Westinghouse Savannah River Company
Aiken, South Carolina

EVALUATION OF CONCRETE CRACKING
Z-AREA SALTSTONE VAULTS

Aiken, South Carolina

By

Kamran Farahmandpour

April 3, 1991

construction technology laboratories, inc.

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INTRODUCTION

A Saltstone vault is a reinforced concrete box structure, open at the top until filled with Saltstone. The vault measures 100 x 600 ft in plan with a height of 25 ft. The vault is divided along its length into two (2) equal 300-ft segments. Each segment is divided into three (3) cells, each measuring 100 x 100 ft in plan. Each segment of the vault has a 2-ft thick mat foundation that supports 18-in. thick walls. The vault stores low-level radioactive waste in the form of Saltstone.

Concern for the structure is due to cracking in the 18-in. thick walls. Some cracks exhibit efflorescence and corrosion deposits. It is our understanding that the majority of the cracks have previously been sealed with various coatings and sealants. However, the most effective method to seal the cracks to date appears to be using an approximate 50-mil thick layer of a bituminous-based, flexible coating applied to the inside of the vault walls.

Project design criterion for these structures requires that cracks be sealed to prevent migration of water through the walls in either direction. It is anticipated that the vaults will be completely encapsulated with clay in approximately 25 to 30 years. A maintenance program will also be established to inspect and repair any new or existing cracks that may exhibit leakage. The maintenance program will involve inspection from the outside of the vaults. It is our understanding that the radiation levels generated by the Saltstone are low, and will not adversely affect performance or durability of repair materials.

Eight (8) concrete core samples were removed from the walls by Westinghouse Savannah River Company (WSRC) personnel and submitted to Construction Technology Laboratories, Inc. (CTL) for laboratory testing. Five (5) of these core were drilled directly over visible cracks. It was reported that some cracks in the structure exhibited light corrosion deposits. However, none of the submitted cores were drilled directly over cracks exhibiting corrosion staining. Results of two (2) separate crack monitoring studies conducted by WSRC were also submitted for CTL's review.

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FINDINGS AND RECOMMENDATIONS

Based on review of project documents, field date by others and laboratory test results, the following findings and recommendations are presented:

Findings:

1. Review of available project documents indicates that a majority of cracks are nearly vertical, and generally extend through the entire thickness of the walls. Also, most cracks exhibit movements due to daily temperature fluctuations. The observed crack movements can greatly increase as the vault structures are subject to seasonal temperature changes. In addition, further movement of the cracks may be anticipated as Saltstone is loaded into the cells.

2. Results of petrographic examination of selected cores removed from the walls indicated concrete of satisfactory quality with estimated water/cement ratios ranging from 0.40 to 0.43. In our opinion, the major cause of the cracks is attributed to temperature effects during initial curing of concrete.

3. Visual and petrographic examinations indicated evidence of two different concrete mixes in several core samples. It is possible that some cracking in the walls may have also occurred due to differential shrinkage of these concretes. It is suspected that the existence of two different concrete mixes in the core samples may have been caused by deficiencies in construction practices during placement of concrete. However, this is not expected to adversely effect the performance of the structure.

4. Results of mechanical soundings by WSRC personnel indicated no concrete delaminations in areas where cracks exhibited corrosion deposits.

Recommendations:

1. All cracks greater than 0.004 in. should be repaired in accordance with recommendations by the American Concrete Institute (ACI) Committee 224 for water retaining reinforced concrete structures. Recommended repair is by injecting cracks with an expandable urethane chemical grout such as "Scotch-Seal Brand Chemical Grout 5600" manufactured by 3M (St. Paul, MN). Preparation of cracks and injection procedures should be performed in accordance with manufacturer's recommendations Manufacturer's information for this product is enclosed in Appendix A. Note that list of candidate materials is not all inclusive. Potential performance of materials should be evaluated by trial and mock-up testing.

2. Rout and seal all exterior visible cracks after the chemical grout has been injected and cured. Guidelines provided by ACI 224 and ACI 504 should be followed in routing the cracks and application of sealer. A rectangular groove 5/8-in. wide and 3/8-in. deep should be centered directly over the crack. Prior to the application of sealant, the grooves must be cleaned and a bondbreaker provided at the inner face of the groove to prevent concentration of stress in the sealant as the cracks move. The bondbreaker may be a polyethylene strip, pressure sensitive tape, or other material that will not bond to the sealant. A flexible sealant may then be installed in the routed grove as directed by the manufacturer. The following sealants are recommended:

   a. "NITOSEAL 225" gun grade two-component polyurethane joint sealer manufactured by Fosroc Inc. (Plainview, NY) (note that NITOSEAL PRIMER may be recommended)

b. "Sikaflex 2c NS" (non-sag) polyurethane elastomeric sealant manufactured by Sika Corporation (Lyndhurst, NJ) (note that priming with Sikaflex 429/202 may be recommended)

Manufacturers' data for these products are attached in Appendix A. Note that list of candidate materials is not all inclusive. Potential performance of materials should be evaluated by trial and mock-up testing.

3. It is recommended that the performance of the bituminous-based coating previously applied over the cracks be evaluated using CTL's accelerated water penetration test, or similar method. If an insignificant number of leaks are detected, coating should be maintained by reapplication of the same material from the inside of the tanks. If the previously applied coating is proved ineffective, all cracks suspected of penetrating through entire thickness of the walls should be routed and sealed as described in paragraph 2 of this section.

4. Due to the potential for reactivity between free sulfate present in the Saltstone and cement paste in the concrete walls, interior surfaces of currently used cells should be coated with Multithane 386 manufactured by Polymer Plastics Corporation (Hauppauge, NY). If future studies indicate that sulfate reaction is not a concern, coating of the entire inner surface of the cells may not be required.

5. A maintenance program should be established to repair leaks that may occur in the sealed joints. All leaking joints should be repaired as soon as possible in accordance with recommendations presented in paragraph 4 above.

OBJECTIVES AND SCOPE OF WORK

The objective of CTL's evaluation was to determine probable cause of concrete cracking, assess the general quality of concrete, and develop recommendations for repair.

CTL's work was conducted within the following scope of work:

1. Available project documents were reviewed.

2. Petrographic and visual examination of eight (8) core samples was performed to evaluate cause of cracking and assess general quality of concrete.

3. This report was prepared outlining our findings and recommendations.

DOCUMENT REVIEW

The following documents were submitted by WSRC and reviewed by CTL:

a. Vault Crack Map #1 included crack map surveys of Vault 1, Cell 1 mapped by Ebasco in mid 1988. Although the map for the entire structure was not provided, the crack maps of Cell 1 were believed to be representative of the entire vault. This document also provided crack sizes.

b. Vault Crack Map #2, also prepared by Ebasco, showed a few representative cracks throughout vault 1 and their respective sizes.

c. Crack Movement #1 included a comprehensive strain gauge study of crack movements in Vault 1, Cell 1.

d. Crack Movement #2 included a comprehensive study of crack movements in Vault 1, Cell 1 using an optical crack comparator. This study also monitored the effects of temperature on crack movement.

Review of the above documents indicated that:

1. Spacing of through-wall cracks ranged from approximately 6 to 30 ft apart.
2. Most cracks are near vertical and extend through the entire thickness of the walls.
3. Cracks ranged from 0.005 to 0.035 in. wide.
4. Strain gauge study indicated strains of 0.0015 in the east wall to 0.008 in the west wall. The temperature differentials that caused these strains ranged from 1° F in the east wall to 30° F in the west wall.
5. Study conducted by a hand-held optical crack comparator revealed that some cracks can widen up to 86% in a daily temperature differential of approximately 25° F. Largest crack movement recorded was 0.007 in.

Due to its largest degree of accuracy and temperature independence, the results of the study conducted using a hand held (Crack Movement #2) were mainly utilized in our evaluation.

LABORATORY TESTING

Laboratory testing consisted of visual inspection of all cores, as well as performing petrographic examinations of eight (8) core samples extracted from the walls. Cores were obtained by WSRC personnel, and were drilled from the outside walls of the vault structure. Length of the cores ranged from 4 to 7 in. long. Four (4) of the cores (A-1, A-3, A-4 , A-5 and A-6) were drilled directly over visible cracks. The remaining cores (A-2, A-7 and A-8) were drilled in areas with no visible cracking.

The following is a summary of findings of petrographic examinations:

1. Core A-2 exhibited subparallel cracking close to the surface of the core.
2. Estimated water/cement in all eight (8) cores ranged from 0.40 to 0.43.
3. The paste-aggregate bond in all cores was found to be tight.
4. The paste in all cores was moderately hard.
5. Cores A-1, A-2, A-7 and A-8 consisted of a relatively consistent mix of metamorphic rock coarse aggregate and siliceous fine aggregate in portland cement and slag paste.
6. Core A-3, A-4, A-5 and A-6 appear to represent two different mixes based on presence of fly ash in the outer end and absence in the inner end. Coarse aggregate concentration appears to be higher in the inner end.
7. A majority of cracks pass around aggregates while some cracks pass through edges of some aggregates. This suggests that cracking is likely attributed to concrete drying shrinkage and/or temperature changes.
8. Disregarding the cracks, the quality of concrete from a materials point of view, is regarded as satisfactory.

