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SYNOPSIS Experimental investigation has been carried out to study the effects due to isolation of foundations subjected to vertical vibration on the displacement amplitude. Tests were conducted on an embedded footing of contact area 45x45 cm. with different embedments and some on the surface of natural ground. Three isolation barriers viz. air gap, saw dust and sand of various depths were used. From the results of the investigation it was found that an open trench (air gap) around the foundation reduces the displacement amplitude around the footing considerably to an extent of about 75%. Saw dust as a barrier, although not as good as air gap, performs better when compared to sand. The coefficient of attenuation is not a constant for a soil medium but varies with static and dynamic loads. The resonant frequency decreases and resonant amplitude increases by providing isolating barriers.

INTRODUCTION

In practice, barriers are commonly used for isolating structures and foundations from external vibrations caused by machinery or traffic. Isolating barriers can also be provided at the source of vibration to intercept the waves coming from the source and to create a zone of lesser vibration amplitude around the source. Open trench, sheet-pile wall, bentonite slurry filled trench, piles, etc., are the few isolating barriers, commonly used in field. Neumeuer(1963) and Dolling(1966) reported successful use of bentonite slurry filled trench for isolation. Barkan(1962) and McNeill et al(1965) have reported both successful and unsuccessful applications of providing trenches and sheet-pile walls as isolating barriers. The lack of the knowledge about the propagation of surface waves through such barriers is the primary reason for such incidences.

Barkan(1962) and Dolling(1966) reported on the effectiveness of barriers and the effect of barrier shape and size based on a field investigation. Woods and Richart(1967) and Woods(1968) conducted a series of investigations to determine the effectiveness of trenches of various dimensions and to develop guidelines for the design of barriers. Segol et al(1978) employed a numerical model to investigate the influence of the trench dimensions, its distance from the source, the frequency of the source, upon the screening of Rayleigh waves. The screening property of sand was also studied. Lysmer and Wass(1972) used lumped mass method to consider the effect of trench depth in homogeneous layer resting on a rigid base. Haupt(1977) using finite element method, studied theoretically the effectiveness of concrete core walls as isolation barrier and found that the isolating capacity does not depend on the geometrical shape of the concrete core wall but only on the cross-section. Woods et al.(1974) using holography, investigated the use of piles and investigated some preliminary criteria for the design of a row of piles as isolating barrier . Liao and Sangrey(1978) conducted experiments on an acoustic model and found that the foundation isolation is feasible when the Rayleigh waves are scattered using cylindrical obstructions like void bore holes, hollow piles, thin and flexible cylindrical shells.

The attenuation of the waves is due to geometrical damping and material damping of the soil medium. Boronitz(1931) combining the geometrical and material damping gave an expression for the attenuation of Rayleigh waves as

$$A = A_1\left(\frac{r_1}{r}\right)^{1/2} \cdot \exp[-\alpha(r - r_1)] \qquad (1)$$

where A_1 is the amplitude at a reference point distance r_1 from the source, A is the amplitude at any point at a distance r from the source, and α is the coefficient of attenuation. The value of α is assumed to be a constant depending on the type of soil. Lo(1977) investigated the attenuation of ground vibration induced by pile driving. No theory is available to prove that the coefficient of attenuation is a constant independent of any other parameter or condition, except the type of soil. It is thus seen from the study of literature that limited research has been done on isolation and that the scope for further investigation is wide and large and there is need for concentrated research study. In this paper, some results which have been obtained on different barriers (air gap, sand, and saw dust) as effective isolation media are presented.

The static and dynamic intensities imparted at the vibration source has also been varied in order to vary the displacement amplitude at the source.

