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Instrumentation to Monitor Bridge Foundation on the Crosstown Project

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Introduction

The Crosstown Bridge Monitoring Project is located at the intersection of Highway 62 and Interstate 35W a few miles south and west of downtown Minneapolis. The bridge being evaluated is at a railroad overpass located midway along the Crosstown expansion. This research project involved placing instrumentation on the bridge foundation and checking the initial instrumentation readings in order to measure the change in the foundation loading during the course of the construction project.

For several years there have been questions pertaining to the forces in the pile foundations that support highway embankments. This project placed strain gages on the pile foundations in order to monitor these forces over time. These gages measure the change in the length of the piles over time (thus, indirectly, the change of the load applied to the piles) and were placed in select locations on the piles prior to being driven into the ground to support the bridge abutments. To protect the gages during driving, steel angles were welded to the piles to cover the gages and the cables. The cables were connected to a data collection system in order to monitor the foundation over time.

This portion of the overall project involved testing the strain gages prior to pile driving and after pile driving in order to determine if any damage to the gages occurred during pile driving. Readings taken using a datalogger and a simple multimeter show the results of this check, with conclusions relating to the mortality of the gages. Although this project is still in its preliminary stages, the objective of the overall project will be to monitor and record the strains and forces in the bridge foundation for several years.

Instrumentation Plan

The project involved the placement of twelve strain gages on each of the three instrumented piles. Six pairs of diametrically opposed gages were welded to the piles, spaced out every ten feet with two sets of gages near the bottom of the pile. Identical gage placement was done for three piles, one standard steel pipe pile and two Teflon-coated steel pipe piles. The piles were 65 feet long and 16 inches in diameter. The piles were first driven to a specified resistance, and then re-struck four days later in order to measure the increase in pile resistance after driving. Data were recorded before driving, a week after driving and finally would have a continuous recording once the bridge abutment was constructed.

The first step of the project was to prepare the piles for the strain gages. This involved significant planning and multiple tasks. The first task was to construct drawings for the piles that provided lengths, dimensions, and other necessary specifications for the angle iron that would protect the devices and cables (see Figure 1a). Once the appropriate lengths of angle iron were obtained, the next step was to obtain angle iron and cut it to the proper lengths. Each pile needed a set of angle iron to encase the gages as well as the cables that would travel to the tip of the pile. A secondary step was also to prepare the angle iron at the pile ends. This involved welding 45 degree angles to the angle to decrease the stress and strain in the angle during driving. Once this was done, holes were drilled at two foot increments for foam to be inserted to secure the cables. This concluded the material preparation.

