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ANALYSIS OF EFFECT OF CYCLIC LOADING AND SEISMIC LOADING ON RC STRUCTURE USING ETABS

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Abstract: This study investigates the effect of Cyclic and seismic loading on RC structures using ETABS software. It aims to enhance their design and resilience. The study employs simulations and analysis to assess structural integrity, deformations and overall performance. ETABS software is used to analyze a multi-story building in seismic zone V of India. Various cyclic loads, including seismic forces, wind pressures and machinery vibrations are applied alongside constant lateral loads. The investigation focuses on aspects such as Peak response displacements, Story drift ratios, Frequencies and Time periods. The results show that introducing cyclic load as Machinery vibration leads to gradual change in displacement, base shear, frequency and time period, emphasizing the seismic impact.

I.INTRODUCTION

India is rapidly urbanizing, leading to notable changes in building construction practices. Multi-story structures with intricate architectural features are on the rise, featuring adaptable construction methods, suspended columns, load management, and flexibility.

This research undertaking centers on the execution of a multi-story building design that introduces a distinct architectural challenge: the utilization of suspended columns. The investigation also assesses how this architectural intricacy influences the building's performance, particularly in regions prone to heightened seismic activity. The outcomes of this research endeavor are anticipated to offer valuable insights and recommendations for the building of multi-story buildings featuring suspended columns, particularly in areas susceptible to seismic occurrences.

Understanding how reinforced concrete (RC) structures behave under different loads is crucial in structural engineering. This study examines the impact of cyclic and seismic loading on RC structures using the ETABS software. By thoroughly analyzing structural responses to dynamic forces, this study aims to uncover insights into RC structures' behavior, stability, and vulnerabilities. This research contributes to the development of safer and more robust infrastructure in seismic regions.

1.1Cyclic loading on RC structure:

Cyclic loading on a reinforced concrete (RC) structure refers to subjecting the structure to repeated cycles of loading and unloading, typically by means of alternating forces, displacements, or deformations. This type of loading is commonly encountered in structures that are exposed to Dynamic or Seismic forces, as well as in structures subjected to other Cyclic loads like Wind, Waves, or Traffic-induced and Machinery vibrations.

In the context of seismic events, cyclic loading is especially important to consider because earthquakes generate ground motions that cause structures to experience varying levels of deformation and stress over time. Unlike static loading, where the structure is subjected to a constant load, cyclic loading introduces the element of fatigue and cumulative damage due to the repeated stress reversals.

1.2 Response Spectrum Analysis (RSA):

Response Spectrum Analysis (RSA) stands as a method of linear-dynamic statistical analysis. This technique gauges the extent to which particular natural mode of vibration contributes, indicating the potential maximum earthquake response of a structure primarily exhibiting elasticity. By utilizing Response spectrum analysis, we gain a deeper understanding of dynamic behavior. This understanding is achieved by assessing Pseudo-spectral Acceleration, Velocity, or Displacement concerning the structural period. This represents the highest response for each instance of the structural period, it's practical to envelop response spectra, forming a smooth curve. The significance of response-spectrum analysis lies in its ability to inform design choices. It establishes a connection between the type of structure selected and its dynamic performance.

Response spectrum analysis is not limited to seismic loads. It can also be applied to other dynamic loads, such as wind loads and machinery vibrations. This allows engineers to understand how these loads impact the behavior of the structure. Engineers can use response spectrum analysis to optimize the design of a structure by adjusting its parameters to minimize undesirable responses. For instance, they can modify the stiffness, damping, or mass distribution of the structure to achieve better performance under seismic loads.

II. ETABS SOFTWARE

ETABS, short for 'Extended 3D analysis of building Systems,' is a software solution created by Computers and Structures Inc. This engineering software finds application in the field of construction and boasts a suite of remarkably efficient programs for analyzing and designing complex multi-story building systems.

It comes equipped with a unified system encompassing modeling tools and templates, load prescriptions in code form, methods for analysis, and solution techniques. Capable of managing the most extensive and intricate building models along with their related setups, the ETABS software incorporates CAD-style drawing tools featuring an interface based on objects and a grid representation

ETABS software exerts significant influence in the construction, design, and modeling sectors in the following ways:

1) In the realm of construction, ETABS software serves as a crucial tool. It performs seismic performance analysis, evaluates the load-bearing capacity of building structures, and ensures their structural integrity.

