Treatment of Landfill Using Dynamic Compaction Technique

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Abstract: Reclamation on a landfill area poses many uncertainties due to the inherent heterogeneity especially if the landfill had not been controlled properly. This paper describes a case study on the treatment of landfill using dynamic compaction technique for a reclamation work. Prior to the dynamic compaction work, a trial dynamic compaction was performed at an area of about 30m by 30m The changes or improvement of the engineering properties of landfill was assessed based on the results obtained from Standard Penetration Tests and Pressuremeter Tests carried out before and after the trial. Ground vibration monitoring was also carried out during the trial dynamic compaction test. From the results of monitoring, the induced ground vibration and the attenuation of particle velocity with distance were established.

1 INTRODUCTION

A development was planned to be carried out on a piece of coastal land which was partially filled with refuse over the last 10 to 20 years while the rest of the site was submersed at normal tide condition. To reclaim this piece of land, it is imperative to treat the soft soil underneath as well as the uncontrolled landfill to prevent excessive settlement. The soft soil was treated using surcharging method and the consolidation settlement was expedited by installation of vertical drains (Chen & Tan, 2002). This paper will not present the treatment of the soft soil but mainly focus on the treatment of the landfill using dynamic compaction technique.

The site layout plan is as shown in Figure 1. At the landfill area, the ground levels generally vary from RL 1m to RL 5m. As the design platform level is at about RL3.1m, part of the landfill will need to be filled up while other parts will be trimmed down and covered by a layer of soil. The platform settlement due to the loose landfill underlying is one of the main concerns. To minimize the potential post construction settlement due to the landfill, dynamic compaction technique was adopted for the landfill treatment. This paper discusses the mechanisms of landfill settlement. It also presents the investigation of the landfill and the design of dynamic compaction. Results of trial dynamic compaction, pre- and post dynamic compaction in-situ tests are also presented. The induced ground vibration will be discussed as well.

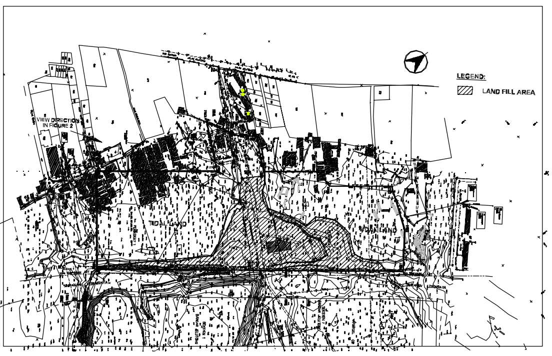

Figure 1 Site layout plan

2 SETTLEMENT MECHANISM OF LANDFILL

The mechanics of landfill settlement are very complex especially when the landfill was not controlled properly. Highly heterogeneity of the landfill is usually expected. In general, the main mechanisms involved in the landfill settlement are the followings (Edil et al, 1990):

Consolidation – similar to organic soil, the landfill will settle due to self weight.

Ravelling – settlement due to the movement of fine material into larger voids.

Physical-chemical change – mainly caused by corrosion, oxidation and combustion.

Bio-degradation – due to aerobic microbial activities and anaerobic fungi and bacterial which will cause the material decompose or decay.

Among these, the landfill settles substantially mainly due to the self weight or when subjected to new load such as introduction of a cover soil or construction of structure on top. Densification using dynamic compaction method can reduce the voids within landfill significantly thus minimise the potential large settlement. However, physical-chemical change and biodegradation cannot be substantially improved. Densification could only reduce the amount of oxygen in the landfill slowing down the rate of decay.

3 SITE INVESTIGATION

Site investigation was planned and carried out prior to the design of dynamic compaction. The investigation consisted of 15 numbers of boreholes with Standard Penetration Test (SPT) carried out at 1.5m depth interval and 15 numbers of self-driving Pressumeter Test (PMT) carried out at 1m depth interval. The main objective of the pre-dynamic compaction site investigation is to determine the thickness of landfill and gather some engineering properties of the landfill for preliminary design. The investigation results revealed that the landfill thickness is about 3 to 6m. Figure 2 shows the types of landfill during a trial excavation for visual inspection purpose.

