DEPARTMENT OF THE ARMY
U.S. ARMY CORPS OF ENGINEERS
441 G STREET, NW
WASHINGTON, DC 20314-1000

REPLY TO
ATTENTION OF

CECW-CE

APR 12 2010

MEMORANDUM THRU Mr. Jimmy Waddle, Chief Engineering and Construction, Mississippi Valley Division, U.S. Army Corps of Engineers, PO Box #80, Vicksburg, MS 39181

FOR Commander, Hurricane Protection Office, U.S. Army Corps of Engineers, P.O. Box 60267, New Orleans, LA 70118-3651

SUBJECT: Inner Harbor Navigation Canal Lake Borgne Barrier Wall-Waiver for Deflections of the Proposed Floodwall

1. Reference memorandum, dated 18 February 2010, subject as above.

2. The waiver for deflections of the proposed floodwall for Inner Harbor Navigation Canal Lake Borgne Barrier is approved.

3. Point of contact is Anjana Chudgar, 513-684-6210.

Encl

JAMES C. DALTON, P.E.
Chief, Engineering and Construction
Directorate of Civil Works

DEPARTMENT OF THE ARMY
HURRICANE PROTECTION OFFICE, CORPS OF ENGINEERS
P.O. BOX 60267
NEW ORLEANS, LOUISIANA 70160-0267

CEMVN-HPO

FEB 18 2010

MEMORANDUM THRU Mr. Jimmy Waddle, Chief, Engineering and Construction, Mississippi Valley Division, U.S. Army Corps of Engineers, Post Office Box 80, Vicksburg, Mississippi 39181

FOR Mr. James Dalton, Chief, Engineering and Construction, Headquarters, U.S. Army Corps of Engineers, 441 G. Street, N.W., Washington D.C. 20314-1000

SUBJECT: Inner Harbor Navigation Canal Lake Borgne Barrier Wall –Waiver for Deflections of the Proposed Floodwall

1. Request a waiver that permits estimated deflection of the floodwall in excess of nearest relevant USACE criteria deflection limitations. Current deflection estimations have been substantiated by using detailed soil-structure interaction (SSI) and finite element (FE) analysis methods based on parameters measured during the geotechnical subsurface investigation and the axial and lateral load tests. This final waiver is requested to maintain the schedule to provide 100-year level hurricane surge protection by June 2011.

2. Below are excerpts from USACE guidance that come nearest to providing relevant criteria.

a. HSDRRS, Updated June 12, 2008: "Maximum structural deflections at pile heads Case with 33⅓% overstress allowed:

Vertical – 0.67 inch or less
Horizontal – 1.0 inch or less

Larger deflections may be allowed for design checks if stresses in the structure and piles are not excessive. Larger deflections are limited to values that remain in the elastic state of the soil."

b. EM 1110-2-2906: "Calculated pile cap deformation should be checked against functional and geometric constraints on the structure. These values are usually ¼-inch axially and ½-inch laterally. For unusual or extreme loads these values should be increased."

3. The HSDRRS criterion is written in reference to sluice gates, fronting protection, flood gates, and T, L, and I-walls. The EM 1110-2-2906 criterion is written in reference to floodwalls, locks, dams, outlet works, and other pile supported structures. None of these structures have historically utilized the type of A-frame design to resist surge loads that the Lake Borgne Barrier Floodwall does.

4. Deflection analyses of the floodwall were performed using conservative soil parameters. These analyses indicate maximum horizontal deflections of the 66-inch plumb piles will be less than 2½ inches under the most conservative load case. To increase the accuracy of the estimated horizontal deflections, a lateral load test was performed at the Lake Borgne site to calibrate the soil model. A sensitivity analysis was also performed to analyze what effect a possible reduction in the soil strengths would have on the structure's response. The analysis indicates that even with soil strengths reduced by over 40%, the predicted deflections are within the elastic ranges of the structural components and connections of the floodwall.

5. The FE analysis also indicates the upper foundation soils are plasticized during a 100-year hurricane event. However, the axial and lateral capacity of the soils above elevation -45 were conservatively ignored in typical limit equilibrium analyses. Additionally, the lower foundation soils, where the majority of the axial soil resistance is derived, are not fully mobilized. Although local inelastic soil behavior exists in the upper soils, the total flood wall system still reacts linearly with the soil variation. In other words, when soil strength and modulus values were incrementally reduced, the estimated deflection at top of the wall varied almost linearly with these reductions. This implies that no significant system yield occurs in the analysis.

