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팽창토에서의 흙과 기초의 상호작용
Examination of Soil-Foundation International in Expansive Clay

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개요(SYNOPISS) : 팽창토에 현장타설된 말뚝기초는 팽창토의 팽창 특성으로 인해 과잉 부마찰력이 발생하여 상부 방향으로 변위를 유발시키며, 때로는 말뚝기초의 구조적 파괴를 일으키기도 한다.

본 논문은 미국 텍사스주 휴스톤대학교내에 있는 NGES (National Geotechnial Experimentation Sites-UH)에 현장타설된 말뚝기초와 팽창토의 팽창효과를 줄이기 위하여 사용된 isolation tube에 의해 둘리싸인 말뚝기초와의 거동을 비교한 것이다.

Expansive clays often impose excessive vertical deformations on light structures, even when such structures are supported on foundations penetrating below the vadose 1zone. These deformations arise from shearing stresses produced by expanding soils within the vadose zone, which elongate the foundation plinths, in some instances producing structural failure in the plinths. This study involves the measurement of vertical movements and stresses within ordinary drilled foundations and drilled foundations constructed within isolation tubes in an expansive clay at the National Geotechnical Experimentation Site at the University of Houston (NGES-UH) in USA. The isolation tubes are double fiber tubes whose annual spaces are filled with asphaltic compounds of varying viscosity, which reduce the uplift forces and extensional displacements of the plinths were reduced by 70 percent when the isolation tubes were used, despite shear strain rates exceeding 1 per day (100 percent strain per day). The least viscous asphalts were slightly more effective than the most viscous asphalts. Fundamental studies of the behavior of a reference drilled shaft cast directly against the soil indicated rapid changes in both vertical movement in the soil and extensional forces in the plinth of the shaft to a depth of approximately 1.0 m with the application of saturating moisture (heavy rain) over a period of 1.5 years. The high values of soil surface heave (35 mm) and uplift force (55 kN) from soil to foundation were observed in the field test.

Key words: Drilled shaft, expansive clay, soil-foundation interaction, isolation tube, NGES-UH

1. INTRODUCTION

Clay soils with a potential for shrinking and swelling are located throughout the United States, as well as many other parts of the world (Johnson and Stroman, 1976). Such soils are termed expansive soils. Naturally occurring expansive soils are generally unsaturated. In a macro sense, the soils are usually shattered, i.e., fissured, with open or filled joints. The soil mineralogy consists of certain amounts of montmorillonite and/or illite. The soil exhibits high strength and low compressibility in most natural conditions. When moisture content of the soil increases, the volume of the soil mass increases. The driving force behind this volume change is the soil moisture retention force termed soil suction. Because ofits greater sensitivity to volume change in comparison to moisture content, soil suction has been shown to be a more sensitive and accurate indicator of potential swell, as well as a more reliable parameter for estimating volume change (Fredlund, 1983; Johnson and Snethen, 1978). Soil suction is a negative pore water pressure that is measure of the tendency of the soil to undergo a change in moisture content and is directly related to the volume change and shear strength characteristics of expansive soils. As the moisture content increases, the soil suction decreases, the shear strength decreases and the soil swells. Heave prediction using soil suction may involve the measurement of soil suction over a moisture content range between shrinkage limit to plastic limit (Johnson and Snethe?n 1978; Mitchell and Avalle, 1984).

Drilled shaft foundations are often used to bypass surF@cial soils that have a high shrink-swell potential but that would otherwise possess strength and compressibility properties adequate to support shallow foundations (O'Neill and Poormoayed, 1980). But expansive clays often impose excessive vertical deformations on light structures, even when such structures are supported on foundations penetrating below the vadose zone. These deformations arise from shearing stresses produced by expanding soils within the vadose zone, which either cause structural failure of the shaft or extraction of the shaft from the soil. (Fig. 1).

