Engineering
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INVESTIGATION OF EXCESSIVE FILL SHRINKAGE FROM EMBANKMENT CONSTRUCTION

This project involved a 40,940 ft. (7.75 miles) long enlargement of an existing levee located along the east side of the Mississippi River. The enlargement included increasing both width and height of the levee. A cross section of the levee enlargement is shown in Figure 1. Figure 1 also depicts the historical construction of this levee, which was originally placed in 1931 and added to in 1945.

The embankment soil obtained from specified borrow areas was required to be compacted to 90% at moisture contents of ±3% and ±6% of optimum for silty and clayey soils, respectively. Given the specified enlargement dimensions, the total volume of compacted embankment was 1,847,823 cy. However, it took the contractor 2,583,781 cy to achieve the required dimensions of the levee enlargement. In other words, the contractor had to transport, process, and compact 1.4 times the material in order to reach the design grade. This magnitude of shrinkage was far beyond what would be normally expected. In addition to the significant effort required to build the enlargement, the contractor found that the fill placed on the existing levee embankment was not sufficiently stable and had to be spread out over the entire 7.75 mile length of the project. Consequently, it took much longer to complete and close out pay sections of the levee enlargement.
An investigation was undertaken by MEA to understand the extraordinary fill shrinkage. This investigation

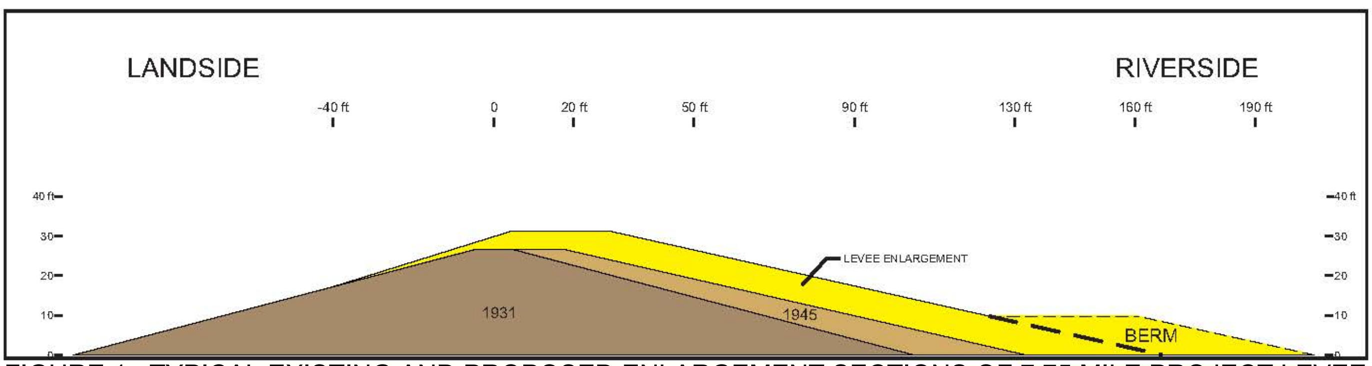

FIGURE 1: TYPICAL EXISTING AND PROPOSED ENLARGEMENT SECTIONS OF 7.75 MILE PROJECT LEVEE

included drilling and sampling the levee and foundation soils, and excavating test pits in the existing levee and fill borrow pits. Testing mainly included determining field moisture/density conditions, and fill compaction as well as the associated strength characteristics and soil compressibility of the existing levee and foundation soils in the lab. From examination of all the site characteristics, the two causes for the extraordinary fill shrinkage were found to be compaction of the lighter borrow soils into a denser state and settlement of the levee foundation soils. Based on the site analyses, it is estimated that an additional 16% of borrow was needed, but the main cause for the excessive demand of borrow material was from levee settlement which resulted in 24% of additional volume (see Figure 2).

