

Dynamic Characteristics Analysis on Wind-Blown Sand Ground under Dynamic Compaction Vibration

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Abstract

In the 6000 kN·m energy level dynamic compaction on Inner Mongolia wind-blown sand foundation treatment process, the dynamic characteristics and dynamic response are measured. Vibration action time, vibration main frequency, peak acceleration and peak velocity are analyzed. The vibration acting time is very short, the vertical average vibration acting time increases obviously with distance increasing, and the horizontal average vibration time does hardly change. The main frequency of vibration is at 4.60 - 24.90 Hz, which depends on the soil properties and soil layer distribution. The peak acceleration and peak velocity space distribution are similar. The maximum of horizontal acceleration peak is close to vertical velocity peak, and is near to 51 g under rammer. The maximum of horizontal velocity peak is close to vertical velocity peak, and is near to 54 m/s under rammer. The peak acceleration and velocity are rapidly attenuated, but the vertical peak acceleration and peak velocity are slowly attenuated than horizontal direction. The effective treating depth arrives 13 m for wind-blown sand, peak acceleration is 1.8 g or so, and peak velocity is 2.1 m/s or so. Horizontal treating range is 2.6 times of rammer diameter, and vertical treating range is 5.65 times of rammer diameter.

Keywords

Wind-Blown Sand Ground, Dynamic Compaction, Vibration Effects, Dynamic Characteristics, Field Experiment

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1. Introduction

Dynamic compaction method is used for the huge compaction hammer to bring shock wave and dynamic stress in the ground and make it compact. So far, dynamic compaction method has been successfully and widely used to deal with all kinds of gravel soil silt, sandy soil, collapsible loess, artificial fill, low saturation and clay, especially the large gravel soil and municipal solid waste or industrial waste composition complex fill, which is difficult to reinforce and construct with the general method. Dynamic compaction has been widely applied to treat various ground foundation, but there is not mature and perfect design theory up to now. The treating effects and treating range of dynamic compaction were based on soil's consolidation theory and wave compression theory. The treating effect is detected by using a standard penetration test, static load test, and the indoor experiment.

Aeolian sand is widely distributed in the surface of plateau and desert area, and the bearing capacity and deformation characteristics of the sand foundation are not made systematic theoretical research [1]. High pressure jet grouting pile and sand cushion reinforcement method was used by Aeolian sand foundation treatment [2], but not suitable for large area processing. In recent years, the engineering practice in desert area proves that dynamic compaction of Aeolian sand is economical and practical [3]. The Aeolian sand foundation is treated by the compaction method in hinterland of the desert, which solves the problem of uneven settlement of Aeolian desert oil exploration rig foundation [4]. The treating effect and its factors are accord with practice by using dynamic measuring [5]–[7]. Based on the engineering background of the project treated by dynamic compaction in Inner Mongolia, through the analysis of dynamic measuring, the dynamic characteristics and dynamic response are studied.

2. The General Situation of Project

2.1. Geological Condition of Project

The treating wind-blown sand project used by dynamic compaction is in Inner Mongolia, According to the super structure load requirement, the bearing capacity of reinforcement is not smaller than 250 kPa, and deformation modulus is 7.0 Mpa. The soil distribution of site is as follows.

Element layer ①—backfill sand: The soil strength is low and deformation modulus is high, engineering properties are instable, expanding property caused by freezing belongs to medium, the thickness is at 0.7 - 5.7 m.

Element layer ②—fine sand: fine sand is formed by wind, granular content is 86.5% which diameter granular is greater than 0.075 mm, and 2.6% which diameter granular is smaller than 0.005 mm. The soil strength is low and deformation modulus is high, expanding property caused by freezing belongs to medium. The thickness is at 1.7 - 6.0 m, the bearing capacity is 100 kPa, and deformation modulus is 3.0 Mpa.

