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Dynamic Analysis of Foundation Supporting Rotary Machine

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ABSTRACT
With the advancement of technology in the field of industry, high speed machinery has been developed. As the speed of machinery has increased, vibrations also increased. Machines transmit vibrations to the structure supporting them. Hence, it is important to design and develop such structure which sustains the vibrations of machinery. Hence, in this study it has been aimed to execute the study on foundations supporting rotary type of machine like blower. In this paper, the most important parameters like frequency and amplitude are considered while execution of analysis of machine foundation supporting blower type machine.
This paper shows, better interface between foundation designer and machine manufacturer for better performance of machine. The design aids/approaches for foundation design is also described in this paper and an attempt has been made to study the dynamic behaviour of a foundation structure for blower type machine subjected to forces due to operation of blower machine. Two different types of foundations for Rotary type Machine that is Blower have been studied in this paper
Keywords- Amplitude, Displacement, Dynamic analysis, Foundation, Frequency, Machine, Modes, Rotary machine, Time history, Vibration

I. Introduction

To define the loads to establish performance criteria, to check resonance condition, to limit amplitude vibration, to proportion various structural members of foundation etc. are the key issues in the design of machine foundation. Yet, behind this straightforward definition lies the need for careful attention to the interfaces between machine, mounting system, and concrete foundation. The basic goal in the design of a machine foundation is to limit its motion to amplitudes that neither threaten the satisfactory process of the machine nor disturb people working in the immediate vicinity. Many engineers with varying circumstances are engaged in the analysis, design, construction, maintenance, and repair of machine foundations. Therefore, it is important that the owner/operator, geotechnical engineer, structural engineer, and equipment supplier collaborate during the design process. Each of these contributors has inputs and concerns that are important and should be effectively communicated with each other, especially considering that machine foundation design procedures and criteria are not covered in building codes and national standards. Some firms and individuals have developed their own standards and specifications as a result of research and development activities, field studies, or many years of successful engineering or construction practices. The cost of the machine foundation is but a small fraction of that of the equipment and incompetently constructed foundations may result in failures and closures exceeding many times the cost of the capital investment required for properly designed and built foundations. A more detailed study became urgent because of the development of machines of higher capacities. Machines of higher ratings gave rise to significantly greater stresses thereby posing problems with respect to performance and safety. Hence it becomes compulsion for development partly in the field of vibration technique and partly in that of soil mechanics. J. G. Sieffert discussed about the recent development in the field& also discussed about the dynamic soil-structure interaction. William E.Saul & Thomas W. Wolf have mentioned that the use of piling for machine foundation can add flexibility for designer, It help to solve special problem and possibly reduce the cost. Z. Huaug & S. Hindiya have explained how the cost of an existing foundation for machine can be minimized by optimizing the parameters. The parameters include the thickness of concrete in the machine pit and platform. The cross-sectional area and the amount of reinforced in piles & the no of piles & the spacing between them. Indrajit Chowdhury stated that foundation of dynamic loading are basically designed as per IS Code, ignoring damping & embedment effect of soil. This will make the foundation more expensive and difficult to design. Thus he propose a method based in which the number of such deficiencies as cited above can be circumvented. Payal Mehta states that dynamic load is not short lived but act over a large period of time. Dynamic force which is generated depend upon the machine type & its operation mechanism & frequency. Rohit R Sharma, Prashant V. Muley, Prashant R. Barbude state about the machine which creates vibration on foundation. due to which higher dynamic forces are generated. So they suggest the designed aids / method for foundation design. The ideas about the characteristics of harmonic force stated by Cyril Harris in his book "Harris' Shock and Vibrations" were proved to be beneficial while making the mathematical model of the looms machine. M. J. Pender gives a review about the main issues in the design of shallow foundation and deep foundation which may be subjected to earthquake loading.

II. METHODOLOGY

The dynamic analysis of foundation for blower type machine is done by following approach.

Reconnaissance Survey which includes visit to the effluent treatment plants, industry and interaction with the industry people for getting a better practical picture of the blower type machine foundation, study of structural system of the machine foundation in industry and understanding the working of the blower type machine.

Collection of necessary machine data such as the dimension of the machine components, its operating speed, frequency of motor and blower, RPM of motor and blower, Mass of motor and blower etc. Also, the data regarding the foundation which includes dimensions of the block and pile have been collected.

Preparation of drawing of foundation plan showing layout of machine position on the foundation floor and pile dimensions in case of pile model using CAD software.

Modelling of Machine Foundation Structure using structural engineering software - STAAD.Pro has been done. Its pre-analysis includes modelling, labelling, assigning geometric properties and loads to various structural components, as well as to assign support conditions and to assign suitable analysis commands. The post-analysis includes studying of various modes shapes and their respective frequencies amplitude and displacement.

Plotting of graphs of various results of frequency and displacements with respect to two types of machine foundation models has been done.

III. MACHINE DETAILS/DATA

Blower:-Blower is used in Effluent Treatment Plant in industry for the purpose of treating water.

Types of blowers:

1. Horizontal blower
2. Vertical blower

There is some flexibility in the configuration of a rotary blower in terms of the locations of gas connections and drive shaft. Depending on the model, the gas connections can be either on the top and bottom of the unit, on the sides or a combination.

When the connections are on the top and bottom, the unit is designated as a "Horizontal" machine and when the connections are on the sides, it is a "Vertical" machine. The designation has nothing to do with the direction of gas flow but comes from the orientation of the blower shafts, i.e., when a plane intersecting the shafts is horizontal, the unit is so designated. Conversely, when the plane is vertical, the machine is designated as vertical. Some units can have the inlet connection on the top and the discharge on the side. Since a plane through the shafts establishes the definition of the orientation, this would be a "Horizontal" machine. This issue is critical when designating the specifics of a blower as some manufacturers define the orientation differently.

