Missouri University of Science and Technology
Scholars' Mine

Jun 1st

Preloading Wastewater Treatment Plant Tanks

K. Lowery
Woodward-Clyde, Baton Rouge, Louisiana

A. N. Wagh
Woodward-Clyde, Baton Rouge, Louisiana

J. B. Falcon
BASF Corporation, Louisiana

Follow this and additional works at: http://scholarsmine.mst.edu/icchge

Part of the Geotechnical Engineering Commons

Recommended Citation

Lowery, K.; Wagh, A. N.; and Falcon, J. B., "Preloading Wastewater Treatment Plant Tanks" (1993). *International Conference on Case Histories in Geotechnical Engineering*. 11.
http://scholarsmine.mst.edu/icchge/3icchge/3icchge-session07/11

This Article - Conference proceedings is brought to you for free and open access by Scholars' Mine. It has been accepted for inclusion in International Conference on Case Histories in Geotechnical Engineering by an authorized administrator of Scholars' Mine. This work is protected by U. S. Copyright Law. Unauthorized use including reproduction for redistribution requires the permission of the copyright holder. For more information, please contact scholarsmine@mst.edu.

Proceedings: Third International Conference on Case Histories in Geotechnical Engineering, St. Louis, Missouri, June 1-4, 1993, Paper No. 7.46

Preloading Wastewater Treatment Plant Tanks

K. Lowery
Assistant Project Engineer, Woodward-Clyde, Baton Rouge, Louisiana

J. B. Falcon
Senior Design Engineer, BASF Corporation, Louisiana

A. N. Wagh
Senior Project Engineer, Woodward-Clyde, Baton Rouge, Louisiana

SYNOPSIS: Storage tanks for a wastewater treatment plant were stage-loaded on weak compressible fine-grained soils. The in situ silt and sand layers/pockets present in the fine-grained soils were theorized to create sufficient drainage paths, so that the use of sand or wick drains were not required. Although the silt and sand layers/pockets were found to be discontinuous, "hydraulic fracturing" was expected to develop continuous drainage paths. A review of the extensive field investigation and geotechnical optimization of the site is presented. Details for the evaluation of the shear strength of the soils, the stage loading schedule and predicted settlements during loading are described. Settlement of the tank foundations and some measurement of the pore pressures were monitored in the field and the data obtained, presented herein, was found to be fairly consistent with the geotechnical analysis results.

INTRODUCTION

The BASF Corporation planned to construct nine tanks for a wastewater treatment plant on a site 20 miles southeast of Baton Rouge in Geismar, Louisiana. The Mississippi River flows south approximately 3,000 feet to the west of the new plant. An intensive geotechnical investigation was performed to optimize the location of the plant with the strongest soils found on the approximate 65-acre site. Since two of the tanks, the final clarifiers, will have settlement sensitive equipment in operation at all times, it was decided to place these tanks on deep foundation systems. Factors of safety near 1.5, considered to be questionable, for edge shear failure necessitated the stage loading of the remaining seven large tanks prior to placing them in service. Included were four 27-foot high, 70-foot diameter reactors, two 29-foot high, 110-foot diameter tanks and one 30-foot high, 131-foot diameter tank.

Stage-loading/preloading/surcharge methods are commonly used to allow consolidation and cause an increase in shear strength in fine-grained soils. The stage-loading of storage tanks allows excess pore water pressures in the soils to build up with the loading and then dissipate with time. The dissipation of excess pore water pressures causes the soil to fill the pore space and consolidate. Sixty to Seventy percent of the consolidation settlements were expected to take place during stage-loading of the tanks. The large settlements prior to service would cause reduced stress and maintenance problems for the large diameter piping connections due to future settlements. The dissipation of excess pore water pressures also causes the effective stress to increase, but it does not cause any change in the shear stress. Thereby, the plot of the effective stress envelope of the soil will shift toward the total stress envelope or to a safer position away from the classic Mohr-Coulomb failure envelope.

