Active Vibration Isolation by Open and In-filled Trenches: A Comparative Study

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Abstract: ***Active isolation of steady-state surface vibrations by open and softer in-filled trenches in an elastic and homogeneous half-space is investigated in this study using PLAXIS 2D. Percentage isolation by barrier is estimated from amplitude reduction factors. Effects of in-fill material parameters are investigated in terms of impedance ratios against the case of a trench of definite geometry. Several cases of softer backfilled trenches with impedance ratios ranging from 0.08-0.42 are studied and their effectiveness is compared with that of an open trench of identical dimension. It is found that softer in-filled trench barriers of impedance ratios lying between 0.08-0.17 exhibit isolation effectiveness comparable to open trenches. Isolation efficiency of in-filled trenches increases with decrease in impedance ratio. Both open and in-filled trenches are found more effective in reducing the vertical vibration component than the horizontal.***

Keywords: vibration isolation, in-filled trench, impedance ratio, Rayleigh wavelength

1. Introduction

Man-made ground vibrations can be mitigated by constructing barriers on the surface in the form of open/in-filled trenches, sheet piles etc. Over the past few decades, barrier isolation has extensively been investigated by several authors. Wood's experimental study on open trench [1], numerical studies of Beskos et al. [2], Leung et al. [3], and Dasgupta et al. [4] on open and in-filled trench isolation are some extensive parametric studies. Open and in-filled trench isolation [5], performance of solid wave obstacles [6], active isolation by open and in-filled trenches [7, 8] are some subsequent investigations.

Impulse load isolation by open and in-filled trenches [9], shock-induced vibration isolation by soft and stiff barriers [10] are few more studies. Vibration screening by trenches and elastic footings [11], studies of Ju [12], Di Mino et al. [13], Hung et al. [14] etc. are some investigations on train-induced vibration isolation. Experimentation on open and geofoam-filled trenches [15], isolation using water-filled trenches [16], analysis and design of open trenches [17] are contemporary studies in the arena.
Previous works primarily studied the effect of geometric parameters of concrete-filled trenches. This work, in contrast, investigates the effects of in-fill material properties on isolation response of an in-filled trench of definite geometry. Active isolation scheme is considered in this study where the barrier is placed close to the source. Several cases of softer backfill are studied and their screening performance is compared with that of and open trench and crucial conclusions are made.

2. METHODOLOGY

The half-space and backfill parameters and key steps of finite element (FE) modeling scheme are summarized in TABLE 1. Half-space and dynamic load parameters are assumed from published literature [11, 18, 19]. The Rayleigh wavelength (L_R) of vibration is estimated to be 3 m. For detailed finite element modelling, readers may refer to author's previous studies [18, 19].

TABLE 1: FINITE ELEMENT MODELLING SCHEME

Assumptions/methods/steps	Description
Half-space soil parameters	Elastic modulus =46000 kN/m^2, density =1800 kg/m^3, Poisson's ratio=0.25, material damping =5%
In-fill material parameters	Elastic modulus =variable, density =1500 kg/m^3, Poisson's ratio=0.25, material damping =5%
Dynamic load parameters and type	Magnitude (P_0)=1 kN, frequency (*f*)=31 Hz, type: steady-state
Type of FE model and size	2-D axisymmetric model of size 35 m $\times$ 15 m
Boundary conditions	Standard fixity
Absorbent boundaries	Specified to bottom and right-hand boundaries
Material model of soil and its type	Linear elastic and 'drained' type
Mesh elements	15-noded triangular elements
Mesh division	Done with 'very fine' elements
Material damping	Assigned in terms of Rayleigh mass and stiffness matrix coefficients
Dynamic time interval	0.5 s.
Time-step of integration	0.0005 s.

Analyses are performed assuming a trench of depth (d)=3 m (=1L_R), width (w)=1.5 m (=0.5L_R) located at a distance (l) of 3 m (=1L_R) from source. Effect of in-fill material parameters is studied in terms of impedance ratio ($IR = V_b\rho_b/V_s\rho_s$). Where V_b, V_s are shear wave velocities in backfill and native soil and ρ_b, ρ_s are the corresponding densities. IR values are altered by changing backfill elastic modulus, keeping other parameters same.

Amplitude reduction is estimated in terms of amplitude reduction ratio (A_r) which is the ratio between maximum surface displacement amplitudes with and without barrier. A_r values are calculated at several nodes beyond the barrier (N=10) and averaged. The % isolation is finally estimated from the average amplitude reduction ratio (A_m) as shown in Eqs. (1a)-(b).

$$A_m = \frac{1}{N}\sum A \quad (1a)$$

% Isolation = (1 - A_m) x 100 (lb)

The numerical model is validated by simulating an open trench (*IR*=0) of dimension d=1L_R, w=0.1L_R, and l=5L_R and comparing with a previous study [5]. Present results are found to be in good agreement with documented results. Readers may refer to author's previous study [19] for model validation.