EXPERIMENTAL INVESTIGATION

The site adjacent to the Soil Mechanics Laboratory, Indian Institute of Science, Bangalore, was chosen for the investigation. A subsurface exploration carried out revealed the soil condition to be nearly homogeneous red earth of lateritic origin. Tests were conducted on both surface and embedded square footings of dimension 45x45x7.5 cm and 45x45x180 cm respectively. Lazan oscillator model LA-1 was used to impart vertical vibration and was run by a variable speed motor. The displacement amplitude was measured using a cathode ray oscillograph, an electrodynamic pick-up and an amplitude measuring unit. The desired variation of static load was obtained by the dead weight of the footing, weight of the oscillator, and extra cast iron bar weights which were securely fixed at the top of the oscillator. The change in the dynamic load was effected by varying the angle between the eccentric masses of the oscillator. If θ is the angle between the eccentric masses and N is the speed in cps, the dynamic force, F, developed is given by

$$F = 2N^2 \sin(\theta/2) \qquad (2)$$

Surface Footing

Frequency-amplitude response were obtained for four static loads, viz. 540, 768, 1000 and 1200 kg and for four dynamic loads, viz. for θ values of 50, 70, 90 and 110 degrees. To find the effect of static and dynamic load on the coefficient of attenuation, α, displacement amplitudes were measured at distances upto 8 ft(240 cm) away from the footing and at the source for four static and four dynamic loads at a constant frequency of 1400 rpm.

Isolation Barriers

Three types of isolation barriers viz. air gap, saw dust and sand were tried. Frequency-displacement amplitude measurements were taken on the embedded footing for two static loads of 1550 kg and 1750 kg and for three dynamic loads with θ equal to 80, 100 and 120 degrees. The displacement amplitudes were also measured with distance upto 6 ft(180 cm) at a constant frequency of 1400 rpm for different static and dynamic loads. The natural soil was removed for a width of about 15 cm and to a depth of 30, 60 and 120 cm at various stages and the above series of experiments were repeated.

The next series of experiments related to measurement of displacement amplitude with distance at different static and dynamic loads, with air gap filled to different depths, either with saw dust or sand. This series enabled to obtain results with different material as isolation barriers.

TEST RESULTS AND DISCUSSION

Fig.1 illustrates the decay of displacement amplitude with distance for three dynamic loads of θ equal to 50, 70 and 90 degrees and four static loads of 540, 768, 1000 and 1200 kg. The displacement amplitude rapidly decreases with distance. The displacement amplitude increases with dynamic load and decreases with static load at any distance from the source.

Table I presents the results of coefficient of attenuation calculated using eqn. (1). It can be seen that the coefficient of attenuation, α, is not constant and varies with static and dynamic loads. Available results on coefficient of attenuation is rather scanty and practically nil. Richart et al.(1970) reported the value of α as 0.0002 to 0.0027 per cm for different soils, whereas Barkan(1962) reported the value of α to range between 0.0003 to 0.0013 per cm. In this investigation, α value ranges from 0.0022 to 0.0054 per cm for the case of red earth. There is a decreasing trend of coefficient of attenuation with static load and increasing trend with dynamic load.

TABLE I. Coefficient of Attenuation, α (1/cm)

Static Load (kg)	θ (Degrees) 50	70	90	110
540	0.0049	0.0048	0.0054	0.0054
768	0.0028	0.0035	0.0029	0.0031
1000	0.0036	0.0031	0.0027	0.0022
1200	0.0032	0.0031	0.0035	0.0039

The results in Fig. 1 have been analysed using regression analysis assuming eqn.(3) can represent the amplitude-distance relationship within the limited distance for which the tests have been conducted.

$$A = \frac{k}{r^\beta} \qquad (3)$$

where k and β are constants. The value of β which is the power of the distance, varies within the range 0.88 to 1.45 (Table II). The effect of dynamic load on β is practically negligible.

TABLE II. Values of β

Static Load (kg)	θ (Degrees) 50	70	90	110
540	1.05	0.98	0.91	0.88
768	1.30	1.40	1.45	1.10
1000	1.23	1.23	1.32	1.31
1200	1.25	1.21	1.26	1.15