SOIL CONDITIONS

The data collected from the field and laboratory investigations depict three basic soil strata. The soils in Strata 1 and 2 are believed to be recent alluvial deposits of Holocene age origin from the Mississippi River, and the soils of Stratum 3 are believed to be of Pleistocene age origin. Stratum 1 is a high plastic clayey crust (CH) with a medium to stiff consistency. A soft to medium consistency silty clay/clayey silt (CL/ML) was encountered in Stratum 2. The third stratum consists of clays (CH) interspersed with pockets or thin layers of silts (ML), silty clays (CL), silty sands (SM), sandy clays (CL), clayey silts (ML) and sandy silts (ML). Overall consistencies in Stratum 3 were stiff to very stiff and the soils were overconsolidated. Besides the layers and pockets in Stratum 3, small layers and/or pockets of silt and sand were found in Stratum 1 throughout all the borings. However, these layers/pockets were not continuous from boring to boring and in fact some of the pockets were vertical streaks in some of the sample cores. Figure 1 presents a generalized geological profile of the soils ranging from west, near the Mississippi River, to east, near BASF's existing plant. As Figure 1 shows, the stiffer Pleistocene age soils increase in elevation or decrease in depth as one moves to the east away from the river. Also, it was found during the geotechnical investigation that the stiff Pleistocene age soils level off and do not increase above a depth of approximately 20 feet. To minimize the effects due to settlement of the softer recent alluvial deposits, the wastewater treatment plant was constructed as far to the eastern part of the proposed site as possible.

LABORATORY TESTING

Atterberg limit tests, moisture content tests, percent passing the number 200 sieve tests and density tests were performed

