

# Thermal Analysis of Mass Concrete for Iowa Bridge Foundations

Presented by Jacob Shaw & Jinxin Li

## What is Mass Concrete?

Mass concrete is defined as any concrete placement with a dimensional size large enough to require that precautions be taken to control the heat of hydration to prevent thermal damage. The current Iowa Department of Transportation developmental specification defines mass concrete as any structural mass concrete footing with a least dimension greater than 5 feet, or any other concrete element with a least dimension greater than 4 feet, excluding concrete drilled shafts.

## Concerns

### Delayed Ettringite Formation

Delayed ettringite formation, or DEF, results from excessively high temperatures in a concrete placement. High temperatures in a placement decompose the ettringite that had been previously formed in the concrete and suppresses further ettringite formation. In the future, if moisture is present in the concrete, ettringite may begin to form in the cement paste, causing expansive pressure in concrete. If the expansive pressures become too extreme, the placement may experience cracking. It has been established that preventing the maximum temperature in the placement from reaching 160°F will reduce the probability of DEF.

### Thermal Cracking

Thermal cracking is the result of large thermal gradients in a massive placement. Thermal gradients induce stress in the placement, which result from the exterior portion of the placement dissipating heat more rapidly than the interior portion of the placement. If the induced stress exceeds the tensile strength of the recently placed concrete, the placement is likely to experience thermal cracking. Historically, keeping the maximum temperature differential below 35°F was found to reduce the likelihood of thermal cracking.

