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"Seismic Analysis of Light Weight Concrete Structure by Response Spectrum Method"

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Abstract: Structural construction requires to forfeitattention in specific stresses generationdue to various loads in buildings via differentacting load. Seismic forces are occasionallydeep earth occurring vibrations but have high impact on the surfacial structural proficient unity of the building. Structural lightweight concretesincorporationoffer design flexibility, ductility and substantial economy by providing less dead load.
The ductility of a reinforced structure is one of the most vital factors affecting its seismic act and behaviour. This work concentrate on analysis of structures with high-rise building under seismic effect based on Normal and Light weight RCC work, this study includes in structural sections. Reinforced light weight concrete section can provide an effective and economic solution to most of problems in average to high-rise buildings.

Key Words: Seismic Loads, Light weight concrete, Flexibility & Ductility

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I. INTRODUCTION

A concise conversation on the difference involving lightweight and normal weight concrete is desirable due to the design differences in the quality and density of aggregate. Numerous tests have been conducted on normal weight concrete but very few tests have been performed on lightweight structures. The term lightweight concrete itself describes a wide range of special aggregate bases. The specific gravities and in terms of density of compactness of these aggregates are significantly lower than that of normal weight concrete aggregates. Air is naturally trapped in the aggregate from its origin which causes the reduced weight of the concrete mixture. The properties of lightweight concrete vary with the type of aggregate and the source and size of the aggregate.

Seismic design for reinforced concrete buildings is an area of research since; the earthquake engineering has started internationally. The building assemblies get damage due to one or combined effect of other reason during earthquakes. Inspite of all the weakness in the structure, either code imperfections or error in analysis and designs, the structural configuration system has played a vital role in devastation. The IS: 1893 (Part-1): 2002 has suggested building configuration system in Section - 7 for the better performance of reinforced concrete buildings during earthquake disturbances.

One of the major contributors to structural damage in structures during strong earthquake is the discontinuities/irregularities in the load path or load transfer. The structure should contain a continuous load path for transfer of the seismic force, which develops due to accelerations of individual elements, to the ground. It is recognized that neither the complete protection against earthquakes of all sizes is economically feasible nor design alone based on strength criteria is justified. The basic approach of earthquake resistant design should be based on lateral strength as well as deformability and ductility capacity of structure with limited damage but no collapse.

Over the last decade or more, other valuable and practical non-destructive evaluation methods have been developed for relatively rapid inspection of damage and deterioration of reinforced concrete structures. Earthquake shaking is random and time variant. But, most design codes represent the earthquake -induced inertia forces as the net effect of such random shaking in the form of design equivalent static lateral force. This force is called as the Seismic Design Base Shear VB and remains the primary quantity involved in force-based earthquake-resistant design of buildings. This force depends on the seismic hazard at the site of the building represented by the Seismic Zone Factor Z.

1.1. Objective of Study.

The foremost objective of the present work is to examine the usability of the light weight concrete asa filling mass instead of normal weight concrete.Utility of lightweight concrete has been investigated by analysis on staad.pro software using response spectrummethod.

1) To study the effect of use of light weight concrete in seismic areas.
2) To compare the compressive, flexural and ductility strength with the given design specification of reinforced light weight concrete in seismic areas.

II. LITERATURE REVIEW

Abdel hamid Charif et. Al. [1], "Ductility of reinforced lightweight concrete beams and columns" in Latin American Journal of Solids and Structures vol.11 no.7 Rio de Janeiro Dec. 2014 found that Lightweight concrete members developed more ductile behavior than their normal concrete counterparts, and this enhanced ductility was more pronounced in columns subjected to axial compression forces.

Barbara Chang [2] "Ductile Reinforced-Concrete Beam-Column Joints with Alternative Detailing" at EERI Annual Meeting February University of California, San Diego 2009 by found that Fracture of longitudinal beam rebar requires consideration (but for demands greater than 7% drift).

