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"Structural Performance Of Rigid And Semi rigid RC and Lightweight Floor System For Multistoreyed Buildings"

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Abstract - *In the contemporary dissertation study, an SMRF building situated in seismic zone-IV has been considered. The linear static and non-linear static analysis are performed on the considered G+7 building models. Main aim of the dissertation work is to comprehend the outcome of rigid and flexible diaphragm floors by reinforced concrete and light weight concrete as material. Also to extract and compare various results such as storey shear, point displacement, and storey drift for both linear static and non-linear static analysis or push over analysis for the considered imposed loads as per IS 875:2002. Also the capacity of the considered building model is obtained and performance point is traced by non-linear static analysis as per ATC 40 and FEMA 256 by obtaining demand and capacity curve. Also the formulation of plastic non-linear hinges and the stratus is identified the complete dissertation work is carried out by using finite element method or analytical software ETABS 9.7.4 version.*

Key Words: Lightweight concrete, Rigid floor Diaphram, Semi-Rigid floor diaphragm and Pushover analysis.

1. GENERAL

1.1 Earthquake

Earthquakes are the most unpredictable and devastating of all natural disasters, which causes shaking of the ground due to large strain energy released at the fault, travels as seismic waves in all directions through the Earth's layers. These waves arrive at various instants of time, have different amplitudes and carry different levels of energy. Amongst the natural hazards, earthquakes have the potential for causing the greatest damages. Since earthquake forces are random in nature & unpredictable.

When an earthquake does occur, there can be considerable variation in the levels of performance experienced by different buildings located on the same site as shown in Fig 1.1 This variability can result from a number of factors, including random differences in the levels of workmanship, material strength, and condition of each structure, the amount and distribution of live load present at the time of the earthquake, the influence of mass and stiffness of structural and nonstructural components, the response of the soils beneath the buildings, and relatively minor differences in the character of the ground motion transmitted to the structures. Many of these factors are trying to identified or quantified at our current level of research works.

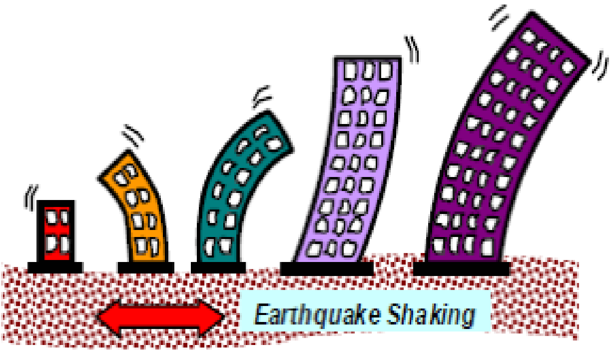


Fig-1: Seismic response of different buildings (Earthquake tips - IITK 2005)

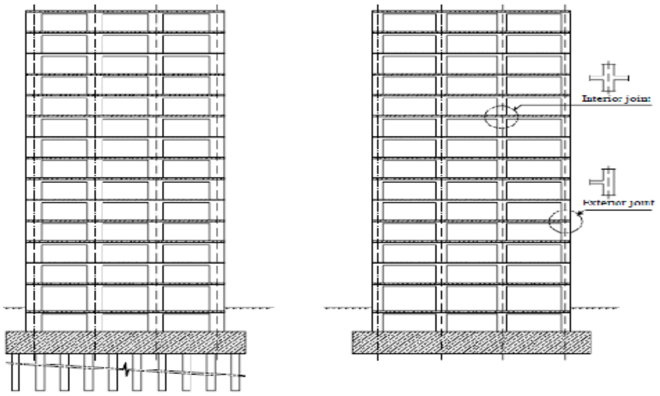
1.2 LIGHTWEIGHT CONCRETE:

Lightweight concrete can be distinct as a type of concrete which includes an expanding agent in that it increases the volume of the mixture while giving additional qualities such as nailability and lessened the dead weight. Floor selection in tall building design is one of the important decision structural engineers have to make, since it composes of around 20% of the total structural weight. Lateral load generated from wind or earthquake is transferred to the lateral load resisting system according to respected lateral stiffness at each floor level. Today, Lightweight Aggregates (LWA) is available in a wide range of densities, strengths, and sizes. This makes it possible to design Lightweight Concrete (LWC) with a very wide spectrum, a concrete of very low density for insulation and, at the same time, a high strength lightweight concrete for structural purposes. The basic advantage of LWC is its low density, which reduces the dead load.