6. It is the opinion of the IHNC Senior Design Team and the Designer of Record that any net set the highly plastic soils in this area will experience due to the hurricane surge, will not affect the long term performance of the structure. Therefore, the estimated deflections are not detrimental to the long term performance of the floodwall. Attached is a brief summary and conclusion of the afore-mentioned sensitivity analysis including details of the floodwall structure and its associated resiliency.

7. The point of contact is Angela DeSoto-Duncan, (504) 595-2543.

Encl

ROBERT A. SINKLER
COL, EN
Commanding

CEMVN-HPO
SUBJECT: Inner Harbor Navigation Canal Lake Borgne Barrier Wall –Waiver for Deflections of the Proposed Floodwall

CF:
Mr. Walter Baumy (MVN) (w/encl)
Mrs. Anjana Chudgar (HQUSACE) (w/encl)
Ms. Angela DeSoto-Duncan (HPO) (w/encl)
Mr. Harold Daigle (OCPR) (w/encl)
Louisiana Office of Coastal Protection and Restoration
8900 Jimmy Weddell
Baton Rouge, LA 70807

Summary and Conclusion of the Lake Borgne Barrier Floodwall Sensitivity Analysis

The estimated deflections for the braced floodwall structure for the IHNC Lake Borgne Hurricane Protection Barrier exceed the maximum deflection requirements set in EM 1110-2-2906 and the HSDRRS Design Guidelines. These requirements were originally set for floodwalls, locks, dams, outlet works, and other pile supported structures. Therefore, a deflection criteria waiver is being sought though deflection criteria for structures such as the braced large-diameter concrete pile floodwall are not specifically addressed. In order to substantiate that request, a parameter sensitivity study has been undertaken to help predict the performance of the braced floodwall under a range of soil properties. The study consisted of three parts: a Plaxis soil strength reduction analysis, a structure serviceability check using SAP2000, and design checks of the structural components and connections under the stresses and moments determined by the previous two analyses. The results of the study indicate the structural performance of the floodwall is relatively insensitive to a change in soil strengths. All three parts of the study looked at the most conservative load case for the structure, Load Case VII, which includes the hurricane storm surge still water level, wave loads, and barge impact loads. Figure 1 (attached) shows the floodwall overlaid by the estimated horizontal deflection.

Plaxis Analysis

The soil strength reduction analysis was carried out using the finite element program Plaxis to determine how sensitive the floodwall structure is to weakened soil strengths. This investigation entails analyzing the floodwall structure with soil strengths that are incrementally reduced over a series of runs. Plaxis is uniquely appropriate for this task because it allows independent soil elements to influence those around one other in order to model the global behavior of the structure and the surrounding soil. Figure 2 shows the relative shear stress of the floodwall subjected to Load Case VII. The relative shear stress is the ratio of the calculated shear stress induced in the soil by the storm loads to the available shear strength. This plot provides an indication of how much of the foundation strength is mobilized. The relative shear stress is shown in the figure as a variation in color from blue (no mobilization or no change in stress on the soil) to red (full mobilization of the soil strength).

The results of the analysis indicate soil strength reduction factors of over 1.75 can be achieved while still providing adequate safety factors and without soil-structure instability of the floodwall system. The strength reduction factor of 1.75 is equivalent to a reduced strength of 1.0/1.75 (or 57% of the base case soil strengths). The maximum lateral deflections of the 66-in vertical pile relative to tip went from approximately 2½ inches (at EL -20 ft) for the base case (using design strengths) to about 3½ inches in the reduced strength case. Figure 3 shows the range of deflections (relative to the tip of the pile) corresponding to the strength reduction factor used. Figure 4 shows how the maximum horizontal deflection (at around elevation -10 ft to -20 ft) changes with changing strength reduction factor.

SAP2000 Analysis

The performance of the structural components under reduced soil strength is calculated by an additional SSI analysis using the structural analysis program SAP2000. This analysis used weakened p-y springs (lateral soil springs that correspond to individual soil layers and simulate resistance to lateral pile movement) to simulate the conditions in the fully softened Plaxis soil strength reduction analysis.

The results of the SAP2000 analysis showed the stress-strain behavior of the structural components remained elastic and within acceptable limits. The change in bending moment of the 66-inch vertical pile from the base soil strength case to the reduced soil strength case is depicted in Figure 5. As the figure shows, the maximum bending moment increased approximately 20% over the base case. Numerical results of the SAP2000 analysis are provided in Table 1.

