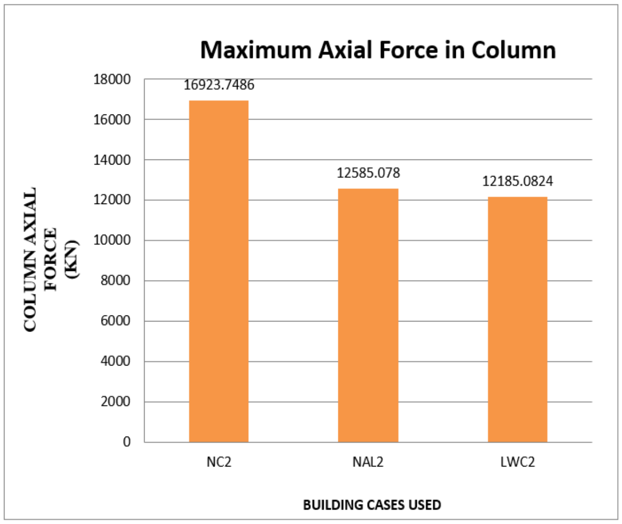

Fig. 9: Maximum Axial Forces

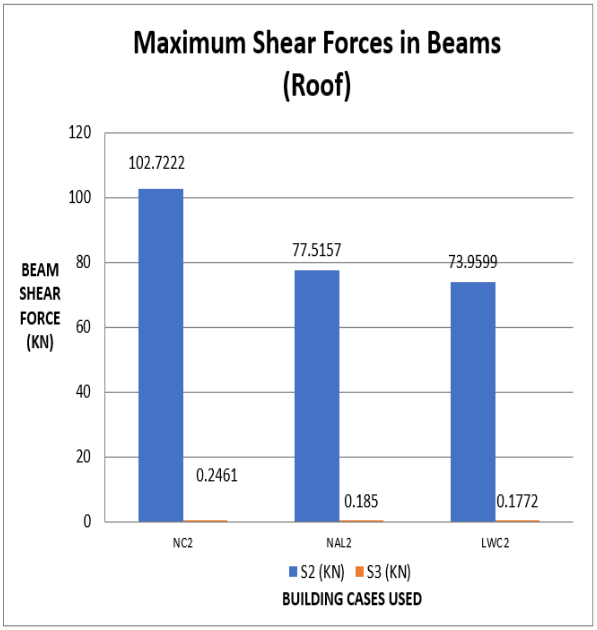

Fig. 10: Maximum Shear Forces in beams (Roof level)

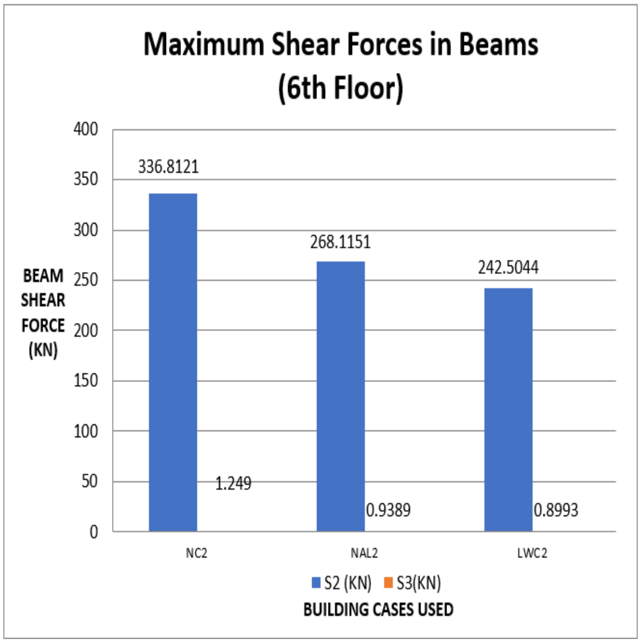

Fig. 11: Maximum Shear Forces in beams (6^{th} floor level)

