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EXPERIMENTAL VIBRATION RESPONSE OF STEEL STRUCTURE USING FFT ANALYZER WITH AND WITHOUT BEARINGS

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Abstract: The present focuses on the essence of different systems in a setting where vibrations are bound to be perceived. If they are exposed to shocks they encounter elevated amplitudes, contributing to the collapse of the system. This thesis is aimed at studying the vibrational reaction of multistoried buildings through experimental and computational methods in FEM-based software. In this study attempt is made to analyze model with bearing and without bearing by experimental method in FFT Analyzer accessible in laboratory and building model preparation using FEM-based software. After that comparison of the impact of bearing on multistoried building vibrational response will be performed and conclusion will be drawn based on the analysis result.

Index Terms: Vibration Analysis, Steel Structure, FFT Analyzer, Staad-pro

1. INTRODUCTION

Vibrations are time dependent displacements of a particle or a system of particles with respect to an equilibrium position. If these displacements are repetitive and their repetitions are executed at equal interval of time with respect to equilibrium position the resulting motion is said to be periodic. One of the most important parameters associated with engineering vibration is the natural frequency. Each structure has its own natural frequency for a series of different modes which control its dynamic behavior. Whenever the natural frequency of a mode of vibration of a structure coincides with the frequency of the external dynamic loading, this leads to excessive deflections and potential catastrophic failures. This is the phenomenon of resonance. An example of a structural failure under dynamic loading was the well-known Tacoma Narrows Bridge during wind induced vibration. [1]

In practical application the vibration analysis assumes great importance. For example, vehicle-induced vibration of bridges and other structures that can be simulated as beams and the effect of various parameters, such as suspension design, vehicle weight and velocity, damping, matching between bridge and vehicle natural frequencies, deck roughness etc., on the dynamic behavior of such structures have been extensively investigated by a great number of researchers . The whole matter will undoubtedly remain a major topic for future scientific research, due to the fact that continuing developments in design technology and application of new materials with improved quality enable the construction of lighter and more slender structures, vulnerable to dynamic and especially moving loads. Every structure which is having some mass and elasticity is said to vibrate. When the amplitude of these vibrations exceeds the permissible limit, failure of the structure occurs. To avoid such a condition one must be aware of the operating frequencies of the materials under various conditions like simply supported, fixed or when in cantilever conditions.

If a system, after an internal disturbance, is left to vibrate on its own, the ensuing vibration is known as free vibration. No external force acts on the system. The oscillation of the simple pendulum is an example of free vibration. If a system is subjected to an external force (often, a repeating type of force), the resulting vibration is known as forced vibration. The oscillation that arises in machineries such as diesel engines is an example of forced vibration. If the frequency of the external force coincides with one of the natural frequencies of the system, a condition known as resonance occurs, and the system undergoes dangerously large oscillations.