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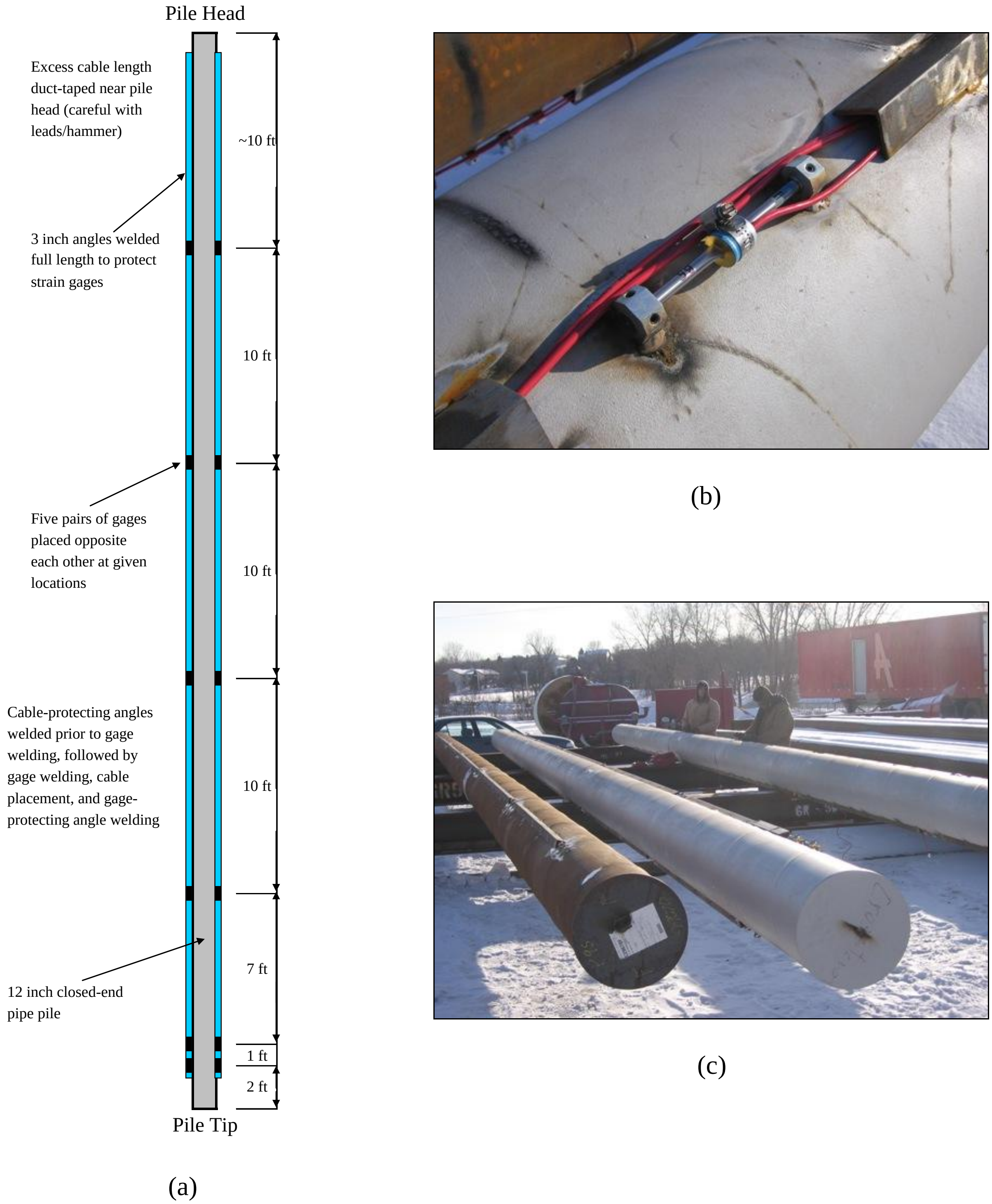

Figure 1. Placement of Strain Gages on Pipe Piles: (a) Schematic showing position of strain gage pairs, (b) Picture showing strain gages welded to pipe pile, (c) placement of strain gages on each of the three instrumented piles at the construction yard.

The next step of the project was to attach and protect the strain gages. The strain gage brackets were welded to the piles, strain gages were attached, and the cables were run the length of the piles (see Figure 1b and Figure 1c). The gages and cables are both heat sensitive, therefore heat prevention and caution were vital. After the gages were installed and the cables were pulled through the angles, they were covered by the larger protective angles and foam was inserted to hold the cables in place during pile driving. The final step of the pre-driving process was to get preliminary readings from the gages for a base reading. This would allow a comparison between the pre-driving and post-driving readings. These initial strain readings are shown in Figure 2.