2) This software facilitates precise manipulation and visualization of analytical models. It automatically generates plans and elevation views at every gridline, ensuring accuracy in design modifications.

3) ETABS software finds extensive utility in analyzing concrete shear walls and concrete moment frames. Its excellence is particularly acknowledged in the static and dynamic analysis of multi-story frame and shear wall buildings.

4) Within the building industry, ETABS stands as one of the most widely used civil design tools. It significantly enhances the productivity of structural engineers and eliminates the need for investing time and resources in general-purpose software solutions, thus saving both time and money.

5) ETABS is tailored to exploit the distinctive physical and numerical attributes of building-type structures. Consequently, it expedites data preparation, streamlines output interpretation, and optimizes overall execution of analysis and design tasks.

III. PROBLEM STATEMENT

In every building, columns extending from their foundation support beams. The current study aims to examine the reactions and responses of reinforced concrete structures when exposed to cyclic and seismic loading conditions. The study further intends to contrast their performance under seismic events for specific combinations of the structure. This investigation involves the utilization of Response Spectrum Analysis on a G+10 model, employing the ETABS2016 software.

MODEL AT:

- Seismic Zone V: Area determines by pro seismically of certain major fault systems. It is seismically the most active region. Earthquakes with magnitudes in excess of 7.0 have occurred in these areas, and have had intensities higher than 10.
- Cyclic Loading: Machinery Vibration Load has been taken into Consideration.

The Tablet press, specifically the KILIAN S250 model is taken, was positioned across multiple floors, Ground Floor (GF), First Floor (FF) & Second Floor (SF). The acquisition of this machinery was made by the company with the purpose of manufacturing tablet-based nutritional supplements.

IV. OBJECTIVE

To study the behavior of G+10 RC building by Response Spectrum Analysis under Cyclic and Seismic loads using EATBS.

Conducting an analysis to determine the Optimal floor for Machine placement by comparing various parameters in the context of cyclic loading applied to different floors.

V. METHODOLOGY

1.The study involves an analysis of a G+10 RC building using the ETABS 2016 software. The building's structural components, as outlined in the problem description, are included in the model.

2.Response Spectrum Analysis is conducted on the assumed building models, and if any components exhibit failure, the assumed dimensions are adjusted until meeting the criteria.

3.It's important to note that not all structural elements are designed in this analysis; instead, they are assumed or incorporated based on common practices and compliance with relevant codes and standards.

4.Procedure for Analysis:

Model Preparation: Develop a detailed structural model of the building or structure using appropriate structural analysis software ETABS2016.

Define all relevant geometric and material properties accurately.

Load Definition: Specify the design seismic spectrum appropriate for the project's location and seismic zone. Apply lateral loads in the form of accelerations or forces to represent the seismic ground motion. These loads are applied to each floor level and Machinery loading applied only to GF, FF, SF.

Modal Analysis: Perform a modal analysis to determine the structure's corresponding modal masses and assigned properties. Extract the first few modes that significantly contribute to the dynamic response.

Parameters: such as Base Shear, Story Drift Ratios, Periods and Frequencies, and Peak Response Displacements of the model compared between different storys with the machinery vibration loading.

V. SPECIFICATIONS:

5.1. Structural Details:

Total Built-Up Area -625sq.m
Area of Machinery load-225sq.m
Col-col dist. @x -5m
Col-col dist. @y -5m
Number of Stories -G+10
Column size -(600 x 600) mm
Beam Size -(400 mm x 500) mm
Slab Thickness -200 mm
Typical height -3m
Total height -36m
Floor-floor height -3m

5.2. Design Data

Concrete Grade M40
Grade of Reinforcement HYSD500
Clear cover of Beam 40mm
Clear cover of Column 40mm
Maximum percentage of Reinforcement 4%
Design Codes IS 456:2000
IS 1893:2002