Element layer ③—fine sand: The fine sand is formed by slop accumulation and well graded. The granular content is 87.3% which diameter granular is greater than 0.075 mm, and 2.7% which diameter granular is smaller than 0.005 mm. The thickness is at 1.1 - 10.3 m, the bearing capacity is 160 kPa, and deformation modulus is 6.5 Mpa.

Element layer ④—filt-fine sand: The sand is formed by flood lashed and poorly graded. The granular content is 84.6% which diameter granular is greater than 0.075 mm, and 2.8% which diameter granular is smaller than 0.005 mm. The thickness is at 1.6 - 7.5 m, the average thickness is 5.0 m, the bearing capacity is 165 kPa, and deformation modulus is 7.0 Mpa.

Element layer ⑤—fine sand: The sand is formed by flood lashed and well graded. The granular content is 89.6% which diameter granular is greater than 0.075 mm, and 2.6% which diameter granular is smaller than 0.005 mm. The thickness is at 10.9 - 17.4 m, the average thickness is 14.7 m, the bearing capacity is 200 kPa, and deformation modulus is 16.0 Mpa.

2.2. Construction Design Parameters

The project design requires the bearing capacity of reinforcement is not smaller than 250 kPa. According to the survey report, bearing capacity of fine sand layer ③ and filt-fine sand layer ④ is respectively 160 kPa and 165 kPa, which satisfied the design requirement revised by depth. Backfill soil layer ① and fine sand layer ② are treated by dynamic compaction.

Rammer diameter is 2.4 m, Rammer weight is 35.2 t. The maximum depth of treating is 10. The heavy rammer of 6000 kN·m energy-level is made use of in first and second times. Rammer points are arranged by square

with spacing 6×6 m. The average settlement of the final two blow is not greater 100 mm. Full rammed energy is 2000 kN·m with two times, lapping joint of rammer print between rammer points is not smaller 1/4 [JGJ79-2002]. The project design requires the bearing capacity of reinforcement is not smaller than 250 kPa. According to the survey report, bearing capacity of fine sand layer ③ and filt-fine sand layer ④ is respectively 160 kPa and 165 kPa, which satisfied the design requirement revised by depth. Backfill soil layer ① and fine sand layer ② are treated by dynamic compaction.

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3. Measuring of Dynamic Compaction in Field

3.1. Field Measuring Purpose

Through the field measuring of dynamic response caused by reinforcing wind-blown sand ground using dynamic compaction method, the dynamic characteristics and dynamic response are studied in order to evaluate the reinforcement effect and effective reinforcement depth.

3.2. Measuring Point Arrangement in Site

The typical location is selected to arrange acceleration sensors along vertical direction at measuring zone, which is separately 2 m, 4 m, 6 m, 9 m, and 13 m. There is an acceleration sensor in horizontal and vertical direction, as shown in **Figure 1**. According to the energy of dynamic compaction method, measurement range of the acceleration sensors is 50 g and 30 g, which is made in Qinhuangdao science and technology limited company. Signal gathering system G01USB32 is made in engineering mechanics research institute of earthquake bureau.

