ISSN XXXX XXXX © 2018 IJESC

Research Article Volume 8 Issue No.8

Steady State Vibration Analysis of Industrial Structures

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Abstract:
Floor vibrations are caused by human activities and machinery systems. In this study we are focused on floor vibrations due to machinery systems only. Two models are taken, first model consists of secondary beams placed perpendicular to primary beams and second model consists of secondary beams placed parallel to primary beams and both models have the same materials and section properties of beams, columns and floor. The hydraulic pump which is having a power of 4000 RPM are placed on both the models. Both models are drafted in SAP 2000 and analyzed for steady state vibrations for vertical excitation only. Results such as plot functions, shell stress, resultant force, bending moment, shear force are compared and graphs are plotted. By comparison it is clearly concludes that secondary beams placed perpendicular to primary beams have more resistance for floor vibrations compared to secondary beams placed parallel to primary beams.

Keywords: Hydraulic pump, Frequency, Steady state vibration, Floor vibration, Damping, Mode Superposition.

1. INTRODUCTION

The industrial buildings are usually one-storey structures but some industrial building may consist of two or more storey. Reinforced concrete or steel-concrete composites slabs are used as a floor system. The rolled steel joistsor plate girders support theseslabs. The design of reinforcedconcrete slabs shall be done asper IS 456-2000. Floorvibrations are by and large caused by powerful loads connected either specifically to the floor by individuals or apparatus or in a roundabout way by moving floor supports after transmissionthrough the building structure or through the ground.

Hydraulic machineryinduced vibrations are best dealt with at source through the provision of isolating mounts or motion arresting pads.Machines introduced in production lines tend to deliver the most extreme vibrations because of their size and the idea of their task. However, floor vibration is rarelya problem in mostfactories, since it is accepted by the workforce as part of the industrialcondition. Once its established, it is very difficult to customizean existing floor to reduce itssusceptibility tovibration, as only major changes to the mass, stiffnessor damping of the floor system will produce any perceptiblereduction in vibrationamplitudes. It is vital along these linesthat the levels of worthy vibration be set up at the ideaconfiguration arrange, givingcareful consideration to the foreseen use of the floors.

Structural vibrations arise from normal human activity and from the operation of mechanical equipment within buildings, from external traffic or from wind storms and earthquakes. Structural vibrations under conditions of normal use were not usually a problem when working stress methods were used to design conventional floor and framing systems with traditional construction. This can be deduced from the minimum guidance provided in existing standards for controlling vibrations in ordinary buildings. However, structural systems arebecoming lighter and more flexible and have lower damping thanbefore. There has been a reduction in the use ofnonstructural members and partitions which in the past provided additional stiffening and damping. Methods of structural analysis and design are growing more refined, the systems are better integrated, and the use of high strength construction materials and welded or bolted joints is now common. Floors of light construction with longer spans afford cost advantages and versatility in multi-purpose buildings.

1.1VIBRATION

Vibration is a mechanical phenomenon whereby motionshappen around a balance point. The word originates from Latin vibrationem ("shaking, waving"). Themotions might be intermittent, for example, the movement of a pendulum orarbitrary, for example, the developmentof a tire on a rock street.

Vibrations briefly classified in two types:

1) Transits vibration.
2) Steady state vibration.

1.1.1. Steady state vibration:

Vertical excitation is regularly experienced in designingsystems. It is generallyproduced by the unbalance in rotating hydraulic machinery. Although pure harmonic excitation is less likely to occur than periodic or other types of excitation, understanding the behaviour of a system undergoing harmonic excitation is essential in order to comprehend how the system will respond to more general types of excitation. Vertical excitation maybe in the form of a force or displacement of some point in the structure.

