# The Behavior of Gypseous Soil under Vertical Vibration Loading

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## ABSTRACT

The dynamic response of foundation rest on collapsible soil in dry and soaked states is studied through wide experimental programmed. Gypseous soil from Tikrit governorate area was obtained and subjected to various physical and chemical analysis to determine its properties. Steel rectangular footing (400x200x20) mm is manufactured. The machine is fitted to the footing, then the model machine foundation is placed centrally over the prepared soil layer in steel container (1200x 1000x1000)mm with proper care to maintain the center of gravity of whole system lie in the same vertical line with container.Then, the footing is subjected to vertical harmonic loading using a rotating mass type mechanical oscillator to simulate different dynamic loads. The effect of soaking and eccentric mass was investigated. The results showed that the amplitude of displacement in dry state is greater than its value at soaked state, while the resonant frequency in the soaked state is greater than in dry state. Also, the results showed that for specific frequency ,an increasing in eccentric mass leads to increase in amplitude of displacement. Moreover, an increasing in resonant frequency can be absoreved when eccentric mass is increased.

**KEY WORDS: Machine foundation, collapsible soil, dynamic response, harmonic loading**

# تصرف التربه الجبسيه تحت تأثير الحمل الاهتزازي العمودي

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**الخلاصه**

لقد تم دراسة الاستجابة الديناميكية للاسس مستنده على تربه انهياريه في الحاله الجافة والرطبة من خلال برنامج عملي واسع.التربه التي اجريت عليها الفحوص هي تربه جبسيه اخذت من محافظة تكريت،حيث اجريت عليها الفحوص الفيزيائيه والكيميائيه لايجاد خصائصها.تم تصنيع اساس حديدي مستطيل الشكل بابعاد(20*200*400)ملم.تم تثبيت الاله على هذا الاساس ،بعد ذلك تم وضع النموذج (الاساس والآلة ) مركزيا على طبقات التربه المحضره في حاويه حديديه بابعاد (1200*1000*1000)ملم مع الاخذ بنظر الاعتبار ان يكون مركز ثقل النظام ومركز الحاويه يقعون على خط عمودي واحد ، بعد لك تم تعريض الاساس الى حمل توافقي باستخدام مذبذب ميكانيكي وذلك من اجل محاكاة احمال ديناميكيه مختلفه.لقد أظهرت النتائج أن سعة النزوح في الحالة الجافة أكبر من قيمتها في الحاله المغموره، في حين أن تردد الرنين في الحاله المغموره أكبر من الحالة الجافة . أيضا، أظهرت النتائج انه لتردد محدد، ان زيادة في الكتلة الغير مركزيه ر يؤدي إلى زيادة في سعة النزوح .كذلك لقد تم ملاحظة زيادة في تردد الرنين بزيادة الكتله الغير مركزيه.

**الكلمات الرئيسيه : اساس ماكنه،تربه انهياريه،الاستجابه الديناميكيه،الحمل المتناسق**

## INTRODUCTION

The gypseous soil is one type of the collapsible soils, it covers wide areas in Iraq. This soil has high bearing capacity in dry state, but it subsides (collapses) upon saturation due to loss of cementation and particle bonding. Therefore, structures supported on unstable soil should be guarded against such danger.

A large number of studies have examined the behavior of collapsible soil in Iraq. The accuracy of these studies depend on manufacturing of test set and sampling techniques and has traditionally relied on routine tests under static condition. However, there is currently lack of knowledge in understanding of the behavior of collapsible soil under dynamic loading. With increases in development, particularly of electrical stations ,factories, roads and other transportation links dynamic loading is often critical. To date this has often been dealt with as a quasi static problem. However, this fails to fully replicate dynamic loadings experience under real environments. Therefore, it is important to study the response of this soil under dynamic loading.

## BACKGROUND

Geotechnical engineers Frequently come across two types of problem in relation to analysis and design of foundations namely (i) foundations subjected to static loads and(ii) foundations subjected to dynamics loads. The characteristics feature of static load is that for given structure the load carried by the foundation at any given time is constant in magnitude and direction. While the characteristics feature of dynamic load is that it varies with time. Purely dynamic loads do not occur in nature. Loads always in combinations of static and dynamic. loads **Saran(2007).**

The main causes of dynamic loads on soils, foundations and structures are due to one of the following:

1. Impact load (pile driving in construction operations),

2.Harmonic excitation (machine foundation), and

3.Acceleration-time history (Earthquake).