Expansive soils were recognized in an NSF study as being one of the six most damaging natural hazards in the United States (Wiggins et al., 1978). Damage caused by expansive soils will be surpassed by only hurricane wind/storm surge by the year 2000 (Snethem and Huang, 1992). Wiggins et al. (1978), indicate that mitigation studies could reduce as much as 35% of the damage associated with expansive soils. Mitigation studies will refer to those studies which provide the profession with a better understanding of the problem and the factors which influence it. For example, reduction of volume change can be achieved through preconstruction treatment or adequate structural design of the foundation, both of which rely on an accurate estimate of the potential volume change. This research focuses on the fundamental behavior of drilled shafts in expansive clays and ways of mitigating the effects of expansion.

2. RESEARCH METHODOLOGY

The problem was be studied at the field site of NGES-UH. The field work included the construction of four instnunented test shafts, one reference shaft with standard design and three test shafts with isolation tubes. The reference shaft was used for study fundamental phenomena, which the shafts with isolation tubes were used to assess mitigation methods.

The isolation tubes were be constructed of simple concentric pressed fiber forms separated by various viscoelastic materials (basically, encapsulated asphalts) and which were placed in the drilled shaft boreholes prior to concreting. Vertical movement of the ground was also be measured at the surface above each column of instruments. The drilled shafts were instrumented with strain gauges and movement points to obtain the coupling of tensile stresses into the shafts and the vertical movements of the shafts themselves.

3. FIELD TEST

Three isolation - tube shafts and one reference drilled shaft, 0.305 m in diameter and 4.2 m deep, were installed to investigate the vertical shaft movement and stress changes in shafts during seasonal ground movement. Six surface elevation points were measured. Three of them were placed between the reference shaft and isolation tube shaft, I-2, and the remaining three points were placed between reference shaft and isolation tube shaft, I-1. Fig. 2 and Fig.3 'show the test site layout, showing locations of surface elevation measuring points and drilled shafts and section view showing dimensions of the drilled shafts and isolation tube. The shafts were placed 1.8 m apart, which is larger than the depth of the potentially expansive soil unit, to avoid interference between individual shafts

Isolation-tubes were also installed to a depth of 2.1m to bypass the potentially expansive soil unit. Three different viscosities were provided in the isolation tubes (Table 1).

The vertical reinforcing steel in each test shaft were instrumented with vertical sister bars, as shown in Fig. 4, to measure the forces generated in the shafts. Each sister bar was machined at its mid-length to provide an adequately smooth surface on which two longitudinal active strain gages were mounted on opposite sides. Temperature compensating gauges were also used.

Table 1. Asphalt used in isolation tubes.

Tube	I-1	I-2	I-3
Asphalt	AR-8000 (most viscous)	AR-40000 (intermediate viscosity)	AC-5 (least viscous)

A benchmark has been established in the middle of research site. The benchmark was set at a depth of9.1 m, which is below the potential expansive zone and which can be considered stable. It served as the reference benchmark for the ground and shaft elevation measurements.

Vertical movement points were established at the surface of ground and at the top of each drilled shaft. The test site had a total of six surface elevation and four drilled shaft elevation points. Elevations were read to the nearest 0.5 mm.

A elevation point for the ground surface and drilled shaft shafts were constructed of 1 m high x 12.7 mm diameter galvanized steel pipes cast in concrete blocks 300 mm x 300 mm x 150 mm high to hold the pipe in position. To facilitate the manometer measurements all the elevation points were monitored relative to the benchmark using 12.7 mm I.D. clear plastic tube using manometer theory.

4. RESULTS

1. Surface Elevation and Shaft Elevation Changes Elevation changes of six surface points and reference drilled shaft are shown in Fig. 5. The elevations of surface and drilled shaft at the time of its installation were considered to be the reference elevation. Each subsequent measurements were reported with respect to the measurement starting month zero elevation. Thus, a positive number indicates an increase in elevation (heave) while a negative change in elevation indicates shrinkage. The drilled shafts were installed in September 1994, hot and dry season in Houston area. Surface elevations decreased until October, rained heavily (385 mm in 3 days). After heavy rain, surface elevations changed abruptly up to 28 mm (C6) and increased continuously with starting of the wet season. The maximum surface change was recorded 40 mm in the point C6 on April 1995, just before dry season starts. On May 1995 the surface elevation started to decrease and continued until October. Ground heaving started again on November 1995.