3. RESULTS AND DISCUSSION

Active isolation by a trench of specific geometry (depth=3 m, width=1.5 m, and distance from source=3 m) is investigated assigning different in-fill parameters. Several cases of softer in-filled trenches of different impedance ratios (*IR*=0.08, 0.17, 0.25, 0.42) and an open trench case (*IR*=0) have been investigated. Plots showing the variation of A_r against dimensionless distance from barrier (X=x/L_R) considering vertical and horizontal vibration components are presented in Figures. 1(a) and 1(b) respectively.

It is evident from Figures. 1(a)-(b) that softer barrier causes considerable reduction in vibration amplitudes. The amplitude reduction is governed by *IR* of in-fill material. Decrease in *IR* leads to higher amplitude reduction. The trend is similar for both horizontal and vertical vibration components. Amplitude reduction curves for *IR*=0.08 and 0.17 are comparable to that of an open trench of similar geometry.

Percentage (%) isolation for all these cases are finally estimated by estimating average amplitude reduction factors using Eqs. (1a)-(1b). Figure 2 shows % isolation in all these cases. It can be seen that isolation efficiency of an in-filled trench is governed by *IR* of in-fill material. Better isolation can be achieved by decreasing the *IR* value. Within a range of *IR*=0.08-0.17, in-filled trench provides isolation efficiency comparable to that of an open trench (*IR*=0).

It can also be concluded that such barriers can more effectively attenuate the vertical vibration component than the horizontal. Within a range of *IR*=0.08-0.17, a trench of depth, d=3 m (1L_R) in active scheme, can isolate nearly 65%-75% of the vertical vibration component and 55%-60% of the horizontal vibration component.

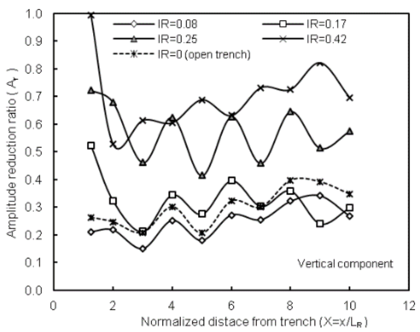

Figure 1(a): Amplitude reduction ratios vs. normalized distances from trench for vertical component

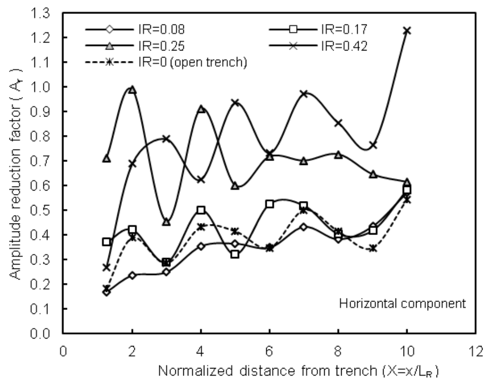

Figure 1(b): Amplitude reduction ratios vs. normalized distances from trench for horizontal component

The case *IR*=0 (that resembles an open trench) for a trench of stated dimension (l=1L_R, w=0.5L_R, and l=1L_R) is compared with a published literature [11]. With reference to Figure. 2, average amplitude reduction factors for vertical and horizontal vibration components are 0.3 and 0.38 respectively (% isolation 70% and 62%). Present results are in close agreements with published values of 0.3 and 0.36 for an open trench similar conFigureuration (except w=0.33L_R).

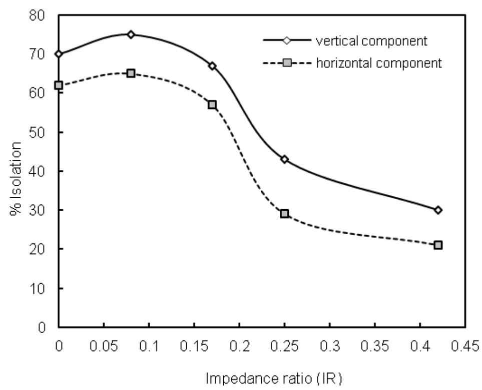

Figure 2: % Isolation vs. *IR*

4. CONCLUSIONS

Active isolation by an in-filled trench of specific dimension is investigated in this study assigning different in-fill material properties. Analyses are performed in PLAXIS 2D assuming a homogeneous and elastic half-space.

Results show that isolation efficiencies of such barriers are largely governed by impedance ratio (*IR*) of in-fill material. Isolation effectiveness increases with decrease in *IR*. Within a range of *IR*=0.08-0.17, an in-filled trench provides effectiveness comparable to an open trench of similar geometry.

