Negative Skin Friction

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A QUICK ITEM OF INTEREST

- Mn/DOT-funded survey to State DOT's
- 41 out of 50 States eventually responded (with some prodding!)
- One of several questions – How much do states use driven piles, vs. drilled shafts, vs. shallow foundations for transportation applications?
- Of the first 35 respondents, the following results were obtained…

RESULTS OF THE STATE DOT SETUP SURVEY

1 – For transportation applications in your state, which of the following best describes the use of Driven Piles:

0	0%	Our agency never uses Driven Piles for transportation applications
1	3%	Our agency rarely uses Driven Piles for transportation applications
2	6%	Our agency occasionally uses Driven Piles for transportation applications
28	80%	Our agency often uses Driven Piles for transportation applications
4	11%	Our agency almost exclusively uses Driven Piles for transportation applications

RESULTS OF THE STATE DOT SETUP SURVEY

2 – For transportation applications in your state, which of the following best describes the use of Drilled Shafts:

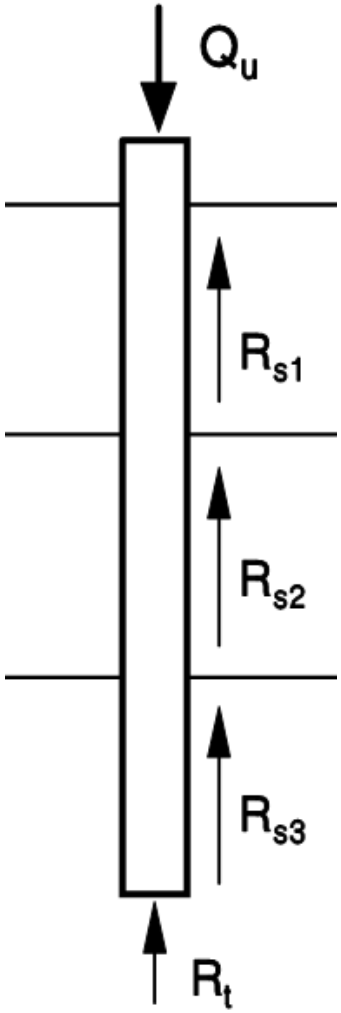
0	0%	Our agency never uses Drilled Shafts for transportation applications
2	6%	Our agency rarely uses Drilled Shafts for transportation applications
20	57%	Our agency occasionally uses Drilled Shafts for transportation applications
13	37%	Our agency often uses Drilled Shafts for transportation applications
0	0%	Our agency almost exclusively uses Drilled Shafts for transportation applications

RESULTS OF THE STATE DOT SETUP SURVEY

3 – For transportation applications in your state, which of the following best describes the use of Shallow Foundations:

0	0%	Our agency never uses Shallow Foundations for transportation applications
8	23%	Our agency rarely uses Shallow Foundations for transportation applications
12	34%	Our agency occasionally uses Shallow Foundations for transportation applications
15	43%	Our agency often uses Shallow Foundations for transportation applications
0	0%	Our agency almost exclusively uses Shallow Foundations for transportation applications

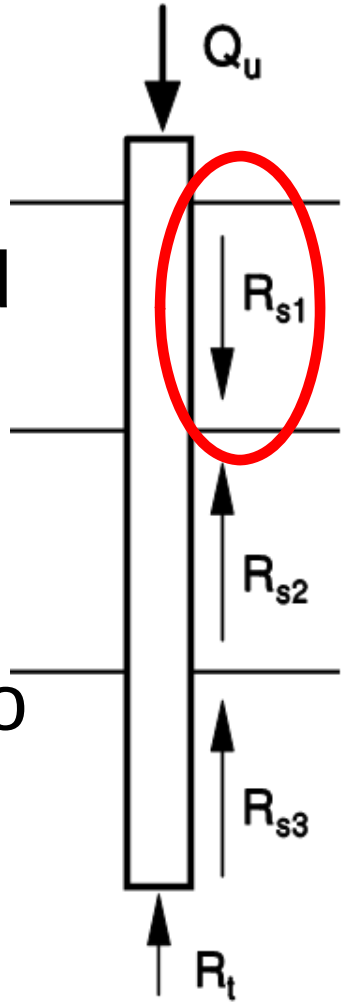
FUNDAMENTAL QUESTION #1: WHAT IS NEGATIVE SKIN FRICTION (a.k.a. DOWNDRAG or DRAGLOAD)?



Downward load at pile top resisted by upward (pos.) skin friction in soil layers and end bearing at the pile toe

- USUALLY -

But, what if the soil moves DOWNWARD with respect to the pile???



FUNDAMENTAL QUESTION #1: WHAT IS NEGATIVE SKIN FRICTION (a.k.a. DOWNDRAG or DRAGLOAD)?

In what situations might this phenomenon occur?

1 – Embankment fill placed after pile driving? (WHY?)

2 – Site dewatering subsequent to pile driving?

3 – Soil liquefaction due to seismic activity or other vibration?

4 - Other cases?

FUNDAMENTAL QUESTION #1: WHAT IS NEGATIVE SKIN FRICTION (a.k.a. DOWNDRAG or DRAGLOAD)?

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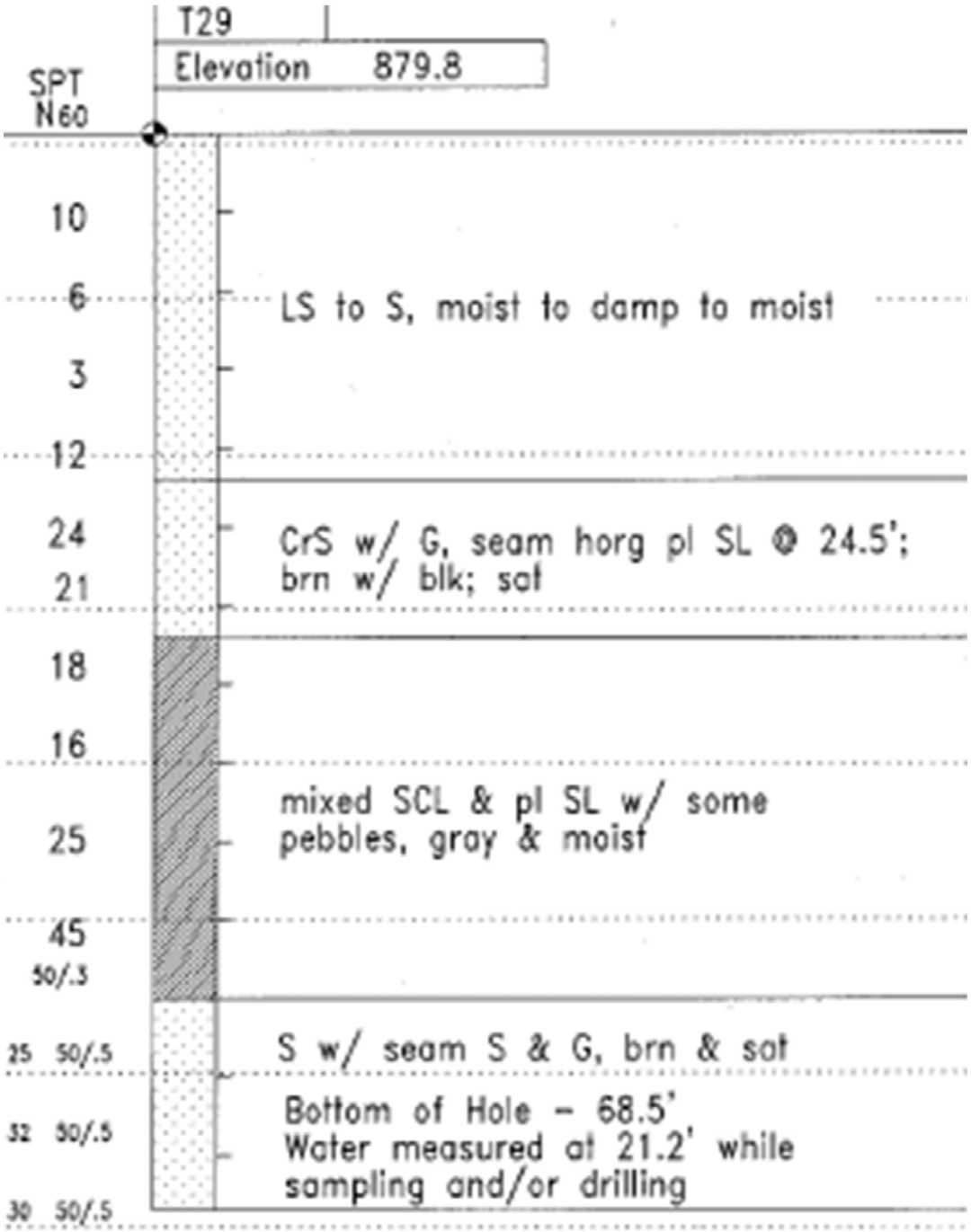
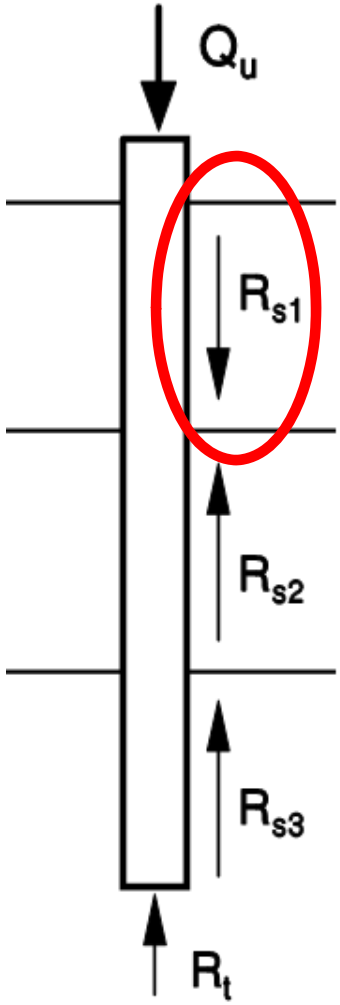
As an example:
Maple Grove, MN
New Interchange
Soil Profile at site =>
Predicted 3-5 inches
of settlement.
Piles driven prior
to fill placement.
PROBLEMS?
(Stay tuned!)



FUNDAMENTAL QUESTION #1: WHAT IS NEGATIVE SKIN FRICTION (a.k.a. DOWNDRAG or DRAGLOAD)?

Should we estimate negative skin friction using the same relationships and calculations as we use for positive skin friction (Nordlund, Tomlinson, etc.)?

