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COMPARISON BETWEEN GROUND VIBRATIONS INDUCED BY IMPACT PILING AND BORED PILING.

Achuhan R., Subashi De Silva G.H.M.J. and Sudhira De Silva

Faculty of Engineering, University of Ruhuna.
E-mail: achu3128@gmail.com, subashi@cee.ruh.ac.lk and Sudhira@cee.ruh.ac.lk

Abstract: During piling activities, vibration is generated from the pile driver to the pile then it transferred at the pile-soil interface. However, the level of ground vibration induced by piling may depend on several factors including energy and distance from the vibration source. The objective of this study is to investigate characteristics of ground vibration that propagate during piling to be done by two different types: bored pilling and impact pilling. Change in characteristics of ground vibration with the distance from the pile driver was also investigated.

Two bored piling sites and an impacted piling site were selected for this study. In the selected piling sites, ground vibrations were measured at 5m, 10m, 15m and 25m distances from the source in three radial directions by using a four channel seismograph. It was found that, for both types of pilling, magnitude of the vibration reduces with the distance. Impact piling induces high magnitude and low frequency vibration whereas bored piling induces low magnitude and high frequency vibration. In transverse direction, impact piling induces a magnitude of 4.21mm/s (PPV) at a frequency of 20Hz, whereas bored piling induces a magnitude of 0.92 mm/s (PPV) at a frequency of 36.5 Hz, at 5m distance from the source. Characteristics similar to the transverse vibration were found in both vertical andlongitudinal vibrations.

Keywords: Ground vibration, bored piling, impact piling, level of ground vibration

1. Introduction

For most of the constructions including high-rise buildings and bridges , driving of piles is inevitable .In populated areas these can have a negative impact on the environment such as disturb inhabitants and, under unfavourable conditions, cause damage to buildings and installations ([1] and [2]). People always feel uncomfortable living due to these vibrations and they tend to response against construction of piling. For an example, in the Southern Transport Development Project, at the end of December 2008 the contractor has received 424 complaints. Most of them were related to blasting activities, pilling and heavy machinery. [3].

Ground vibration due to the pile driving is part of a complex process. Vibration is generated from the pile driver to the pile. As the pile interacts with the surrounding soil type, vibrations are transferred at the pile-soil interface. The vibration propagates through the ground and interacts with structures, both above ground and underground. The vibration continues into the structure where it may disturb occupants and/or damage the structure [4]. The level of ground vibration depends on source energy, distance from the source of vibration, soil characteristics, characteristics of wave propagation. [5].Significant amount of vibrations propagates from these pile driving to adjacent buildings which can be highly damaged due to these vibrations.

Ground and structural vibration can be reduced by decreasing dynamic loads from construction source [6].

In Sri Lanka bored piling is widely used in high-rise buildings and lager span bridges .Impact piling is widely used in smaller span bridges mainly in the road network construction. In order to find out the reasons for the structural damage and people discomfort due the ground vibration induced by different types of piling a comparison of the characteristic of the ground vibration induce by impact piling and bored piling is necessary. This will further help to select the appropriate type of piling to be done, in order to provide an effective solution for damages and complains.

2. Objectives

Objective of the current study is to investigate and compare characteristics of ground vibration that propagate during impact piling and bored piling.

3. Methodology

3.1 Site selection

Two bored piling sites and an impact piling site were selected for monitoring ground vibration in three radial directions at 5m, 10m, 15m and 25m distance from the source (Figure 1). Bored piling site measurements were recorded during the excavation of the soft soil and the excavation of the hard rock. In the impact piling site, measurements were recorded when load weight of 5 tons drops approximately 3m above to the pile top.

Vibration measurement

Ground vibration was measured for the selected sites using two seismographs: four channel seismograph was connected to a tri-axial geophone and six channel seismograph was connected to two tri-axial geophones.

Seismograph is capable in measuring vibration in traverse, vertical and longitudinal direction up to 254mm/s with a resolution of 0.127 mm/s in the frequency range 2Hz-250Hz. The geophone was placed on the ground and its ground spikes were inserted (length of the spike is 65mm) in to the ground (Figure 03(a) and Figure 3(b)). Before measuring, it was programmed to record vibration in the continuous mode and fixed time stop mode. Arrow mark located on the top of the geophone was pointed towards the direction of the source.

