Slurry Trench Stability Analysis – Constructing Cement-Bentonite Slurry Trench Adjacent to Existing Soil-Bentonite Backfill

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ABSTRACT

Vertical containment walls have been used as barriers to cut off hazardous fluid and chemical flow in the ground at contaminated sites. An application of this technique in South Carolina is to construct a 1.6-mile long containment wall along a dike using cement-bentonite slurry, which features low permeability and high compressive strength. However, concerns about the stability of the cement-bentonite slurry trench have been raised because an existing soil-bentonite wall will be in very close proximity to the alignment of the cement-bentonite slurry trench; and the shear strength of the existing soil bentonite backfill is considered to be low. Excessive overbreak of the new trench sidewalls is anticipated during construction.

Utilizing the data obtained from the geotechnical borings drilled on the dike and CPT results, a parametric study was carried out in order to establish the minimum distance between the cement-bentonite slurry trench and the existing soil-bentonite backfill. Different cases were analyzed according to the strength parameters of the soil-bentonite backfill and the water level of the pond. In this paper the authors present the method and results of the stability analyses of the cement-bentonite slurry trench against wall collapsing. The calculated factor of safety with varying soil-bentonite backfill friction angles is plotted as function of the distance to the proposed trench. The results are discussed and recommendations are given to minimize the probability of trench overbreak. As a means to monitor the stability of the dike, inclinometers were installed prior to trench excavation. With the new trench being advanced, the measurements from the inclinometers show the movement of the dike due to trenching. These data are also discussed in the paper.

INTRODUCTION

Since 1950s, vertical barrier walls or cutoff walls have been constructed in various applications around the nation (Soletanche, 1977; Meier and Rettberg, 1978; Brunner, 2004; Opdyke and Evans, 2005). In most cases, they are used as containment walls to cut off flow of clean or contaminated ground water. The backfill material includes soil bentonite (SB) mixture, cement bentonite (CB) slurry, jet-grouts, etc. Selecting the backfill material and technology depends on the function of the containment wall, site condition, contamination type, and budget. Particularly for slurry cutoff walls, the following issues also need to be considered before construction: slurry mix design, compatibility with the site soil and ground water, site slope stability, and trench stability. In this paper the authors present an application of cement bentonite slurry cutoff wall and discuss the issues of trench stability during construction.

Slurry trench stability is always of great concern during trench excavation. Engineers and researchers have done great amount of work to analyze different situations and to find solutions to increase the stability of trenches (Filz et al, 2004; Fox, 2004). Collapsing of the surrounding soil into the trench, however, is almost inevitable during trenching because of either removal of obstructions or instability of the trench walls. When it happens, it will take the contractor more time to remove the collapsed material and clean the trench; it will increase the sand content in the trench, therefore increase the permeability of the cutoff wall and influence the performance of the wall. Sometimes the collapsing of soil, or overbreak, happens at certain depths in the slurry filled trench and may not be visible from the ground surface. However, since it will result in more fresh slurry being introduced into the trench, engineers can always estimate the degree of overbreak by overbreak ratio, which is defined as the volume of slurry introduced into the trench divided by the theoretical volume of the designed trench. Usually in slurry trenching this ratio is controlled by the surrounding soil properties, ground water level, slurry level, and the workmanship. If the overbreak is excessive, it may jeopardize the stability of the whole site and surrounding structures and cause much more serious problems.

Trench stability can be maintained by increasing the hydraulic pressure of the slurry against the trench walls. One of the commonly adapted procedures is to increase slurry level by raising the platform height. It may be limited by the site condition though. Another means is to decrease the ground water level and therefore increase the hydraulic gradient between the slurry and the ground water. Some practitioners can also achieve trench stability by increasing the sand content in slurry but at the same time maintain the permeability of the final product. Some of these methods were used in the case history described in this paper.

