Session 63

Farouk Mahama

University of Florida

Validation of Stresses Caused by Thermal Gradients in Segmental Bridges

Topic Description

AASHTO LRFD and AASHTO Segmental Design Specifications require the superposition of a thermal gradient across the height of bridge superstructures when analyzing the bridge for serviceability. The gradient can be both positive (deck warmer than web) and negative (deck cooler than web). The negative gradient can cause high tensile stresses to develop in the top few inches of the bridge deck, requiring large prestress forces to counteract this tension. There is, however, no data in which actual stresses have been measured during these peak gradients to verify that the stresses are indeed as high as predicted by analysis. One reason for this is the difficulty of direct stress measurement in concrete. Furthermore, it takes hours for thermal gradients to develop in bridges. Consequently, creep may tend to reduce the very high local stresses that could otherwise develop if the process were more rapid.

This study is aimed at quantifying the state of stress in concrete due to the AASHTO nonlinear design gradients using a combined experimental and analytical approach.

Speaker Biography

Farouk Mahama (E.I.) is currently a doctoral student in the Department of Civil Engineering at the University of Florida, Gainesville. He obtained B.S. and M.S. degrees in civil enegineering in 2001 and 2003, respectively.

VALIDATION OF STRESSES CAUSED BY THERMAL GRADIENTS IN SEGMENTAL CONCRETE BRIDGES

By
Farouk Mahama, Graduate Research Assistant
University of Florida

Research Team:
PI: H. R. Hamilton, Co-PI: G. R. Consolazio
Graduate Research Assistant: David C. Walter
University of Florida

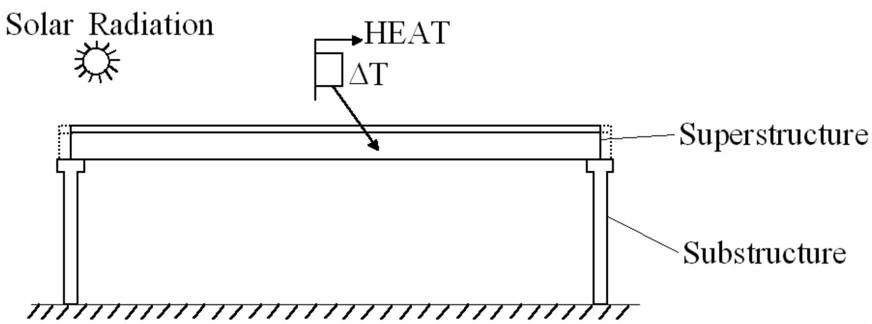
FDOT DESIGN CONFERENCE
2006

Agenda

- Introduction
- Background
- Objective
- Experimental Program
  - Laboratory set-up
  - Experimental tasks
- Numerical Modeling

