Dynamic Analysis of Machine Foundation Using Ansys

P.M. Shimpale [1], Sindhu Panapalli [2]
[1]Asst.Prof
[1, 2] M.G.M's College Of Engineering, Nanded, Maharashtra

Abstract- *The analysis of Machine Foundation involves not only static loads but also the dynamic loads which are caused due to the working of the machine. Therefore, the machine foundation should survive these loads. Therefore, it becomes vital to reduce the natural frequency of soil beneath the foundation. One such treatment is to prepare a layered soil beneath the foundation by trenching the soil and placing different types of isolation materials.*

Keywords– Frame foundation, Sinusoidal load, Rubber, Rock basalt, springs,ansys etc

I. INTRODUCTION

Foundations may be subjected to either static loads or a combination of static and dynamic loads; the latter lead to motion in the soil and mutual dynamic interaction of the foundation and the soil. The design of foundations subjected to dynamic forces is part of soil dynamics. 'Soil Dynamics' may be defined as that part of soil mechanics which deals with the behaviour of soil under dynamic conditions. The effects of dynamic forces on soil are under this topic which is relatively a new area of Geotechnical Engineering. The sources of dynamic forces are numerous; violent types of dynamic forces are caused by earthquakes, and by blasts engineered by man. Pile driving and landing of aircraft in the vicinity, and the action of wind and running water may be other sources. Machinery of different kinds induces different types of dynamic forces which act on the foundation soil. Most motions encountered in Soil Dynamics are rectilinear (translational), curvilinear, rotational, two-dimensional, or three-dimensional, or a combination of these. The motion may be a periodic or periodic, and steady or transient, inducing 'vibrations' or 'oscillations'.

Impact forces or seismic forces cause 'shock', implying a degree of suddenness and severity, inducing a periodic motion in the form of a 'pulse' or a transient vibration. This may lead to settlement of foundations and consequent failure of structures. Since dynamic forces impart energy to the soil grains, several changes take place in the soil structure, internal friction, and adhesion. Shock and vibration may induce liquefaction of saturated fine sand, leading to instability. The primary aim of Soil Dynamics is to study the engineering behavior of soil under dynamic forces and to develop criteria for the design of foundations under such conditions. The fields of application of Soil Dynamics are varied and diverse, and include (i) vibration and settlement of structures, and of foundations of machinery, (ii) densification of soil by dynamic compaction and vibration, (iii) penetration of piles and sheet piles by vibration or impact, (iv) dynamic and geophysical methods of exploration, (v) effects of blasting on soil and rock materials, and (vi) effects of earthquakes and earthquake-resistant design of foundations. The increasing use of heavy machinery, of blasting operations in construction practice, and of various kinds of heavy transport in the context of industrial and technological progress point to the importance of 'Soil Dynamics'. 'Dynamics of Bases and Foundations' forms an important part of 'Industrial Seismology', a branch of mechanics devoted to the study of the effects of shocks and vibrations in the fields of engineering and technology; in fact, the former phrase happens to be the title of a famous book on the subject by Professor D.D. Barkan in Russian (English Translation edited by G.P. Tschebotarioff and first published by McGraw-Hill Book Company, Inc., New York, in 1962). This is a monumental reference book on the subject, based on the original research in Barkan's Soil Dynamics Laboratory. The Book "Vibration Analysis and Design of Foundations for Machines and Turbines" by Alexander Major (1962) also ranks as an excellent and authoritative reference on the subject, while a more recent Book "Vibrations of Soils and Foundations" by Richart, Hall and Woods (Prentice Hall, Inc., New York, 1970) is also an excellent treatise. The design of machine foundations is more complex than that of foundations, which support static load only. Loads acting on such foundations are dynamic in nature. These loads may result from various causes such as vibratory motion of machines, movement of vehicles, impact of hammers, earthquakes, wind waves, nuclear blasts, mine explosions, pile driving etc. It is, therefore, necessary to understand the effects of dynamic forces in the foundation soil. In general a machine foundation weighs several times as much as the machine it supports. Also a dynamic load associated with the moving parts of a machine is generally small as compared to its static load. However, in machine foundations, dynamic loads act repetitively over a very long period of time. It is therefore necessary that the soil should be elastic, or else deformation will increase with each cycle of loading until the amplitude of deformation becomes larger and out of the acceptable limit. The amplitude of motion of a machine at its operating frequency is the most important parameter to be determined in designing a machine foundation, in addition to determining the system's natural frequency.