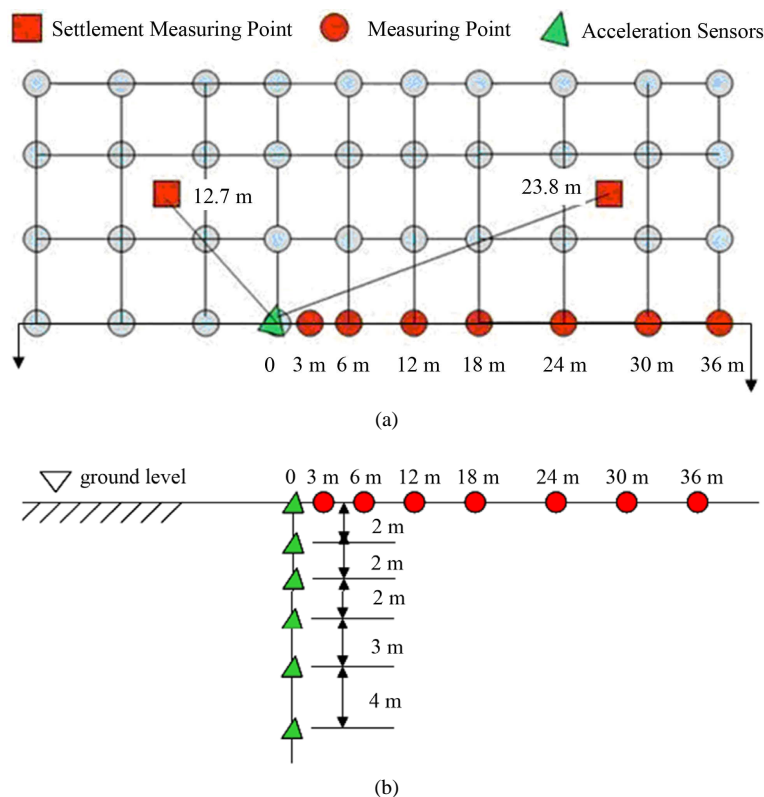


Figure 1. Arrangement scheme of measuring point of 6000 kN·m energy-level. (a) Plane figure; (b) Profile figure.

4. Dynamic Measuring Results Analyses of Dynamic Compaction

4.1. Vibration Acting Time Caused by Dynamic Compaction

When energy level is 6000 kN·m, acceleration change curves with time at typical rammer point are as shown in **Figures 2-5**. Acceleration curve form has the similar form as the exploding vibration. The acting time of Vertical vibration is at 0.349 - 2.096 Sec, and that of horizontal vibration is 0.204 - 1.02 Sec. Generally the Vertical vibration acting time is longer than the horizontal vibration time in the same measuring point. Vibration acting time depends on the distance between rammer point and measuring point, soil properties. When the distance between rammer point and measuring point is constant, the vibration acting time along the vertical distributing point is nearer. The Vertical average vibration acting time increases obviously with distance increasing, and the horizontal average vibration time does hardly change.

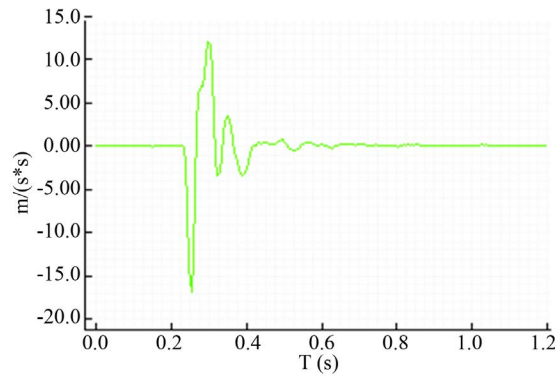


Figure 2. $a_x \sim t$ curve ($x = 3$ m, $z = 6$ m).

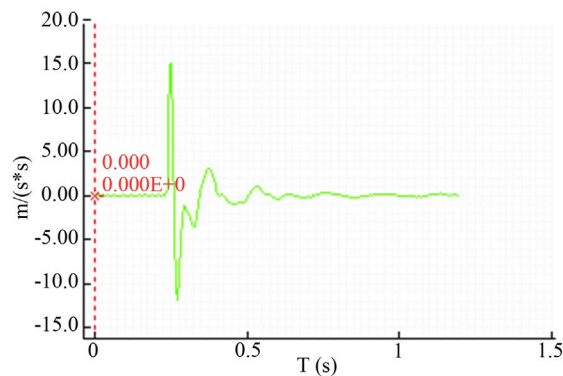


Figure 3. $a_z \sim t$ curve ($x = 3$ m, $z = 6$ m).

