US Army Corps of Engineers ®
Jacksonville District

Portugues Dam

RCC Materials Investigation

Portugues Dam
RCC Materials Investigation

- **Outline**
  - Goals
  - Mix Design Parameters
  - Materials
  - Test Program
  - Tests on Laboratory Simulated Lift Joints
  - Conclusions

Portugues Dam
RCC Materials Investigation

- **Goals**
  - Determine behavior/characteristics of potential project materials
  - Determine properties for use in design analysis
  - Determine mix proportions for use in test fill placement(s)
  - Provide information for use in adjusting mixtures during production

Portugues Dam

- **Mix Design Parameters**
  - **Workability**
    - **Vebe Consistency 14 to 20 seconds**
    - **Entrapped Air Content 1.0%**
    - **Coarse aggregate proportions and aggregate grading:**
      - **EM 1110-2-2006, "Roller Compacted Concrete"**
      - **Sand aggregate volume selected to limit segregation**
    - **Fine aggregate content:**
      - **Selected by trial mixes to limit segregation**
  - **Strength**
    - **Compressive Strength Range 3000 to 5000 psi**
    - **Tensile Strength 300 psi +/-**

    (Design based on potential of materials!)
  - **Pozzolan**
    - **Targeted 40% cement replacement by volume based on previous experience and "comfort" level of designers.**

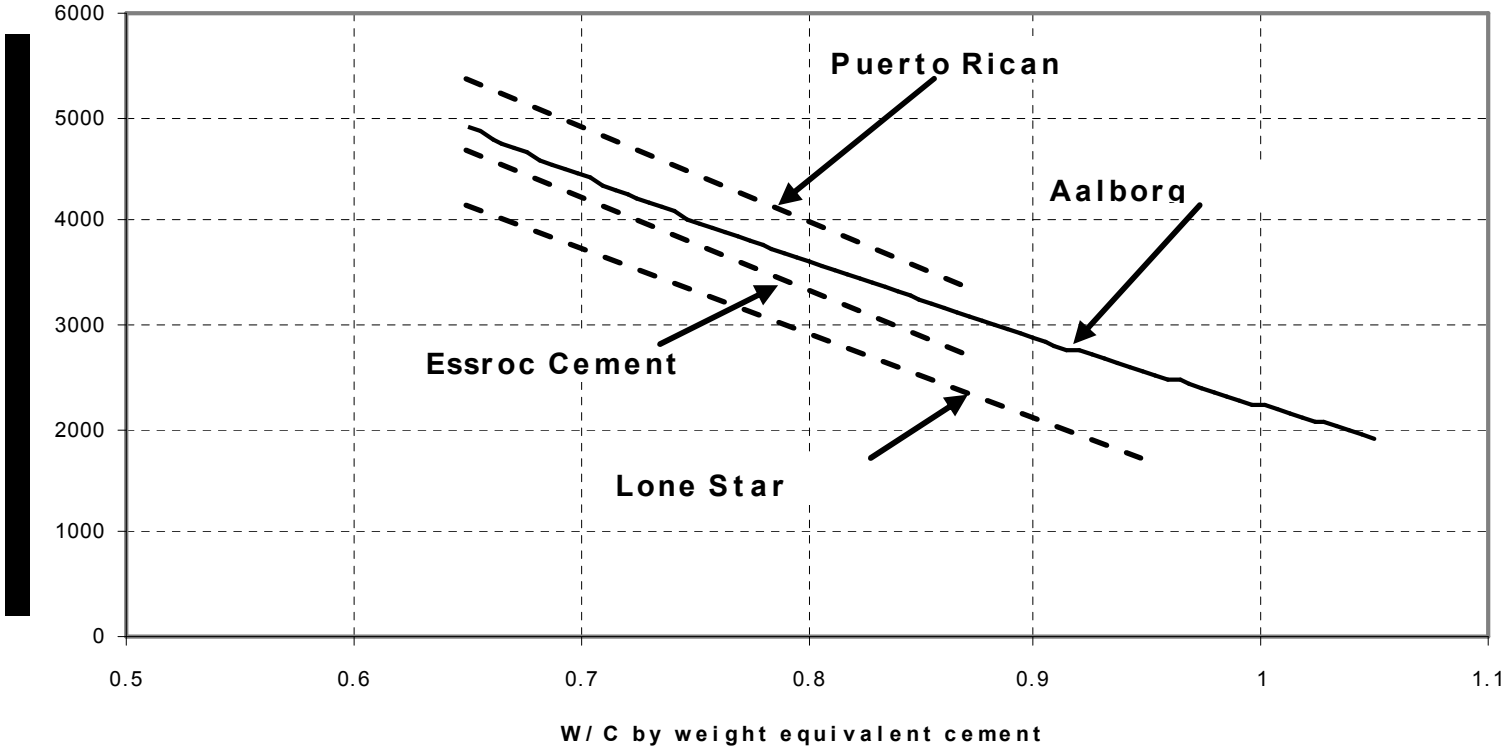
Portugues Dam

- **Materials**
  - **Aggregates: Crushed diorite from government-owned quarry**
  - **Cement:**
    - **San Juan Cement Co., Type I, San Juan**
    - **Puerto Rican Cement Co., Type I, Ponce**
    - **Antilles Cement Co., Type I/II, Aalborg (Denmark)**
    - **Lone Star Cement Co., Type I/II, (Control)**
  - **Pozzolan:**
    - **Dolet Hills, Class F**
    - **Martin Lake, Class F**
  - **Slag:**
    - **Holnam GGBS, Grade 100, Chicago**
  - **Admixtures:**
    - **Master Builders WRA, Pozzolith 220N and 100-XR**

