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FIELD ASSESSMENT OF DYNAMIC CONE PENETRATION TEST TO EVALUATE SAND DENSITY

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Rapid and accurate in-situ measurement of soil properties is still a challenge facing the construction industry and there is a need for new and advanced devices and methods. Dynamic cone penetration test (DCPT) is an effective device used for field exploration and quality assessment of subsoil. DCPT could be used to predict the engineering properties of sand because it is difficult to perform conventional density tests, such as the sand replacement method, especially when loose or submerged sandy soil is encountered. Two cases of DCP field testing were conducted in Al-Jubail and Ras Al-Khair, eastern Saudi Arabia, where the major petrochemical industries are located. These tests were utilized to evaluate the potential use of DCPT to assess the density during the construction of backfills, whereby the nuclear gauge was also used to accurately measure the in situ soil density and water content. The DCP-nuclear gauge data clearly indicated that there is a good correlation between the dry density obtained from the nuclear gauge and the dynamic cone penetration (DCP) readings, which proves that the DCPT is an effective and reliable tool in the assessment of in situ compaction of sand backfills.

Keywords: DCPT, Nuclear gauge, Compaction, Backfills, Field tests.

1 INTRODUCTION

Sand is the most predominant type of soil in the Eastern Province of Saudi Arabia which is confined by sand deserts from three directions (Aiban 1994). The nuclear gauge is nowadays the most common device used to measure in-situ density of soil because it provides rapid and accurate results with the minimal effect of human error (Adams *et al*. 2007). Unfortunately, there are many restricted regulations for using such a device with a nuclear source due to its negative effects on health (Adams *et al*. 2007). Furthermore, the nuclear gauge has a limited reach of about 300 mm depth only.

Because of the lack of cohesion, it is not possible to obtain undisturbed samples of sand. Therefore, DCPT has been used widely for field exploration and quality assessment of subsoil layers (Hamid 2013). DCP testing can be used in the characterization of subgrade and base material properties in many ways. Perhaps the most important advantage of the DCP device is related to its ability to provide a continuous record of relative soil strength with depth (Burnham and Johnson 1993). Dynamic cone penetrometer device is distinguished by its economy and simplicity to operate and its superiority to provide repeatable results and rapid property assessment. DCPT has the main features similar to CPT and SPT (Salgado and Yoon 2003).

Webster *et al*. (1994) reported that the thickness and location of a weak soil layer in a pavement can be determined using DCPT. Abu-Farsakh *et al*. (2005) showed that, based on laboratory and field studies using DCP, plate load test (PLT), falling weight deflectometer (FWD), and (CBR), dynamic cone penetration test can be used to evaluate subgrade and pavement layers. Moreover, they developed empirical correlations from DCP results with elastic modulus, resilient modulus, and CBR. In addition, they indicated that the DCP test was an efficient tool for compaction control. Zhang *et al*. (2004) indicated good correlations among the test data from the DCPT, falling weight deflectometer, and plate load test, which can be used in the future for the quality control of backfills

Therefore, there is a genuine need to investigate the possibility of using DCPT as a technique to assess the density of eastern Saudi sands in the field. The main objective of this study was to evaluate the potential usage of dynamic cone penetration test (DCPT) to assess the density of sands.

2 FIELD STUDY

The DCP tests were conducted in accordance with ASTM D 6951. It was planned to penetrate soils to a depth of 1 m with a 20 mm diameter cone, a 60-degree cone, and a hammer of 8 kg weight, as shown in Figure 1.

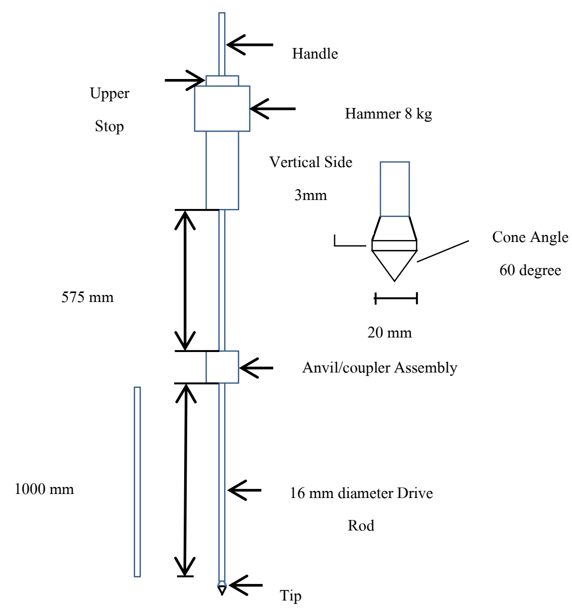
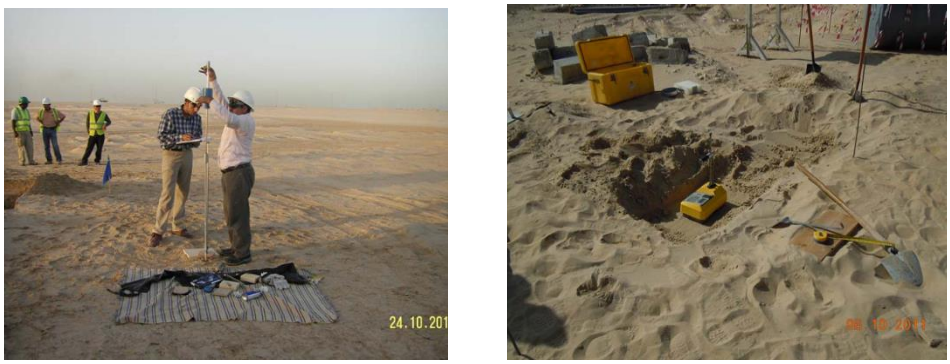