Design Checks

The third part of the study indicated the serviceability performance of the steel battered piles, the pre-stressed concrete vertical piles, and their connections to the precast cap are satisfactory. Each component responds in an essentially elastic manner under the weakened soil strengths and the resulting factors of safely all exceed one. This indicates that even considering soil strengths with a reduction factor of 1.75 (strengths of 57% of the base case), the functional performance of the floodwall under the critical design event is acceptable.

Conclusions

Based on the results of this study and past investigations of the Lake Borgne Barrier Floodwall, the braced floodwall provides satisfactory functional performance when subjected to the critical design load case in weakened soil conditions. This provides reliable indication that the battered floodwall will continue to perform as it was designed under repeated loadings throughout its design life. Hence, it is reasonable to exceed the maximum deflection requirements set in the HSDRRS Design Guidelines or EM 1110-2-2906.

Table 1. Maximum values determined by the SAP2000 Sensitivity Analysis of the 66-inch vertical battered pile.

		SRF = 1	SRF = 1.75
Axial Force	(kips)	351	394
Shear Force	(kips)	210	213
Bending Moment	(kip-ft)	4614	5550
Vertical Deformation	(in)	0.036	0.052
Horizontal Deformation*	(in)	-2.41	-3.24

*The analysis indicates the maximum horizontal deformation will approximately occur at elevation -10 feet.