Complete laboratory reports are included in Appendix B.

CONCLUDING REMARKS

This report presents an evaluation of concrete cracking of the 2-Area Saltstone Vaults, Westinghouse Savanannah River Company, Aiken, South Carolina. Findings of the evaluation and recommendations are summarized in the section entitled "Findings and Recommendations".

APPENDIX A

Manufacturers' Data

This Spec-Data sheet conforms to editorial style prescribed by The Construction Specifications Institute. The manufacturer is responsible for technical accuracy.

1. PRODUCT NAME
Chemical Grout Scotch-Seal™ Brand Chemical Grout 5600 (Foam)

2. MANUFACTURER

3M Construction Markets
3M Center Bldg. 225-4S-08
St. Paul, Minnesota 55144-1000
Phone: (612) 733-1140

3. PRODUCT DESCRIPTION

Basic Use: Scotch-Seal™ Brand Chemical Grout 5600 (Foam) is a single component, moisture reactive urethane grout that is designed to seal leaking cracks, fractures, joints and holes in clay tile pipe, concrete and masonry. Properly applied, the grout adheres to the surface area and forms a flexible, tough, rubbery gasket that stops water. Scotch Seal Brand Chemical Grout 5600 cures to form a three-way seal by:

- Bonding chemically to the surface
- Forming a mechanical anchor within the pores or fissures in the wall
- Forming a compression seal within the joint or crack.

Chemical Grout 5600 is suggested for helping prevent and correct infiltration and exfiltration problems in sewage systems, manholes, storm and drain culverts, tunnels, clean water reservoirs, dams, foundations and other structures exposed to water. In the cured state, Scotch-Seal Chemical Grout 5600 is EPA approved for use with potable water. EPA and FDA documents are available upon request.

Composition and Materials: Scotch-Seal Brand Chemical Grout 5600 (Foam) is a single component, moisture curing urethane liquid, (similar in viscosity and appearance to medium weight motor oil). See Technical Data Table 1 for more information. Chemical Grout 5600 is hydrophilic and contains Toluene Diisocyanate (TDI) and Acetone.

Limitations: Scotch-Seal Brand Chemical Grout 5600 (Foam) must be applied to a clean surface. All cracks, fractures, holes, etc. should be thoroughly flushed with clean water to remove dirt, dust and other contaminants. If joints or cracks that are being sealed are dry, water should be pumped into the joint or crack before injecting unmixed grout. Scotch-Seal Chemical Grout 5600 (Foam) is extremely water reactive, consequently opening and closing containers may cause the material to cure prematurely. Furthermore, solvents used must not contain water. Moisture impermeable hoses are recommended for use where grout is being pumped. Hose liners such as butyl or polyethylene are recommended. Nylon reinforcement should *not* be used. The cured material has a 700% to 800% elongation (See Technical Data Table 2). Gloves, face shields and other necessary protective equipment must *always* be worn. Store in cool, dry place where temperatures do not exceed 80°F (27°C) for prolonged periods.

Sizes: The chemical grout material is in liquid form and is packed in closed head metal/plastic 5 gallon pail with 2″ barrel flange and plastic plug, 1 gallon closed head metal cans with pour spout. 1 quart poly bottles are packaged in a chemical grout kit.

4. TECHNICAL DATA

Applicable standards see Tables 1, 2 and 3.

5. INSTALLATION

Applicator: Scotch-Seal Brand Chemical Grout 5600 (Foam) is intended for use by applicators having the proper equipment as determined by the user for the specific application. Grouting equipment designed for the application of this material is available.

Preparation: Clean all areas to be grouted. Cracks may have mineral deposits left from long term leakage of water. Mineral deposits should be removed if they interfere with grout injection. The grout requires no mixing. In many applications grout is pumped directly into cracks, holes or joints, so clean wet surfaces are necessary for the best seal to occur (See Limitations).

Methods: Scotch-Seal Brand Chemical Grout 5600 (Foam) is either injected directly in joints, holes and wall cracks or is used in conjunction with a carrier medium such as oil free oakum to stop highly active leaks. It will be necessary to drill injection holes to fill cracks.

Basic steps for crack repair are:

- Clean the area to be grouted
- Drill holes for grout injection
- Install grout injectors
- Flush the crack with water
- Grout injection
- Remove injectors
- Patch injector holes
- Remove excess surface grout
- Apply a surface sealer to crack surface

Offset drill one or two test holes, at a distance from the crack of ½ the depth of the concrete, at an angle sufficient to intersect the crack at approximately half the thickness of the concrete. (Injection hole spacing is normally 7 inches up to 25 inches apart, depending upon the width of the crack. Generally, the wider the crack, the greater the distance of grout travel; therefore, the farther apart the injection holes.) The purpose of the test holes is to pump water into the crack to determine spacing for injectors along the crack. For example: If the concrete is 16 inches in thickness, then the injection hole shall be drilled 8 inches from the crack at a 45° angle to intersect the crack at half the thickness. Beyond concrete thickness of 36 inches, injection holes over 18 inches deep are not necessary, provided sufficient pumping pressure is available. In thin concrete walls of 6″ or less, the injection holes should be drilled directly into the crack itself to prevent damage to the concrete. (In

3M Construction Markets
May 1990
(Supersedes February 1989)
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Crack, Hole and Joint Sealer

such cases, the spacing between injections should be approximately the same as the wall thickness.)

The sealing of large cracks in concrete can be accomplished by using several approaches.

Chemical Grout 5600 can be used to seal large cracks in essentially the same way as for fine crack sealing. However, the application of a surface "dam" such as activated oakum, lead wool, or quick-set hydraulic cement may first be needed to prevent rapid flow of grout from the crack. Injectors should be installed into offset drilled holes which intersect the crack. However, injectors may be set directly into the crack when access is restricted (See Figure 1). Where highly active leaks are encountered, it may be advantageous to offset drill diversion holes. Injectors can be set into the diversion holes with the male zerk fitting removed from the injectors. The fitting is then screwed into the injector which is to be pumped. This approach can be used sequentially, "chasing" water along the crack until the last injector is pumped and the crack sealed.

Activated Oakum Technique: To fill large cracks, either dry or leaking water, use oil free oakum saturated with grout and mixed with water. Hold the oakum for 2 to 3 minutes to allow foaming and insert oakum into the crack, hole or joint. The water in the joint will continue to activate the grout absorbed by the oakum.

Then follow injection procedure. Note: If grout areas are dry, water should be sprayed into area before inserting the activated oakum.

See Table 1 for cure time.

Scotch-Seal™ additives can be used to accelerate cure time.

Scotch-Seal Brand Chemical Grout 5600 (Foam) in some applications is used in combination with Scotch-Seal™ Brand Chemical Grout 5610 (Gel). Chemical Grout 5600 (Foam) is used with activated oakum to stop gushing leaks and Chemical Grout 5610 (Gel) is injected to seal large cracks, fill voids and consolidate the surrounding soil (See Spec-Data Chemical Grout Scotch-Seal™ Brand Chemical Grout 5610 [Gel]).

Activated Foam Technique: (See Figures 2 and 3.)

- Clean the joint to be sealed, removing any material that could inhibit adhesion. Use a wire brush and a scraper.
- Cut the foam backer rod into convenient lengths to meet the job requirements. The backer rod must be twice the width of the joint. For example: 1" joint use 2" backer rod. Backer rod must be compressed 50% in a joint to achieve optimum performance.
- Pour 5600 Primer into a plastic pail and soak foam backer rod in primer. Compress the backer rod in your hands several times to ensure that it is thoroughly saturated with the 5600 Primer. The wetted backer rod may be stored for several hours, or even days, prior to its use. Store in sealed plastic pail.
- Remove backer rod from the 5600 Primer and squeeze rod to remove all excess primer. Squeeze excess primer into the pail for re-use.
- Pour Scotch-Seal 5600 Grout (Foam) into dry plastic pail until there is sufficient grout to immerse the backer rod. Immerse backer rod in the grout. Compress the backer rod several times to allow maximum absorption of grout into the cellular structure. Only soak as much backer rod as can be applied in one minute.
- Brush or spray the joint several times with 5600 Primer before placing backer rod in the joint.
- The saturated backer rod should be gently compressed using blunt instrument or probe into joint or crack so that 5600 Grout is not squeezed out from the backer rod.
- The installed saturated backer rod should be misted several times with 5600 Primer to promote cure and adhesion.
- Several layers of the saturated backer rod may be used in a joint or crack, but too much rod may result in excessive expansion causing the rod to be forced out the front or back of the joint.
- Allow the grout to cure, then clean up excess cured grout as needed.

Product Safety Information: Refer to Material Safety Data Sheet available from manufacturer for product safety information.

6. AVAILABILITY AND COST

Availability: Scotch-Seal™ Brand Chemical Grouts are available throughout the U.S. and overseas.

Cost: "In place" cost of Scotch-Seal Brand Chemical Grout 5600 (Foam) may vary with the project conditions and regional considerations. Specific job costs may be obtained from any product distributor or applicator.

7. WARRANTY

Contact manufacturer, applicator or distributor for details.

Our recommendations for use of the product are based upon tests believed to be reliable. Since field conditions vary widely, the user must determine the suitability of the product for the particular use and specific method(s) of application.

