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Mass Concrete and Thermal Cracking, a Joint ACI-JCI Seminar

Editors:
Melissa Harrison and Christopher C. Ferraro

SP-325

American Concrete Institute
Always advancing

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Preface

Thermal cracking and damage from high internal temperatures during construction are concerns for the mass concrete of dams, bridges, buildings, and power plants. The design, planning and execution of placements which involve mass and thermally controlled concrete must consider hydration of cementitious materials within the concrete mixture to avoid thermal-related distress. Without such considerations, durability, and in some cases, structural integrity can be affected. This Special Publication is intended to help owners, designers, contractors, and concrete suppliers understand and address concerns with mass and thermally controlled concrete.

To highlight state-of-the-art developments in defining, designing, testing and modeling mass and thermally controlled concrete, American Concrete Institute (ACI) Committee 207 and the Japan Concrete Institute (JCI) held a full-day technical session at the ACI Fall Convention, Cincinnati, Ohio, October 16-20, 2011. This Special Publication (SP) contains eight of the papers presented at the technical session. The subjects of these papers include: (1) defining mass and thermally controlled concrete (2) design and planning considerations for mass concrete; (3) modeling and prediction of in-place concrete temperature development, and (4) physical testing of mass concrete.

On behalf of ACI Committee 207 and JCI, the editors sincerely thank all authors and presenters for their efforts and contributions to the technical session and this SP volume. Special thanks are given to the reviewers of the original manuscripts for their constructive comments and suggestions. The editors are also indebted to the ACI staff for their assistance in organizing this session and in preparing this SP. The editors earnestly hope that the information presented at the ACI session and in this SP will facilitate significant improvements in defining mass concrete, as well as the design, planning and control of mass concrete. This SP will serve as a valuable resource for researchers and engineers to make such improvements.

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TABLE OF CONTENTS

Planning and Execution of a Mass Concrete Placement utilizing Insulation Regimen

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Abstract

This paper summarizes the planning and execution stages of a critical mass concrete placement performed during summer months. The subject structure was a critical component of a large heavy industrial facility, consisting of large load bearing elevated flexural members. The planning and execution of this critical mass placement consisted of multiple tasks.

A laboratory study was performed for the purpose of making improvements to the mixture proportions existing and currently in use, admixture dosages and investigating placement temperature options. Adiabatic and semi adiabatic temperature rise was also measured during the laboratory study along with set times. Final proportions and admixture dosages were selected as a result of the laboratory phase. Primary outcome was increase in fly ash percentage from the existing mix design to control heat of hydration.

Based on the findings of the measured adiabatic temperature rise, a thermal control plan was developed adapting the new approach to structural mass concrete placements. A thermal protection/insulation regimen was developed using the mix parameters, expected ambient temperatures following placement, member dimensions and formwork/blanket insulation properties. The pre-placement modifications to the mixture proportions and the delivery temperature requirements protected the concrete against high internal temperatures and potential of Delayed Ettringite Formation (DEF), while the insulation regimen protected the concrete against rapid cooling and occurrence of thermal gradients between core and perimeter.

As part of the thermal control plan analysis, target placement temperatures were recommended to control maximum temperatures to prevent occurrence of DEF, in light of the heat rise of the modified mix. The placement temperature was accomplished by starting the placement at night and the use of ice to draw the temperature down. Upon completion of finishing, a curing compound was applied in lieu of water curing and the placement was insulated.

The thermal control plan simulation predicted a gradual reduction in the temperature of the placement, within limits of maximum internal temperatures and temperature gradients. The actual placement was monitored for core and perimeter temperatures using maturity probes. Monitoring enabled the team to react to abrupt changes in temperature if any was to occur. The placement was completed successfully with internal temperatures and gradients controlled within the desired ranges.

Keywords: mass concrete, adiabatic heat rise, thermal control plan, fly ash, thermal cracking, heat or hydration

Introduction

This paper summarizes the planning and execution stages of a critical mass concrete placement performed during summer months. The subject structure was a critical component of a large heavy industrial facility, consisting of large load bearing elevated flexural members, with minimum dimensions in the order of 2.1 meters (7 ft) [Figure 1]. The planning and execution of this critical mass placement consisted of multiple tasks.

Figure 1 Overview of beams showing reinforcement congestion.

Planning and execution consist of the following stages:

1. Laboratory Study
2. Development of the Thermal Control Plan and Batching Temperature
3. Post-Placement Thermal Monitoring
4. Curing, Insulation and Protection against Temperature Changes

Laboratory Study

Subject mass concrete placement was scheduled to occur during summer months. The existing concrete mixtures used on site were not utilized to date in a mass concrete placement of this significance and under the summer ambient conditions. Therefore the concrete mixture planned for use was reviewed in light of the placement specifics. A laboratory study was performed to revise the concrete mixture to achieve desirable performance objectives in the mass concrete placement under summer ambient conditions.

Existing concrete mixture utilized class F ASTM C 618 (ASTM, 2008) fly ash at a replacement rate of 25% of total cementitious material content. Existing concrete mixtures typically used type A (lignin based) water reducers meeting ASTM C 494