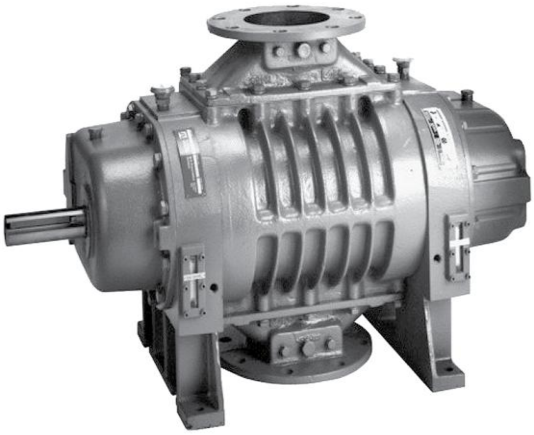


Fig.1 Horizontal blower[2]

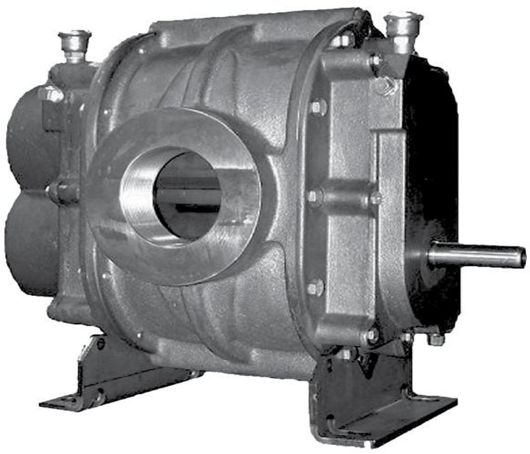


Fig.2Vertical blower[2]

Table 1 Blower Details/Data

Particular	**Details**
Operating Speed	1450 RPM
Dimensions	0.8m x 0.85m
Mass	1100 Kg
Frequency	23.33 cycles/sec

Table 2 Motor Details/Data

Particular	**Details**
Operating Speed	1450 RPM
Dimensions	0.8m x 0.85m
Mass	1100 Kg
Frequency	70 cycles/sec

IV. LOADS CONSIDERED

4.1*Construction load*

Self-weight of all structure and non-structural elements, considering density of reinforced cement concrete as 25 kN/m^3. It also includes a uniformly distributed load of 0.8KN/m^2 due to floor finish.

4.2*Live load*

Machine load of 10 kN is distributed evenly among its four floor supports. Along with it, an additional live load of 2.0 kN/m2 is also applied to the floor.

4.3*Time History Load*

Harmonic Load is generated due to the unbalanced force being produced by the vibration of blower and motor. The Harmonic Load caused by the blower ad motor movement is applied.

V. ANALYSIS METHOD AND FOUNDATION CONFIGURATION

Model 1:- Hollow Block Foundation with piles

The dimensions considered for hollow block foundation with piles are 3.0m x 1.20m x 0.6m. The hollow block foundation with piles is as shown in fig 3. The length of Rubble Stone filled is 2.8m and width is 0.8m. This foundation is designed as such that block is resting on ground so that support condition is given around piles and bottom of block foundation. This foundation is designed as such that block is resting on ground so that support condition is given around piles and bottom of block foundation. The foundation has been supported by soil springs as per structural subgrade modulus of soil. The structural model of this type foundation is shown in fig.4