1.2 Basic Definitions

I. Vibration (or Oscillation): It is a time-dependent, repeated motion which may be translational or rotational.
II. Periodic motion: It is a motion which repeats itself periodically in equal time intervals.
III. Period: The time in which the motion repeats itself is called the 'Period'.
IV. Cycle: The motion completed in a period is called a 'Cycle'.
V. Frequency: The number of cycles in a unit of time is known as the 'frequency'. It is expressed in Hertz (Hz) in SI Units (cycles per second). The period and frequency are thus inversely related, one being simply the reciprocal of the other.
VI. Degree of Freedom: The number of independent co-ordinates required to describe the motion of a system completely is called the 'Degree of Freedom.

1.3 Types of Machine Foundations:

Foundations for machines are generally of the following types, based on their structural shapes, as shown in Figure 11.1.

1. Block type (rigid foundations)
2. Box or caisson type
3. Wall type
4. Framed type
5. Non rigid or flexible type

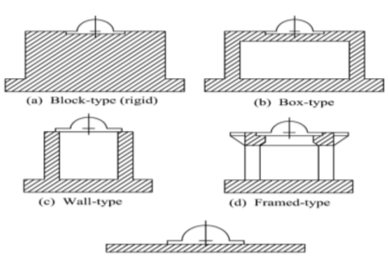


Fig1.1: Common types of machine foundations

1.3.1 There are many kinds of machines that generate different types of time-dependent forces. The three most important categories are:

(1)Reciprocating Machines:

Machines that produce periodic unbalanced force (such as compressor and reciprocating engines) belong to this category. The operating speeds of such machines are usually 2 less than 600 r.p.m. For analysis of their foundations, the unbalanced forces can be considered to vary sinusoidally.

(2) Impact machines:

Machines that produce impact loads like forging hummers and punching press are included in this category. Their speeds of operations are usually from 60 to 150 blows per minute. In these machines, the dynamic force attains a peak value in a very short time and then dies out gradually.

(3) Rotary machines:

High-speed machines like turbo generators or rotary compressors may have speeds of more than 300 r.p.m and up to 10,000 r.p.m. Foundation.

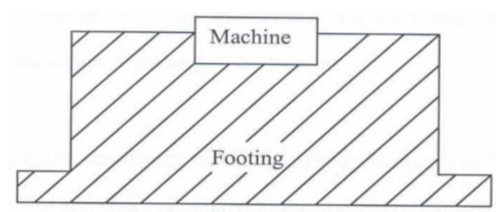


Fig1.2: Block-type machine foundation

Because this type of foundation is easy for construction and very commonly in use, this thesis is concerned with the analysis of such foundations, but taking into account that they can generally be embedded in a layered formation. Recently developed closed-form expressions for the dynamic stiffness and dashpot coefficients of the underlying soil are employed unlike the conventional approach, which 3 involve some degree of empiricity to estimate these quantities and add arbitrary magnitude of soil mass in addition to the actual mass of the machinery and its foundation.

1.4General requirements of machine foundation

The following requirements should be fulfilled from the design point of view of machine foundations

(a) The foundation should be able to carry the superimposed loads without causing shear or crushing failure of the underlying soil.
(b) The settlement should be within the permissible limits.