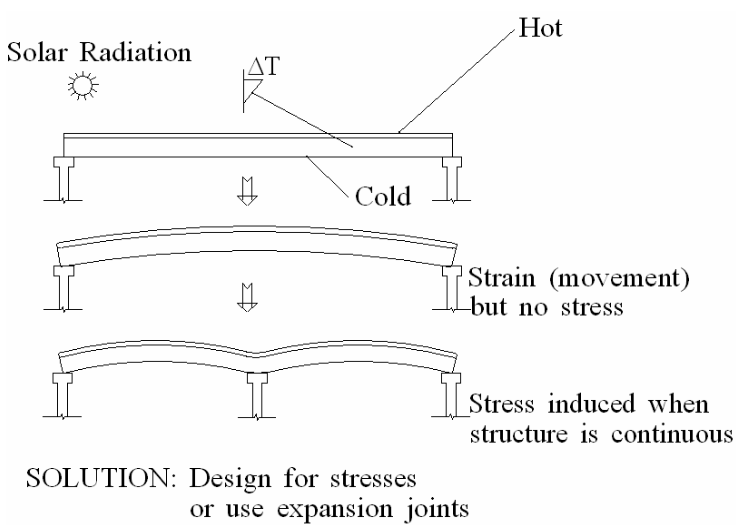
Thermally Induced Stresses

- Uniform Temperature



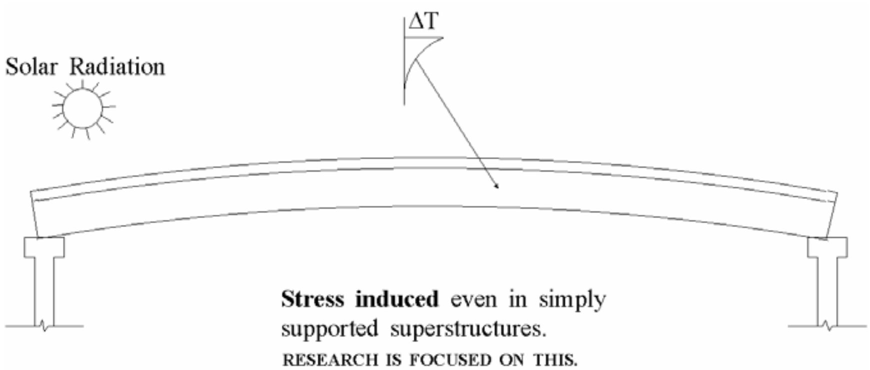
Thermally Induced Stresses

- Linear Temperature Gradient

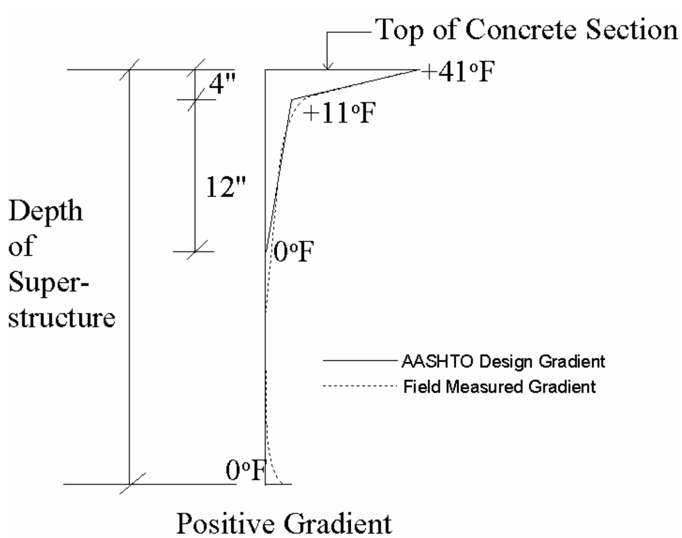


Thermally Induced Stresses

- Nonlinear self-equilibrating temperature

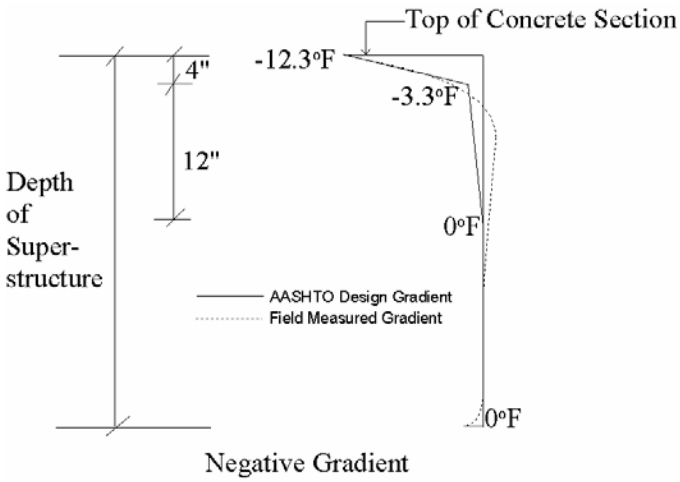


AASHTO - Positive Gradient



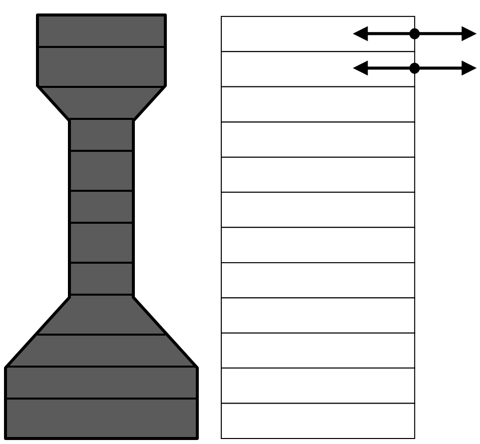
Confirmed with field measurements