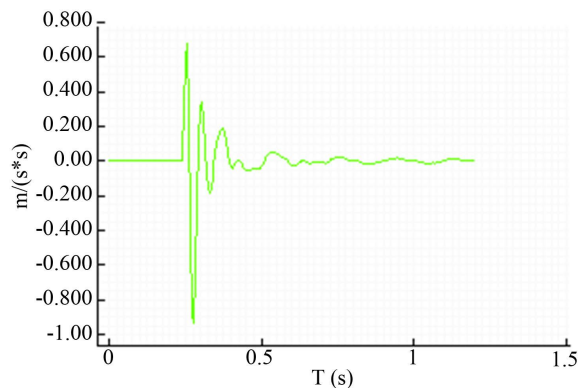


Figure 4. $a_x \sim t$ curve ($x = 3$ m, $z = 9$ m).

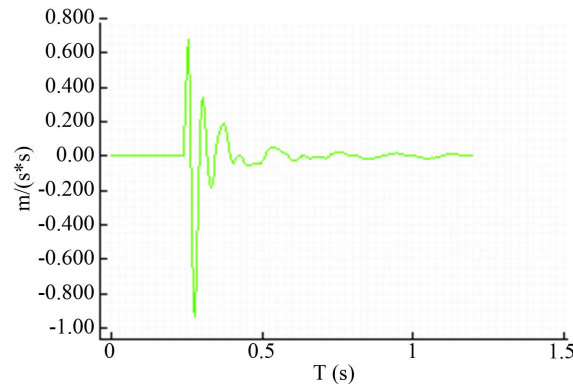


Figure 5. $a_z \sim t$ curve ($x = 3$ m, $z = 9$ m).

4.2. The Main Frequency of Vibration

The measuring results show that main frequency of vertical vibration is at 5.10 - 24.90 Hz in No. 1 blow and at 4.60 - 23.94 Hz in No. 2 blow. The main frequency of horizontal vibration is 5.10 - 24.45 Hz in No. 1 blow, and at 4.60 - 24.20 Hz in No. 2 blow. After the No. 1 blow, the main frequency changes because of variation of soil properties. The main frequency depends on the soil properties between the hammer point and measuring point.

4.3. Peak Acceleration Results

Figure 6 and **Figure 7** are respectively horizontal and vertical peak acceleration color map in plane xz plane. As shown in **Figure 7**, the horizontal peak acceleration $a_{x\max}$ is at 47.4 g - 51.1 g, when z is at 2 - 6 m, while is near 1.9 g or so when z is at 9 - 13 m. At $z = 4$ m and $0 \leq x \leq 36$ m, the horizontal peak acceleration of measuring point arrives maximum, and $a_{x\max}|_{z=4\text{ m}, 6 \leq x \leq 36\text{ m}} = 4.09 - 4.25$ g, which is larger than that of other measuring point in the same hammer point. As shown in **Figure 8**, $a_{z\max}$ is equal to 51 g at measuring point ($x = 0$ m, $z = 2$ m), maximum point is at $z = 6$ m, and $a_{z\max} = 45.2$ g. $a_{z\max}$ changes very small and is near 1.8 g when $z > 6$ m.

Figure 8 and **Figure 9** are respectively horizontal and vertical peak acceleration attenuation curve with the horizontal distance. The peak acceleration attenuates rapidly in horizontal direction. The influence is remarkable within 6 m, that is $x/R < 2.6$. The vertical peak acceleration is remarkable within $z < 9$ m, and is near constant at $z = 9 - 13$ m. According to ii-site survey report, backfill soil thickness is 7 - 10 m.

4.4. Treating Effective of Dynamic Compaction

Figure 10 and **Figure 11** are the color contour of peak acceleration in xz plane when energy level is 6000 kN·m. When hammer beating energy is 6000 kN·m, measuring results show that the effective reinforcement depth arrives 13 m for wind-blown sand peak acceleration is 1.8 g or so. Horizontal reinforcement range is $x/R < 2.6$, vertical reinforcement range is $z/R < 5.7$.

5. Conclusions

1) The vibration of wind-blown sand caused by dynamic compaction has the similar form as the exploding vibration, and vibration acting time is very short. Generally the Vertical vibration acting time is larger than the horizontal vibration time in the same measuring point. Vibration acting time depends on the distance between rammer point and measuring point, soil properties. The Vertical average vibration acting time increases obviously with distance increasing, and the horizontal average vibration time does hardly change.