Both open and softer barriers are more effective in isolating the vertical vibration component than the horizontal. Within *IR*=0.08-0.17, a trench of depth, d=1L_R as an active barrier, can screen off nearly 65%-75% of the vertical vibration and 55%-60% of the horizontal vibration.

References

[1] R. D. Woods, "Screening of surface waves in soils," Journal of Soil Mechanics and Foundations Division, 94 (SM 4),1968, pp. 951-979.

[2] D.E. Beskos, B. Dasgupta, and I.G. Vardoulakis, "Vibration isolation using open or filled trenches: Part 1: 2-D homogeneous soil," Computational Mechanics, 1 (1), 1986, pp. 43-63.

[3] B. Dasgupta, D.E. Beskos, and I.G. Vardoulakis, "Vibration isolation using open or filled trenches: Part 2: 3-D homogeneous soil," Computational Mechanics, 6 (2), 1990, pp. 129-142.

[4] K.L. Leung, D.E. Beskos, and I.G. Vardoulakis, "Vibration isolation by trenches in continuously non-homogeneous soil by the BEM," Soil Dynamics and Earthquake Engineering, 10 (3), 1991, pp. 172-179.

[5] S. Ahmad and T.M. Al-Hussaini, "Simplified design for vibration screening by open and in-filled trenches," Journal of Geotechnical Engineering,117 (1), 1991, pp. 67-88.

[6] T.M. Al-Hussaini and S. Ahmad, "Design of wave barriers of reduction of horizontal ground vibration," Journal of Geotechnical Engineering,117 (4), 1991, pp. 616-636.

[7] T.M. Al-Hussaini, S. Ahmad, and K.L. Fishman, "Investigation on active isolation of machine foundations by open trenches," Journal of Geotechnical Engineering,122 (6), 1996, pp. 454-461.

[8] T.M. Al-Hussaini, S. Ahmad, and K.L. Fishman, "Investigation on active isolation of machine foundations by open trenches," Journal of Geotechnical Engineering,122 (6), 1996, pp. 454-461.

[9] T.M. Al-Hussaini and S. Ahmad, "Active isolation of machine foundations by in-filled trench barriers," Journal of Geotechnical Engineering,122 (4), 1996, pp. 288-294.

[10] R.K. Shrivastava and K.N. Rao, "Response of soil media due to impulse loads and isolation using trenches," Soil Dynamics and Earthquake Engineering, 22 (8), 2002, pp. 695-702.

[11] M.H. El Naggar and A.G. Chehab, "Vibration barriers for shock-producing equipments," Canadian Geotechnical Journal, 42 (1), 2005, pp. 297-306.

[12] Y. Yang and H. Hung (1997), "A parametric study of wave barriers for reduction of train-induced vibrations," International Journal for Numerical Methods in Engineering, 40 (20), 1997, pp. 3729-3747.

[13] S.H. Ju, "Three-dimensional analyses of wave barriers for reduction of train-induced vibrations," Journal of Geotechnical and Geoenvironmental Engineering, 130 (7), 2004, pp. 740-748.

[14] G. Di Mino, M., Giunta and C.M. Di Liberto, "Assessing the open trenches in screening railway ground-borne vibrations by means of artificial neural network," Advances in Acoustics and Vibration, 2009, 2009, pp. 1-12.

[15] H.H., Hung, Y.B. Yang, and D.W. Chang, "Wave barriers for reduction of train-induced vibrations in soils," Journal of Geotechnical and Geoenvironmental Engineering, 130 (12), 2004, pp. 1283-1291.

[16] A. Alzawi and M.H. El-Naggar, "Full scale experimental study on vibration scattering using open and in-filled (geofoam) wave barriers," Soil Dynamics and Earthquake Engineering, 31 (3), 2011, pp. 306-317.

[17] S.H. Ju and H.C. Li, "3D analyses of open trench barriers filled with water," Journal of Geotechnical and Geoenvironmental Engineering, 137 (11), 2011, pp. 1114-1120.

[18] G.L.S. Babu, A. Srivastava, and K.S.N. Rao, "Analysis and design of vibration isolation system using open trenches," International Journal of Geomechanics, 11 (5), 2011, pp. 364-369.

[19] A. Saikia, "Numerical study on screening of surface waves using a pair of softer backfilled trenches," Soil Dynamics and Earthquake Engineering, 65, 2014, pp. 206-213.

[20] A. Saikia and U.K. Das, "Analysis and design of open trench barriers in screening steady-state surface vibrations," Earthquake Engineering and Engineering Vibration, 13 (3), 2014, pp. 545-554.

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