THE FOLLOWING IS MADE IN LIEU OF ALL WARRANTIES, EXPRESS OR IMPLIED, INCLUDING IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. Seller's and manufacturer's only obligation shall be to replace such quantity of the product proved to be defective. NEITHER SELLER NOR MANUFACTURER SHALL BE LIABLE FOR LOSS OR DAMAGE, DIRECT, INCIDENTAL OR CONSEQUENTIAL, REGARDLESS OF THE LEGAL THEORY ASSERTED, INCLUDING NEGLIGENCE AND/OR STRICT LIABILITY.

The foregoing may not be altered except by an agreement signed by officers of seller and manufacturer.

8. MAINTENANCE

None required.

9. TECHNICAL SERVICES

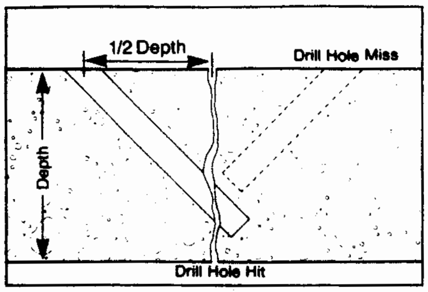
Manufacturer: Call collect (612) 733-1140 and ask for Chemical Grout Products.

Area Representation: Contact above location and a representative will provide personal service.

10. FILING SYSTEMS

Electronic SPEC-DATA®
SPEC-DATA® II
Sweet's

Figure 1:
CRACK DRILLING (CROSS-SECTIONAL VIEW)



Drill holes for injectors must intersect cracks.

Figure 2:
JOINT DETAILS

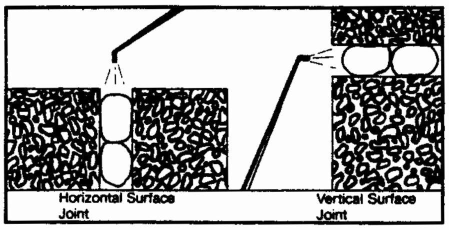
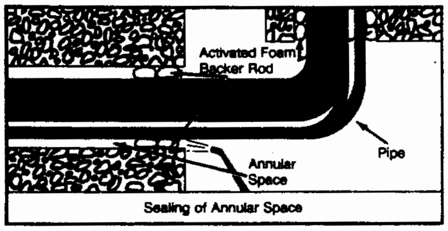


Figure 3:
ANNULAR SPACE DETAILS



TECHNICAL DATA

TABLE 1: PRODUCT PROPERTIES UNCURED MATERIAL

Property	Measuring Standards and Conditions	Results
Solids content	ASTM D 1010	82-88%
Viscosity	ASTM D 1638 @ 70°F	300-600 cps
Color	Visual	Amber
Weight per gallon	ASTM D 1638 per gallon (+/−.1)	9.15 lbs.
Flash point (Pensky Martens)	ASTM D 93	25°F
Corrosiveness		Noncorrosive
Toxicity		See handling instructions
Shipping class		Flammable liquid, NOS (caulking compound, NOI) flammable liquid

Contains Toluene Diisocyanate (TDI) and Acetone

TABLE 2: PRODUCT PROPERTIES CURED MATERIAL

Property	Measuring Standard and Conditions	Results
Density	ASTM D 3574-86	14 lbs./ft.^{3}
Tensile strength	ASTM D 3574-86	80-90 psi
Elongation	ASTM D 3574-86	700-800%
Shrinkage	ASTM D 756 Procedure G, ASTM D 1042	18% linear shrinkage
Toxicity		Cured material is essentially nontoxic.

TABLE 3: CHEMICAL RESISTANCE DATA
SCOTCH-SEAL™ BRAND CHEMICAL GROUT 5600 (FOAM)

The following table shows the effect of chemicals and solvents on Chemical Grout 5600 (Foam) samples. These environments represent different types of effluents found in typical industrial wastewater. The concentration in parentheses is probably many times more severe than that which actually exists.

Environment/Concentration in Water	Time (Weeks)	Appearance (Visual)
Acids		
Hydrochloric (2%)	26	Moderate darkening and slight fragmentation
Acetic (2%)	26	No change
Sulfuric (2%)	26	Moderate darkening-intact
Bases		
Sodium Hydroxide (1%)	26	Moderate darkening and slight fragmentation
Potassium Hydroxide (1%)	26	Moderate darkening - 25% dissolved
Salts		
Sodium Chloride (salt water)	26	No change
Ammonium Sulfate (2%)	26	No change
Potassium Chlorate (5%)	26	No change
Organic Solvents		
Ethylene Glycol (100%)	26	No change
Isopropanol (100%)	26	No change
Heptane (gasoline) (100%)	26	No change
Carbon Tetrachloride (100%)	26	Slight darkening
Methyl Ethyl Ketone (100%)	26	Swelled 20-30%
Toluene (100%)	26	No change
Gas		
Hydrogen Sulfide (100% in wet condition)	9	No change
Hydrogen Sulfide (80% in wet condition)	1	No change

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5-90-2102

3M

Fosroc®

NITOSEAL 225

Gun grade two component polyurethane joint sealant

USES

For sealing movement joints in buildings, pre-cast panels, glazing systems and metal curtain walls.

ADVANTAGES

- **High Performance** - High movement capability. Excellent adhesion to most common substrates
- **Durable** - Excellent UV resistance
- **Versatile** - Suitable for use in wide joints
- **Ease of Use** - Easy to mix and apply

DESCRIPTION

NITOSEAL 225 is a two part gun grade urethane based joint sealant which cures to produce long-lasting elastomeric seals with excellent extension recovery, adhesion and UV resistance properties. When cured, NITOSEAL 225 can accommodate large cyclic movements over a wide range of ambient temperatures.

STANDARDS & SPECIFICATIONS

Meets requirements of U.S. Federal specification TT-S-00227E, Type II, Class A.

PROPERTIES

Movement Accommodation Factor: 50% (Total)

Shore A Hardness: 20-25

Service Temperature Range: -20°F. to 180°F

Minimum Application Temperature: 40°F

Pot Life: 3 hours minimum at 75°F/50% R.H.

Initial Set: 6-8 hours at 75°F/50% R.H.

Tack-Free Time: 36 hours at 75°F/50% R.H.

Typical Performance Characteristics

(TT-S-00227E Test Methods)

Adhesion in Peel: Mortar 9 lbs. Aluminum 10 lbs. Glass 8 lbs.

Durability (bond and cohesion): Passed (on mortar glass and aluminum at +-25% movement).

Sagging: None up to 122°F

Hardness (aged): 25 (Shore A) after 7 days at 75°F plus 21 days at 158°F.

Low Temperature Flexibility: -60°F

Staining: None

Joint Design

Joints should be designed so that movement due to concrete shrinkage and thermal changes does not exceed the 25% Movement Accommodation Factor related to the joint width.

Minimum size of joint shall be four times the anticipated movement.

Minimum Joint Width - 1/4"

Maximum Joint Width - 2"

Joint Width -	1/4" to 1/2"	1/2" to 1"	1" to 2"
Sealant Depth -	equal to width	1/2"	1"

Sealant width/depth ratio must be between 1:1 and 2:1.

Sealant depth should never exceed joint width. All movement joints subject to trafficking should be recessed 1/4" below flush so that during joint contraction the sealant does not protrude above the surface.

INSTRUCTIONS FOR USE

Joint Preparation

The joint interface must be clean, dry and free from loose mortar or laitance. Depending upon the substrate type and suitability a thorough wire brushing, grinding or sandblasting may be required. The presence of form release agents, waterproofing, damp-proofing, or other contaminants, will require grinding or sandblasting to expose clean concrete. Blow all joints clean using dry, oil-free compressed air.

All previous sealants, mastic or joints fillers should be mechanically removed by routing or saw cutting. Joint faces should then be ground or sandblasted to expose clean concrete.

Closed cell joint backing should be installed in the joint at a point where the depth of the sealant is desired. Choice of joint backing size should allow for the backing foam to be compressed by 30%. To produce neat edges to the joint, masking tape is recommended prior to priming.

Priming

Brush apply NITOSEAL PRIMER to the prepared joint faces, and allow to dry before applying NITOSEAL 225.

Mixing

The components of NITOSEAL 225 are supplied in the correct mixing ratio. Add the entire contents of the color pack and the hardener container into the base container. Mix together for 3 minutes using the recommended mixing paddle and slow speed electric drill (400/500 rpm). The sides of the container should then be scraped down to ensure that unmixed components do not remain around the sides. Continue mixing for a further 3 to 5 minutes. Total mixing time 6 to 8 minutes.

Application

After thorough mixing, place the single hole follower plate over the NITOSEAL 225 and draw material into a caulking gun. Gun the sealant into the joint in a continuous bead taking care not to entrap air between the sealant and the joint backing. The sealant must be firmly pressed into the joints to achieve proper substrate wetting and maximum adhesion. The surface may be struck off with a joint shaping tool. Strip off any masking tape immediately after tooling.

Cleaning

Uncured NITOSEAL 225 can be cleaned off with FOSROC SOLVENT 102. Cured sealant can only be removed mechanically.