1.1. Fast Fourier Transform

An FFT (Fast Fourier Transform) spectrum analyzer works in an entirely different way. The input signal is digitized at a high sampling rate, similar to a digitizing oscilloscope. The resulting digital time record is then mathematically transformed into a frequency spectrum using an algorithm known as the Fast Fourier Transform or FFT. The FFT is simply a clever set of operations which implements Fourier's basic theorem. The resulting spectrum shows the frequency components of the input signal. Now here's the interesting part. The original digital time record comes from discrete samples taken at the sampling rate. Fourier's basic theorem states that any waveform in the time domain can be represented by the weighted sum of pure sine waves of all frequencies. If the signal in the time domain (as viewed on an oscilloscope) is periodic, then its spectrum is probably dominated by a single frequency component. What the spectrum analyzer does is represent the time domain signal by its component frequencies.[2]
The basic criteria while providing superior seismic resistance of a building is the difficulty in minimizing the inter storey drift and floor accelerations simultaneously. Large inter story drifts cause damage to nonstructural components. These drifts can be minimized by stiffening the structure, but this leads to amplification of the ground motion, which leads to high floor acceleration, which can damage non-structural components. Making the system more flexible can reduce floor acceleration, but this leads to large inter story drifts. The only practical way of reducing inter-storey drift and floor acceleration simultaneously is to use Base Isolation, which provides the necessary flexibility, with the displacements concentrated at the isolation level. In traditional approaches, inorder to achieve capacity we should increase the elastic strength or else to maintain ductility. This leads to increase in floor accelerations and damage to structural components. Whereas in Base Isolation, rather than increasing capacity we decrease demand as we cannot indefinitely increase the strength of the structure. As earth quakes cannot be predicted or controlled, we modify demand by mitigating effects of the foundation to super structure. There are many possible ways to strengthen the system by introducing several devices in structural system. These include elastomeric bearings, sliders, rollers, sliding plates, rocking foundations etc. Of these elastomeric bearings and sliding foundations are most practical ones. Seismic isolation is intended to prevent earthquake damage to structures, buildings and building contents. One type of seismic isolation system employs load bearing pads, called Isolators. Since the isolators carry large vertical loads and deform to significant lateral displacement, the components of the structure above and below the isolator need to be designed properly. Specifically, to make isolation system work in proper manner, the structure should be free to move in any direction up to the maximum specified displacement. Base isolation is achieved by inventing several isolation devices to meet the desired requirements of an earthquake resistant structure. [3].

2. STATE OF DEVELOPMENT

According to the A. Siddika et. al. Free vibration analysis and studies the behavior of framed structure under different frequency of vibration using ANSYS software and shaking table. A small scale uniaxial shaking table was prepared in laboratory, which can produce lower to moderate vibration, regarding frequency and velocity. Moment resisting framed structures constructed with connecting beam and column elements of mild steel wire of different dimensions were tested in shaking table and analyzed using ANSYS software. The effect of masses and stiffness of structures on its natural frequency and deflection under certain ground vibration also studied and discussed. The test results showed that, this shaking table is satisfying the general concept of free vibration. The height of structures has an inverse effect on its natural frequency for same lateral stiffness. After several shaking, structure's natural frequency started to decreases with their decreasing stiffness. Therefore, the fabricated shaking table can used in free vibration analysis

According to the Ajit Vilas Karande et. al. Structures are built close to each other in various cities and urban areas where cost of land is high and availability of land is difficult. Due to this closeness, the structures may collide with each other when subjected to any vibration or earthquake. This collision of buildings or its different parts during the vibration is called pounding which result in architectural and structural damages or collapse of the entire structure. The Among the possible structural damages, seismic induced pounding has been commonly observed in several earthquakes. As a result, a parametric study on buildings pounding response as well as proper seismic hazard mitigation practice for adjacent buildings is carried out. Therefore, the needs to improve seismic performance of the built environment through the development of performance-oriented procedures have been developed. To estimate the seismic demands, nonlinearities in the structure are to be considered when the structure enters into inelastic range during devastating earthquakes. Despite the increase in the accuracy and efficiency of the computational tools related to dynamic inelastic analysis, engineers tend to adopt simplified non-linear static procedures instead of rigorous non-linear dynamic analysis when evaluating seismic demands. This is due to the problems related to its complexities and suitability for practical design applications. The push over analysis is a static, nonlinear procedure that can be used to estimate the dynamic needs imposed on a structure by earthquake ground motions. Papers aims at studying seismic gap between adjacent buildings by dynamic and pushover analysis in software. A parametric study is conducted to investigate the minimum seismic pounding gap between two adjacent structures by response Spectrum analysis for medium soil and Elcentro Earthquake recorded excitation are used for input in the dynamic analysis on different models.. The effect of impact is studied using linear and nonlinear contact force on models for different separation distances and compared with nominal model without pounding consideration. Pounding produces acceleration and shear at various story levels that are greater than those obtained from the no pounding case, while the peak drift depends on the input excitation characteristics. Also, increasing gap width is likely to be effective when the separation is sufficiently wide practically to eliminate contact. The results of pushover analysis viz. pushover curves and capacity spectrum for three different lateral load patterns are observed to study the effect of different lateral load pattern on the structural displacement to find out minimum seismic gap between buildings.

