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SUMMARY REPORT

# Vermilion, Ohio, Bridge Pier Mass Concrete Temperature Simulations

## Vermilion, Ohio
## Spring 2002

### FHWA MCL Project # 0201

Federal Highway Administration
Office of Pavement Technology
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# Summary Report

## FHWA Mobile Concrete Laboratory Report 0201

## Mass Concrete Temperature Simulations

## Vermilion, Ohio, Bridge Piers, Spring 2002

This report presents the results from a concrete materials test program conducted by Federal Highway Administration's (FHWA) Mobile Concrete Laboratory (MCL) for the Vermilion, Ohio bridge caisson placements (ODOT Project Erie-60-3.100). The objective of the MCL involvement with this project was to aid ODOT with temperature simulations to evaluate the potential for thermal crack development. FHWA was initially contacted by Charles Eberhardt with ODOT in February, 2002. Concrete constituent materials were sent to FHWA's research facility in McLean, VA (TFHRC) from Hull Builders Supply of Vermilion, Ohio, on February 15,2002. The materials were used to batch approximately 3 cubic feet of concrete in accordance with the mixture design approved by Tim Keller of ODOT office of Structural Engineering. A series of test specimens were cast and material was tested in a semi-adiabatic calorimeter to determine the concrete mixtures' heat of hydration. After laboratory testing was complete, the Quadrell software program was used to model and forecast temperature developments inside two separate caissons for several weeks after concrete placement. The caissons were 12' in diameter approximately 80' long. The caissons were drilled through as much as 50' of soil and embedded into as much as 35' of rock. The rock was assumed to be limestone. Detailed subsurface information was not made available to FHWA for this analysis. During construction, the caissons were instrumented with thermocouples at various locations to verify specification adherence, and offered an opportunity to examine the accuracy of the temperature predictions. Table 1 presents both the measured and predicted temperatures for these caissons. Temperature predictions made by CTL, Skokie, Illinois (data provided by Doug Fullerton of Hull Building Supply)) as part of the initial evaluation are presented for informational purposes only.

Table 1 Comparison of Measured and Predicted Caisson Temperatures

| | | Height from Bottom (ft) | Soil Type | Max T (F) | Time of Max T (h) | Max Temp Diff. (F) | Time of Max Temp Diff. (h) |
|---|---|---|---|---|---|---|---|
| Caisson 1 | Measured | 20 | Rock | 81 [1] | 140-180 | 10 [4] | 110-160 |
| | FHWA Simulation | - | | 117 | 168 | **36** | 192 |
| | CTL Simulation | - | | 115 | 75 | 35 | 75 |
| | Measured | 41 | Soil/Rock | 84 [1] | 80-150 | 20 [4] | 50-100 |
| | FHWA Simulation | - | | 117 | 172 | 32 | 160 |
| | CTL Simulation | - | | 115 | 75 | 35 | 75 |
| | Measured | 60.5 | Soil | 109 [1] | 100-125 | 18 [4] | 120-140 |
| | FHWA Simulation | - | | 118 | 178 | 28 | 132 |
| | CTL Simulation | - | | 115 | 75 | 35 | 75 |
| Caisson 3 | Measured | 7 | Rock | 111 [2] | 110-120 | 18 [5] | 100-150 |
| | FHWA Simulation | - | | 117 | 168 | **36** | 192 |
| | CTL Simulation | - | | 115 | 75 | 35 | 75 |
| | Measured | 16 | Rock | 111 [2] | 100-140 | 18 [5] | 100-160 |
| | FHWA Simulation | - | | 117 | 168 | **36** | 192 |
| | CTL Simulation | - | | 115 | 75 | 35 | 75 |
| | Measured | 24 | Rock | 110 [3] | 110 | 18 [6] | 100-150 |
| | FHWA Simulation | - | | 117 | 168 | **36** | 192 |
| | CTL Simulation | - | | 115 | 75 | 35 | 75 |

[1] Max temperature taken at 12" from center of crossection
[2] Max temperature taken at 8" from center of crossection
[3] Max temperature taken at 22" from center of crossection
[4] Temperature differential measured between outside of caisson and 12" from center
[5] Temperature differential measured between outside of caisson and 8" from center
[6] Temperature differential measured between outside of caisson and 22" from center

**Notes:**
FHWA Simulations used soil/rock temperatures of 48F (probably conservative)
CTL Simulations used soil/rock temperatures of 50F
FHWA Simulations are based upon average soil/rock properties
FHWA Simulations did not account for water-table elevations
FHWA simulations assumed rock to be limestone
Length of caisson approximately 80'
Values **underlined** are outside maximum allowable (160F max T and 35F max temp. difference)

**Comments/Conclusions:**

- Specification limits max. temperature to 160°F, and max. differential to 35°F
- Caissons were cast through soil and embedded into rock. Depth of soil and rock embedment varied.
- For caisson 1, simulations were performed for three different boundary conditions; 1) rock, 2) rock/soil and 3) soil. For caisson 3, only rock was simulated.

- Predictions are in all cases conservative (overestimate both max. temperature and temperature differential).
- Average max. temperature overprediction for caisson 1 was 26°F – simulation results were better for the soil boundary condition than for the rock and rock/soil boundary conditions.
- Average temperature overprediction for caisson 3 was just over 6°F– this is considered very good.
- Predicted time of maximum temperature was anywhere from 8 to 60 hours later than observed (typically 50 hours). This is unacceptable.
- Average max. temperature differential overpredicition for caisson 1 was 16°F Differential is taken as difference between temperature at center of caisson and temperature at outside of caisson (outside of caisson temperature was measured with thermocouples embedded near the surface of the concrete caisson).
- Average max. temperature differential overprediction for caisson 3 was 18°F.
- Predicted time of maximum temperature differential was anywhere from 2 to 80 hours later than observed (typically 60 hours). This is unacceptable.
- In light of the lack of specific construction and subsurface information, Quadrell does a reasonable job of forecasting the maximum temperatures experienced inside the caissons. The prediction of maximum temperature differentials are much less satisfactory – in four of the six locations modeled, the simulation forecast a temperature differential outside the specified limits. Similarly, the difference in predicted and observed times of maximum temperatures and maximum temperature differentials is significantly greater than desired.
- Predictions made by CTL and FHWA were reasonably close for max. temperature, time of max. temperature, and max. temperature differential.
- This data highlights the importance of detailed site and member information.

If you have any comments or questions about these findings/results, please contact Leif Wathne, Concrete Materials Engineer with the FHWA Mobile Concrete Laboratory at (202) 366-1335 or *leif.wathne@fhwa.dot.gov*.