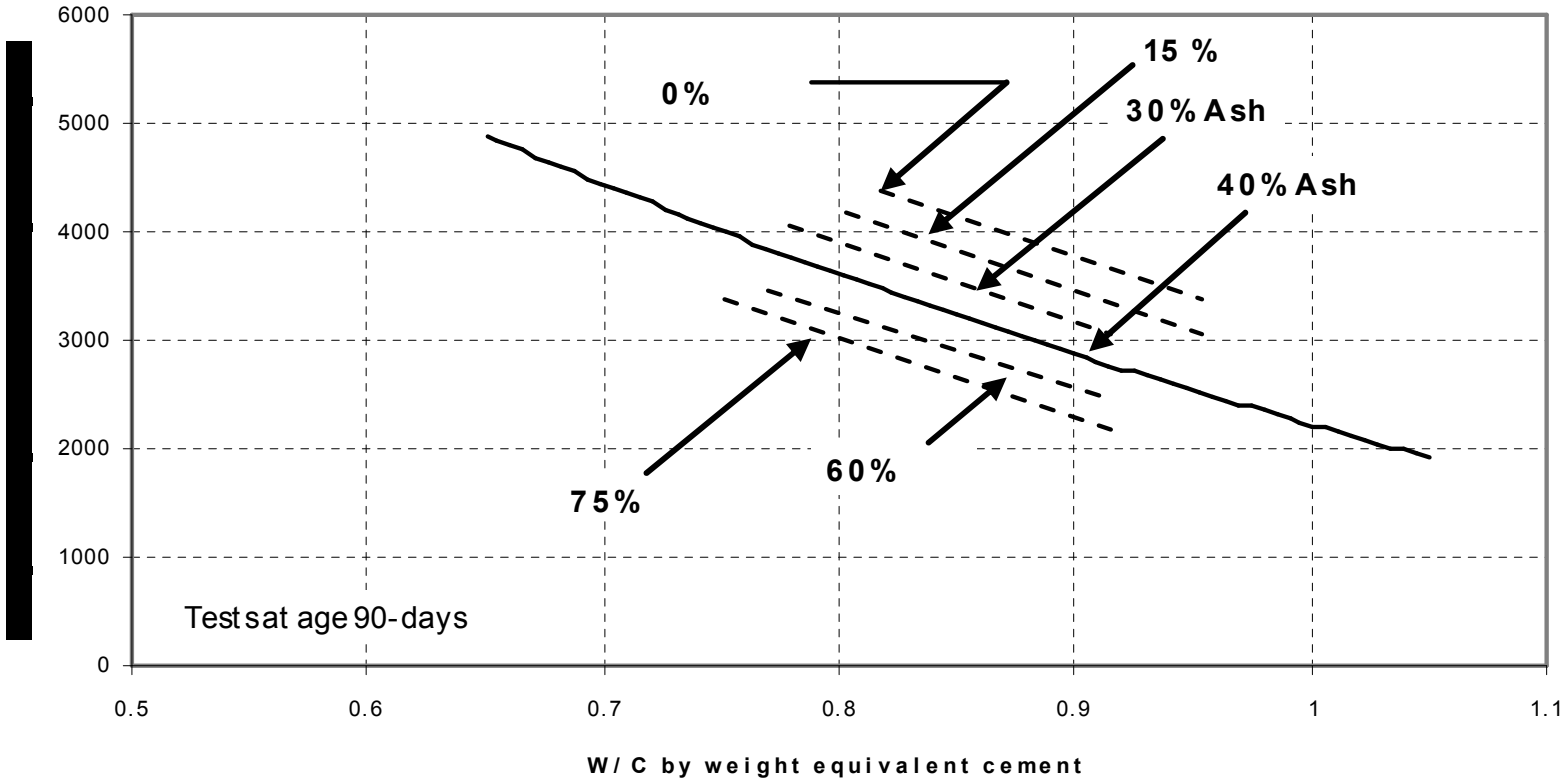
Portugues Dam

- **Materials Investigation Program**
  - **Phase I**
    - **Establish baseline proportions for RCC mixtures**
    - **Proportion series of mixes to span 1-year compressive strength of 2000 to 5000 psi (including modulus of elasticity)**
    - **Proportion series of mixes to evaluate effect of cement and pozzolan type**
    - **Proportion series of mixes to evaluate use of slag**
    - **Proportion series of mixes to investigate effect of pozzolan content**
    - **Proportion series of bedding mortar mixes**
    - **Perform direct tensile strength tests on "jointed" 6x12-inch cylinders**
    - **Select "design" mix**

Compressive Strength vs W/C
(w/40% Dolet Hills Ash)



Compressive Strength vs W/C
(Aalborg Cement with varying Ash %)



Portugues Dam

- **Materials Investigation Program**
  - **Phase I Supplemental**
    - **Perform dry rodded unit weight tests to verify coarse aggregate proportions**
    - **Proportion series of mixes at varying sand contents to verify sand aggregate content**
    - **Proportion series of mixes to further investigate use of higher pozzolan contents (60 and 75-percent cement replacement by volume)**
    - **Proportion series of mixes with varying WRA/Retarding admixture dosage to evaluate effect on time of set**
    - **Perform sand degradation tests to investigate sand balling anomaly**
    - **Proportion mix with "clean" sand to evaluate effect on compressive strength and workability (water content)**
    - **Perform "modified" accelerated cure strength tests to evaluate compressive strength gain of high pozzolan content mixes**