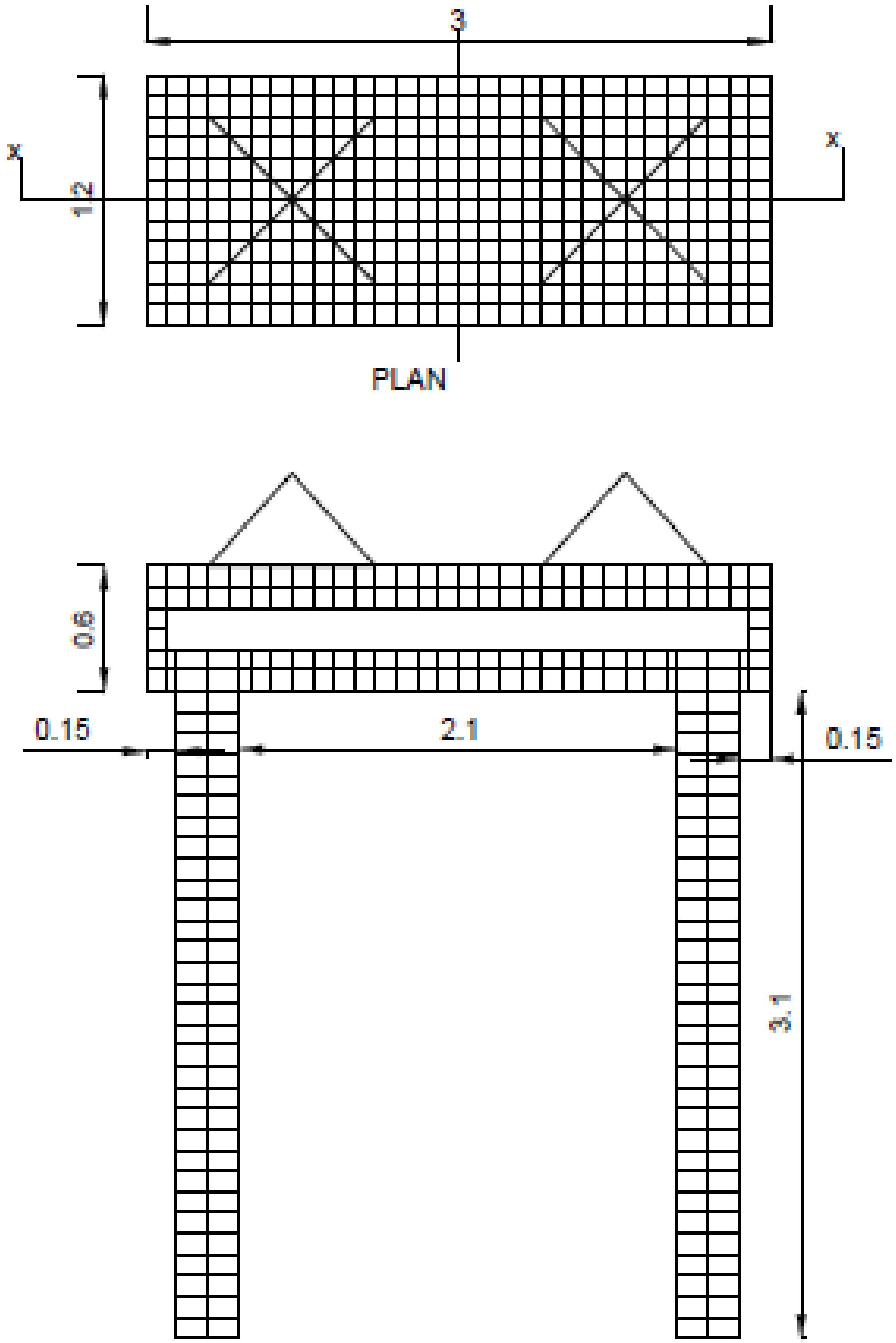


Figure 3 Plan and sectional elevation of Hollow Block Foundation

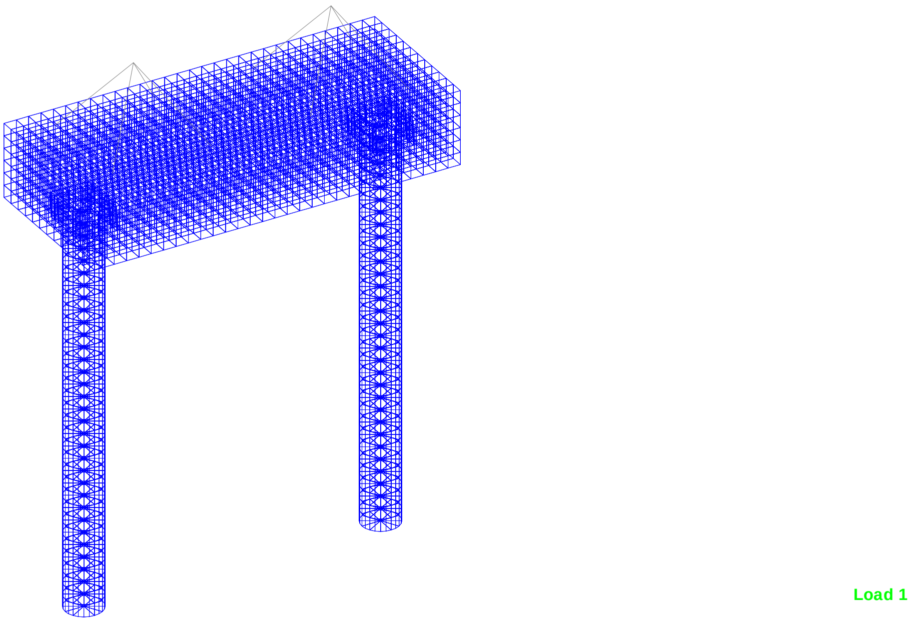
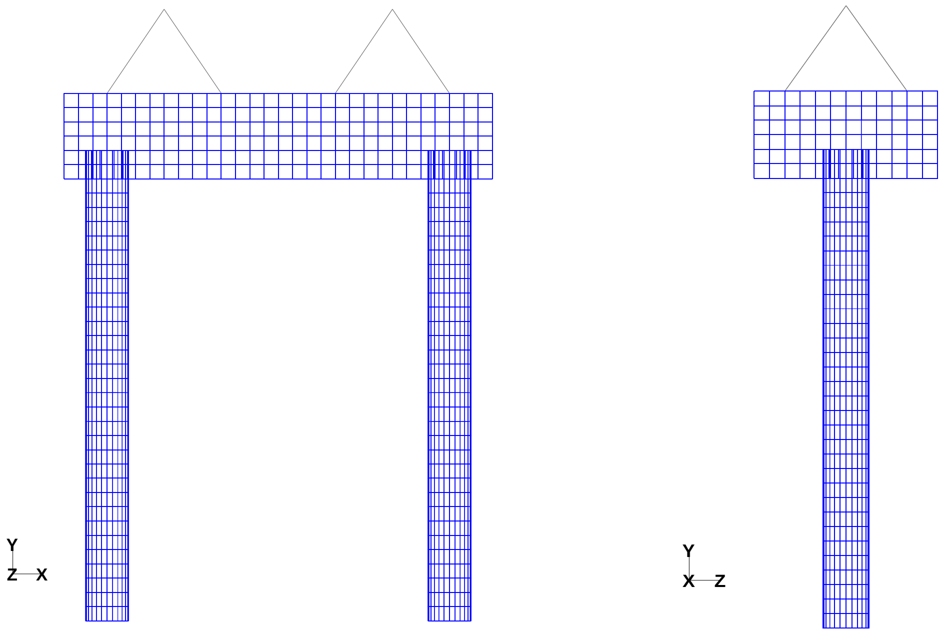


Figure 4 3D View of Hollow Block Foundation with PilesModel for Blower Machine in STAAD.Pro



(a) X-Y Plane (b) Y-Z Plane

Fig. 5 2D View of Hollow Block Foundation with Pileswith Piles Model for Blower Machine in STAAD.Pro

Model 2:- Table Mounted Block Foundation

This type of foundation is adopted when good soil strata is available at great depth below the level where machine is to be fixed. In such case, R.C.C. walls are constructed from top of block foundation up to base level of machine and on these R.C.C walls, machine is to be fixed. The typical sketch of this type of foundation is as shown in fig.6. The foundation has been supported by soil spring as per subgrade modulus of soil. The structural model of foundation is as shown in fig.7