Figure 1. Schematic of standard DCPT (Hamid 2013).

Two peoples are commonly required to force DCP test into the soil. However, the manpower can be reduced to one person by using an electronic device to record the DCPT data, as depicted in Figure 2(a). In order to measure accurately the in-situ soil density and water content, the nuclear gauge was conducted for different test locations where the DCP tests were conducted, as shown in Figure 2(b).



(a) (b)

Figure 2. Testing Setup in the field (a) DCPT Setup, (b) Nuclear gauge Setup.

In this investigation, dynamic cone penetration tests (DCPTs) were performed on sand at two different sites; one in Al-Jubail, and the other in Ras Al-Khair, Eastern Province, Saudi Arabia. For each test of the two sites, the dynamic cone penetration test and nuclear gauge test were conducted at several different locations, whereby one nuclear gauge testing was conducted between two DCP tests.

2.1 Case Study 1: Al-Jubail, Kingdom of Saudi Arabia

The study area was allocated at Al-Jubail Industrial City, Saudi Arabia, where the largest petrochemical complex in the world is located. DCP was used to assess the variation of the density for a depth of the backfill ranging from 1.2 m to 2.4 m, while the nuclear gauge was used to assess the dry density data for the top 1.2 to 1.6 m of the soil backfill within the same compacted areas for possible correlation with the DCP data. DCPT and nuclear gauge tests were performed at randomly selected locations, distributed over five phases of a large housing project area in Jubail. DCP tests were carried out to the depth of the backfill for each phase. The backfill material consisted mainly of poorly graded dune sand and the backfilling thickness was variable depending on the original ground.

In this study, forty five (45) DCP tests were performed to accomplish such assessment and nuclear testing was performed at three random locations to assess the DCPT-nuclear gauge correlations. These three reference locations were referred to as the control locations and the readings were taken as the control readings.

2.2 Case Study 2: Ras Al-Khair, Kingdom of Saudi Arabia

A field study, using the DCP, was performed to examine the compactness of the top 5 m of soil within the area allocated in Ras Al-Khair, eastern Saudi Arabia. The nuclear gauge dry density data were used for the correlation with the DCP data for the top 1.8 m of soil at two different locations. The material consisted mainly of sand. In some places, there seemed to be little cementation at the top layers. In this study, a total of 29 DCP tests were performed at randomly selected locations.

3 RESULTS AND DISCUSSIONS

3.1 Al-Jubail Site Results

The data in Figure 3 indicate that the soil compactness was lower than the acceptable ranges for most of the tested locations for the thickness of the backfills (less than 5 blows/100 mm). The density of the sand backfill was reflected by the DCP results which indicate good correlation between the two techniques. In general, there are variations in the degree of compaction within the same location. Such variability was clear both laterally and with depth, as indicated in Figure 3. The DCP blow counts per unit depth decreased significantly as the depth increased for many tests. This is an indication of inconsistent degrees of compaction. When sands exist at low densities, they can settle easily upon wetting or due to loading from the super-structure. This will certainly have an effect on future settlement on the buildings as well as the utility pipes supported on or buried within such soil.