According to the Chinedum Anthony Onuorahet. al. Advancement and Development of technology and smart devices increases the demand for comfort and safety, especially in transportation, where more emphasis is placed on ride comfort and safety by vehicle manufacturers. The ability to measure lower frequency vibration with high precision can cooperate in this regard.This paper proposes a portable and low cost vibration detection device. Enhanced vibration calculation, reduction of error and low storage memory are complementary accomplishments of this research. The device consists of a MEMS capacitive accelerometer sensor and microcontroller unit, which operates based on a novel algorithm designed to obtained vibration velocity, bypassing the usual time-based integration process. The proposed algorithm can detect vibrations within 15Hz - 1000Hz frequencies. Vibration in this frequency range cannot be easily and accurately evaluated with conventional low cost digital sensors. The proposed technique is assessed and validated by comparing results with an industrial grade vibration meter.

According to the G.Mounica, Dr. B.L.Agarwal (2016) "Seismic analysis offixed and base isolated structures" Voluminous studies have been made on Design of Structures resisting effects of earthquakes. Various modes and means of reduction of effects of earthquakes are making structures good resistant enough and ductile. Structures should be made lighter in order to thwart attraction of larger earthquake forces. Use of dampers, sand base and piles, use of suitably designed spring based devices, shear walls to relieve columns of larger bending actions and even base isolators. Most structures are designed on the basis of Dynamic Analysis/ responses and/ or by mixing the above techniques. Only fewer are being provided base isolation systems or devices. Base Isolators have been in large use since three decades and have been used mostly in bridges. These base isolators should be effective for members/ supports under compression and tension. Various advancements had taken place from the earlier periods till now to build earth quake resistant structures such as Mud layer below the structure, Sand layer, Roller and Rubber bearings as foundation support, Laminated rubber bearing system, New-Zealand bearing system, Sliding resilient-friction system, Friction pendulum system, Sleeved pile isolation system, Viscous damping devices such as Visco-Elastic dampers (VEDs),Tuned Liquid dampers (TLDs),Shape Memory Alloy Dampers (SMADs) etc., Here we shall be studying earthquake resistivity of structure by analyzing the Base isolated structure to compare its structural performance with fixed base structure. We have analyzed a fixed building and isolated building with EQ loading conditions using ETABS software and discuss all the possible advantages by using isolators in the structure whichmake the structure flexible and rigid simultaneously to achieve resistance against natural calamity such as earthquakes.

According to the Yogesh Narayan Sonawane et. al. (2016) "Base Isolation for Multistoried Buildings with Lead Rubber bearing "Seismic base isolation is a simple structural design approach to ease earthquake damage possible. The concept of seismic isolation has become a practical reality with the development of multilayer elastomeric bearings. These bearings are very stiff in the vertical direction and can carry the vertical load of the building but are very flexible in horizontally, thereby enabling the building move laterally like a rigid mass under strong ground motion. The main purpose of this study is to check the behavior of the buildings in seismic zone by using base isolation concept, and reduce the story acceleration, story drift and increase the period of oscillation due to earthquake ground excitation, applied to the superstructure of the G+8 building by installing base isolators like lead rubber bearing (LRB) at the foundation level then compare the performance between the fixed base condition and base isolated condition by using SAP software.