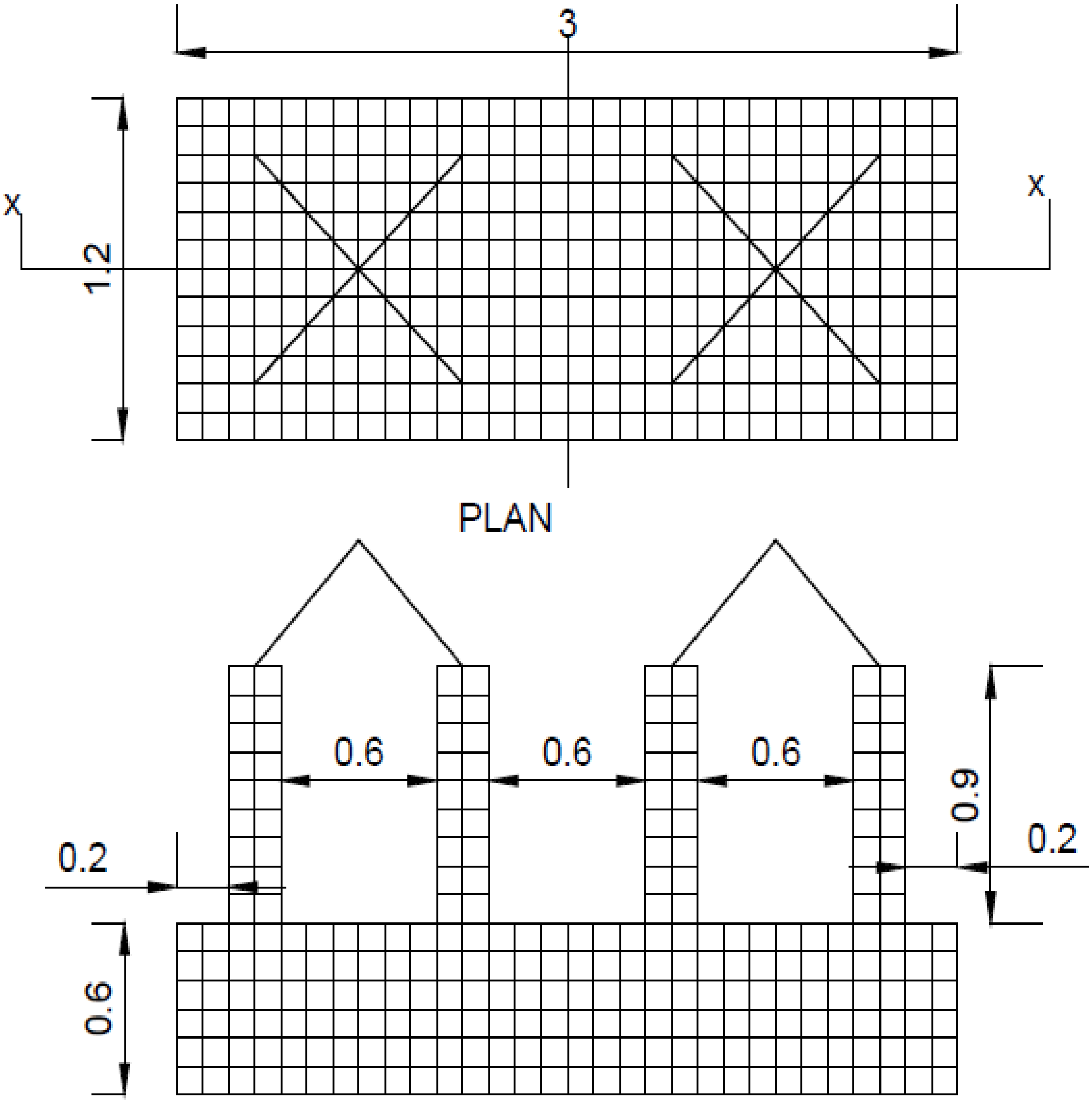


Fig 6 Plan and Sectional Elevation of Table Mounted Block Foundation

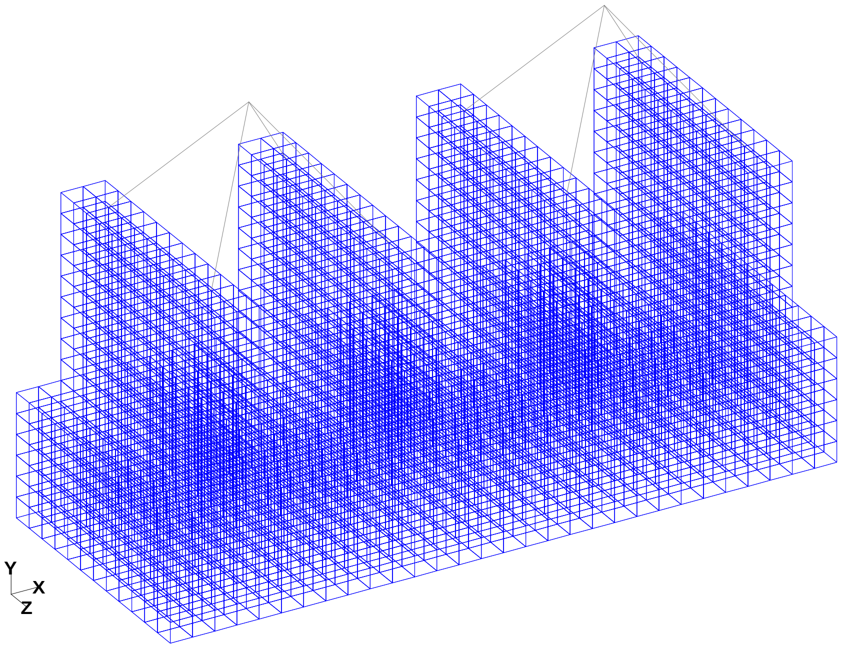
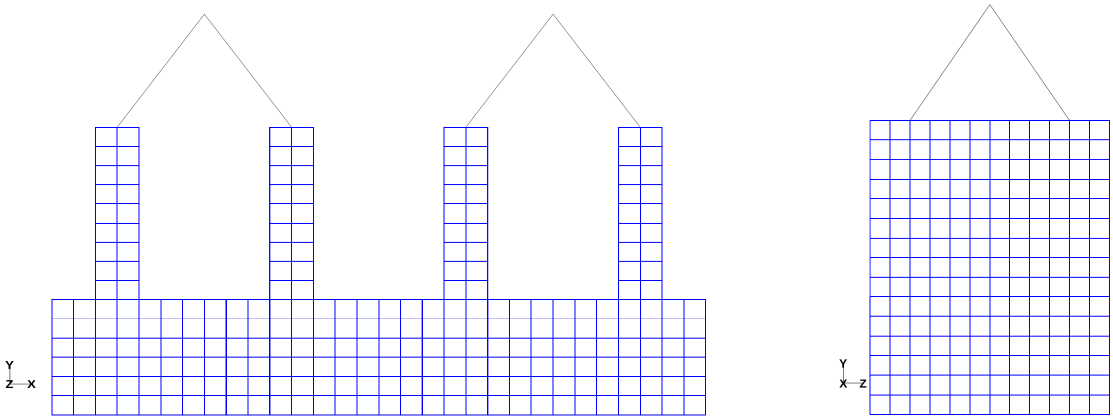


