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A STUDY OF PILE DRIVING EFFECTS ON NEARBY BUILDING

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ABSTRACT: Piles are used to support many major structures such as buildings and bridges. It is known that pile driving activity creates vibrations in the ground and may affect nearby building and structure. However, the different pile size and shape as well as installation distances factors remain as interesting subjects for studies. The effect of hammer driven piles installation were studied using laboratory scale model. Three main effects were studied in which they are the response on top and bottom of a building, the vibration creates by three different distances of driven pile and the vibration produced by two different pile sizes. It can be concluded that the effect of vibrations are higher at the bottom of the building. The result also indicated that the nearest distance of piling activity produced higher vibration. However, it is interesting to note that the smaller pile creates larger vibrations.

Keywords: Pile, Piling Vibration, Building, Laboratory Model.

1. INTRODUCTION

It is known that pile driving activity creates vibrations in the ground and may affect nearby building or structure. Propagation of vibrations to the surroundings depends on the weight of the ramming equipment, impact velocity, impact duration, shape of the pile, surrounding and underlying soil, cross-sectional area of the pile, straightness of the pile and eccentric or oblique strokes. Piling and sheet piling work on construction sites affects the environment in different ways depending on geological conditions. Usually, piling cause noise, vibration, settlement or heaving close to the site. The effects are dominated by the energy introduced into the subsoil, the distance from the source and because of subsoil condition. Settlement quickly occurs in non-cohesive soil.

It is expected that vibration level associated with pile driving may vary with distance from the pile driving site. This is because the resulting wave is of periodic nature which is highly attenuated after short distance and harmonic frequencies are low vibration level.

Ground vibration generated by construction sources consists of transient vibration and steady state vibration. Transient vibration is the single event or sequence vibrations. Each transient pulse of varying duration decaying before the next impact occurs. For example air, diesel or steam impact pile drivers by dynamic compaction of loose sand and granular fills by highway and quarry blast. Abdel-Rahman [1] surveyed and concludes that the force vibration caused by pile driver, double acting impact hammers operating at high speed and heavy machineries affect surrounding buildings. It causes or propagates crack and failure.

Energy that is produced by pile driving and spread into the ground travels from the pile to structures within. The amplitude of this vibration depends on many factors. The energy propagating away from driven pile depends on pile driver and the pile type itself [2]. Massarsch and Fellenius [3] described three types of ground waves created by pile driving namely surface wave, spherical wave from the pile toe and cylindrical wave from the pile shaft.

The main thrust of this study is to identify the various physical parameters involve in the propagation of vibration energy that affect surrounding building or structure by means of laboratory model. Over the years, several researchers ([2], [4], [5], [6] and [7]) have used scale model to carry out experiments related to piling. In this study, it is expected that relationship of the various parameters such as pile size, pile type, distance, trench depth and driving methods can be established. The empirical relationships can then be used in the actual operational condition as preliminary strategy to reduce or eliminate pile driving effects on nearby building or structure.

2. MATERIAL AND METHODS

Laboratory scale model was used to carry out experiments. A suitable sand container was fabricated to be used as a testing ground. The laboratory testing container was scaled from real construction site with 1:20 scale. This box was filled with river sand as soil. The size of container is 1.35 meter for the length, 1.0 meter for the width and 0.6 meter from the depth. Figure 1 shows the testing container used in this study. The size of the container is designed to accommodate dimensional similitude of a model building structure. Similar container size has been used before by other researchers as described in previous paragraph.

Figure 1: Sand container

2.1 Building/Structural Model

Model of building was built by using stainless steel bar. This model was scaled as 1:20 from 3 storey building and the height of the model building is 0.9 meter. The width and the length of the building is 0.3 meter. Stainless steel were cut into pieces and welded to the shape of skeleton building structure. The foundation of this building is raft foundation. The model of the building is shown in Figure 2.

Figure 2: Building Model

2.2 Pile

Piles used for this study are squared piles with 150mm x 150 mm and 200mm x 200 mm dimension. The size of pile was scaled down to 7.5mm x 7.5mm for the size of 150mm x150mm and 200mm x 200mm was scaled to 10mm x 10mm. The pile shoe scaled to 20 mm for both types of pile.

