GROUND CONDITIONS IN THE 2011 DROUGHT

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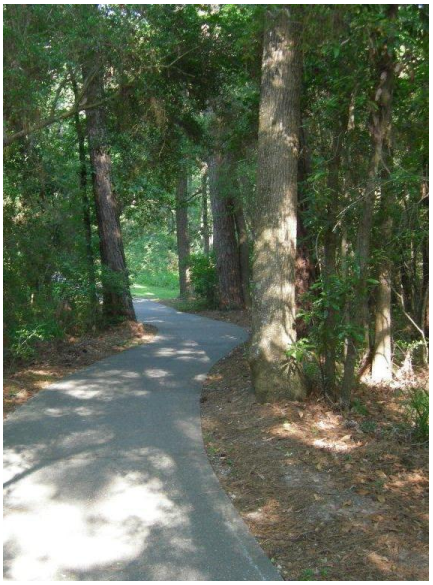
The expansive clays typical of the Texas Gulf Coast shrink with moisture losses, and swell with moisture gains. Changes in subsoil moisture result in settlement or heave of foundations and underground utilities bearing within the active zone. The 2011 drought altered the subsoil moisture profile, increasing the potential vertical rise (PVR).



2010 Photo

2011 Photo

The 2011 Drought

"The current drought" has been the most intense one-year drought in Texas since at least 1895 when statewide weather records begin, and …it probably already ranks among the five worst droughts overall." The summer's average temperatures were 2°F above the previous Texas record…(Henry, 2011).

Houston's climate is humid subtropical, and the average rainfall is ±50 inches. In 2010, the average rainfall was 43 inches which is slightly less than the average (~85% of average) but the 2011 average rainfall was only 25 inches (~50% of the average). However, about 40 percent of the 2011 rainfall occurred in the last quarter of 2011 which skews the average.

What is very significant is that only 17 inches of rainfall (~35% of average) occurred in a 12 month period between the last quarter of 2010 and the third quarter of 2011 (October 2010/October 2011). The 14 inches of winter rain that occurred in the fourth quarter of 2010 and first quarter of 2011 including the spring rain in the second quarter of 2011 were insufficient to recharge the moisture content of the clays for the upcoming summer months.

The mean temperature in Houston is 70° F, and the mean temperature in 2011 was 72° F (2° F above mean). August was the hottest month on record, and the high on August 27 matched the record temperature of 109° F set on September 4, 2000.

The combination of low rainfall and record heat has resulted in unusually low moisture content of the clay subsoils. The average depth of waterlines in Houston is about 4 feet placing them within the active zone. The City of Houston normally experiences 12 waterline breaks a day. However, more than 10 times this number of waterline breaks occurred per day during the 2011 drought. The low ground moisture and high heat has devastated Houston's trees. The Bayou Land Conversancy estimates that the greater Houston area could lose 10 percent of its trees (~66 million trees). Many trees are located adjacent or nearby residences, commercial building, and roadways. As the trees suck moisture from below the concrete slabs and paving to survive, increased settlement is occurring.

Site 1

Site 1 is located in the southwest side of Houston near the intersection of US 90A and N. Promenade. Geotechnical engineering studies had been performed in 2004 for an office/warehouse building. Additional borings were drilled in 2011 for a new office/warehouse building.

The subsoils are clays with a high to very high shrink/swell potential. The liquid limit ranged from 51 to 95, and the plasticity index ranged from 36 to 74. The moisture content of the upper 6 feet of clay was relatively wet in 2004, and moist below. However, the moisture content was dry to a depth of 12 feet in November 2011.

The depth of the active zone (seasonal moisture change) was judged to be about 10 feet in 2004, and it was 12 feet in 2011. The moisture content of the upper clays was very dry in 2011. The volumetric swell ranged from 10 to 15 percent in the upper 10 feet (extremely high).

Site 2

Site 2 is located in the southwest side of Houston on West Bellfort west of the Sam Houston Tollway. Geotechnical engineering studies had been performed in 2007 for a data center building. Additional borings were drilled in July 2011 for a large expansion to a warehouse.

The subsoils have a moderate to high shrink/swell potential to a depth of 10 feet. The liquid limit ranged from 36 to 66, and the plasticity index ranged from 23 to 48. The clays are underlain by a layer of water bearing clayey to sandy silt. The moisture content of the clays was relatively wet to 12 feet in January 2007. However, the moisture content was dry to a depth of 8 feet in July 2011 becoming wet below 10 feet.

The depth of the active zone (seasonal moisture change) was judged to be 8 feet in 2007, and it was at 10 feet in 2011. The moisture content of the upper 8 feet of clays was very dry. The volumetric swell ranged from 4 to 10 percent in the upper 8 feet (high to very high). Upward moisture migration of water from the layer of silt by suction prevented the clays from below 10 feet from drying out.

Site 3

Site 3 is located on the west side of Eldridge between I-10 and Memorial. Geotechnical engineering studies had been performed for a 14-story office building in April 1998 (not constructed). Additional studies were performed for an 18-story office building in November 2011.

The subsoils generally have a moderate to high shrink/swell potential. The liquid limit ranged from 21 to 81, and the plasticity index ranged from 8 to 60. The upper clays were moist to wet to a depth of 7 feet in April 1998, and they were moist below. However, the clays were dry to a depth of 8 feet in November 2011 becoming wet below 10 feet.

The depth of the active zone (seasonal moisture change) was judged to be 8 feet in April 1998, and it was 10 feet in November 2011. However, the upper 8 feet of clay was very dry in 2011. The volumetric swell ranged from 3 to 8 percent in the upper 8 feet (moderate to high). Upward migration of water by suction from a water bearing layer of clayey sand at 12 feet prevented the clays from drying out below the depth of 10 feet.

Site 4

Site 4 is located at the interchange of North Houston Rosslyn at West Road in NW Houston. Geotechnical engineering studies had been performed for an office/warehouse building in 2010. Additional studies had been performed in 2011 after the site plan had changed.

The subsoils are clays with a low to moderate shrink/swell potential. The liquid limit ranged from 27 to 38, and the plasticity index ranged from 9 to 23. The moisture content of the upper 2 feet of clay was dry in August 2010 becoming wet below 8 feet. However, the clays were very dry to 10 feet in October 2011.

The depth of the active zone (seasonal moisture change) was judged to be 8 feet in August 2010, and it was at 10 feet in October 2011. However, the upper 10 feet of clay was very dry in 2011. The volumetric swell of one sample of sandy clay with a PI of 15 (meets criteria of select fill) was 4 percent (high) due to its low moisture content.

Lessons Learned

The following are lessons learned from the 4 case histories:

- The depth of the active zone (seasonal moistures change) was about 8 to 10 feet prior to the drought. The depth of the active zone was deepened about 2 feet by the 2011 drought.

- The moisture content of the clay subsoils was unusually dry to depths of 8 to 10 feet.

- The presence of water bearing layers of permeable soil will cause upward movement of moisture by suction to recharge the clays limiting the depth of the active zone.

- Clays with a low to moderate shrink/swell potential can exhibit high swell when their moisture content is low.

- The low moisture content of the clays and increased depth of the active zone increase the potential vertical rise (PVR) of the clay subsoils.