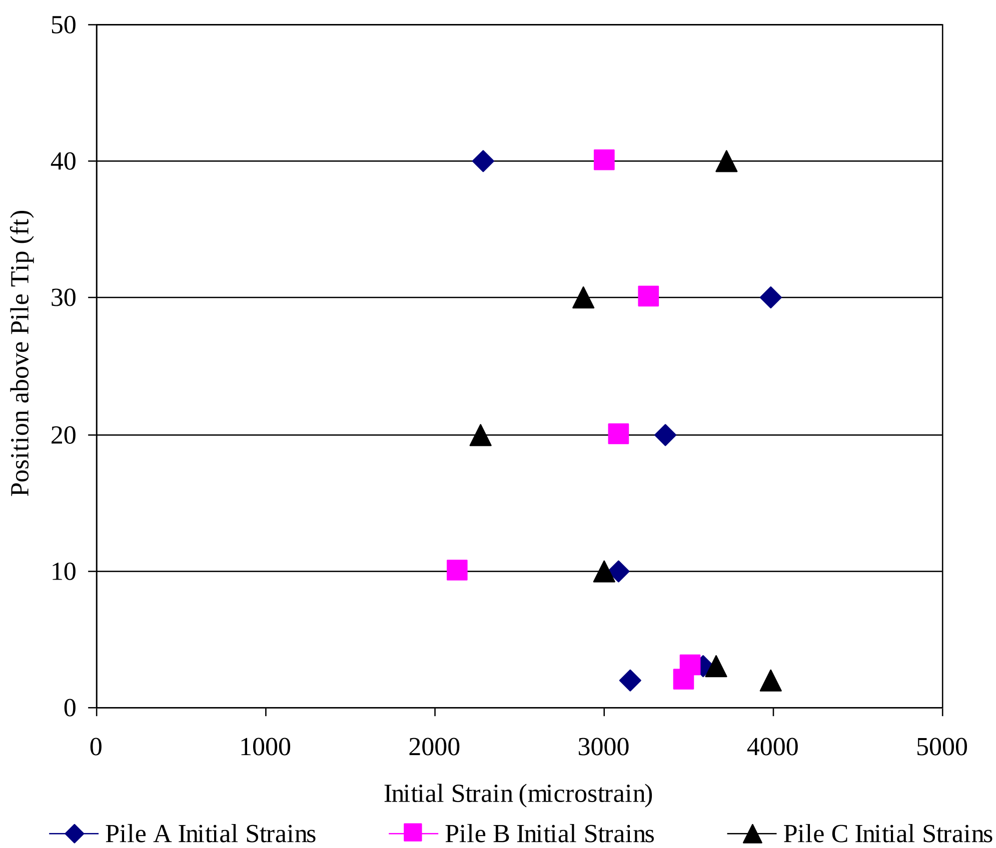

Figure 2. Initial Strain Readings for Instrumented Pipe Piles

The final step of the pre-driving preparation was the fastening and securing of the cables to the top of the pile to hold them in place during mobilization and driving. This was one of the main concerns of the project due to the long travel of the piles and the shaking due to the pile driving hammer blows. The cables were bound and wrapped with a cloth to prevent them from shifting as they were driven. They were then bound with multiple ratchet straps to hold them in place. After this, they were ready to be transported to the site and driven into the foundation soil. Figure 3 shows the piles after mobilization to the site (Figure 3a), the carefully wrapped cables near the top of the pile (Figure 3b) and one of the piles being driven into the foundation soil (Figure 3c).

a) b) c)

Figure 3. Instrumented Pile Mobilization and Driving on Crosstown Project: a) Three instrumented piles on the construction site, b) Cables carefully wrapped near the top of the pile, c) An instrumented pile being driven.

The strain gages were a vital component of the project. The gages measure both strain and temperature at the outer edge of the pile. The gages sent the data via cable to a data receiver which relayed the information through a transfer unit to the data logger.

This data could then be downloaded onto a computer directly or saved on the logger to be retrieved at a later date. The information was collected over 90 second intervals with an average reading being recorded after a period of nine minutes, after which the process is repeated.

Pipe Pile Description

One of the main components of the project is the piles that were to be driven. The instrumented piles were three of over 30 piles used for the northeast abutment of the bridge. The piles were 16 inches in diameter and 65 feet long. The three piles that were chosen were a standard steel pipe pile and two Teflon-coated steel pipe piles. These pipe piles were shown in Figure 1 and Figure 3. Figure 4 shows most of the piles driven for the bridge abutment discussed for this project.

Figure 4. Pictures of Instrumented Piles and Additional Piles at Project Site.