AASHTO - Negative gradient



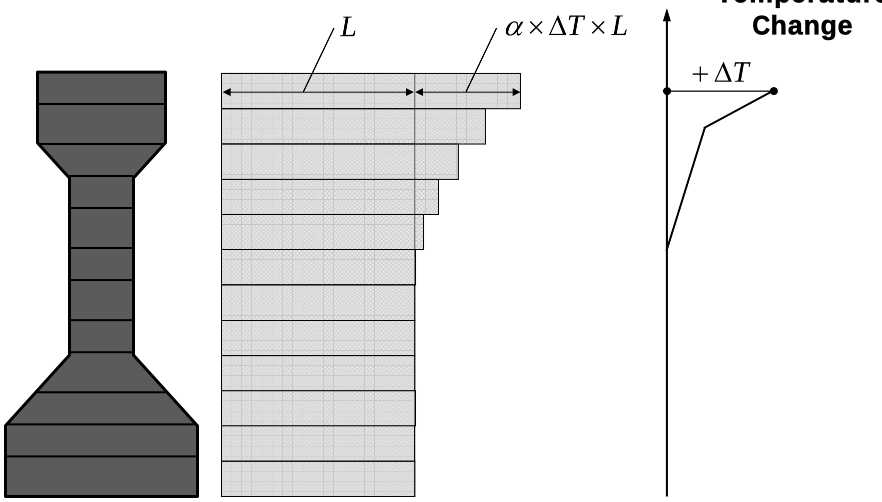
Positive * -0.3

Self-equilibrating Thermal Stresses - Model

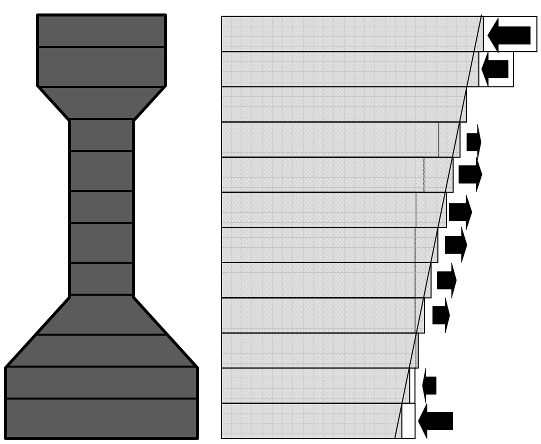


Assume slices can move independently when temperature changes

Self-equilibrating Thermal Stresses - Positive



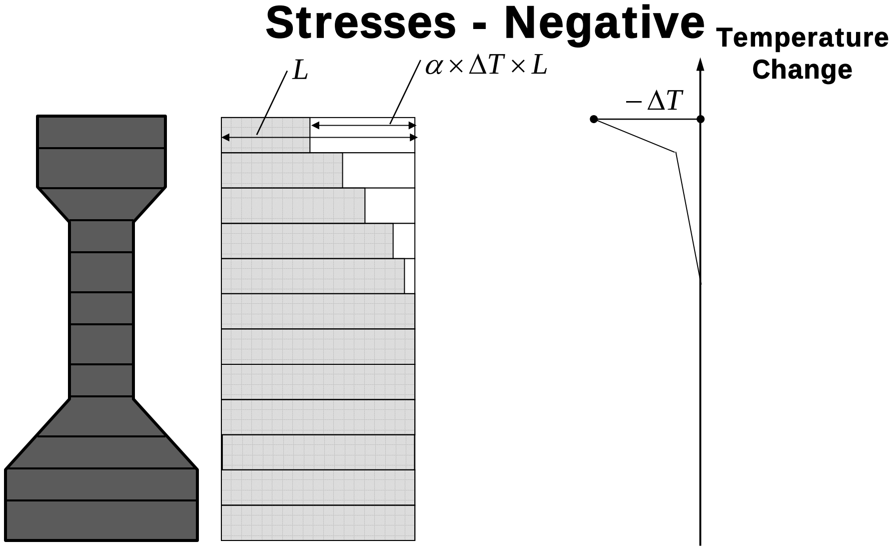
Self-equilibrating Thermal Stresses - Positive



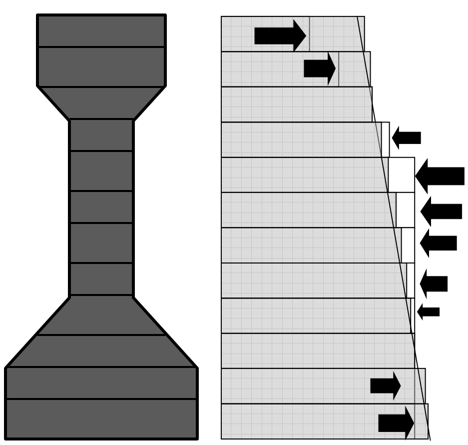
In the real beam, the slices can't move independently.