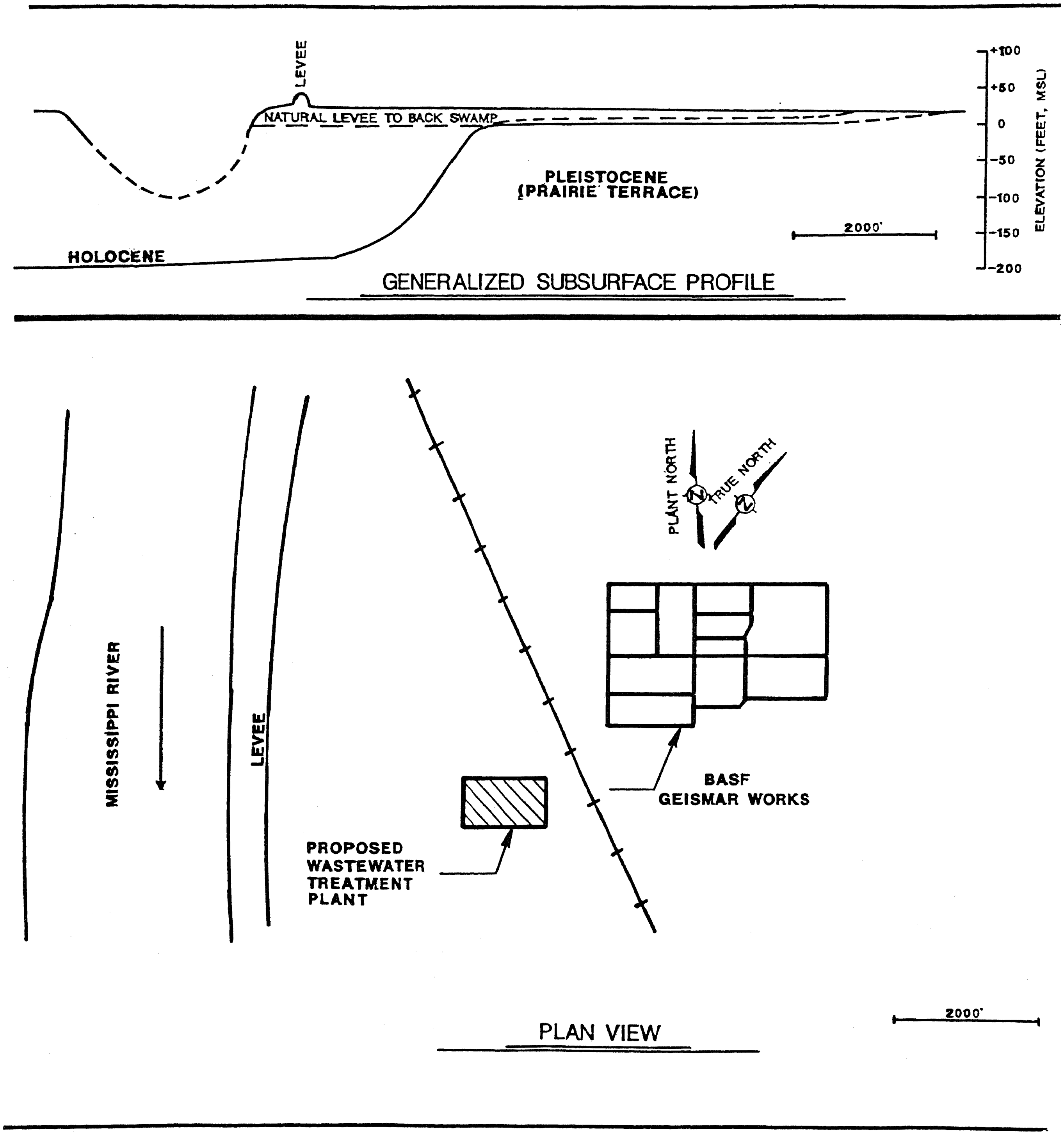


Figure 1 Generalized Geologic Profile

to classify the soils encountered in the borings. Triaxial compression tests and consolidation tests were performed on selected samples of the predominantly fine-grained soils to evaluate the shear strength and compressibility characteristics, respectively, of the soils. The results from consolidated, undrained (CU) triaxial compression tests were used to determine:

(1) the Mohr-Coulomb failure envelope.

(2) Skempton's 'A'-value for pore pressure increase due to loads and calculate Skempton's plane strain Correction Factor β (See Skempton and Bjerrum, 1957) for each of the soil stratum.

ANALYSIS

The factors of safety against base and edge shear beneath the tanks were calculated by using a bearing capacity method developed by Duncan and D'Orazio (1984). Due to the soil layering and the relatively shallow depth as compared to the tank diameter of the stiff Pleistocene age soils found beneath the site, an edge shear failure is more critical than a base shear failure. The calculated edge shear for the shallow soils gave a marginal safety factor near 1.5; therefore, it was decided to increase the shear strength of the fine-grained soils by allowing consolidation during stage-loading. Terzaghi's one-dimensional consolidation theory (1925) was used to analyze the time rate of settlement for the soils beneath the tanks during stage loading. The discontinuity of the sand and silt layers/pockets found in the soils made the estimation of the drainage paths (H_{dr}) very difficult. It was theorized that the discontinuous sand and silt pockets/layers would build up enough pressure during stage loading to cause a phenomenon similar to hydraulic fracturing in the clays between the layers/pockets. Due to a belief in this phenomenom, the sand and silt layers/pockets would become interconnected and allow any excess pore pressures in the clays to dissipate. If this theory was true, the actual amount of time needed to consolidate the fine-grained soils beneath the tanks would be substantially less then with the apparent continuous clay layers. With this theory H_{dr} in some of the layers found on site would be reduced to as small as 3 to 4 feet.