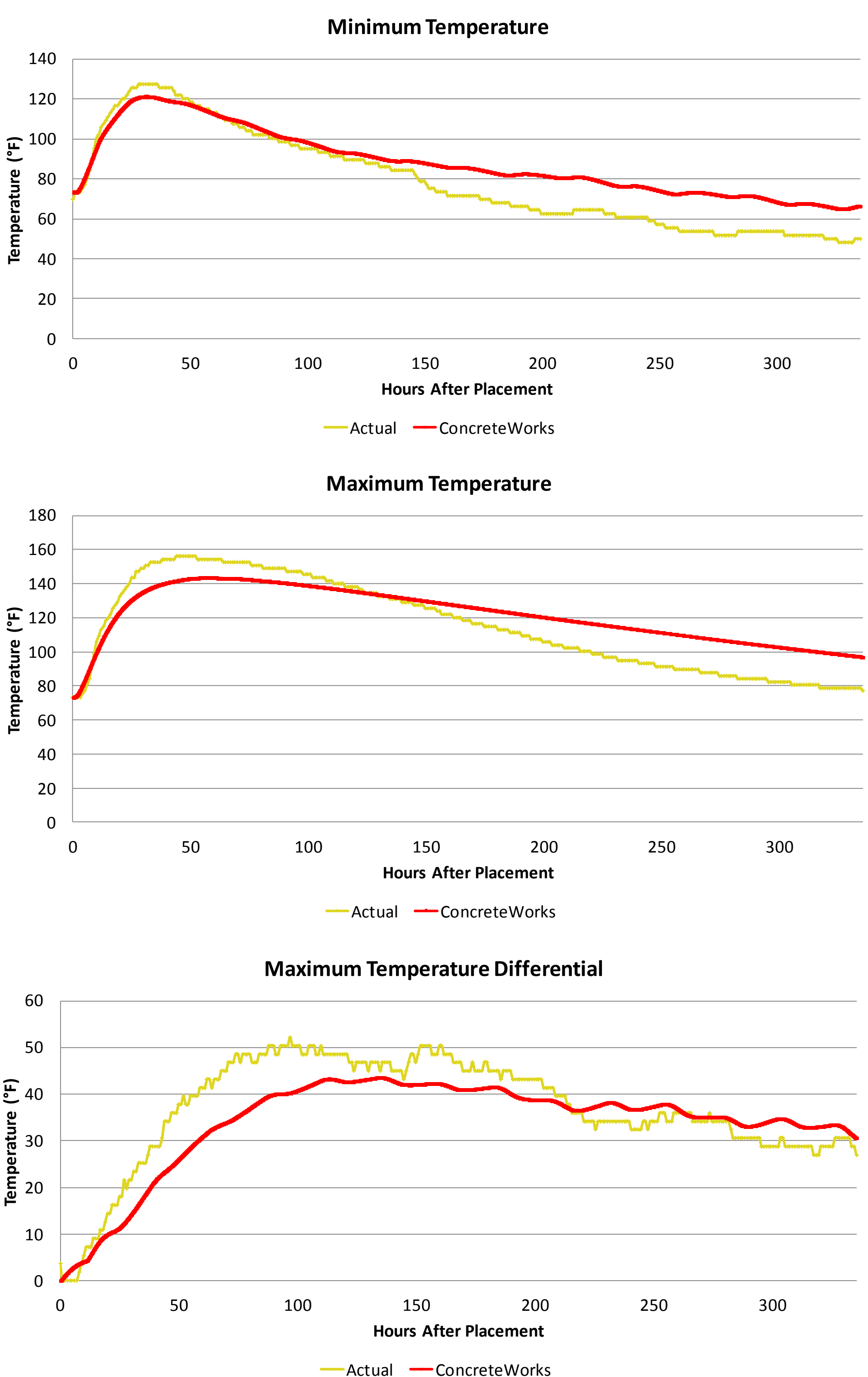


Column from I-80 WB over the Missouri River Bridge

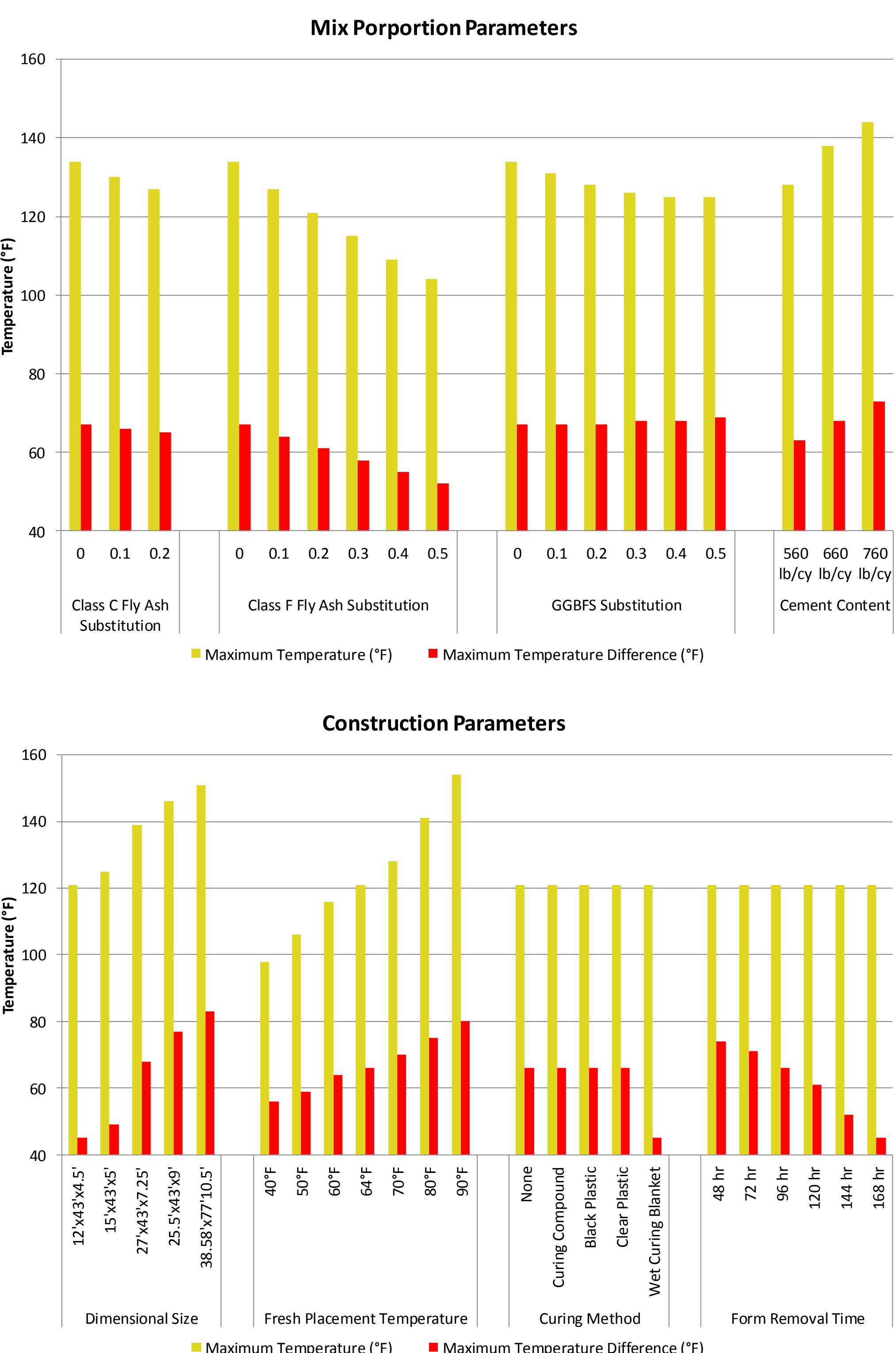
## Research

The research consisted of verifying and exercising a concrete thermal analysis software program. The software program used was ConcreteWorks, an early age thermal analysis software that was developed at the Concrete Durability Center at the University of Texas. The software program was verified with data that was collected for I-80 WB over the Missouri River Bridge. The software program was exercised through the completion of a sensitivity study examining construction, environmental, and mix proportion parameters commonly used for mass concrete projects.

## ConcreteWorks vs. Recorded Data



## Sensitivity Study



## Results

The results show that both dimensional size and fresh placement temperature greatly affect the maximum temperature and maximum temperature difference. In addition, the form removal time greatly affects the maximum temperature difference of a placement, but has no effect on the maximum temperature. The curing method seems to have little effect on the thermal development except for wet curing, which greatly reduces the maximum temperature difference. The results show that both cement content and substitution of class F fly ash greatly affects both the maximum temperature and the maximum temperature difference of the placement. The substitution of class C fly ash as well as GGBFS fly ash greatly affects the maximum temperature of a placement, but have little effect on the maximum temperature difference.