Lightweight aggregates concrete (LWAC) has been widely applied because of its many advantages such as low density, good thermal insulation and fire resistance. Sometimes the need to reduce the weight of a structural element has not less importance than increasing its strength, especially in heavy structures such as tall buildings and bridges where the own weight of the structure is one of the main problems that faces the designers. Another important demand in concrete structures is to get monolithic fair-faced concrete, which does not only possess high visual qualities.

Monolithic concrete structures are also particularly durable, and the fact that no plastering or cladding is required leads to cost savings and makes buildings more sustainable and easier to reuse.

From the economic point of view, using LWC in construction of the floor slabs in tall buildings will reduce the total costs of tall buildings through reduction of steel reinforcement amount, foundation type and volume in addition to reduction of vertical members cross-sections that saves the used horizontal area (Figure 2). Therefore, one more experimental study was done to investigate the behaviour of interior and exterior joints between LWC beams and NC columns under seismic loads, because they are the most affected components of tall buildings during earthquake excitations.



(a) Normal concrete floor slabs (b) Lightweight concrete floor slabs

Fig-2: Layout comparison for tall buildings with normal and lightweight concrete floor slabs.

1.3. RIGID0AND FLEXIBLE DIAPHRAGM:

The rigid diaphragm is a convenient analytical technique for distributing the lateral forces to the frames and walls; forces are distributed to those elements as a function of their relative stiffness and position.

The diaphragm constructed of un topped steel decking or wood structural panels are permitted to be idealized as flexible in structures in which the vertical elements are steel or composite steel and concrete braced frames, or concrete, masonry, steel, or composite shear walls.

1.4 OBJECTIVES OF THE STUDY

The objectives of the study are as follows:

- To perform linear static (Equivalent static) and non-linear static (Pushover analysis) for the SMRF building models considered, situated in seismic zone IV as per IS 1893:2002(PART-1).
- To extract and compare various results like point displacement, storey shear, storey drift, for both linear static and non-linear static analysis.
- To find the performance point in terms of base shear and displacement by performing non-linear static pushover analysis.
- To obtain capacity curve or pushover curve by performing non-linear static pushover analysis

2. SEISMIC ASSESSMENT METHODS

2.1 METHODS OF SEISMIC EVALUATION

Once the structural model has been selected, it is possible to perform analysis to determine the seismically induced forces in the structures. There are different methods of analysis provides different degrees of accuracy. Currently seismic evaluation of buildings can be divided into two categories

- ➢ Qualitative method
- ➢ Analytical method

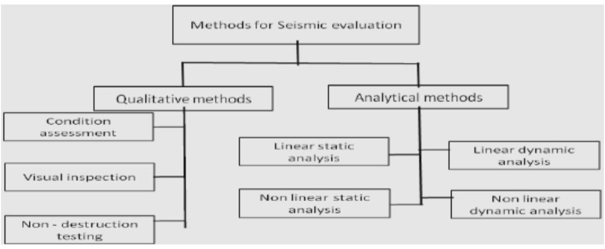


Fig-3: Different methods of seismic evaluation

The different analytical methods are categorized below as follows:

1. Linear static analysis or equivalent static Analysis

2. Linear dynamic analysis by response spectrum Method

3. Nonlinear static analysis (pushover analysis)

2.1.1 LINEAR STATIC ANALYSIS OR EQUIVALENT STATIC ANALYSIS

Equivalent static method of analysis is a linear static procedure, in which the response of building is assumed as linearly elastic manner. The analysis is carried out as per IS: 1893- 2002 (Part 1). Here the total design lateral force or design base shear along any principal direction is given in terms of design horizontal seismic coefficient and seismic weight of the structure. Design horizontal seismic coefficient depends on the zone factor of the site, importance of the structure, response reduction factor of the lateral load resisting elements and the fundamental period of the structure

2.1.2. LINEAR DYNAMIC ANALYSIS BY RESPONSE SPECTRUM METHOD

The response spectrum represents an envelope of upper bound responses based on several different ground motion records. For the purpose of the seismic analysis the design spectrum given in IS 1893 (Part 1):2002 is used. This spectrum is based on strong motion records of eight Indian earthquakes.

