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An Experimental Investigation on Trench Isolation Techniques for Vibration Control

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AN EXPERIMENTAL INVESTIGATION ON TRENCH ISOLATION TECHNIQUES FOR VIBRATION CONTROL

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Abstract: One of the methods of controlling vibration amplitudes at source is by adopting active isolation techniques. Trench barriers are identified as methods of isolation. This paper deals with series experimental investigation carried out on block vibration tests with active isolation trench barriers. The parameters like depth of embedment, dimensions of trench, fill material in trench etc., are studied by carrying out the block vibration test in field. The results are analysed to identify the influence of those parameters.

Introduction: In Any industry, the machines perform certain pre-assigned activities. Though the machine works within the permissible amplitude, at times, the vibrations transmitted may become objectionable for adjacent sensitive instrument/machine. Hence, there exists a necessity of either isolating machines at source (i.e. active isolation) or isolating sensitive instruments away from the source (i.e. passive isolation).

This paper presents the experimental details and results of field tests carried out on active isolation. The investigation involves a series of block vibration tests and monitoring of block and ground vibrations with and without active isolation techniques.

Review of Literature: It is convenient to subdivide the problem of filtering elastic waves by trench isolation into two categories namely (i) Active isolation and (ii) Passive isolation. Active isolation is the employment of barriers close to or surrounding the source of vibrations to reduce the amount of wave energy radiated away from the source. Passive isolation, is the employment of barriers at points remote from the source of vibrations but near a site where the amplitude of vibration must be reduced. Barkan (1962) reported the study on the application of an open trench and sheet wall barrier to isolate a building from road/rail traffic induced vibrations. Richart *et al.* (1970), reported the results of investigation based on the use of Bentonite slurry filled trench to isolate industry vibration which has given encouraging results. It is accepted that open trenches were widely used as the barrier isolation. It can be noted that a thin crack is sufficient to screen the waves in an elastic medium however, keeping open trenches is not acceptable from the points of view of safety and performance. Techniques using different fill materials help for a better successful active isolation method.

Details of Apparatus, Properties of ground and fill materials :

A foundation block was subjected to vertical vibrations under various excitation forces measured interms of angle of eccentricity. The vibrations of block and ground amplitudes along the axes X and Y were measured keeping the block i) on ground ii) at 50% embedment. Active isolation trench was made and various fill materials were used for their influence in screening the vibrations.

The experimental investigation was carried out at J.N.T.U campus, Hyderabad, India. The block used in the investigation is of size 1.5m x 0.7m x 0.7m having 1,650 Kg weight. The vibrations are generated using a mechanical oscillator with double eccentric mass causing quadratic excitation. The dynamic force can be increased by increasing the eccentricity from 0 to 140^0. The oscillator has a maximum speed limit of 3,000 rpm. Due to generation of vibrations, the displacement of block and ground were measured using geophone and vibration meter.

Soil Properties at the test site The soil at the test site generally consists of dense gravelly sandy soil with little clay fraction. The properties of the soil are furnished in Table – 1.

Table – 1 Soil Properties at the test Site

Property	Value
Unit weight of soil	$18.0 kN/m^3$
Field moisture content	4.5%
D_{60v}	3.68mm
D_{10}	2.60 mm
Specific gravity of soil solids	2.65

The materials used to refill in isolation trench are natural soil, quarry dust, rice husk

Experimental Programme:

The experimental investigation involved conducting a series of block vibration test (all the tests were conducted under vertical vibrations) and measuring block and ground vibrations. The vibration studies are made with and without isolation trenches. Tests were performed initially by keeping the block on the ground without any vibration isolation. This observations served as the reference values to study the effect of isolation techniques.

Factors considered in this investigation include

i) Influence of eccentricity
ii) Effect of trench dimensions
iii) Ground motion observations with open trench
iv) Embankment and influence of fill materials on block vibrations.
v) Ground motion observations with trench filled with materials.

Influence of Eccentricity: In order to determine the influence of eccentricity, the foundation block resting on the ground was subjected to vertical vibrations under four eccentricity values of e = 50°, 60 °, 70 ° and 80 °. The data obtained in this test series helped in finding the role of eccentricity on the resonant frequency and the peak amplitude.

