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SYNOPSIS A deteriorated 600 ft. long pier in Quincy, Massachusetts consisting of timber pile supported relieving platform and anchored steel sheet pile bulkhead sections was replaced with a new pier. The majority of the new pier consists of a deadman anchored steel sheet pile bulkhead. Due to the proximity of adjacent structures and another existing pier, two areas along the new pier could not accommodate an anchored bulkhead system. In these two areas, relieving platform and double steel sheet pile wall systems were constructed. Inclinometer data showing horizontal movements in the sheeting during the construction and post-construction periods are presented.

INTRODUCTION

Pier No. 3 is a pier located along the Weymouth Fore River in Quincy, Massachusetts at the site of a former shipyard. The site is currently operated by the Massachusetts Water Resources Authority (MWRA). The pier was reconstructed in 1990 to serve the recently completed MWRA Sludge Processing and Disposal Facility (SP&DF). The SP&DF treats sludge transported to the site on barges. Due to its deteriorated condition, the previously existing pier was reconstructed to provide a facility for the barges to dock and unload sludge.

PREVIOUSLY EXISTING CONDITIONS

The previously existing pier consisted of timber pile supported relieving platform and anchored steel sheetpile bulkhead sections. The SP&DF was constructed adjacent to the pier. At its northern end, Pier No. 3 is adjacent to another relieving platform structure, Pier No. 2. At its southern end, Pier No. 3 abuts a steel sheet pile cellular cofferdam of an adjacent drydock facility as shown on Figure 1.

The previously existing pier was approximately 600 ft. long. The northern 500 ft. of the pier consisted of a timber pile supported relieving platform. A typical section across this portion of the pier is shown on Figure 2. The relieving platform was approximately 40 ft. wide. Vertical and battered piles were situated in bents spaced approximately 5 ft. on-center along the length of the pier. The relieving platform timber deck supported miscellaneous soil fill and two 10 ft. high concrete "walls" which, in turn, supported a crane which ran along the pier. The relieving platform included a timber bulkhead to retain the adjacent soil.

The southern 100 ft. of the old pier consisted of a steel sheet pile anchored bulkhead. The dredge line to top of wall height varied from 25 to 30 ft. The bulkhead consisted of PZ38 size interlocking steel sheeting connected to 3 in. diameter steel tie-rods spaced approximately 6 ft. on-center. The tie-rods were anchored to a massive H-pile supported concrete deck which was used in connection with former shipbuilding activities at the site.

A survey of the previously existing relieving platform indicated that the timber bulkhead and many of the timber piles were rotted. In the anchored bulkhead portion of the pier, corrosion had led to the development of holes in the steel sheeting, resulting in the loss of retained fill and ground subsidence.

Based on the deteriorated condition of the previously existing pier, it was determined that a replacement pier was required to service the new SP&DF.