SOUTH CAROLINA CANADYS CEMENT BENTONITE WALL

The cement bentonite containment wall built in Canadys, South Carolina is to contain Active Ash Pond, a 95-acre ash storage pond (Fig. 1). The dike top is at an elevation of about 80.0 feet and the pond water level is at an elevation of about 72.0 feet. Both side of the dike has a slope of about 3:1 (H:V), while the outboard slope is a little steeper (Fig. 2). The ground water level on the outboard side of the dike is at about El. 59.1 feet. Previously, a soil bentonite (SB) wall was built around the pond. Recent investigation showed that a certain amount of contaminants was found in the ground water outside the pond and it was suggested that a new containment wall be built to minimize the leakage of the contaminated pond water.

The proposed cement bentonite wall is 8,300 feet long, 3 feet wide and about 40~55 feet deep. The cement bentonite mix was designed to achieve a hydraulic conductivity of less than

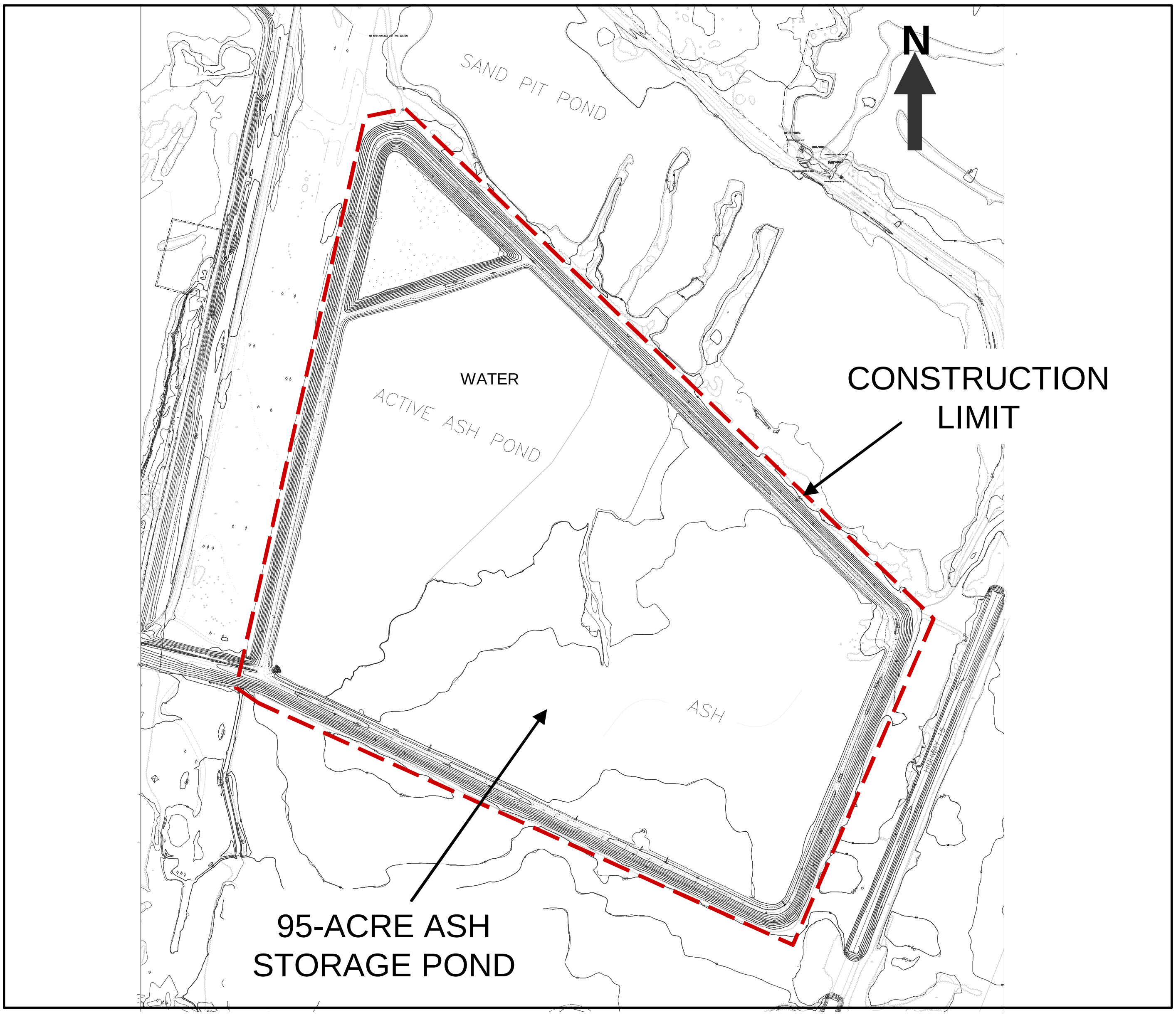

Fig. 1. An 8,300 feet CB wall was built around the 95-acre ash pond.

10^{-7} cm/sec and to have the compressive strength of at least 75 psi after it is cured. The mix was also tested for compatibility with the on-site water. The wall is designed to key in at least 3 feet into the Cooper Marl formation, a hard, low permeable material. The alignment of the wall is to be in close vicinity to the existing soil-bentonite backfill (Fig. 2). Most portions of the CB wall are in the inboard side of the dike with regard to the SB backfill. The distance between the CB wall and the existing SB backfill varies from 0 to 17 feet.

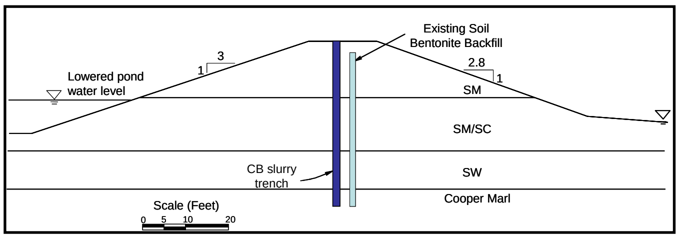

Fig. 2. Typical cross section of the dike. The distance between the CB slurry trench and the existing SB backfill varies from 0 to 17 feet.

Concerns were raised before the construction. At several locations during the SPT sampling and CPT tests, the existing SB backfill showed very low strength (SPT sampler dropped with weight of hammer). It is possible that the SB backfill will collapse into the new trench if the excavation is close to it. How close can the new CB trench be excavated beside the SB backfill without causing trench stability problems? What can be done to prevent excessive overbreak? These questions lead to the analyses that were carried out to determine the safe distance between the CB slurry trench and the existing SB backfill, which will be described in the following section.

