Numerical Study on Effect of Barriers on Vibrations Induced by Construction Activities

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Abstract

Construction activities like pile driving, dynamic compaction, or blasting can be the sources of adverse effects on adjacent structures and sensitive installations.It is often suggested that vibrations can be interrupted using wave barriers. The properties of barriers affect on their efficiency. In this research, the performance of TDA in-filled open trenches, made of pieces of scrap tiresis compared with geofoam in-filled barriers due to low cost of production and its benefits in road construction.Vibration transmission from the source to target is modeled by means of Finite Difference Method. Based on the presented models, the variation of amplitude reduction has been investigated. Finally, considering the impact of barriers to reduce vibrations, the suitablemodes for barrierdimensions and distance from vibration source are investigated.

Key words: Wave Barriers, Construction activities**,** FDM, Vibration Amplitude

1. Introduction

Construction activities like pile driving, dynamic compaction, blasting, or breaking pavement can be the sources of adverse effects on adjacent structures and sensitive installations. In addition to environmental problems such as noise and air pollution, vibrations generated from these activities may cause settlement, heave, or structural and non-structural damage in nearby buildings. Accordingly, despite some advantages, these methods have been limited or even forbidden in urban areas.

Source of vibrations could be contained within the soil medium, e.g. pile driving, or situated on the ground surface, e.g. machine foundation.To reduce the vibration problems caused by construction activities, some methods have been recommended in the literature, such as pre-drilling, jetting, and pile cushioning. One of the most efficient methods is using barriers in the path of vibrations induced by construction activities. Barriers can be made of different types of materials. Wave barriers can be built in the form of open trenches filled by concrete, bentonite, or geofoam. Also, they may take the form of sheet pile walls, rows of solid or hollow piles, or gas-cushion screen system. The principle of operation of a barrier is to reflect wave energy back toward the source or absorb energy to prevent or limit it from propagating beyond the barrier toward a target building.

Obviously, the properties of barriers affect on amount of vibrations received by target structures. Dimensions of wave barrier and properties material in-filled open trenches are basic parameters that must be proportioned to the waves to be screened. Amplitude of wave transmitted through soil-barrier is a function of impedance ratio between them. Impedance is dependantto density and elasticity module of material.

In recent years, the use of geofoam as fill material in open trenches has been prevalent.Geofoam is expanded polystyrene manufactured into lightweight blocks varied in size. Theproperties of geofoam are suitable to attenuate amplitude of waves beyond the barriers.

On the other hand, TDA is another option that can be used in open trenches. TDA is an engineered product made by cutting scrap tires into small pieces using specialized equipment, which includes shredders and shearing equipment.Also, TDA can be used for other aims like lightweight fill material for embankment or retaining wall construction. Besides, TDA can be utilized as thermal insulation to reduce frost penetration under highways, in addition to attenuation of vibrations amplitude.

TDA and geofoam both are lighter than soil. Although, the density of geofoam is less than that of TDA, elasticity modulus of TDA is lower than geofoam. Since impedance reduces with decrease of elasticity module, TDA can also transmit fewer waves.Since, the unit cost of TDA is cheaper than that of geofoam, it is seems using in-filled TDA trenches is economically better than geofoam.

2.Review of Historical Evidence

Investigations conducted in the wave barriers subject could be divided in two sections of experimental and numerical studies. The first surveys conducted about the effect of wave barriers on vibration screening goes back to 1960's. Barkan (1962) investigatedthe effect of open trenches and sheet piles on control of vibrations induced by a heavy vibrator in silty soils.

Furthermore, a series of field test performed by Dolling (1970). He used bentonite slurry as the filling material for open trenches. Conducting a series of model tests in laboratory, Haunt (1981) compared the efficiency of open trenches, rows of bore holes, and concrete in-filled trenches for screening vibrations.Massarsch (1991) suggested a new method including gas-cushion screen system installed ina deep trench, which is then filled with a self-hardening cement–bentonite grouts.

In terms of numerical studies, Using FEM, Haupt (1978) utilized the influence-matrix boundary concept to investigate the effectiveness of using concrete walls. Baker (1994) carried out some model tests of trenches filled by concrete or bantonite. Then he used boundary element method to model these trenches and compare the numerical and experimental results. Al-Hussaini and Ahmad (1996) developed a numerical study to evaluate the effect of a rectangular barrier on control of vibrations. Al-Hussaini et al. (2000) compared the BEM results and experimental data and reported a reasonable agreement between the predicted values for the average amplitude reduction ratio. El Naggar and Chehab (2005) use numerical methods to compare the effectiveness of different types of material as wave barrier. Andersen and Nielsen (2005) conducted a FEM–BEM model to investigate the reduction of ground vibrations by means of barriers.Wang (2008) conducted a numerical study to investigate the performance of expanded polystyrene geofoam in open trenches to protect buries structures against blasting.