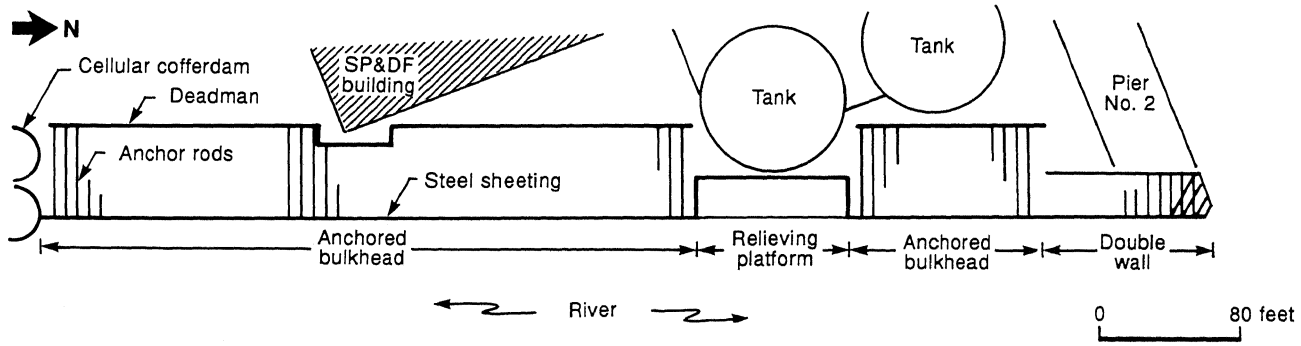

Figure 1 - Site Plan

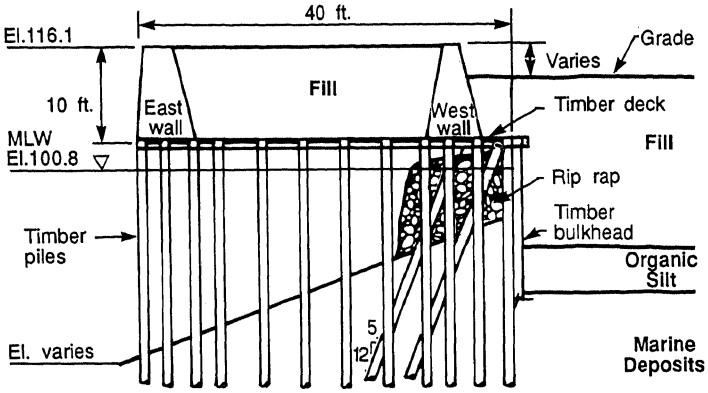

Figure 2 - Previously Existing Relieving Platform

SUBSURFACE CONDITIONS

The site is underlain from ground surface down by:

Miscellaneous Fill - Miscellaneous fill, ranging in thickness from 9 to 25 ft. typically, was encountered immediately inshore of the old Pier No. 3 along its entire length. The fill consisted of loose to medium dense coarse to fine sand, trace silt, and varying amounts of gravel and cobbles. Portions of this fill were replaced with crushed stone and granular soil backfill during construction of the new pier.

Organic Deposits - Organic deposits consisting of soft to stiff organic silt, little to trace sand and clay, were encountered in thicknesses up to 7 ft. The organic stratum was not continuously encountered along the length of the pier.

Glaciomarine Deposits - These deposits at the site consist of interbedded medium stiff to very stiff silty clay and clayey silt, and loose to dense fine sand and silty fine sand. Immediately inshore of the pier, the stratum was encountered in thicknesses ranging from 50 to 80 ft.

Glacial Till: The glacial till consists of very dense coarse to fine sand with varying amounts of silt and gravel. Where present, the top of glacial till was encountered at depths ranging from 90 to 120 ft. below ground surface.

Bedrock: Subsurface explorations were advanced into the top 3 ft. of bedrock. This portion of the bedrock consists of weathered argillite.

A typical soil profile of the upper strata is shown on Figure 2.

Water levels in the Weymouth Fore River are tidal, with Mean High Water at El. 110.4 and Mean Low Water at El. 100.8 or approximately 6 and 16 ft., respectively, below the top of the pier. Elevations included herein are in feet and referenced to Metropolitan District Commission Datum which is 105.62 ft. below U.S. National Geodetic Vertical Datum.

REPLACEMENT PIER DESIGN

Anchored Bulkhead

A deadman anchored interlocking steel sheet pile bulkhead was adopted as the replacement system for the majority of the pier as the most economical option. Based on an analysis performed using the Free-Earth Support Method with appropriate moment reduction, PZ40 size steel sheet piling was selected for the new bulkhead. The bulkhead consists of 60 ft. long steel sheet piles anchored to a concrete deadman with 3 in. diameter steel tie-rods spaced 6.5 ft. on-center. Sections of the new bulkhead superimposed on the previously existing pier are shown on Figures 3a and 3b.