TRENCH STABILITY ANALYSIS

The dike soil profiles were established by utilizing the data obtained from the geotechnical borings drilled on the dike, existing CPT results, and undisturbed sample tests of the existing SB wall material.. Wedge method was used to calculate the factor of safety against trench wall collapsing.

Soil profile and properties

The general cross-section of the dike shown in Fig. 2 was developed for the stability analysis based on the data obtained from test borings WR-3 and WR-7OW. The soil layers from the top of the dike are silty sand (SM), clayey sand (SC/SM), widely graded sand (SW) and the Cooper Marl formation. The generalized section includes an assumed lowered ground water level at Elevation 65.0 feet in the embankment.

The engineering properties of the materials that were used in the analyses are summarized in Table 1.

The shear strength parameters (cohesion and friction angle) were estimated based on laboratory soil classification test results, the CPT and SPT test results. In the analysis, the friction angle of the soil-bentonite backfill is estimated to be in the range of 10 to 30 degrees.

Wedge method (Fig. 3) was used to estimate the factor of safety with respect to the existing soil-bentonite backfill sliding into the new trench as the distance between the two trenches varies. The wedge, in consideration, is between the edges of the CB trench and the existing SB backfill. The assumption behind this is that the soil-bentonite backfill could separate from the dike soil and cracks will be formed along the interface of the SB backfill and the wedge. When the strength of the SB backfill is low, it will push the wedge towards the trench and cause collapsing. The width of the wedge is defined as X (Fig. 3), which varies from 1 to 8 feet in the analysis. The two forces that control the wedge stability are:

- P_s: the force exerted by the hydraulic pressure of CB slurry;
- P_a: the force exerted by the wedge itself and the SB backfill, which is next to the wedge.