Storage

The shelf life of NITOSEAL 225 and NITOSEAL PRIMER is 12 months when stored in the original unopened containers below 75°F.

PACKAGING

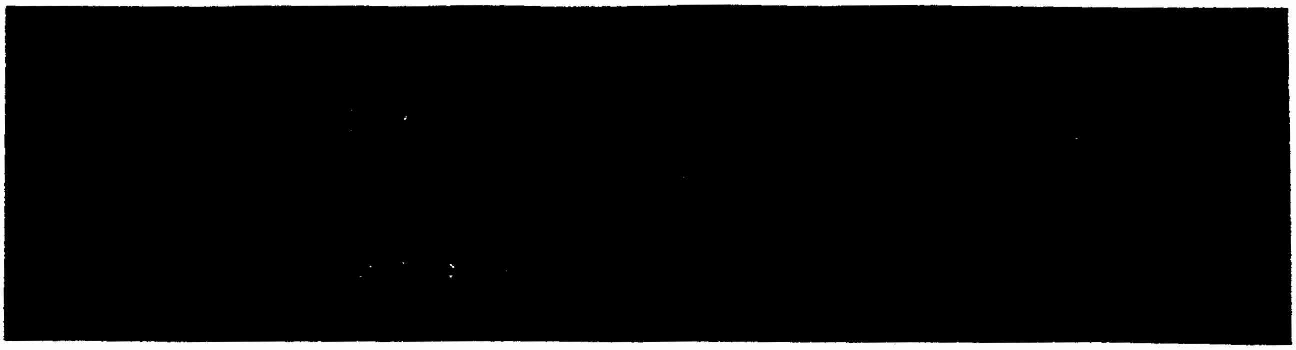
NITOSEAL 225 - 1.6 gallon pack (6 litre)

(Base, Hardener and Color Pack).

Accessories

FOSROC SOLVENT 102

TOLL FREE: 1-800-645-3954 • IN NY: 516-935-9100



Description:

Sikaflex-2c is a 2-component, premium-grade, polyurethane-base, elastomeric sealant. Principally a chemical cure in a non-sag and self-leveling consistency. Available in 43 colors with convenient Color-Pak.

Where to Use:

- Intended for use in all properly designed working joints with a minimum depth of ¼ in.
- Ideal for vertical and horizontal applications.
- Placeable at temperatures as low as 40F.
- Adheres to most substrates commonly found in construction.

Advantages:

- Capable of ±50% joint movement.
- Chemical cure allows the sealant to be placed in joints exceeding ½ in. in depth.
- High elasticity with a tough, durable, flexible consistency.
- Exceptional cut- and tear-resistance.
- Exceptional adhesion to most substrates without priming.
- Available in 43 architectural colors.
- Color uniformity assured via Color-Pak system.
- Non-sag even in wide joints.
- Self-leveling consistency is easy to apply into horizontal joints.
- Jet fuel resistant.
- Paintable with water-, oil-, and rubber-base paints.
- Both grades meet ASTM C-920.
- Both grades meet Federal Specification TT-S-00227E.

Coverage:

1 gal yields 231 cu in. or 154 lin ft of a ½-in. X ¼-in. joint.

Packaging:

1.5-gal. Available on special order, 3-gal units.

Typical Technical Data for Sikaflex-2c:
(Material and curing conditions 73F and 50% R.H.)

Colors:	A wide range of architectural colors are available. Special colors available on request.
Shelf Life:	One year in original, unopened container.
Storage Conditions:	Store dry at 40-95F. Condition material to 65-75F before using.
Application Temperature	40 to 100F, ambient and substrate temperatures. Sealant should be installed when joint is at mid-range of its anticipated movement.
Service Range:	-40 to 167F

Property:	**Non-sag**	**Self-leveling**	**Test Method**
Application life:	3-4 hr	3-4 hr	TT-S-00227E
Tack-free Time:	6-8 hr	6-8 hr	ASTM C-679
Final Cure:	3 day	3 day	
Shore A Hardness:	25±5	40 ± 5	ASTM D-2240
Tensile Strength at Break:	200 psi	200 psi	ASTM D-412
Tensile Elongation:	650%	650%	ASTM D-412
100% Modulus:	75 psi	100 psi	ASTM D-412
Tear Strength:	125 lb/in.	125 lb/in.	ASTM D-624

Adhesion in Peel:				TT-S-00227E
Substrate	Peel Strength	% Adhesion Loss	Peel Strength	% Adhesion Loss
Aluminum	30 lb	Zero	30 lb	Zero
Glass	30 lb	Zero	30 lb	Zero
Concrete	25 lb	Zero	30 lb	Zero

Weathering Resistance:	Excellent
Ozone Resistance:	Excellent
Chemical Resistance:	Good resistance to water, diluted acids, diluted alkalines, and residential sewage. Consult Technical Service for specific data.

How To Use

Surface Preparation: All joint-wall surfaces must be clean, sound, and frost-free. Joint walls must be free of oils, grease, curing compound residues, and any other foreign matter that might prevent bond. Ideally this should be accomplished by mechanical means.
Bond breaker tape or backer rod must be used in bottom of joint to prevent bond.

Priming: Priming is typically not necessary. Most substrates only require priming if testing indicates a need or where sealant will be subjected to water submersion after cure.
Consult Technical Service or Sikaflex Primer Technical Data Sheet for additional information on priming.

Mixing: Pour entire contents of Component 'B' into pail of Component 'A'. Now add entire contents of Color-Pak into pail and mix with a low-speed drill (400- 600-rpm) and Sikaflex paddle. Mix for 3-5 minutes to achieve a uniform color and consistency. Scrape down sides of pail periodically. Avoid entrapment of air during mixing.

Color pak must be used.

Note: When mixing 3-gal unit **two** containers of Component'B' and **two** Color Paks must be used.

Application: Recommended application temperatures 40F-100F. Pre-conditioning units to approximately 70F is necessary when working at extremes. Move pre-conditioned units to work areas just prior to application.

Apply sealant only to clean, sound, dry, and frost-free substrates. Sikaflex-2c should be applied into joints when joint slot is at mid-point of its designed expansion and contraction. When placing self-leveling grade, pour sealant into joint slot in one direction and allow sealant to flow and level out as necessary. Tool as required.
To place non-sag grade, load directly into bulk gun or use a follower plate loading system. Place nozzle of gun into bottom of joint and fill entire joint. Keeping the nozzle deep in the sealant, continue with a steady flow of sealant preceding nozzle to avoid air entrapment. Also, avoid overlapping of sealant since this also entraps air. Tool as required.
For use in horizontal joints in traffic areas, the absolute minimum depth of the sealant is ½ in. and closed cell backer rod is recommended over open cell to offer greater support.

Limitations:

- The ultimate performance of Sikaflex-2c depends on good joint design and proper application.
- Minimum depth in working joint is ¼ in.
- Maximum expansion and contraction should not exceed 50% of average joint width.
- Do not cure in the presence of curing silicones.
- Avoid contact with alcohol and other solvent cleaners during cure.
- Allow 3-day cure before subjecting sealant to total water immersion.
- Avoid exposure to high levels of chlorine.
- Do not apply when moisture vapor transmission condition exists since this can cause bubbling within the sealant.
- Avoid over-mixing sealant.
- Minimum depth of sealant in horizontal joints subject to traffic is ½ in.

Caution:

Combustible: Keep away from open flames and high heat. Contains xylene; avoid breathing vapors. Use with adequate ventilation.

Irritant: Avoid skin and eye contact. Use of NIOSH/MSA approved organic vapor respirator, safety goggles, and chemical-resistant gloves recommended. Remove contaminated clothing and shoes.

First Aid: In case of skin contact, wash thoroughly with soap and water. For eye contact, flush immediately with plenty of water for at least 15 minutes; contact physician. Wash clothing before re-use. Discard contaminated shoes.

Clean Up: Uncured material can be removed with approved solvent. Cured material can only be removed mechanically. For spillage, collect, absorb, and dispose of in accordance with applicable local, state, and federal regulations.

KEEP CONTAINER TIGHTLY CLOSED **KEEP OUT OF REACH OF CHILDREN**

NOT FOR INTERNAL CONSUMPTION **FOR INDUSTRIAL USE ONLY**

CONSULT MATERIAL SAFETY DATA SHEET FOR MORE INFORMATION

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APPENDIX B

Laboratory Test Reports

Construction Technology Laboratories, Inc.

5420 Old Orchard Road, Skokie, Illinois 60077-1030 Phone: 708/965-7500
Telex: 9102401569 CTL.SKO Fax: 708/965-6541

PETROGRAPHIC SERVICES REPORT

CTL Project No.: 101714 Date: January 23, 1991

Re: Evaluation of Concrete Quality, Z-Area Vaults, Savannah River Site

INTRODUCTION

Three concrete cores, labeled A-1, A-2, and A-3 (Fig. 1 through 3), were received on November 27, 1990 from Mr. Kami Farahmandpour of CTL. The samples were submitted on behalf of Mr. Dennis Thompson, Engineer, of Westinghouse Savannah River Company, Aiken, South Carolina. The cores were reportedly taken from a cracked wall of a cell in the Z-Area Vaults. Petrographic examination of the three cores was requested to determine the cause of cracking and assess the quality of the concrete.