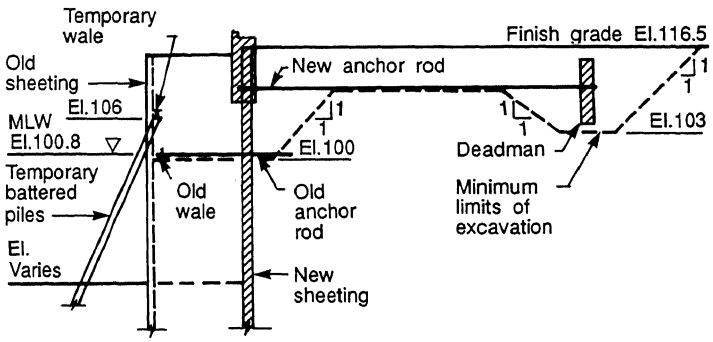

Figure 3a - Anchored Bulkhead at Previously Existing Anchored Bulkhead

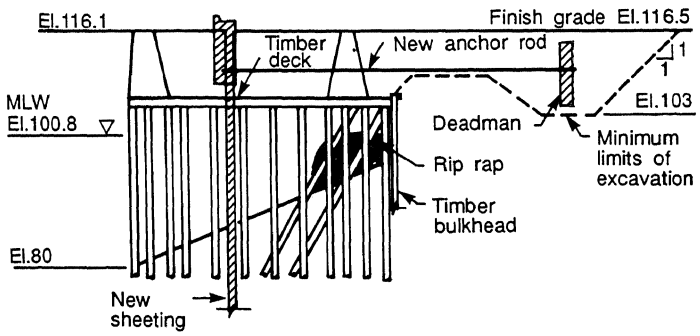

Figure 3b - Anchored Bulkhead at Previously Existing Relieving Platform

Relieving Platform

Along a section of the new Pier No. 3, a pile supported 80 ft. diameter elevated tank was constructed for the SP&DF immediately adjacent to the pier. Because of the proximity of the tank piles, a concrete deadman could not be constructed in this area. A relieving platform consisting of vertical and battered 16 in. diameter concrete-filled steel pipe piles supporting a reinforced concrete deck was adopted for this 80 ft. length of the pier. The relieving platform included PZ40 size steel sheet pile walls incorporated into the deck to retain the soil behind the pier as shown on Figure 3c.

Double Wall

The northernmost portion of Pier No. 3 abuts the old Pier No. 2 approximately perpendicularly. An existing mass concrete structure separates the two piers. Due to the presence of Pier No. 2, an anchored bulkhead could not be constructed in this portion of the pier and a double wall system was adopted for the northernmost 100 ft. of Pier No. 3. The double wall section consists of two rows of 70 ft. long PZ40 size steel sheet piles connected across with anchor rods as shown on Figure 3d. The zone between the walls was backfilled with crushed stone.

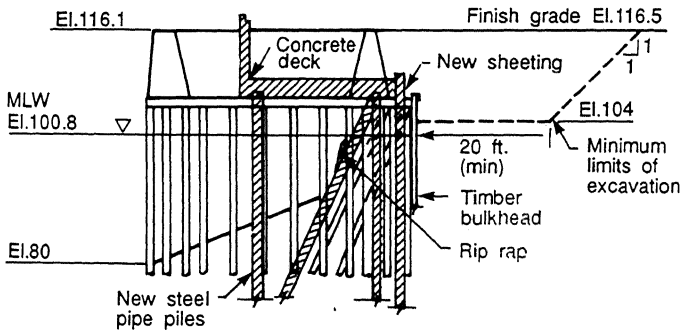

Figure 3c - New Relieving Platform

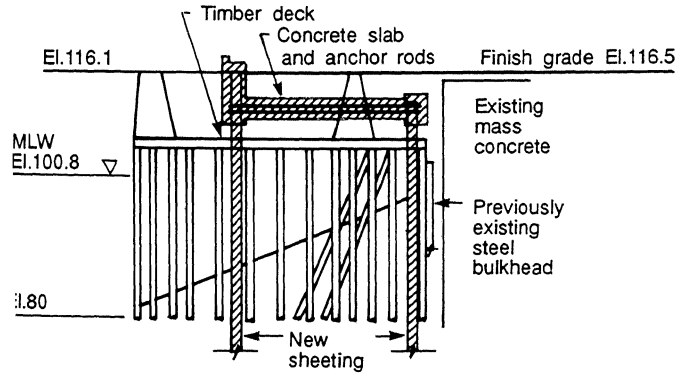

Figure 3d - Double Wall

PERFORMANCE OF THE PIER

Nine inclinometers were installed along the pier to monitor its performance during the construction and post-construction periods. The inclinometers were installed in steel housings consisting of 6 in. x 6 in. x 3/8 in. steel angles welded onto the inshore side of the steel sheet piles.