4 PRELIMINARY DYNAMIC COMPACTION DESIGN

Dynamic compaction consists of using a heavy tamper that is repeatedly raised and dropped from varying heights to impact the ground. The degree of improvement is a function of the applied energy i.e. the tamper weight, drop height, grid spacing and the numbers of drops at each point. Figure 3 illustrate the dynamic compaction. The selection of suitable tamper weight (W) and drop height (H) depends on the thickness (D) of landfill. The empirical relationship between the improved depth and tamper weight and drop height is as follow:

$$D = n\,(WH)^{1/2} \qquad (1)$$

The empirical coefficient *n* accounts for factors that may affect the improved depth other than the tamper weight and drop height. The variation in *n* is attributed to the efficiency of the drop mechanism, soil types, presence of energy absorbing layer or hard layer above or below the soil layer being densified, contact pressure of tamper and total energy applied. In general, the *n* values are about 0.3 to 0.8 (Menard and Broise, 1975, Mayne et at, 1984). The average *n* value of 0.5 is generally adopted for preliminary design. For heterogeneous soil or landfill in this case, conservative *n* value of 0.3 was adopted.

Figure 2 Landfill at site

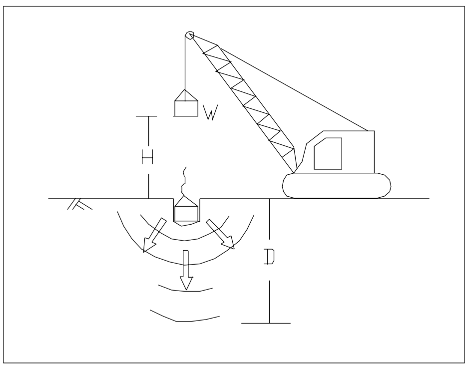

Figure 3 Dynamic compaction

5 TRIAL DYNAMIC COMPACTION

A 15 ton pounder dropped from 20m height which delivering 300 ton-m energy was selected for the trial dynamic compaction. Trials 1 and 2 have similar grid spacing of 5m with 8 and 12 blows per point respectively. Trials 3 and 4 have grid spacing of 5.5m also with 8 and 12 blows per point respectively. Ironing phase of 2 blows per point was carried out in all trials. Figure 4 shows the plan view of the trials.

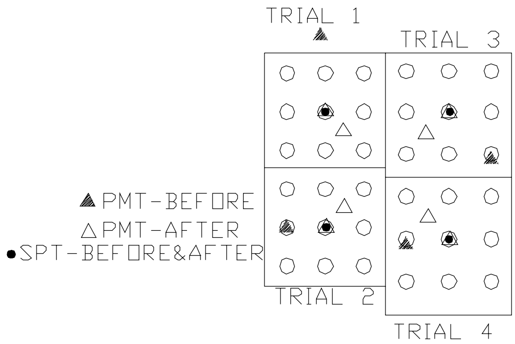

Figure 4 Plan view of trial tests

The results of pressumeter tests carried out before and after the trial dynamic compaction are as shown in Figure 5. In all trials, the pressuremeter limits increased after the landfill had been dynamic compacted. However, there is not much different between each trial. As ground heaving is an indication whether the soils are being densified or only deformed plastically at no volume change, heave and penetration test (HPT) was conducted during the trials to evaluate the optimum numbers of blow to be applied at every print. The penetration-heave curve should stabilize when landfill had been compacted to refusal. If too many blows applied at the same print, the pounder may punch through the landfill layer and penetrate into the underlying soft clay. An increase in the ground heave can be observed and the effectiveness of the compaction will be reduced. Figure 6 shows the results of HPT test. The penetration-heave curve stabilized at about 10 blows and increased again with the increase in numbers of blow. The monitored ground heave against numbers of blows also indicates that the ground starts to heave when the number of blow is more than 10. Boreholes carried out inside the prints after the trials reveal that the thickness of the landfill has been compressed from about 3m to about 0.5m to 1m.