(c) The combined center of gravity of machine and the foundation should be on the vertical line passing through the center of gravity of the base plane.
(d) There should be no resonance; that is the natural frequency of the foundation-soil system should be either too large or too small compared to the operating frequency of the machines. For low-speed machine, the natural frequency should be high and vice-versa.
(e) The amplitude of motion at operating frequencies should not exceed the limiting amplitude, which is generally specified by machine manufacturers. If the computed amplitude is within tolerable limit, but is close to resonance, it is important that this situation be avoided. 4
(f) Where possible the foundation should be planned in such a manner as to permit a subsequent alteration of natural frequency by changing base area or mass of the foundation as may subsequently be found necessary.

1.4.1 From the practical point of view, the following requirements should be fulfilled:

(a) The ground-water level should be as low as possible and ground-water level should be at least deeper by one-forth of the width of foundation below the base plane. This limits the vibration propagations, ground water being a good conductor of vibration waves, especially P-waves
(b) Machine foundations should be separated from adjacent building components by means of expansion joints.
(c) Any steam or hot air pipes, embedded in the foundation must be properly isolated
(d) Machine foundation should be taken to a level lower than the level of the foundations of adjacent buildings.
(e) The foundation must be protected from machine oil by means of acid resistant coating or suitable chemical treatment.

II. MATERIAL MODELING

The definition of the proposed numerical model was made by using finite elements available in the ANSYS code default library. SOLID186 is a higher order 3-D 20-node solid element that exhibits quadratic displacement behavior. The element is defined by 20 nodes having three degrees of freedom per node: translations in the nodal x, y, and z directions. The element supports plasticity, hyperelasticity, creep, stress stiffening, large deflection, and large strain capabilities. It also has mixed formulation capability for simulating deformations of nearly incompressible elastoplastic materials, and fully incompressible hyperelastic materials. The geometrical representation of is show in SOLID186.

This SOLID186 3-D 20-node homogenous/layered structural solid were adopted to discretize the concrete slab, which are also able to simulate cracking behavior of the concrete under tension (in three orthogonal directions) and crushing in compression, to evaluate the material non-linearity and also to enable the inclusion of reinforcement (reinforcement bars scattered in the concrete region).The element SHELL43 is defined by four nodes having six degrees of freedom at each node. The deformation shapes are linear in both in-plane directions. The element allows for plasticity, creep, stress stiffening, large deflections, and large strain capabilities. The representation of the steel section was made by the SHELL 43 elements, which allow for the consideration of non-linearity of the material and show linear deformation on the plane in which it is present.

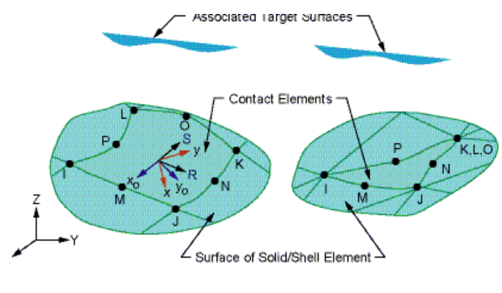


Fig 2.1 CONTA 164

The modeling of the shear connectors was done by the BEAM 189 elements, which allow for the configuration of the cross section, enable consideration of the non-linearity of the material and include bending stresses. CONTA174 is used to represent contact and sliding between 3-D "target" surfaces (TARGE170) and a deformable surface, defined by this element. The element is applicable to 3-D structural and coupled field contact analyses. The geometrical representation of CONTA174 is show in fig4. Contact pairs couple general axisymmetric elements with standard 3-D elements. A node-to-surface contact element represents contact between two surfaces by specifying one surface as a group of nodes. The geometrical representation of is show in TARGET 170.

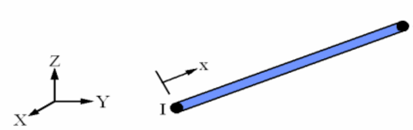


Fig.2.2 Beam 189

The TARGET 170 and C0NTA 174 elements were used to represent the contact slab-beam interface. These elements are able to simulate the existence of pressure between them when there is contact, and separation between them when there is not. The two material contacts also take into account friction and cohesion between the parties.