2.1.3 NON LINEAR STATIC ANALYSIS (pushover analysis)

The pushover analysis of a structure is a static non-linear analysis under permanent vertical loads and gradually increasing lateral loads. The load is incrementally increased in accordance to a certain predefined pattern. The analysis is carried out up to failure, thus it enables determination of collapse load and ductility capacity. On a building frame, plastic rotation is monitored, and a plot of the total base shear versus top displacement in a structure is obtained by this analysis that would indicate any premature failure or weakness.

3. MODELING AND ANALYSIS

Table-1: DETAILED DATA FOR DISSERTATION

STRUCTURE TYPE	SMRF
RESPONSE REDUCTION FACTOR	5
SEISMIC ZONE	ZONE-1V
SEISMIC ZONE FACTOR	0.24
HEIGHT OF THE BUILDING	3.0 m
SOIL CONDITION	Type II (Medium)
THICKNESS OF SLAB	150 mm
BEAM SIZE	860x1000 mm
COLUMN SIZE	1400x1400 mm
LIVE LOAD	3.5 KN/m2
WALL LOAD	11.5 KN/m
FLOOR FINISH	0.75 KN/m2
MATERIAL PROPERTIES	M30
	Fe415

M1- G+7 Bare frame RC Rigid Diaphragm building

M2- G+7 Bare frame Lightweight Semi-Rigid Diaphragm building

The plan layout and 3D view of the building models M1, M2, are as shown in the below Fig 4.1 to Fig 4.4 respectively**.**