Portugues Dam

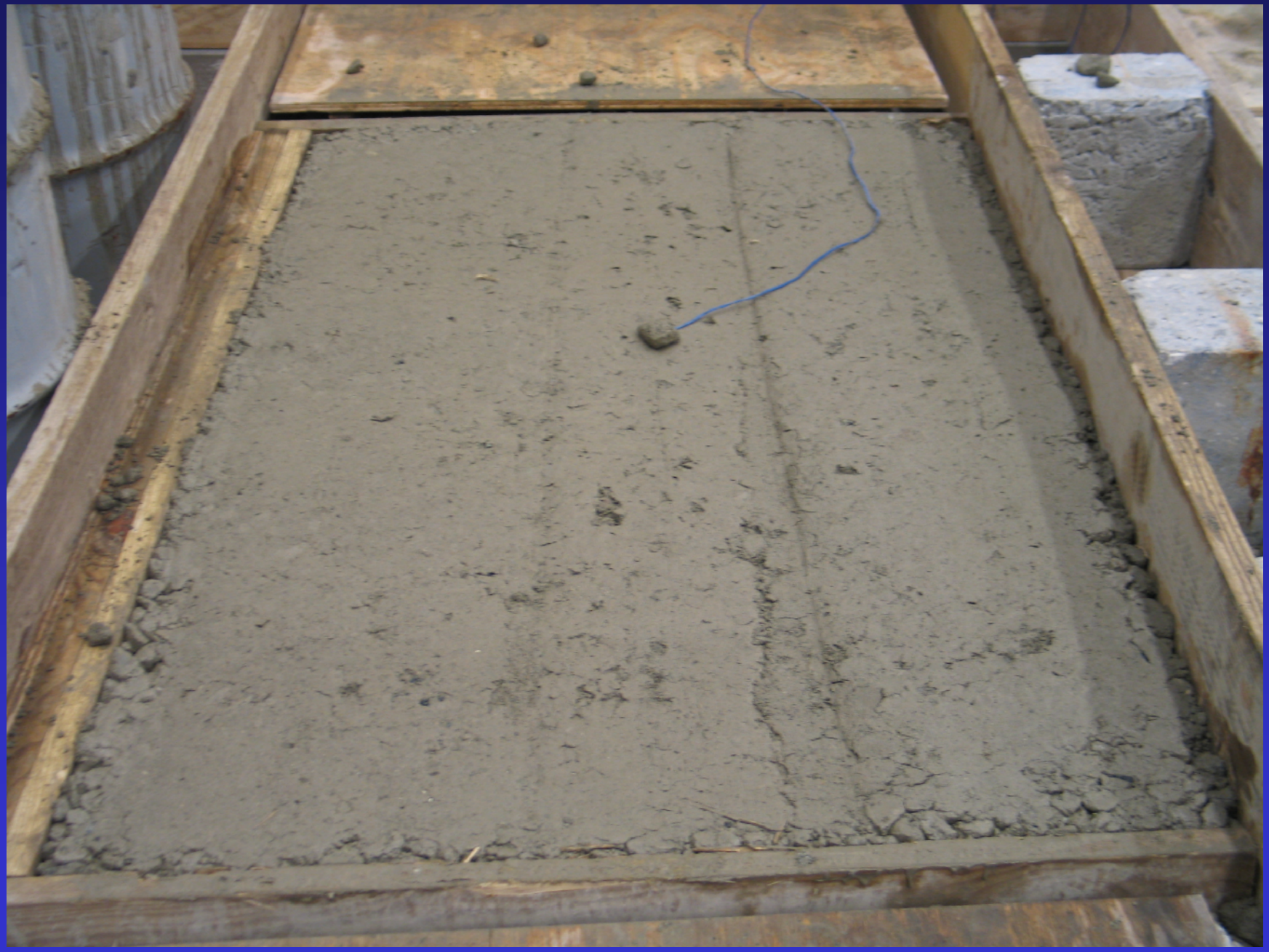
- **Materials Investigation Program**
  - **Phase IIa**
    - **Construct series of panels to investigate direct and splitting tensile strength and biaxial direct shear strength of lift joints**
  - **Phase II**
    - **Modulus of Elasticity and Poisson's Ratio Tests**
    - **Creep and Autogenous Volume Change Tests**
    - **Adiabatic Temperature Rise Tests (Including Q-drum)**
    - **Thermal Diffusivity**
    - **Coefficient of Thermal Expansion**
    - **Specific Heat**
    - **Tensile Strain Capacity**