Sometimes it is not always an easy task for an engineer to decide whether the obtained solution is a good or a bad one. If experimental or analytical results are available it is easily possible to verify any finite element result. However, to predict any structural behaviour in a reliable way without experiments every user of a finite element package should have a certain background about the finite element method in general. In addition, he should have fundamental knowledge about the applied software to be able to judge the appropriateness of the chosen elements and algorithms.

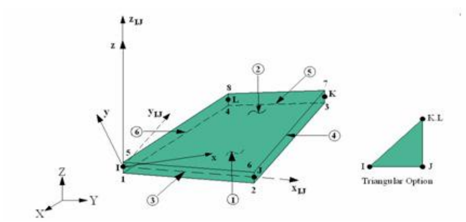


Fig 2.3 shell 43

This paper is intended to show a summary of ANSYS capabilities to obtain results of finite element analyses as accurate as possible. Many features of ANSYS are shown and where it is possible we show what is already implemented in ANSYS.16 Workbench.

III. METHODOLOGY

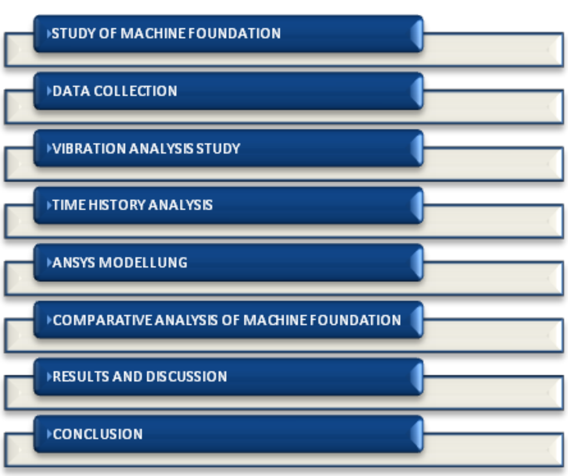


Fig 3.1:Flow Chart

IV. PROBLEM STATEMENTS

For the comparative analysis purpose following two models are selected

MODEL NO.1	BLOCK TYPE MACHINE FOUNDATION
MODEL NO.2	FRAME TYPE MACHINE FOUNDATION

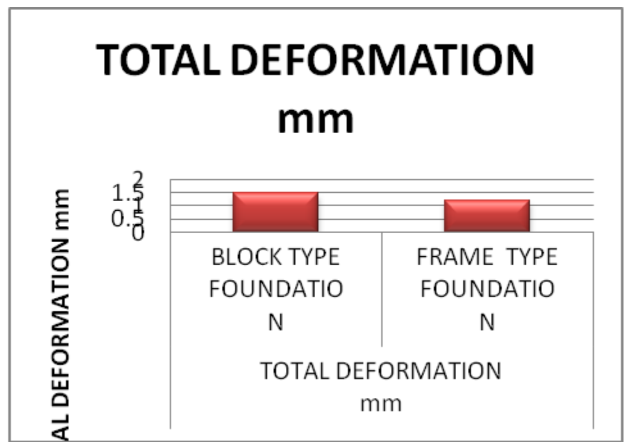
RESULT AND DISCUSSION

Static Load Result

TOTAL DEFORMATION:

a	
BLOCK TYPE FOUNDATION	FRAME TYPE FOUNDATION
1.496	1.1968

Table No4.1: TOTAL DEFORMATION



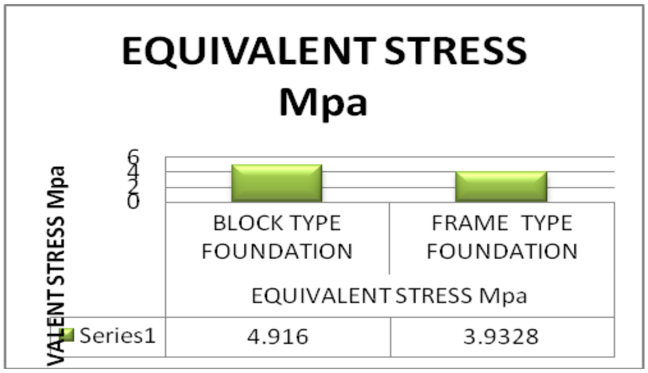
Graph No4.1: TOTAL DEFORMATION

Total Deformation of block type foundation is 1.496 and frame type foundation is 1.2.