Figure 7 3D View of Table Mounted Block FoundationModel for Blower Machine in STAAD.Pro



(a) X-Y Plane (b) Y-Z Plane

Figure 8 2D View of Table Mounted Block Foundation Model for Blower Machine in STAAD.Pro

VI. RESULTS

The results consist of three parts

1. To obtain Displacement in X-Direction and Y-Direction at a particular Node where the displacement is maximum.
2. To obtain Frequency of Foundation in various Modes of Vibration.
3. To study Von Mises Stress (N/mm^2) contours according to loads.

6.1 Displacement

Displacement is obtained in X and Y Direction at Nodes which are located at corner of foundation where displacement is maximum.

Results are tabulated in tables and as shown graphically in following Figures.

6.1.1 To obtain Displacement in X-Direction at a particular Node

Table 1 X-Direction (Displacement)

X Displacement (m)		
Node	**Hollow Block Foundation with piles**	**Table Mounted Block Foundation**
Top Node Displacement	0.135	0.207
Bottom Node Displacement	0.1025	0.2109

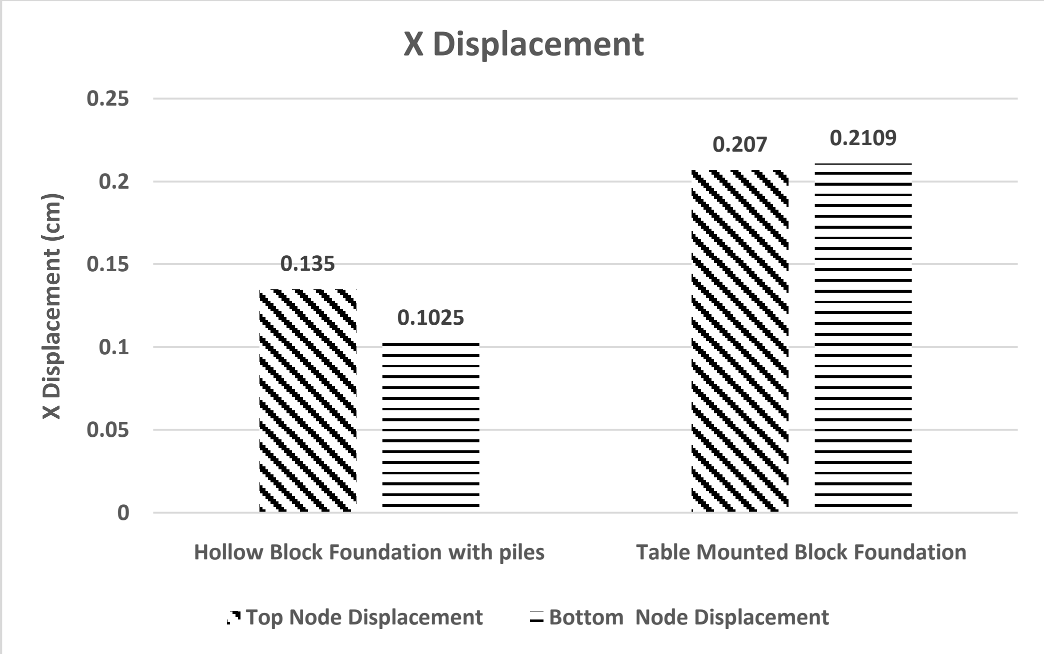


Figure 9 X-Direction Displacement

6.1.2 To obtain Displacement in Y-Direction at a particular Node

Table 3 Y-Direction Displacement (Top Node)

Y displacement (m)		
Node	**Hollow Block Foundation with piles**	**Table Mounted Block Foundation**
Top Node 1 Displacement	0.0888	0.1276
Top Node 2 Displacement	0.083	0.1276
Top Node 3 Displacement	-0.0813	-0.1417
Top Node 4 Displacement	0.0871	-0.1417