Each location from the source, magnitudes and the dominate frequencies of the ground vibration were measured for a time 10s (ten continuous records of 1 second) with the sampling time is equal to 1/1024 s

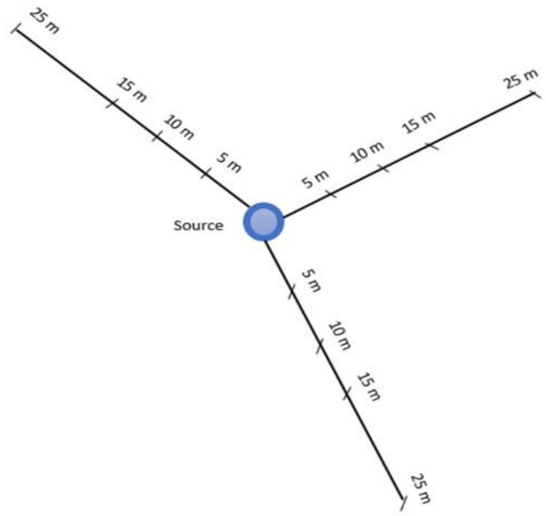

Fig 1: Ground vibration monitoring location

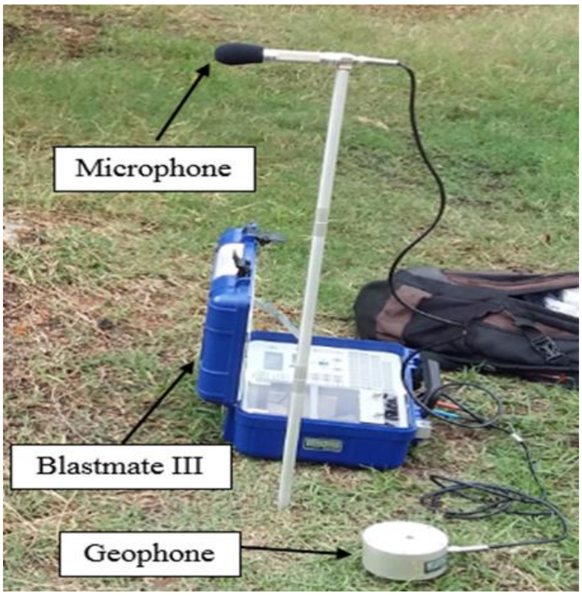

Fig 2: Measuring ground vibration using four channel seismograph

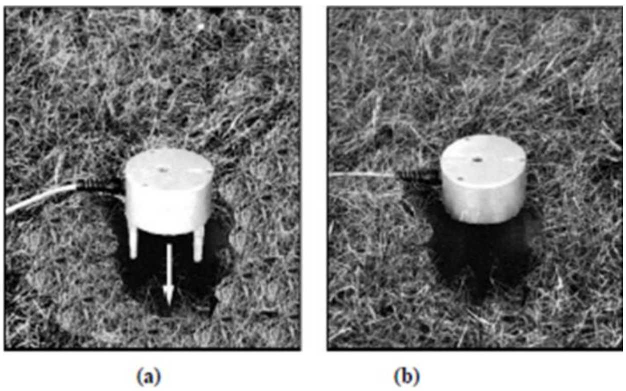

Fig 3: (a) Installing the Geophone using the ground spikes, (b) Final installation with ground spikes fully inserted to the ground.

4. Results and Discussion

4.1 Bored piling

In three radial directions (Figure 1) maximum PPV of ground vibration at each distance was selected and averages were determined. Average PPV of ground vibration in transverse, vertical and longitudinal direction are compared in Figure 4.