5.3. Loads Assigned

Dead Load Self-weight multiplier -1kN/sq.m
Floor Finish -1.5kN/sq.m &
at Terrace FF -1kN/sq.m
Terrace Finish -1kN/sq.m
Live Load -2.5kN/sq.m
At Terrace -2kN/sq.m
Inner Wall Load -9kN/sq.m
Outer Wall Load -13.8kN/sq.m
Cyclic Load Max. Machinery Load -35kN/sq.m

5.4. Seismic Parameters

Seismic zone -Zone V
Zone Factor (Z) -0.36
Response Reduction Factor (R) -5
Seismic intensity -Moderate
Rock/Soil Type -Medium Stiff
Damping Ratio -5% `(0.005)
Importance Factor (I) -All General Buildings I=1
Frame system -Special RC Moment Resisting Frame

5.5. Wind Parameters

Wind Speed -50 m/s
Terrain Coefficient -II
Structure Class -B
Windward Coefficient -0.8
Leeward Coefficient -0.5
Risk Coefficient -1
Topographic Factor -1

We use the code provisions of IS 456:2000 and IS 1893:2002 Parts to analyze the structure. These codes provide information on how to design earthquake-resistant structures and the loading parameters that need to be considered for different types of loads.

VI.MACHINE USED FOR CYCLIC LOADING: KILIAN S250 MODEL

Production capacity refers to the number of tablets that the press can produce per hour. The higher the production capacity, the more energy the press will consume and the more vibrations it will produce. Molding pressure is the force that is applied to the tablet during the molding process. The higher the molding pressure, the more vibrations will be produced. Tablet diameter refers to the size of the tablet. Overall dimensions of the machine (L x W x H in mm): 1500x1500x2500.The larger the tablet diameter, the more vibrations will be produced.

The tests that were conducted under different machinery operating modes allowed researchers to study how the vibration levels produced by the press machinery changed as each of these factors was varied. This information can be used to design floor structures that are more resistant to vibration damage.

Mode 1: shows the results of measurements of the amplitude and precipitation of vibrations on the floor structure for a press productivity of 80,000 to 1,10,000 tablets per hour and a molding pressure of 30 to 35 KN. These measurements were taken while producing a large (11 mm in diameter) flat tablet.

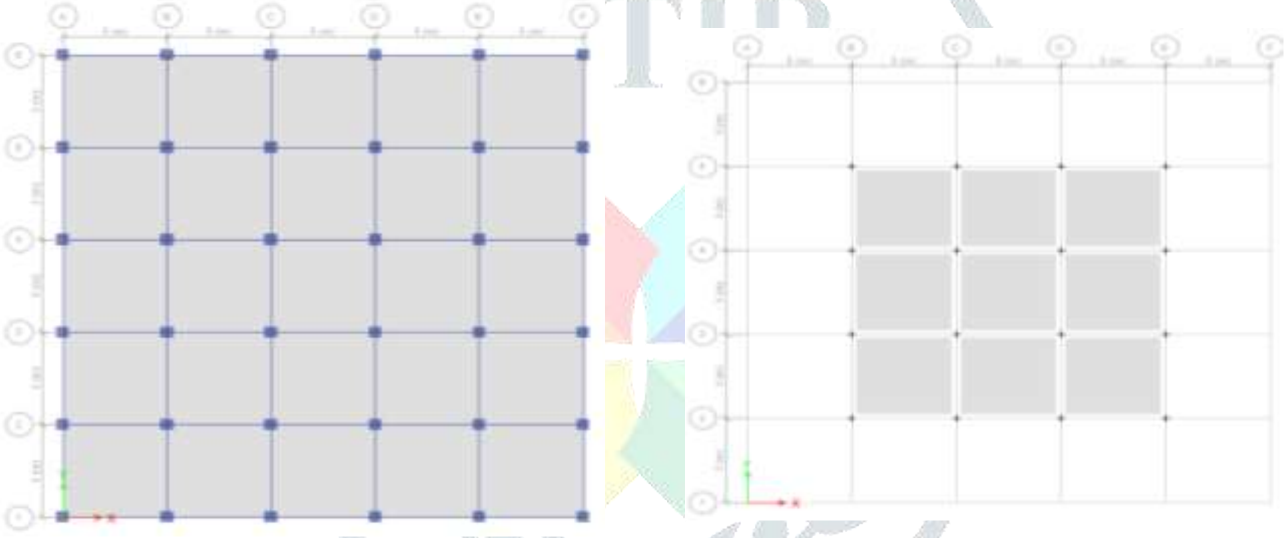
Mode 2: The results of measurements of floor structures for a press productivity of 1,30,000 tablets per hour, a molding pressure of 32 KN, and the production of a small (6 mm in diameter) flat tablet.