6 GROUND VIBRATION

When the pounder strikes the ground, vibrations are transmitted off site. The magnitude of ground vibration depends on the applied energy and distance from the impact point. As there are some utilities and structures near to the site, excessive ground vibration may damage these structures. Monitoring was carried out during the trials to assess the relationship between the induced ground vibration, the applied energy and the attenuation of ground vibration with distance. With the established relationship, the potential of damage to the nearby utilities and structures can be assessed and under controlled. An open trench of about 2.5m deep was introduced as cut-off trench for the assessment of the effectiveness in reducing the vibration. Figure 7 shows the monitored peak particle velocity (PPV) at various distances from the impact point with different drop height. The following relationships can be observed from the monitoring results: 1) peak particle velocity decreases with distance and 2) higher impact energy generates higher particle velocity. Figure 8 shows the relationship between the monitored peak particle velocities and scale distance (square root of the energy divided by the distance from the impact point). Apparently the induced ground vibration can be reduced with the introduction of a cut-off trench. Based on the monitoring results, the following empirical relationships are established:

$$PPV = 14\ [(WH)^{0.5}/D]^{0.95} \quad \textit{without cut-off trench} \quad (2)$$

$$PPV = 9\ [(WH)^{0.5}/D]^{0.9} \quad \textit{with cut-off trench} \quad (3)$$

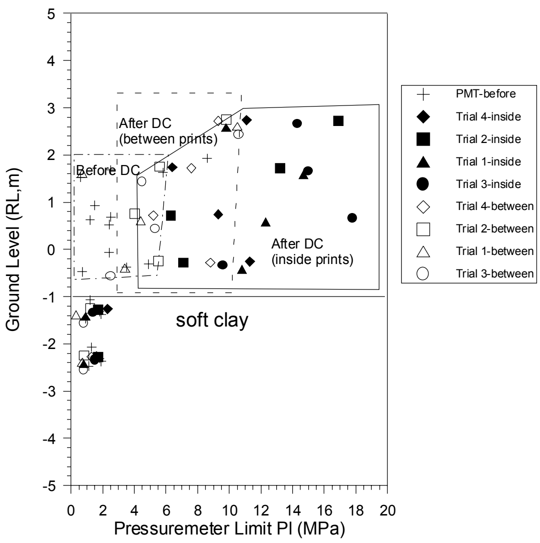

Figure 5 Pressuremeter test results at the trial zone.

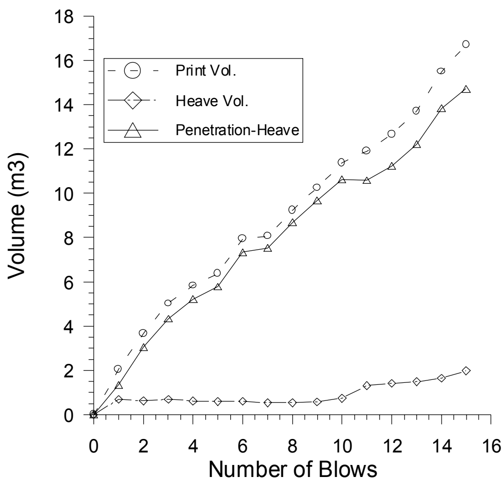

Figure 6 Result of heave and penetration test

7 APPLICATION OF THE DYNAMIC COMPACTION

From the trial results, it was concluded that the landfill at site could be treated by the dynamic compaction technique to a satisfactory condition. To apply this technique over the whole landfill area, a grid spacing of 5.5m and 10 blows per point were adopted. An about 1m thick sand layer was placed on top of the landfill to form a working platform prior to the commencement of the work. After completion of dynamic compaction, investigation consisted of 8 numbers of SPT and 8 numbers of PMT was carried out. The SPT was conducted inside the impact point to assess the thickness of landfill after compacted. PMT was conducted inside and between impact points. Figure 9 shows the results of pressuremeter tests carried out before and after the dynamic compaction. It can be found that the landfill has been improved significantly after the compaction.