The nature of each of these loads is quite different from another.

There are aspects that should be taken into account in the criteria for satisfactory action of foundation under dynamic load:

1. No resonance should occur; the natural frequency of the machine-foundation- soil system should not coincide with the operating frequency of the machine. Generally, a zone of resonance is defined and the natural frequency of the system should lie outside this zone (**Saran,2006**) .The frequency ratio (r) (defined as the ratio of operating frequency to natural frequency) should be :

   i. In reciprocating machines (IS:2975 pt I-1982)
   
   for important machines : $r > 2.0$ and $r < 0.5$
   
   for ordinary machines : $r > 1.5$ and $r < 0.6$

   ii. In impact machines (IS:2975 pt II-1980)
   
   $r > 1.5$ and $r < 0.4$

   iii. In rotary machines (IS:2975 pt III-1992)
   
   $r > 1.25$ and $r < 0.8$

2. The amplitudes of motion at operating frequencies should not exceed the limiting amplitudes specified by the manufacturer**(Prakash and Puri , 2006).**

3.The vibrations must not annoy the persons working in the shops or damp the other precision machines **(Prakash and Puri ,2006).**

4.Foundation block should be structurally adequate to carry the loads **(Rao, 2011).**

5.The combined center of gravity (CG) of machine and foundation and the center of contact area (with the soil) should lie on the same vertical line as far as possible **(Rao, 2011),** so that the bearing capacity of all the system will increase.

6. Where possible, the foundation should be planned in such a manner as to permit a subsequent alteration of natural frequency by changing the base area or mass of the foundation as may subsequently be found necessary **(Arora,1997).**

7.The ground-water level should be as low as possible, and it should be at least deep by one-fourth of the width of foundation below the base plane, (Arora,1997).

8.Machine foundations should be separated from adjacent building components by means of expansion joints **(Arora,1997).**

9.Machine foundation should be taken to a level lower than the level of the foundations of adjacent buildings (Arora,1997), so that the wave transmitted through soil will not cause damage to the adjacent foundation.

**Mandal and Baidya (2003)**, studied experimentally the dynamic response of a foundation subjected to vibration in vertical mode on dry sand. The tests were carried out in two different pits in the field; one with rigid base and the other with a large depth simulating the half space. The damping factor and stiffness are calculated from the test results and corresponding to governing equation of motion using single degree of freedom. mass-spring-dashpot model, the solution for the displacement is obtained.

**Moreschi and Farzam (2005)** studied the application of the harmonic analysis resonant frequencies of individual structural members in large steam-turbine generator foundations. They proposed a methodology for the accurate determination of the local structural vibration properties.

**Prakash and Puri (2006)**, studied the methods of analysis for determining the response of foundation subjected to harmonic excitation. Analogy based on the elastic- half space solutions were used, and soil stiffness considered frequency independent for design of machine foundations. They found that the embedment of a foundation strongly influences its dynamic response.

## EXPERIMENTAL PROGRAM

The soil of this investigation was taken from Tikrit Governorate, north of Iraq, has been implemented for the testing program; Table (1) shows the physical and chemical properties of the soil.

## APPARATUSES OF MODEL

The apparatuses of modle includs as fallow:

a.Steel box with dimension (1200x100x100)mm

b.Mechanical oscillator

c. Piezoelectric accelerometer

d. Piezoelectric- vibration pickup

e. Digital storage oscilloscope

f. Variable frequency drive

g. Vibration meter

h.R.S interface cable

i. Digital tachometer

j.Computer device

## PLACEMENT OF SOIL

The density of the gypseous soils used through the experiments was controlled by means of the raining technique. This technique included raining of the soil through different heights of drop that gives different placing densities. Many investigators used this technique**, (Lee, et al, 1973), (Sanjeev, 2007), and (Denver,**

**1983)**. The relations between height of drop, placement density, void ratio and relative density of gypseous soils is shown in Figures (1) .It was decided to employ density (14.0) kN/m3 of gypseous soils, which corresponds to height of drop (35) cm .