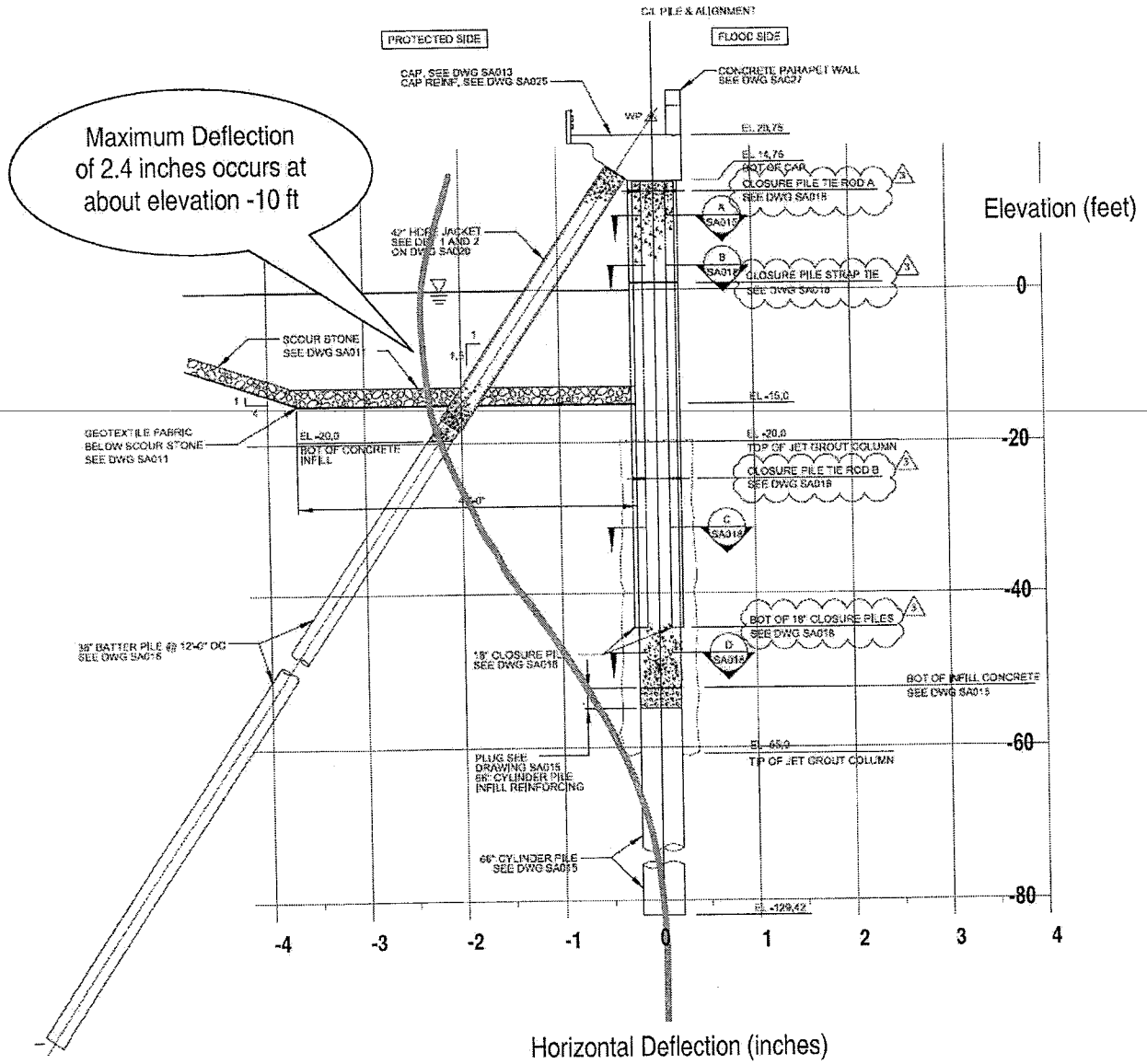

Figure 1
Lake Borgne Barrier
Typical Floodwall Section
with Estimated Deflections
Overlaid

Inner Harbor Navigation
Channel Hurricane Protection
Project
Orleans & St. Bernard
Parishes, LA

Horizontal Deflection (in inches) of the 66-inch vertical pile according to SAP2000, a soil-structure interaction analysis tool.