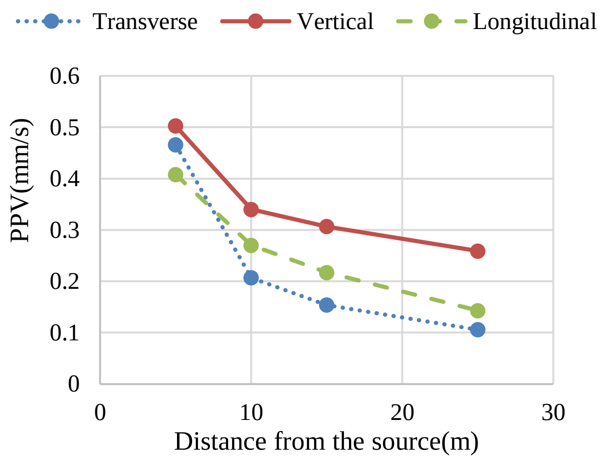

Fig 4: Average PPV variation with distance induced by bored piling

In the bored piling it can be identified that PPV in all three directions decays with the distance from the source. Vertical direction wave has the maximum magnitude when comparing with transverse and longitudinal wave. At the 5m distance from the source magnitude of the vertical wave is 0.503mm/s and transverse and vertical wave magnitudes are 0.466mm/s and 0.408 mm/s respectively. As a result damage to structures could often be occurred due to the vertical ground vibration, although the self-weight of the structures might have some resistance to vibrate the structures due to vertical vibration. In three radial direction (Figure 1) dominant frequency of each locations were selected and maximum and minimum dominant frequency were extracted then its represented as a rage of dominant frequency at that location. Table 1 shows the dominant frequency of the ground vibration along all three longitudinal lines in bored piling.

Table 1: Variation in the dominant frequency of bored piling.

Frequency of vibration (Hz)	Distance from the source (m)			
	5	10	15	25
Transverse	13-24	9- 10	11-26	12-15
Vertical	16-24	6-26	25-26	25.5
Longitudinal	11-18	8-12	8- 23	11-25.5

4.2 Impact piling

In three radial direction lines maximum PPV of each distance was selected and averages were calculated. Average PPV of ground vibration in transverse, vertical and longitudinal directions are shown in Figure 5.

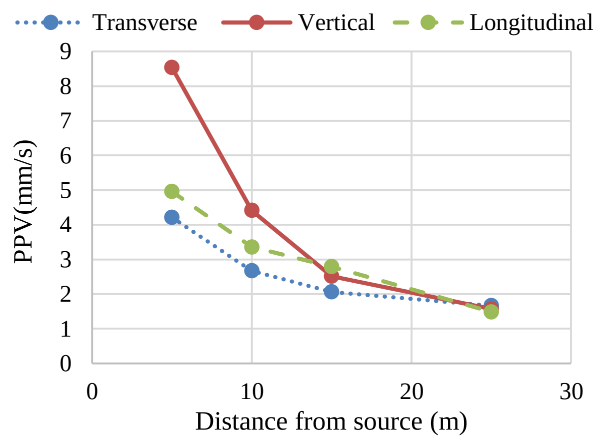

Fig 5: Average PPV variation with the distance in vertical, transverse and longitudinal directions induced by impact piling.

In the impact piling, for all three orthogonal directions PPV decays with the distance from the source. In the impact piling magnitude of the vertical vibration is greater than that in other two directions: transverse and longitudinal. At 10 m distance from the source, the magnitude of vertical wave is 4.41mm/s and magnitude of transverse and longitudinal waves are 2.67mm/s and 3.36mm/s respectively. In three radial direction (Figure 1) dominant frequency of each locations were selected and maximum and minimum dominant frequency were extracted then its represented as a rage of dominant frequency at that location. Table 2 shows the dominant frequency of the ground vibration along all three radial directions (Figure 1) for the impact piling.

Table 2: Variation in the dominant frequency of impact piling.

Frequency of vibration (Hz)	Distance from the source (m)			
	5	10	15	25
Transverse	13-32	9-18	10-18	7-9
Vertical	9-19	9-25	8-11	7-12
Longitudinal	7-24	9-20	7-32	8-22

4.3 Comparison of level of vibration induced by bored piling in soft soil and hard rock.

In three radial directions (Figure 1) maximum PPV and maximum dominate frequency of each distance were determined and averages were calculated. Table 3 shows the average PPV of the ground vibrations induced along all three radial directions. Figure 6(a), Figure 6(b) and Figure 6(c) compared PPV values in transverse wave, vertical wave and longitudinal wave, respectively, during hard rock and soft soil excavation.