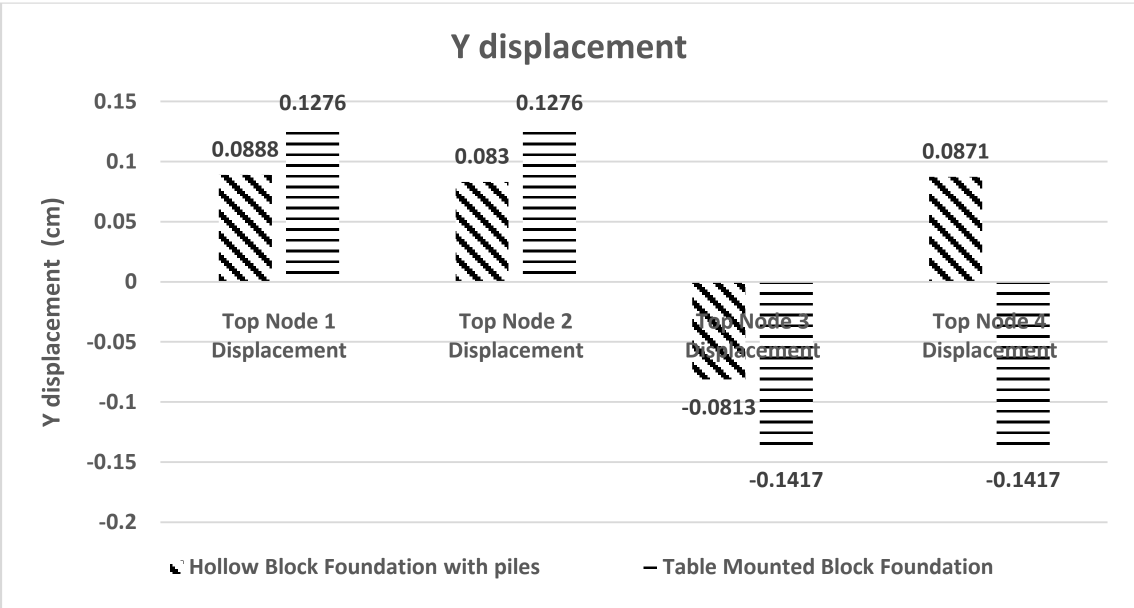


Figure 10Y-Direction Displacement (Top Node)

Table 4 Y-Direction Displacement (Bottom Node)

Y displacement (m)		
Node	**Hollow Block Foundation with piles**	**Table Mounted Block Foundation**
Bottom 5 Node Displacement	0.0888	0.1276
Bottom 6 Node Displacement	0.083	0.1276
Bottom 7 Node Displacement	-0.0872	-0.1417
Bottom 8 Node Displacement	-0.0871	-0.1417

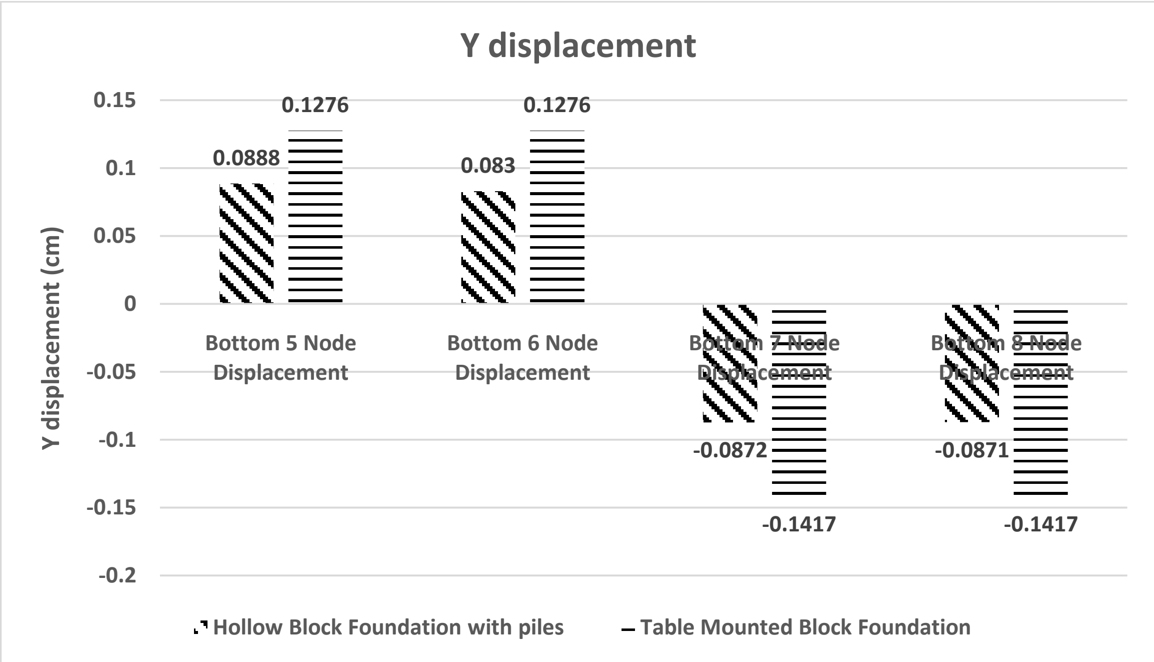


Figure 11 Y-Direction Displacement (Bottom Node)

6.2 Frequency

Table 5Comparison of frequency in various modes

Mode Shape	Frequency (cycles/second)	
	Hollow Block Foundation with piles	**Table Mounted Block Foundation**
Mode 1	2.607	1.232
Mode 2	2.75	1.564
Mode 3	3.414	2.666
Mode 4	6.03	2.69
Mode 5	9.348	2.944
Mode 6	14.833	3.786