Mode 3: shows the results of measurements of floor structures for a press productivity of 1,30,000 tablets per hour, a molding pressure of 18 KN, and the production of a small (6 mm in diameter) flat tablet.

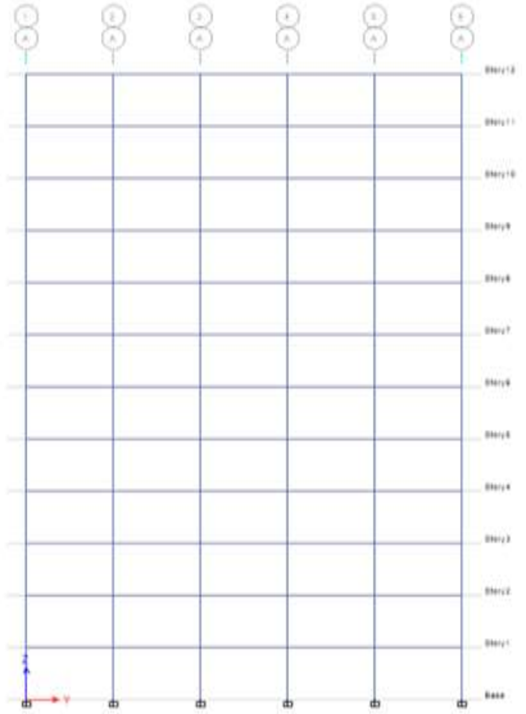
In accordance with the paper "Study of the vibration influence on load-bearing floor structures in case of machinery operation" by IOP Conf. Series: Materials Science and Engineering 708 (2019).

VII.MODELING IN ETABS:

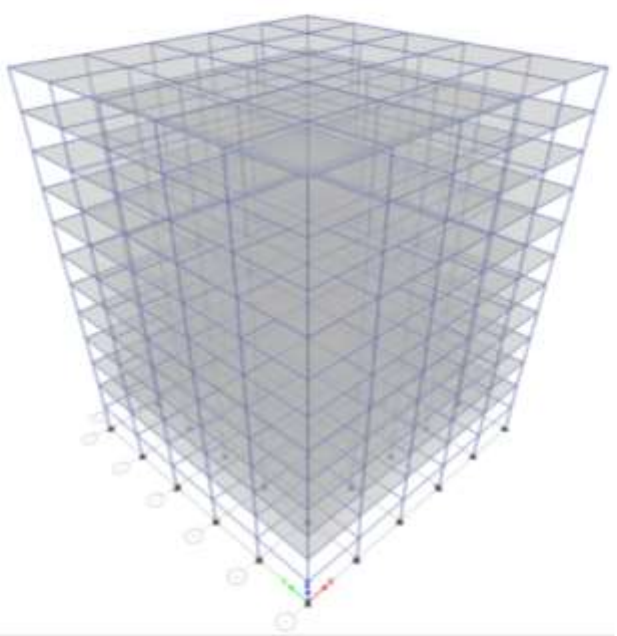
A description of the modeling details is provided below. In ETABS, a 3D representation of the building's structure is formulated to execute Response Spectrum Analysis. The structural components, such as beams and columns, are depicted as rectangular framed elements, and their material and section attributes are outlined. Each sharing identical material properties.