3. Research Methodology

In this approach, wave propagation and the effect of geofoam and TDA in-filled open trenches in the vibration path have been simulated with Finite Difference Method (FDM). Flac is one of powerful software ofFDM for simulating different geotechnical issues. The properties of soil and filling material of trenches have been presented in Table 1.

Table 1. Properties of Materials in Modeling

Parameter	Clay	Dense Coarse Grained	TDA	Geofoam	Unit
Model	Mohr Coulomb	Mohr Coulomb	Elastic	Elastic	-
C	0.4	0	-	-	kg/cm^2
φ	0	35	-	-	degree
E	-	-	5.17	8.0	Mpa
Density	1850	2100	640	20	Kg/m^3
Poisson's Ratio	0.45	0.3	0.5	0.286	-
K	145	860	-	-	Mpa
G	15	400	-	-	Mpa

4. Discussions and Results

4.1. Comparison of TDA and Geofoam in-filled Open Trenches

In this section of modeling, open trenches are filled with Geofoem and once again with TDA. Figure 1comparesthe amplitude reduction percent in these two modes in clay. For low frequencies, there is noconsiderable difference between TDA and Geofoem. At frequencies between5to 10 Hz, barriers, whether with geofoam or TDA, have most effect on vibration amplitude. With increasing frequency, the effect of trenches on vibration amplitude will decrease. Although, the efficiency of Geofoem and TDA to attenuate the vibration amplitude is similar, it is seems geofoam could be more effective as filling material for open trenches, especially in frequencies higher than 20 Hz.

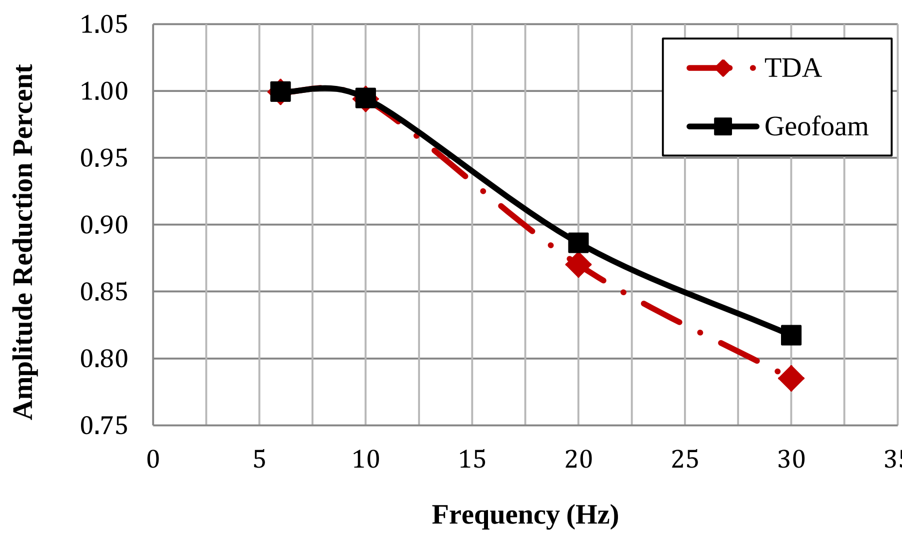

Fig 1: Comparison of TDA and Geofoam In-filled Open Trenches in Clay

Also, the modeling of vibration propagation was conducted for both geofoam and TDA in very dense coarse grained soil. The results of these models are presented in Figure 2. It is clear that in low frequencies, the barriers' effect in clay is better than their effect in dense coarse grained soil, while for higher frequencies; barriers reduce vibration amplitudes more in coarse grained soils. According to Figure 2, the efficiency of geofoam is a little better than that of TDA in open trenches, especially in higher frequencies.