The inclinometers were surveyed periodically during construction and through a 17 month period after the completion of the pier. Data obtained in four of the inclinometers representative of each of the different sections are discussed below together with corresponding construction activities in the vicinity of the particular instrument.

Anchored Bulkhead - Sheet Pile Bulkhead Section

Inclinometer I-1 was installed in the portion of the anchored bulkhead along the previously existing steel sheet pile bulkhead. Inclinometer surveys are presented graphically on Figure 4 and discussed below, along with corresponding construction activities.

1. The following construction activities were performed prior to inclinometer installation: (i) the concrete deadman was constructed; (ii) a temporary bracing system using battered H-piles was installed to support the existing bulkhead prior to cutting the old anchor rods; (iii) the anchor rods were cut and the new steel sheeting was installed inshore of the old sheeting.

2. On 9 October 1990, the anchor rods in this area were installed. On 10 October, inclinometer I-1 was installed and surveyed.

3. Backfill was placed behind the steel sheeting to near finished grade on 11 October. An inclinometer survey performed on 18 October indicated resulting total outward horizontal movements of 0.3 in. It is likely that existing fill between the new and old steel sheeting contributed to limiting horizontal movements to these levels.

4. From 26 November to early December, the concrete encasement over the wale and top of sheeting was constructed and backfilling completed to the finished grade of El. 116.5. A survey performed on 3 January 1991 indicated total outward horizontal movements of up to 1.3 in.

5. In December 1990 and January 1991, the old steel sheet pile wall and temporary bracing system were cut off at mudline and removed. The fill between the old and new sheeting was excavated to El. 80. A survey performed on 11 February 1991 indicated total outward lateral movements of up to 2.3 in. with the largest movements occurring just above the mudline, as expected.

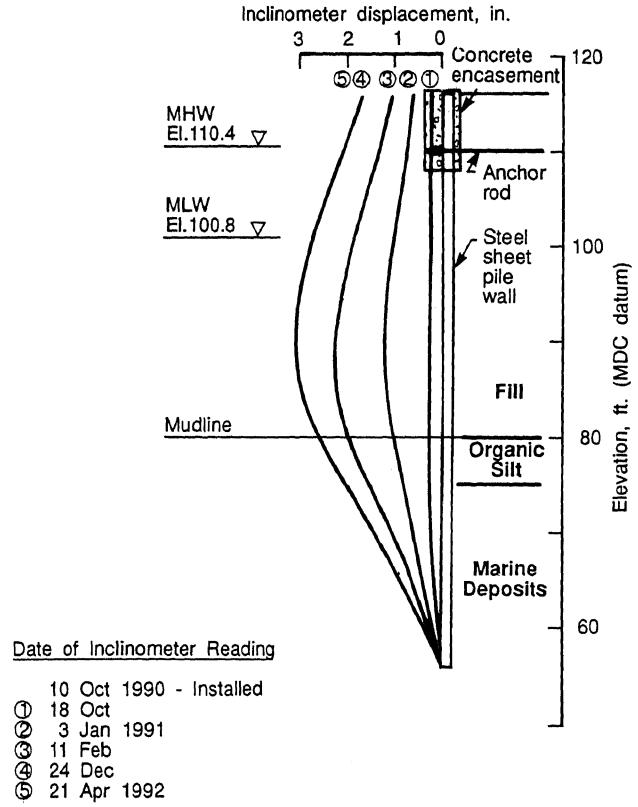

Figure 4 - Measured Displacements at Inclinometer I-1

6. Periodic inclinometer surveys performed during the 15 month period following the completion of construction activities indicated outward horizontal movements continued at a decreasing rate, and stabilized after approximately one year, as shown on Figure 5.