More interesting, however, was the cause for the unexpected and significant foundation settlement and the greater than expected shrinkage from compaction. The culprit was found to be the instability of the placed borrow material, even though it was compacted to specifications. Lab tests showed that when compacted to within specification, the various borrow-to-fill soils would be too weak to support the necessary construction traffic (see Figure 2). This fill instability resulted in the need to extend the wet fill lifts along the entire project

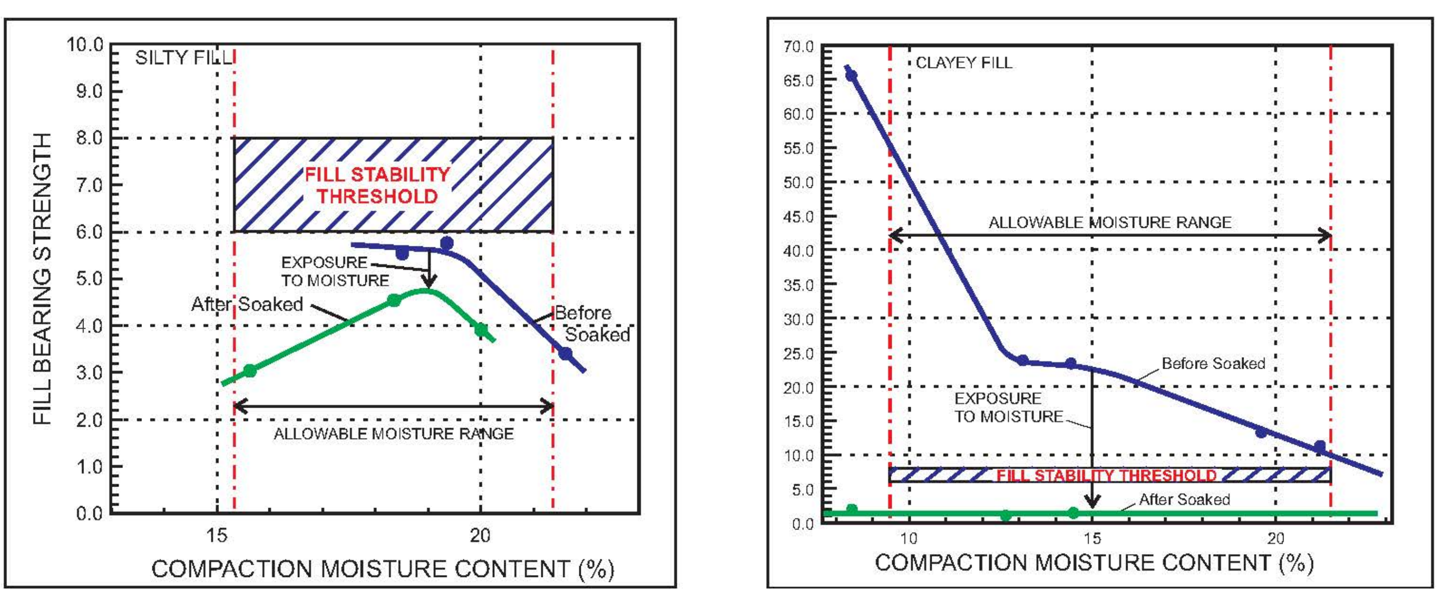

FIGURE 2: FILL STRENGTH WHEN COMPACTED UNDER CONDITIONS ALLOWED IN THE SPECIFICATIONS

reach in order to minimize disturbance from processing, which significantly delayed completion of levee sections.

In addition to extending fill lifts along the project levee, the borrow material had to be dried to levels less than what was allowed, and compacted to greater densities in order to create at least some stability. About 5% of the fill compaction shrinkage occurred due to the densification of the borrow requiring a higher percent compaction than was specified.

Although thick compressible clayey deposits would be expected along the project reach in this river laid geologic environment, the considerable time that was needed before a levee section could be completed allowed for these clay soils to be compressed and the levee to settle. This resulted in much greater borrow volume to complete a section of the enlargement. Measuring the volume of fill required to compensate for the settlement which occurred during embankment placement can be problematic with the use of one settlement plate. Yet, in the specifications, the instructions to quantify added embankment volume from underlying settlement were based on measuring one settlement plate in the riverside crown of the old embankment. At this location the underlying foundation soils were much stiffer from long term compression under the weight of the old levee. Therefore, measurements from this one specified plate location severely underestimated the fill volume loss from foundation settlement under the riverside toe and beyond (see Figure 3). In other words, the distribution of settlement, especially when significant time dependent movement is present, is not directly proportional to the height of the fill placed as the specified settlement plate method assumed.