Portugues Dam
Standard Procedures

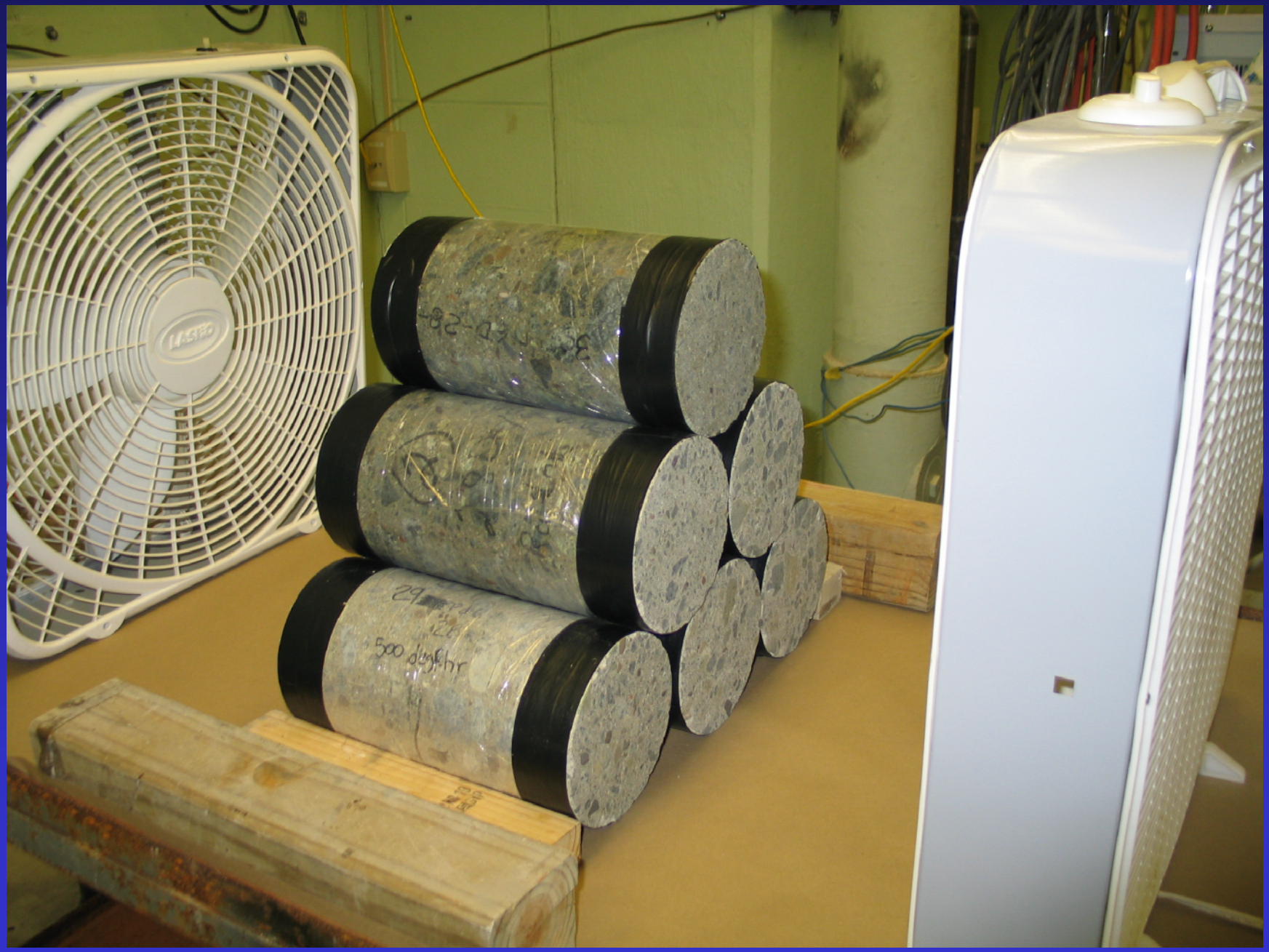
Simulated Lift Joints

- Nominal 46 x 72 x 12-inch thick panels
- Constructed in two lifts using varying lift joint treatments
- RCC consolidated using walk-behind vibratory roller
- Core and sawn block samples for direct and in-direct tensile strength, bi-axial direct shear strength
- Results intended for use in evaluating effect of fly ash, retardation, joint maturity, fines content