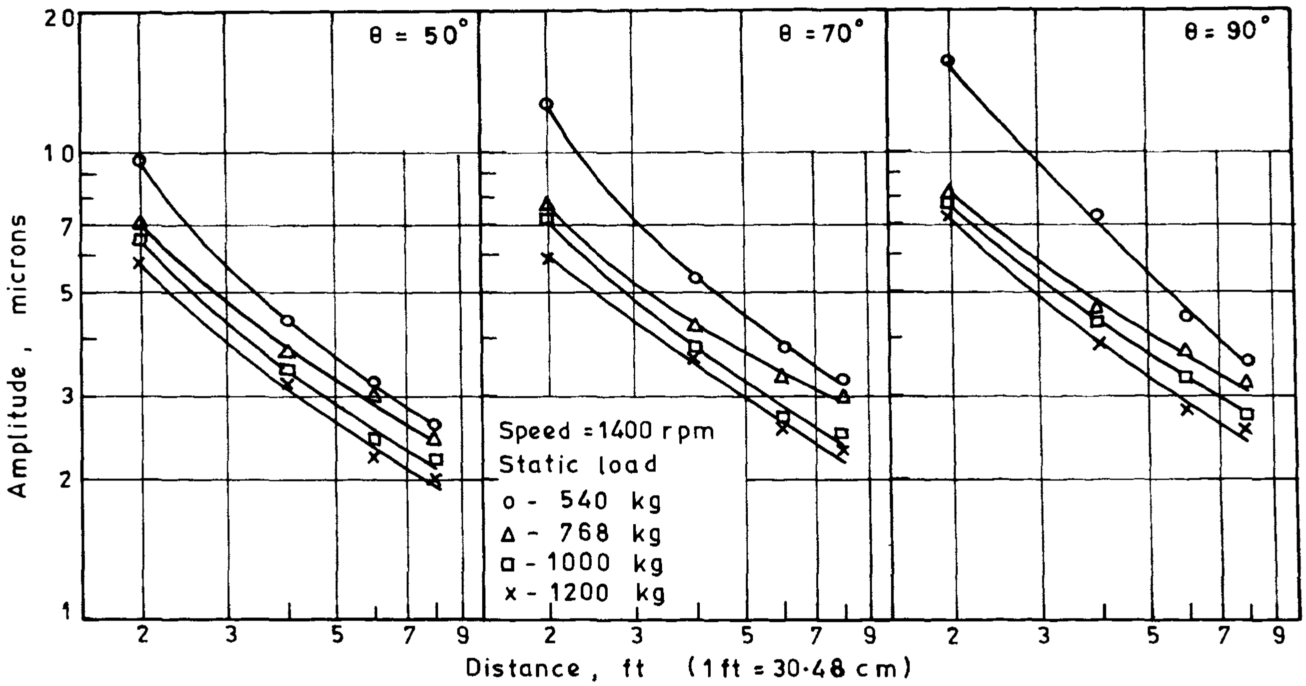

Fig. 1. Variation of Displacement Amplitude with Distance

Table III presents the resonant frequency and resonant amplitude of embedded footing(embedment = 180 cm) under different conditions of (i) natural soil surrounding the footing to full depth (ii) with air gap surrounding the footing to different depths viz. 30, 60 and 120 cm and (iii) with sand surrounding the embedded footing to a depth of 120 cm. It is clear that as the depth of air gap increases the resonant frequency decreases significantly. The decrease in resonant frequency with increase in air gap depth is primarily due to the decrease in effective spring constant of the system. As the dynamic load increases the resonant frequency decreases. With sand surrounding the footing to a depth of 120 cm, the resonant frequency increases slightly when compared with air gap. However, it is far less, when compared with natural soil surrounding the footing.

Table III also shows the significant increase in the resonant amplitude, when the surrounding natural soil is removed. This is primarily attributed to the restoring force exerted by the frictional and cohesive forces by the natural soil around the footing. The results of 120 cm of sand shows that it is not as effective as the natural soil in reducing the resonant amplitude.

Fig. 2 brings out the effectiveness or otherwise of air gap, saw dust and sand as isolation barriers. The displacement amplitude is least with air gap as barrier. The effectiveness as barrier is in the order of air gap, saw dust and sand. It can be seen that the maximum amplitude without barrier(natural soil and footing) about 3-4 times that with barrier(120 cm air gap around the footing).