Trench Dimensions: After conducting the block vibration test for the block resting on ground, an all-round trench is made to a depth of 35cm(half the height of the block). The width of trench has been preferred as shown in Fig. 1

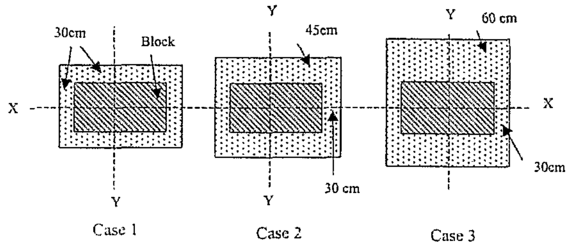

Fig. 1 Trench Dimensions

For each of the case the vibrating block was resting on the ground. In

For each of the case the vibrating block was resting on the ground. In each of the above case block was vibrated at different eccentricities. and corresponding response for the block were obtained.

Ground Motion Observations with open trench: In order to study the efficiency of the active isolation trench, measurements of vibration of ground have been made positioning one geophone near the block and a second geophone at suitable points on the ground in X and Y directions as shown in Fig. 2. The investigation carried out in this phase helps to study the influence of trench dimensions on vibration transmission. The vibrations are initially measured at all these points before making the trench serve as reference data.

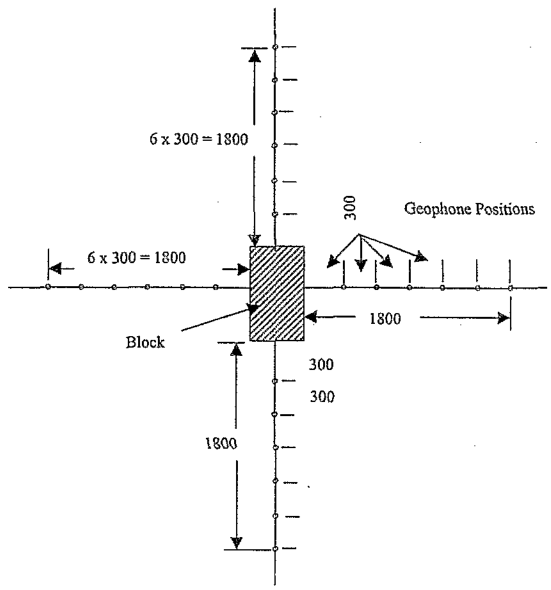

Fig. 2 Plan showing Locations of Ground vibrations observations

<u>Influence of embedment and fill materials on block vibrations</u>: After the investigation on the effect of trench width, with block placed at ground level, the effect of embedment was studied. For this part of the investigation the block was positioned in an open pit which provided an alround trench width of 30cm width in X – direction and 60cm width in Y – direction and a depth of embedment of 35cm (50% of block height). In this phase of investigation study has been carried out to examine the influence of embedment and the role of different types of fill materials, in the trench, in reducing the amplitude of foundation block and the adjacent ground.

Initially the block was vibrated without any surrounding material. As the block was subjected to vibration the vibration amplitude of block and surrounding soil (ground) at different distances were measured. The vibration test was performed at four angles of eccentricities (i.e. e = 50^o, 60^o, $70\ ^o$ and $80\ ^o$). After studying the block and ground vibrations with empty tench the investgation was carriedout by filling the trench with i) rice husk, ii) quarry dust and iii) natural soil. For this part of study the trench excavated around the foundation block was filled with Rice husk in three layers. After compacting the fill material the foundation block was subjected to vertical vibrations and the amplitude of block vibrations are measured. The rice husk was then excavated out and the trench was filled and compacted with quarry dust in three layers. The vibration test was conducted with quarry dust in the trench. The procedure was repeated with natural soil compacted in the trench. The results of the above tests helped to identify the importance of backfill material for embedded foundations in controlling the vibrations of foundation block, instead of leaving the trench as open.

<u>Measurement of Ground vibrations</u>: During the block vibration tests with and without active isolation, amplitudes of ground vibrations are measured at different distances from the face of the block at different locations as shown in Fig. 2.