C. V. R. Murty et. Al. [3] "Some Concepts in Earthquake Behaviour of Buildings" a book published by Gujarat State Disaster Management Authority in (2002) shows the structural behaviour of various building members under various condition of seismic loading.

Jan A. Overli et. Al. [4] "Increasing ductility in heavily reinforced LWAC structures" in Engineering Structures Volumes 62–63, Jensen founded that the ductility index proved to be the same for beams with fibre or stirrups, and was almost doubled for beams with both fibre and stirrups and The effect of adding steel fibre reinforcement in the compressive gradient zone of full-scale, over-reinforced LWAC beams was much more pronounced regarding ductility than the effect achieved from tests of stress–strain relationships on cylinders with the same fibre reinforced LWAC.

Ninad P. Pawar et. Al. [5] "Ductility Requirements of Earthquake Resistant Reinforced Concrete Buildings" concluded that In earthquakes, failure of buildings occurs due to non-ductile behaviour of its components, so following members should be designed with appropriate ductile detailing, for flexural members. The structural elements and their connections enhance the ductility of the structure which will enable the structure to absorb energy during earthquake and to sustain large inelastic deformation without sudden collapse of the structure.

H. Bomhard et. Al [6] "Lightweight concrete structures potentialities, limits and realities" This paper was published as part of the Proceedings of the CI80 Congress on Lightweight Concrete, London; The International Journal of Lightweight Concrete, Volume 2, Number – 4 Dec, (1980) by concluded that Structural lightweight concrete can be economical especially in the combination of high load-bearing capacity and low density, but also by the low density alone.

Hjh Kamsiah Mohd. Ismail et. Al. [7] "Study of Lightweight Concrete Behaviour" This research work thesis is carried (2004) and the initial findings have shown that the lightweight concrete has a desirable, strength to be an alternative construction material for the industrialized building system. The foamed lightweight concrete is not suitable to be used as non-load bearing wall as the compressive strength is 27% less than recommended. Nevertheless the compressive strength is accepted to be produced as non-load bearing structure.

X.-K. Zou et. Al. [8] "Optimal seismic performance-based design of reinforced concrete buildings using nonlinear pushover analysis" published in Engineering Structures (2005) by concluded that, It has been demonstrated that steel reinforcement plays a significant role in controlling the lateral drift beyond first yielding and in providing ductility to an RC building framework. a restrictive move limit imposed on the steel reinforcement design variables is necessary to ensure a smooth and steady on vengeance of the inelastic drift design process.

a. Summary from literature Go-Through.

The structural details, layout, location, loads coming and designing process and methodology adopted on it, is very much important in respect to analysis of any building for safety prospective point of view. Better the structural data available with the designer better will be the design result obtained. In case of seismic analysis of the structure the load data is very important such as dead load and the seismic load propagation path and vibration time period of earthquake.

The material used usually provides the stability as well as ductility to the structural members but if not properly employed may cause high dead load and stresses in building. Lightweight concrete insures lower dead weight or load and high ductility with low dense mass providing less compatible medium to seismic waves to propagate and making building structure safe from being damaged. Lower the dead weight or load higher the building could be raised with better seismic stability allowing safe damping of forces even if there is any structural damage it could save life of people by heavy weight structure under if any get trapped and easily could be removed.

III. METHODOLOGICAL BACKGROUND

The setupof this workconcentrates within; calamitous loss of life and wealth after seismic activity, leaving behind bulk of dismantled and scraped mass of structure. This is weighty and requires large machineries for removing of debried scrap.

Heavier the mass; higher will be the time period as well as the cost of removal and transportation at damping site, too will be on higher side. Large and big machinery requires large amount of fuel consumption and higher operational cost. Most importantly lighter the building structure mass lesser will be the chances of casualty and faster will be the rescue operation if required at an reasonable cost.

Estimate the probable seismic load coming on the building structure and design the structural members as per codal provision guidelines. Prevent brittle failure mechanisms to take place prior to ductile yielding. Moment resisting frame has three components namely Beams, Columns and Rigid joint between beams and columns.