The general equation for steady state vibration is given as:

$$P(\omega) = \sum_j s_j f_j(\omega)\, p_j e^{i\Theta_j} = \sum_j s_j f_j(\omega)\, p_j(\cos \Theta_j + i\sin\Theta_j)$$

1.2 INTRODUCTION TO HYDRAULIC PUMP

The combined pumping and driving motor unit is known as hydraulic pump. Thehydraulic pump takespressure driven liquid (for the most part some oil)from the storage tank and delivers it to the rest of the hydrauliccircuit. In general, the speed of pump is constant and thepump delivers an equal volumeof oil in eachrevolution.The sum and course of liquidstream is controlled bysome outer components. In some cases, the hydraulic pump itself is operated by a servo controlled motor but it makes the systemcomplex. The hydraulicpumps are characterized by its described by its stream rate limit, control utilization, drive speed, weight conveyed at the outlet and effectiveness of the pump.

The pumps are not 100% efficient. The efficiency of a pump can be specified by two ways. One is the volumetric efficiencywhich is the proportion of genuine volume of liquid conveyed to the greatesthypothetical volumeconceivable. Second is control effectiveness which is the proportion of yieldwater driven capacity to the info mechanical/electrical power. The normal efficiency of pumpsvaries from 90 to 98%.

1.3 DYNAMIC FORCE IN HYDRAULIC PUMP

In this study we took 4000 RPM hydraulic pump which dynamic force test is already conducted and results are plotted in the table below:

Table 1. Dynamic force with respective frequency

Frequency (HZ)	Dynamic Force (N)
0	0
500	0.02
1000	0.08
1500	0.19
2000	0.34
2500	0.53
3000	0.76
3500	1.04
4000	1.36

2. METHODOLOGY

To establish the objectives of the study,

- SAP2000 software is used to carry out the steady state vibration analysis of different orientation of structures.
- Analyse the model for steady state vibration by using steady state function.
- Concrete mix M25 and steel of Fe415 is considered for whole structure.
- Acceptable member sizes are considered for analysis of the structure.
- Comparison is made for both the buildings and results are plotted based on that conclusion is remarked.

2.1 PARAMETERS ADOPTED IN THE ANALYSIS:

- Grade of concrete for beams and columns
- is M25
- Modulus elasticity of reinforced concrete 20000 N/mm^2 for beams and columns
- Poisson's ratio is 0.15
- Weight density of concrete25 kN/m^3
- Mass density of concrete2.55x10^{-9} N-sec^2/mm^4
- Machine speed is4000 rpm
- Beam 230 X 600 mm
- Column 300 X 600 mm
- No. of storey is G+1

2.2 MODELLING:

2.2.1 GENERAL:

A 3-Danalytical model of the structure consisting of beams, floors and the supporting columns is developed using SAP2000 (Version 20.0). , columns are considered fixed at their bottom ends, The hydraulic machine having a power of 4000 RPM placed on the floor.

2.2.2 GEOMETRY:

The analytical models having a dimension of 8 x 5m and 5m X 8m. In the first model all secondary beams placed perpendicular to primary beams and in second model all secondary beams placed parallel to primary beams as shown below:

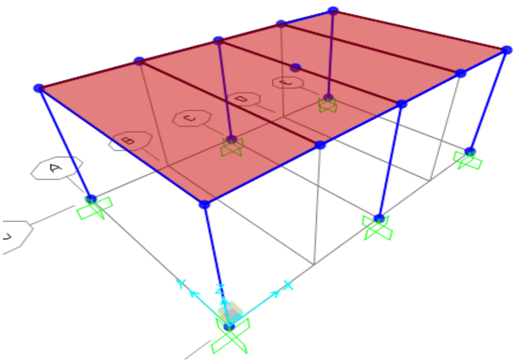

FIG.2.1,Modal 1

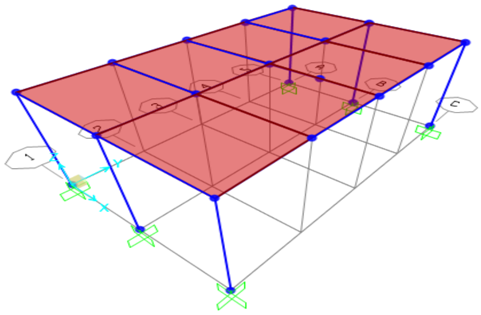

FIG.2.2,Modal 2

3. ANALYSIS:

3.1 Analysis of the structure

- After the modelling of both the structure in SAP2000,assign all the material properties, section properties, loads are applied
- Define the steady state function by applying dynamic force value
- The analysis results are shown in following figure.