Neutral plane and other approaches are available to identify where negative friction stops and positive friction begins.

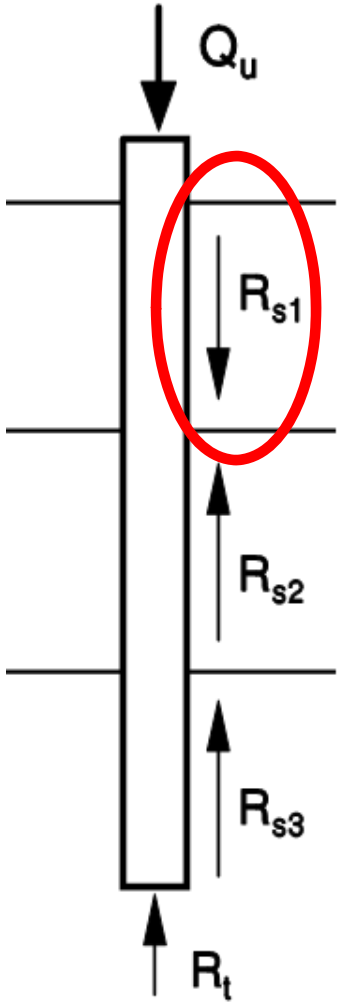


FUNDAMENTAL QUESTION #1: WHAT IS NEGATIVE SKIN FRICTION (a.k.a. DOWNDRAG or DRAGLOAD)?

With respect to Load and Resistance Factor Design (LRFD), how should dragload be appropriately dealt with?

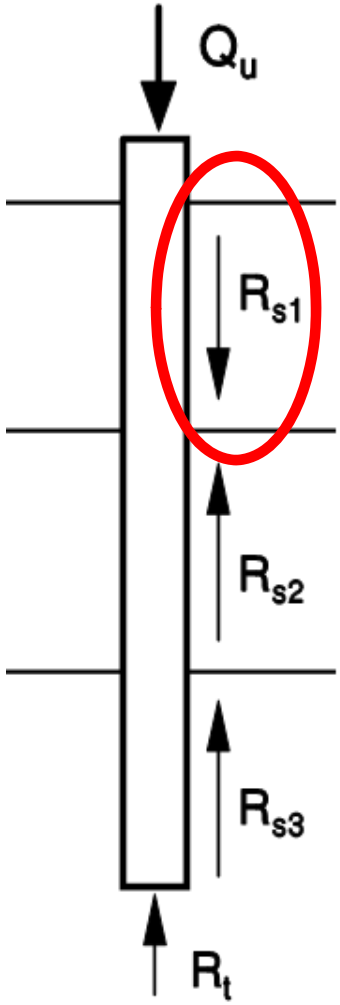
- Reduced pile capacity!
- Dead Load?
- Live Load?

Which load factor is appropriate?



FUNDAMENTAL QUESTION #2: HOW MUCH DOWNDRAG LOAD EXISTS?

Mn/DOT has funded several studies to quantify the magnitude of downdrag experienced. Several sites have been monitored where settlement of the foundation material with respect to the piling was anticipated (i.e., fill placed near piles AFTER pile driving.)



HOW CAN WE MEASURE R_{s1}?

HOW TO MEASURE DOWNDRAG LOAD

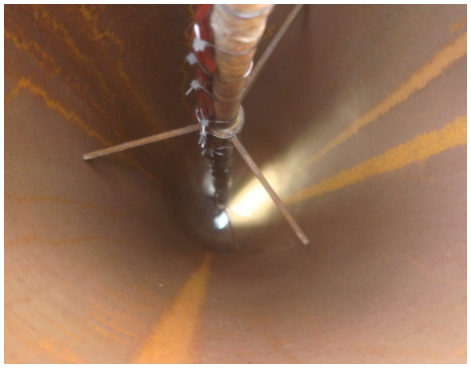
VIBRATING WIRE GAGES

FIBER OPTIC or RUGGEDIZED RESISTANCE GAGES

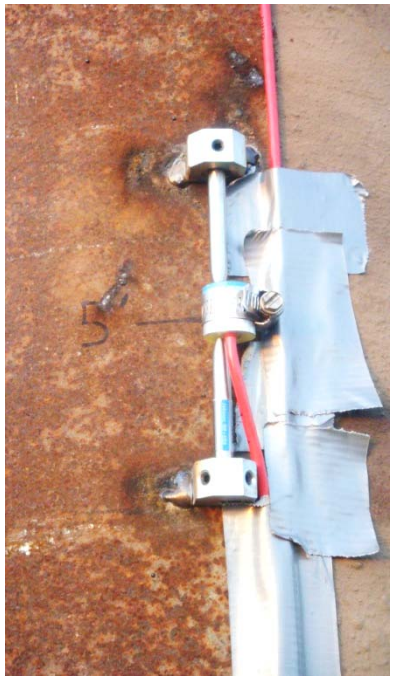
Do you install gages before or after driving?

INSTRUMENTATION OF A BRIDGE (GAGES INSTALLED BEFORE DRIVING)

INSTRUMENTATION OF A BRIDGE (GAGES INSTALLED AFTER DRIVING)



INSTRUMENTATION OF A BRIDGE (GAGES INSTALLED AFTER DRIVING)



INSTRUMENTATION OF A BRIDGE

WHAT ARE THESE?

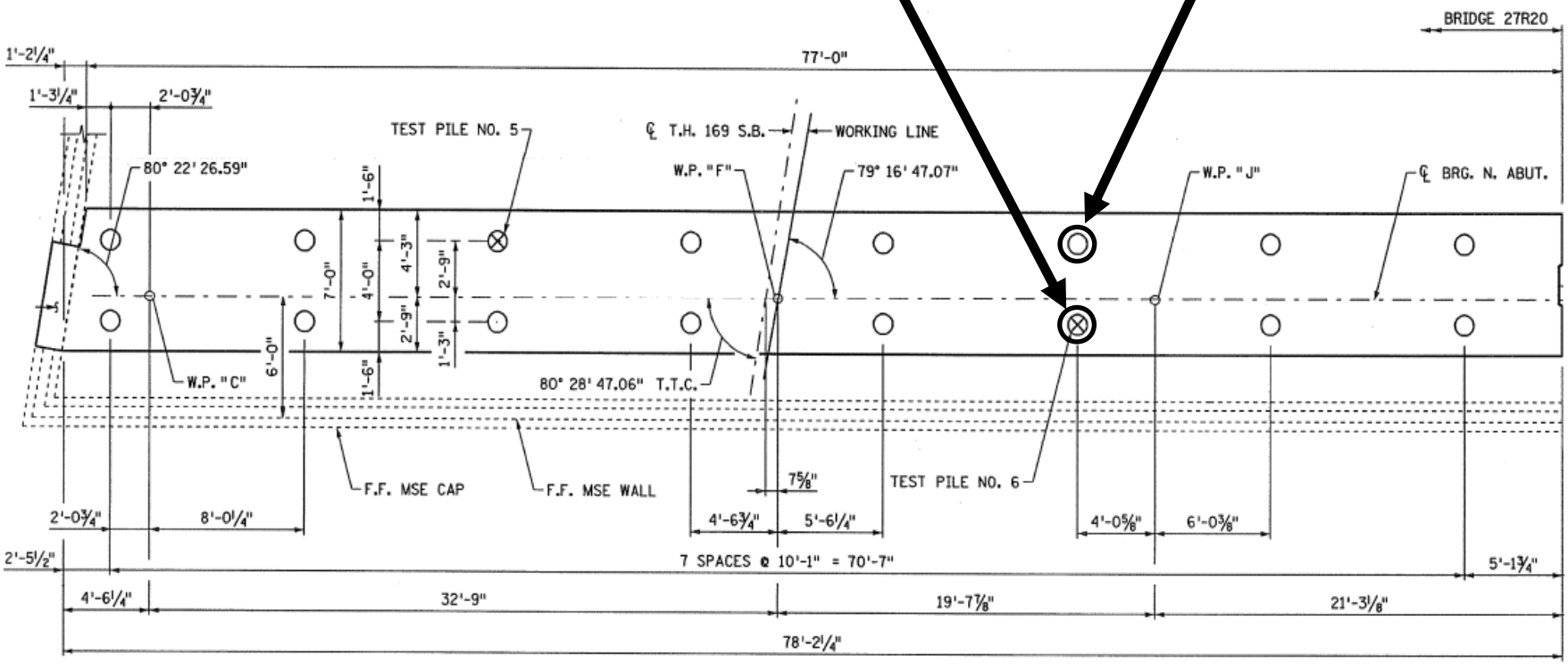
OPTIONS AVAILABLE TO REDUCE NEGATIVE SKIN FRICTION?

- **BITUMEN COATING**
- **PLASTIC COATING**
- **TEFLON COATING**
- **PILE SLEEVES**

INSTRUMENTATION OF A BRIDGE
MAPLE GROVE, MN

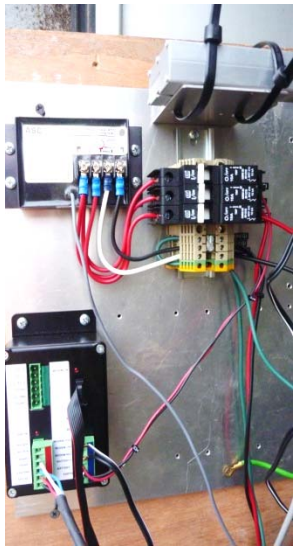
Instrumented Sleeved Pile

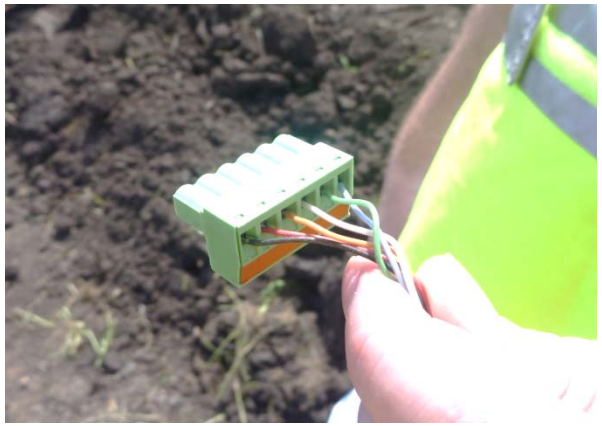
Instrumented Unsleeved Pile



INSTRUMENTATION OF A BRIDGE
MAPLE GROVE, MN

ShapeAccelArray (SAA)