The experimental setup was done to analyze the effects of structural lightweight concrete seismic behaviour in High - rise building by framing out simulation model in STAAD.Pro software tool. The building is having fifteen stories and overall 44.8 m assembled as G + 14. The building to be analyzed here is completely made up of lightweight concrete; structural members include both horizontal and vertical members. The building is located at seismic zone II, which is highly prone to after seismic effects and regular seismic actions due to various internal disturbances.

Structural details of LWC (G + 15) building:

i. Number of storey =15 (G + 14)
ii. Height of storey = 2.8 m with G.F column and storey column 3.0 m
iii. Cross-section of beams = 350 x 300
iv. Cross-section of columns = as follows 350 x 400 in Outer section,
400 x 400 in intermediatesection,
500 x 600 in corecolumnsand base.
v. Span of beam = 4m(x-dir) & 4 m(y-dir).
vi. Grade of concrete = M35
vii. Grade of steel = Fe 415
viii. Dead Load = -1 factor load and-2.5 kN/m2 as floor load.
ix. Live Load = -1.5KN/m2 on Floor and 2 on beams.
x. Seismic Load = As per IS: 1893– 2002,with Z = 0.1,
xi. RF = 5, I = 1, SS = 1, DM = 0.045

Analysis of Building: Analysis is done by using STAAD. Pro under design consideration IS: 456 - 2000 and IS: 13920 - 1993.

Appling the Response Spectrum command loading for dynamic analysis. This capability allows for analyzing the structure for seismic loading. For any supplied response spectrum (either acceleration vs. period or displacement vs. period), joint displacements, member forces, and support reactions may be calculated. Modal responses are combined using the complete quadratic combination (CQC), methods to obtain the resultant responses. Results of the response spectrum analysis may be combined with the results of the static analysis to perform subsequent design. to account for reversibility of seismic activity, load combinations can be created to include either the positive or negative contribution of seismic results.

Complete Quadratic Combination (CQC) method. The maximum response from all the modes is calculated as

$$r_{\max} = \sqrt{\sum_{i=1}^{n} \sum_{j=1}^{n} r_i \, \alpha_{ij} \, r_j}$$

Where r_i and r_j are maximum responses in the i^{th} and j^{th} modes, respectively and α_{ij} is correlation coefficient given by

$$\alpha_{ij} = \frac{8\left(\xi_i\ \xi_j\right)^{1/2}\left(\xi_i + \beta\xi_j\right)\beta^{3/2}}{\left(1-\beta^2\right)^2 + 4\ \xi_i\xi_j\beta\left(1+\beta^2\right) + 4\left(\xi_i^2 + \xi_j^2\right)\beta^2}$$

Where ξ_i and ξ_j are damping ratio in i^{th} and j^{th} modes of vibration, respectively and $\beta = \frac{\omega i}{\omega j}$ and $(\omega i > \omega j)$ also; the range of coefficient, α_{ij} is $0 < \alpha_{ij} < 1$ and 1. $\alpha_{ii} = \alpha_{jj} = 1$