According to the Vikram Talekar (2015) Rolling element bearings are one of the major machinery components used in industries like power plants, chemical plants and automotive industries that require precise and efficient performance. Bearing failure occurs due to heavy dynamic loads and also contacts forces which exist between the bearing components, study of vibrations plays an important role in condition monitoring of the ball bearing/machinery. Unfortunately we cannot observe that defects by naked eyes in initial stage of failure. But when these faults are increased to large amount, they will leads to severe damage so it is very necessary to detect faults in bearing at an earlier stage. FFT analyzer can helps to detects in various components without disturbing setting of that component. Condition monitoring of bearings is important to avoid severe failures. Vibration analysis gets much advantage in factories as a predictive maintenance technique. In presented paper vibration response of non- defective bearing has taken and then purposefully various defects various component of bearings have made. It shows that every defect excites the system at its characteristic frequency. The location of the faults is indicated by the FFT Frequency domain spectrum. Also Signature analysis of bearing to observe unbalance, misalignment with increase in speed has done.

3. Problem Statement

The present project work is targeted to investigate the impact of bearing in vibrational response of multistoried building by experimental and analytical method in FEM based software. In this research attempt is made to analyze model with bearing and without bearing by experimental method in FFT Analyzer available in laboratory and preparation of models of building by using FEM based software .After that comparison of effect of bearing on vibrational response of multi-storeyed building will be done and conclusion will be drawn based on the result of analysis.To calculate vibrational response of a steel frame (G+1, 2 bay) with following dimensions and properties.

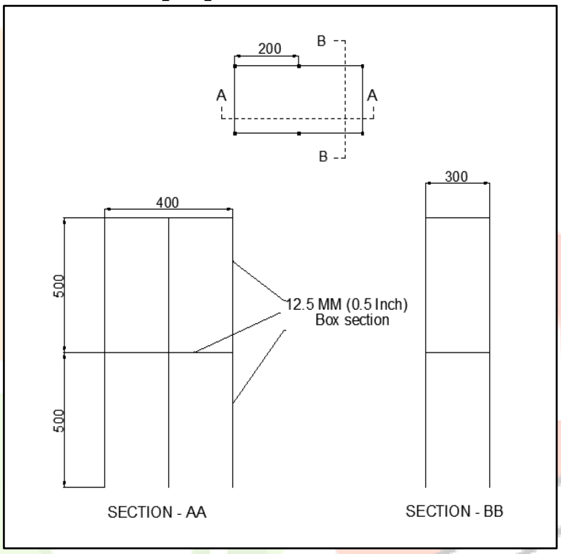


Fig 1 Model Description

1) Fixed Base Steel Frame Model

- Size: (L*B*H) = (0.4*0.3*1) m
- Each floor has height = 0.5 m
- Each bay has length = 0.3 m
- Material: Stainless steel
- Section size: 12.5 MM (0.5 inch) Box section
- E = 197.30 KN\mm^2
- Poisson’s ratio = 0.3
- Density = 7833.41 Kg/m^3

2) Bearing base steel frame model.

- Size: (L*B*H) = (0.4*0.3*1) m
- Each floor has height = 0.5 m
- Each bay has length = 0.3 m
- Material: Stainless steel
- Section size: 12.5 MM (0.5 inch) Box section
- E = 197.30 KN\mm^2
- Poisson’s ratio = 0.3
- Density = 7833.41 Kg/m^3

3) Bearing Details

- Size 50 x 50 mm
- Max Compressive Load (kg) – 76, 100 , 120
- Bolt – M10 x 1.5P x 22L
- Nut – M10 x 1.5P x 12 Deep