The factor of safety can be calculated by:

$$FS = \frac{P_a}{P_s}. \quad (1)$$

Note that the estimated groundwater level within the embankment was also considered in the analyses.

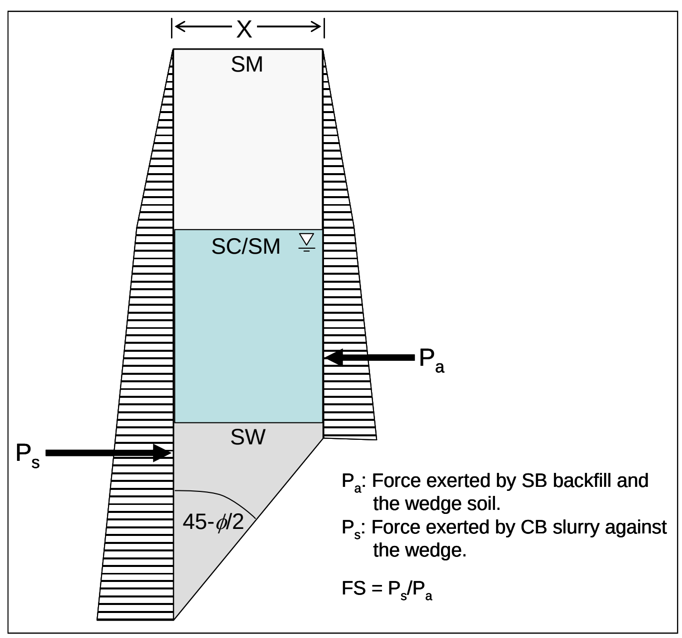

Fig. 3. Wedge method was used to determine the safe distance between the CB trench and the existing SB backfill.

Table 1. Soil parameters used in the analyses

Material	Average N-value	Estimated Moist Unit Weight (pcf)	Estimated Saturated Unit Weight (pcf)	Estimated Friction Angle (degrees)	Estimated Cohesion (pcf)
SM	33	110	130	34	0
SC/SM	18	105	125	30	0
SW	30	110	125	32	0
Existing Soil-Bentonite Backfill	3	130	130	10~30	0
Cement Bentonite Slurry	-	-	70	-	-

<u>Trench Stability Analysis Results and Discussions</u>

The evaluation of the factor of safety against trench sidewall failure was completed by varying X, the distance between the two trenches. Three cases were analyzed for the SB backfill friction angle of 10, 20 and 30 degrees. The distance between the proposed trench and the existing soil-bentonite backfill varies from 1 foot, 3 feet, 5 feet, and 8 feet. The calculated factor of safety is summarized in Fig. 4.

The analysis results indicate that the trench stability against wedge sliding from the existing SB backfill to the new CB trench drops dramatically when the distance between the SB backfill and the CB trench decreases or when the SB strength (friction angle) decreases. Although the lab test showed that at one location, the SB backfill may have a friction angle higher than 30 degrees, the strength of the backfill is considered moderately low because of the data variation and conservatism.
The stability of the trench, however, is also controlled by the ground water level and the unit weight of the CB slurry. With the knowledge that the strength of the SB backfill varies along the trench alignment, caution should be taken when the CB trench is very close to the backfill. Pond water level was suggested to be lowered to El. 65 feet to decrease the water level in the embankment; and the level of CB could be raised by building berms along the trench. The excavator operator should also take caution not to disturb the slurry level too much in order to avoid unnecessary collapsing of trench walls.