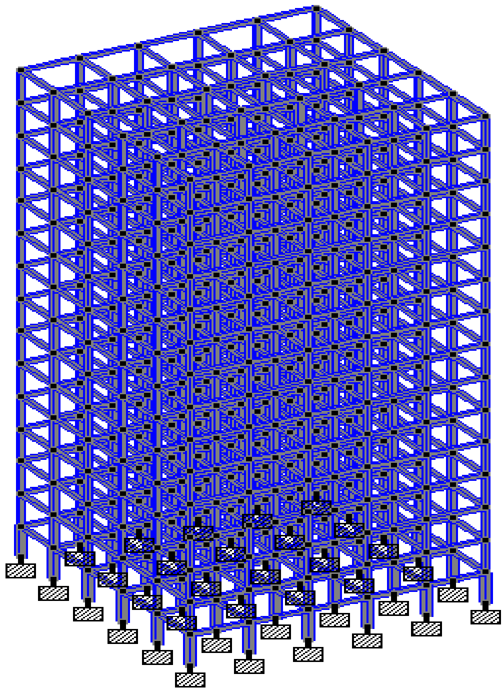


Figure 3.1: LWC RCC structure framed in Staad.Pro

IV. RESULT ANALYSIS

A light weight concrete structure is analyzed on the basis of codal provisions and in STAAD.pro software with different specifications of design details as specified previously in methodology. The result analysis is obtained by the software as per the entered data. Here result is shown on the basis of tables and graphs obtained from analysis.

a. TABULAR RESULTS –

Table I - Max Displacement under applied loads for M35 grade concrete with fe415.

	Beam	L/C	Node	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
Max Fx	70	9 GENERATED INDIAN CODE GENRAL STRUCTURES 6	46	1886.193	-0.384	55.116	1.361	288.589	0.303
Min Fx	1435	1 LOAD CASE 1	3	-501.485	0.023	68.364	0.944	21.041	0.027
Max Fy	334	10 GENERATED INDIAN CODE GENRAL STRUCTURES 7	139	0.420	116.807	0.026	-0.013	-0.053	208.240
Min Fy	334	9 GENERATED INDIAN CODE GENRAL STRUCTURES 6	145	0.420	-116.807	-0.026	0.013	-0.053	208.240
Max Fz	91	10 GENERATED INDIAN CODE GENRAL STRUCTURES 7	15	1774.542	-0.346	141.177	0.575	-337.643	-0.812
Min Fz	97	9 GENERATED INDIAN CODE GENRAL STRUCTURES 6	21	1774.542	-0.346	-141.177	-0.575	337.643	-0.812
Max Mx	188	4 GENERATED INDIAN CODE GENRAL STRUCTURES 1	68	1597.267	63.416	3.217	12.194	7.749	100.078
Min Mx	187	4 GENERATED INDIAN CODE GENRAL STRUCTURES 1	103	1512.396	-63.416	-4.821	-12.194	-6.716	-93.789
Max My	74	9 GENERATED INDIAN CODE GENRAL STRUCTURES 6	50	1513.000	-0.012	127.697	1.197	344.559	-0.010
Min My	62	10 GENERATED INDIAN CODE GENRAL STRUCTURES 7	38	1513.000	-0.012	-127.697	-1.197	-344.559	-0.010
Max Mz	334	9 GENERATED INDIAN CODE GENRALSTRUCTURES 6	145	0.420	-116.807	-0.026	0.013	-0.053	208.240
Min Mz	334	11 GENERATED INDIAN CODE GENRAL STRUCTURES 8	139	0.252	-83.231	-0.026	0.013	0.053	-181.686

Table II - Max beam forces and moments under applied loads for M35 grade concrete with fe415