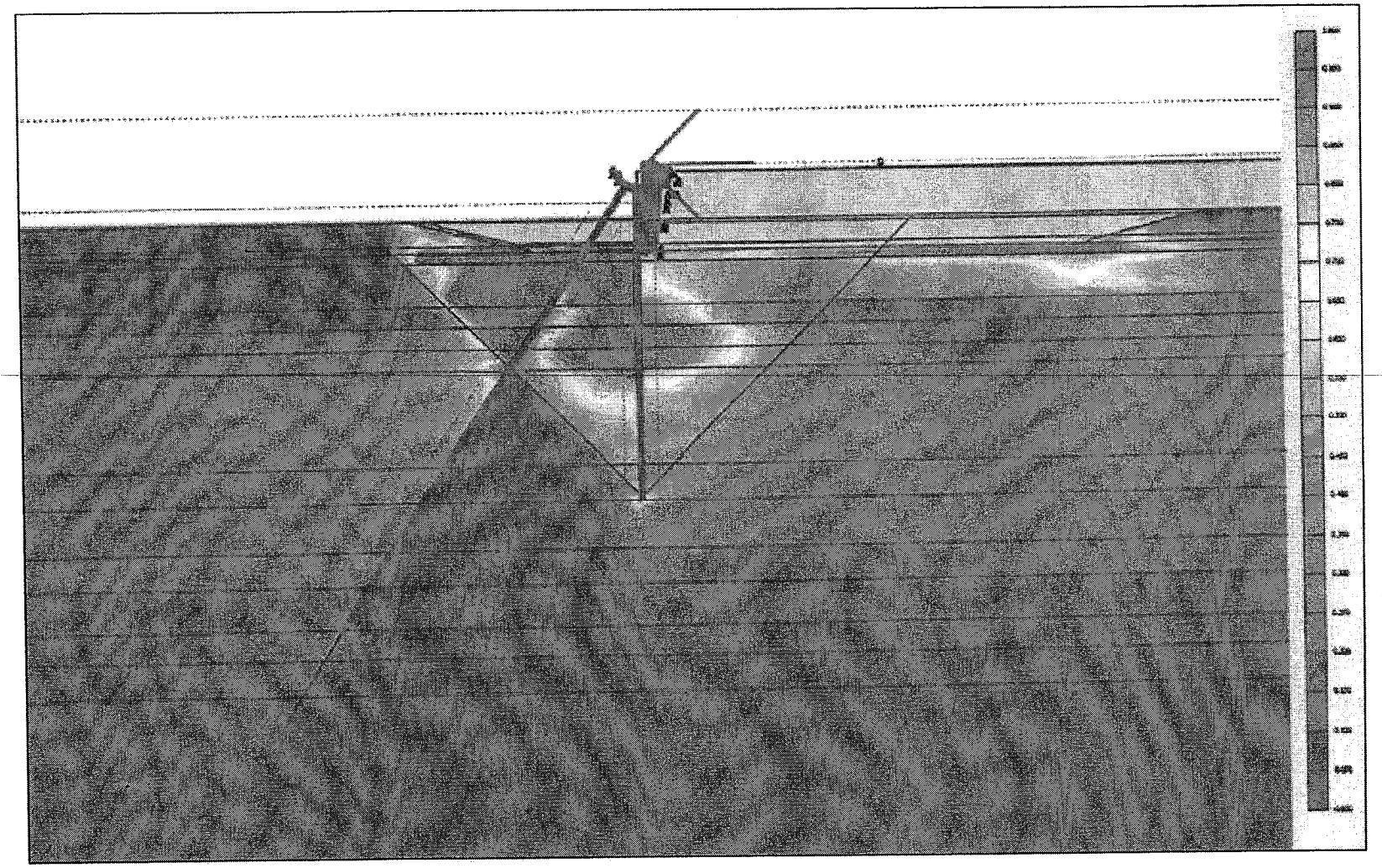

Figure 2. Relative shear stress under LC VII with Strength Reduction Factor = 1.0 (no reduction). The scale on the right depicts fully mobilized shear strength in red and no shear stress in blue.