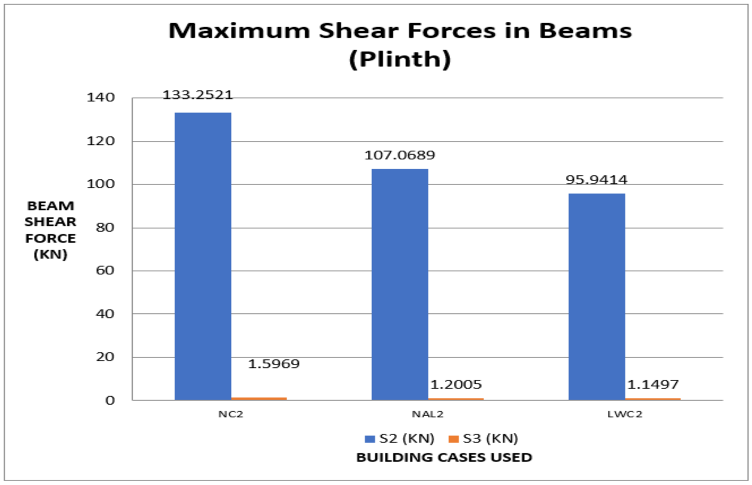

Fig. 12: Maximum Shear Forces in beams (plinth floor level)

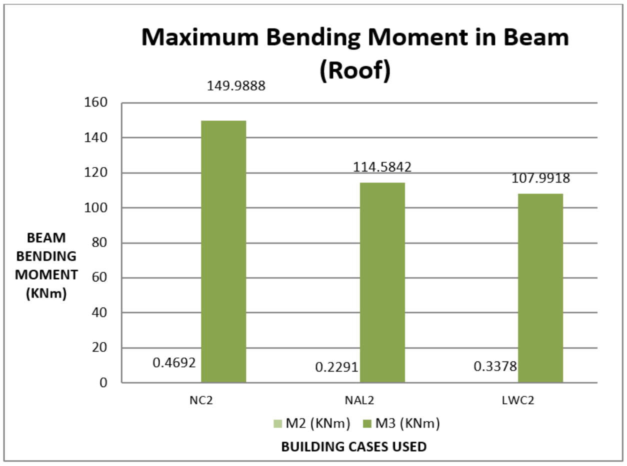

Fig. 13: Maximum Bending Moment in beams (Roof level)

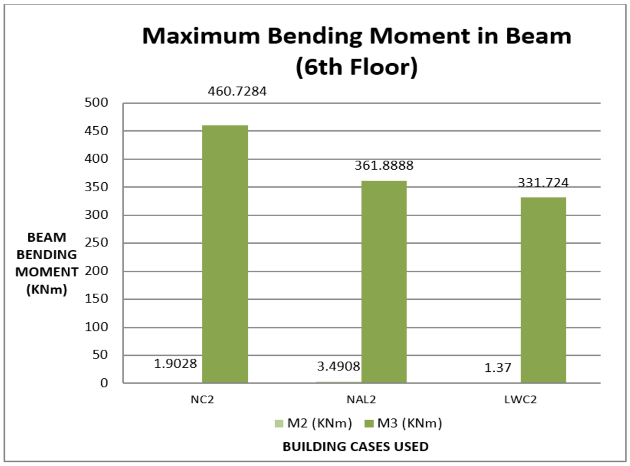

Fig. 14: Maximum Bending Moment in beams (6th floor level)