FINDINGS AND CONCLUSIONS

Based on the results of the petrographic examination, the following findings and conclusions are presented:

1. Cores A-1 and A-2, and the inner end of Core A-3 consist of crushed metamorphic rock coarse aggregate and siliceous fine aggregate in portland cement and slag paste. The paste-aggregate bond is tight and the paste is moderately hard.
2. The outer end of Core A-3 (Fig. 4c) consists of siliceous fine aggregate and scarce coarse aggregate in portland cement and fly ash paste. The paste-aggregate bond is tight and the paste is

moderately hard. Core A-3 appears to represent two different mixes, based on the presence of fly ash in the outer end and absence on the inner end.

3. The estimated ratio of water/cementitious material is 0.40 to 0.43.
4. Cracking occurs in all three cores (Fig. 4). Cracks subparallel to the outer wall surface occur in Core A-2. Cracks in Cores A-1 and A-3 cut the cores at a steep angle to the core axis and pass around most aggregate particles. Fine microcracks occur subparallel to the major cracks and the paste is carbonated in the vicinity of the cracks. Passage of cracks through some aggregate particles indicates the paste had hardened when cracking occurred. Cracking may be thermally related or may have another cause such as ordinary drying shrinkage.
5. Disregarding the cracks, the quality of the concrete from a materials point of view, is regarded as satisfactory.

Additional data from the petrographic examination are contained in the attached forms.

METHODS OF TEST

Petrographic examination of cores A-1, A-2, and A-3 was performed in accordance with ASTM C 856-83, "Standard Practice for Petrographic Examination of Hardened Concrete." The cores were cut longitudinally and one half of each was lapped and examined using a stereomicroscope at magnifications up to 45X. Freshly broken surfaces were also studied with the stereomicroscope. A rectangular block was cut from the top (outer surface of wall) of each core to a depth of approximately 1.8 in. An additional block was cut from the lower portion of Core A3. The blocks were placed on glass microscope slides with epoxy resin and reduced to a thickness of approximately 20 micrometers (0.0008 in.). The thin sections were examined using a polarized-light microscope at magnifications up to 400X to determine aggregate and paste mineralogy and microstructure.

L. J. Powers-Couche
Associate Petrographer
Petrographic Services

D. H. Campbell
Principal Petrographer
Petrographic Services

LJP/DHC/cjd

101714

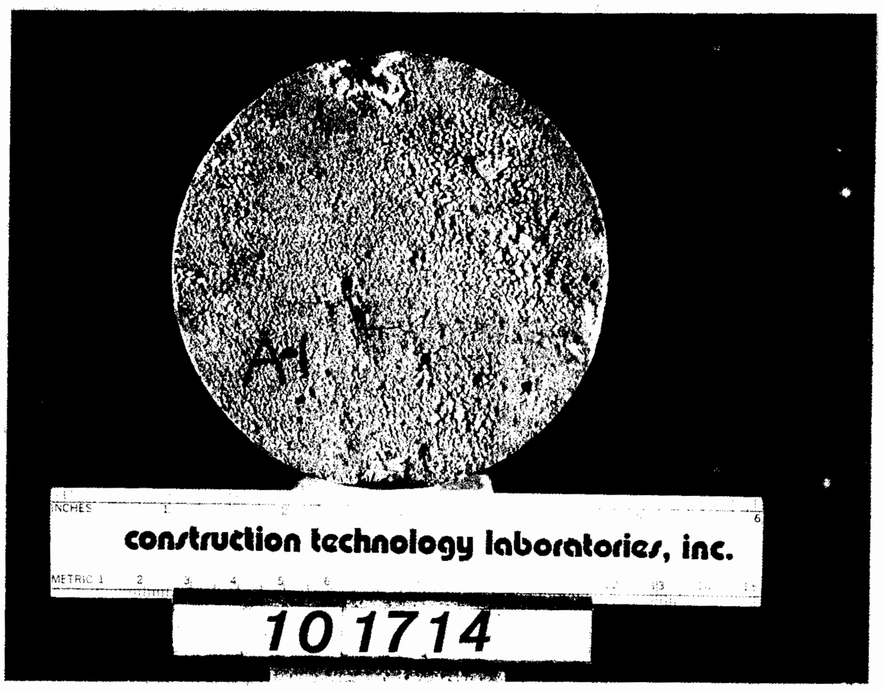

FIG. 1a. TOP VIEW OF CORE A1 AS RECEIVED FOR EXAMINATION.

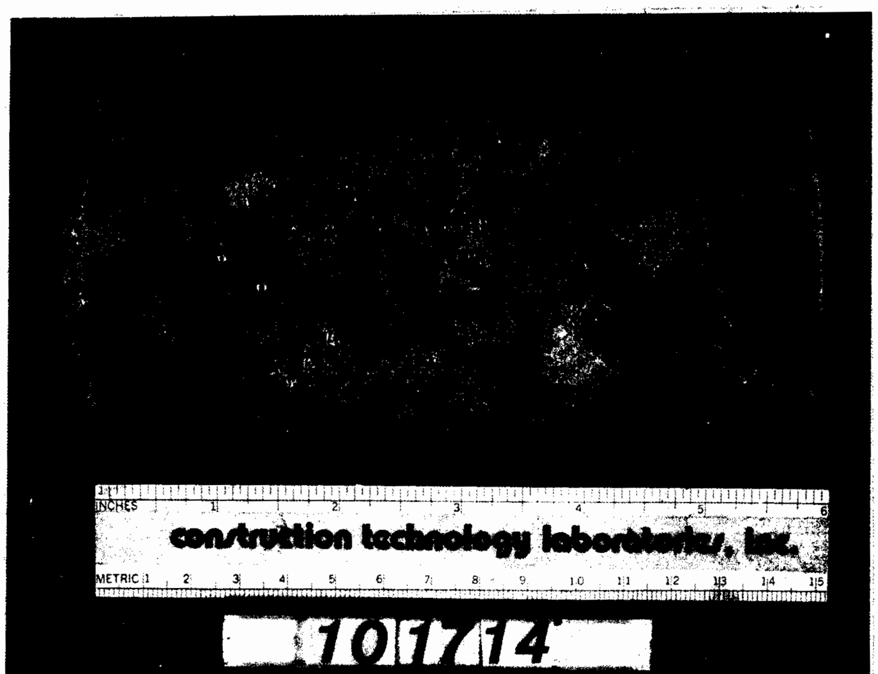

FIG. 1b. SIDE VIEW OF CORE A1 AS RECEIVED FOR EXAMINATION.

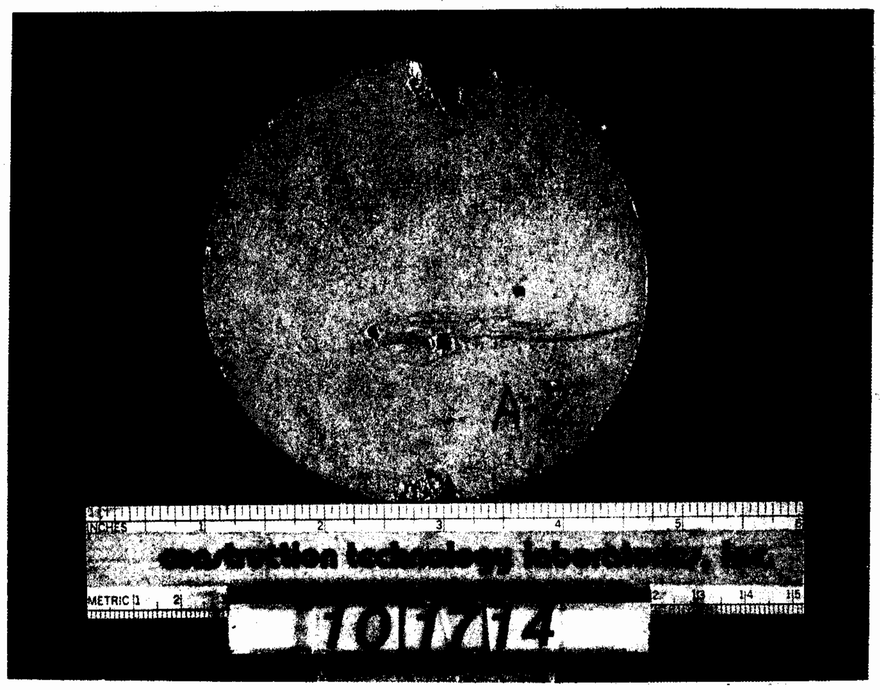

FIG. 2a. TOP VIEW OF CORE A2 AS RECEIVED FOR EXAMINATION.