EQUIVALENT STRESS:

EQUIVALENT STRESS Mpa	
BLOCK TYPE FOUNDATION	FRAME TYPE FOUNDATION
4.916	3.9328

Table No4.2: EQUIVALENT STRESS



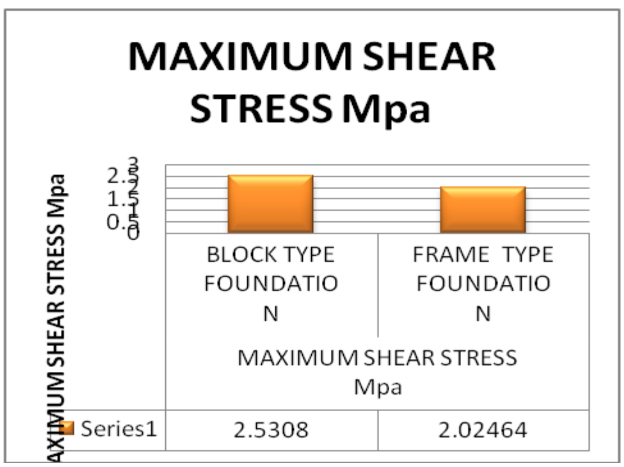
Graph No4.2: EQUIVALENT STRESS

Equivalent Stress of block type foundation is 4.916 and frame type foundation is 3.9328.

MAXIMUM SHEAR STRESS:

MAXIMUM SHEAR STRESS Mpa	
BLOCK TYPE FOUNDATION	FRAME TYPE FOUNDATION
2.5308	2.02464

Table No4.3: MAXIMUM SHEAR STRESS



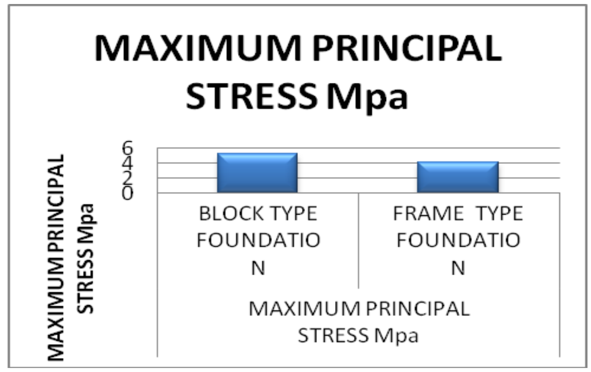
Graph No4.3: MAXIMUM SHEAR STRESS

Maximum Shear Stress of block type foundation is 2.5308 and frame type foundation is 2.02464.

MAXIMUM PRINCIPAL STRESS:

MAXIMUM PRINCIPAL STRESS Mpa	
BLOCK TYPE FOUNDATION	FRAME TYPE FOUNDATION
5.169	4.1352

Table No4.4: MAXIMUM PRINCIPAL STRESS



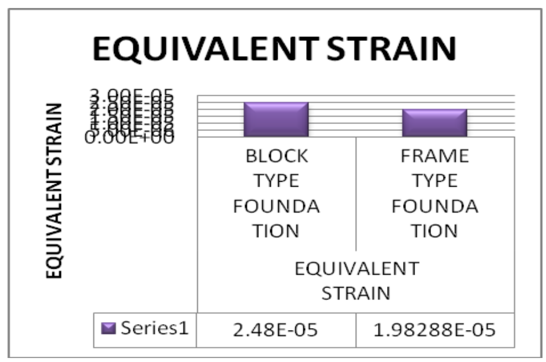
Graph No4.4: MAXIMUM PRINCIPAL STRESS

Maximum Principal Stress of block type foundation is 5.169 and frame type foundation is 4.13.