The comparison of vertical movement change between reference drilled shaft and isolation tube shafts was shown in Fig. 6. The maximum vertical movement change of reference drilled shaft was recorded 5.0 mm, while isolation tube shafts 1.5 mm (I-l). Most viscous tube (I-1) recorded up to 1.5 mm and intermediate and least viscous tube recorded 1. O mm.

2. Uplift Force Changes in Drilled Shafts Uplift forces were measured at three different depths, 0.45 m, 1.1m, and 2.0 m of the shaft. Fig. 7 shows uplift force changes at three different depths in shafts. Maximum uplift force in reference drilled shaft were recorded 55 kN at the depth of 2.0 m on March and April 1995, on which the maximum surface elevation recorded. Uplift forces in isolation tube shafts were recorded less than 5 kN, which was about 10 percent of that of reference drilled shaft. Negative values, downdrag forces, were recorded in isolation type 2 tube shaft. The general trend of uplift force change in the reference drilled shaft was very similar with that of surface elevation .

5. CONCLUSIONS

Based on the field test observations vertical movements ofisolation tube shafts was about 30 per cent of that of reference drilled shaft. The uplift forces were reduced by 90 percent when the isolation tubes were used. The least viscous asphalts were slightly more effective than the most viscous asphalts. Fundamental studies of the behavior of a reference drilled shaft indicated rapid changes in both vertical movement in the soil and uplift forces in the plinth of the shaft to a depth of approximately 1.0 m with the application of saturating moisture (heavy rain). The high values of soil surface heave (35 mm) and uplift force (55 kN) from soil to foundation were observed in the field test.

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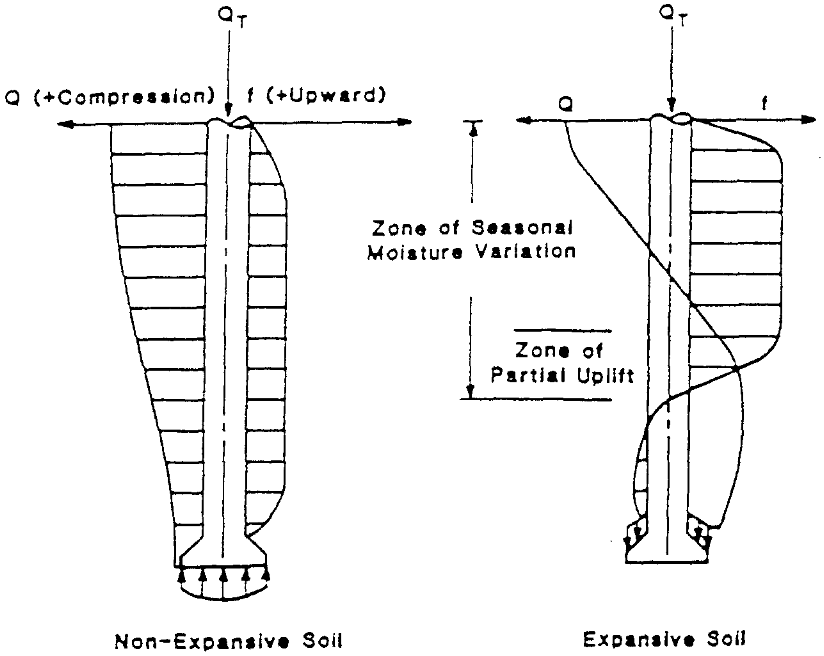
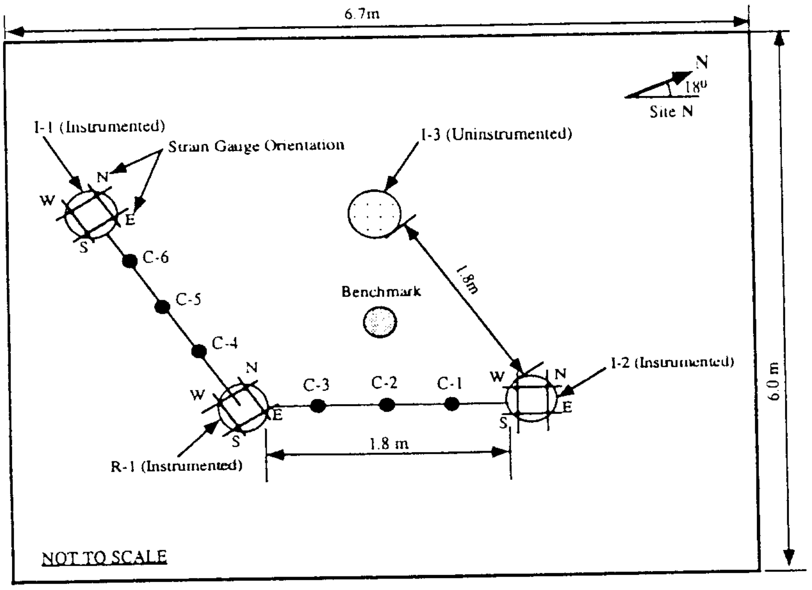