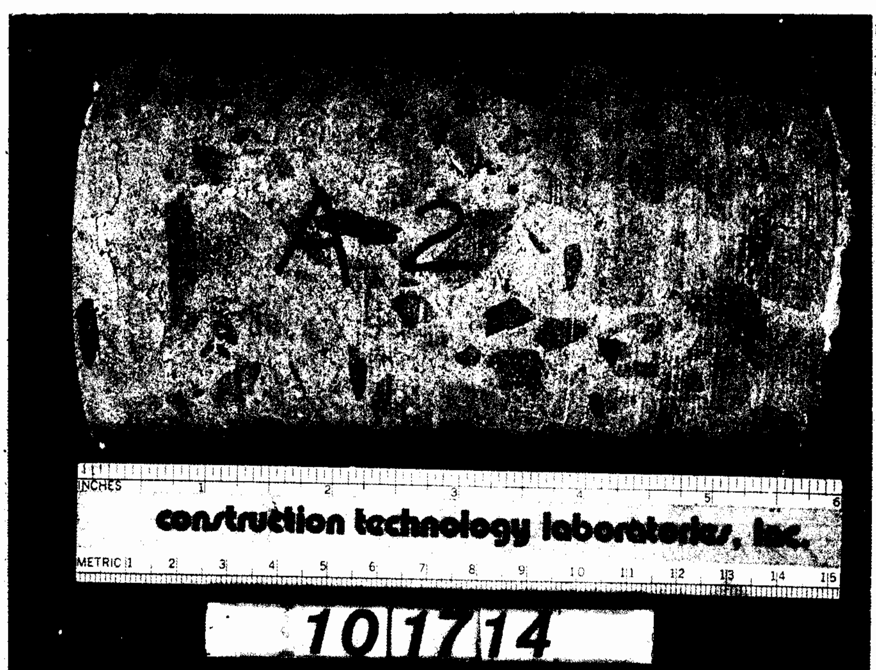

FIG. 2b. SIDE VIEW OF CORE A2 AS RECEIVED FOR EXAMINATION.

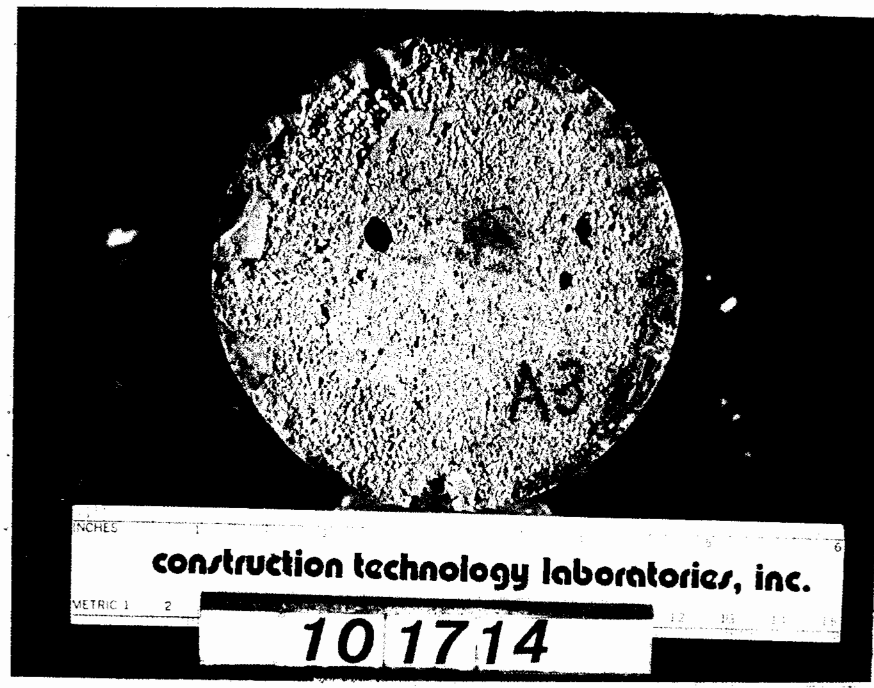

FIG. 3a. TOP VIEW OF CORE A3 AS RECEIVED FOR EXAMINATION.

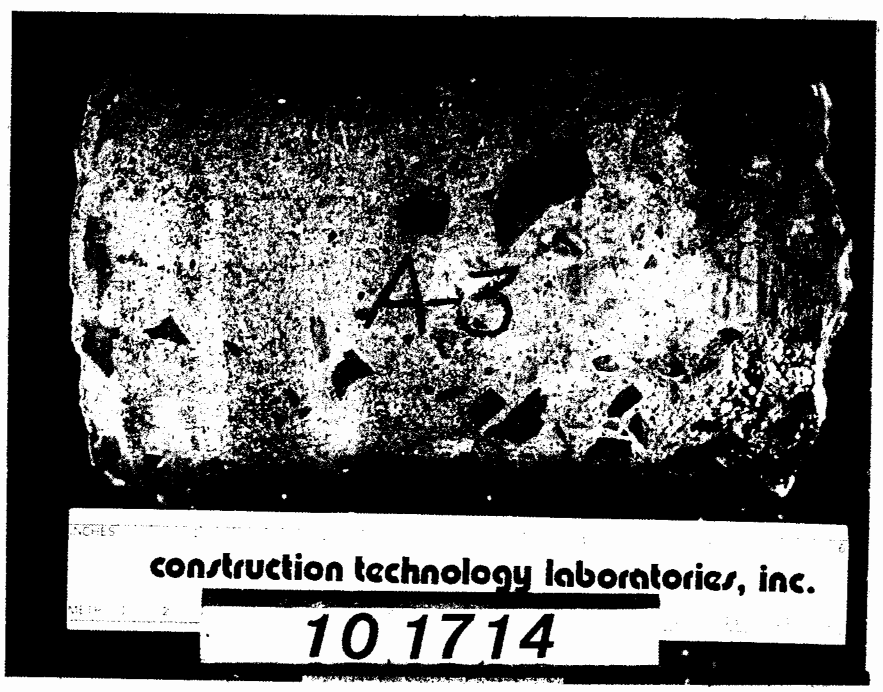

FIG. 3b. SIDE VIEW OF CORE A3 AS RECEIVED FOR EXAMINATION.

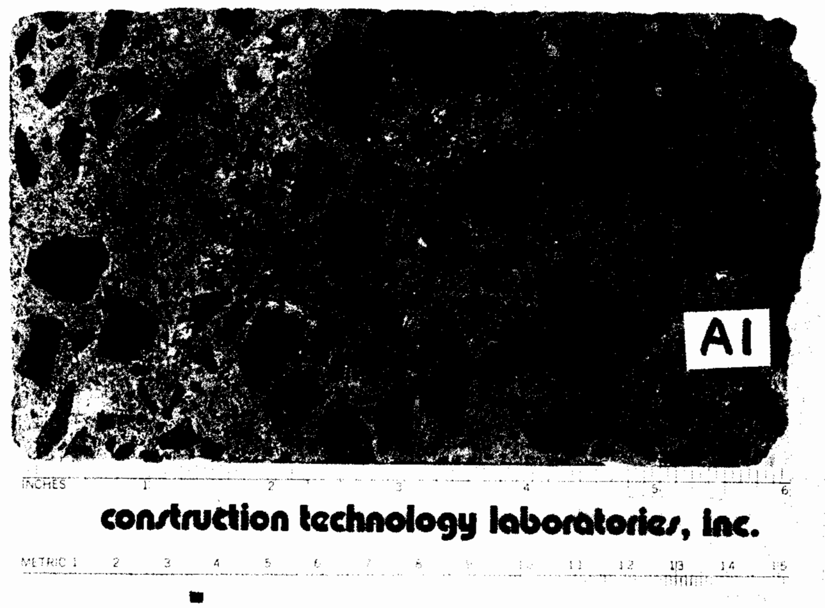

FIG. 4a. CUT AND LAPPED LONGITUDINAL SECTION OF CORE A1. ARROW INDICATES CRACK.

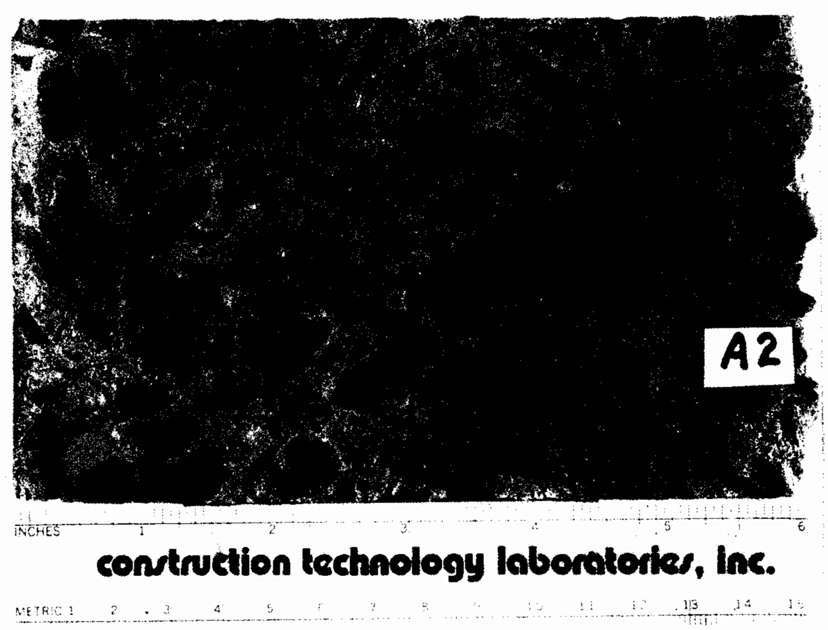

FIG. 4b. CUT AND LAPPED LONGITUDINAL SECTION OF CORE A2. ARROW INDICATES CRACK PARALLEL TO TOP SURFACE.