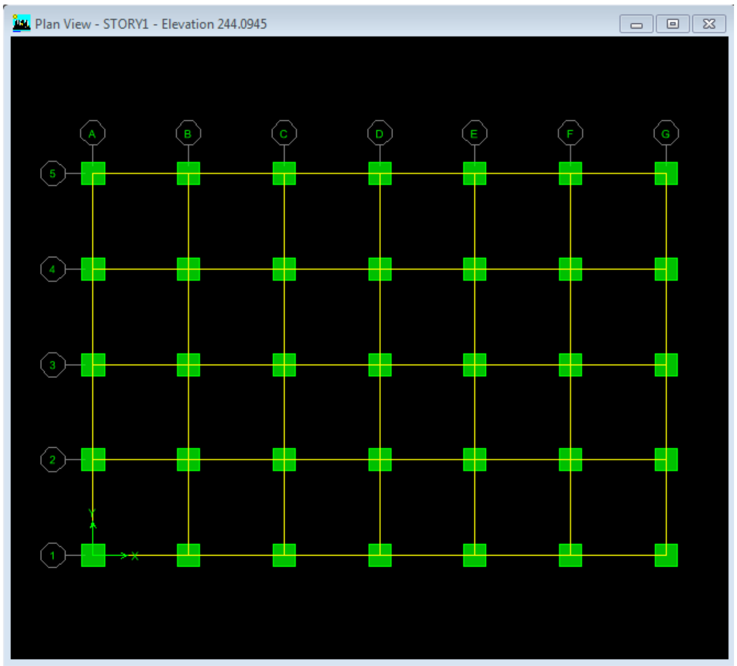


Fig-4: Plan of building models M1 and M2

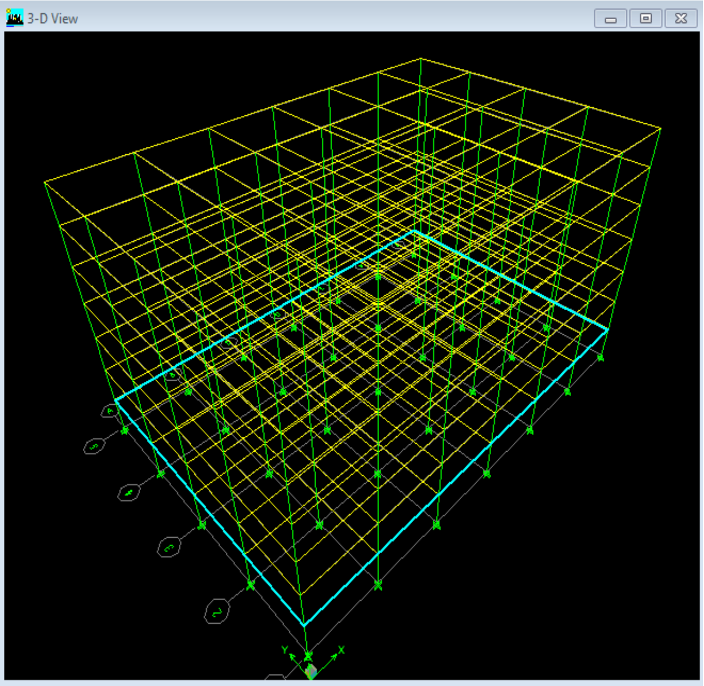


Fig-6: 3-D view of models M1 and M2

4 RESULTS

4.1 COMPARISION OF STOREY SHEAR

Here Table 1 shows the storey shear for G+7 storey building models. Similarly chart 1 indicates the plot of storey shear versus storey number. Storey shear is compared for both the equivalent static and pushover analysis in longitudinal directions.

Table-1: Storey shear for G+7 building model for both equivalent static analysis and pushover analysis

STOREY NO	STOREY SHEAR			
	M1		M2	
	EQX	PUSHX	EQX	PUSHX
7	1693.98	2866.75	6763.47	10851.52
6	3312.92	5606.52	13227.3	21222.3
5	4437.19	7509.14	17716.08	28424.24
4	5156.72	8726.82	20588.9	33033.47
3	5561.45	9411.76	22204.85	35778.48
2	5741.33	9716.18	22923.06	36778.48
1	5786.3	9792.29	23102.61	37066.56
BASE	0.00	0.00	0.00	0.00

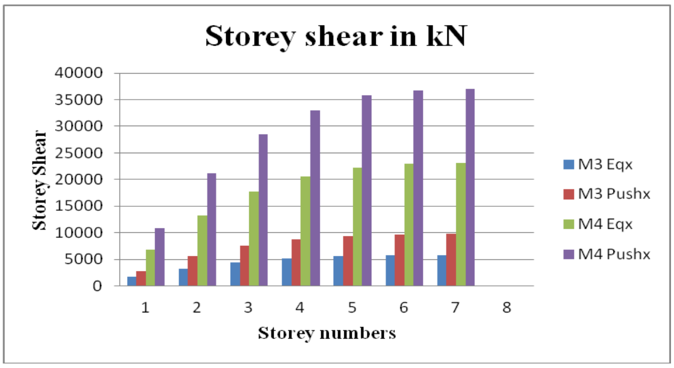


Chart-1: Comparison of Base shear for G+7 building model for both linear static and nonlinear static analysis

4.2 COMPARISION OF STOREY DRIFT

Here Table 2 shows the storey drift for G+7 storey building models. Similarly chart 2 indicates the plot of storey drift versus storey number. Storey drift is compared for both the equivalent static and pushover analysis.

Table-2: Storey drift for G+7 building model for both equivalent static analysis and pushover analysis

STOREY NO	STOREY DRIFT			
	M1		M2	
	EQX	PUSHX	EQX	PUSHX
7	0.008	0.035	0.036	0.059
6	0.012	0.051	0.050	0.084
5	0.016	0.065	0.064	0.106
4	0.018	0.074	0.072	0.121
3	0.018	0.076	0.074	0.124
2	0.016	0.067	0.066	0.109
1	0.008	0.035	0.035	0.058
BASE	0.000	0.000	0.000	0.000