Anchored Bulkhead - Relieving Platform Sections

Inclinometer I-2 was installed in a portion of the anchored bulkhead along the previously existing timber relieving platform. Inclinometer surveys are presented graphically on Figure 6 and discussed below, along with corresponding construction activities.

1. The following construction activities were performed prior to inclinometer installation: (i) the concrete deadman was constructed; (ii) portions of the old relieving platform were demolished as necessary to construct the new bulkhead; demolition included extraction of wood piles along the new sheeting line; (iii) the new steel sheeting was installed.

2. On 2 October 1990, the anchor rods were installed. Inclinometer I-2 was installed and surveyed on the same day.

3. On 4 October, the majority of the backfill behind the steel sheet pile wall was placed to approximately finished grade, El. 116.5. A survey performed on 10 October indicated total outward horizontal movements of up to 1 in.

4. From 16 to 26 November, the concrete encasement was constructed and backfilling behind the sheeting completed. A survey performed on 26 November indicated total outward horizontal movements of up to 1.3 in. with the largest movements occurring just above mudline, as expected.

5. Periodic inclinometer surveys performed during the 17 month period following the completion of construction activities indicated outward horizontal movements continued at a decreasing rate, and stabilized after approximately one year, as shown on Figure 5.

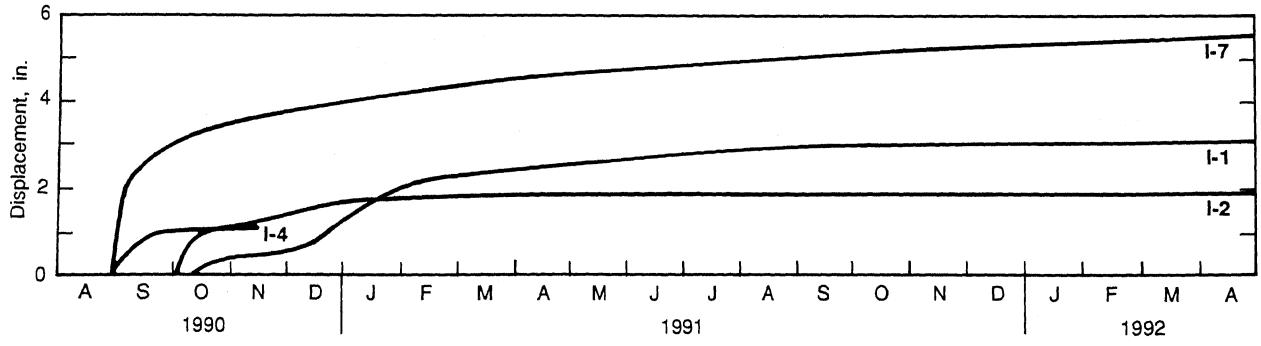

Figure 5 - Inclinometer Measured Maximum Horizontal Displacements vs. Time

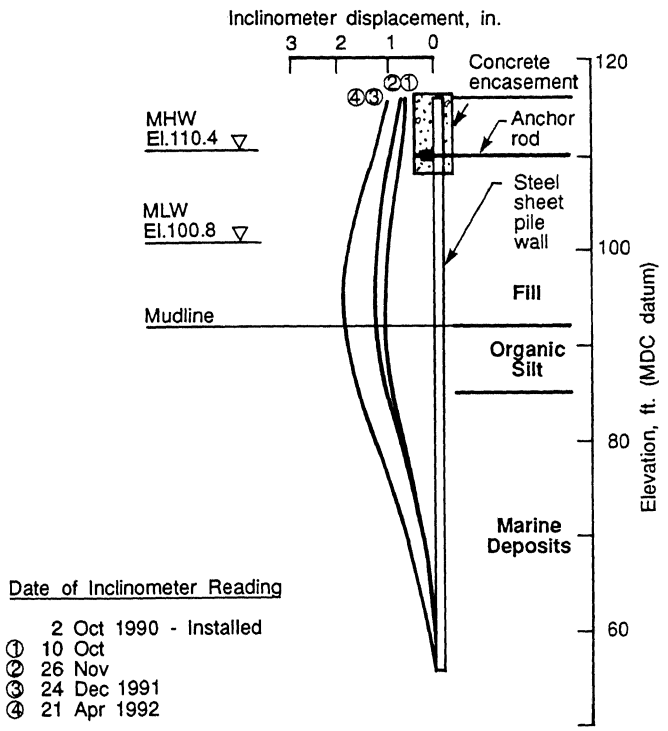

Figure 6 - Measured Displacements at Inclinometer I-2

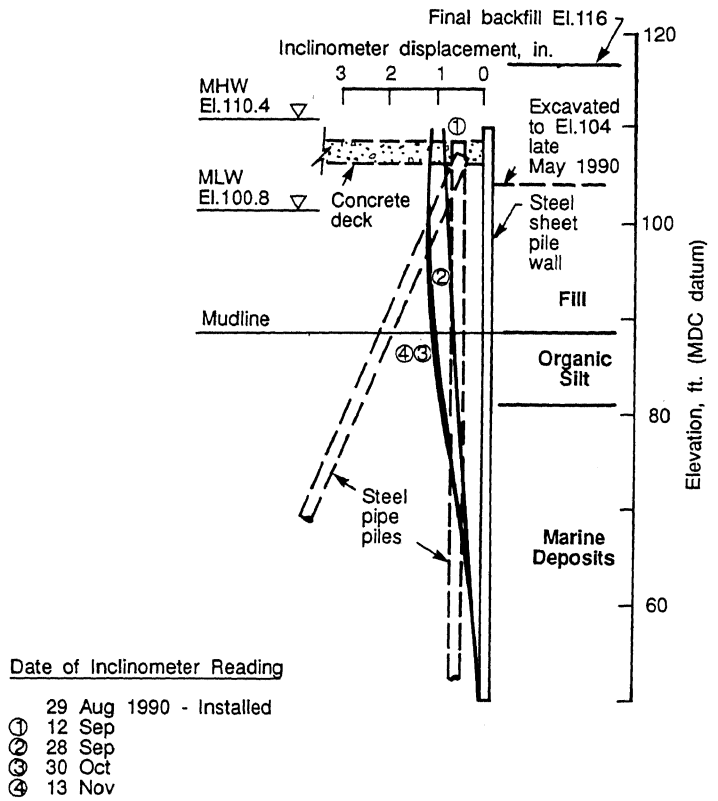

Figure 7 - Measured Displacements at Inclinometer I-4

elieving Platform

nclinometer I-4 was installed in the new elieving platform. Inclinometer surveys are esented graphically on Figure 7 and discussed low, along with corresponding construction tivities.