Table 3: Comparison of PPV during the excavation of soft soil and hard rock in bored piling (S.S: Soft Soil and H.R: Hard Rock)

Magnitude of vibration PPV (mm/s)		Distance from the source (m)			
		5	10	15	25
Transverse	S.S	0.46	0.21	0.15	0.11
	H.R	0.92	0.54	0.44	0.37
Vertical	S.S	0.5	0.34	0.31	0.26
	H.R	0.56	0.34	0.37	0.32
Longitudinal	S.S	0.41	0.27	0.22	0.14
	H.R	1.15	0.69	0.35	0.3

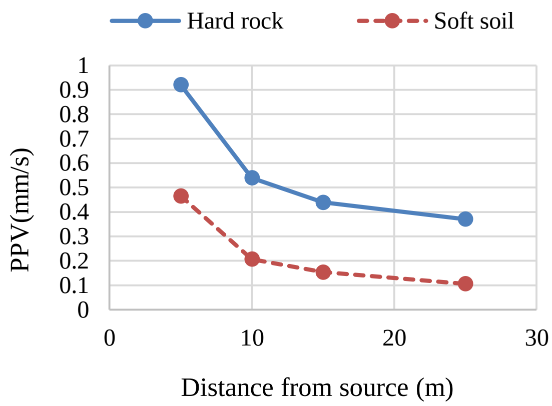

Fig 6(a): Comparison of magnitude of transverse wave during the exaction of soft soil and hard rock

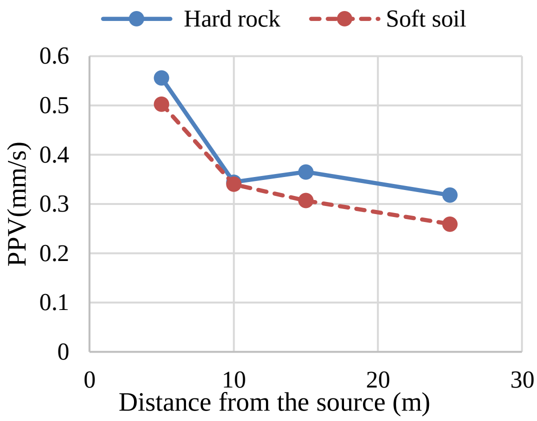

Fig 6(b): Comparison of magnitude of wave during the exaction of soft soil and hard rock

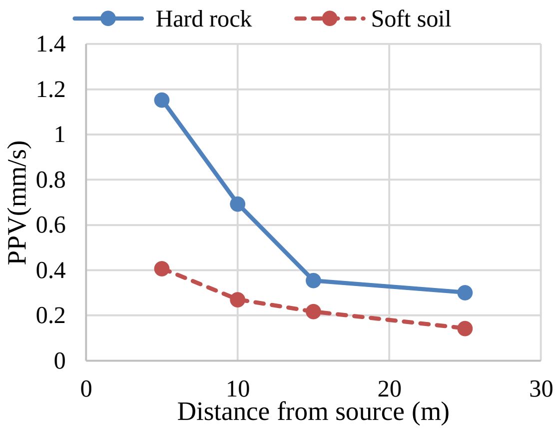

Fig 6(c): Comparison of magnitude of wave during the exaction of soft soil and hard rock

It can be identified that magnitude (i.e PPV) during the excavation of hard rock is higher than that for the excavation of the soft soil. This was well clear in all three wave directions: transverse, vertical and longitudinal. However comparing the magnitude deviation during the excavation of hard rock and soft soil it clearly shows that deviation in the vertical wave magnitude is lesser when comparing transverse and longitudinal waves.

4.4 Comparison in characteristics of ground vibration induced by impact piling and bored piling.

Table 4 shows the comparison of the PPV of ground vibration induced by impact piling and bored piling along various distances (i.e 5m, 10m, 15m and 25m). Figures 7(a), 7(b) and 7(c) show a comparison of PPV in transvers, vertical and longitudinal waves, respectively, between impact piling and bored piling. Table 5 shows the comparison of frequency between impact piling and bored piling along various distances (i.e, 5m, 10m, 15m and 25m). Figures 8(a), 8(b) and 8(c) show a comparison of frequency in transvers, vertical and longitudinal waves between impact piling and bored piling along the distance from the source.