EQUIVALENT STRAIN:

EQUIVALENT STRAIN	
BLOCK TYPE FOUNDATION	FRAME TYPE FOUNDATION
2.48E-05	1.98288E-05

Table No4.5: EQUIVALENT STRAIN



Graph No4.5: EQUIVALENT STRAIN

EQUIVALENT STRAIN of block type foundation is 2.4 and frame type foundation is 1.98.

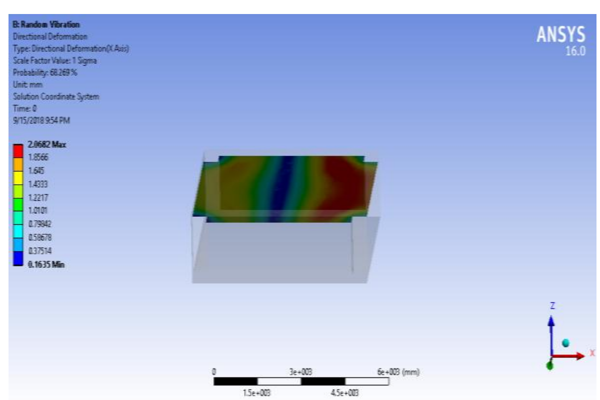


Fig No: 4.1: Directional Deformation

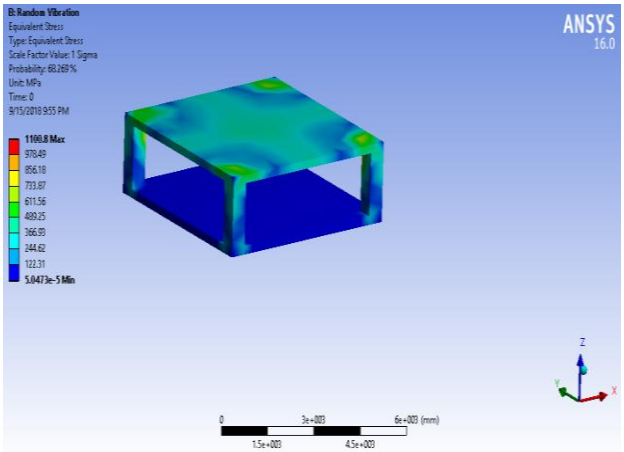


Fig No: 4.2: Equivalent Stress

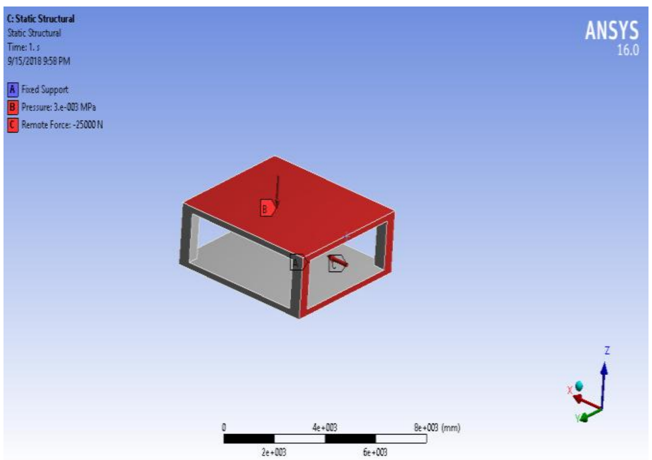


Fig No: 4.3: Static structural

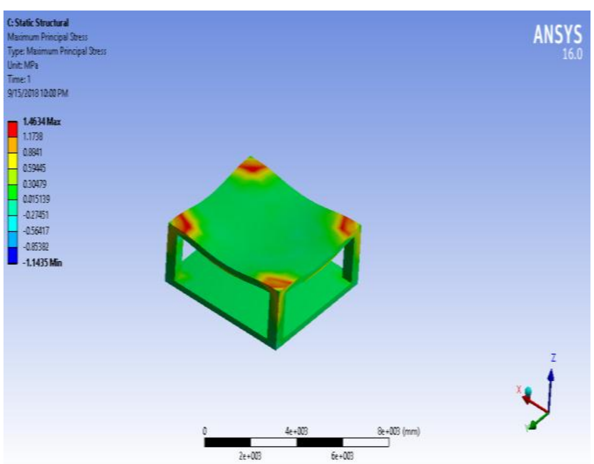


Fig No: 4.4: Maximum principal Stress

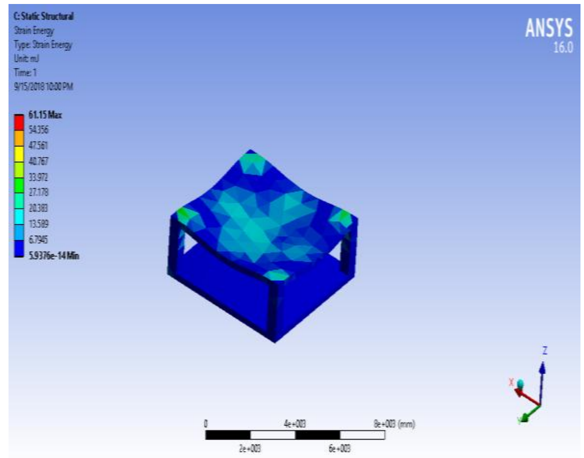


Fig No: 4.4: Strain energy

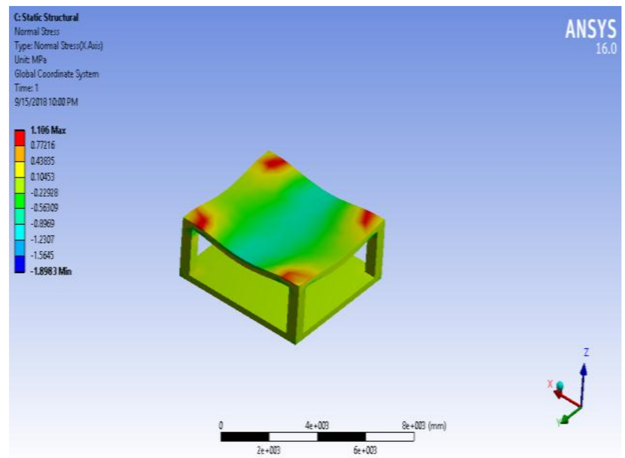