In order not to surpass the Mohr-Coulomb failure envelope developed from the CU tests in Strata 1 and 2, a stage loading program incorporating the estimated H_{dr} and the coefficient of consolidation (C_v), from the consolidation tests, was established. Foster and Ahlvin's (1954) influence chart for a uniform circular load was used to determine the stress distribution in the soils due to the loads from the tanks. The total settlement and the settlement of the tank due to each stage load was predicted using Terzaghi's one-dimensional consolidation theory (1925) and then corrected using Skempton's pore pressure factor, β, (Skempton and Bjerrum, 1957) for each stratum. The predicted amount of total settlement for the center and the edge of the tanks is presented in Table 1. The percentage of the settlement for each load over time using Terzaghi's (1925) C_v and H_{dr} for each stratum was predicted. The solid lines shown in the upper parts and lower parts of Figures 2 through 8 show the estimated loading schedules versus time and the corresponding settlement curves versus time, respectively, for all the stage-loaded tanks.

TABLE 1: Predicted Tank Settlement

Tank	Diameter (ft)	Height (ft)	Settlement at center (in)	Settlement at edge (in)
R-410A	70	27	7 to 9	3 to 6
R-410B	70	27	7 to 9	3 to 5
R-460A	70	27	6 to 8	3 to 5
R-460B	70	27	7 to 9	3 to 6
TK-210	110	29	7 to 9	3 to 5
TK-211	110	29	9 to 11	4 to 7
TK-401	131	30	7 to 9	3 to 6

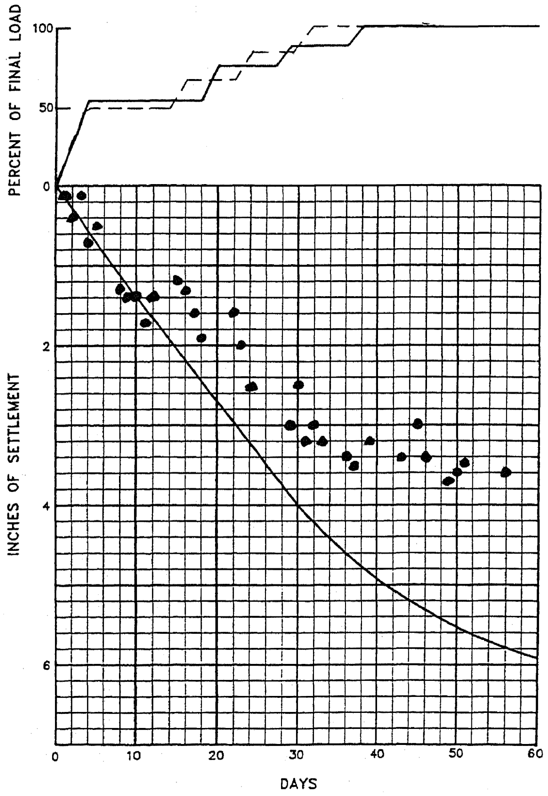
FIELD MONITORING

A field monitoring program was implemented to determine whether the soil response in the field would correspond with the soil response predicted from the analysis. Also, this monitoring would be important to help ascertain whether the excess pore pressures in the fine-grained soils were dissipating rapidly enough so that shear failure due to the next increment in load would not occur. Eight brass settlement markers were spaced equally in the exterior part of each tank ringwall. On opposite sides of each of the tanks, pneumatic piezometers were placed near the midpoints of Strata 1 and 2. Shallow wells placed outside the area of construction were monitored to measure the rise and fall of groundwater due to environmental factors such as rainfall or the rise and fall of the Mississippi River. The monitoring of the groundwater was incorporated into the pneumatic piezometer readings to determine the change in pore pressure due to the staged loads. However, the shallow depth and the horizontal location of the pneumatic piezometers, outside the footprint of the tank, made the pore pressure readings inconclusive. Therefore, the measurements of the settlement along the edge and at the center of the tanks were used to monitor the stage loading performance.