## PREPARATION AND TESTS PROCEDURE

The required amount of the gypseous soil(clean and passing sieve no.4) is placed into the steel container in sixteen layers with a uniform field density using the raining technique. The surface was leveled and checked by a bubble ruler (balance).The model machine foundation is placed centrally over the prepared gypseous soil layers. Proper care is taken to maintain the center of gravity of whole system and the footing to lie in the same vertical line with center of gravity of the container.

For the test under soaked condition, the steel box left for (24) hours to ensure that all soil was completely soaked, and in the second day the model machine foundation is placed , then the test was began . In this investigation, three different eccentric settings ($m_e$ = 55, 75, and 105 gm) are used to simulate three different dynamic force level. The oscillator is then run slowly through a motor using speed control unit(Variable frequency drive )to avoid sudden application of high magnitude dynamic load. Thus the foundation is subjected to vibration in the vertical direction. the dynamic response and the waveform produced by mechanical oscillator are measured and recorded at the same time using two transducers which are placed previously on top of the footing . To obtain a foundation response and locate the resonant peak correctly, the displacement amplitudes are noted at a frequency interval approximately of 5 to 25 Hz. A sufficient time between two successive measurements has been given to reach equilibrium, which facilitates accurate measurement of frequency and the corresponding displacement amplitude.

## RESULTS AND DISCUSSION

The main object of this test in this research is to determine the dynamic response of the gypseous soil under the effect of harmonic vertical mode of vibration. The dynamic system is the soil medium through which wave propagate outward from the source of industrial vibrations. the input signal of the system is the impulse response of the ground at the place of installation of machine foundation. The output signal is the dynamic response of location of interest situated on the surface of the foundation receiving vibration, this response in this study investigated as displacement. And to make a clear image of the gypseous soil behavior under this mode of vibration the dry soil is tested as well soaked under different eccentric settings. The curves of the displacement amplitude of vibration with respect to changes in the frequency of the oscillator is plotted for each force level. The results of these test are shown in the figure (2) .it can be seen that an increase in the value of ($m_e$) leads to (i)decrease in resonant frequency. (ii) increase in resonant displacement amplitude. These differences come from the fact that different forces cause different strain levels below the foundation .see figure (2).

A series of forced vertical vibration test was conducted on gypesous soil under different dynamic force level and soaked condition. The results of the these tests showed that the displacement response of the foundation on dry gypseous soil is more than that on soaked one. Also it showed increasing in resonant frequency clearly, if it compares with the same dynamic force level in dry state. when gypseous soil soaked with water it suffers high compressibility due to dissolution of gypsum and loss of cementation and particle bounding ,this could explain the small displacement amplitude of soaked gyoseous soil in comparison of dry one.see figure(3).the relationship of eccentric mass with maximum displacement amplitude and resonant frequency is shown in the figures (4)and(5) respectively.

## CONCLUSION

The following conclusions are drawn**:**

1. The displacement response of the foundation resting on dry gypseous soil is more than that on the soaked gypseous soil, while the resonant frequency is increased when gypseous soil is soaked with water.

2. An increasing in eccentric mass lead to an increasing in amplitude of displacement for the specific frequency and decreasing in resonant frequency.