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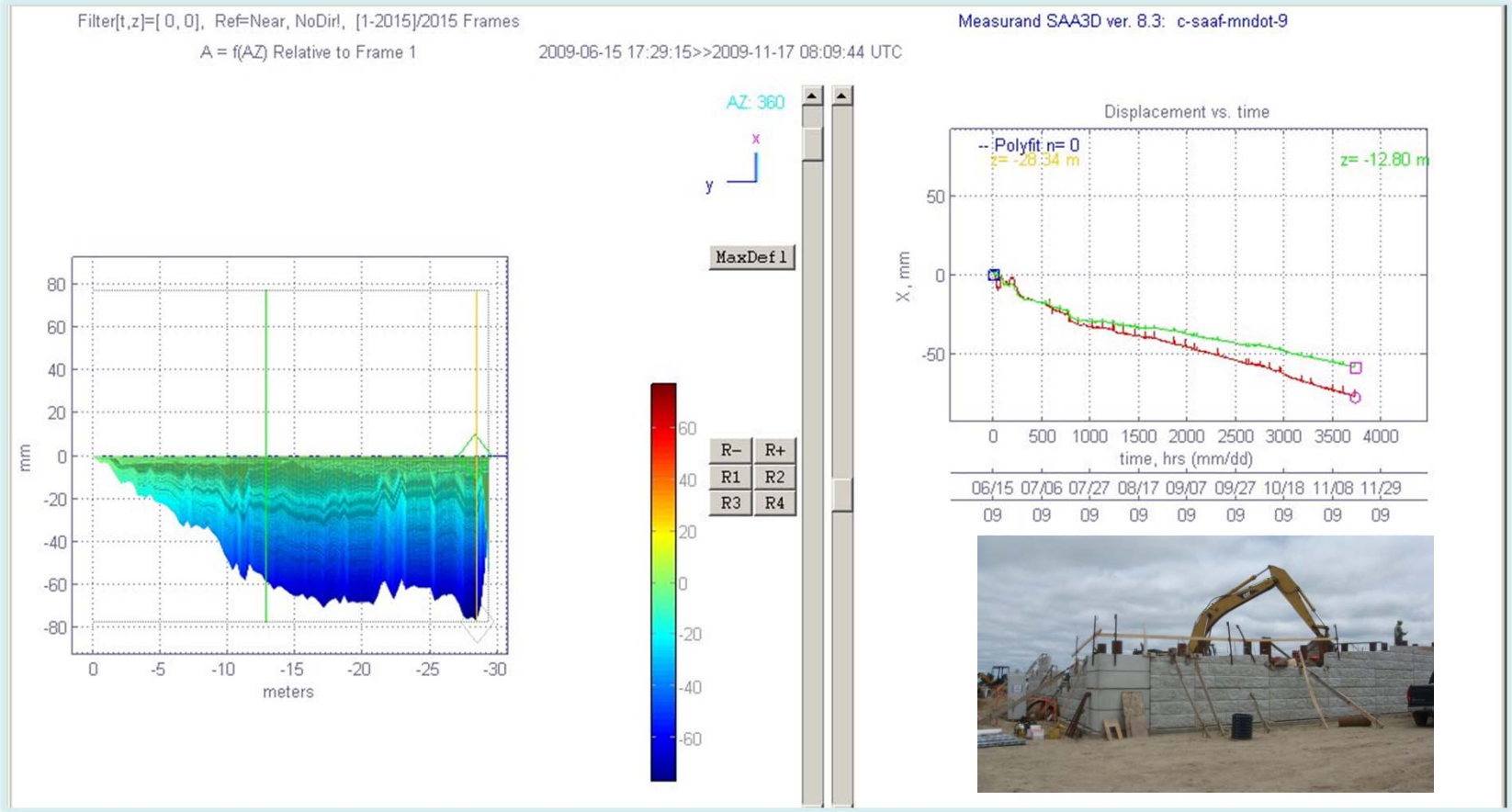
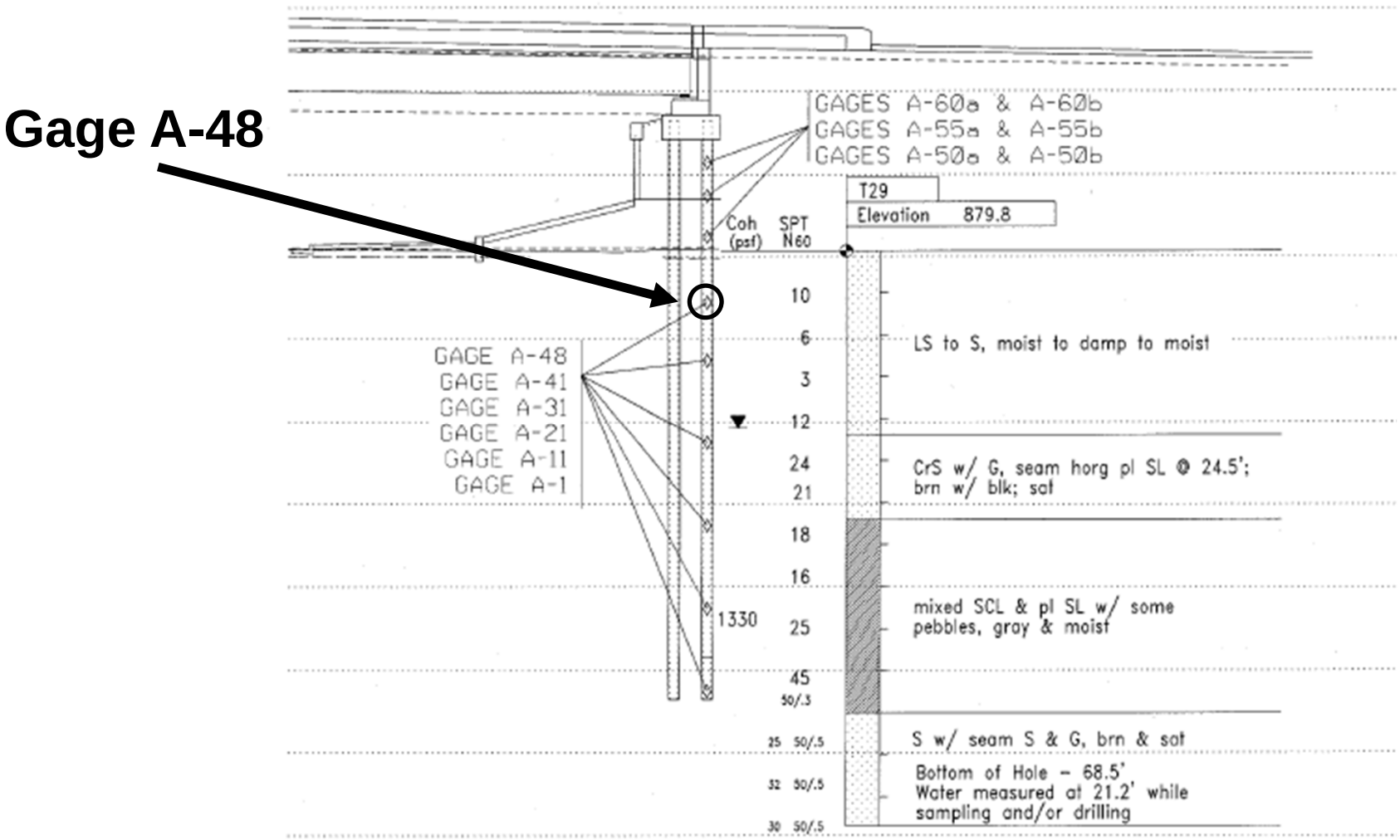
MAPLE GROVE, MN

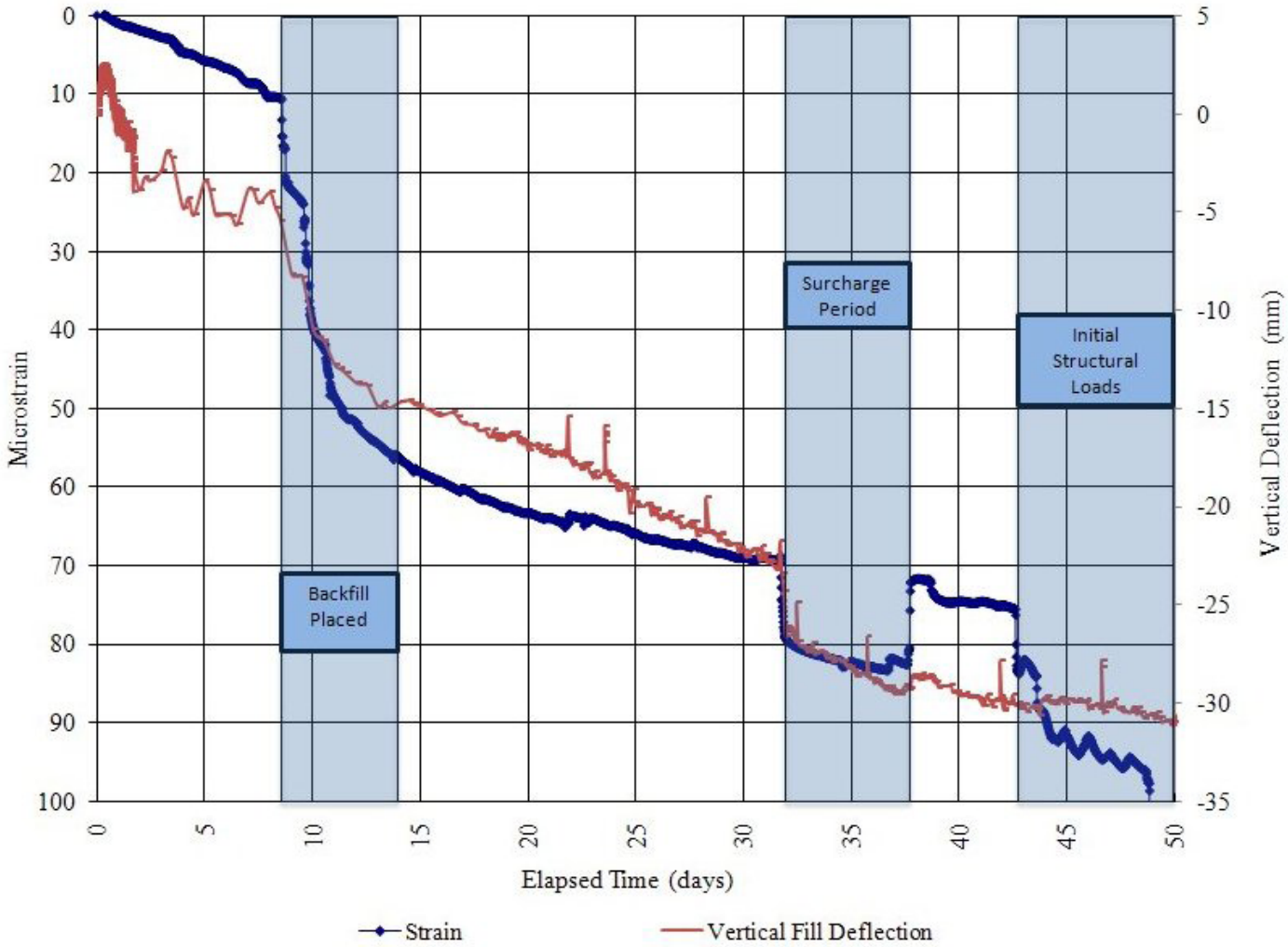
ShapeAccelArray (SAA)