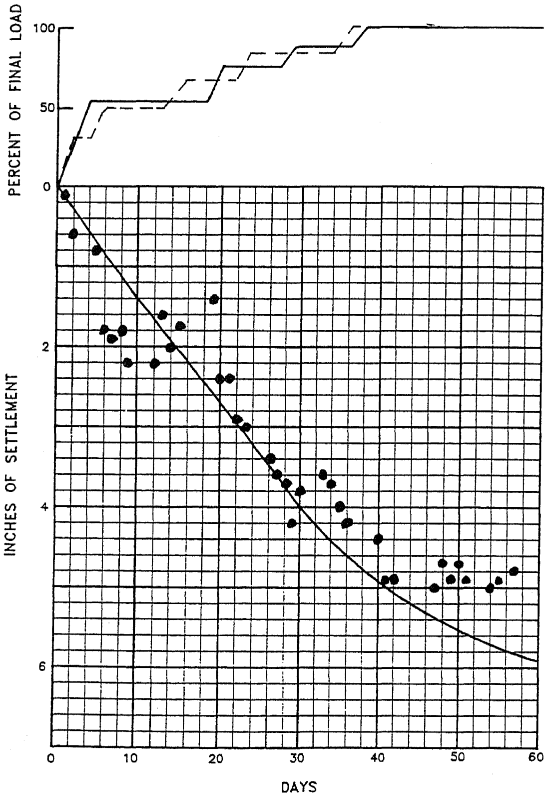
The four smaller reactor tanks, R-410A, R-410B, R-460A and R-460B, were load tested prior to loading the larger tanks. The actual loading sequence for these tanks are shown as the dashed line in the upper portion of Figures 2 through 5. The actual settlement trends of the tanks are shown as dots on the lower portion of the figures. As these figures indicate, the actual loading sequence was somewhat different then the predicted sequence. These modifications were made in conjunction with the actual settlement readings of the tanks. Each load was held for a minimum of one week or until the amount of settlement in the center of the tank did not increase more than an average of 0.1 inch for three days. The loading period for these tanks ranged between 50 and 57 days. The other three tanks, TK-210, TK-211 and TK-401, were being loaded at the time of submission for this paper's publication. Figures 6 through 8 show the up-to-date plots of the actual versus predicted settlements and loading patterns for Tanks TK-210, TK-211 and TK-401.

CONCLUSIONS

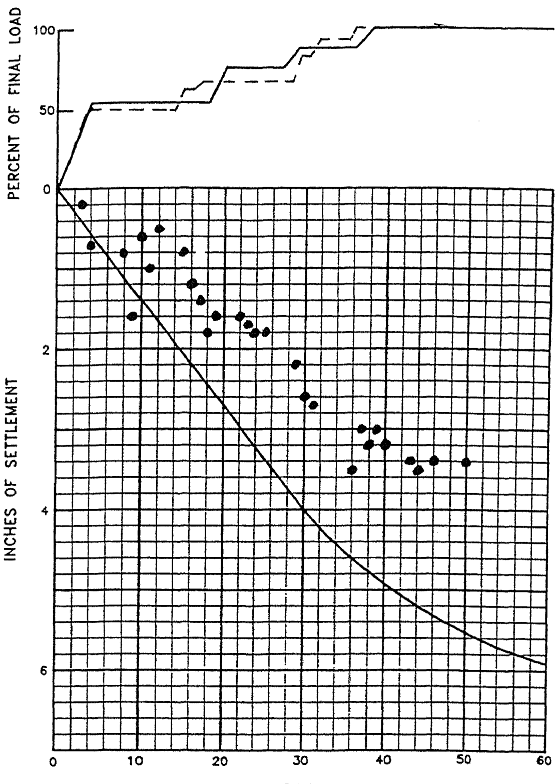
The field monitoring results, as shown on Figures 2 through 8 indicate the actual settlements at the center of the tanks correlate well with the predicted. Somewhat lesser settlements for the tanks R-410A and R-460A as compared to tanks R-410B and R-460B are attributed to the fact that R-410B and R-460B are further east. The thickness of the soft recent alluvial soils is believed to be thinner for the tanks further east. The stage-loading allowed the soils to consolidate and strengthen prior to placing the tanks in service. Future maintenance problems due to settlement for services such as piping have been minimized. The settlement of the fine-grained soils occurred much too quickly to assume a case of large continuous clay layers. The recorded settlement rates shown in Figures 2 through 8 tend to substantiate the theory of drainage paths created by the linking of silt and sand lenses/pockets.



