Y-AES-Z-00002
Revision 0

Saltstone Disposal Unit (SDU) 6

Floor and Roof Repair Study

Savannah River Remediation
A URS COMPANY TEAMED
WITH BECHTEL | CH2M HILL | B&W | AREVA

Savannah River Site
Aiken, SC 29808

Prepared for the U.S. Department of Energy Under
Contract Number DE-AC09-09SR22505

DISCLAIMER

This report was prepared for the United States Department of Energy under Contract No. DE-AC09-09SR22505 and is an account of work performed under that contract. Reference herein to any specific commercial product, process, or service does not necessarily constitute or imply endorsement, recommendation, or favoring of same by Savannah River Remediation LLC or by the United States Government or any agency thereof. The views and opinions of the authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

APPROVAL PAGE

Prepared By: _____ 3/22/16
Gavin Winship
Team Facilitator
Date

Approved By: _____ 3/23/16
Noel Chapman
Project Engineering Manager
Date

_____ 3/23/16
Jon Lunn
SDU 6 Project Manager
Date

_____ 3/28/16
George Matis
Director, DWPF and Saltstone
Date

_____ 3/28/16
Kent Fortenberry
Chief Engineer
Date

TABLE OF CONTENTS

EXECUTIVE SUMMARY **8**

1.0 BACKGROUND **9**

2.0 PROCESS **9**

2.1 SELECTION OF STUDY TEAM MEMBERS 11
2.2 PROBLEM AND MISSION STATEMENT 12
2.3 BRAINSTORMING 12
2.4 SCREENING 12
2.4 DEVELOP EVALUATION CRITERIA 14
2.5 DATA DEVELOPMENT 15
2.6 EVALUATION 16
2.6.1 Criteria Weighting 16
2.6.2 Scoring 17
2.6.3 Ranking 18
2.6.4 Sensitivity Analysis 19
2.6.5 Risk Assessment 19

3.0 DISCUSSION OF RESULTS **20**

4.0 RECOMMENDATION **20**

5.0 REFERENCES **21**

6.0 APPENDICES **21**

LIST OF FIGURES

FIGURE 2-1: STUDY PROCESS 10
FIGURE 2.6.1-1: ANALYTICAL HIERARCHY 17
FIGURE 2.6.1-2: CRITERIA WEIGHTS 17
FIGURE 2.6.3-1: RESULTS 18

LIST OF TABLES

TABLE 2.1-1: TEAM MEMBERS 11
TABLE 2.4-1: BRAINSTORMING AND SCREENING RESULTS 14
TABLE 2.6.2-1: SCORING GUIDE SCALE 18

List of Acronyms and Abbreviations

ACI	American Concrete Institute
BFS	Blast Furnace Slag
C&DA	Closure and Disposal Assessment
CSH	Calcium Silicate Hydrate
DOE	Department of Energy
EPDM	Ethylene-Propylene Diene Monomer
EVA	Ethylene-Vinyl Acetate
HDPE	High Density Polyethylene
HMWA	High-Molecular-Weight Aggregate
PA	Performance Assessment
PMMA	Polymethylmethacrylate
R&D	Research and Development
SA	Special Analysis
SCDHEC	South Carolina Department of Health and Environmental Control
SCM	Supplementary Cementitious Material
SDU	Saltstone Disposal Unit
SEE	Systems Engineering Evaluation
SME	Subject Matter Expert
SRNL	Savannah River National Laboratories
SRR	Savannah River Remediation (LLC)
SRS	Savannah River Site
TR&C	Task Requirements and Criteria (document)
WDA	Waste Disposal Authority

Summary of Revision

Revision Number	Date	Description of Change
A	3/16/16	Issued for Team Review
0	3/22/16	Initial issue

Executive Summary

SDU 6 foundation failed the leak test (hydrostatic testing) due to potential leaks through cracks in the floor slab and suspected leaks through construction joints between floor sections. It is important to note that the tank passed the no measurable loss testing specified in ACI 350.1 and walls exhibited no signs of dye. Subsequent investigative work cored the floor and concluded all cracks were not surface shrinkage cracks, but some were full depth through the core sample(s). A Nonconformance Report was issued documenting that the floor slab cracks combined with the failure to pass leak tightness test yield SDU 6 indeterminate in meeting structural requirements, leak tightness requirements and Performance Assessment (PA)/Special Analysis (SA) requirements. The SDU 6 roof also exhibits similar cracks as those observed in the floor.

While other teams are addressing the PA/SA and structural requirements, a team was chartered to perform a Systems Engineering Evaluation (SEE) to identify viable concrete repair and coating/lining options in order to recommend a preferred repair technique(s) to address the leak tightness requirements for the floor and roof of SDU 6. The SEE process used for this evaluation was a structured alternative analysis with weighted evaluation criteria.

The SEE team initially identified 25 potential slab repair options for consideration. The 25 options were subsequently reduced to 14 options through a viability screening process. The evaluation of the 14 final options resulted in the team recommending the installation of a synthetic elastomeric liner in SDU 6 with additional recommendations that the risk handling strategies identified as part of the premortem process be implemented to return the SDU to functional compliance through a successful hydrostatic leak test. This option requires a change in the current requirement that the SDU structure itself be leak-tight without coatings or linings.