	Beam	L/C	Node	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
Max Fx	70	9 GENERATED INDIAN CODE GENRAL STRUCTURES 6	46	1886.193	-0.384	55.116	1.361	288.589	0.303
Min Fx	1435	1 LOAD CASE 1	3	-501.485	0.023	68.364	0.944	21.041	0.027
Max Fy	334	10 GENERATED INDIAN CODE GENRAL STRUCTURES 7	139	0.420	116.807	0.026	-0.013	-0.053	208.240
Min Fy	334	9 GENERATED INDIAN CODE GENRAL STRUCTURES 6	145	0.420	-116.807	-0.026	0.013	-0.053	208.240
Max Fz	91	10 GENERATED INDIAN CODE GENRAL STRUCTURES 7	15	1774.542	-0.346	141.177	0.575	-337.643	-0.812
Min Fz	97	9 GENERATED INDIAN CODE GENRAL STRUCTURES 6	21	1774.542	-0.346	-141.177	-0.575	337.643	-0.812
Max Mx	188	4 GENERATED INDIAN CODE GENRAL STRUCTURES 1	68	1597.267	63.416	3.217	12.194	7.749	100.078
Min Mx	187	4 GENERATED INDIAN CODE GENRAL STRUCTURES 1	103	1512.396	-63.416	-4.821	-12.194	-6.716	-93.789
Max My	74	9 GENERATED INDIAN CODE GENRAL STRUCTURES 6	50	1513.000	-0.012	127.697	1.197	344.559	-0.010
Min My	62	10 GENERATED INDIAN CODE GENRAL STRUCTURES 7	38	1513.000	-0.012	-127.697	-1.197	-344.559	-0.010
Max Mz	334	9 GENERATED INDIAN CODE GENRALSTRUCTURES 6	145	0.420	-116.807	-0.026	0.013	-0.053	208.240
Min Mz	334	11 GENERATED INDIAN CODE GENRAL STRUCTURES 8	139	0.252	-83.231	-0.026	0.013	0.053	-181.686

Table III - Max beam stresses under applied loads for M35 grade concrete with fe415.

Mode	Frequency Hz	Period seconds	Participation X %	Participation Y %	Participation Z %
1	0.757	1.320	78.193	0.000	0.000
2	0.777	1.288	0.000	0.000	77.645
3	0.854	1.170	0.000	0.000	0.000
4	2.306	0.434	9.737	0.000	0.000
5	2.371	0.422	0.000	0.000	9.762
6	2.581	0.387	0.000	0.000	0.000

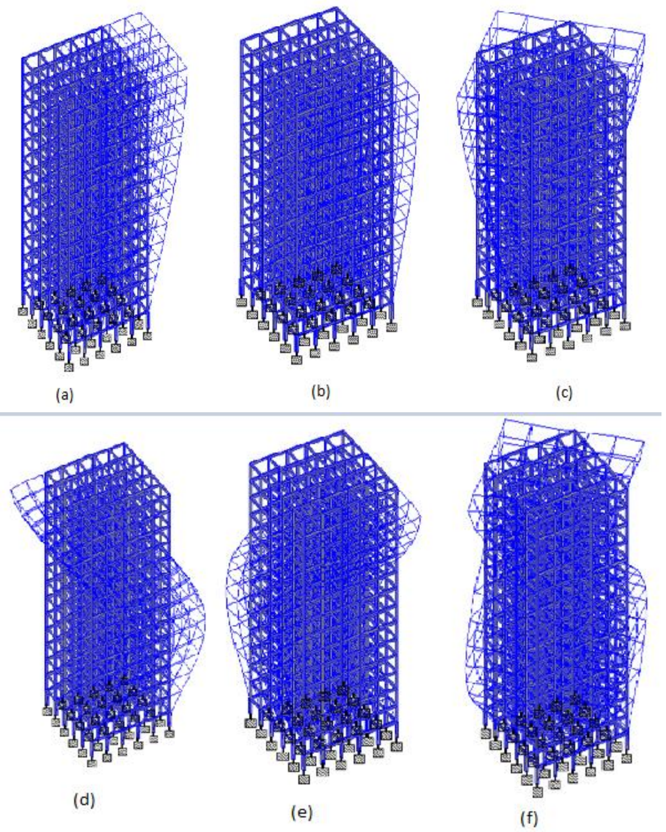
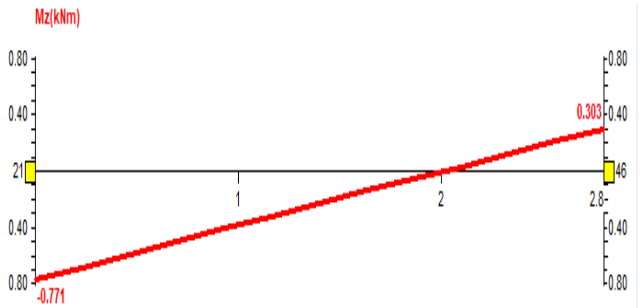
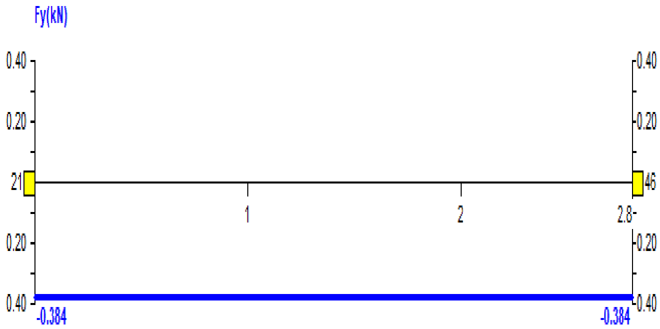