Analysis of Test Results: The experimental results obtained in this investigation were analysed to examine the influence of the following factors on the block and ground vibrations:

i) influence of eccentricity
ii) effect of embedment
iii) trench dimensions
iv) ground vibrations without fill material
v) influence of embedment and fill material
vi) ground vibrations with fill material

<u>Influence of Eccentricity</u>: Figs. 3 and 4 show the response curves for the block under different exciting forces (measured in terms of eccentricity). From Fig. 3 it can be observed that as the exciting force is increased, corresponding amplitudes of block also increased and a marginal decrease in resonant frequency is noticed. This effect was observed when the block was either on ground or embedded in the ground.

<u>Effect of embedment</u>: Fig. 4 show the response curves obtained for the block when it was embedded, into a pit, to 50% of its height. From the comparison of Figs. 3 and 4 it can be noted that there is about 50% of reduction in block vibration amplitudes because of embedment.

<u>Effect of Trench Dimensions:</u> To study the effect of trench dimensions on block vibrations the block vibration tests were conducted under the following six cases (Table – 2). Each of the block vibration tests was conducted under four different eccentricities of forces as mentioned earlier.

Fig. 5 shows the response curves obtained for cases A to F(details furnished in Table-2) when the vibrating force had an eccentricity of 50^o. From Fig. 5 it can be observed that the amplitude of vibration at a given frequency is maximum for curve-A, indicating when there is no isolation trench the vibration amplitude is maximum. It can also be observed from Fig. 5 that the amplitude of vibration is reducing from case B to D. This indicates that as the lateral dimensions of trench are increased the amplitude of block vibrations is decreasing. Further it can be observed that the curves E and F (which represent the case of 50% embedment of block) have very small amplitudes of vibrations when compared to all other cases.

This indicates that there is a considerable reduction of vibration due to embedment. Similar trend was observed when the block was subjected to different eccentricity of forces.

Table – 2 Trench dimensions

Case	Trench width (cm) in the direction of			Embed-ment Ratio* (%)	Remarks
	x-x	y-y	z-z		
A	-	-	-	Zero	For all cases of B to F, the trench was kept open (i.e. no back fill)
B	30	30	35	Zero	
C	30	45	35	Zero	
D	30	60	35	Zero	
E	30	60	35	50%	
F	30	60	35	50%	

Embedment ratio = (Depth of block below ground/ height of block) x 100

Ground vibrations without fill material:

During the block vibration test, the amplitude of ground vibrations were measured at different distances in X and Y directions as shown in Fig. 2. The ground amplitudes measured for the cases A, B, C, and D are presented in Table – 3. The results presented in Table – 3 were obtained when the block was resting on ground with different trench dimensions without any fill material in it. From Table – 3 it can be observed that for all the trench dimensions the ground amplitude is reducing with increase in distance from the block. Further it can be observed that the ground amplitude is maximum for Case – A and reduced for cases B to D.

Table – 3 Ground Vibrations without Fill Materials (Eccentricity e = 50°)

Sl. No.	Dist-ance (mm)	Ground Vibrations in Microns for the CASES							
		A	B	C	D	A	B	C	D
		X – Direction				Y – Direction			
1	300	46	-	-	-	50	-	-	-
2	600	25	22	22	26	30	27	21	-
3	900	20	19	19	21	24	23	17	22
4	1200	18	15	16	19	20	20	13	19
5	1500	16	14	15	16	16	15	11	15
6	1800	13	13	13	14	13	13	10	13

Table – 4

Ground Vibrations with Fill Materials

Sl. No.	Distance (mm)	Ground Vibrations in Microns for the CASES									
		1	2	3	4	5	1	2	3	4	5
		X – Direction					Y – Direction				
1	600	29	29	36	32	34	-	-	-	-	-
2	900	25	28	26	26	28	29	38	35	36	37
3	1200	24	26	24	23	25	27	27	34	30	34
4	1500	21	25	23	22	24	21	25	27	29	29
5	1800	20	24	22	21	23	17	20	20	23	26

Table 4(a)