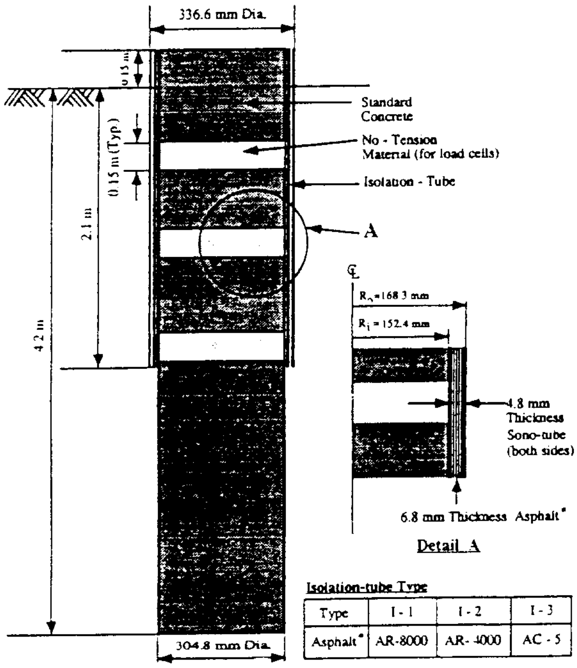
Fig. 1. Idealized Loads and Soil-shaft Interface Stresses at Working Load (O'Neill, 1988)



● Measuring Point of Surface Elevation

◎ 7.9 m Deep Benchmark for Surface Elevation and Drilled Shaft Movement Reference

Fig. 2. Test Site Layout, showing Locations of Drilled Shafts and Surface Elevation Measurement



Isolation-tube Type

Type	I - 1	I - 2	I - 3
Asphalt*	AR-8000	AR- 4000	AC - 5

NOT TO SCALE

Fig. 3. Section View of Isolation-tube Drilled Shaft.

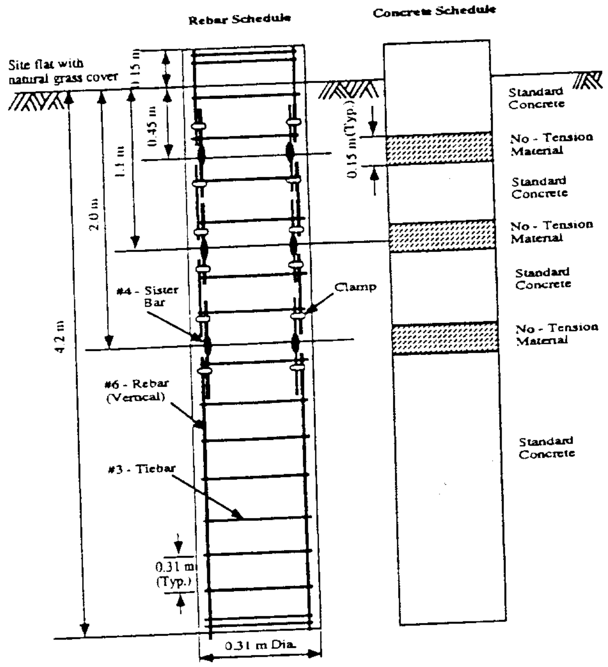


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Fig. 4. Schedule of Rebar and Concrete in the Drilled Shafts