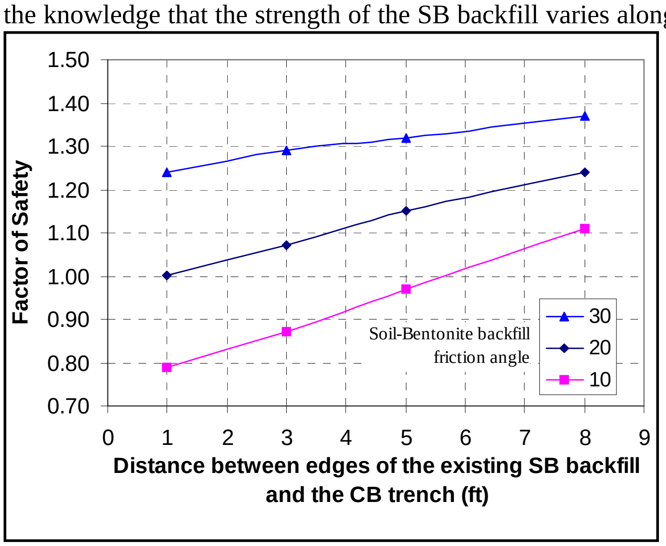

Fig. 4. Wedge method analysis results show the factor of safety of the wedge sliding with different scenarios of SB backfill friction angle and various width of the wedge.

TRENCH CONSTRUCTION

The construction phase of the containment wall includes two stages: a test section and a production section. In the test section, construction equipment, workmanship, monitoring system, test procedure, productivity, and constructed wall quality are investigated and detailed recorded. The construction procedure and QA/QC procedure were fine tuned in the test section and contributed to the completion of the production section. The excavation of the trench by modified long beam backhoe is shown in Fig. 5.

Fig. 5 Construction of the CB slurry trench.

Two inclinometers were installed on the outside of the dike before excavation. WR-1I is at Station 20+50 and 14 feet from the trench center line. WR-2I is at Station 21+20 and 4 feet from the trench center line (Fig. 6). Both inclinometers monitored the ground horizontal movement from dike top to the Cooper Marl formation in two directions parallel and perpendicular to the trench alignment.

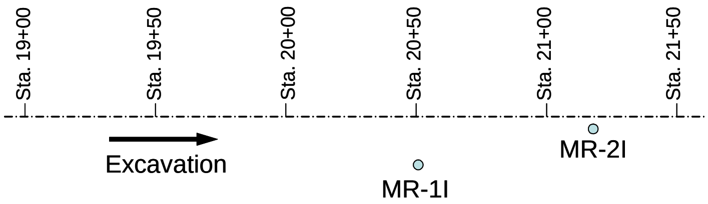

Fig. 6. Inclinometers were installed on the dike. WR-1I is at Sta. 20+50; WR-2I is at Sta. 21+20.

WR-1I readings did not show significant horizontal ground movement (<0.2 inch) during trenching in either directions. WR-2I, however, showed that horizontal ground movement of about 2 inches towards the trench at the top of the dike during construction (Fig. 7). This was correlated to the excavation around Station 21+20, where the distance between the CB wall and the SB backfill is about 7 feet. Since the excessive horizontal movement happened only within the top 10 feet, it is not likely that severe collapsing occurred. In addition, there was no noticeable collapsing from the dike surface either.

The trench was completed with an overall overbreak of 1.3, which shows that the existing SB backfill had not caused great collapsing problems during the trench excavation. The field inspection report also showed that only very localized collapsing was noticed during the construction.