TABLE III. Resonant Frequency(rpm) and Resonant Amplitude(Microns) with Different Barriers

Test Details		θ (Degrees) 80	100	120
Natural soil	Frequency	1600	1580	1565
	Amplitude	390	480	520
30 cm air gap	Frequency	1350	1300	1280
	Amplitude	510	570	650
60 cm air gap	Frequency	1230	1215	1200
	Amplitude	700	760	900
120 cm air gap	Frequency	1180	1165	1150
	Amplitude	820	900	1050
120 cm sand	Frequency	1220	1210	1190
	Amplitude	740	810	950

CONCLUSIONS

Based on the above study the following conclusions could be listed.

By providing a trench(air gap) around the footing, the displacement amplitude around the footing can be reduced considerably and to an extent of about 75%.

The vibration isolation is very effective if the trench is unfilled(air gap) and the performance is better with saw dust when compared with sand.

The coefficient of attenuation is not a constant for a soil medium. There is a decreas-.ng trend with static load and increasing trend with dynamic load.

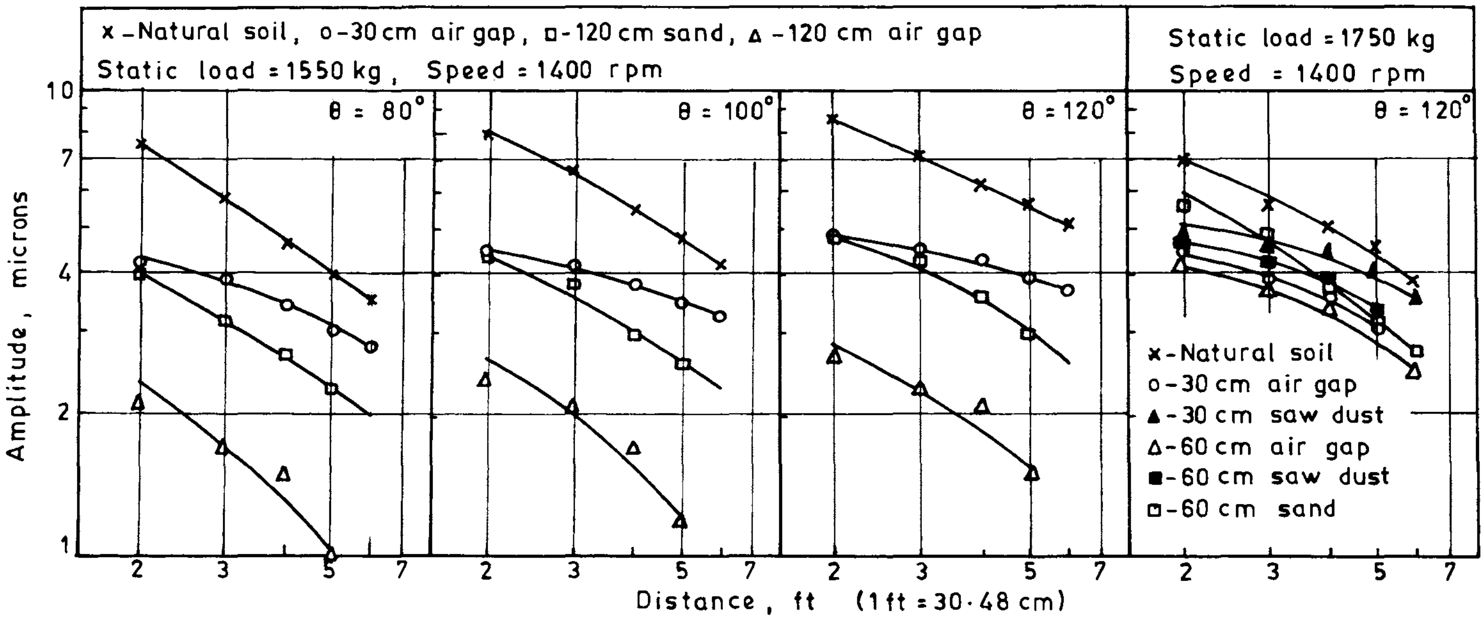

Fig. 2. Variation of Displacement Amplitude with Distance

There is significant decrease in resonant frequency and increase in resonant amplitude of the footing with the provision of air gap around the footing.

The displacement amplitude(A) at any distance r from the source could be expressed in the form $A \propto 1/r^{\beta}$. The value of β varies in between 0.9 and 1.45. The effect of dynamic load on β is negligible.

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