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Iowa Mass Concrete for Bridge Foundation Study – Phase I

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RESEARCH PROJECT TITLE
Iowa Mass Concrete for Bridge Foundation Study – Phase I

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Early-age thermal development of structural mass concrete elements has an important impact on the future durability and longevity of bridge foundations.

Objectives

The objectives of this research are to provide insight on the early-age thermal development of mass concrete, provide recommendations for the Iowa Department of Transportation (DOT) mass concrete specification, and present best practices for mass concrete construction.

Background

The early-age thermal development of structural mass concrete elements has a significant impact on the future durability and longevity of the elements. If the heat of hydration is not controlled, the elements may be susceptible to thermal cracking and damage from delayed ettringite formation.

The present study is aimed at developing guidelines for the design and construction of mass concrete placements associated with large bridge foundations. The study consists of two phases: (1) literature review and preliminary thermal stress analysis, and (2) in-depth thermal stress analysis and guideline development. This report describes the research activities conducted and results obtained from the Phase I study.

Research Description

In the Phase I study, published literature and current specifications on mass concrete, as well as the results of construction monitoring from the I-80 bridge at Council Bluffs, Iowa, were reviewed. Two computer programs, ConcreteWorks and 4CTemp&Stress, for thermal analysis of mass concrete were explored.

Conclusions and Recommendations

Using ConcreteWorks, a sensitivity analysis was performed and various mix proportion, environmental, and construction parameters were examined. The results indicate that, not only concrete materials (such as fly ash and ground granulated blast furnace slag or GGBFS) and mix proportions (such as cement content), but also fresh concrete placement temperature, curing methods, and time of form removal have significant effects on thermal cracking.

Various mix proportion, construction, and environmental parameters can have a large effect on the thermal development of structural mass concrete elements, as illustrated by the sensitivity study. The results of the sensitivity study have been compiled in Table 1.

Table 1. Sensitivity study results

Sensitivity Study		Input	Maximum Temperature	Maximum Temperature Difference	Cracking Potential
Dimensional Size		Reducing Dimensional Size	*	*	*
Fresh Placement Temperature		Reducing Fresh Placement Temperature	*	*	*
Curing Method		Curing Compound			
		Black Plastic			*
		Clear Plastic			*
		Wet Curing Blanket		*	*
Form Removal Time		Increasing Form Removal Time		*	*
Forming Method	Cracking After Form Removal	Steel Formwork		*	*
		Soil Formwork		*	*
	Cracking Before Form Removal	Wood Formwork		*	*
		Soil Formwork		*	*
Placement Date		Cooler Seasons	*		
		Warmer Seasons		*	*
Cement Content		Reduce Cement Content	*	*	
Fly Ash		Substitute Class F Fly Ash	*	*	*
		Substitute Class C Fly Ash	*	*	*
GGBFS		Substitute GGBFS	*		*

* indicates a reduction in the category

The following is the list of most-beneficial practices to reduce the likelihood of thermal damage to structural mass concrete elements. The list is in order of most beneficial to least beneficial.

1. Keep fresh placement temperatures as low as reasonably possible.

2. Use wet curing methods when possible; if wet curing is not possible, use plastic wrap curing methods.

3. If possible, use extended form removal times.

4. Use soil form placements when possible. Use wood formwork with possibly additional insulation when there is considerable concern about cracking before the formwork is removed. Use steel formwork for placements when there is less concern about cracking when formwork is in place.

5. Include supplemental fly ash and GGBFS in the concrete mix design, preferably Class F fly ash over both Class C and GGBFS.

6. If there is relatively less concern for excessive maximum temperatures in the concrete, place elements in warmer ambient temperatures when possible.

7. Use mix designs with lowered cement contents.

Implementation Benefits

Further understanding of the effect of each parameter on mass concrete thermal properties will help the Iowa DOT and contractors to identify the most convenient and cost-effective methods to reduce the risk of thermal damage in mass concrete construction.