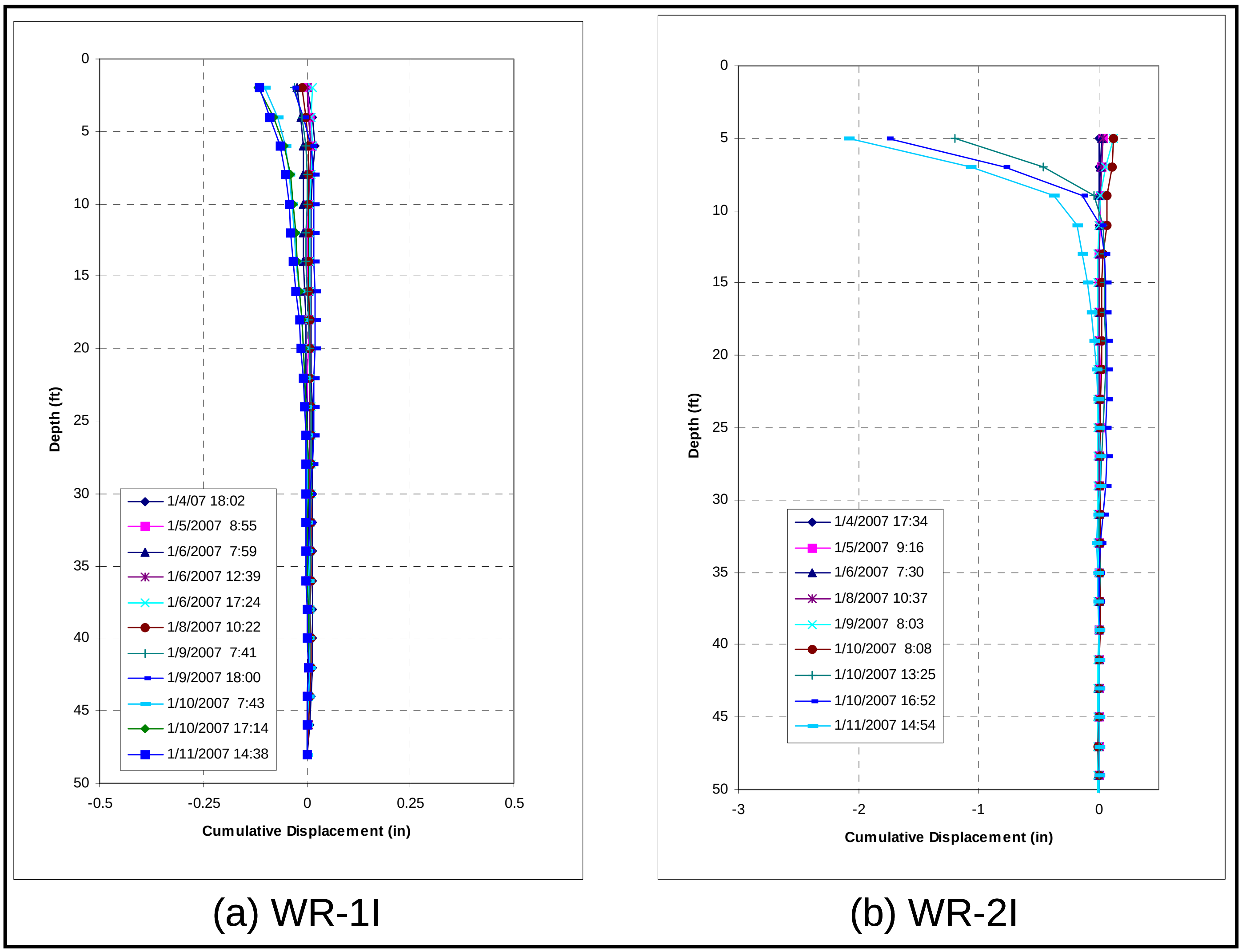

Fig. 7. Inclinometer (WR-1I and WR-2I) readings of ground horizontal movement perpendicular to the trench alignment during the construction.

CONCLUSIONS

The application of CB slurry trench as a ground water cutoff wall in Canadys, South Carolina brought up an issue of trench stability with excavating trench in vicinity of existing low strength backfill. The authors used wedge method to analyze the safe distance from the existing SB backfill to the CB slurry trench. The analysis results and recommendations to improve trench stability were discussed. The trench was completed with an overall overbreak ratio of 1.3 and did not show severe soil collapsing during the whole construction.

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