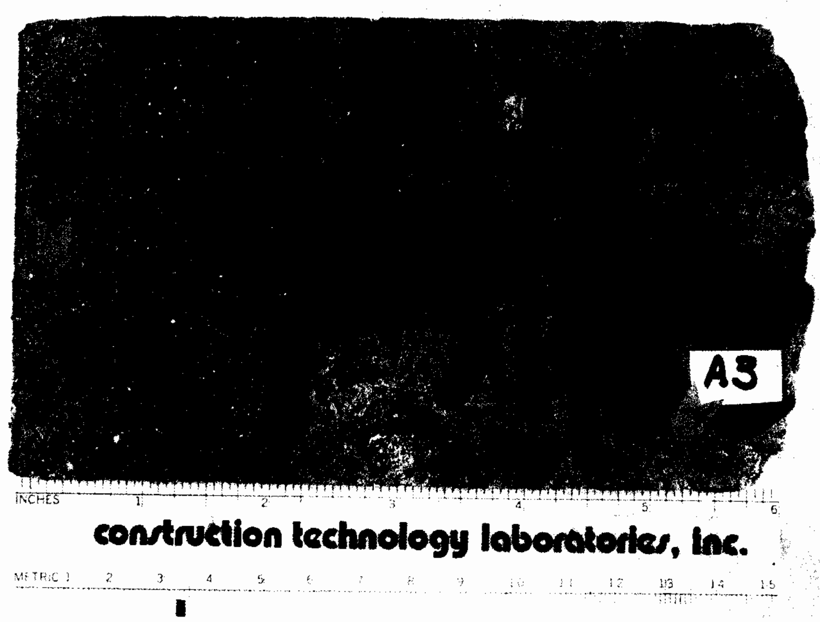

FIG. 4c. CUT AND LAPPED LONGITUDINAL SECTION OF CORE A3. ARROWS INDICATE CRACK FROM TOP OF CORE TO BOTTOM. NOTE SEGREGATION OF COARSE AGGREGATE.

Construction Technology Laboratories, Inc.

PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE, ASTM C 856

CTL PROJECT NO.: 101714 DATE: January 22, 1991

CLIENT: Westinghouse Savannah River Company PROBLEM: Quality/Cracking

STRUCTURE: Z-Area Containment Vaults EXAMINED: L. Powers-Couche

LOCATION: Savannah River, South Carolina

SAMPLE

IDENTIFICATION: A-1.

DIMENSIONS: Diameter = 3.75 in. Length = 6.35 in.

OUTER END: Formed surface, abraded exposing fine aggregate.

INNER END: Broken exposing aggregate.

CRACKS, JOINTS, LARGE VOIDS: Major crack to depth of 4 in. passes through some coarse aggregates and cuts core at steep angle to core axis. Maximum crack width on sawn, lapped surface is 0.013 in.

REINFORCEMENT: None observed.

AGGREGATES (A)

COARSE (C): Crushed rock fragments consisting predominantly of metamorphic rocks: granite, granitic gneiss and quartzite.

FINE (F): Natural sand and crushed rock fragments consisting of quartz, granitic gneiss, muscovite and chlorite.

GRADATION & TOP SIZE: Well graded to top size 0.5 in.

SHAPE & DISTRIBUTION: CA is subangular to angular, elongate to equidimensional and uniformly distributed. FA is subrounded to angular, equidimensional to elongate and uniformly distributed.

PASTE

COLOR: Buff in upper 3 in. Mottled buff and green below 3 in.

HARDNESS: Moderately hard.

LUSTER: Subvitreous.

CALCIUM HYDROXIDE*: 2-4% small crystals in paste and patches adjacent to aggregate particles.

UNHYDRATED PORTLAND CEMENT CLINKER PARTICLES (UPC's)*: 10-12; paste also contains approximately 3-5% residual slag.

DEPTH OF CARBONATION: 0.15 in.

AIR CONTENT: 4-6% air entrained concrete. Nonuniform distribution of air voids. Body of concrete contains entrapped air voids up to 0.1 in. Many areas contain coalescing voids or clusters of voids.

FLY ASH*: None observed.

PASTE-AGGREGATE BOND: Tight.

SECONDARY DEPOSITS: None observed.

MICROCRACKING: Network of microcracks penetrates paste adjacent to major crack. Cracks pass around aggregate particles.

*percent by volume of paste

ESTIMATED WATER-CEMENT RATIO: 0.40 to 0.43.

MISCELLANEOUS: Paste adjacent to cracks is intensely carbonated and interlaced with microcracks.

Construction Technology Laboratories, Inc.

PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE, ASTM C 856

CTL PROJECT NO.: 101714

DATE: January 22, 1991

CLIENT: Westinghouse Savannah River Company

PROBLEM: Quality/Cracking

STRUCTURE: Z-Area Containment Vaults

EXAMINED: L. Powers-Couche

LOCATION: Savannah River, South Carolina

SAMPLE

IDENTIFICATION: A-2.

DIMENSIONS: Diameter = 3.75 in. Length = 6.00 in.

OUTER END: Smooth formed surface.

INNER END: Broken exposing aggregate.

CRACKS, JOINTS, LARGE VOIDS: Crack subparallel to formed surface at depth 0.3 in. passes around aggregate. Several irregularly shaped air voids up to 0.25 in. measured in longest dimension.

REINFORCEMENT: None observed.

AGGREGATES (A)

COARSE (C): Crushed rock fragments, predominantly granite, granitic gneiss, and calcite-veined quartzite.

FINE (F): Natural sand and crushed rock fragments consisting of quartz, quartzite, and mica.

GRADATION & TOP SIZE: Moderately well graded to top size 0.5 in.

SHAPE & DISTRIBUTION: CA is subangular to angular, mostly elongated particles, uniformly distributed. FA consists of subrounded to angular particles, mostly equidimensional, uniformly distributed.

PASTE

COLOR: Buff to beige in top 2.5 in. Mottled buff and green below 2.5 in.

HARDNESS: Variable moderately soft to moderately hard in body of concrete.

LUSTER: Variable subvitreous to dull in top 2 in.

CALCIUM HYDROXIDE*: 2-4% small crystals in paste. Larger crystals in paste adjacent to aggregate particles.

UNHYDRATED PORTLAND CEMENT CLINKER PARTICLES (UPC's)*: 10-15%; also 2-4% residual slag particles.

DEPTH OF CARBONATION: 0.2 in.

AIR CONTENT: 3-5% air entrained concrete. Air void system is non-uniform. Clustering of voids and higher air in top 3 in.

FLY ASH*: Trace.

PASTE-AGGREGATE BOND: Moderately tight.

SECONDARY DEPOSITS: None observed.

MICROCRACKING: Paste contains several to 1 to 2 mm long microcracks in the top 0.4 in. Cracks do not occur near aggregate. Narrow portions of cracks are filled with calcium hydroxides.

*percent by volume of paste

ESTIMATED WATER-CEMENT RATIO: 0.40 to 0.43.

Construction Technology Laboratories, Inc.

PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE, ASTM C 856

CTL PROJECT NO.: 101714 DATE: January 22, 1991

CLIENT: Westinghouse Savannah River Company PROBLEM: Quality/Cracking

STRUCTURE: Z-Area Containment Vaults EXAMINED: L. Powers-Couche

LOCATION: Savannah River, South Carolina

SAMPLE

IDENTIFICATION: A-3, two thin sections were made A3T - from top, paste-rich portion; A3B - from lower portion of core.

DIMENSIONS: Diameter = 3.75 in. Length = 6.25 in.

OUTER END: Even formed surface, abraded revealing fine aggregate.

INNER END: Broken exposing aggregate.

CRACKS, JOINTS, LARGE VOIDS: Irregular voids up to 0.3-in. long are observed on sides of core and on top surface. Crack with maximum observed width 0.020 in. passes through aggregate and runs entire length of core. The crack is subparallel to core axis.

REINFORCEMENT: None observed.

AGGREGATES (A)

COARSE (C): Crushed, medium to coarse-grained metamorphic rocks including granite, granitic gneiss and quartzite.

FINE (F): Natural sand and fragments of crushed rock consisting of quartz, mica, and quartzite.

GRADATION & TOP SIZE: Well graded to top size 0.5 in.

SHAPE & DISTRIBUTION: CA is subangular to angular and mostly elongated. CA is absent from top third of the core. FA is subrounded to angular, equidimensional.

PASTE

COLOR: Gray top 2.5 in. Mottled buff, gray, and green below 2.5 in.

HARDNESS: Moderately hard.

LUSTER: Subvitreous.

CALCIUM HYDROXIDE*: 1-3% small crystals in paste. Larger crystals adjacent to aggregate.

UNHYDRATED PORTLAND CEMENT CLINKER PARTICLES (UPC's)*: 5-7% UPC's and 2-4% residual slag.

DEPTH OF CARBONATION: 0.15 to 0.25 in.

AIR CONTENT: Air entrained 2-4%. Nonuniform distribution of voids; some clustering of air voids.

FLY ASH*: In paste-rich area 5-10%. Section from lower portion of core contains trace amount (<1%) fly ash.