The details of Cases for Table – 4

Case No.	Trench Size in mm, in the Directions			Back Fill Material
	X – X	Y – Y	Z – Z	
1	300	600	350	Air Gap
2	450	600	350	Air Gap
3	450	600	350	Rice Husk
4	450	600	350	Quarry Dust
5	450	600	350	Natural Soil

Effect of Fill Material on Block Vibrations: The response curves of the block without and with different fill materials in the trench are shown in Fig. 6. It can be observed that the peak amplitude of block vibration is maximum when the trench was empty and reduced by the use of fill material. While comparing the effect of different material it can be observed from Fig. 6 that, by the use of rice husk the reduction in the amplitude of the block is minimum, the reduction is maximum when quarry dust was used and the use of the natural soil as fill material the vibration reduction is intermediate. The reduction in block vibration is due to the frictional resistance between the surrounding material and the side faces of the block.

Effect of Fill Material on Ground Vibrations:

Table – 4 shows the vibration amplitude of ground at different distance from the face of the block in X and Y directions. From the table it can be observed that the ground vibration at different radial distances for the cases 1 & 2 (for case details see Table – 4a) indicates that the air gap in the trench reduces the transmission of vibrations in lateral direction to a minimum. Further it can be observed that, there is no significant difference between the cases 1 & 2 indicating that there is no effect of width of trench on vibration isolation. It can also be observed that the ground vibrations are more when there is a fill material. This may be due to the fact that, when the block is vibrating its vibrations are being transferred laterally by the surrounding media. However, it may be noted that there is no significant effect of type of material used in the vibration of ground. The results in Table – 4 are for angle of eccentricity of 50°. Similar observations are made for the other angle (60°, 70° and 80°) of eccentricity and are reported else where Paul (1992).

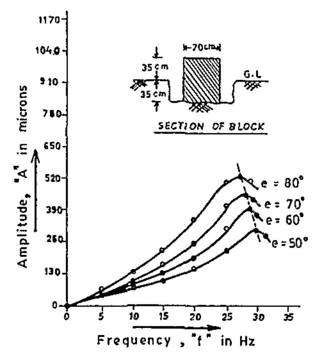

FIG. 4 : RESPONSE CURVES OF "A" Vs. "f" WHEN THE BLOCK EMBEDDED TO HALF THE DEPTH OF BLOCK

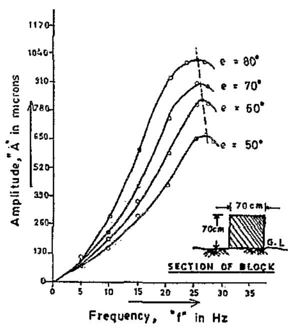

FIG :3. RESPONSE CURVES OF "A" Vs. "f" WHEN THE BLOCK KEPT ON GROUND

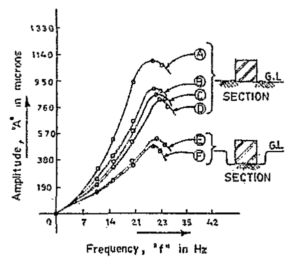

FIG.5 RESPONSE CURVES OF BLOCK VIBRATIONS AT e = 50°

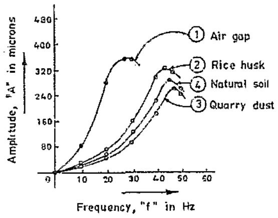

FIG. 6. RESPONSE CURVES OF BACKFILLS AT $e = 50^{\circ}$

Conclusions:

Based on the analysis of test results in this paper the following conclusions are drawn

1) Vertical vibrations of a block reduces significantly (50%) it it is embedded.
2) The block and the surrounding ground vibrations can be reduced by providing alround trench for the block.
3) Vertical vibrations of the block is reduced when the surrounding trench is filled with material this because of friction between the surrounding material and the sides of the block. The block vibration was observed to be minimum when the trench was filled with quarry dust and it was maximum when the trench was empty.

The transfer of vibrations in lateral direction in the ground was observed to be reduced by the provision of trench. The vibration in the surrounding media was observed to be minimum when the trench was empty and it was increased when the trench was filled with material.

There was considerable reduction in block vibration if the dimensions of the trench is increased but there is no such effect of trench dimensions on reducing ground vibrations

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