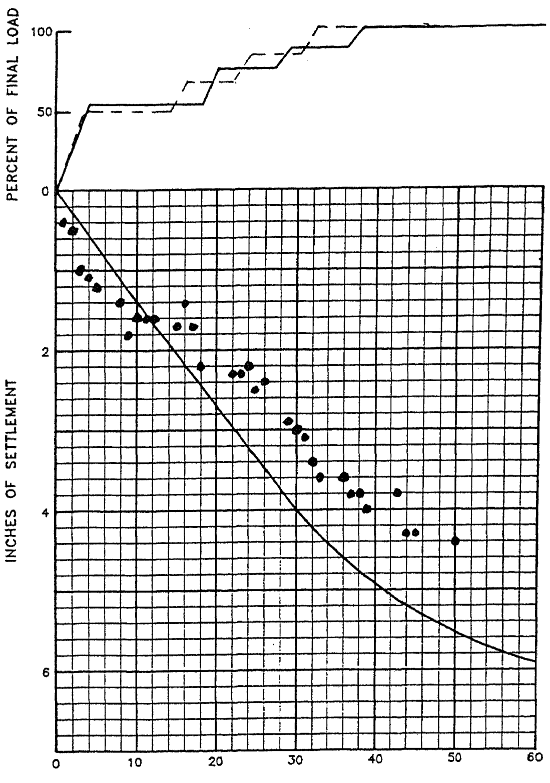
Predicted (——)
Actual (- - -) and (•)
Figure 2 Time Rate of Settlement Tank R-410A



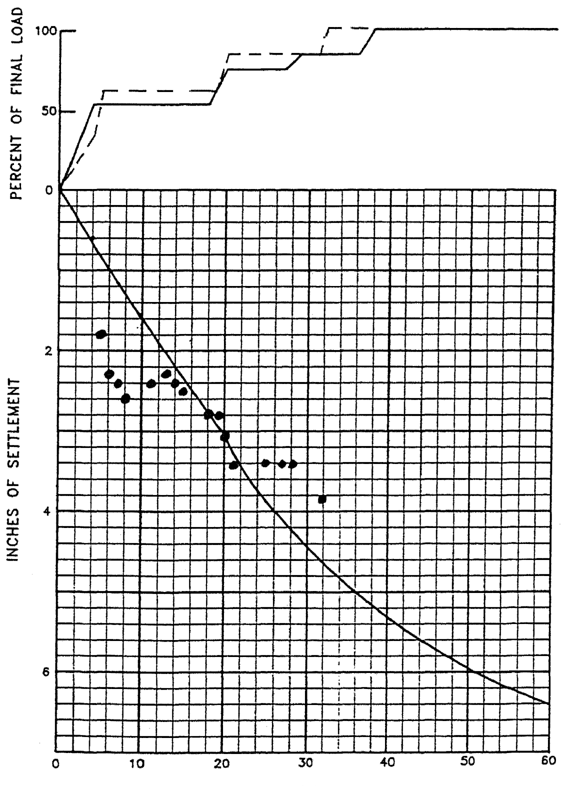
Predicted (——)
Actual (- - -) and (•)
Figure 3 Time Rate of Settlement Tank R-410B