Stresses are generated when compatibility is enforced

Self-equilibrating Thermal Stresses - Negative



Self-equilibrating Thermal Stresses - Negative



In the real beam, the slices can't move independently.

Stresses are generated when compatibility is enforced

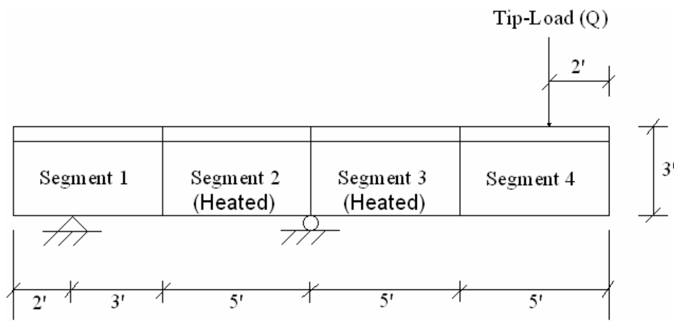
Motivation

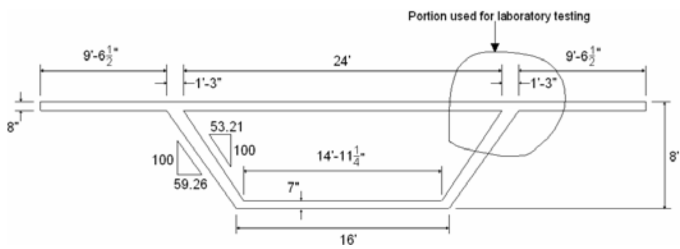
- Thermally induced stresses – AASHTO procedure.
- Service III – Design and LR
- Traditional concrete stress measurement: measure strain, convert to stress
- Effect of creep
- Variation in CTE

Objective

Quantify thermal stresses due to AASHTO nonlinear thermal gradients.

Experimental Program

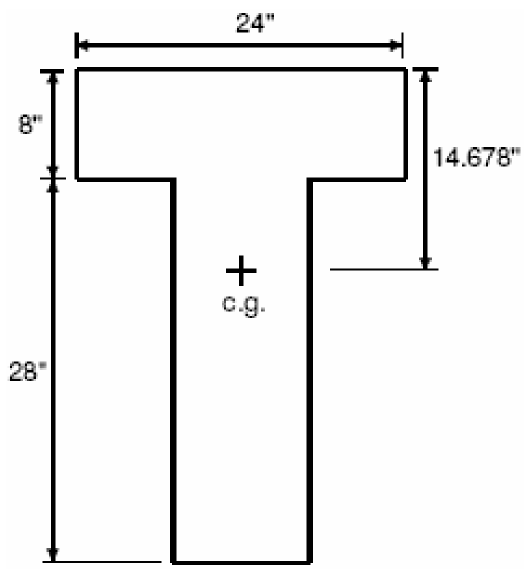




Experimental Program

- Main reasons for using representative portion of box-girder section
  - Cross-section shape independence.
  - Full-scale gradients.
  - Conduction + Convection vs. radiation.