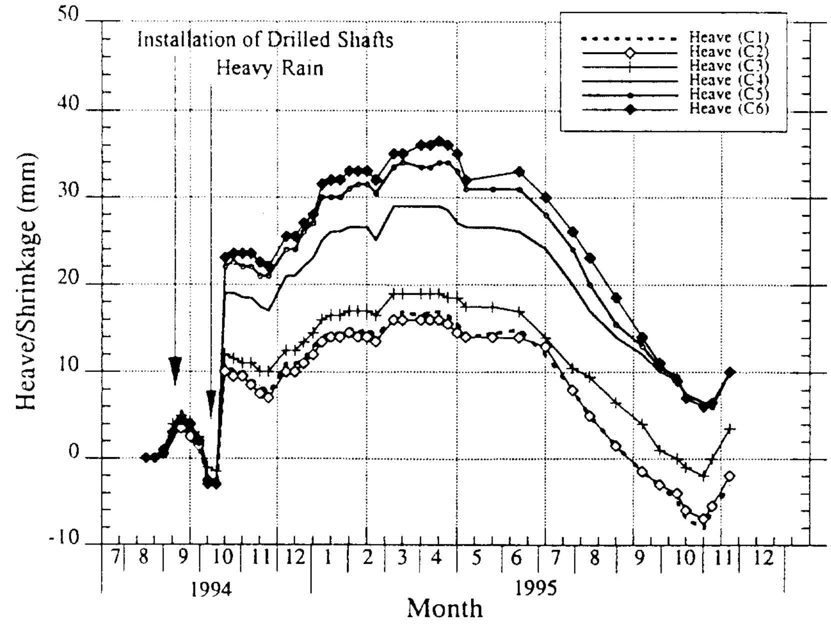


Fig. 5. Surface Elevation Changes at Each Point

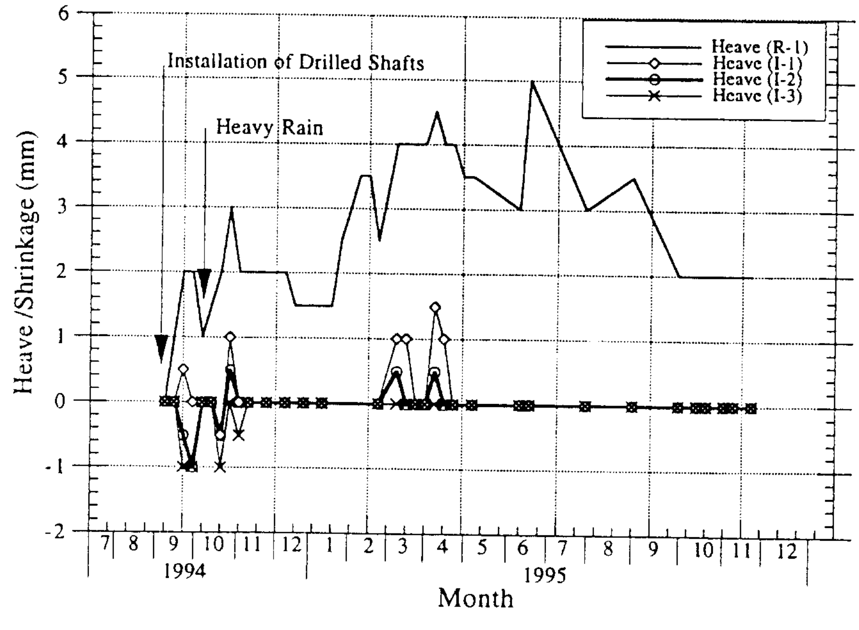
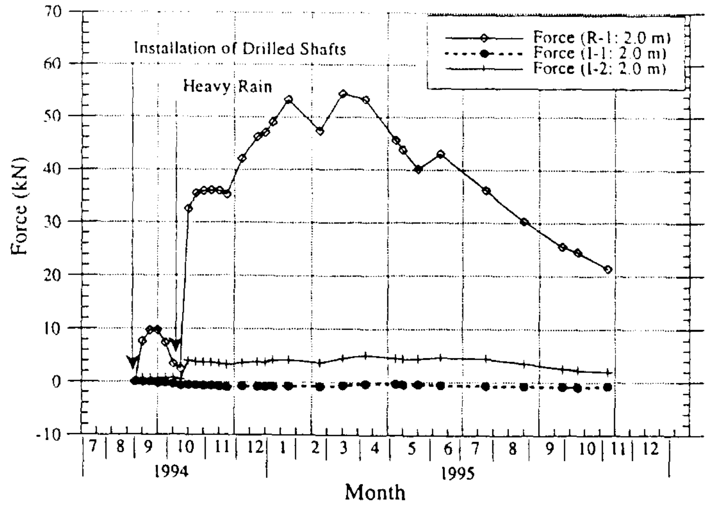
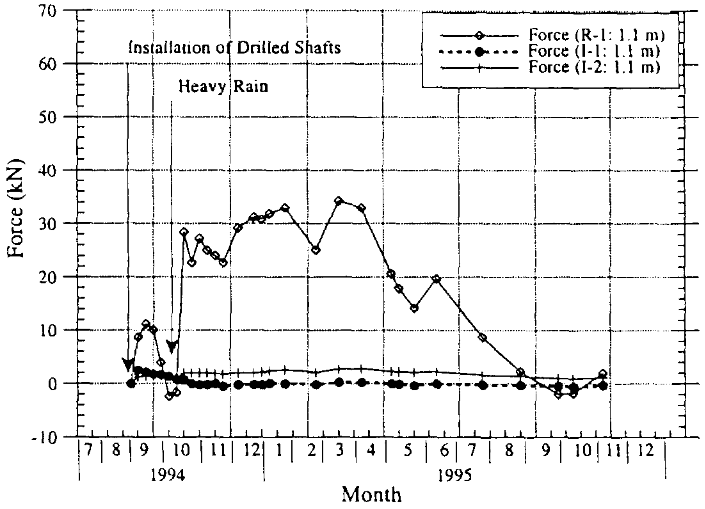