PASTE-AGGREGATE BOND: Tight.

SECONDARY DEPOSITS: None observed.

MICROCRACKING: Cracks in paste subparallel to major crack and pass around aggregate. Microcracks branch off of major crack. Paste is carbonated adjacent to cracks.

*percent by volume of paste

ESTIMATED WATER-CEMENT RATIO: 0.40 to 0.43.

Construction Technology Laboratories, Inc.
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SUPPLEMENT TO PETROGRAPHIC EXAMINATION

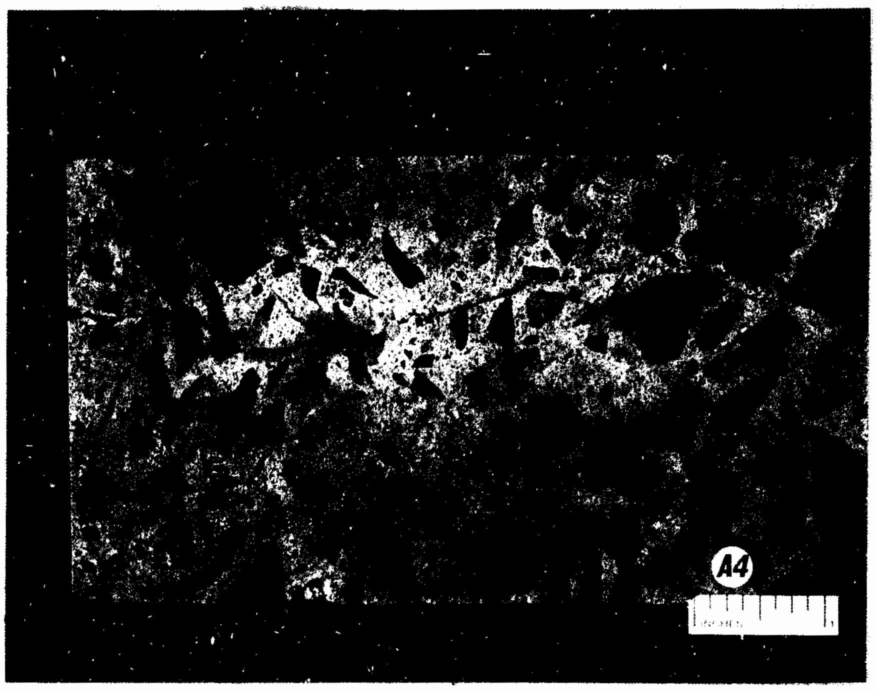
Five additional concrete cores (Figs. 5 through 9) from the Savannah River Z-Area vaults were submitted on March 18, 1991 by Mr. Kami Farahmandpour. Brief petrographic examination of each core was requested to assess the condition of the concrete.

Summary of Findings

1. Core A4 has a generally uniform distribution of aggregate particles, paste, and air voids. The paste in the outer 2.2 in. to 2.8 in. of the core (outer wall) is gray. The paste in the inner portion of the core (inner wall) is mottled buff and blue-green. Pending preparation of additional thin sections, and by analogy with data obtained from thin sections of Core A3, the paste in the outer portion of the core contains portland cement, fly ash and minor slag. The paste in the inner part of the core contains portland cement and slag. Core A4 appears to represent two mixes. One large crack passes through the length of the core and opens toward the formed outer surface. The crack passes around aggregate particles, for the most part, and the crack trace is visible on the formed surface.
2. Cores A5 and A6 display features similar to those previously described for Core A3. The outer 2 in. to 3 in. of both cores is paste-rich. Longitudinal cracks occur from the formed surface through the

thickness of the paste-rich concrete. These cracks may have resulted from differential shrinkage. The cracks open toward the formed surface and the average crack width is 0.005 in. Crack traces were observed on the formed surface of both cores. Like Core A4, these cores appear to represent two mixes.

3. Cores A7 and A8 contain evenly distributed paste and aggregate and no cracks were observed. Coloration of the paste indicates that these cores may also represent two different mixes. In Core A7 the boundary between mixes occurs at approximately 4 in. from the outer formed surface. The boundary occurs at about 3 in. in Core A8 and in both cores the boundary is somewhat irregular.



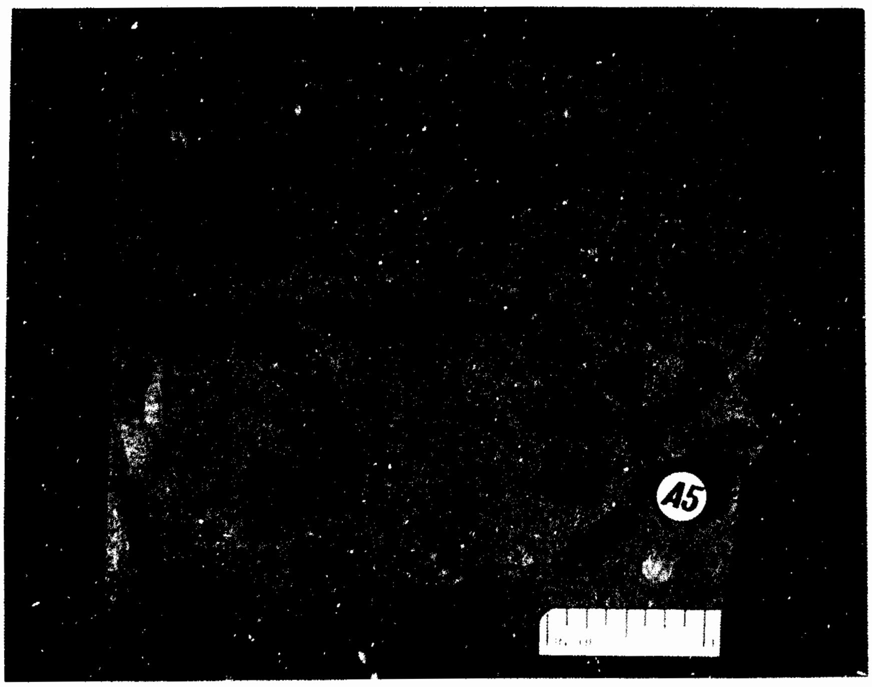


FIG. 5 (UPPER PHOTOGRAPH) LONGITUDINALLY CUT AND LAPPED SURFACE OF CORE A4. ARROWS SHOW OLD CRACK THROUGH CORE.

FIG. 6 (LOWER PHOTOGRAPH) LONGITUDINALLY CUT AND LAPPED SURFACE OF CORE A5. ARROWS SHOW CRACK THROUGH CORE. NOTE ABSENCE OF COARSE AGGREGATE PARTICLES.

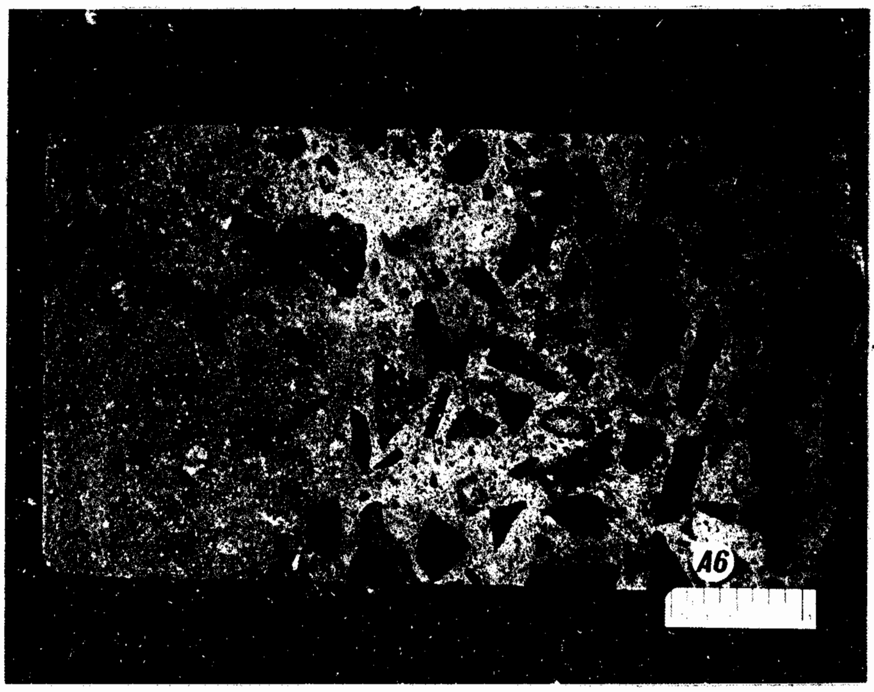


FIG. 7 (UPPER PHOTOGRAPH) LONGITUDINALLY CUT AND LAPPED SURFACE OF CORE A6. ARROWS SHOW OLD CRACK IN PASTE-RICH PORTION OF CORE. NOTE MOTTLING OF PASTE IN RIGHT HALF OF CONCRETE.

FIG. 8 (LOWER PHOTOGRAPH) LONGITUDINALLY CUT AND LAPPED SURFACE OF CORE A7. ARROW SHOWS AREA OF MOTTLED PASTE.

FIG. 9 LONGITUDINALLY CUT AND LAPPED SURFACE OF CORE A8.