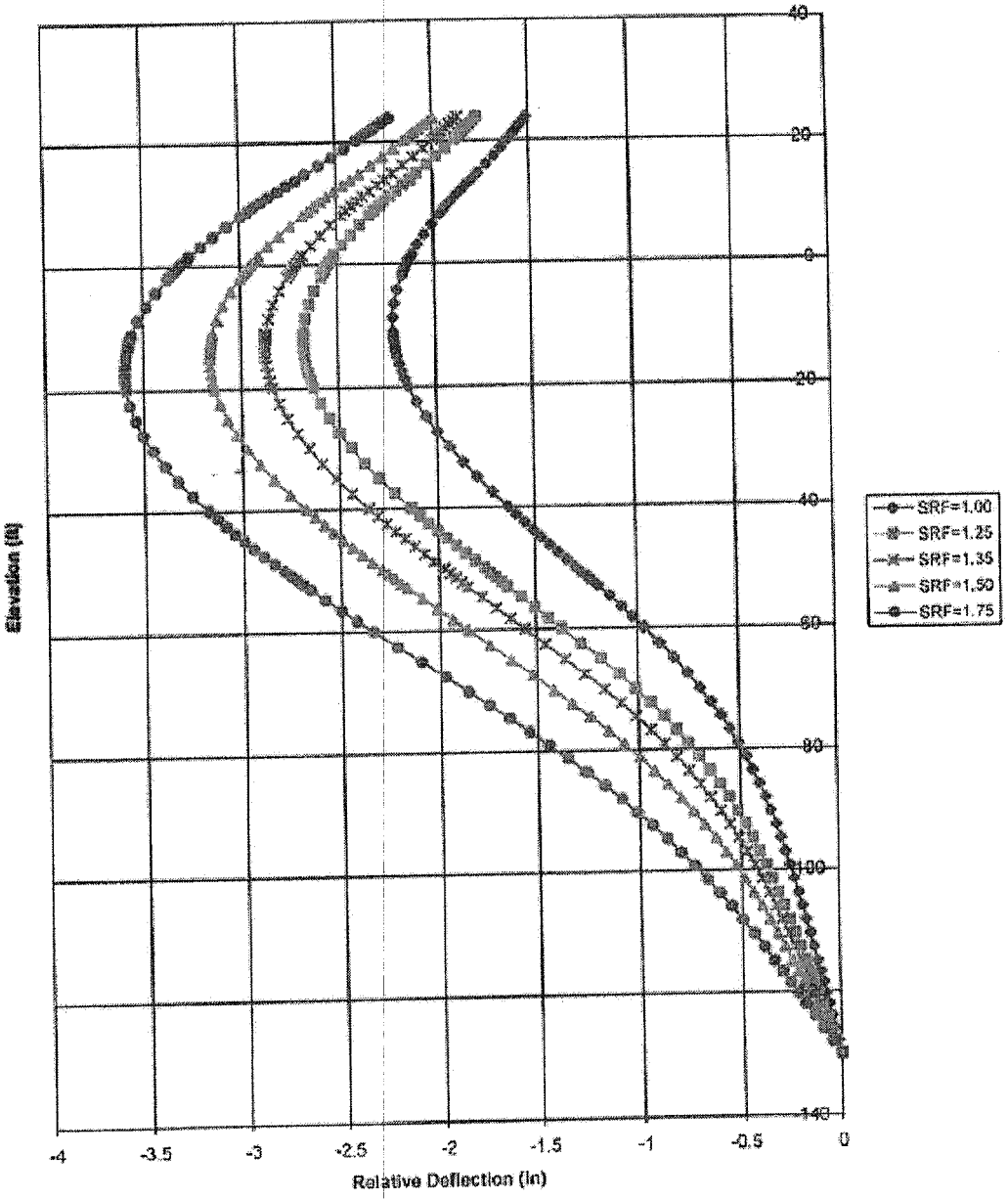

Figure 3. Relative (to pile tip) horizontal deflections of the 66-inch vertical pile for different strength reduction factors (SRF).

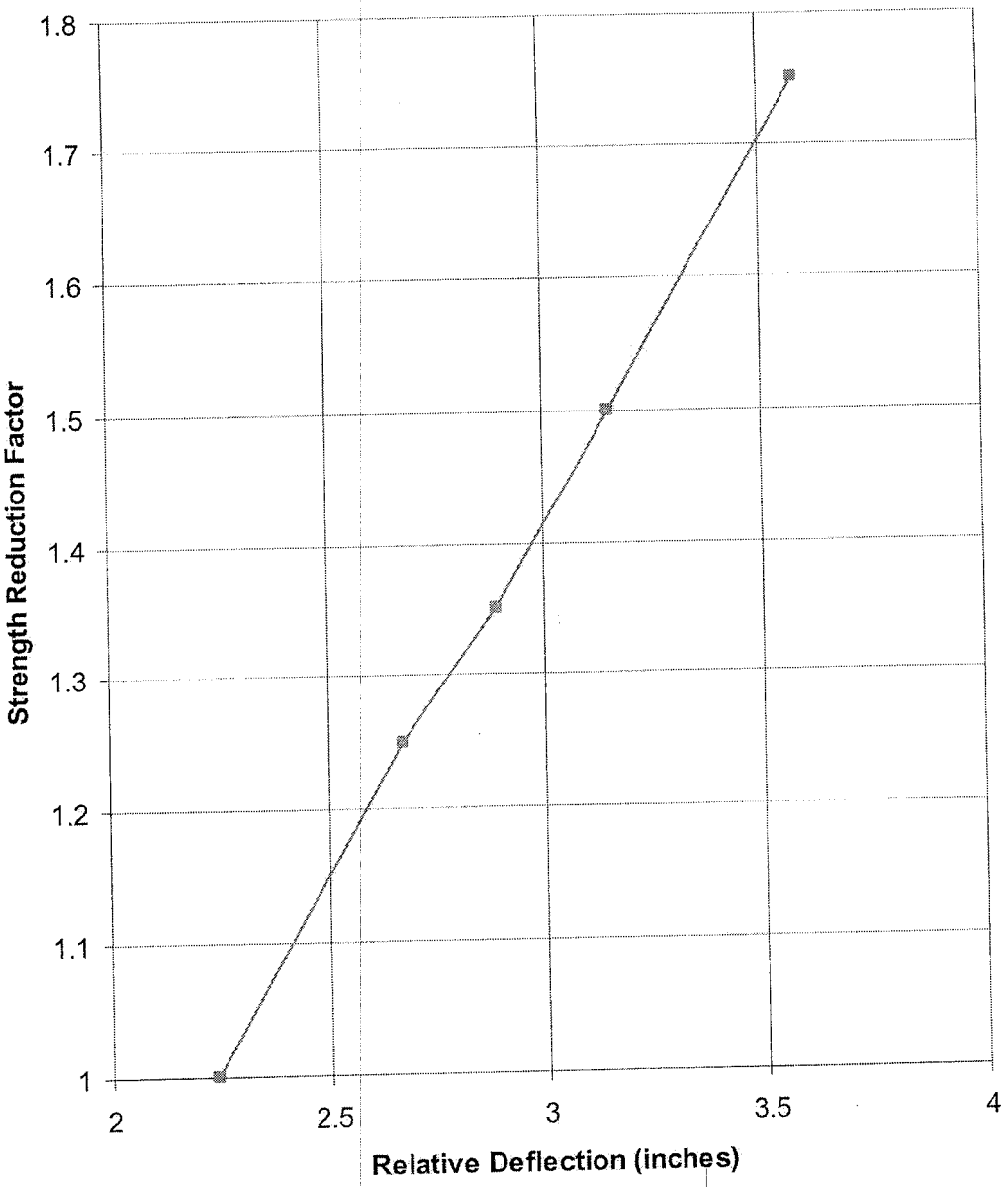

Figure 4. Strength Reduction Factor vs. Horizontal Deflection provided by Plaxis.