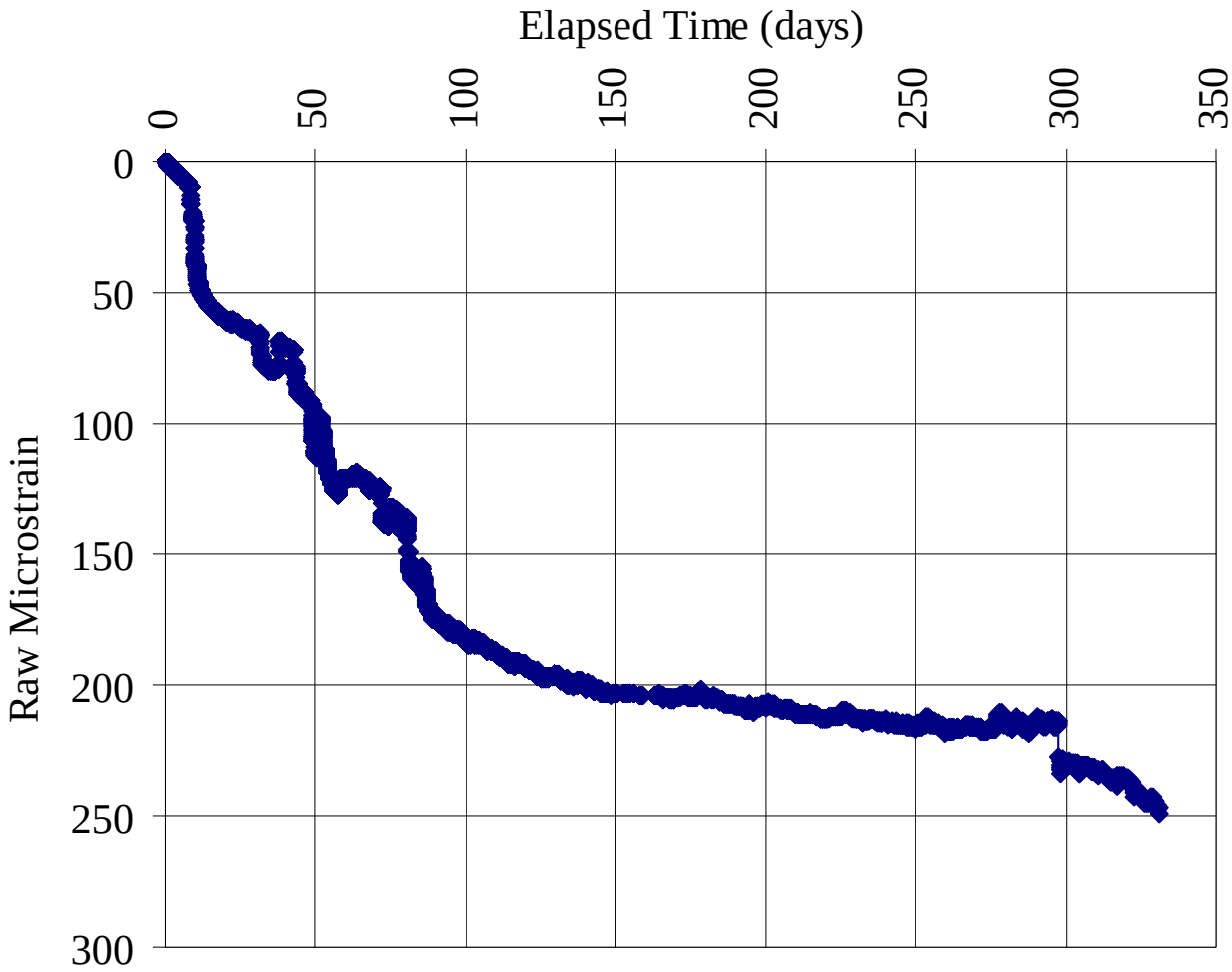
INSTRUMENTATION OF A BRIDGE
MAPLE GROVE, MN