Figure 4.1: Mode shapes (a, b, c, d, e & f) for LWC RCC structure framed in Staad.Pro

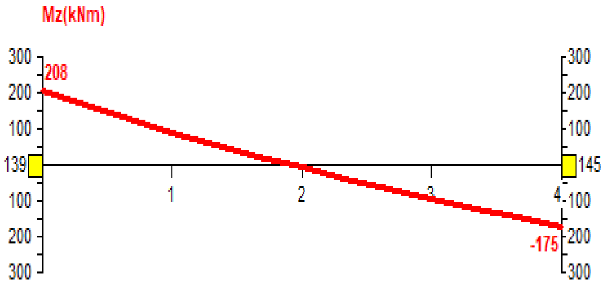
b. GRAPHICAL RESULTS –



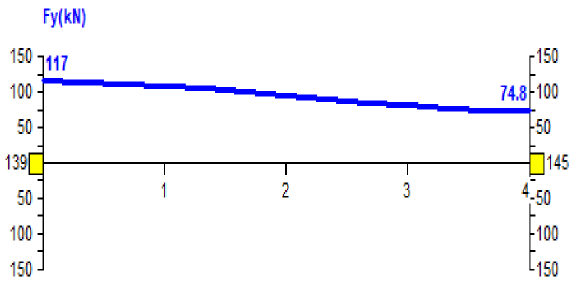
Graph I – Moments (z – Direction) critical Beam No. 70 under combination load - 9.



Graph II. – Shear Force (y – Direction) critical Beam No. 70 under combination load - 9.



Graph III. – Moments (z – Direction) critical Beam No. 334 under combination load - 10.



Graph IV – Shear Force (y – Direction) critical Beam No. 334 under combination load - 9.

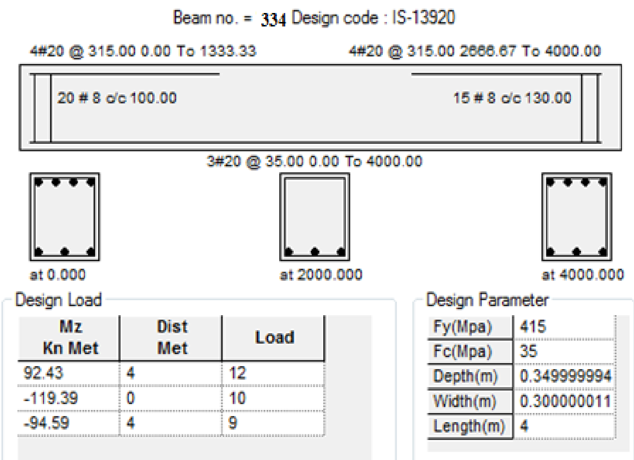
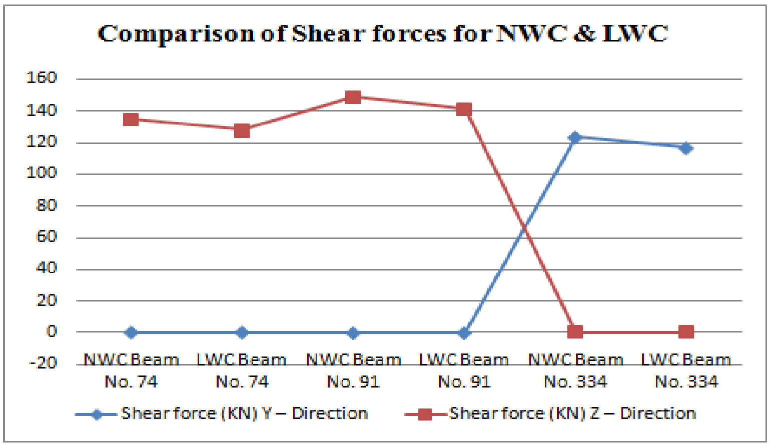