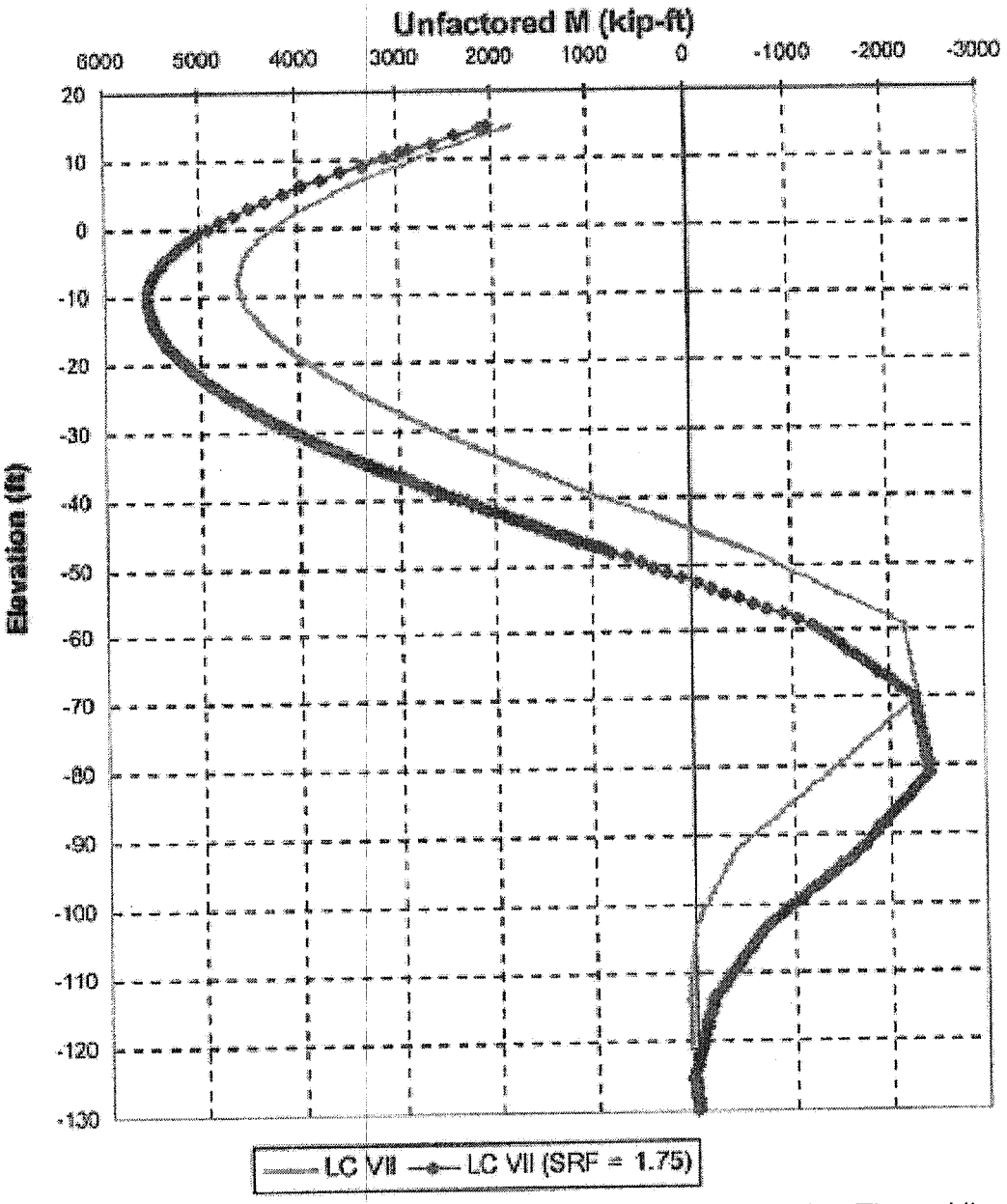

Figure 5. Variation in bending moment in the 66-inch vertical pile. The red line represents the analysis with no strength reduction, the blue line the case using a strength reduction factor of 1.75.