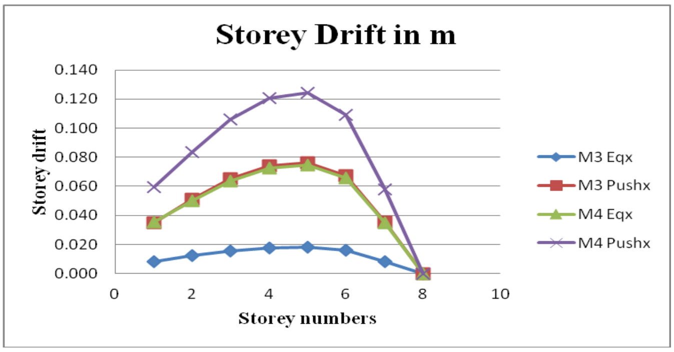


Chart-2: Storey Drift for G+7 building model for both linear static and non-linear static analysis in longitudinal X direction

4.3 PUSHOVER ANALYSIS RESULTS

Table-3: Performance levels for G+7 building model M1 in longitudinal direction PUSHX

Pushover Curve for M1		
Step no	Displacement	Base Force
0	0	0
1	0.47	1092.81
2	0.95	2185.62
3	1.42	3278.42
4	1.89	4371.23
5	2.37	5464.04
6	2.84	6556.85
7	3.31	7649.66
8	3.78	8742.47
9	4.26	9816.18
10	4.41	10167.40
11	4.41	9185.25

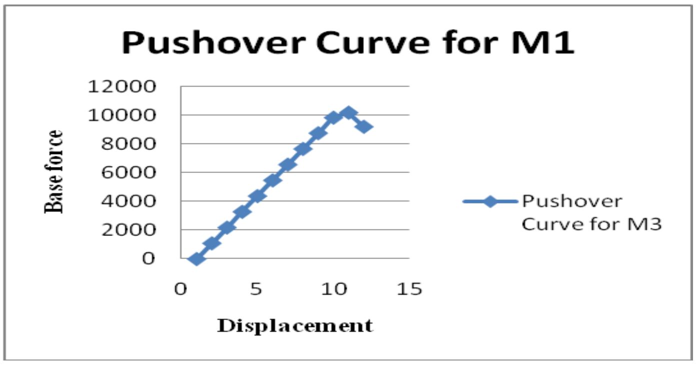


Chart-3: Performance curve for G+7 building model M1 in longitudinal direction PUSHX

Table-4: Performance levels for G+7 building model M2 in longitudinal direction PUSHX

Pushover Curve for M2		
Step no	Displacement	Base Force
0	0.00	0.00
1	0.15	34709.11
2	0.19	40487.82
3	0.36	51635.45
4	0.38	52807.26
5	0.38	52001.69
6	0.39	52205.19
7	0.39	52062.23
8	0.39	52202.61
9	0.34	37066.55

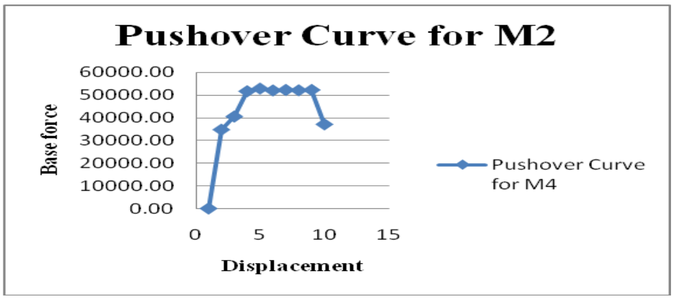


Chart-4: Performance curve for G+7 building model M2 in longitudinal direction PUSHX

4.4 Performance point of the building using capacity spectrum method.

Table-5: Data for capacity spectrum curve for G+7 storey building model M1 in PUSH X direction

Performance point for M1			
sd (C)	sa (C)	sd (D)	sa (D)
0.000	0.000	3.307	0.019
0.352	0.000	3.307	0.019
0.703	0.000	3.307	0.019
1.055	0.000	3.307	0.019
1.407	0.000	3.307	0.019
1.759	0.010	3.307	0.019
2.110	0.012	3.307	0.019
2.462	0.014	3.307	0.019
2.814	0.016	3.307	0.019
3.165	0.018	3.296	0.019
3.280	0.019	3.293	0.019
3.492	0.018	2.967	0.015