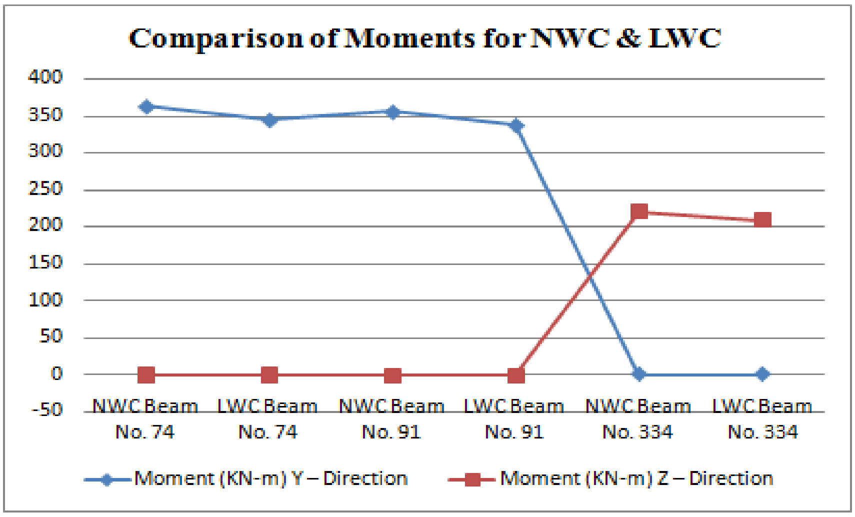
Figure 4.2: RCC design details of beam No. 334 as per loads applied.

Table No. - 4.4. Comparison between normal weight and light weight RCC effects on structure building under same load case.

S.No	Description	Shear force (KN)		Moment (KN-m)		Remark
		Y – Direction	Z – Direction	Y – Direction	Z – Direction	
1	NWC Beam No. 74	-0.011	**134.538**	**362.934**	-0.013	Shear force & Moment of NWC is greater than LWC in all conditions for similar member under same load case.
2	LWC Beam No. 74	-0.012	**127.697**	**344.559**	-0.010	
3	NWC Beam No. 91	-0.399	**148.727**	**-355.685**	-0.918	
4	LWC Beam No. 91	-0.346	**141.177**	**-337.643**	-0.812	
5	NWC Beam No. 334	**123.489**	0.028	-0.055	**219.510**	
6	LWC Beam No. 334	**116.807**	0.026	-0.053	**208.240**	



Graph V. – Comparison of Shear forces for NWC & LWC under applied loads.