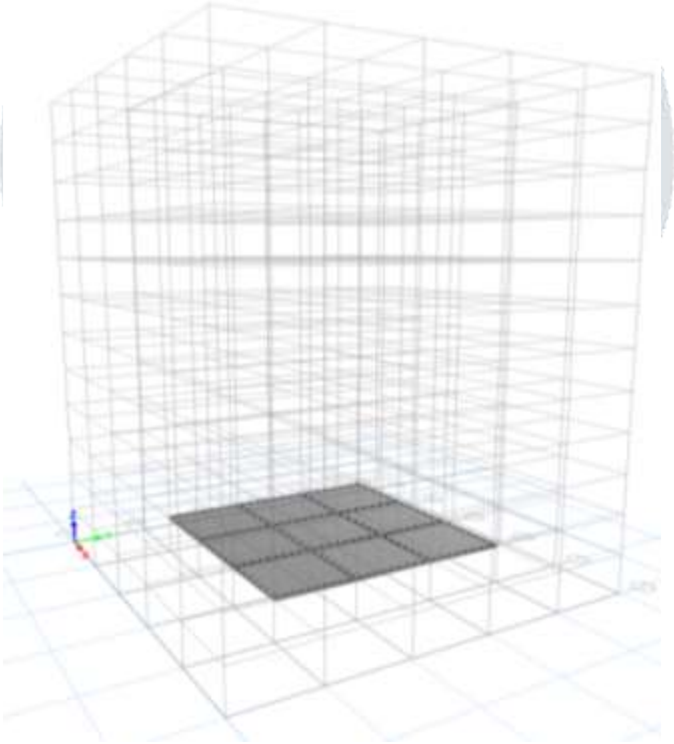
Floor Plans with Machinery vibration load and Without Machinery vibration load



Elevation



3D View of the Structure



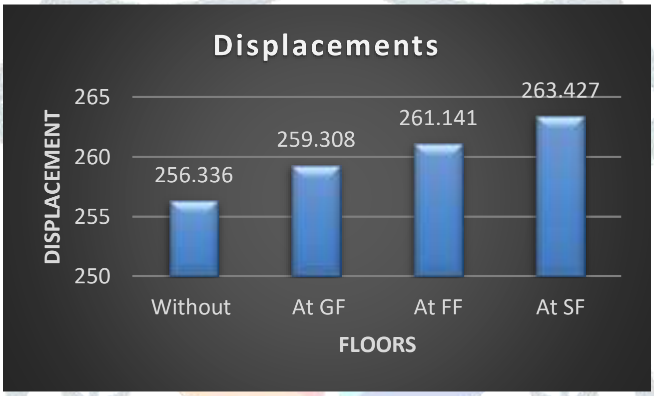
3D View of the Structure with Machinery Loading

VIII. COMPARISON OF THE RESPONSES OF THE MODELS

8.1. Displacements:

Elevation	Displacements			
	Without	At GF	At FF	At SF
Story12	256.336	259.308	261.141	263.427
Story11	250.354	253.172	254.97	257.262
Story10	240.614	243.234	244.958	247.239
Story9	226.941	229.366	230.991	233.22
Story8	209.68	211.944	213.48	215.629
Story7	189.201	191.35	192.827	194.903
Story6	165.774	167.846	169.299	171.346
Story5	139.57	141.568	143.035	145.11
Story4	110.754	112.64	114.139	116.245
Story3	79.677	81.363	82.852	84.697
Story2	47.35	48.67	49.904	50.686
Story1	17.107	17.725	18.18	18.363
Base	0	0	0	0

Displacement Without Machine and Machine at GF,FF,SF



Maximum Displacements

8.2. Drifts:

Elevation	Drift			
	Without	At GF	At FF	At SF
Story12	0.002496	0.002677	0.002652	0.002593
Story11	0.004067	0.004324	0.00432	0.004246
Story10	0.005557	0.005823	0.005872	0.005824
Story9	0.00677	0.007011	0.007089	0.007089
Story8	0.007733	0.007947	0.00802	0.008055
Story7	0.008519	0.008698	0.008762	0.008807
Story6	0.009219	0.009365	0.009416	0.009453
Story5	0.009883	0.010017	0.010051	0.010078
Story4	0.01048	0.010615	0.010652	0.010734
Story3	0.010807	0.010963	0.011063	0.011378
Story2	0.010133	0.010327	0.010632	0.01083
Story1	0.005702	0.005908	0.00606	0.006121
Base	0	0	0	0