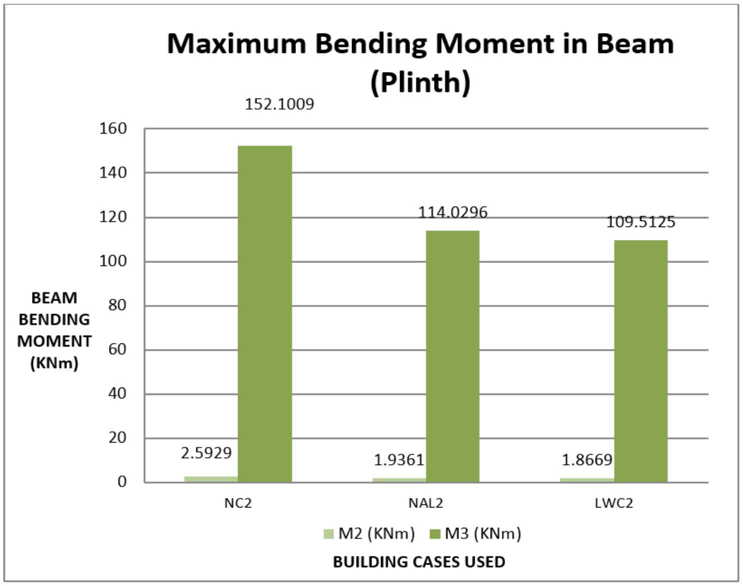

Fig. 15: Maximum Bending Moment in beams (plinth floor level)

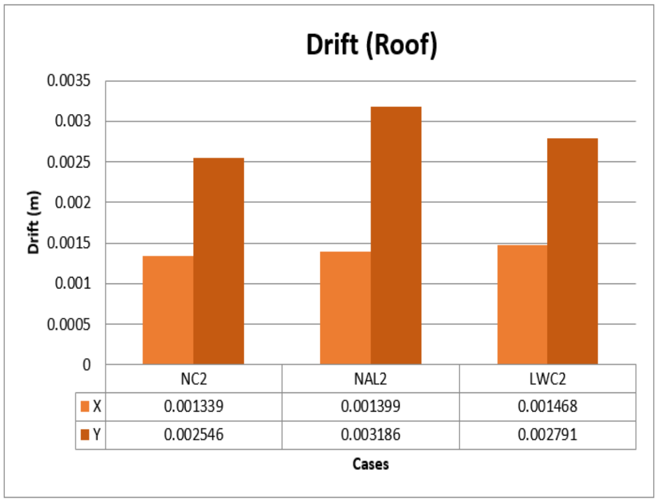

Fig. 16: Maximum Storey Drift (Roof level)6

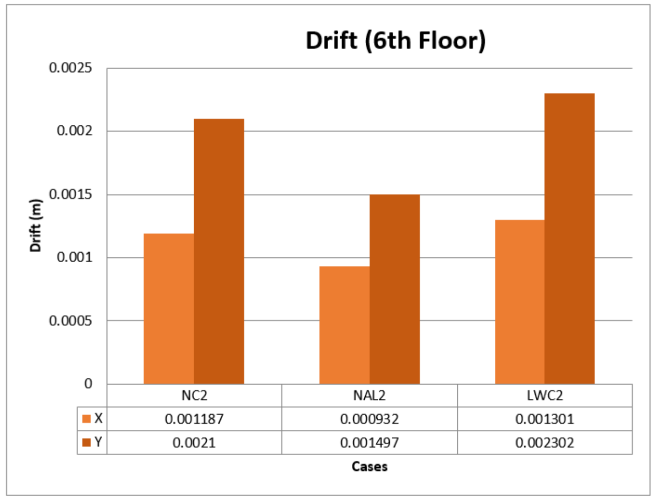

Fig. 17: Maximum Storey Drift (6th floor level)