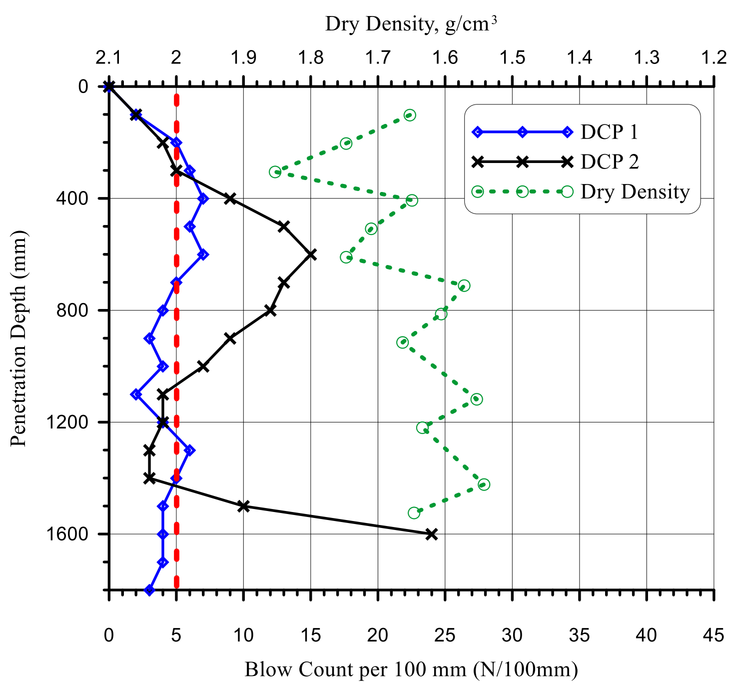


Figure 3. Variations of the DCP data and dry density data with depth for Al-Jubail site.

3.2 Ras Al-Khair Site Results

The field data in Figure 4 revealed that the soil compactness was very good for all the tested locations. The density of the sand backfill was reflected by the DCP results that indicates good correlation between the DCPT and nuclear gauge techniques. In general, there is consistency in the degree of compaction within the tested locations. The soil seems very densely compacted at the top layer (around 500 mm); a situation resulting from traffic loading during the construction activities. Furthermore, these top layers (within 1000 mm) show little cementation between the sand particles, as reflected by producing high penetration resistance in most of the tested locations. Below about 500 to 1000 mm of the top layer, the penetration resistance was reduced but still indicating a very dense material because a DCP blow count per 100 mm larger than 5 for sands indicates a very dense material (Hamid 2013). This is confirmed by the nuclear gauge density readings, as shown in Figure 4. It was observed that an increase in the dry density resulted in an increase in the number of blows. Based on the field investigation, it appears that the soil compaction at Ras Al-khair site was consistent and shows a sandy material at a very dense state. The top 500 mm was always an exception; it could be loose due to disturbance or very dense due to traffic loading and little cementation from dust.

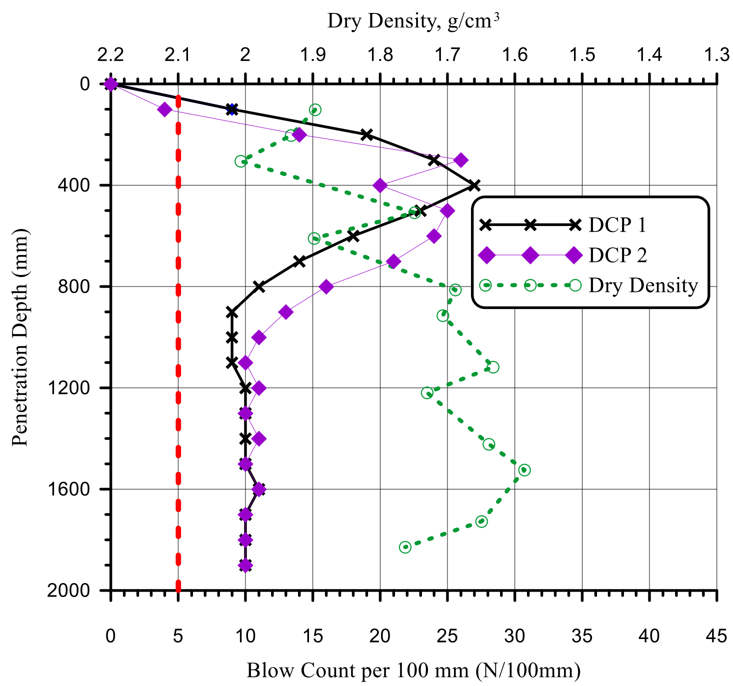


Figure 4. Variations of the DCP data and dry density data with depth for Ras Al-Khair site.

4 CONCLUSIONS

Based on the results reported herein, the following conclusions could be drawn:

1) All the field data on Al-Jubail site clearly indicate that the sand backfill was loose and the backfill could be susceptible to compression upon wetting, vibrations or change in loading. The field data have clearly indicated the non-homogeneity of the sand compaction. The variations were clear for the same location (variation with depth) and between different locations. These variations clearly indicate the superiority of the DCP testing and its potential use for quality control of deep backfilling (within 3 to 5 meters).

2) The field investigation on Ras-Alkhair site indicates that the soil compaction was consistent and displayed a sandy material at a very dense state. The top 500 mm was always an exception; as it could be loose due to disturbance or very dense due to traffic loading and little cementation from dust. All field data clearly indicated that the sandy material at the top 5 m was homogeneous in density.

3) The dynamic cone penetration test has proven to be an effective tool in the assessment of in situ strength of sand backfills.

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