DATA COLLECTED – FIRST 50 DAYS



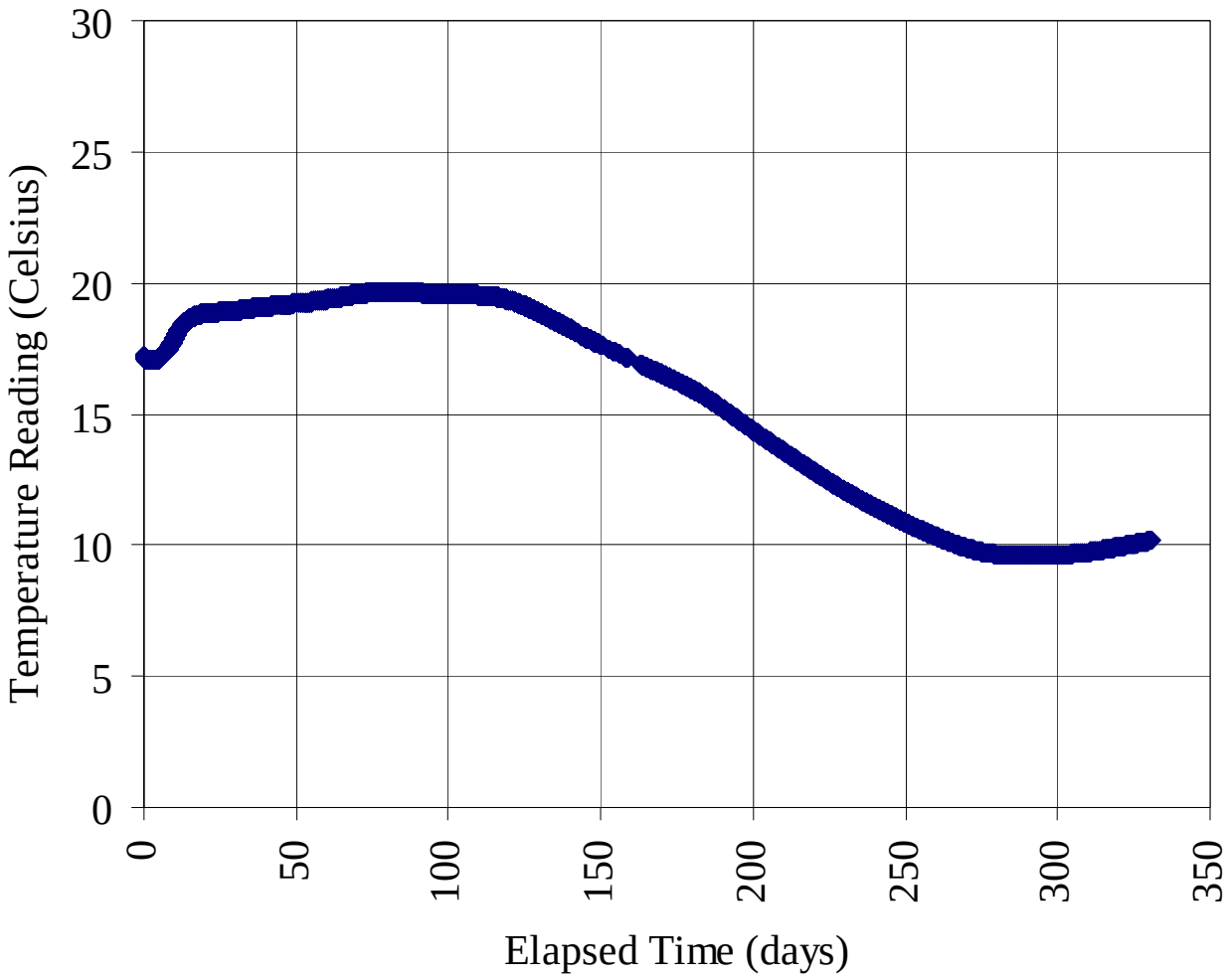
STRAIN DATA COLLECTED – 11 MONTHS



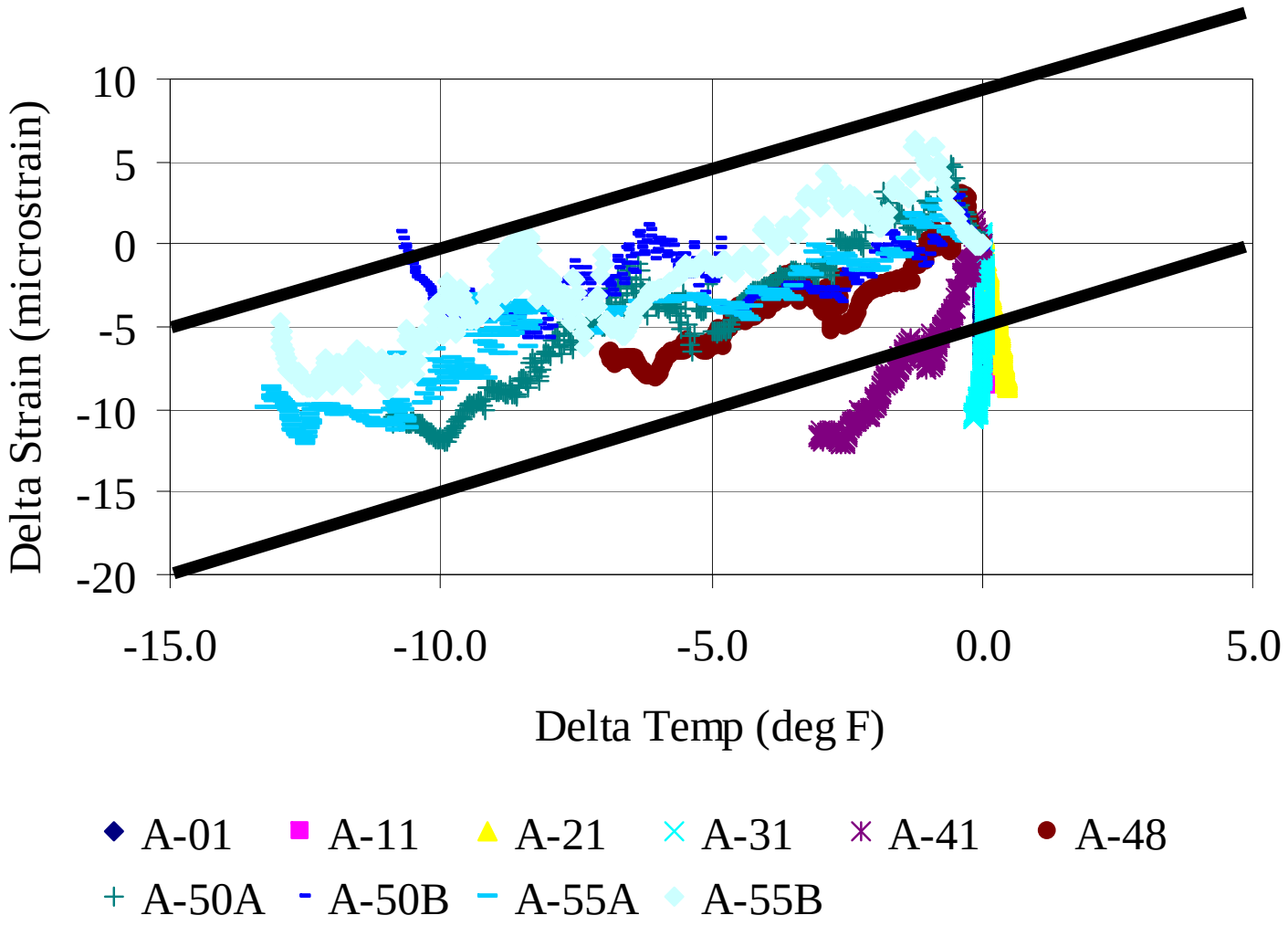
A CLOSER LOOK AT TEMPERATURE

- With the apparent “creep” during periods of minimal construction activity, the thermal strain effects were of interest
- Basic idea – if the temperature changes in the soil/pile such that the pile wants to change length but cannot (due to friction forces of the soil), thermal induced strains will be measured by the gages that should NOT be included in the downdrag/pile load response.