2) The measuring results show that main frequency of vibration is at 4.60 - 24.90 Hz. The main frequency depends on the soil properties between the hammer point and measuring point.

3) The peak acceleration and peak velocity space distribution are similar. The maximum of horizontal acceleration peak is close to vertical velocity peak, and is near to 51 g under rammer. The maximum of horizontal velocity peak is close to vertical velocity peak, and is near to 54 m/s under rammer. The peak acceleration and

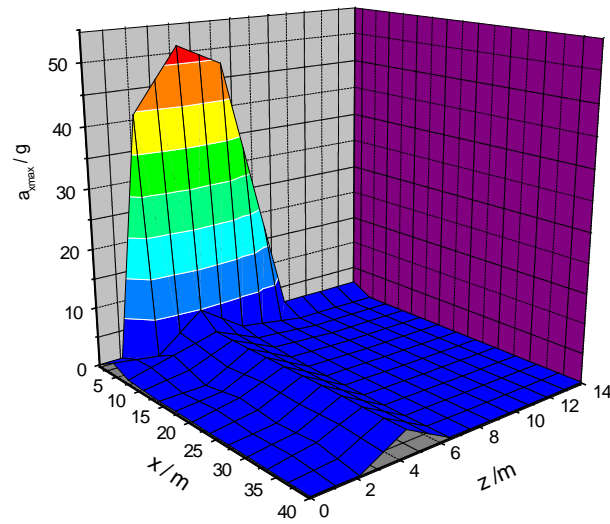


Figure 6. $a_{x\max}$ color map in xz plane (No. 1).

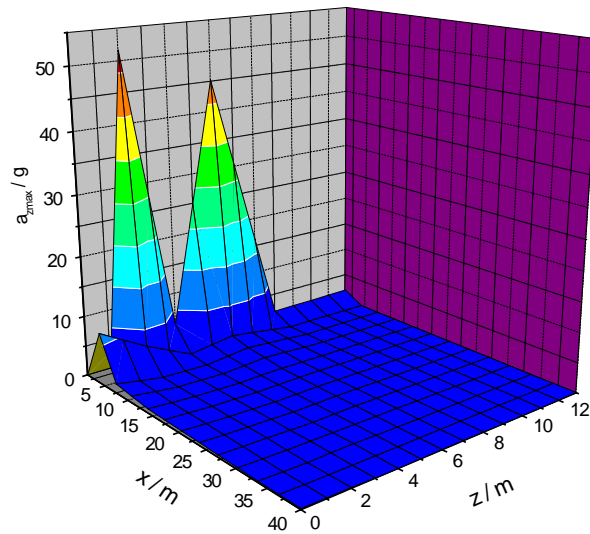


Figure 7. $a_{z\max}$ color map in xz plane (No. 1).