The following construction activities were performed prior to inclinometer installation: (i) fill inshore of the previously existing timber relieving platform was excavated to El. 104 to partially relieve lateral earth pressures against the new and old sheeting during construction; (ii) the relieving platform was demolished and wood piles extracted as necessary to allow for the installation of new steel sheeting and steel pipe piles; (iii) the steel sheet piles and steel pipe piles were installed.

On 29 August 1990, inclinometer I-4 was installed and surveyed. A survey performed on 12 September indicated total outward horizontal movements of up to 1 in. at the top of the steel sheeting, which was acting as a cantilevered system during this period. Visual observations indicated significant outward horizontal movements had occurred prior to installation of the inclinometer. These movements were caused by lateral earth pressures against the sheeting from the existing fill, disturbance from construction activities and reduction in passive earth resistance in front of the sheeting due to the wood pile extraction.

3. On 17 September, the relieving platform concrete deck was constructed, engaging the lateral resistance provided by the battered steel pipe piles. A survey performed on 28 September indicated total outward horizontal movements of up to 1.2 in.

4. On 30 September, backfilling was performed behind the steel sheeting and above the relieving platform deck to approximately finished grade, El. 116.5. A survey performed on 3 October indicated that the filling caused negligible movements of the sheeting. The final survey performed on 13 November indicated no additional movements from the previous reading, suggesting the relieving platform had stabilized, as shown on Figure 5.

Double Wall

Inclinometer I-7 was installed in the outshore wall of the double wall section. Inclinometer surveys are presented graphically on Figure 8 and discussed below, along with corresponding construction activities.