Table 4: Variation in the magnitude of ground vibration between impact piling and bored piling (I.P: Impact Piling and B.P: Bored Piling)

Magnitude of the vibration PPV(mm/s)		**Distance from the source (m)**			
		5	10	15	25
Transverse	I.P	4.21	2.67	2.06	1.67
	B.P	0.92	0.54	0.44	0.37
Vertical	I.P	8.54	4.41	2.51	1.57
	B.P	0.56	0.34	0.37	0.32
Longitudinal	I.P	4.96	3.36	2.79	1.49
	B.P	1.15	0.69	0.35	0.3

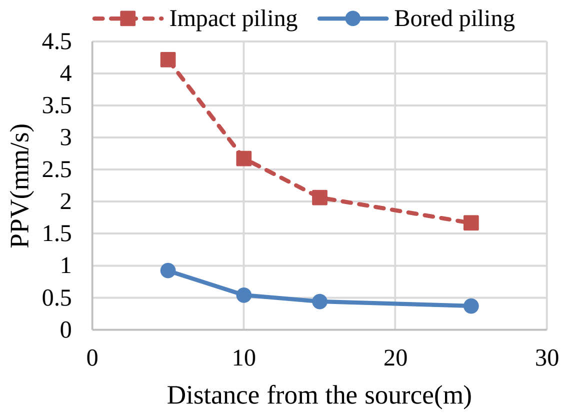

Fig 7(a): Variation in the magnitude of ground vibration impact piling and bored piling in transverse direction.

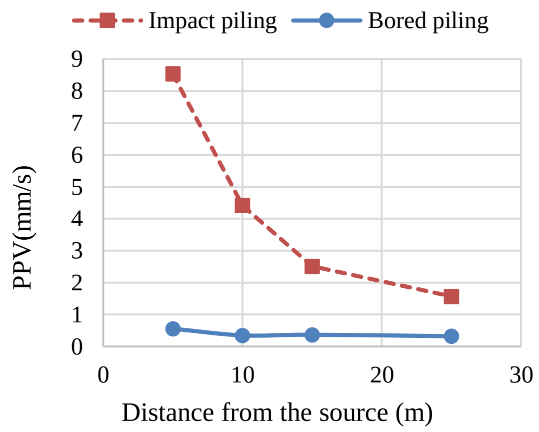

Fig 7(b): Variation in the magnitude of ground vibration between impact piling and bored piling in vertical direction.

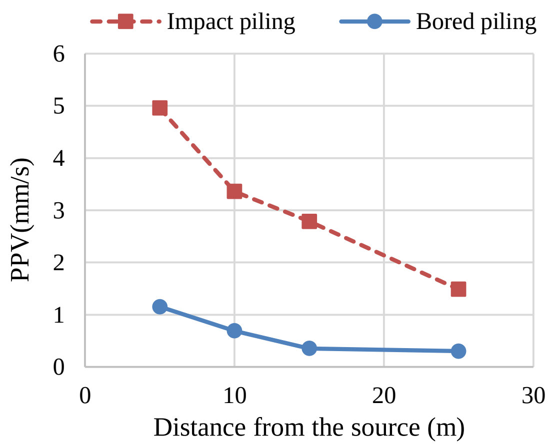

Fig 7(c): Variation in the magnitude of ground vibration between impact piling and bored piling in longitudinal direction.

Table 5: Variation in the frequency of ground vibration between impact piling and bored piling (I.P: Impact Piling and B.P: Bored Piling).

Frequency of the vibration (Hz)		**Distance from the source (m)**			
		5	10	15	25
Tran. Freq.(Hz)	I.P	20	12.65	15.2	8.42
	B.P	36.5	19	19.5	19.4
Vert. Freq.(Hz)	I.P	12.97	15.87	9.53	10.2
	B.P	28.25	17.12	16.5	12.17
Long. Freq.(Hz)	I.P	13.6	13.6	16.17	12.27
	B.P	24.4	21.57	25.25	24.08

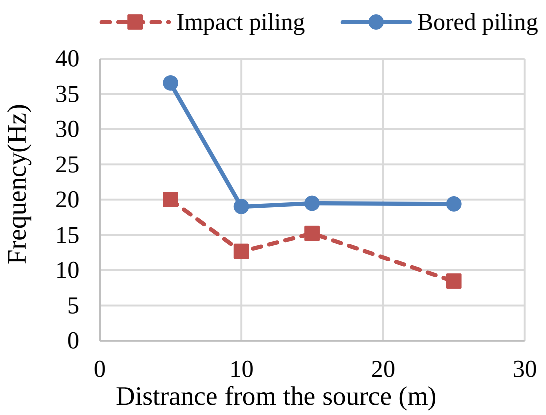

Fig 8(a): Variation in the frequency of ground vibration between impact piling and bored piling in transverse direction.