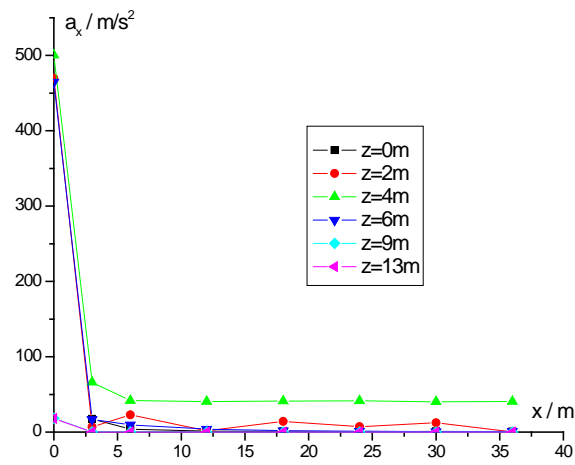
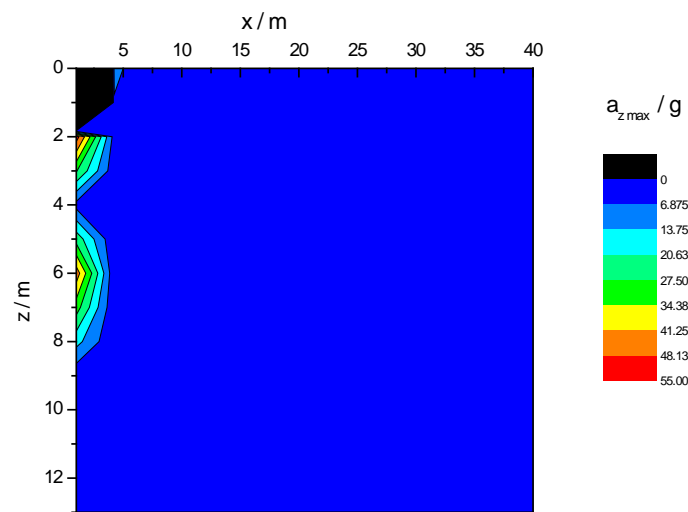
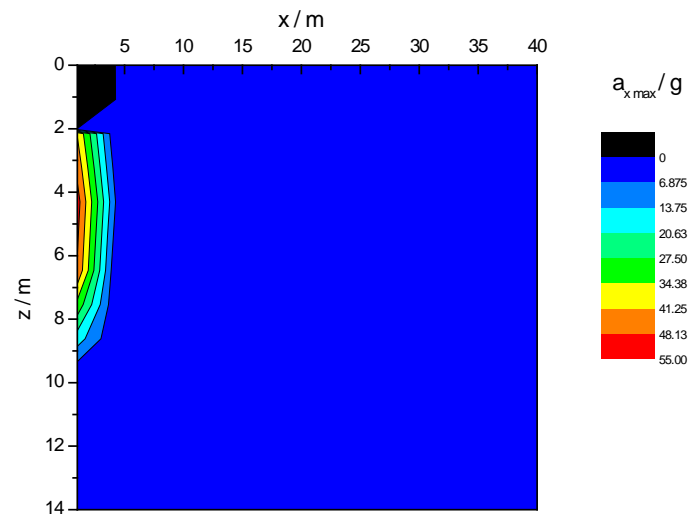
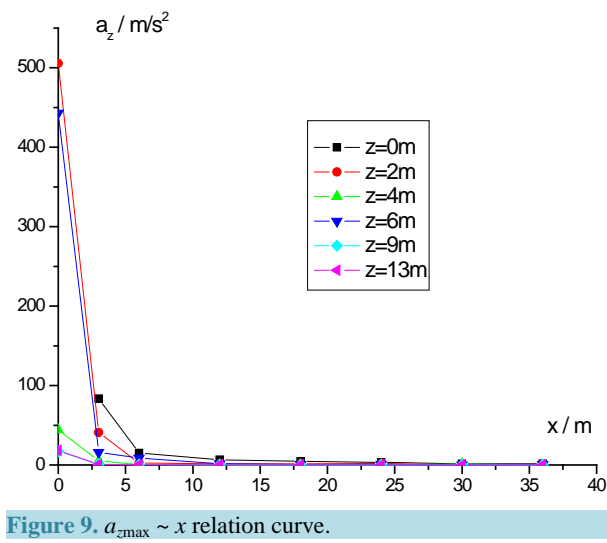


Figure 8. $a_{x\max} \sim x$ relation curve.



velocity are rapidly attenuated in horizontal and vertical direction, but the vertical peak acceleration and peak velocity are slowly attenuated in horizontal direction.

4) When hammer beating energy is 6000 kN·m, the color contour shape of peak acceleration is similar to peak velocity, the effective reinforcement depth arrives 13 m for wind-blown sand, peak acceleration is 1.8 g or so, and peak velocity is 2.1 m/s or so. Horizontal reinforcement range is $x/R < 2.6$, and vertical reinforcement range is $z/R < 5.7$.

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