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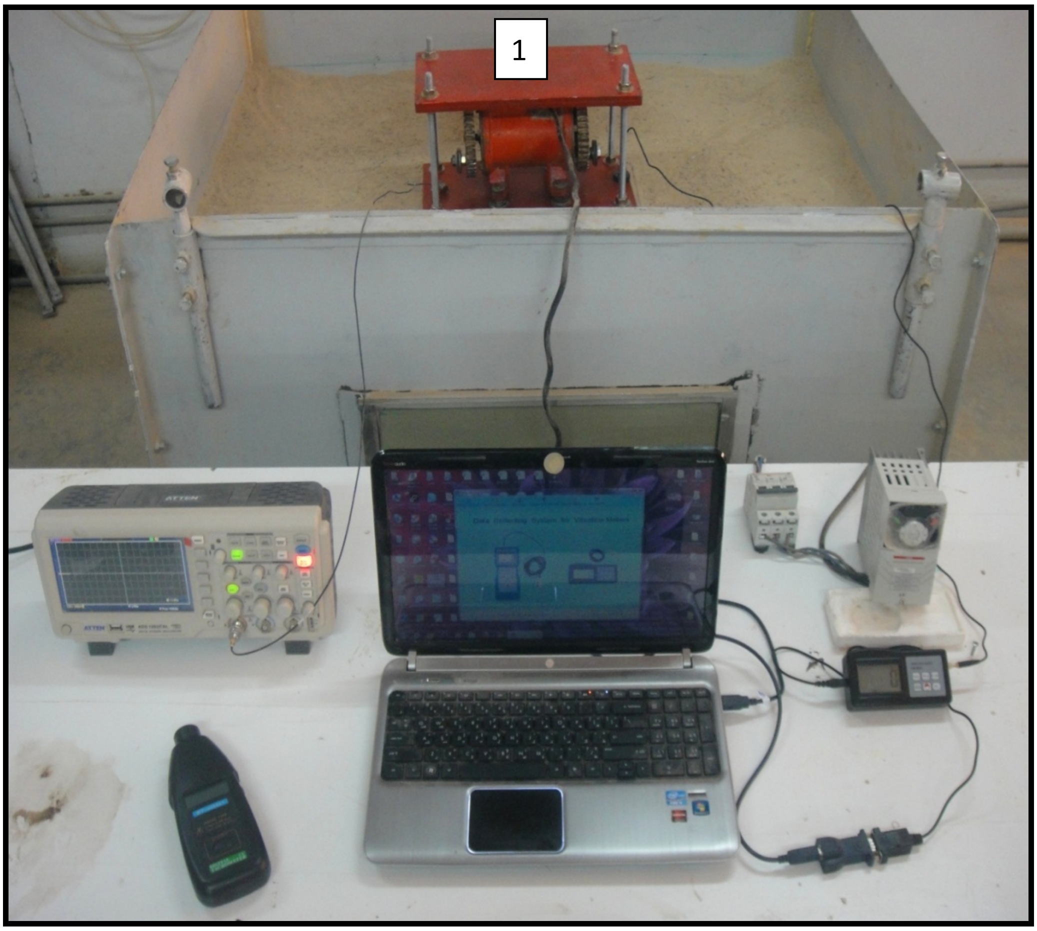
**Table (1). Physical and Chemical Properties of Gypseous Soil**

| | |
|---|---|
| Soil classification | SP-SM |
| Liquid Limit (L.L %) | 21 |
| Plastic Limit (P.L %) | 19.6 |
| Plasticity Index (IP) | 1.4 |
| Maximum Dry density($kN/m^3$) | 14.8 |
| Minimum Dry Density ($kN/m^3$) | 11 |
| Specific Gravity (Gs) | 2.43 |
| TSS % | 42.02 |
| Gypsum content % | 43.10 |
| SO3 % | 19.8 |
| PH | 8.5 |