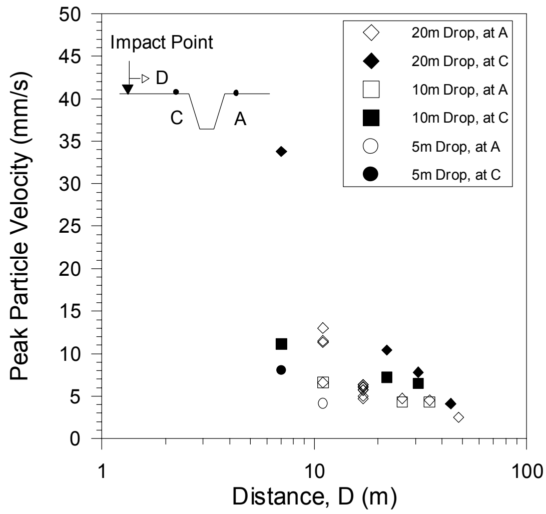

Figure 7 Ground vibration monitoring results

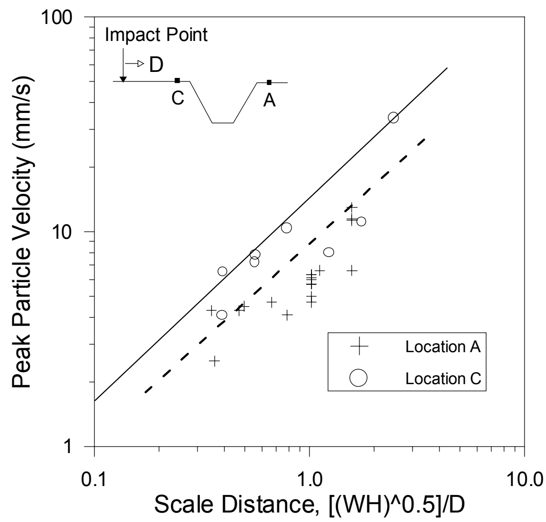

Figure 8 Relationship of PPV and Scale Distance

8 CONCLUSIONS

Settlement of landfill is very complex. However, most of the settlement is mainly due to the self weight or when subjected to external loading and movement of fine materials into larger voids. Dynamic compaction technique can densify the landfill significantly and therefore minimize the potential of excessive settlement. The densification has also reduced the amount of oxygen in the landfill which helps in slowing down the process of biodegradation as well. Before carry out the dynamic compaction work, a trial is recommended for the assessment of the effectiveness and selection of most suitable design parameters. The induced ground vibration should be assessed if there are structures surrounding.

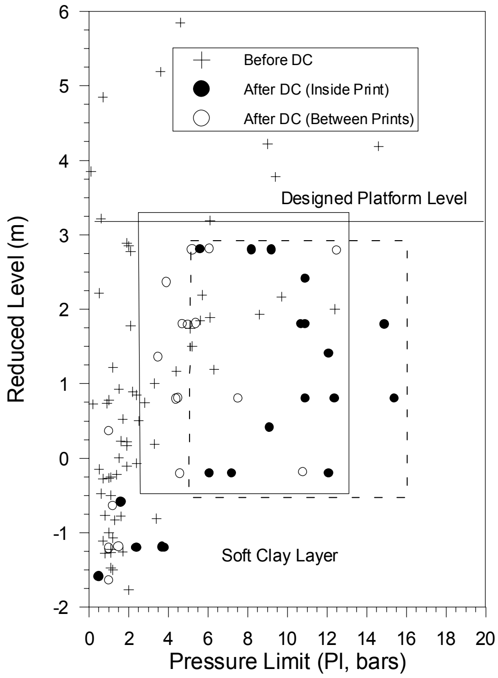

Figure 9 Results of Pressuremeter Tests

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