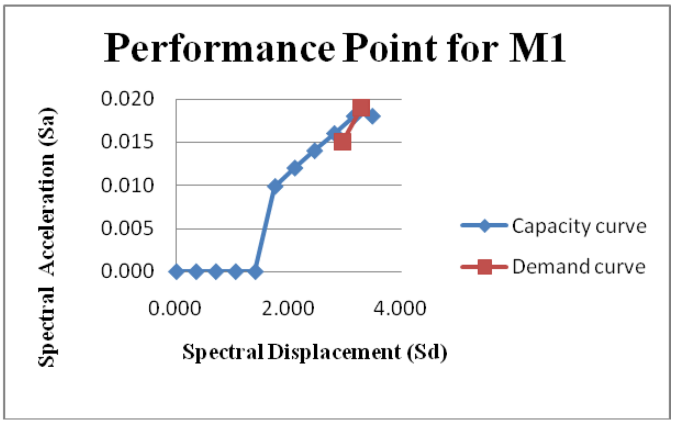


Chart-5: Performance point for G+7 storey building model M1 by combining capacity spectrum curve and demand spectrum curve in push x direction

Table-6: Performance point for model M1

Base Shear in kN	Displacement in m
10158.61	4.419

Table-7: Data for capacity spectrum curve for G+7 storey building model M2 in PUSH X direction

Performance point for M2			
sd (C)	sa (C)	sd (D)	sa (D)
0.000	0.000	0.197	0.113
0.111	0.064	0.197	0.113
0.138	0.074	0.185	0.099
0.267	0.096	0.174	0.063
0.287	0.099	0.175	0.060
0.287	0.097	0.174	0.059
0.289	0.098	0.174	0.059
0.289	0.098	0.174	0.059
0.291	0.098	0.174	0.009

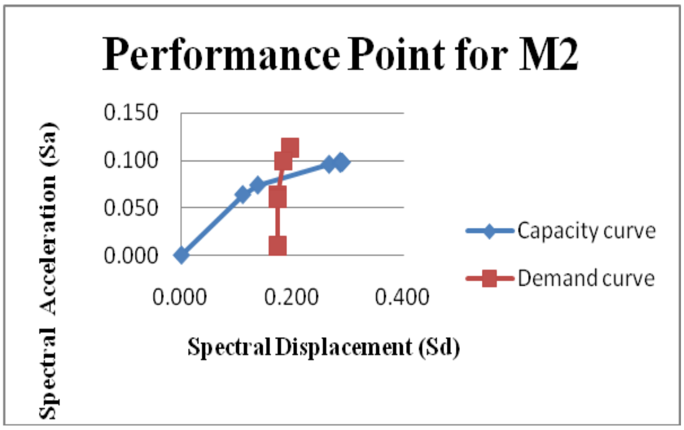


Chart-6: Performance point for G+7 storey building model M2 by combining capacity spectrum curve and demand spectrum curve in push x direction

Table-8: Performance point for model M2

Base Shear in kN	Displacement in m
44196.69	0.244

CONCLUSION

- The models with Reinforced concrete and Rigid floor diaphragm yields better results where as models with lightweight concrete and semi-rigid floor diaphragm are vulnerable in the considered EQ zone-IV.

- As the mass and storey floors increases the resisting base shear goes on increases and also representive storey shear goes on decreases.

- From the results obtained for Storey shear, Storey drift, Point displacement perciened that the increase in weight of building these results also increases but corresponding point displacement decreases.

- The pushover analysis is performed by which number of steps and Base shear v/s roof displacement curve or pushover curve are obtained and shown from Table 3 and 7 and chart 3 and 4.

- The total capacity of the building model or the maximum resisting load after which the building models tends to move from elastic to plastic state can be determined by its performance point as seen in Table 5 and 7 and chart 5 to Fig 6.

SCOPE OF FURTHER STUDY

1. The dissertation work can be further carried out for Tall buildings by considering wind force effect.
2. The dissertation can also be carried out for linear dynamic and non-linear dynamic method of analysis.
3. Also other material can be used rather than reinforced concrete with flexible floor diaphragm.

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