Beam Cross-Section

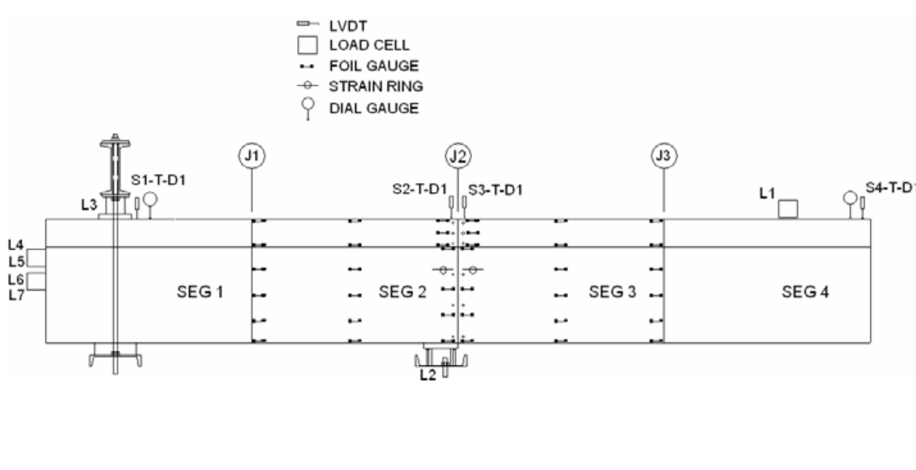


Experimental Program

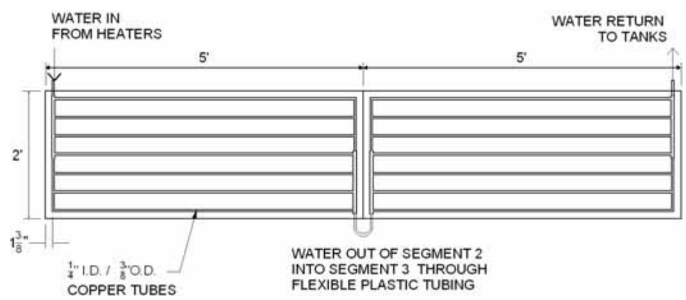
- Reference stress states – typical
  Service III stresses w/o thermal.
- Joint-opening creates known (zero) stress condition.
  - Eliminates effects of creep and shrinkage
- Joint-opening load – quantify thermal stress via back-calculation.