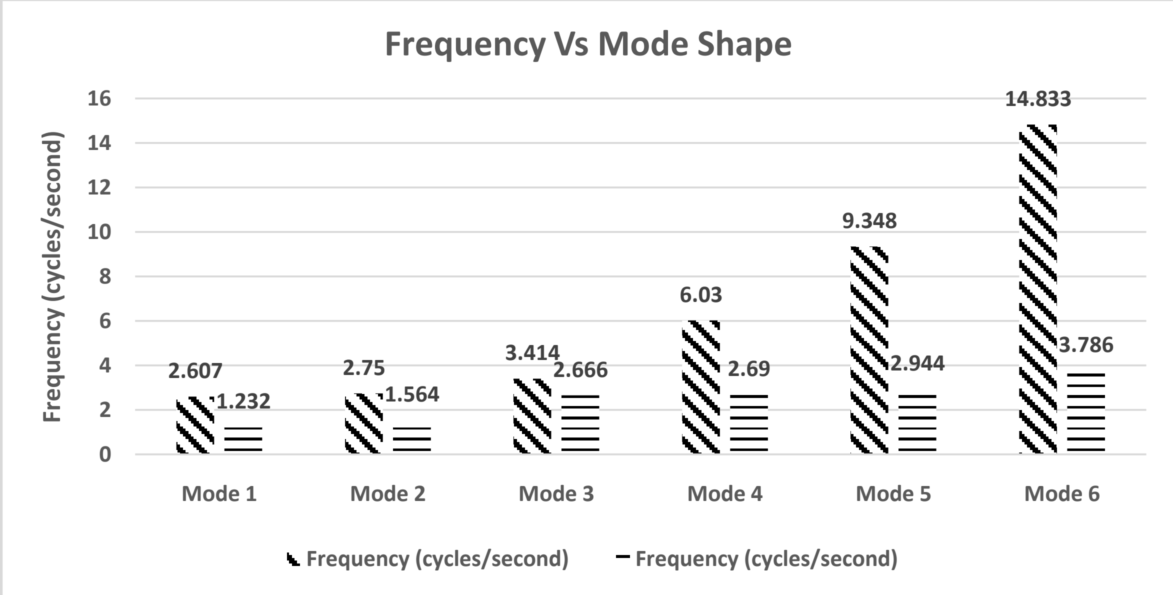


Figure 12 Frequency-Mode Shape

6.3 Von Mises Stress comparison (N/mm^2)

Table 6 Von Mises Stress (N/mm^2)

Model	Von mises (N/mm²)					
	Dead Load		Live Load		Harmonic Load	
	Max.	Min.	Max.	Min.	Max.	Min.
Hollow Block Foundation with piles	0.154	0.00065	1.569	0.0058	0.488	0.00058
Table Mounted Block Foundation	0.1024	0.00078	0.6488	0.00133	0.034	0.00013

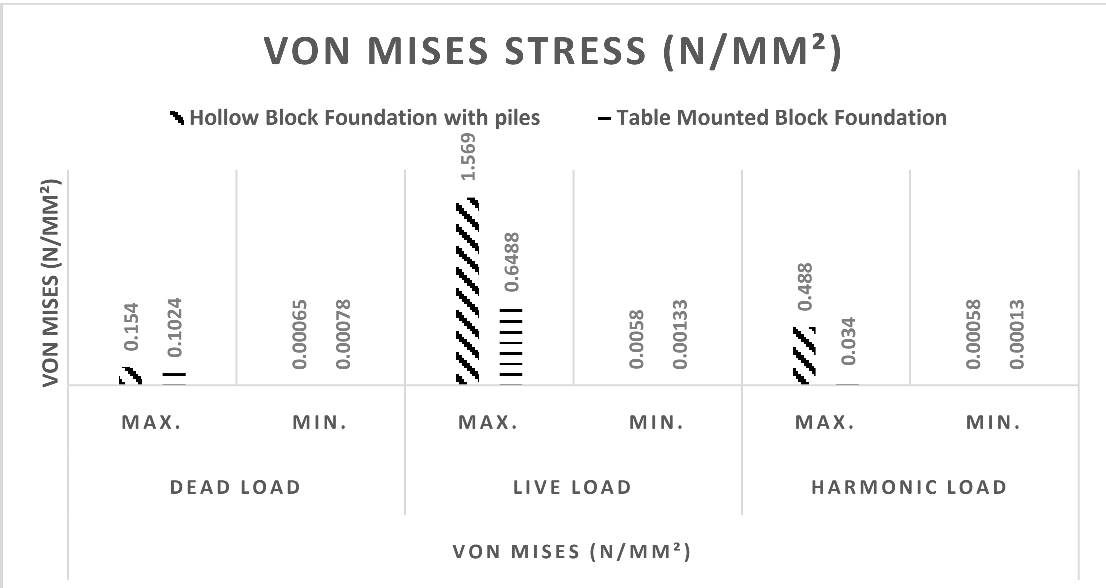


Figure 13Von mises stress (N/mm^2)