1. The following construction activities were performed prior to inclinometer installation: (i) the relieving platform was demolished and wood piles extracted as necessary to allow for the installation of new steel sheeting; (ii) the steel sheet piles were installed.

2. On 28 August 1990, the anchor rods connecting the two walls of the double wall were installed. On 29 August, inclinometer I-7 was installed and surveyed.

3. On 30 August, the zones between the double walls and inshore of the double wall were backfilled to El. 109, or just below the anchor rod elevation. A survey performed on 6 September indicated total outward horizontal movements of up to 2.4 in.

4. On 26 September and 17 October, the concrete slab and encasement, respectively, were constructed. A survey performed on 18 October indicated outward horizontal movements of up to 3.2 in.

5. On 22 October and 5 November, backfilling was completed above the concrete slab to finished grade at El. 116.5. A survey performed on 14 November indicated small additional outward movements of up to 0.4 in. from this activity.

6. Subsequent surveys performed for the 17 month period after the completion of construction activities indicate movements continuing but at a decreasing rate, as shown on Figure 5.

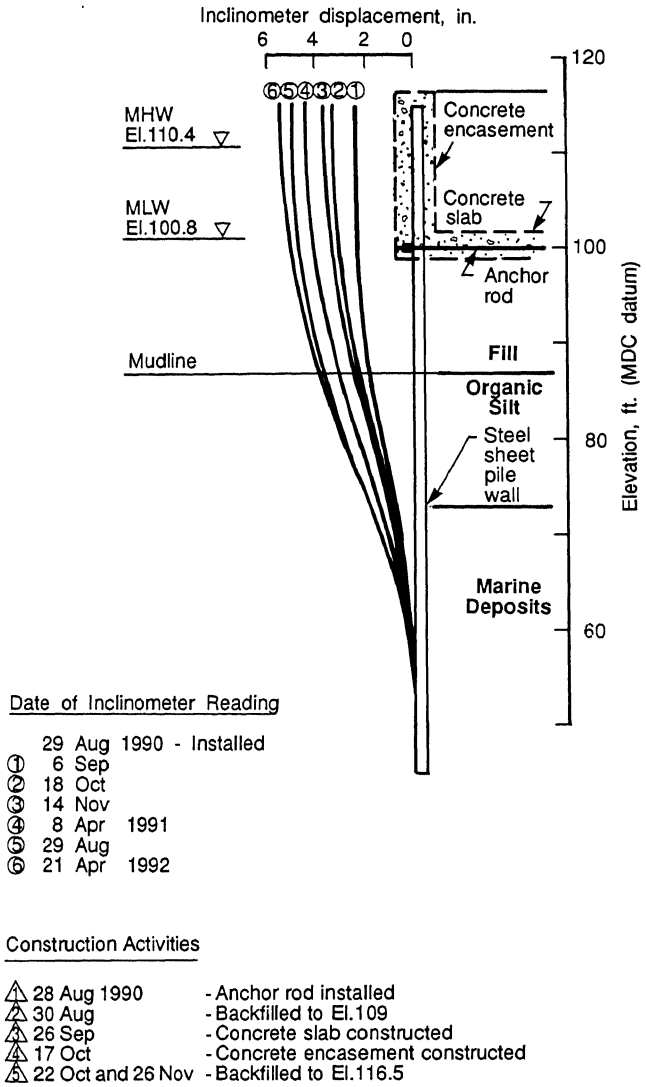

Figure 8 - Measured Displacements at Inclinometer I-7

CONCLUSION

The inclinometer surveys performed during the pier construction and post-construction periods indicated good correlation between construction activities and measured movements of the steel sheeting. The surveys provided useful information to assess the effects of particular construction activities on pier performance, namely the magnitudes, configurations and rates of pier movements. Post-construction surveys provided information on the long-term effects of construction activities and have indicated that pier movements essentially stabilized approximately one year after its construction. The surveys have indicated that the total magnitudes of the movements have been within expected and tolerable ranges for the satisfactory performance of the pier.

ACKNOWLEDGEMENT

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