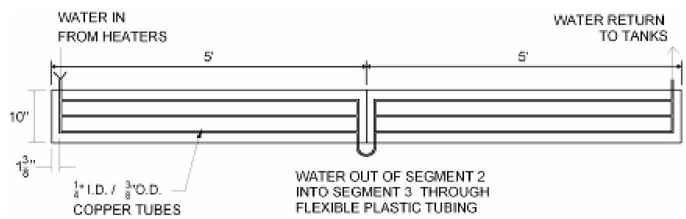
Laboratory Set-up

Instrumentation

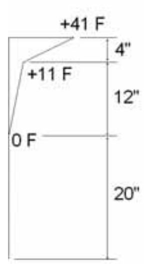


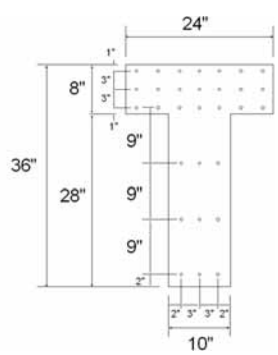
Thermal Control





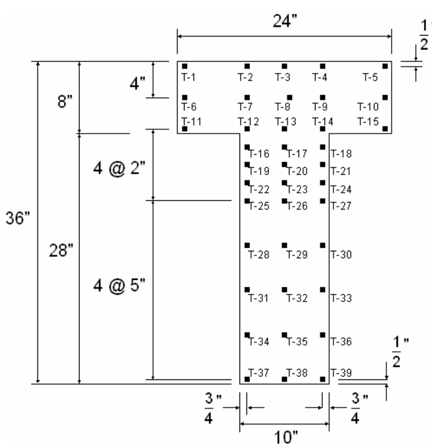
Thermal Control

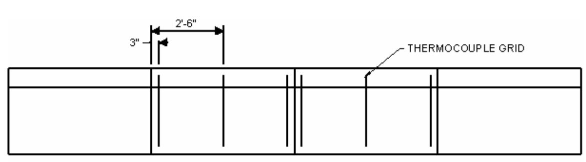




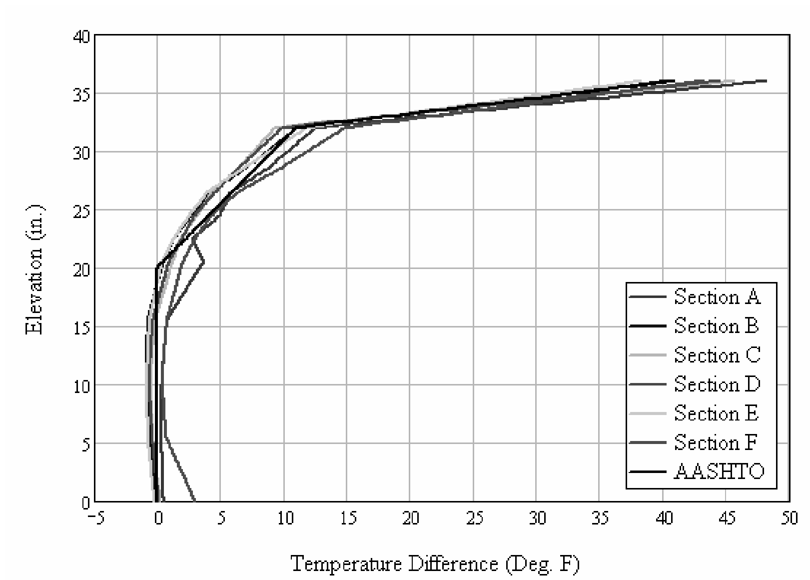
Thermocouples

Thermocouples

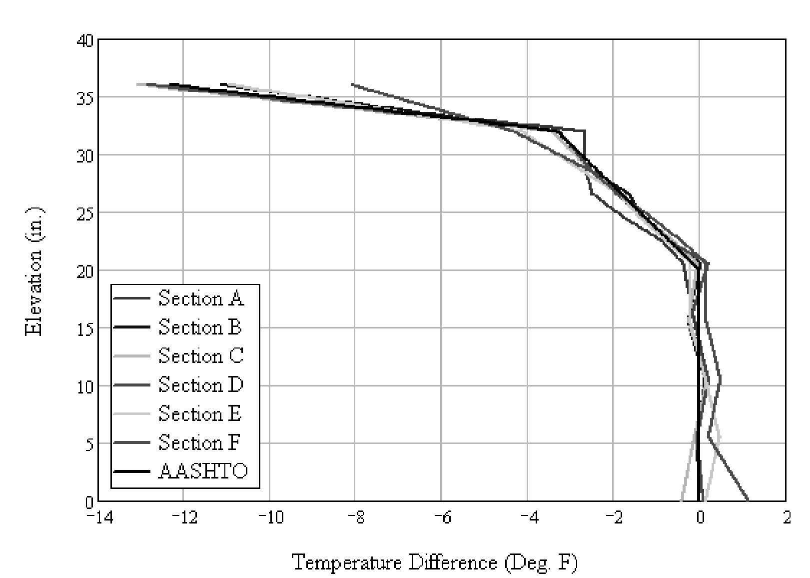




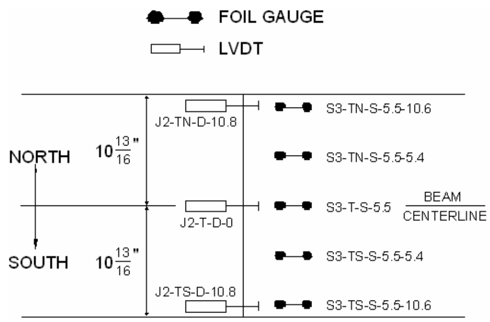
AASHTO Positive Gradient

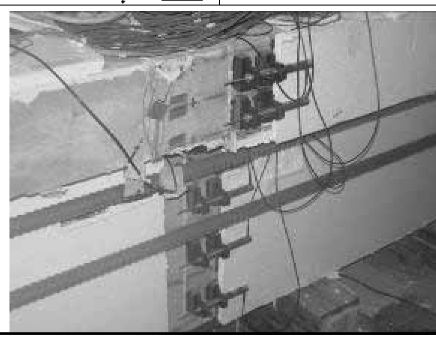


AASHTO Negative Gradient



LVDTs





Tasks

- In-situ coefficient of thermal expansion of heated segments.
- Joint-opening tip-loads (SRB bridge midspan, support stress states).
- Duration of thermal load application.

Summary

- Experiments
  - Create zero stress condition
  - Quantify thermal stresses
  - Data for numerical model calibration
- Numerical Modeling
  - Parametric studies (creep, CTE, elastic modulus)
- Development of design provisions
  - Thermal stress modification factor?

Acknowledgements

- FDOT Research Office
- Mr. Marc Ansley, Project Manager
- Test Specimen Fabrication: David Allen, Frank Cobb, Steve Eudy, Tony Johnston, Paul Tighe, FDOT Structures Research Center
- Chuck Broward, University of Florida