3500PSI

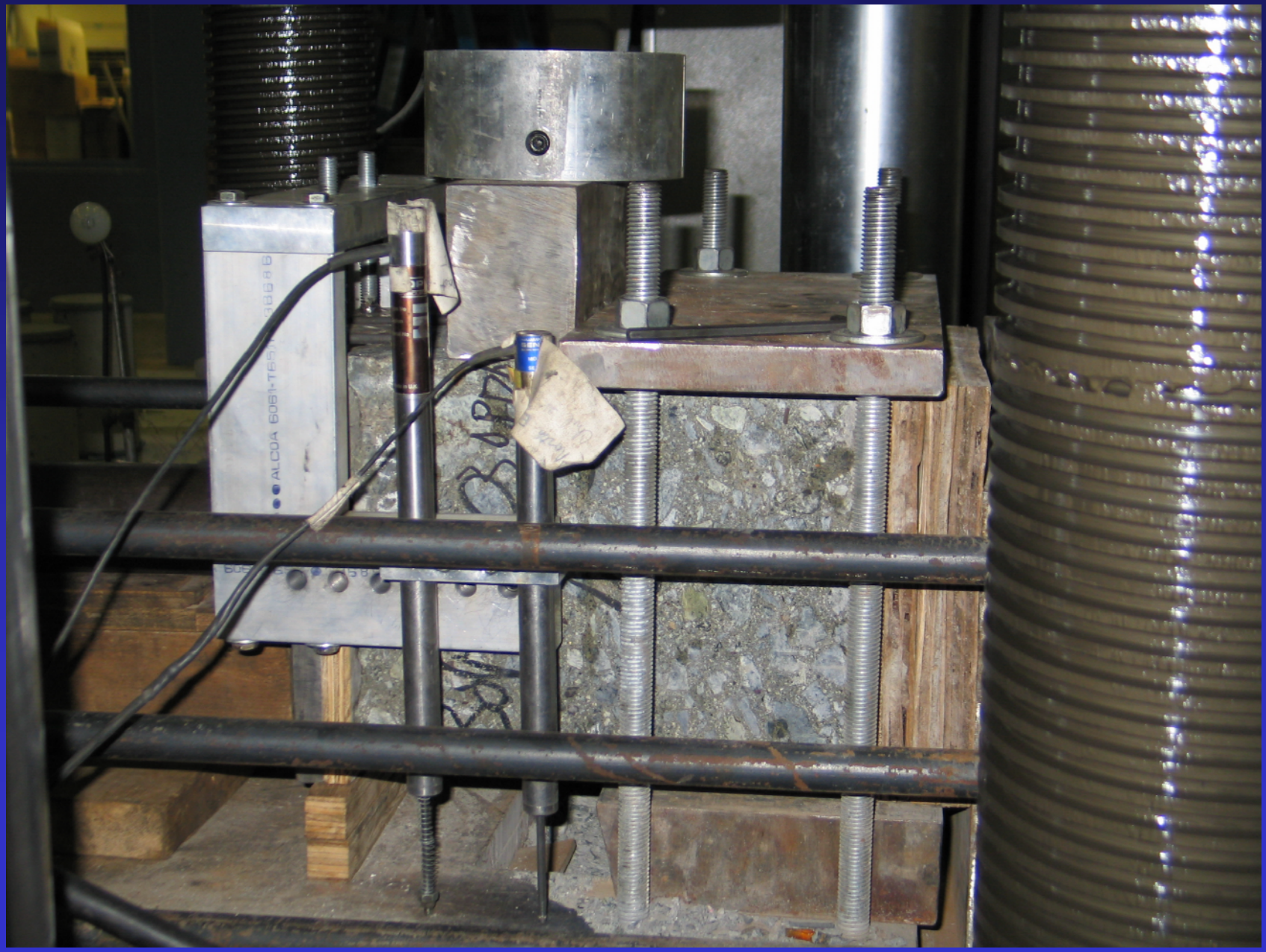


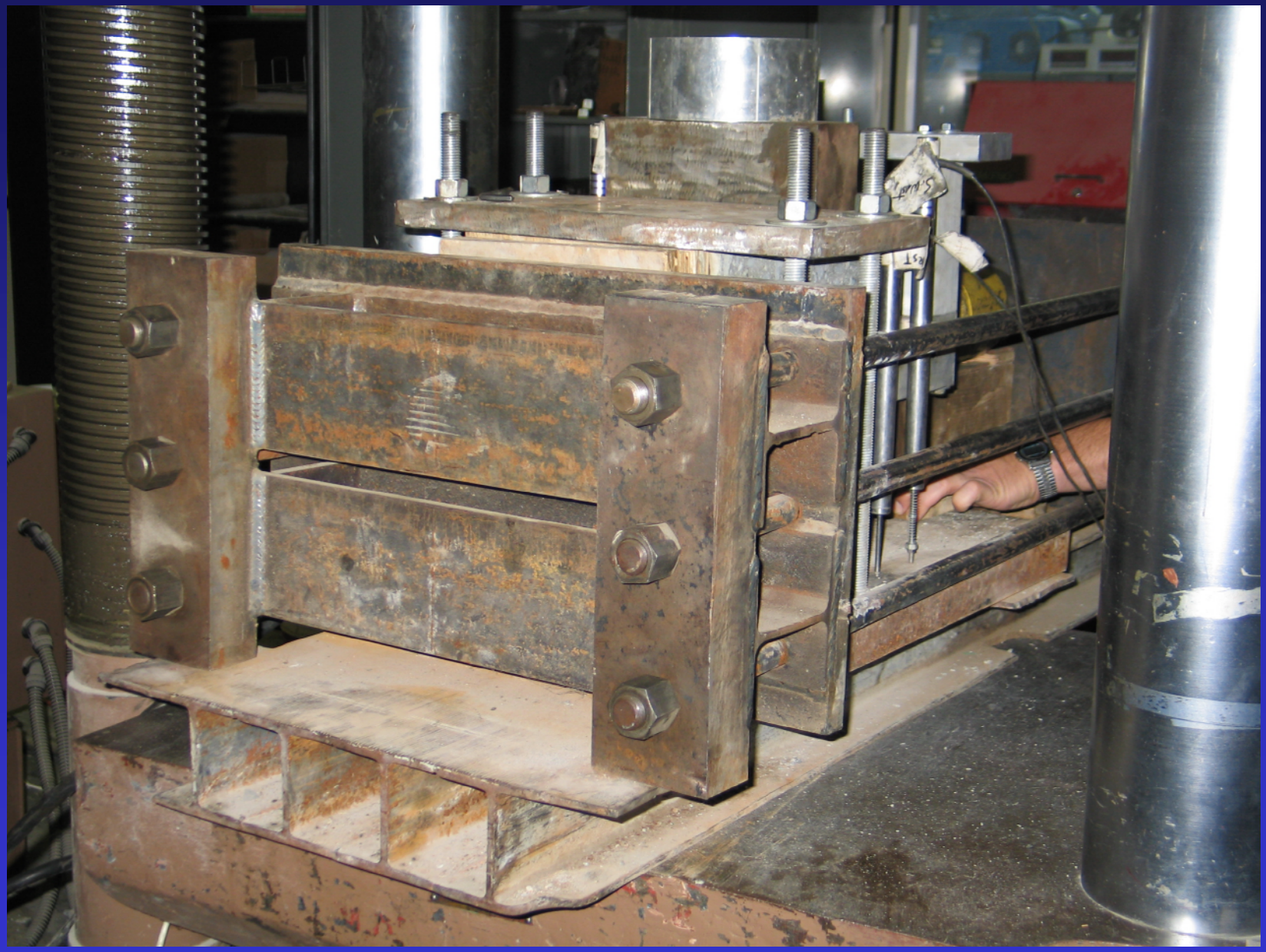