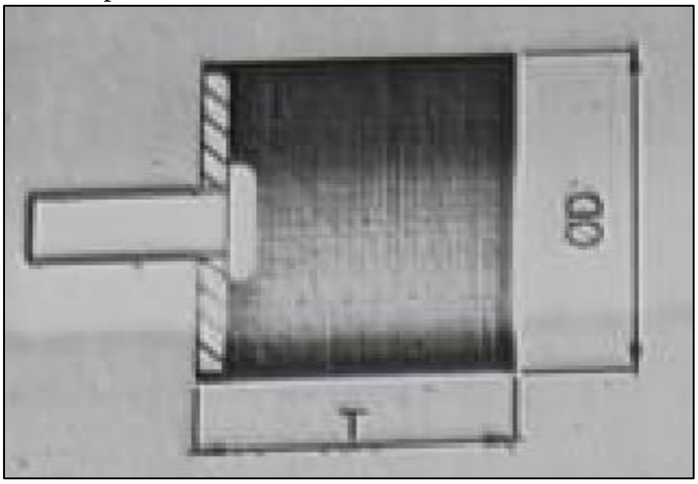


Fig 2 Bearing Details

4.Result and Discussion

- **Software results analysis**

Table 1 Models

Model 1	Fixed Base Steel Frame Model
Model 2	Bearing base steel frame model

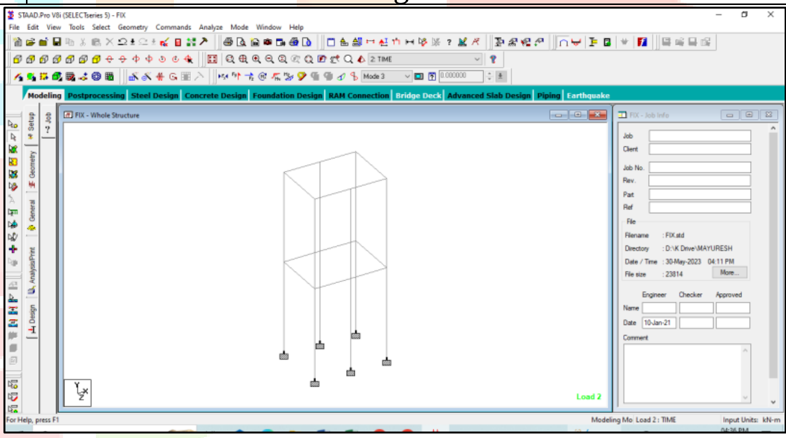


Fig 3 Fixed Base Steel Frame Model

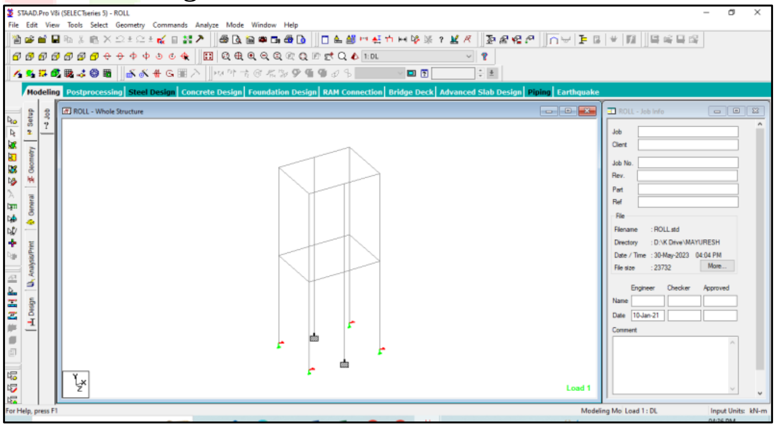
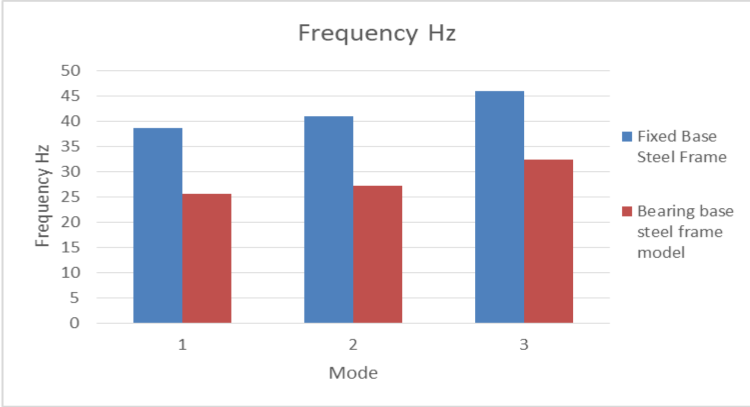