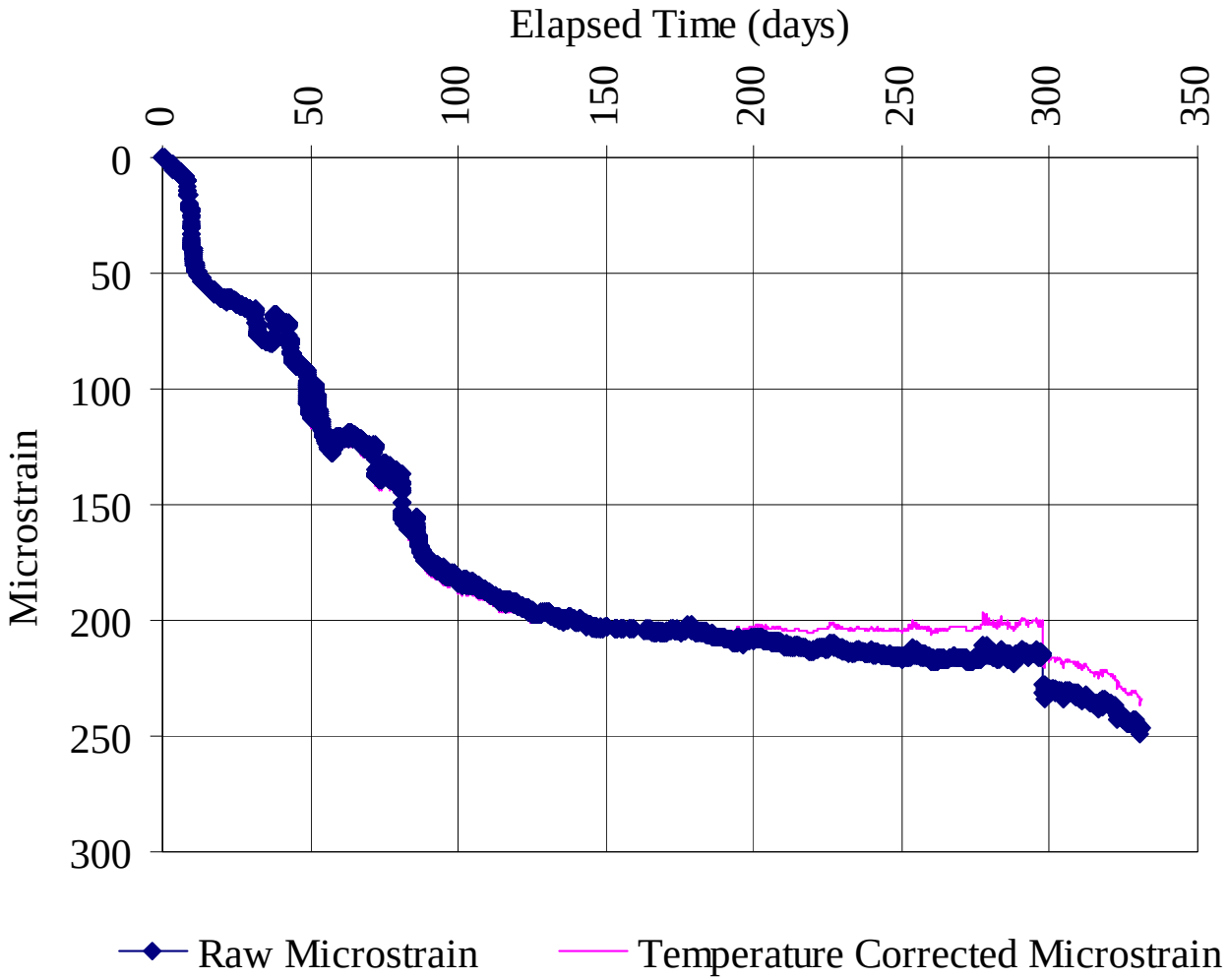
TEMP DATA COLLECTED – 11 MONTHS



A CLOSER LOOK AT TEMPERATURE



CORRECTED DATA – 11 MONTHS



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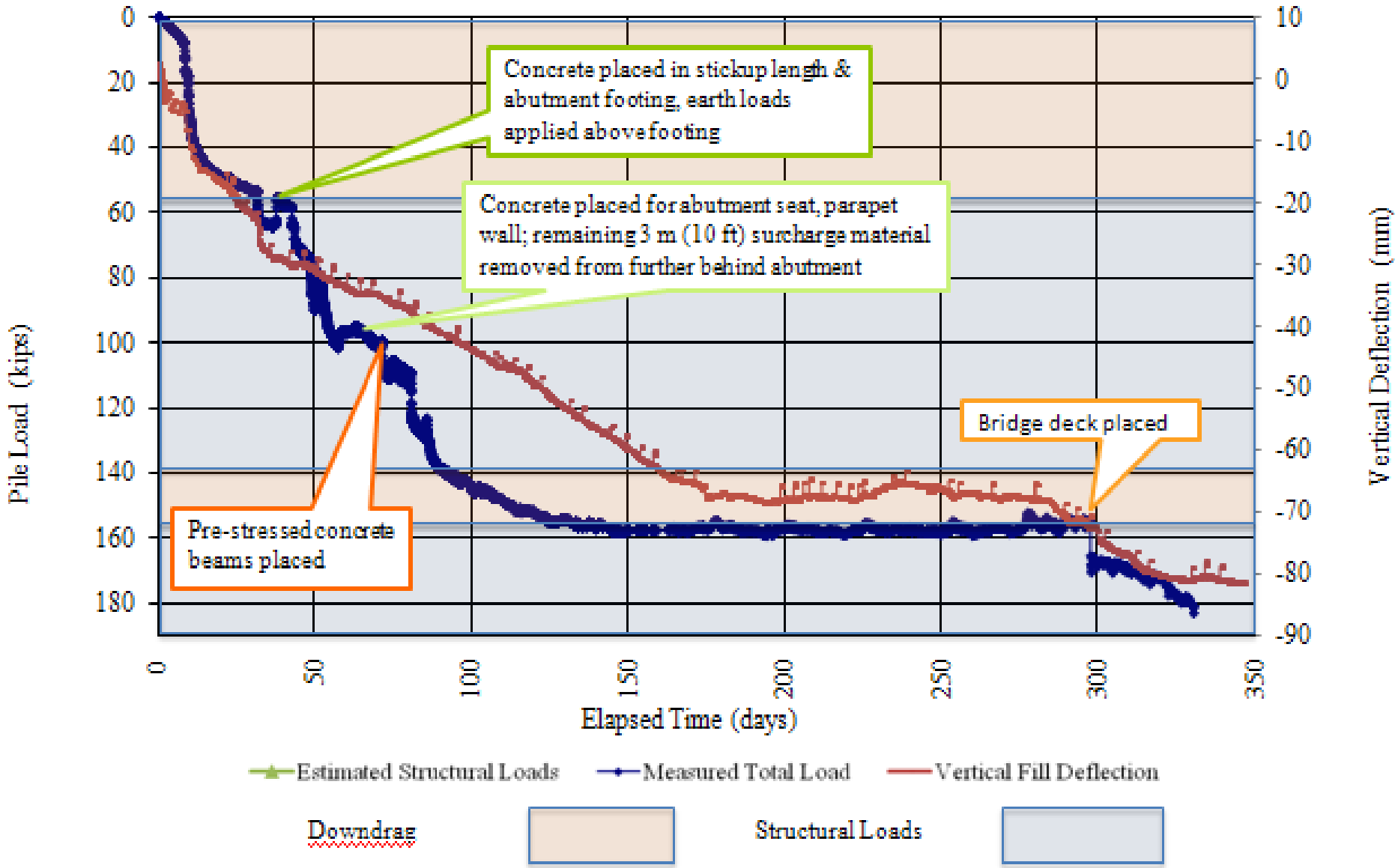
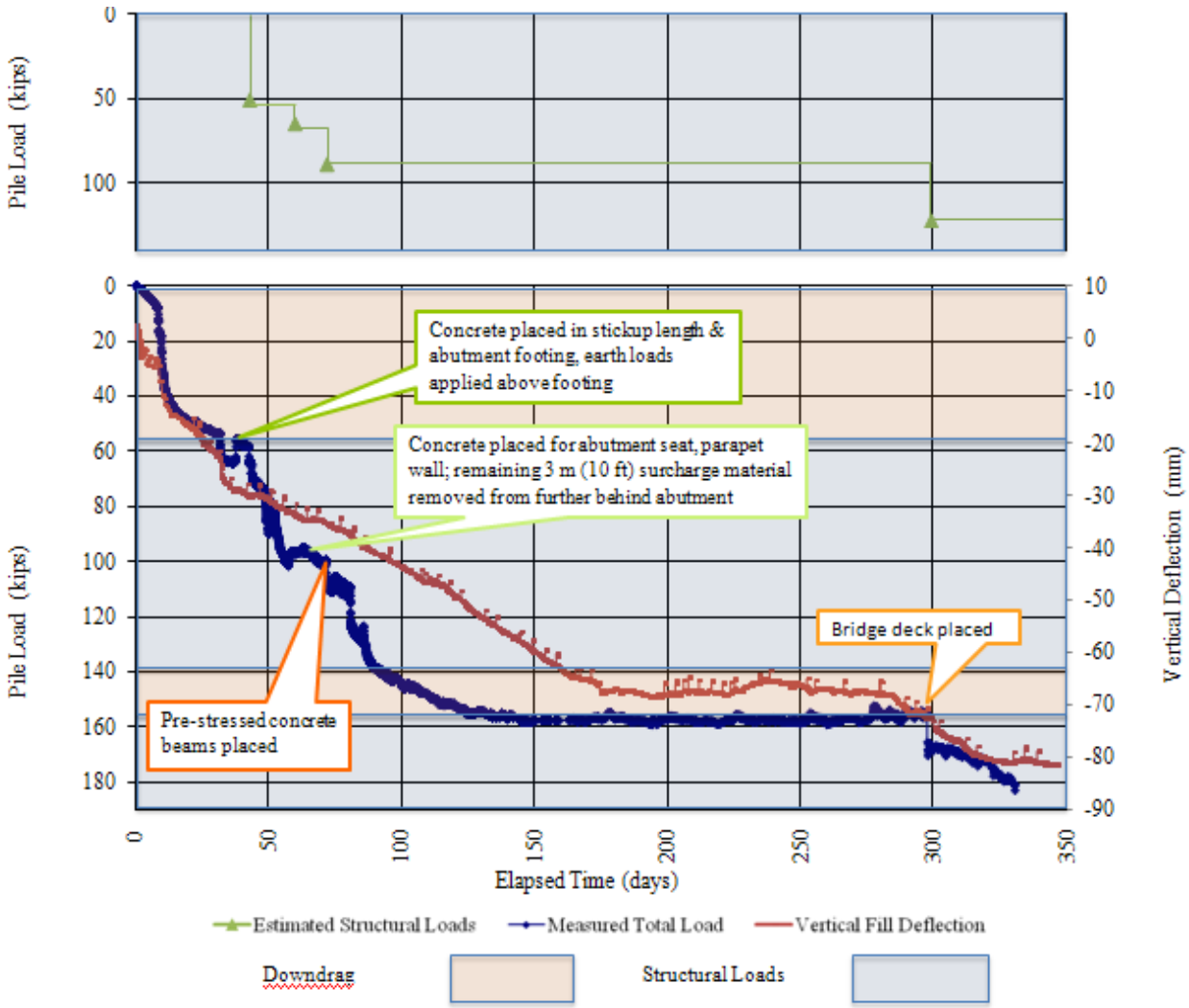
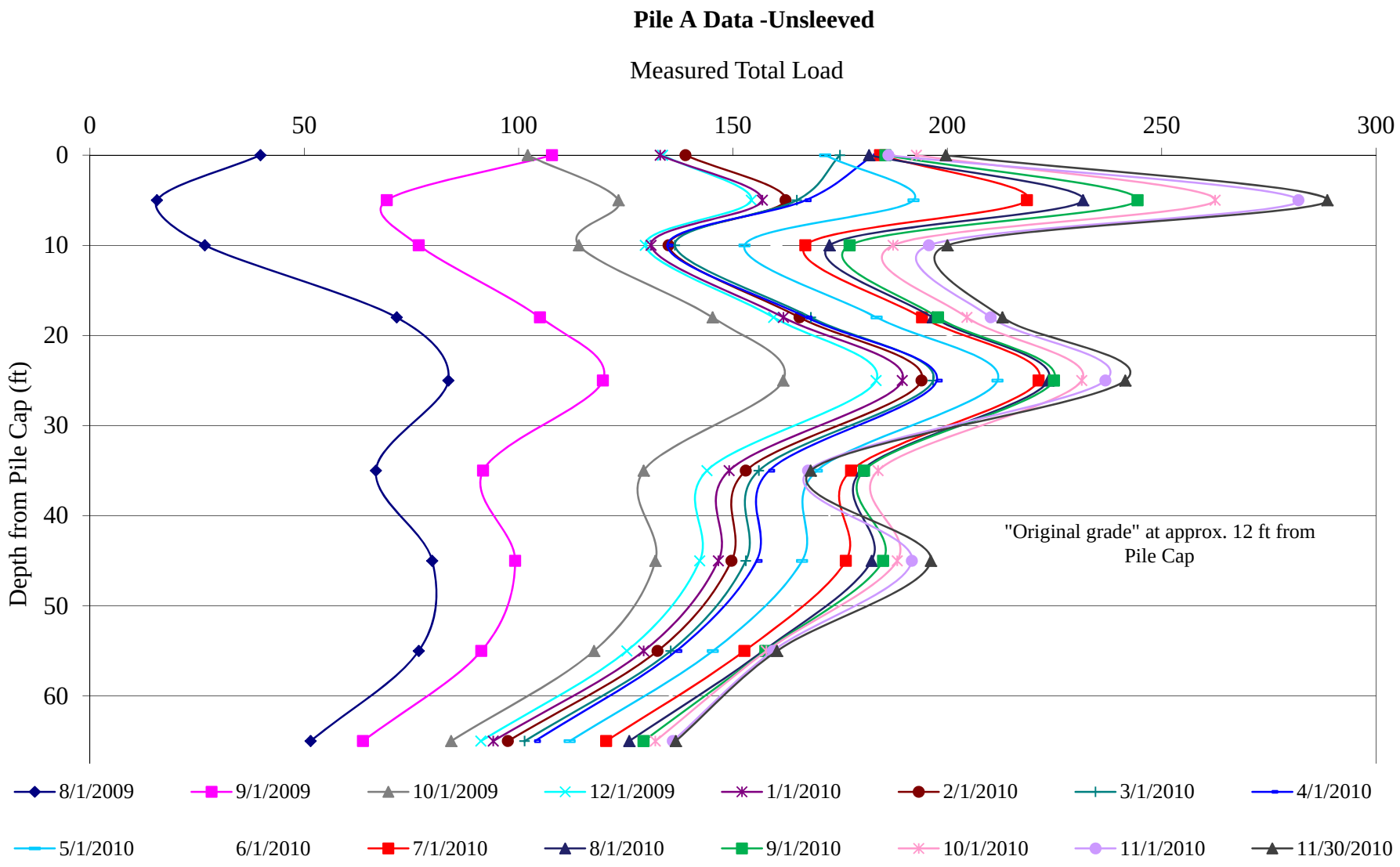