PANEL F
PANEL F
PANEL F

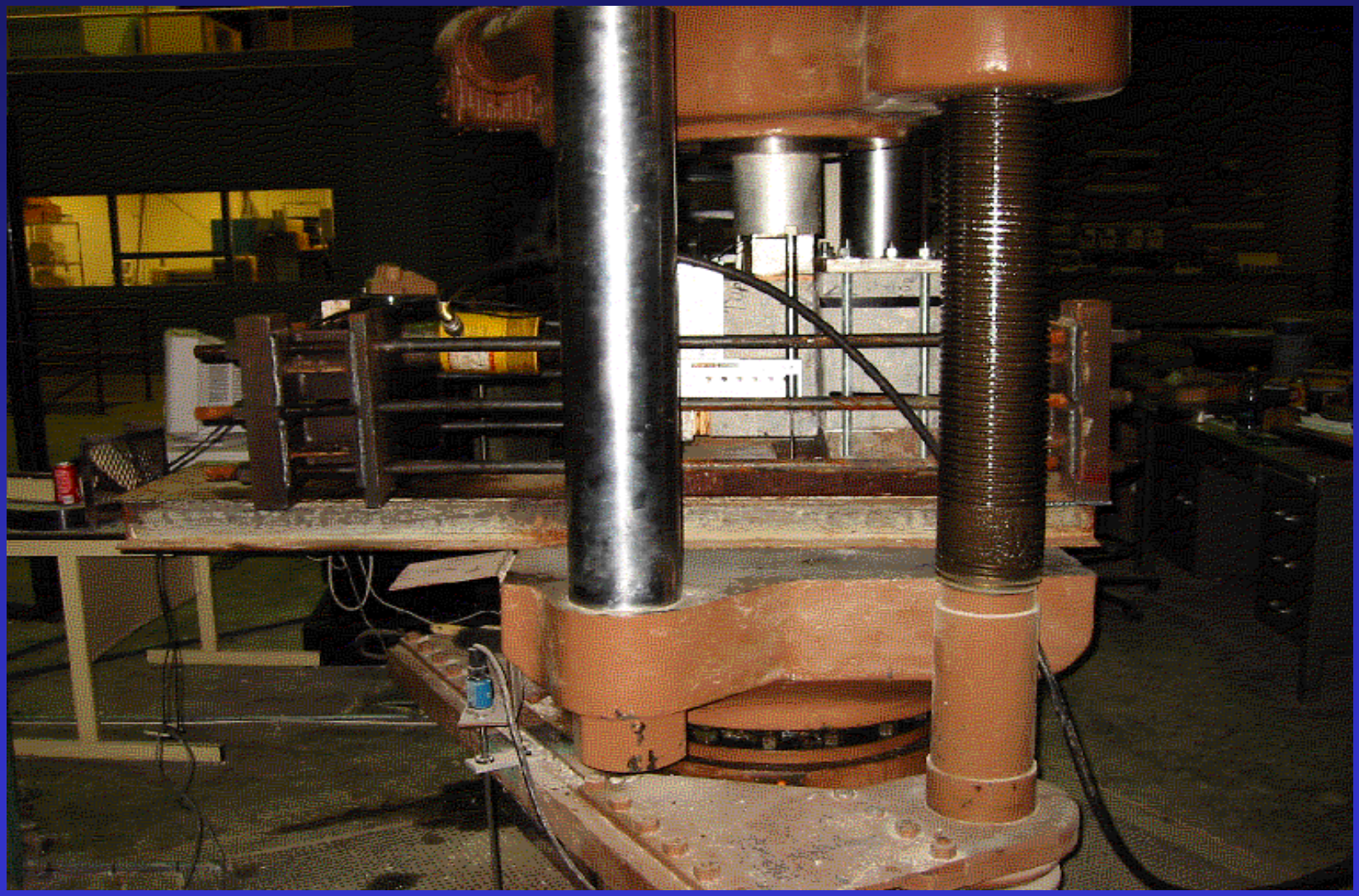

500 dpm/hr


(3)
(2)