Fig 4 Bearing base steel frame model

Table 2 Frequency for both models Hz

Mode shape	Fixed Base Steel Frame	Bearing base steel frame model
1	38.551	25.637
2	40.96	27.149
3	45.861	32.341



Graph 1 Natural Frequency for both models

As shown in above results of frequency for six mode shapes in staad pro, the natural frequency for fix base steel frame is 38.55 Hz and bearing base steel frame model is 25.63 Hz the frequency for fix base steel frame is more than bearing base steel frame model for each mode shape by around 30-35%

- **Experimental Results Analysis**

Initially, fixed base frame mounted on FFT analyzer, beam sensor has placed on each member of steel frame, (beam & column) successively Every time, whenever sensor has placed on beam/ column excite has produced by FFT hammer. Very slight hammering is been done on each element of steel frame, to induce natural viberator in the frame responses of every element of frame is recorded in the FFT analysis software, which belongs to MIT College of engineering , Loni.

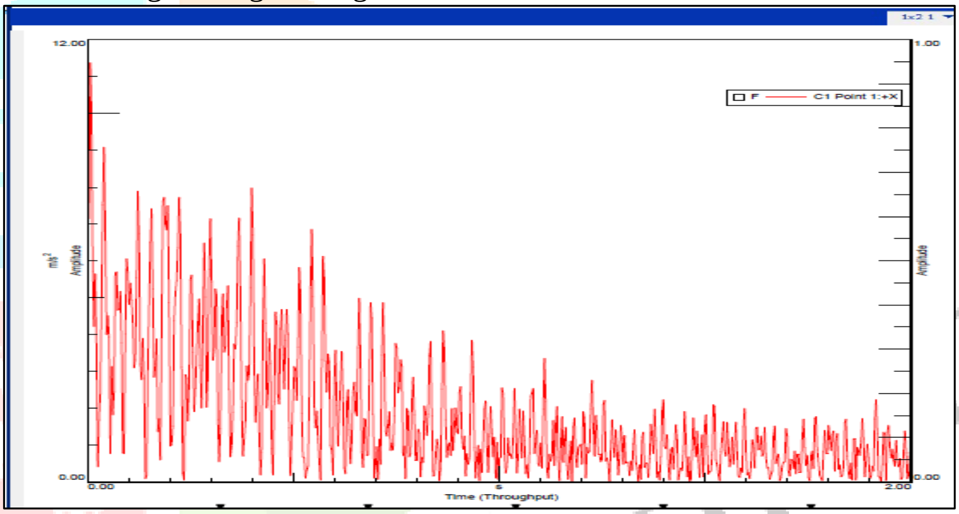


Fig 4 Response for 16 member of fix base frame in FFT

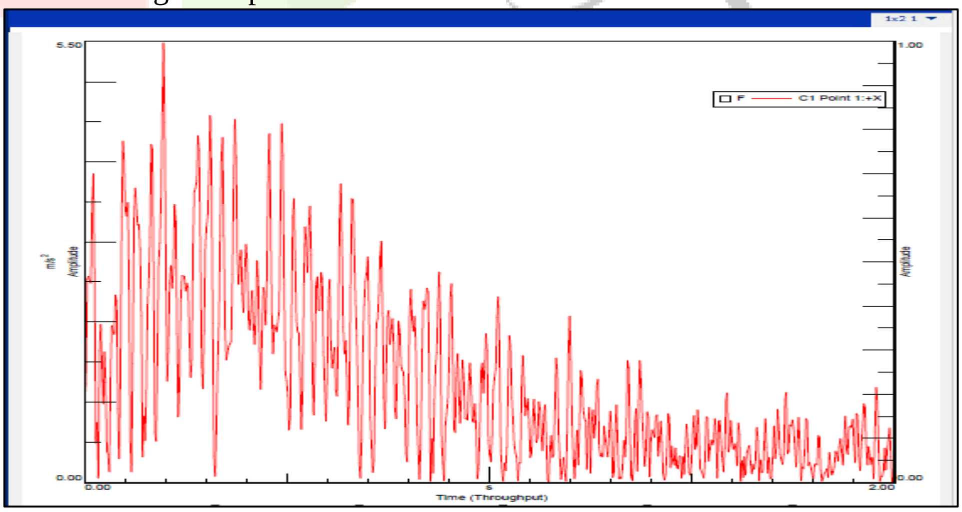


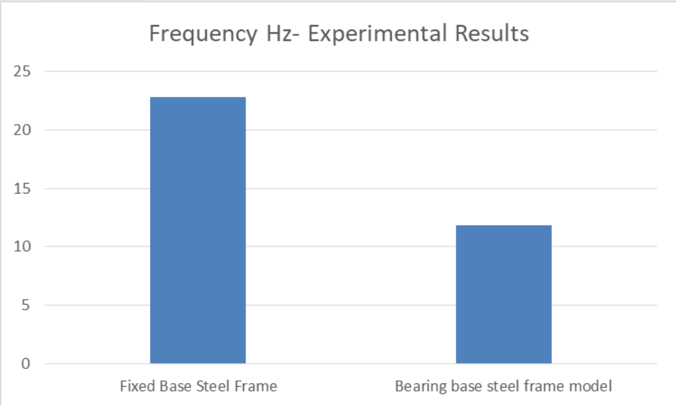
Fig 5 Response for 16 member of Bearing base steel frame model in FFT

Table 3 Frequency Response for 16 member

Hammering No	Fixed Base Steel Frame	Bearing base steel frame model
1	29.9	13.7
2	24.9	11.4
3	20.7	13.2
4	27.3	10.1
5	29.2	15.2
6	12	5.5
7	15.2	8.96
8	18.5	10.21
9	26.1	12.2
10	22.5	9.85
11	24.2	13.23
12	23.34	17.2
13	22.6	13.62
	22.80308	11.87462

Table 4 Experimental Results

SR NO	MODEL	EXPERIMENTAL
1	Fixed Base Steel Frame	22.80 Hz
2	Bearing base steel frame model	11.87 Hz