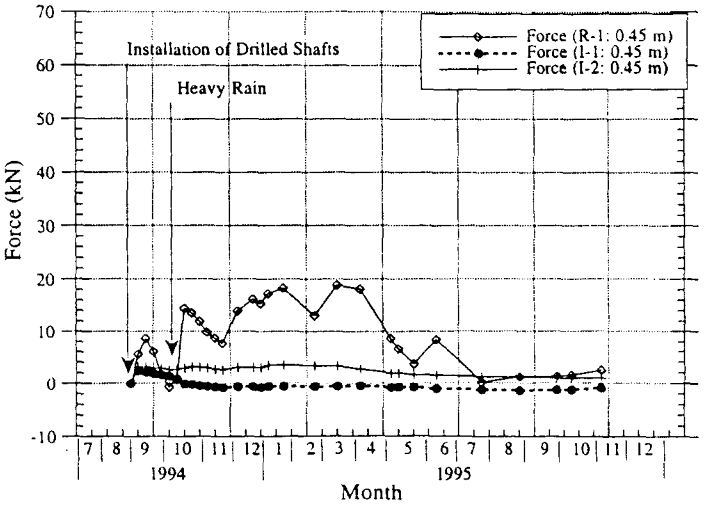
Fig. 6. Vertical Movements at the Top of Reference and Isolation-tube Drilled Shafts.



(a) 2.0 m



(b) 1.1 m



(c) 0.45 m

Fig. 7 Uplift Force Changes in Drilled Shafts