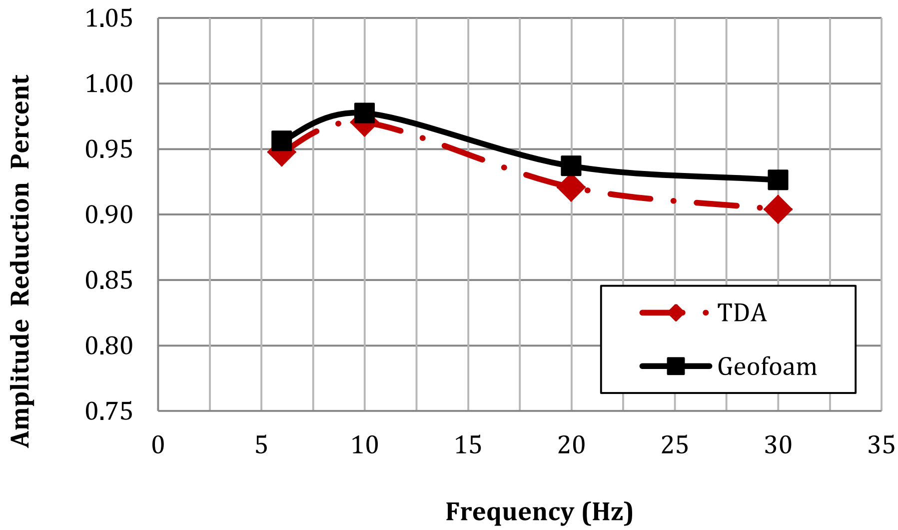

Fig 2:Comparison of TDA and Geofoam In-filled Open Trenches in Coarse Grained Soil

4.2. Effect of Distance from Vibration Source in Horizontal Barriers

Horizontal layers of TDA are used in road construction or as lightweight fill materials in soil embankments. In this section, these horizontal layers have been simulatedas wave barriers. In the first stage, the constant value of 0.2 m is supposed for depth of barrier in clay, and with variation of barrier's width (B) based on wavelength (λ)that is under vibration source with frequency of 20 Hz, the amplitude reduction percent is depicted in Fig 3. As presented in this figure, with increasing width of barrier, the amplitude reduction rises. In the other words, as expected, the efficiency of barriers increases with barrier width increment. Besides, the amplitude reduction rises in further targets from source of vibration.According to Fig. 3, there is no considerable difference in percent of amplitude reduction between barriers with width of λto 2λ. Accordingly, the range of λ to 2λ may be supposed as effective range for barrier width.

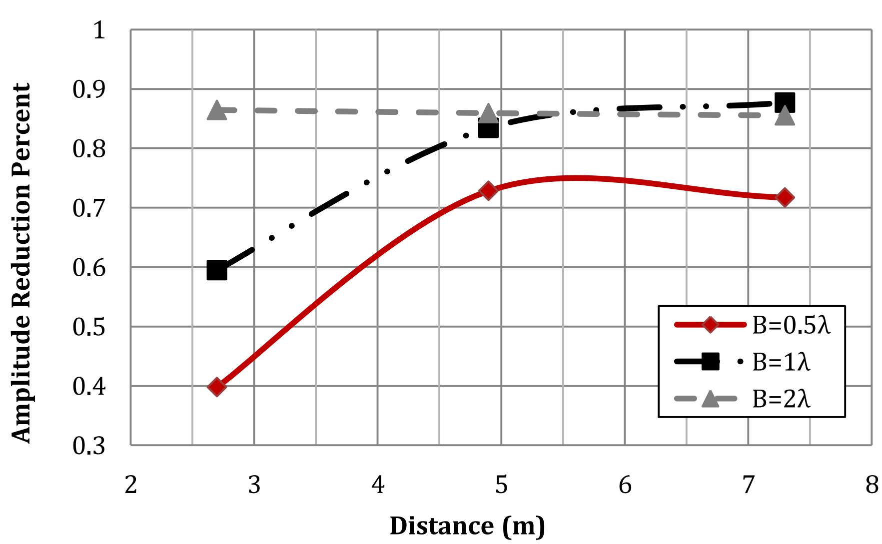

Fig 3:Comparison of horizontal barriers' effect to distance in Different Widths(Depth=0.2 m, Frequency=20 Hz)

In the second stage, the width of horizontal barrier is assumed to be constant value of 0.5 λ and the embedded depth is varied from 0.2 to 0.8 m. Based on Fig 4, it can be inferred that there is an optimum depth for establishing horizontal barrier that is directly proportioned by wavelength and distance. It seems that the embedded depth about 0.01λ(0.4≈0.01*4.5) is suitable for depth of horizontal barriers. The amplitude reduction factor of horizontal barriers is higher in further distances.