Graph 2 Experimental Results

As shown in above results of natural frequency for FFT analysis, the frequency for fix base steel frame is 22.8 Hz and bearing base steel frame model is 11.87 Hz , frequency for Fixed Base Steel Frame is more than Bearing base steel frame by around 35-40%.

5.CONCLUSION

The vibration analysis of a structure holds a lot of significance in its designing and performance over a period of time. The steel frame with bolt will resemble any structural defects present in the structures consisting of the flats and their frequency analysis will help us understand the variations that are bound to occur in the frequency because of the defects present in them. The vibration analysis of the foundations of various machines will help us design the foundations such that their serviceability is increased.

- Results comparison of natural frequency for Fixed Base Steel Frame and Bearing base steel frame model in software, experimental and analytical and from the results its conclude that natural frequency for Fixed Base Steel Frame is more in each method than Bearing base steel frame model.
- Results of frequency for six mode shapes in staad pro, the natural frequency for fix base steel frame is 38.55 Hz and bearing base steel frame model is 25.63 Hz the frequency for fix base steel frame is more than bearing base steel frame model for each mode shape by around 30-35%
- Results of natural frequency for FFT analysis, the frequency for fix base steel frame is 22.8 Hz and bearing base steel frame model is 11.87 Hz , frequency for Fixed Base Steel Frame is more than Bearing base steel frame by around 35-40%

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