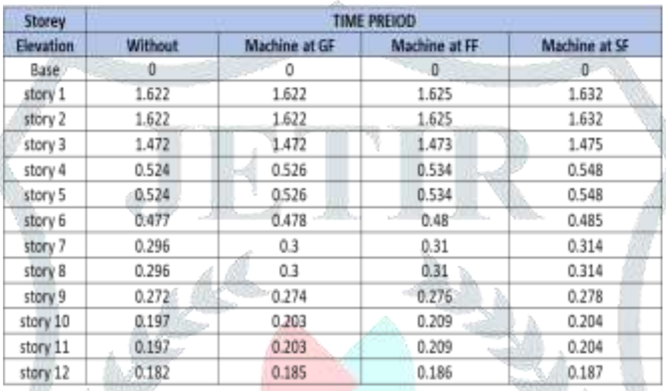
Drifts without Machine and Machine at GF, FF, SF

8.3. Base Shear:

Elevation	Shear			
	Without	At GF	At FF	At SF
Story12	4421.7162	4920.7777	4742.653	4538.7706
Story11	9597.3593	10413.6268	10282.5812	9980.0529
Story10	13567.3223	14355.0396	14438.3234	14231.9959
Story9	16600.3407	17282.559	17464.08	17420.7704
Story8	18977.1753	19597.2883	19742.7023	19800.8787
Story7	20908.5259	21429.406	21556.7386	21640.4929
Story6	22682.8006	23101.9492	23206.4515	23265.5503
Story5	24482.8844	24879.3961	24923.1173	24913.2032
Story4	26301.7604	26694.008	26722.3536	26630.7122
Story3	28070.0172	28490.4759	28515.2975	30095.8467
Story2	29495.0345	30085.5873	31519.9733	31735.2335
Story1	29832.035	31598.2552	31961.1207	32105.5162
Base	0	0	0	0

Base Shear without Machine and Machine at GF, FF, SF

8.4. Time Period:

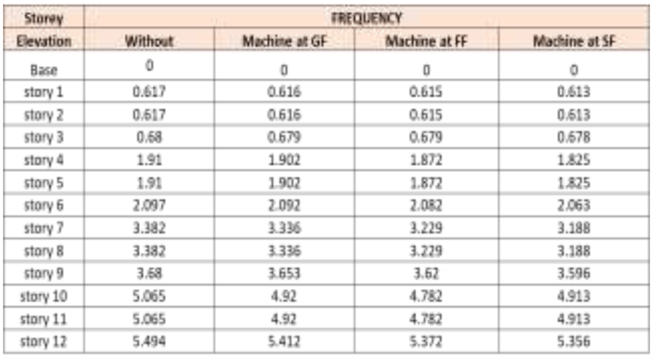


Storey	TIME PREIOD			
Elevation	Without	Machine at GF	Machine at FF	Machine at SF
Base	0	0	0	0
story 1	1.622	1.622	1.625	1.632
story 2	1.622	1.622	1.625	1.632
story 3	1.472	1.472	1.473	1.475
story 4	0.524	0.526	0.534	0.548
story 5	0.524	0.526	0.534	0.548
story 6	0.477	0.478	0.48	0.485
story 7	0.296	0.3	0.31	0.314
story 8	0.296	0.3	0.31	0.314
story 9	0.272	0.274	0.276	0.278
story 10	0.197	0.203	0.209	0.204
story 11	0.197	0.203	0.209	0.204
story 12	0.182	0.185	0.186	0.187