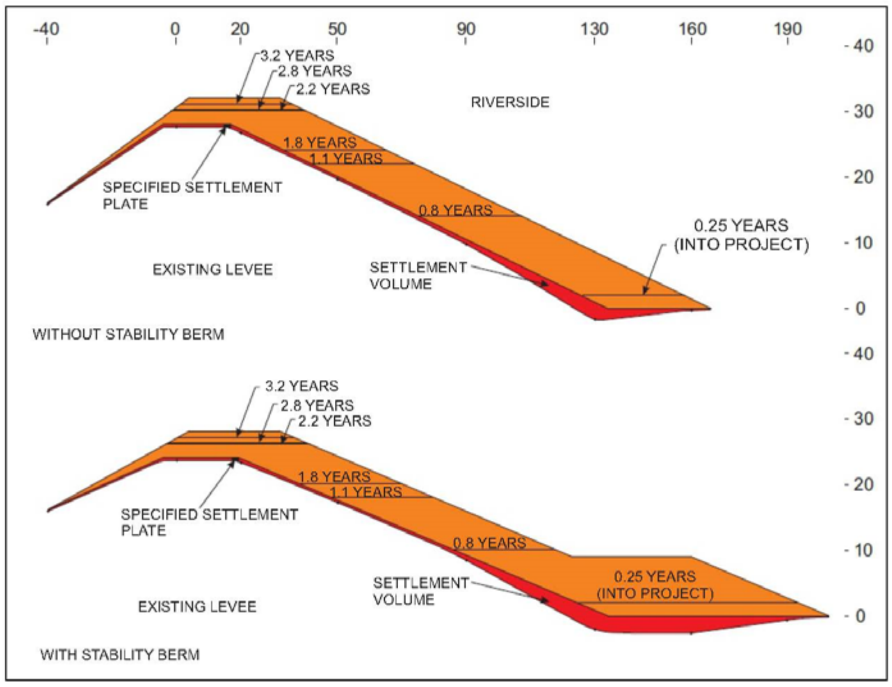

FIGURE 3: CALCULATED TOTAL SETTLEMENT DUE TO THE LEVEE ENLARGEMENT

SUMMARY

An extraordinary amount of earth fill was needed to complete a 7.75 mile levee enlargement along the Mississippi River. The two causes for this were compaction of the lighter borrow soils and settlement which occurred during construction. Although these two factors would be involved in any similar project, the 40% added volume needed to meet the levee grades was far greater than what would be normally encountered. Ultimately, the excessive densification and the settlement of the fill from what would have been expected were rooted in the infeasibility of compaction requirements which caused the placed fill to be too unstable for levee construction.

LESSON LEARNED

- In design, consider the constructability of the compaction requirements.
- To assess settlement loss, perform accurate pre-fill cross-sectional surveys in addition to the closeout sections required for release of the embankment section.
- To minimize foundation settlement, finish embankment sections as soon as possible. Do not extend lower lifts over longer reaches resulting in sustained loads on the subsoils which tend to be much more compressible.

Other Engineering UPDATES of Interest:

UPDATE 22: Smart Coal Extraction with Varying Soft Floor Conditions

UPDATE 4: Improvement of Mine Support Saves Pipeline from Subsidence Event

UPDATE 32: Developer Avoids Substantial Risk of Subsidence Damage

ABOUT MEA: Marino Engineering Associates, Inc. focuses on engineering research, practice and expert evaluations and is licensed in 25 states in the U.S. Our projects primarily have an emphasis on Geotechnical Engineering, however, we also have significant experience in projects involving transportation, subsidence engineering, laboratory testing, training, and geophysical exploration. Gennaro G. Marino, Ph.D., P.E., D.GE is president and principal engineer of Marino Engineering Associates, Inc., and has been a licensed professional engineer since 1984. To obtain additional information on MEA, one can also visit our website at www.meacorporation.com.

FOR MORE INFORMATION: There is a significant amount of additional information that is available on the above subject. For more information, please contact MEA at the address listed below.

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