**Plate(1)General View of Vibration Test Setup**

**1-Mechanical oscillator**

**2- Piezoelectric accelerometer**

**3. Piezoelectric- vibration pickup**

**4. Digital storage oscilloscope**

**5. Variable frequency drive**

**6. Vibration meter**

**7.R.S interface cable**

**8. Digital tachometer**

**9.Computer device.**

**10.Container.**

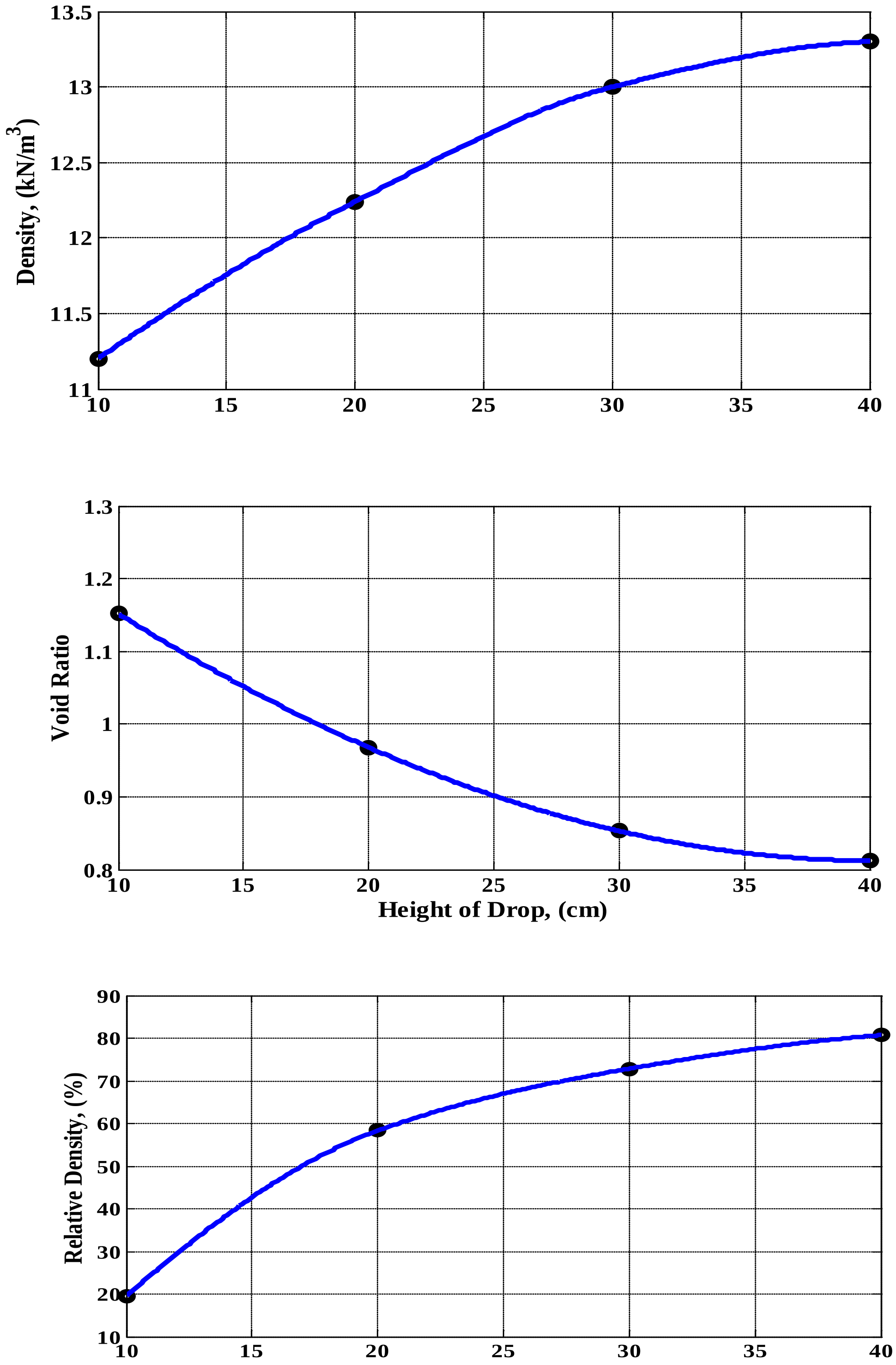



**Fig. (1) Density Calibration Curves for Gypseous Soil By Raining Technique.**

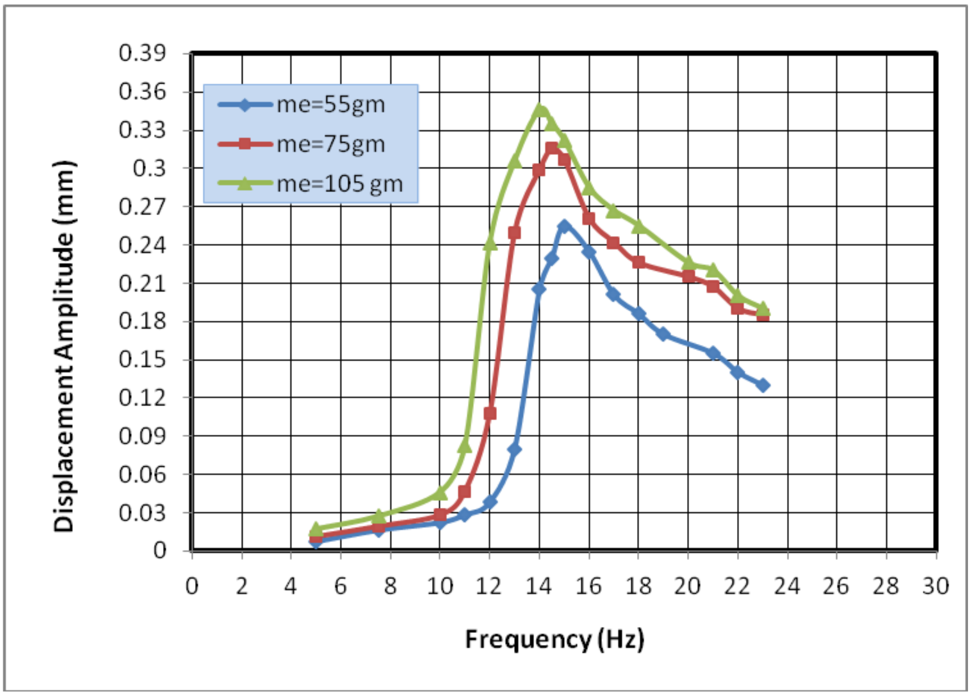



**Fig. (2) Variations of Displacement Amplitude with Frequency for Different Values of ($m_e$) Dry State**

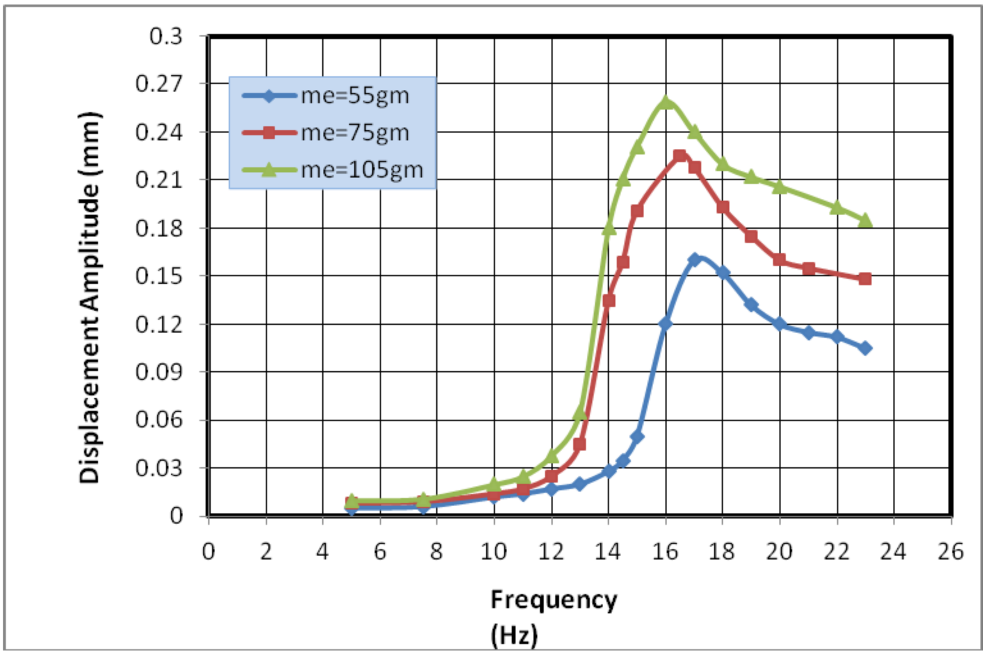