Time Period without Machine and Machine at GF, FF, SF

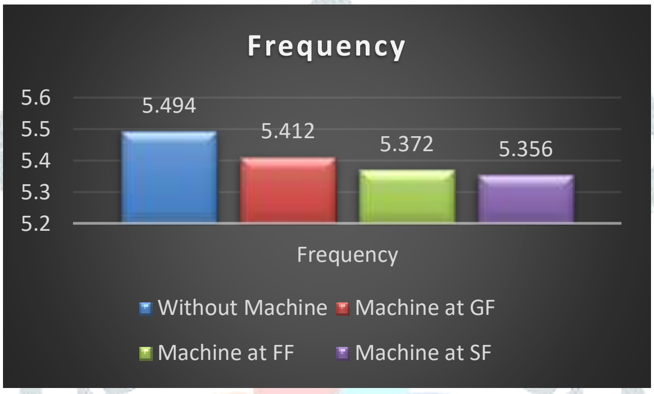
Maximum Time Period

8.5. Frequencies:



Storey	FREQUENCY			
Elevation	Without	Machine at GF	Machine at FF	Machine at SF
Base	0	0	0	0
story 1	0.617	0.616	0.615	0.613
story 2	0.617	0.616	0.615	0.613
story 3	0.68	0.679	0.679	0.678
story 4	1.91	1.902	1.872	1.825
story 5	1.91	1.902	1.872	1.825
story 6	2.097	2.092	2.082	2.063
story 7	3.382	3.336	3.229	3.188
story 8	3.382	3.336	3.229	3.188
story 9	3.68	3.653	3.62	3.596
story 10	5.065	4.92	4.782	4.913
story 11	5.065	4.92	4.782	4.913
story 12	5.494	5.412	5.372	5.356

Frequencies without Machine and Machine at GF, FF, SF



Maximum Frequencies

IX. RESULTS AND DISCUSSION

When applying cyclic loads to different floors of a reinforced concrete (RC) structure, the variation will depend on the distribution of load, the structural configuration, the stiffness of the various components, and the overall response of the structure. We subjected all floors (Ground Floor, First Floor, Second Floor) of the structure to a uniform cyclic load of 35kN/m2, in addition to Earthquake and Wind loads. Anticipated outcomes included a fairly uniform response across all floors.

Displacement of the structure:

Higher floors are typically more vulnerable due to lower stiffness, larger spans and higher energy dissipation and Lower floors have less displacement due to their greater stiffness and proximity to the building's foundation. However, we observed a gradual increase in Displacements under the Machinery load, **like 256.336mm Without Machine load, 259.308mm at GF, 261.141mm at FF, 263.427mm at SF**. As compared to the structure Without Machinery load the Machine at Ground floor has the lower and nearer displacement values than other 2 floors.

Storey Drift of the Structure:

Drift is a term commonly used to describe the relative lateral displacement between two points in a structure, often expressed as a ratio of the displacement to the height of the structure.

Drift values obtained from the analysis we made comes under the limitations specified by the IS 1893-2002 standards.

Base Shear of the structure:

Base shear is the maximum expected lateral force on the base of the structure due to seismic activity, hence load distributed more or less uniformly throughout the height of the building, The design should facilitate controlled deformation, allowing for the dissipation of energy. The safety of our structure can be assessed based on the obtained Base shear values from the analysis.

Time Period and Frequency:

The Time period refers to the time it takes for the structure to oscillate back and forth from its initial position. It's inversely related to the Frequency of the structure.

Time period and Frequency values obtained from the analysis are, Without Machinery load 0.182m/s & 5.494Hz, Machine at Ground floor 0.185m/s, 5.412 Hz, first floor 0.186m/s, 5.372Hz, second floor 0.184m/s, 5.356Hz.

A Structure with higher Natural Frequency will have the shorter Time Period. When the time period is shorter, the structure tends to possess greater stiffness and enhanced stability. This in turn leads to a lesser risk of resonance, resulting in reduced structural damage.

X. CONCLUSION

The study demonstrates that different floors of an RC structure respond distinctively to cyclic and seismic loading.

The Machine load at the Ground floor has lesser Displacement because of its higher stiffness, loads generated by ground shaking are properly distributed to the foundation, Stiffer base, higher energy dissipation compared to other floors of structure and drift value should be in the limit of 0.004 times storey height. hence drift values obtained from the analysis we made comes under the limitations.

Machine at Ground floor experiences higher base shear forces during cyclic events because of its higher stiffness compared to upper floors.

The Machinery load at the Ground floor has higher Frequency and lower Time Period values than other floors because it is stiffer, proper load distribution to the foundation, higher stability compared to First floor, second floor of the structure.

Considering all the result obtained from the Analysis made using ETABS2016 lead to, the Ground floor is the optimal place for the Machine placement compared to other floors of the structure.

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