The assumed length of piles is 6m on site and it was scaled to 300 mm for the model. There are three piles for each size and will be allocated at different distance. The two sizes of piles chosen was the common pile sizes used for low rise building construction. The difference of pile size is expected to produce different level of vibration to the nearby building.

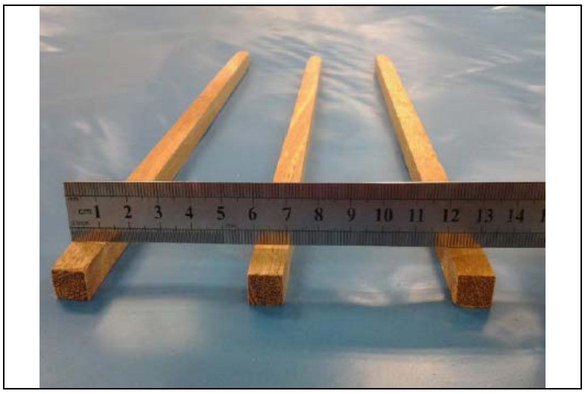

Figure 3: Equivalent 200mm square Pile of 10mm x 10mm

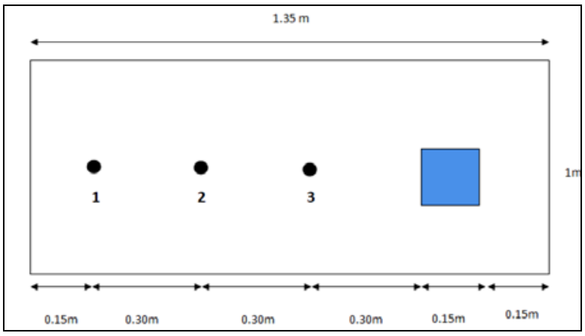

Figure 4: Pile arrangement at various distance from building

2.3 Pile driving hammer

On site hammer weight considered for this study is 1 ton and it was scale down to the ratio 1:20. The model hammer weight now becomes 120 gram. The dimension of container is 50 mm x 50 mm x 50 mm and filled with sand to the required weight. Hammer weight will be released at 150 mm height to the top of pile. Vibration at nearby model building were recorded when the hammer reach the pile. Hammer weight and hammer drop distance are constant throughout this experiment.

Figure 5: Hammer system

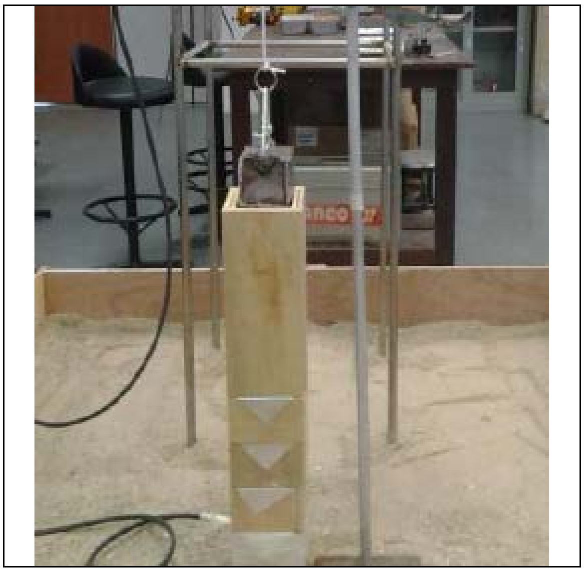

Figure 6: Use of special casing to make sure hammer drop on top of pile.

2.4 Testing Procedure

The steps conducting this experiment were explained further as below:

1) Two vibration transducers (accelerometer) were connected to the top and bottom of building and also connected to a dynamic data-logger as it will record the vibration data in computer.

2) Pile with the size 7.5 mm x 7.5 mm was positioned at point three. Pile was aligned at the centre of building as measured before. Pile was braced by formwork to make sure pile still standing correctly during driven activity.

3) When pile is ready, the hammer will be aligned with the pile. A casing with 150 mm height was installed to make sure hammer drop distance is constant and the hammer will be drop just over the pile. It also to make sure there is no disturbance from others such as wind or any movement.

4) The vibration data will be recorded for every 10 mm penetration of pile to the sand.

5) Formwork was divided into parts. After 50 mm penetration, part of formwork will be dismantling to hammer pile again.