**Fig. (3) Variations of Displacement Amplitude with Frequency for Different Values of ($m_e$) , soaked State.**

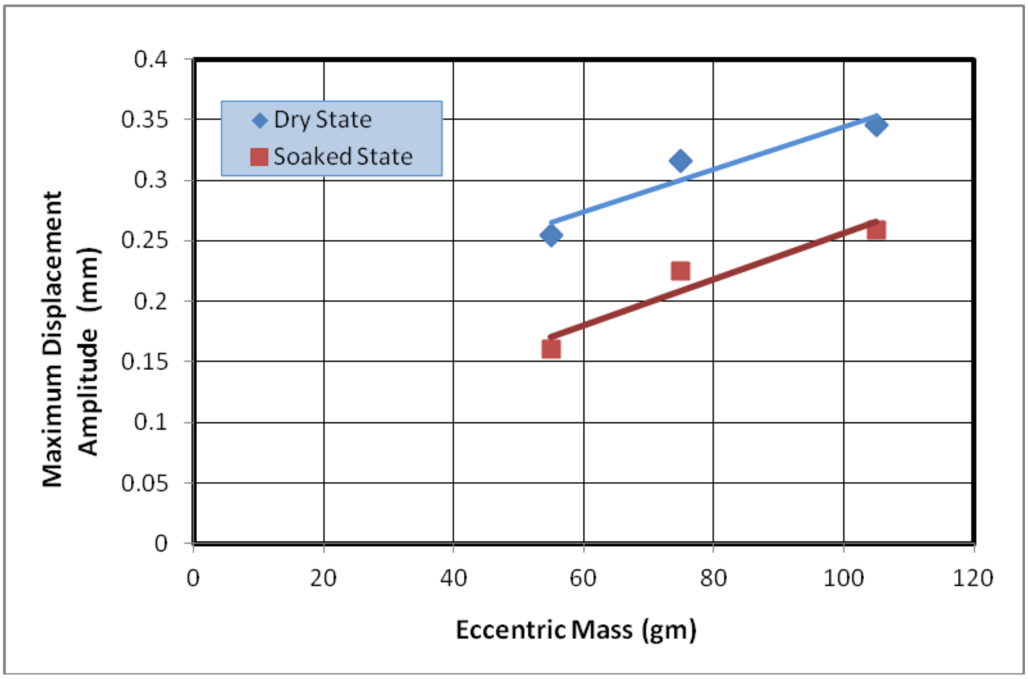



**Fig.(4)The Maximum Displacement Amplitude and Eccentric Mass Relationship**

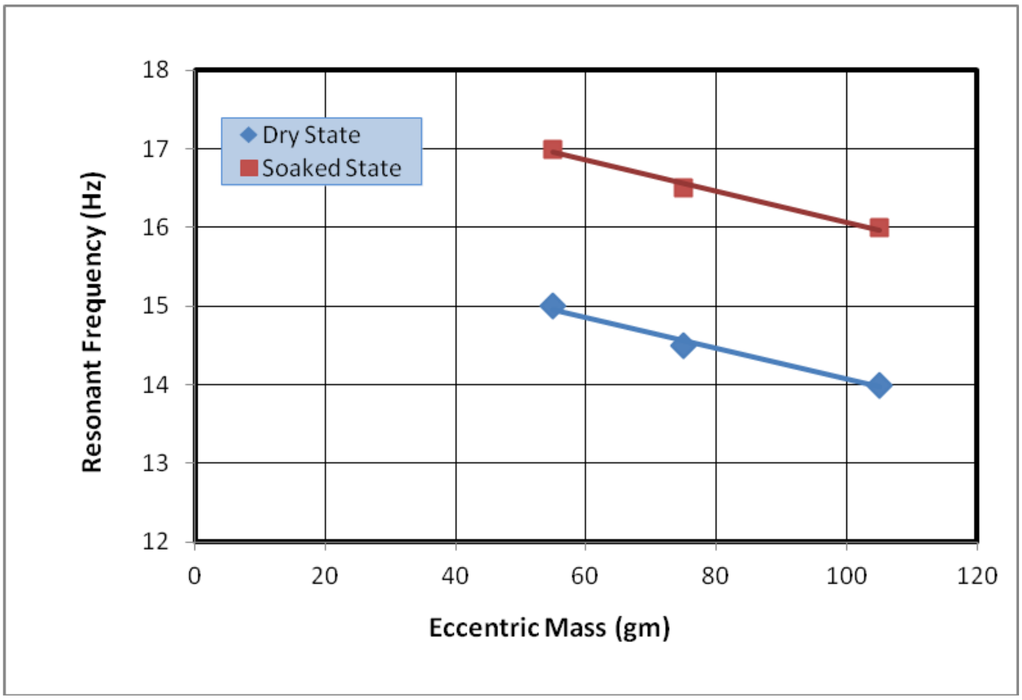



**Fig.(5)The Resonant Frequency and Eccentric Mass Relationship**