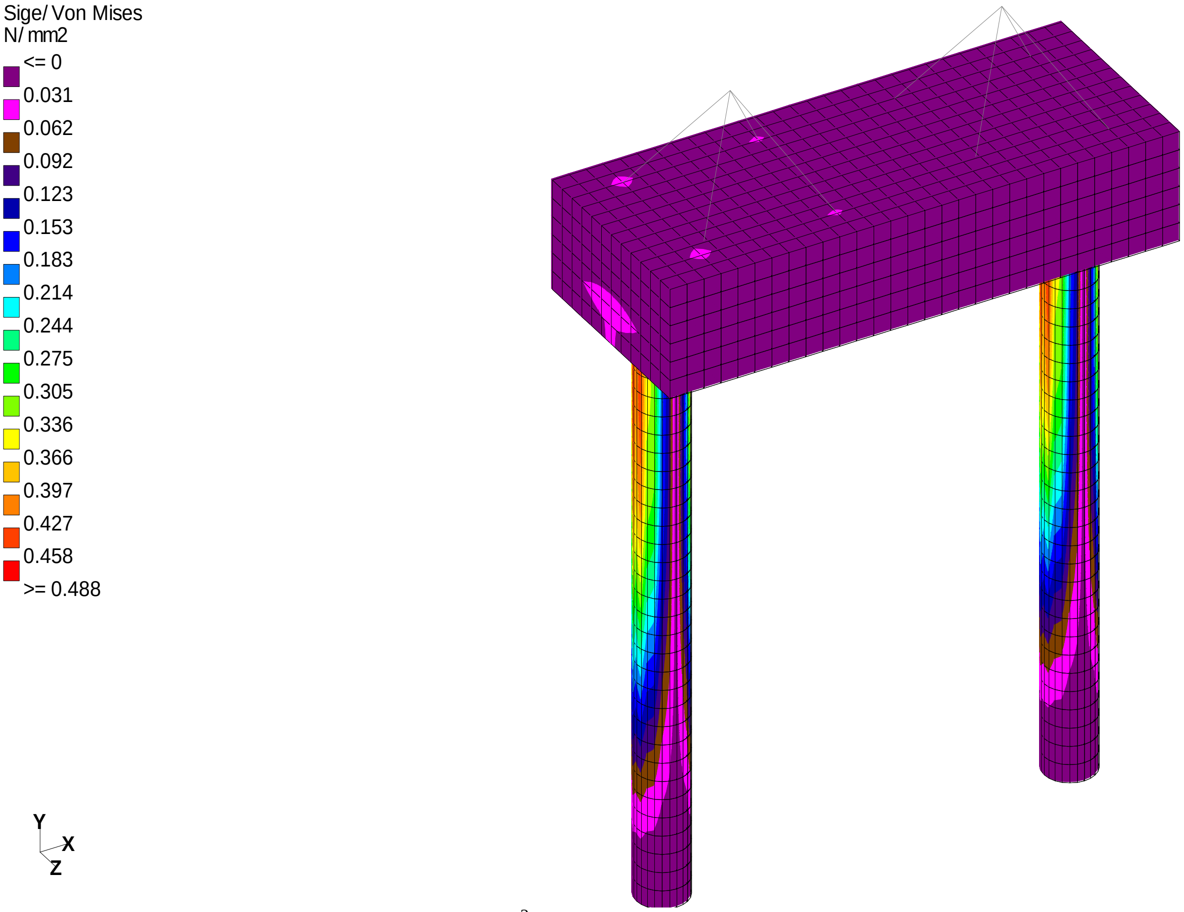


Figure 14Von Mises Stress (N/mm^2) contour for Hollow Block foundation with piles

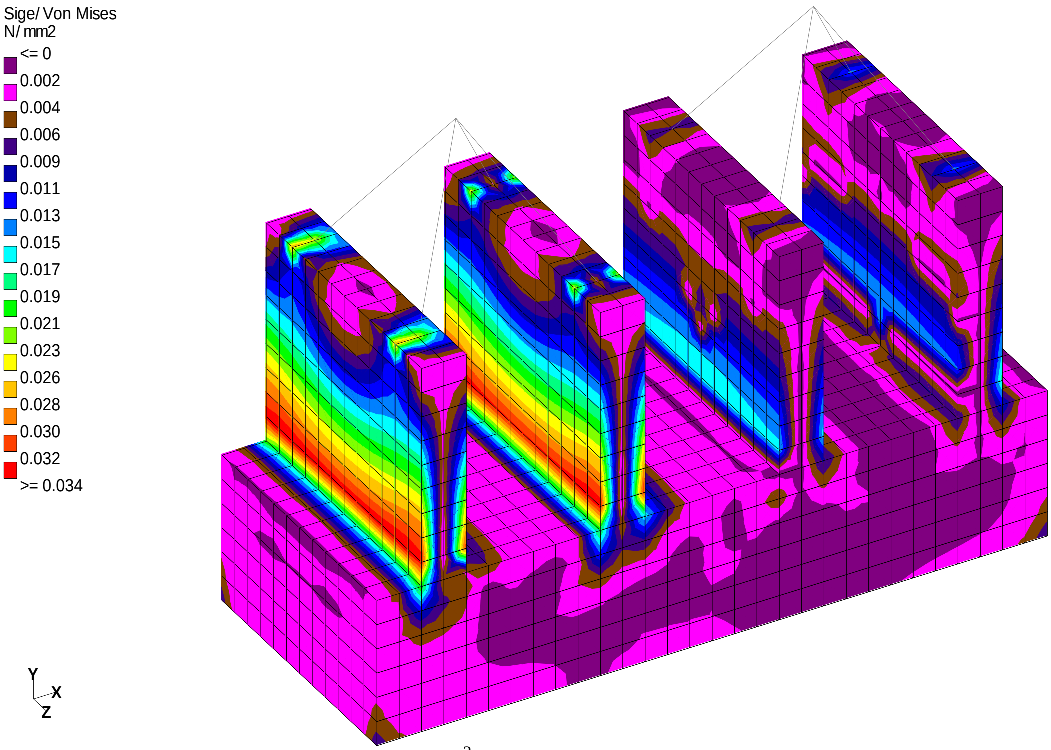


Figure 15Von Mises Stress (N/mm^2) contour for Table Mounted Block Foundation

VII. CONCLUSION

As far as X-direction displacement is concern, Hollow Block Foundation with Piles shows good performance as compare to Table Mounted Block Foundation. From the Fig. 11 it is clearly visible that Table Mounted Block Foundation has maximum displacement in X-direction at top node and bottom node than Hollow Block Foundation with Piles because Table Mounted Block Foundation shows more flexible behaviour structurally. From table 5, it can be seen that frequency values are very less in case of table mounted block foundation as compared to hollow block foundation with piles. Hence, displacement is more in case of table mounted block foundation.

As far as Y-direction displacement is concern, Hollow Block Foundation with piles is better in performance as compare to Table Mounted Block Foundation. The reason behind that is Hollow Block Foundation with piles has piles below block foundation which helps in preventing Y-direction (vertical) displacement.

Hollow block foundation with piles shows a great variation in frequency as compared to table mounted block foundation. The variation in frequency from mode 1 to mode 6 in case of hollow block foundation with pile is about 496% and in case of table mounted block foundation is 207%. The hollow block foundation with pile is more stiff foundation due to provision of pile below and hence frequency is more.

Von Mises stresses are more in Hollow Block Foundation with Piles as all the forces transferred by machine to block is ultimately taken by piles and hence, entire blocks foundation is in lower stress zone. In table mounted block foundation, there exist no piles hence all the loads are to be transmitted by R.C.C walls and block foundation to the soil below and hence values of von Mises stress contours is more

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