ESTIMATED VS. MEASURED



LOAD PROFILES



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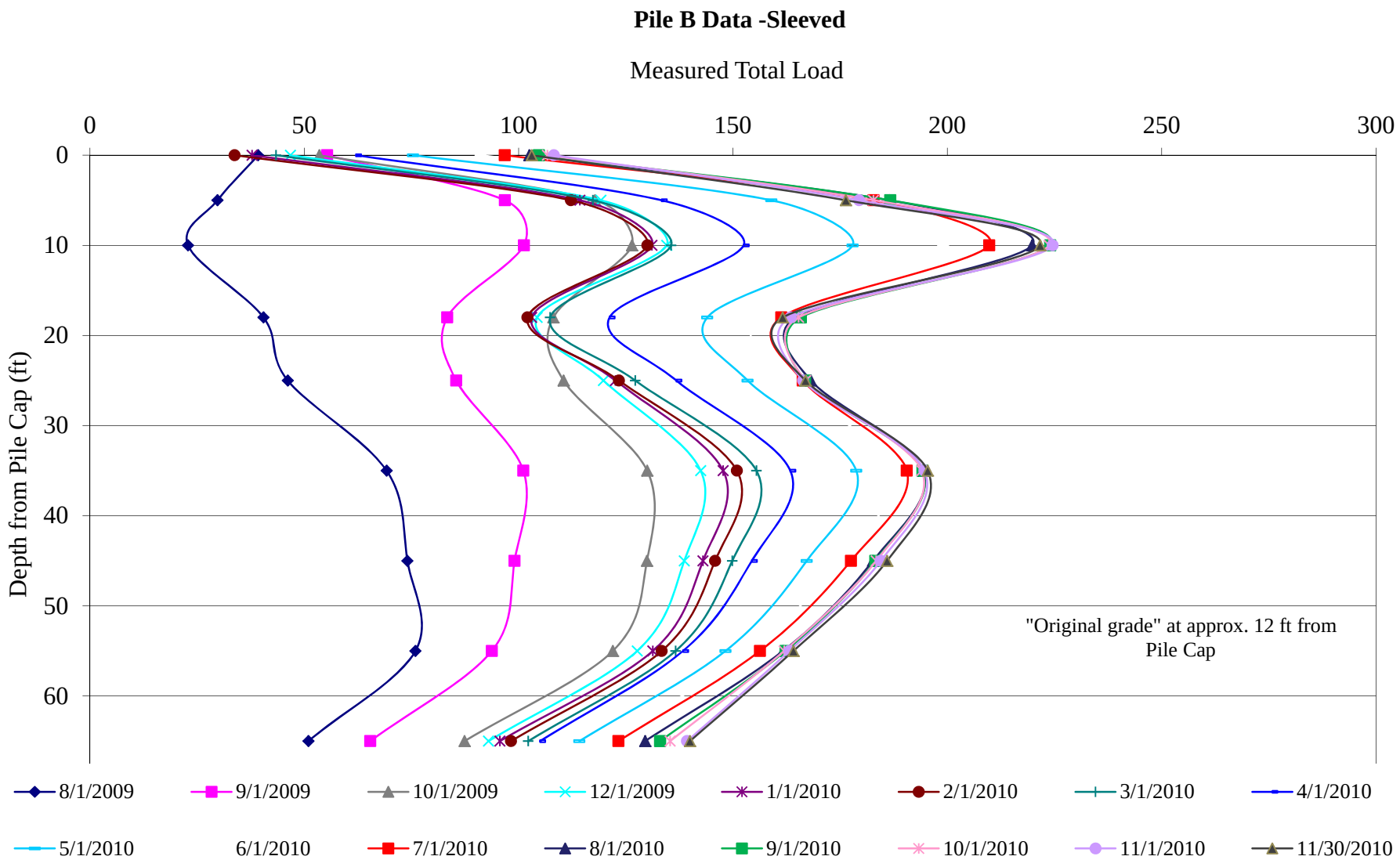
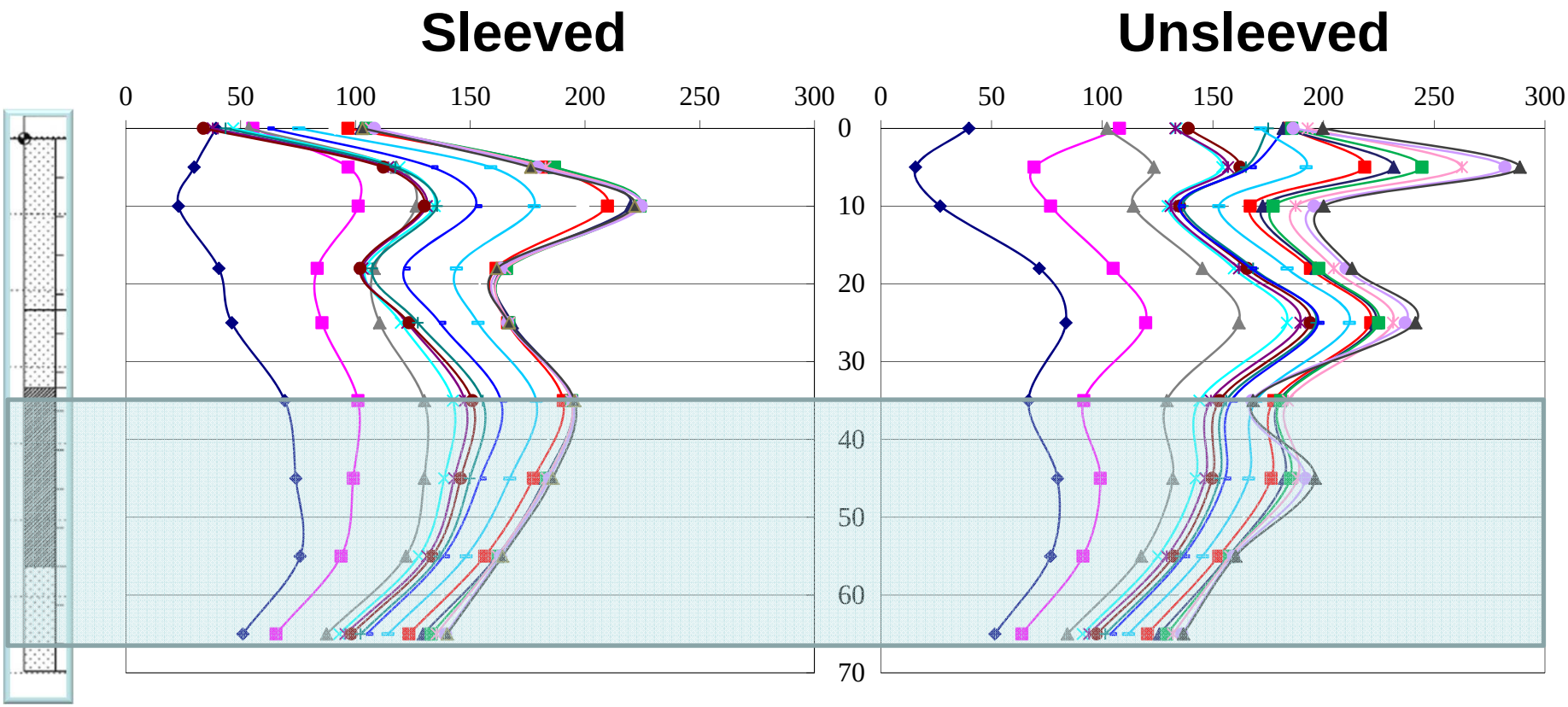


LOAD PROFILE REGIONS



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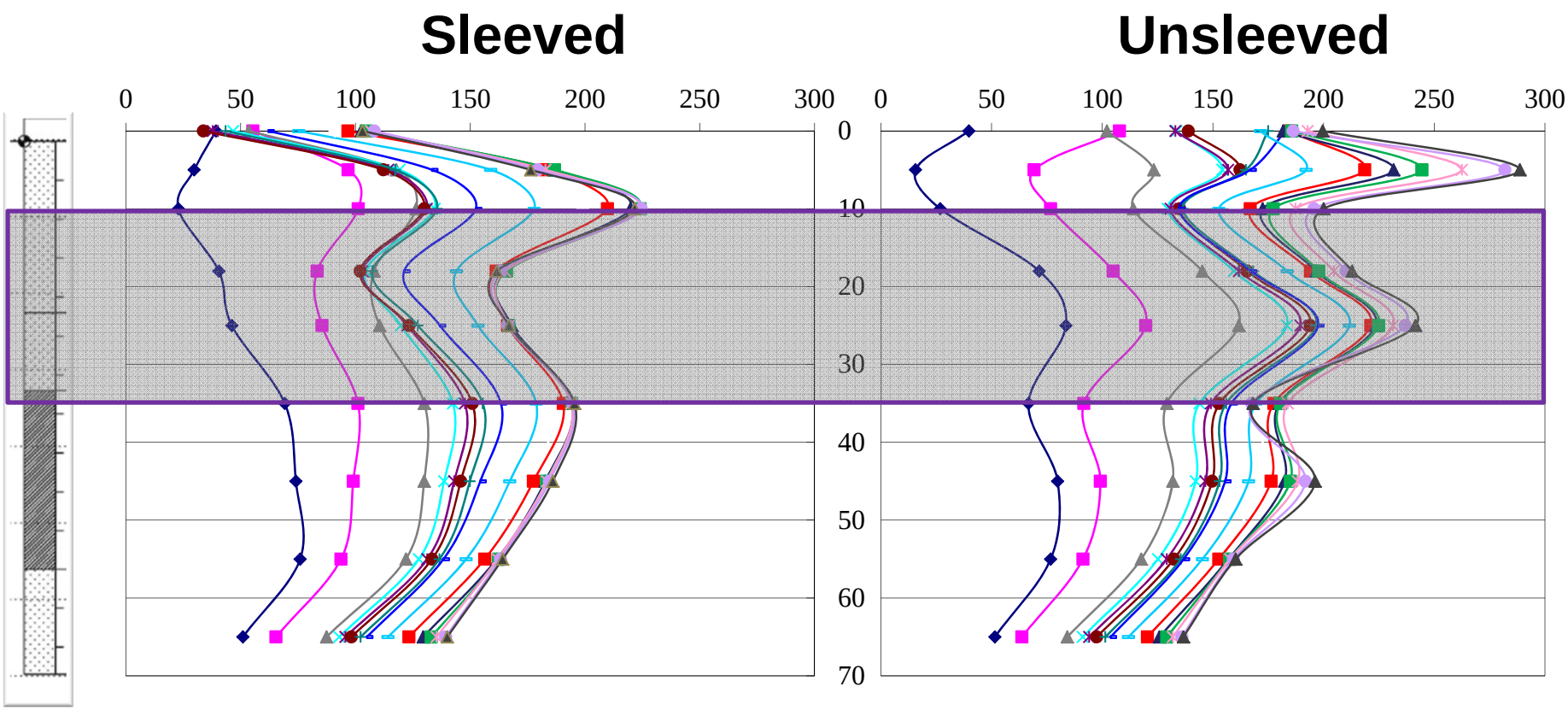

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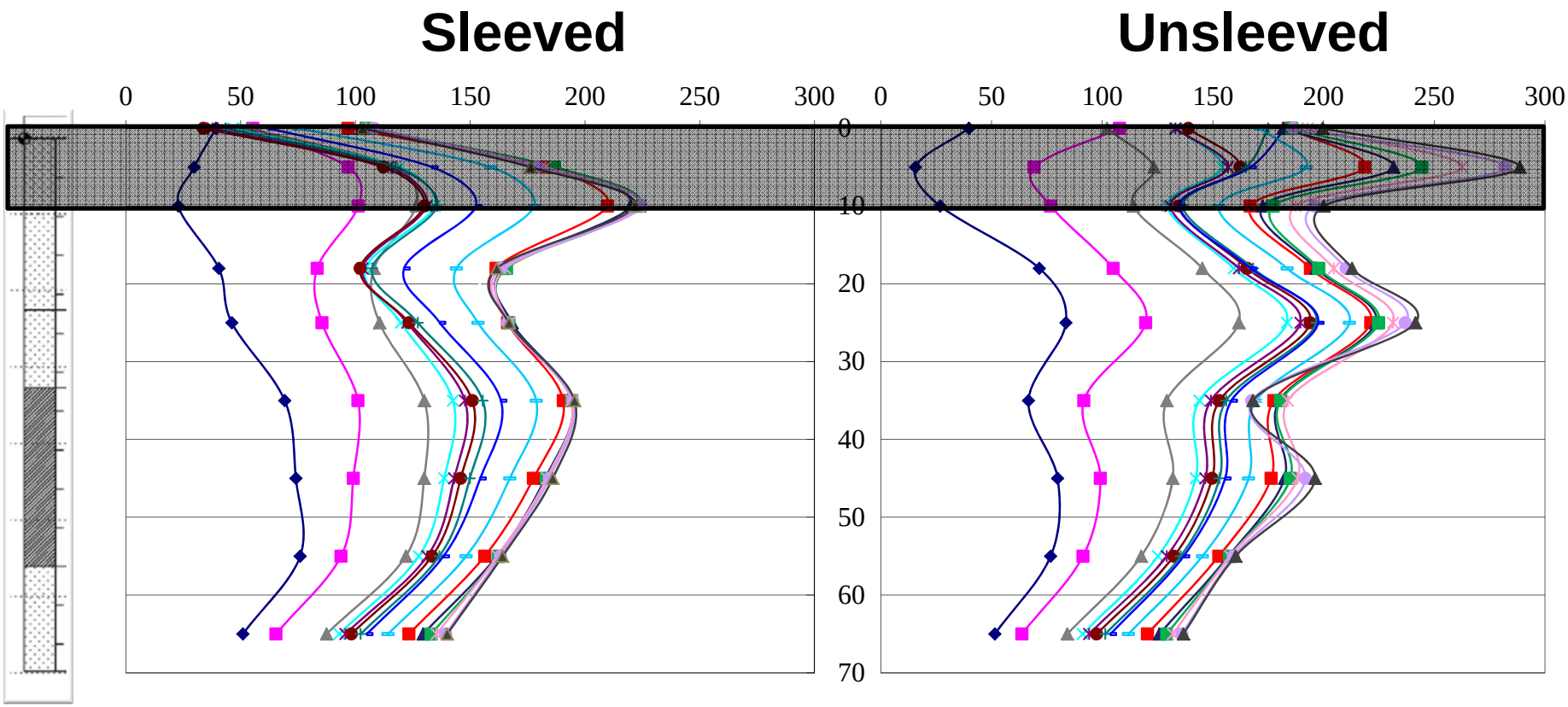