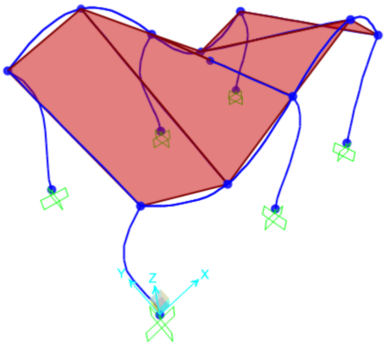

Fig.3.1, Deflected shape of the Structure.(modal 1)

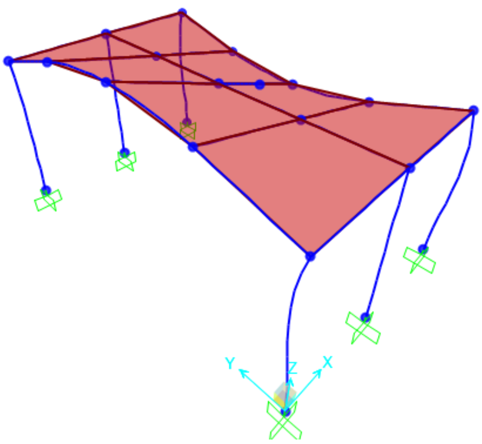

Fig.3.2, Deflected shape of the Structure.(modal 2)

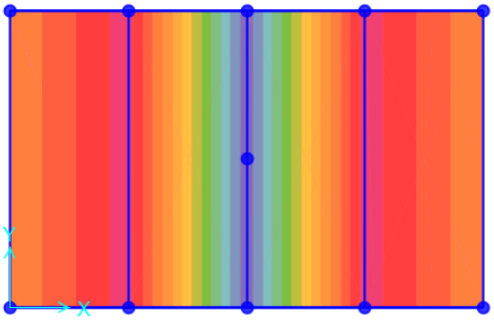

Fig.3.3, Resultant force of the structure.(modal 1)

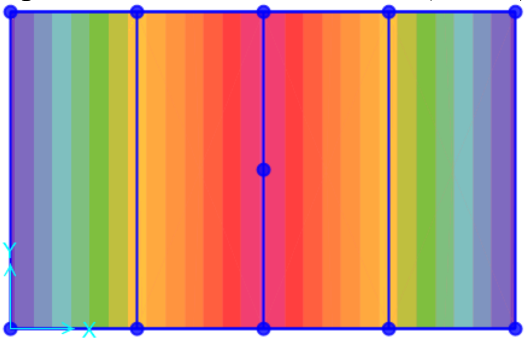

Fig.3.4, Shell stress of the structure.(modal 1)

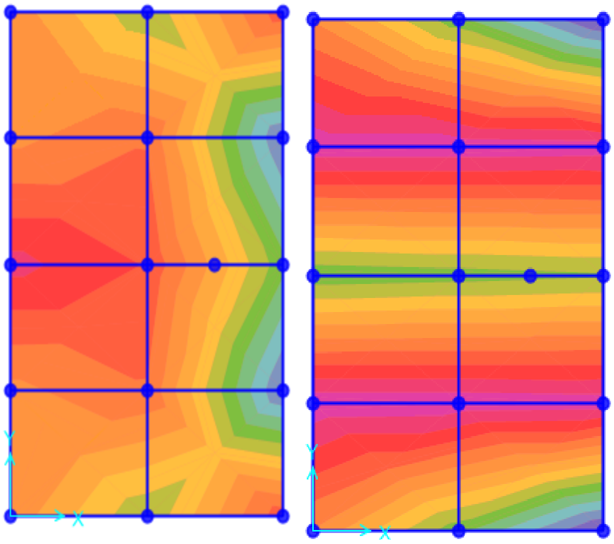

Fig.3.5, Resultant force and shell stress of the structure.(modal 2)

4. RESULTS AND DISCUSSION:

After the analysis of both the models results are plotted and comparisons are made.