6) The process will be continued until pile penetrated up to 250 mm. The steps will be repeated to the other pile for point 2 and point 1.

7) The process continuously repeated for other pile installation.

3. RESULTS AND DISCUSSION

Laboratory testing model result is based on vibrations occurs during pile driving. These results were divided into three parts. The first is the result of comparison between vibration impact on top and bottom of the nearby building. It involved both sizes of piles which is 7.5 mm x 7.5 mm (150 mm x 150 mm) on site and 10 mm x 10 mm (200mm x 200 mm) on site. The scale ratio of sizes of pile is (1:20).

The next part involves the analysis and discussion of comparison of vibration impact on nearby building based on three different distances which are 900 mm, 600 mm and 300 mm from the building. The scale used is 1:20 and it means the real distance from buildings is 18 m, 12 m and 6 m on site.

The last part of analysis for this study is comparison of vibration impact on existing building with different sizes of piles. The comparison values of vibration impact based on two sizes of piles that were driven on same distance from the building.

3.1 Effect based on pile size

Table 1(a): The comparison between sizes of pile on top of building (vibration level in mV/g)

TOP	7.5 X 7.5	10.0 X 10.0
Point 1	1810	1392
Point 2	1560	1884
Point 3	4394	5061

Table 1(b): The comparison between sizes of pile on bottom of building (vibration level in mV/g)

BOTTOM	7.5 X 7.5	10.0 X 10.0
Point 1	2037	1602
Point 2	3119	2690
Point 3	5656	6241

At the top of building, it shows that the resulting vibration was higher from point 1 (farthest) for the smaller 7.5 mm pile. As piling work moved closer to the building the bigger pile produce higher vibration at the top as indicated by point 2 and point 3 (nearest).

This is possibly because heavier pile reduces the vibration amplitude. It was similarly reported before that when the pile is small, the vibration amplitude can be inadequate at the pile base. This can also result in too much transverse vibration and sometime lead to a broken pile [9].

Similarly, the bottom transducers produce higher vibration record as a result of 7.5mm pile from position 1 and 2. Only when it is very close to the model building at position 3 that the bigger 10mm pile cause higher impact.

3.2 Effect based on driving distance

Table 2 (a): The comparison on the effect based on of 7.5 x 7.5 mm piles (vibration level in mV/g)

7.5 x 7.5	POINT 1	POINT 2	POINT 3
Top	1810	1560	4394
Bottom	2037	3119	5656

Table 2 (b): The comparison on the effect based on of 7.5 x 7.5 mm piles (vibration level in mV/g)

10.0 x 10.0	POINT 1	POINT 2	POINT 3
Top	1392	1884	5061
Bottom	1602	2690	6241

Table 2 clearly indicates that the vibration level from various pile sizes increases as it moves closer to the model building.

The risk of driving piles next to a building may vary according to the types of structure and method of piling but in general vibration will be higher nearer to the building.

3.3 Effect to the top and bottom of building

Table 3(a): The comparison between top and bottom vibrations on 7.5 x 7.5 mm piles (vibration level in mV/g)

7.5 x 7.5	**TOP**	**BOTTOM**
Point 1	1810	2037
Point 2	1560	3119
Point 3	4394	5656

Table 3(b): The comparison between top and bottom vibrations on 7.5 x 7.5 mm piles (vibration level in mV/g)

10.0 x 10.0	**TOP**	**BOTTOM**
Point 1	1392	1602
Point 2	1884	2690
Point 3	5061	6241

The tables above show that the effect of driven pile activity was higher at the bottom for both sizes of pile. This is mainly because the ground vibrations is nearer to the bottom part of the building and the effect is diminishing towards the top.

4. CONCLUSION

It is known that pile driving activities creates vibrations in the ground. Those vibrations may affect the nearby structures or disturbed people in the neighborhood of pile driving activity. In this study, the result naturally shows that vibrations effect were higher at the bottom of building compared to the effect on the top of building. Also, the nearer distance cause higher vibrations compared to the one further from the building. However, the smaller pile creates more vibrations towards the nearby building. This could be due to pile density reaction towards resisting forces from soil. Further study is required to identify a matrix of pile type, sizes and suitable distance for use in practical selection of pile size in works associated with pile installation near existing building or structure.

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