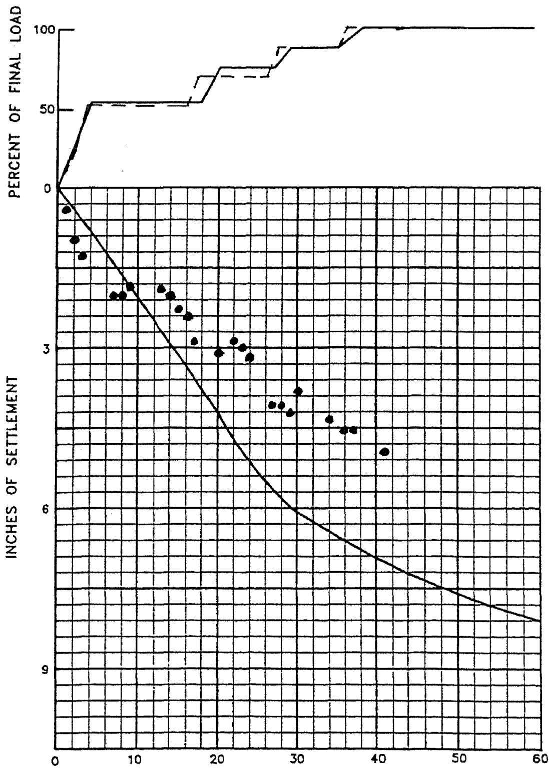
Predicted (——)
Actual (- - -) and (•)
Figure 4 Time Rate of Settlement Tank R-460A



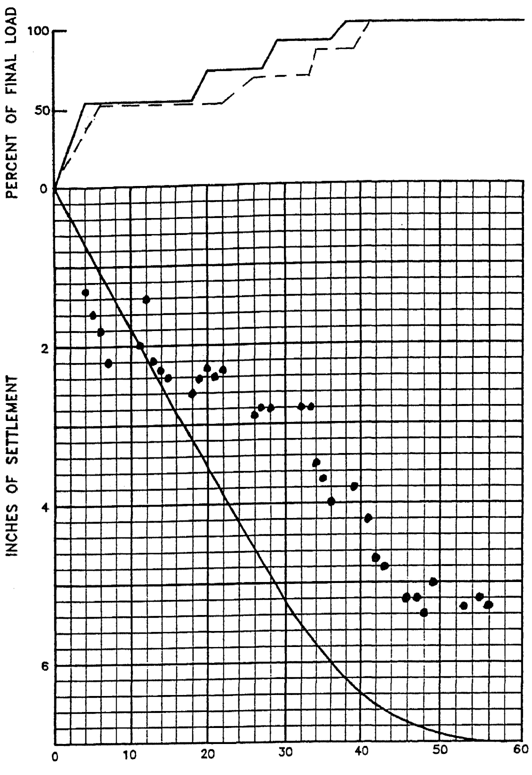
Predicted (——)
Actual (- - -) and (•)
Figure 5 Time Rate of Settlement Tank R-460B



Predicted (——)
Actual (- - -) and (•)
Figure 6 Time Rate of Settlement Tank TK-210



Predicted (——)
Actual (- - -) and (•)
Figure 7 Time Rate of Settlement Tank TK-211



Predicted (——)
Actual (- - -) and (•)
Figure 8 Time Rate of Settlement Tank TK-401

REFERENCES

Duncan, J.M. and D'Orazio, T. B. (1984), "Stability of Steel Oil Storage Tanks", Journal of Geotechnical Engineering, ASCE, Vol. 110, No. 9, September, pp. 1219-1238.

Foster, C. R. and Ahlvin, R. G. (1954), "Stresses and Deflections Induced by a Uniform Circular Load", Proceedings of the Highway Research Board, Vol. 33, pp. 467-470.

Skempton, A. W. and Bjerrum, L. (1957), "A Contribution to the Settlement Analysis of Foundations on Clay", Geotechnique, Vol. 77, pp. 168-179.

Terzaghi, K. (1925), Erdbaumechanik auf Bodenphysikalischer Grundlage, Franz Deuticke, Leipzig und Wein.