Fig No: 4.6: Normal stress

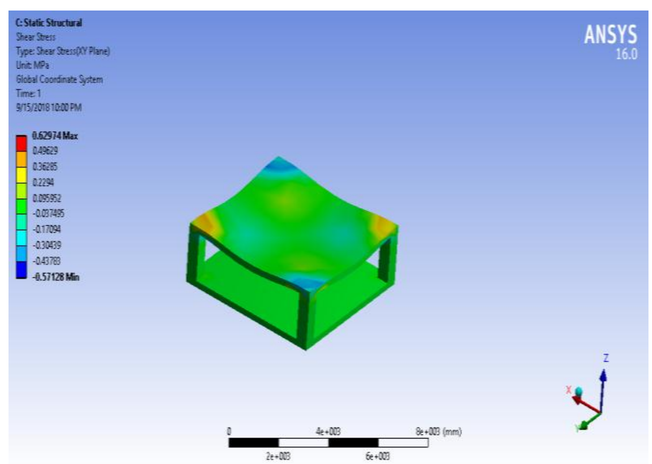


Fig No: 4.7: Shear stress

V. CONCLUSION

in this paper the 2 types of machine foundation i.e. is studied subjected to vibrations, BLOCK TYPE FOUNDATION, FRAME TYPE FOUNDATION and following results are obtained

- The natural frequencies in block foundation is observed more than rcc framed foundation which indicates less time period for vibration
- The deformation,equivalent stress,principal stress observed 15-20% less in frame type foundation
- Hence it can be concluded that frame type foundation should be preferred over block type foundation

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