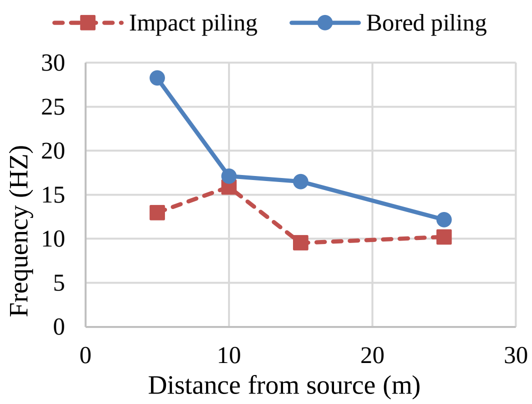

Fig 8(b): Variation in the frequency of ground vibration between impact piling and bored piling in vertical direction.

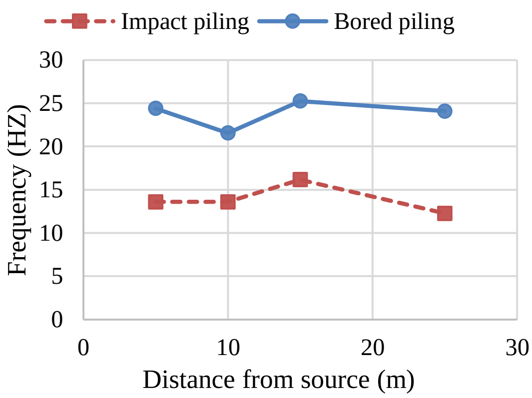

Fig 8(c): Variation in the frequency of ground vibration between impact piling and bored piling in longitudinal direction

It can be identified that PPV in impact piling is higher than that for bored piling in all three directions: transverse, vertical and longitudinal. Frequencies of ground vibration induced by impact piling is lesser than that for bored piling for all three directions: transverse, vertical and longitudinal waves. Magnitudes of impact piling induced by ground vibration in all directions are very high when comparing the level of vibration induced by bored piling. For an example at 10 m distance from the source, in the transverse direction, 4.21mm/s was found for impact piling and 0.92 mm/s was found for bored piling. However when comparing impact piling and bored piling, bored piling induced higher dominant frequency than that by impact piling. At 15m distance from the source, in the transverse direction dominant frequency of the ground vibration is 15.2 Hz for impact piling and that is 19.5Hz for bored piling. This trend is well clear in longitudinal and vertical directions.

People feel discomfort and building damage due to the impact piling because of the high magnitude of the ground vibration and structures may easily resonance due to the low frequency of the ground vibration costing structural damage.

However, bored piling needs high technology machineries such as pile boring machineries and different types of drilling bits and well trained works to operate the machineries. In addition, it requires bentonite circulation during the pile concreting, whereas such need is not necessary for impact piling. Impact pilling needs less technology machineries (only a mobile crane and load) and unskilled labours. In impact piling, precast concrete piles are installed by using dynamic forces. Bored pilling are costly and time consuming when comparing impact piling.

Due to high ground vibration induced at low frequencies, impact piling is not recommended to use, although for construction project located in rural areas or less populated area (Round 50m no buildings or houses are located) would get less effect due to impact piling Bored piling can be used for projects that located in urban areas and high populated areas, although they are costly.

However in the case of piling induced ground vibration, the introduction of open in- ground barriers is not effective. Because it is often difficult and impossible to install and maintain open trench to the require depths and widths, especially in the country like Sri Lanka where there is a heavy rain during the monsoon period [7]. Therefore it is essential to provide in-fill trenches. It was found that in the ground vibration induce by roller compaction was screen up to 49% by using bottom ash as the in fill material [7]. Currently, this research is continued to find out applicability of bottom ash as the infill material for screening ground vibration induced by piling activities.

5.Conclusions

In this study, characteristics of ground vibration induced by impact piling and bored piling were investigated and compared.

Bored piling induced low magnitude high frequency ground vibration and impact piling induced high magnitude low frequency ground vibration. Magnitude of ground vibration induced by bored piling and impact piling decay with the distance from the source. Higher frequency range of ground vibration was found with bored pilling compared to that of impact piling.

In bored piling it was found the vertical ground vibration is dominant throughout the distance from the source.

In bored piling, magnitude of the ground vibration induced during the excavation of soft soil is lesser than that during the excavation of hard rock in transverse, vertical and longitudinal wave.

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