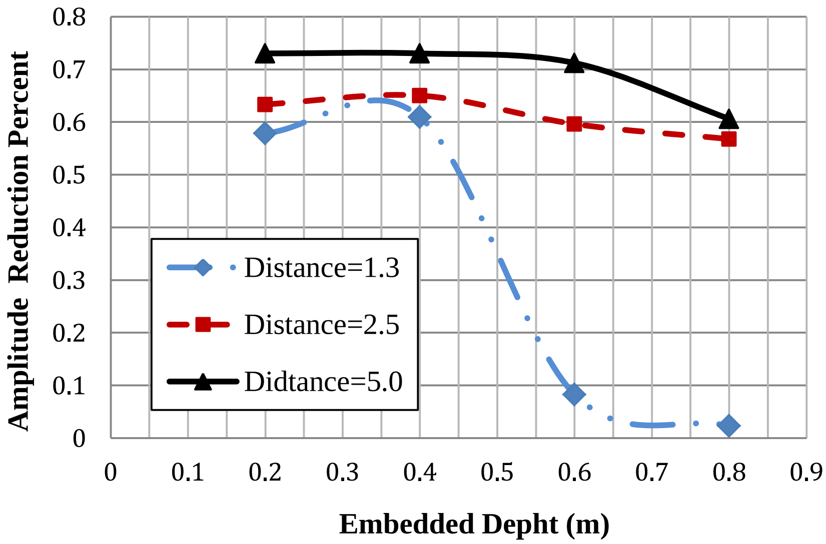

Fig 4:Comparison of horizontal barriers' effect to distance in Different Embedded Depths (Width=0.5λ, Frequency=20 Hz)

4.3. Effect of Distance from Vibration Source in Vertical Barriers

In this section, the effect of verticalbarrier's distance (R) from source of vibration has been investigated. The barrier location is varied from 0.25λ to 1.5 λ and the amplitude reduction percent has been calculatedin different distances.

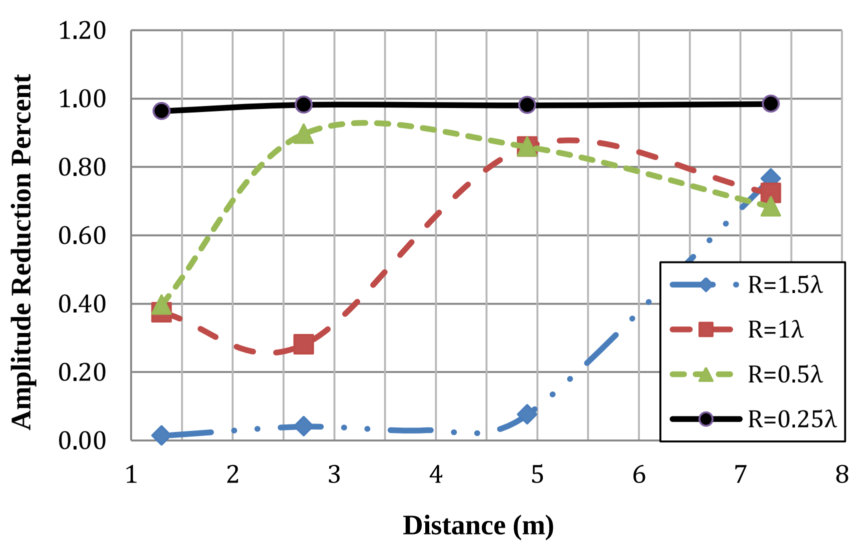

Fig 5:Variation of Amplitude Ratio Reduction with distance for various locations of barrier (Frequency=20 Hz)

As shown in Figure 5, if the distance of wave barrier is closer to vibration source, the effect of barrier on reduction of vibration amplitude will increase.For vertical barriers in different distances, the most efficiency is indicated in closest target behind the barrier, while, for further targets, the amplitude reduction percent will decrease andfor points ahead of barrier, it is low or even negligible.

5. Conclusion

- The in-filled TDA trenchesareslightly less efficient compared with in-filled geofoam barriers. However, considering lower cost of TDA to geofoam, it sometimes seems logical to substitute TDA for geofoam, especially in low frequencies.
- Generally, open trenches have better performance in clay for low frequencies (5- 15 Hz), like dynamic compact, while for higher frequencies (15-30 Hz), wave barriers attenuate the amplitude more in coarse grained soils.
- The embedded depth of 0.01λ is suitable for depth of horizontal barriers. The amplitude reduction percent of horizontal barriers is higher in further targets.
- For horizontal barriers with TDA, an effective width between λ to 2λ has been suggested that the amplitude reduction percent will be in suitable level in this range.
- By and large, vertical trenches have better performance compared with horizontal barriers. However, horizontal barriers have better efficiency in further targets, while for vertical barriers the most efficiency is indicated in closest target behind the barrier.

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