This test is intended in part to compare the behavior of the more costly Teflon-coated piles to the standard piles. The Teflon-coated piles, theoretically, are supposed to minimize the downward force of the soil on the pile during embankment construction by limiting the friction between the pile and the soil. This friction on the pile is advantageous if the pile is supported by the soils, which is typically the case with the soil pushing up on the sides of the pipe for traditional piles. The nature of this project was to determine if the soil was acting in the opposite fashion, actually pushing the piles downward as the embankment was constructed and the soil located around the piles was forced downward with respect to the pile. The information collected from the Teflon-coated and standard pile would be useful for situations when there is a high probability of downward force; the more expensive Teflon-coated pile should not be affected by this and thus be worth the increased cost. The Teflon-coated piles added increased labor during the installation of the gages as well. The Teflon needed to be ground down so the welds could securely attach the gages as well as the angle iron protection.

Data Collection and Analysis

Data collection was taken several times. The first data collection was taken on 7 March 2008, before the pile driving. This data was used as a baseline for the strains in the piles (data shown in Figure 2). It was used as a comparison to the post-driving stresses. The second reading was taken on 20 March 2008, a week after the initial driving and shortly after the restrike driving. This reading will provide an idea of the post-driving stresses in the pile and will also be the baseline for additional readings as construction proceeds. At this point, the gage resistance was recorded as well as the strain recording. The third reading was taken on 10 April 2008, about one month after the driving of the piles. This reading was taken after the bridge foundation was poured but before the abutment was placed. Continuous data readings will be taken when the abutment is poured and will occur for a period of several years. There currently is a data collection box at the project location that will collect the strains over time and hold them until data collection is desired. Figure 5 shows the data collection system during the initial sets of readings after pile driving.

Figure 5. Data Collection Following Pile Driving

Data Analysis is a vital part of this project. For this particular project, initial data verification is the key component. Strain data will be collected for several years but this portion of the project is the initial setup and recording. Data were recorded before and after pile driving as mentioned previously. The resistances of each gage and the strains were recorded; the resistances to make sure the gages were functional and the strains to get a base reading. The data collected showed that Gage #1 and Gage #2 of Pile A were suspicious. Gage #1 was a non-functional while Gage #2 showed questionable results. These can be seen by the bold items in the Table 1. The rest of the data reviewed, approved, plotted and recorded to be compared to data later in the project. This left us with 34 of 36 working gages.

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Table 1. Strain Gage Resistances Following Pile Driving for Pile A

Pile A (k ohms)		
Gage #	Red-Black	White-Green
1	**3000**	**1000**
2	**138.6**	**5.67**
3	173.4	5.61
4	173.1	5.78
5	173.9	5.67
6	175.4	5.66
7	174.6	5.69
8	174.2	5.61
9	173.2	5.49
10	172.0	5.57
11	172.6	5.62
12	175.4	5.57

There were several complications and sources of potential error in the project. The violent pile driving can be damaging to the cables and gages. One problem was that one of the piles was started in the wrong location; this required it to be removed and re-driven. The removal squeezed the angles against the cables and potentially damaged the cables. A secondary issue was the lifting of the piles into the pile leads. The choker used to raise the pile upright compressed the angles and forced them against the cables as well. The last major source of complications was securing the excess cables during the pile driving. Anywhere from 20 to 80 feet of cable was needed to reach from the top of the pile to the end of the bridge abutment at the data collection location. Properly securing the cables from sliding down the pile or shearing off on the tip of the pile was one issue that proved to be difficult.

One process that was used to ensure that the gages properly worked after pile driving was a multimeter. The resistance across the gages and cables was measured after driving and compared to the manufacturer's specifications. It was noted that two gages had errant measurements (as shown in Table 1), one proved to be a failed reading while the other had inconsistent readings; the other 34 gages had proper readings. Another source of checking gage errors is with the data collection system. The pre-drive and post-drive data was compared and checked for outliers or other errant data. This provided the data needed to conclude that one gage was faulty, one gage was damaged and has inconsistent readings, and the last 34 gages are properly working.

Conclusions

The project was not only an accomplishment of adequately placing multiple strain gages on several piles in a bridge abutment, but also a learning experience as a student. The majority of working gages and initial readings has provided a solid foundation for a larger and broad based project to monitor pile sizing, movement, and support. This will not only help accurately provide a safe support for bridges, but also save the public money due to less wasted material and potentially less maintenance due to proper pile use. The project currently has in place a data recording box with the instrumentation at the site for a continual recording of the strain.

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