29PD6D-DT-365d-3


ALCOA 6061-T6



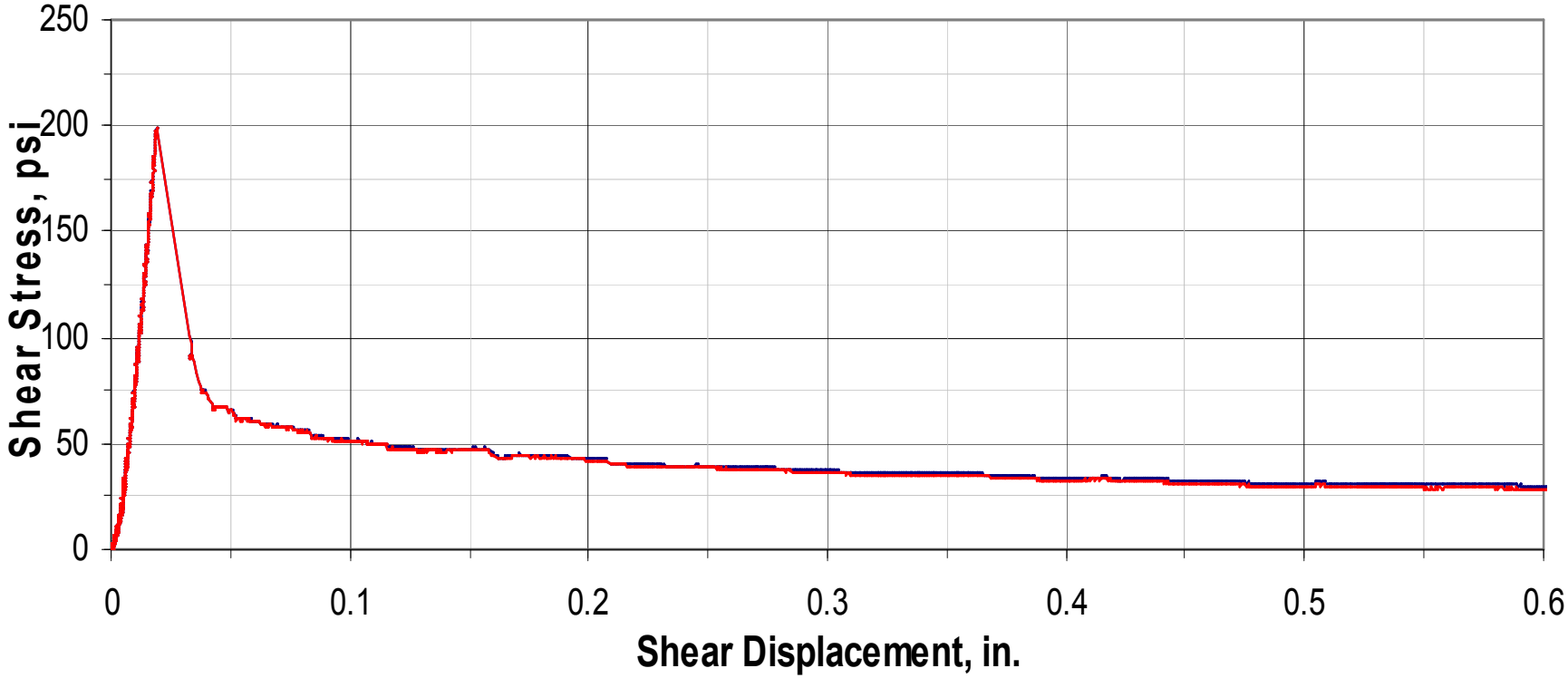


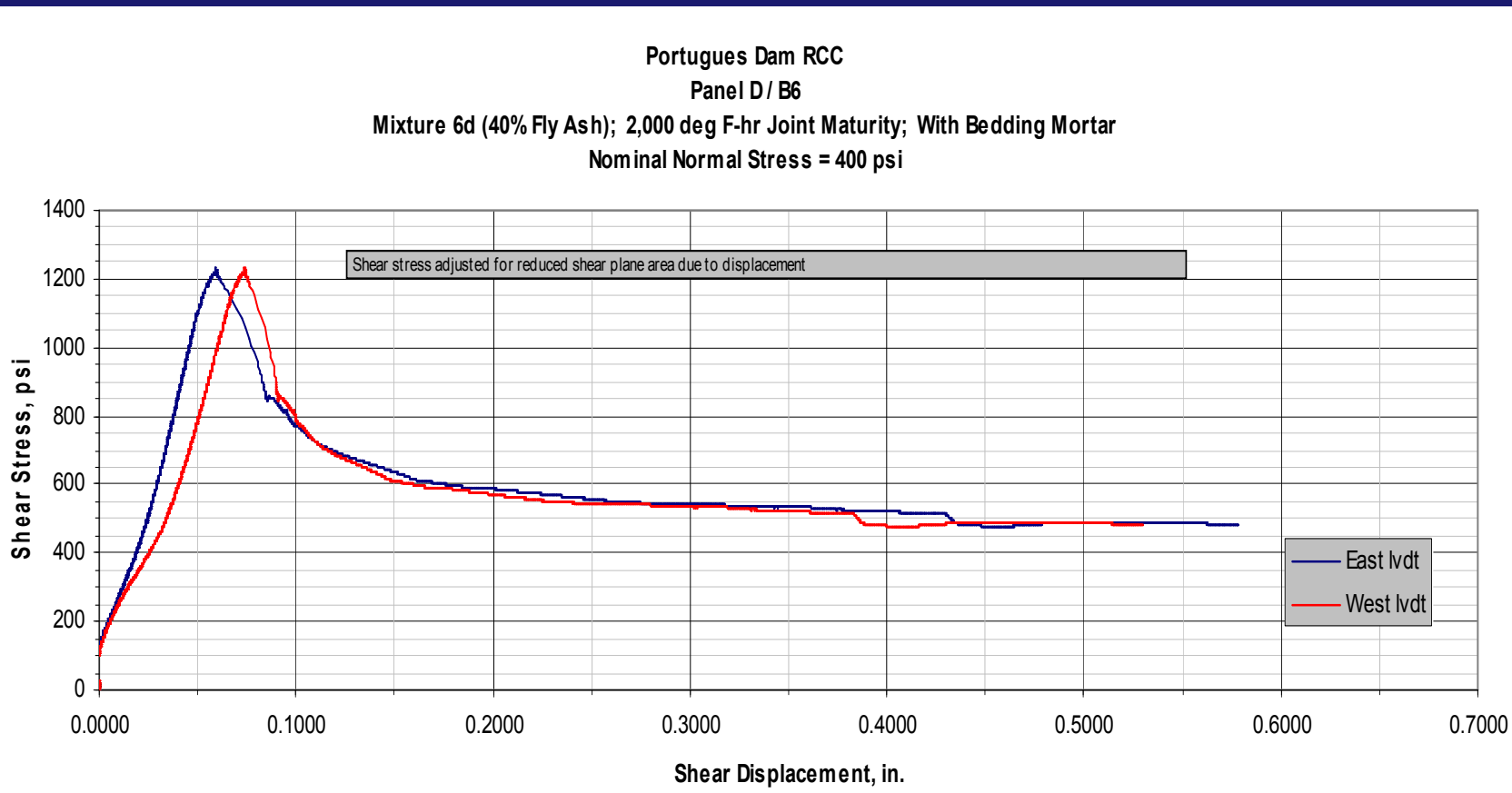

SATEC

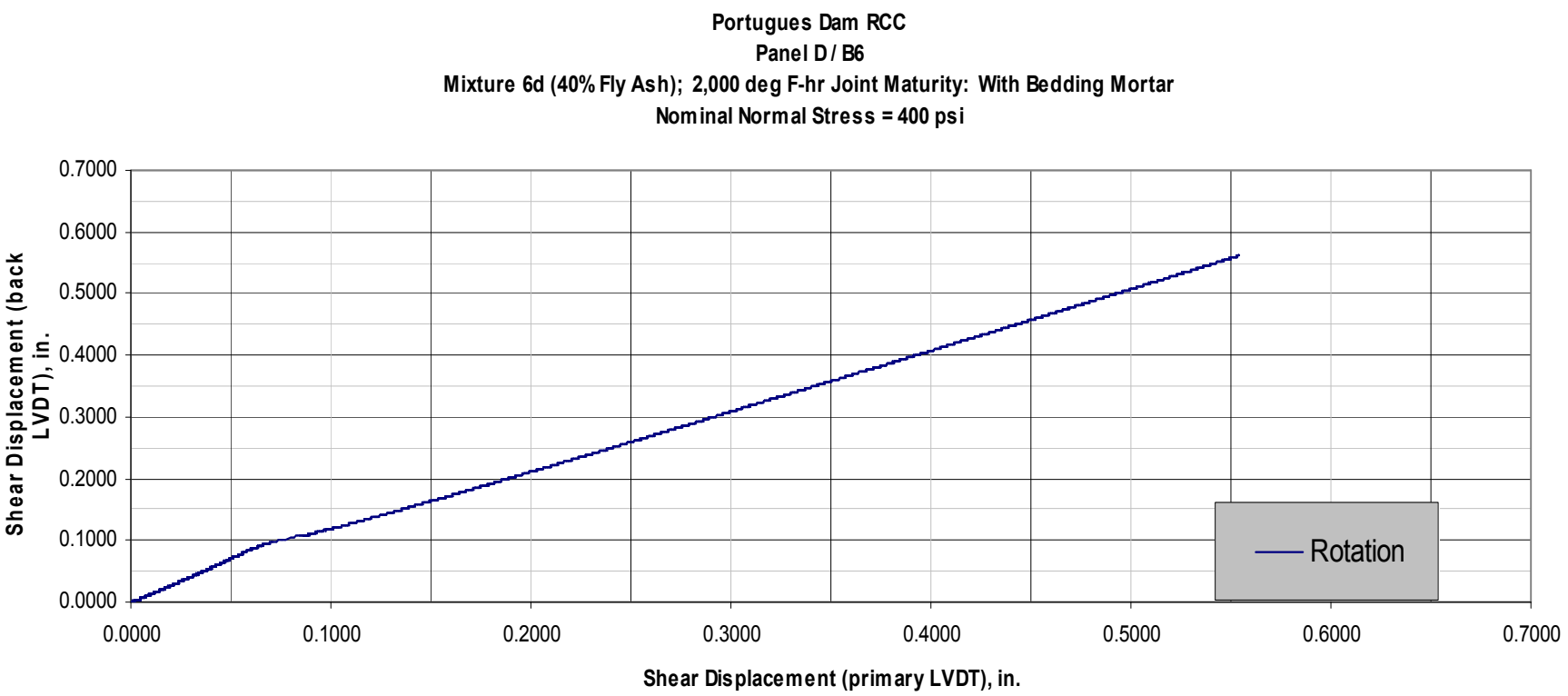
Portugues Dam

2000 °F-hr Joint Maturity with Bedding Mortar

Normal Stress = 100 psi




Portugues Dam RCC
Panel D / B6
Mixture 6d (40% Fly Ash); 2,000 deg F-hr Joint Maturity; With Bedding Mortar
Nominal Normal Stress = 400 psi
Shear stress adjusted for reduced shear plane area due to displacement
Shear Stress, psi
1400
1200
1000
800
600
400
200
0
0.0000
0.1000
0.2000
0.3000
0.4000
0.5000
0.6000
0.7000
Shear Displacement, in.
East lvdt
West lvdt


Portugues Dam RCC
Panel D / B6
Mixture 6d (40% Fly Ash); 2,000 deg F-hr Joint Maturity: With Bedding Mortar
Nominal Normal Stress = 400 psi
Shear Displacement (back LVDT), in.
0.7000
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
0.0000
0.1000
0.2000
0.3000
0.4000
0.5000
0.6000
0.7000
Shear Displacement (primary LVDT), in.
Rotation

Selected Results: BiAxial Direct Shear

Joint Treatment	Peak/Initial* Cohesion, psi
Design Mix, 500°F-Hr	266
Design Mix, 2000°F-Hr	275
75% Ash, 2000°F-Hr	139
Design Mix, 2000°F-Hr w/bedding	448
Design Mix, 2000°F-Hr Retarded	408
Design Mix, 2000°F-Hr Clean Sand	316

***Tests at age 90-days**

Selected Results: Direct Tensile Strength Tests

Joint Treatment	Direct Tensile* Strength, psi
Design Mix, 500°F-Hr	385
Design Mix, 2000°F-Hr	220
75% Ash, 2000°F-Hr	180
Design Mix, 2000°F-Hr w/bedding	345
Design Mix, 2000°F-Hr Retarded	275
Design Mix, 2000°F-Hr Clean Sand	285

***Tests at age 365-days**

Conclusions

- The comprehensive test program conducted for the Portugues Dam Project has provided invaluable insight on the behavior and characteristics of RCC and other concreting materials.
- The COE has significant expertise in the design, evaluation and use of RCC. This expertise is readily accessible through the RCC DX and Materials CoP.

Questions?

(Thank You!)