INSTRUMENTATION OF A BRIDGE
CROSSTOWN COMMONS EXPANSION

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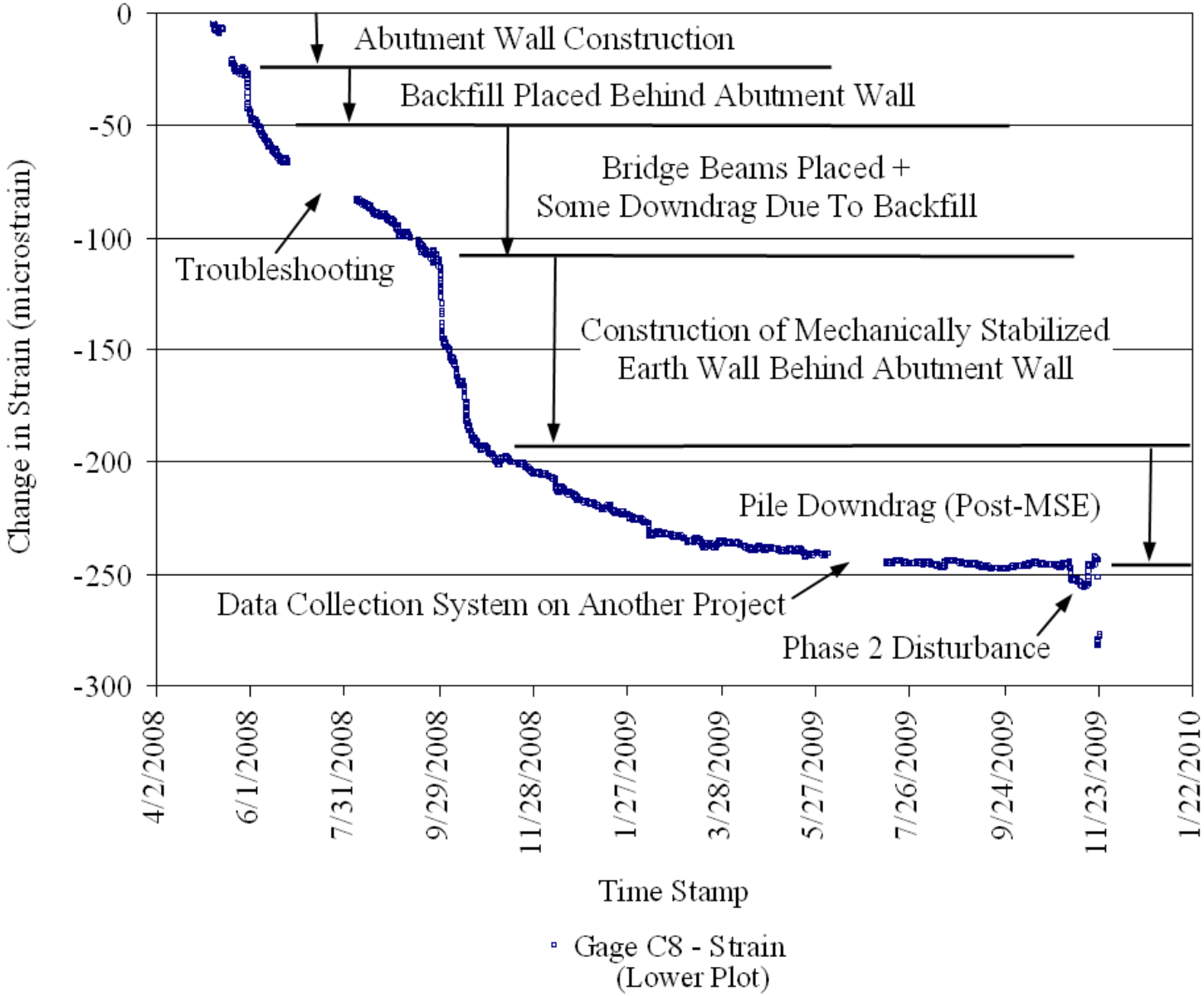

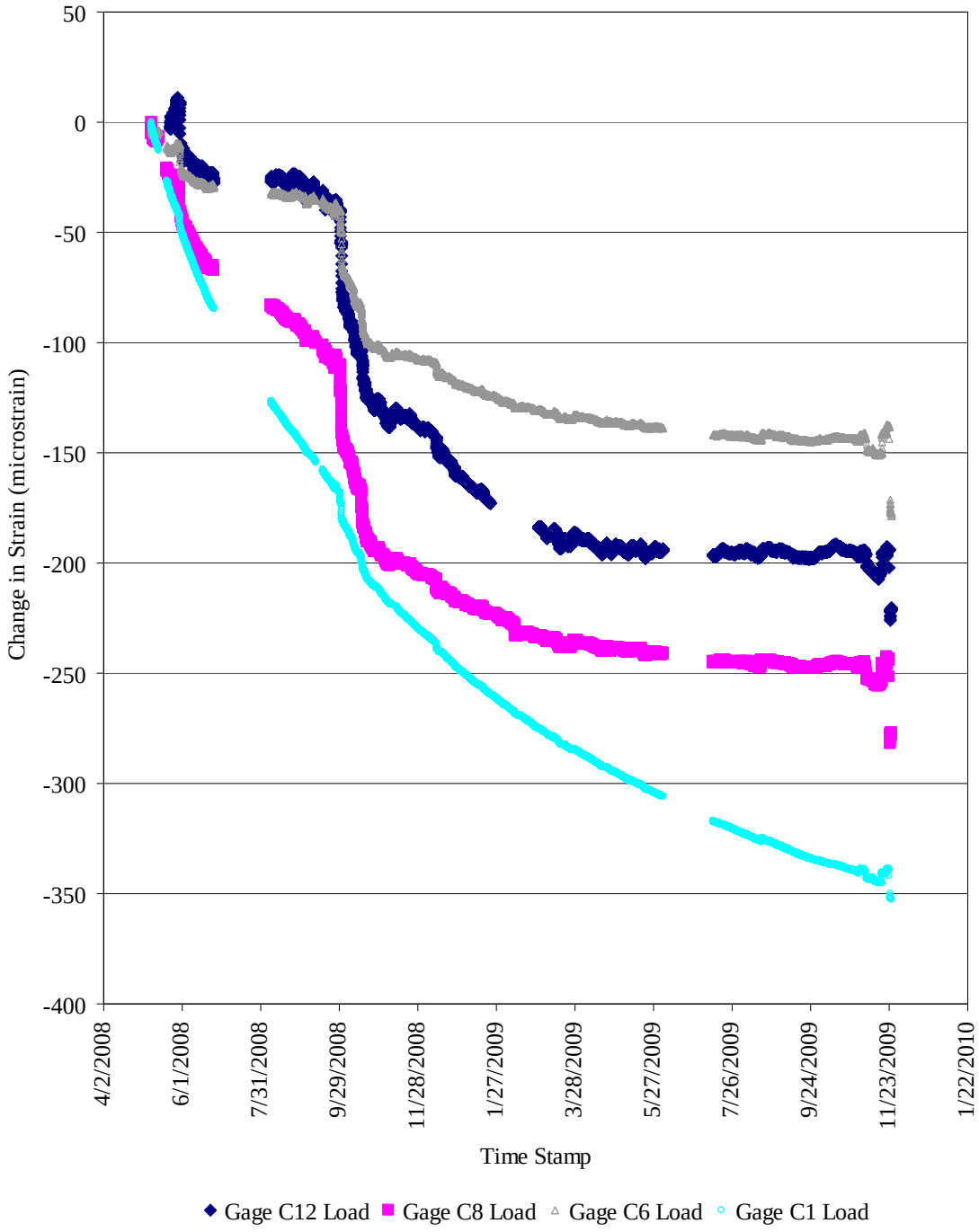
50
0
-50
-100
-150
-200
-250
-300
-350
-400
Change in Strain (microstrain)
4/2/2008
6/1/2008
7/31/2008
9/29/2008
11/28/2008
1/27/2009
3/28/2009
5/27/2009
7/26/2009
9/24/2009
11/23/2009
1/22/2010
Time Stamp
Gage C12 Load
Gage C8 Load
Gage C6 Load
Gage C1 Load

CONCLUSIONS

At both sites, downdrag was measurable; at Maple Grove observed pile strains began to increase immediately when embankment fill was placed over compressible soils, prior to the application of any ‘structural’ loads.

At Crosstown, increases in strain continued for weeks after wall construction was completed, corresponding to continued consolidation of foundation soils.

CONCLUSIONS

The strain and deflection data suggest that additional strain, and therefore loading, is intimately linked with the soil consolidation behavior and construction and placement of the bridge components.

Temperature effects were observed to add complexity to strain gage data evaluation, although a period of steady-state load and variable temperatures offered a method to develop a correction factor.

CONCLUSIONS

Pile strains were observed to decrease only with the removal of the temporary soil surcharges; added loads always appeared to result in corresponding increases in pile strain.

Vibrating wire strain gages and SAA deflection monitoring systems were shown to be effective sensors for the long term performance monitoring of downdrag impacts.

CONCLUSIONS

Mn/DOT continues to move forward with similar monitoring projects (currently one underway with Steele County and a second underway with Washington County) to improve understanding with respect to the magnitude of negative skin friction with the intent of developing a better design strategy in the future.

Questions???

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