Graph VI. – Comparison of Moments for NWC & LWC under applied loads.

```
**************  CONCRETE  TAKE OFF  **************
      (FOR BEAMS AND COLUMNS DESIGNED ABOVE)

TOTAL VOLUME OF CONCRETE =      463.56 CU.METER

              BAR DIA         WEIGHT
              (in mm)         (in New)
              --------        --------
                 8            133294.69
                10             59910.91
                12            115746.36
                16            108680.84
                20            129237.57
                25             12780.56
                           ============
              *** TOTAL=      559650.94
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**************  CONCRETE  TAKE OFF  **************
      (FOR BEAMS AND COLUMNS DESIGNED ABOVE)

TOTAL VOLUME OF CONCRETE =      656.88 CU.METER

              BAR DIA         WEIGHT
              (in mm)         (in New)
              --------        --------
                 8            152651.20
                10             54193.09
                12            170535.33
                16            163291.27
                20            144149.50
                25             43907.62
                32             22293.79
                           ============
              *** TOTAL=      779022.69
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Figure 4.3: Comparison between materials i.e. concrete and steel requirement in construction as per LWC & NWC specifications under applied loads.

Table 4.5.: Estimation of Cost for Designed Building.

Item No	Particulars of item	No.	Qty	Unit	Rate	Amount
1	NWC M35	1	656.88	m³	10000	6568800
	Steel Req Fe450	1	77902.3	kg	55	4284626.5
						10853426.5
2	LWC M35	1	463.56	m³	11000	5099160
	Steel Req Fe450	1	55965.1	kg	55	3078080.5
						8177240.5
					Difference	2676186

V. RESULT DISCUSSION

In the dynamic analysis i.e. response spectrums CQC method is applied and the viability of the structure is checked. The structural evaluation of member like beam and column is tried to solve by providing examples like; beam (no. 70, 74, 91 & 334) and column (no. 188). This thesis work defines the basic adequacy of member against the applied load condition and combinations as per provisions allowed. It is observed that mass participation percentage is decreased by using lighter weight or say lower dense materials in filling. It also reduces the structural modes of failures under torsions, shear and bending, due to reduction in vibration media of member.

On comparison between normal weight and light weight RCC building structure under similar load cases; it have been observed that; Shearing, Tearing and Moments are considerably reduced in LWC Structure. The percentage of reinforcement required is also reduced for LWC RCC members as moment acting on the member gets reduced. The critical load case obtained in this analysis is load combination. The dynamic analysis results so obtained also; shows that structure undergoes high lateral deformation and deflection but remain safe even under critical values of forces.

Results as obtained astabular and graphical representations show that there is substantial fall down in shearing forces and moments along all coordinate axes under defined structural loads like; dead, live and seismic loadings. The loads causes significance vibrations, which make structure to deform or get displaced from connecting joints, or say; the node to node displacements. Statisticsguides that the structural entitiesassembliesare at most on critical region as if not appropriately investigated for seismic time period and its after affects (eg. bursting out of column and beams in lateral direction) which might be calamitous.

The confined experience in this research work study reveals that the Light weight concrete reduces theforward movement of seismic vibrations and hence; reduces the threat of structural collapse under base shear, storey drift and soft storey effect. Lower density material reduces seismic vibration effect by allowing forces to pass through structural members. Amount of reinforcement required in Light weight concrete structure is lesser than Normal weight concrete as the value of moments get reduced as shown in Table no.4.5 above. Danger of story drift under seismic response is reduced by increasing stiffness of members. Ductility of structure is also increased by using light weight concrete due to reduction in dense medium, which retards and dumps the seismic vibrations within it.

VI. Conclusion

i. Light weight concrete structural members have lower value of joint displacement under axial and lateral loads applied as a result of seismic forces.
ii. Light weight concrete structural members have lower value of shear forces and bending moment applied as a result of seismic forces.
iii. Light weight concrete due to lower density reduces effect of seismic vibrations and reduces threat of structural collapse under base shear effect.
iv. Amount of reinforcement required in Light weight concrete structure made up of different grades like M35 lower the grade lesser will be the reinforcement area.
v. Amount of reinforcement required in Light weight concrete structure is lesser than Normal weight concrete.
vi. Danger of story drift is reduced by increased stiffness within the structure along the floors. As the ductility of structure is also increased by using light weight concrete as the shear reinforcement is enhanced.
vii. Even though the building collapsed made up of light weight concrete might help to reduce demolition cost and saving considerable life and accessories.
viii. Light weight concrete construction helps to save worthy amount of capital invested in any construction project.

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