Table 2: Frequency comparison

MODE	FREQUENCY (Hz) (Modal 1)	FREQUENCY (Hz) (Modal 2)
5	42.953	15.563
10	89.767	71.834
15	118.456	104.164
20	147.962	133.462
25	198.913	161.78
30	308.282	239.846
33	462.475	264.931
35	N/A	270.783
40	N/A	310.712
45	N/A	403.707

Table 3: Resultant force

FREQUENCY (Hz)	RESULTANT FORCE (kN/m) (Modal 1)	RESULTANT FORCE (kN/m) (Modal 2)
10	0.000203	0.003315
20	0.000264	0.005227
30	0.005301	0.015394
40	0.111914	0.134327
50	1.026558	0.057818
60	0.202755	0.05954

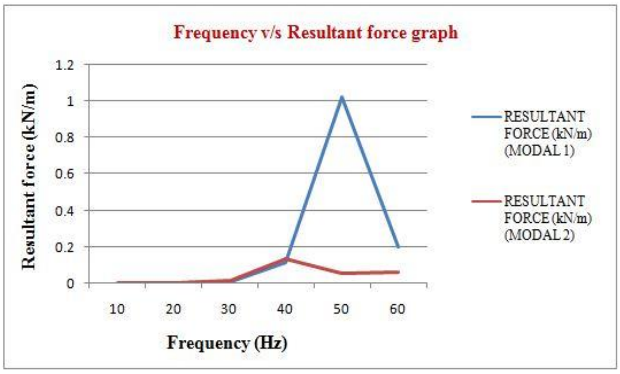

Fig.4.1, Resultant force comparison graph

Table 4: Shell stress

FREQUENCY (Hz)	SHELL STRESS (kN/m²) (Modal 1)	SHELL STRESS (kN/m²) (Modal 2)
10	0.000654	0.012275
20	0.000847	0.016039
30	0.017165	0.04991
40	0.360803	0.45659
50	3.321073	0.197608
60	0.649605	0.209796

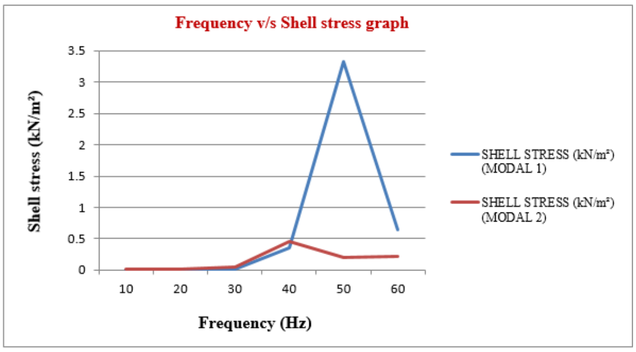

Fig.4.2, Shell stress comparison graph

Table 5: Bending moment

FREQUENCY (Hz)	BENDING MOMENT(kN-m) (Modal 1)	BENDING MOMENT (kN-m) (Modal 2)
10	0.0242	0.0151
20	0.1326	0.0561
30	0.4021	0.135
40	1.8042	0.2357
50	1.0194	0.3
60	1.2997	0.4778

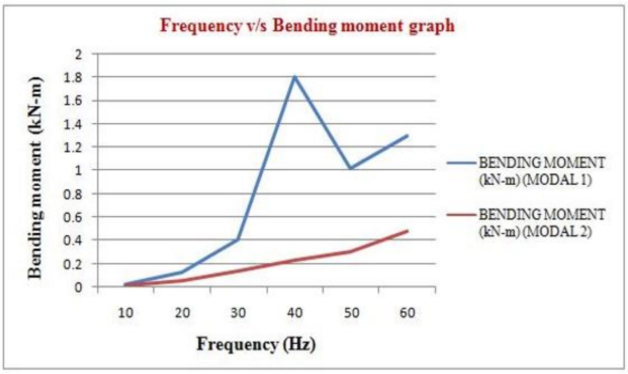

Fig.4.3, Bending moment comparison graph.