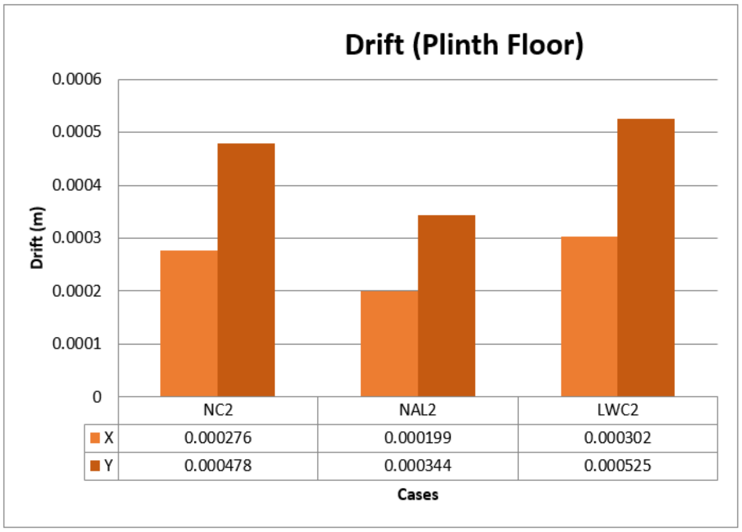

Fig. 18: Maximum Storey Drift (plinth floor level)

VI. CONCLUSIONS

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

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

For roof level,

a) The displacement values decreases by 15.54% in X direction and increases by 3.37% 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 37.11% in X direction and decreases by 30.70% 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 27.86% in X direction and decreases by 28.11% in Y direction when comparing normal concrete (NC) with normal & light weight concrete (NAL).

b) The displacement values increases by 9.62% in X direction and increases by 9.61% in Y direction when comparing normal concrete (NC) with light weight concrete (LWC).

2) Observing base shear values, since the plan area is unsymmetrical in both X and Y plane, comparing with normal concrete (NC) for X and Y directions, the base shear decreases by 28% and 28% for normal & light weight concrete (NAL) and decreases by 28% and 28% for light weight concrete (LWC) respectively.

3) Comparing maximum axial forces in column with unsymmetrical plan area, with normal concrete (NC) the values decreases by 25.64% 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 unsymmetrical plan area.

For roof level,

a) The shear force values decreases by 24.54% in V2 direction and decreases by 24.83% 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 20.40% in V2 direction and decreases by 24.83% in V3 direction when comparing normal concrete (NC) with normal & light weight concrete (NAL).

b) The shear force value 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 19.65% in V2 direction and decreases by 24.82% 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).

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

For roof level,

a) The bending moment values decreases by 51.17% in M2 direction and decreases by 23.60% in M3 direction when comparing normal concrete (NC) with normal & light weight concrete (NAL).

b) The bending moment values decreases by 28.01% 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 83.% in M2 direction and decreases by 21.45% 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 25.33% in M2 direction and decreases by 25.03% 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 unsymmetrical plan area,

For roof level,

a) The storey drift values increases by 4.48% in X direction and increases by 25.14% in Y direction when comparing normal concrete (NC) with normal &light weight concrete (NAL).

b) The storey drift values increases by 9.63% in X direction and increases by 9.62% in Y direction when comparing normal concrete (NC) with light weight concrete (LWC).

For 6th floor level,

a) The storey drift values decreases by 21.48% in X direction and decreases by 28.71% 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 9.62% in Y direction when comparing normal concrete (NC) with light weight concrete (LWC).

For plinth level,

a) The storey drift values decreases by 27.90% in X direction and decreases by 28.03% in Y direction when comparing normal concrete (NC) with normal & light weight concrete (NAL).

b) The storey drift values increases by 9.42% in X direction and increases by 9.83% in Y direction when comparing normal concrete (NC) with light weight concrete (LWC).

This project concluded that when The use of NAL or LWC in unsymmetrical plan area buildings can lead to a reduction in lateral forces (base shear and storey drift) and internal forces (axial forces in columns and shear force and bending moment values). This is because these materials have a lower density and higher strength than normal concrete, which results in a lighter and stronger structure. However, it is important to note that storey drift values may increase slightly, especially in the upper floors of the building. Overall, the use of NAL or LWC can improve the structural performance of unsymmetrical plan area buildings.

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