Trench Barriers to Protection of Structures under Dynamic Loadings-2

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Abstract

Wave barriers are intended to mitigate the transmission of vibrations in the soil. In this study, two-dimensional finite difference element analysis has been carried out, to investigate the efficiency of open and in-filled barriers under dynamic loading without or with presence of the structure. In this contribution, on the basis of the general basis for yield, failure and potential functions in plasticity in soil, two constitutive models to studying the rate of soil response in the elastic and elastoplastic range have been investigated. From numerical analysis be concluded that the results achieved with assigning elastic properties to the soil material doesn’t follow the trend with the result that have been achieved from analysis of the model with non-linear properties of soils, with higher values at all points. Presence of structure has a significantly larger effect on efficiency of barriers on reducing surface wave energy with assigning nonlinear modulus to soil.

Keywords: Wave Barrier, Soil Displacement, Strain-Hardening and Elastic Model.

1. Introduction

Wave barriers are used to reduce ground-borne vibrations induced by different sources such as machine foundations, earthquake, dynamic compaction, high speed trains and etc. Most of these vibrations propagate in the soil in the form of surface waves and can travel for long distances. The geometry, location and composition of the wave barrier influence the isolation performance. Regarding the literature on ground-borne vibrations, Barkan (1962), as the first scientist, used screening against vibration waves with open trenches and reported that open trench dimensions are large enough relative to the wavelength of the surface motions [1]. In three past decades an extensive research have been carried out by Russian scientists like Musyaev V.K. and others to investigation barriers efficiency in screening of surface waves in soil[3-5].

The finite difference method is perhaps the oldest numerical technique used for the solution of sets of differential equations, given initial values and/or boundary. In this study the 2D finite difference element model was developed by utilizing the FLAC package. In the analysis of geotechnical problems, the choice of an appropriate constitutive model may have a significant influence on the numerical results. Every constitutive model has its advantages and limitations.

2. State of research

To studying the efficiency of open and in-filled barriers under dynamic loading with or without structure, the developed models analyzed, with assuming two behavior models for soil; strain hardening(nonlinear) and elastic(linear). Based on standard some available tests, general parameters have been developed for determination of nonlinear constitutive material parameters. In all analysis the properties of concrete and structure have been assumed linear and in elastic mode, so only soil materials have been assumed non-linear or in linear one. The soil was modeled in a half-space. The dynamic properties of soil and other materials that have been used in analysis were found to be as following (Table.1).

In this study, the structure (10 meters in width and 15m in height) was approximated to an equivalent rectangular shape. The structure was located on the right side of barrier at ground surface. Mat foundation of structure located at the 1.0m depth under the ground surface. In this paper be assumed that the vertical
impulse dynamic load in triangular shape induced on surface of soil with one meter diameter on the left hand of barrier (duration=0.1 second). The maximum amount of dynamic loads was $P=1.0$ MN. All Geometrical parameters that have been used in model are shown in Figure 1 and also be listed in Table 2 (see table 2 ref. [6]).

### Table 1. Material properties of the building-soil-trench-building system

<table>
<thead>
<tr>
<th>Material</th>
<th>Mass density ($\rho$, kg/m³)</th>
<th>Shear modulus ($G$, E8*Pa)</th>
<th>Bulk modulus ($K$, E8*Pa)</th>
<th>C (kPa)</th>
<th>$\Phi$ ($^\circ$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Half-space</td>
<td>1865</td>
<td>0.288</td>
<td>0.625</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Concrete</td>
<td>2400</td>
<td>104</td>
<td>138.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structure (concrete) *</td>
<td>432 *</td>
<td>18.8*</td>
<td>25.2*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*derived value

An important point that must be mentioned that the most researches have been focused on effectiveness barriers with presences no structure and assigning elastic modulus for soils under sinusoidal or regular excitation dynamic loadings, but in this study also we have studied effects of structure and nonlinear behavior of soils on effectiveness barriers under impulse loading. The developed 2D finite difference element models were studied by comparing the achieved results from analysis models with the elastic and strain-hardening modulus for soil in terms of attenuation amplitude of displacement on surface ground ($A_r$) (see Eq.1 ref.[6]).

3. Result

The structure was assumed that located at a distance of 25m from right-hand of trench, and disturbance source located at a distance of 8m from the left side of trench. Figures 1a,b,c,d shows the decay curve of the ground motion vs. distance on a semi-logarithmic scale, under exciting impulse loading. As it can be seen from figures, the results that were achieved from analysis model with elastic modulus for soil don’t follow the trend of the hardening soil results, with higher values at all points. It is observed that material damping have some influence in efficiency of barrier and aren’t less significant. This may be attributed to that; the ground motion is damped both geometrically and materially, which indicates that the soil damping is relatively high. Another source for the discrepancy between the linear and nonlinear results is that under dynamic loading, large strains can induce plastic areas in nonlinear materials, which induce local soil inhomogeneities and significant damping. Thus, because of nonlinear behavior of soils, the model with nonlinear properties can be reliably used to extrapolate the results and conduct an extensive parametric study to better understand the open and in-filled trench barrier behavior.
To study the influence of the proximity of source disturbance on the protective effectiveness of isolation system, as mentioned above three locations were chosen to place the excitation system; 3.0, 8.0, and 16.0 m from the left side of trench.

Figures 2a,b,c and 3a,b,c show the effects of the presence and absence of structure on soil displacement under impulse loading for case of open and without barrier. These figures illustrate maximum horizontal displacement of soil particles on ground surface with considering strain hardening properties for soil. As it can be noted from the figures, the structure has a significantly larger effect on barriers efficiency in reducing surface wave energy with assigning nonlinear modulus to soil. In models with structure in both cases; with or
without barriers, efficiency of trench-barriers for the screening energy of surface wave in soil has been increased against the induced vibration due to impulse loading on earth surface. In this regard also it can be observed that with presence of structure and increasing the distance of load source and the trench-barrier, the wave barriers protective effectiveness was increased based on the achieved reduction in soil particle response.

Also from figures can be seen that in two sides of barriers the structures made noticeable difference on maximum horizontal displacements soil particles in comparison of models with no structure.

Figure 2: ground motion for exciting impulse loading without and with structure in case of without trench, depth of trench=10m W=50cm.

a) distance structure of trench (L) be assumed; 3m.

b) distance structure of trench (L) be assumed; 8m

c) distance structure of trench (L) be assumed; 16m
Figure 4: ground motion for exciting impulse loading with structure in case of open trench, depth of trench=10m and width trench=50cm.

a- distance structure of trench (L) be assumed; 3m.
b- distance structure of trench (L) be assumed; 8m.
c- distance structure of trench (L) be assumed; 16m.

5. Conclusion

In conclusion, this current study aimed to provide a few general guidelines for the design of vibration isolation measures by means of trench-barriers. In this study the wave barriers protective effectiveness was evaluated based on the achieved reduction in soil particles displacements on ground surface under impulse loading. Obtained results can be summarized as below:

(1) The results have been achieved of the elastic properties for soil doesn’t follow the trend of the strain hardening soil, with higher values at all points.

(2) After barrier the results show a very steep decay in non-linear soil behavior in comparison of elastic modulus. It can be discussed because of nonlinear behavior of soils and material damping.
(3) In models with structure in both cases; with or without barriers, efficiency of trench-barriers for the screening energy of surface wave in soil has been increased against the induced vibration due to impulse loading on earth surface.

(4) It has been observed that with increasing the distance of load source from trench, the structure efficiency on efficiency of trench-barrier become increased.

6. References.