Table 6: Shear force

FREQUENCY (Hz)	SHEAR FORCE(kN) (Modal 1)	SHEAR FORCE(kN) (Modal 2)
10	0.015	0.02
20	0.084	0.064
30	0.256	0.143
40	1.148	0.246
50	0.648	0.425
60	0.827	0.641

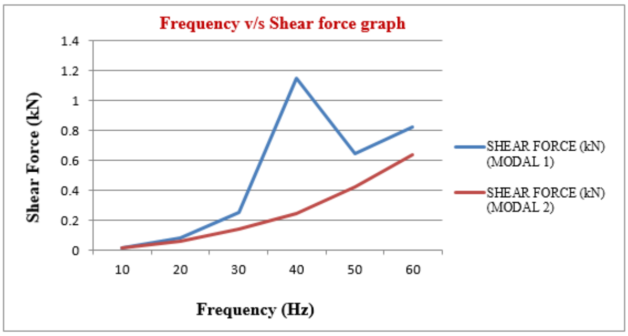

Fig.4.4, Shearforce comparison graph

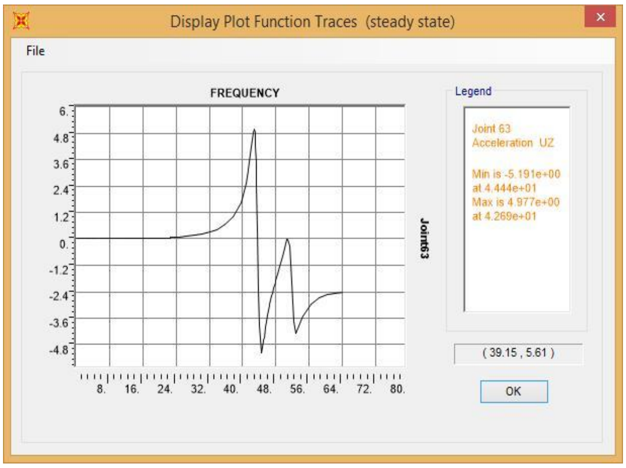

Fig.4.5, Plot function graph for modal 1

- Figure 4.1 and 4.2 shows the comparison of resultant force and shell stress of the modals.
- Figure 4.3 and 4.4 shows the comparison of bending moment and shear force of the models.
- Figure 4.5 and 4.6 shows the Plot functions of the modal 1 and modal 2.

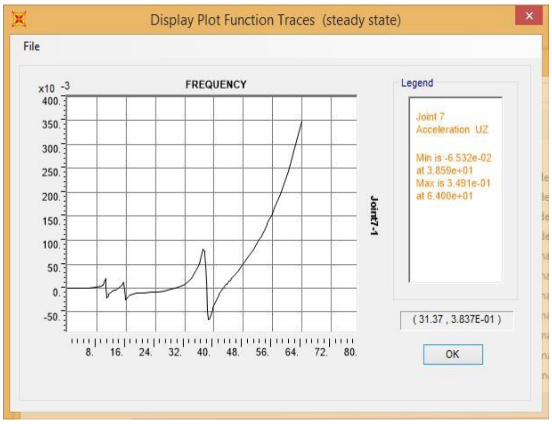

Fig.4.6, Plot function graph for modal 2

5. ACKNOWLODGENMENT

I am extremely thankful to guide **Mr. Sunil KumarK, Head of the Department, Dept. of Civil Engineering, Sahyadri College of Engineering and Management, Mangalore**, for his valuable guidance, encouragement and suggestions offered throughout my project work. He played an important role in completion of my project and for making me work to the best of my abilities.

6.CONCLUSIONS

- The results shown storey vibrations of buildings, which consists of secondary beams parallel to primary beams and primary beams perpendicular to secondary beams.
- The values obtained from plot functions clearly shows that secondary beams placed perpendicular to primary beams have more resistance for vibrations against compared to other structures.
- The mode shapes are slightly higher for secondary beams placed parallel to primary beams compare to secondary beams placed perpendicular to primary beams.
- By keeping the same dynamic force for both structures plot functions are obtained and there is a drastic difference observes in them.
- By comparing shell stress secondary beams placed perpendicular to primary beams have more resistance against shell stress.
- By comparing resultant forces secondary beams placed perpendicular to primary beams have more resistance against force vibration.
- There is no drastic change in shear force and bending moment of the structures.

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