Additionally, the team recommended the application of GacoFlex S-20 coating on SDU 6 roof to seal and resolve roof leakage issues. This coating was previously used on Vault 4 roof for similar purposes.

This report documents in detail the activities and recommendations of the team.

1.0 Background

SDU 6 foundation failed the leak test (hydrostatic testing to an approximate head of 41 feet) due to potential leaks through cracks in the floor slab and suspected leaks through construction joints between floor sections. It is important to note that the tank passed the no measurable loss testing specified in ACI 350.1 and walls exhibited no signs of dye. Subsequent investigative work cored the floor in five locations to understand crack propagation. This investigative work concluded all cracks were not surface shrinkage cracks, but some were full depth through the core sample(s). A Nonconformance Report 2016-NCR-15-DZC-0005 was issued documenting that the floor slab cracks combined with the failure to pass leak tightness test yield SDU 6 indeterminate in meeting structural requirements, leak tightness requirements and PA/SA requirements. The SDU 6 roof also exhibits similar cracks as those observed in the floor.

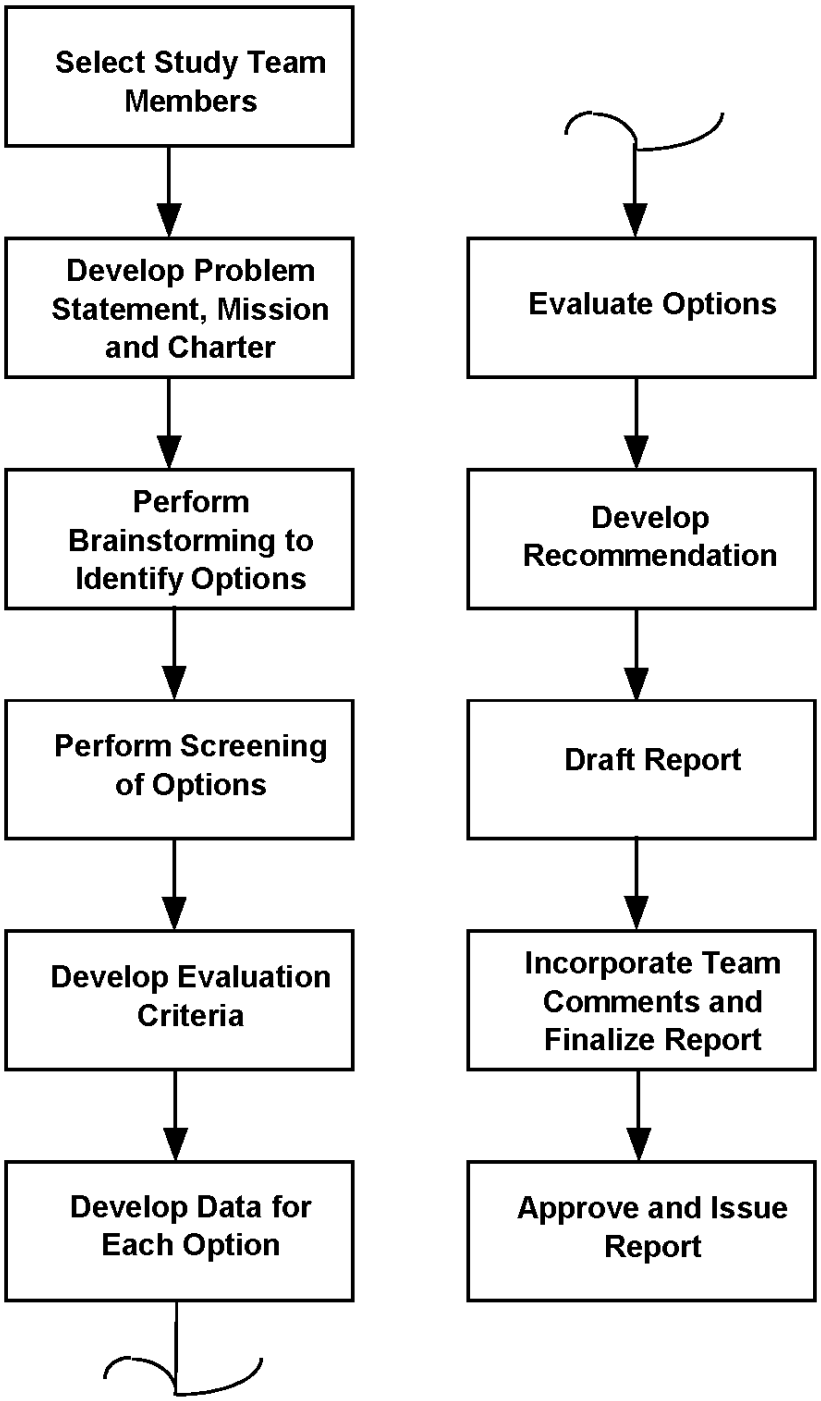
While other teams addressed PA/SA and structural requirements (For reports see References 5.4. and 5.5), a team was chartered to perform a SEE to select a preferred repair technique(s) to address the leak tightness requirements for the floor and roof of SDU 6 (Reference 1). This report documents the activities and recommendations of the team.

2.0 Process

The process used for this evaluation was a structured alternative analysis with weighted evaluation criteria. The team used alternative study methods defined in E7 Manual procedure 2.15 (Reference 5.2) and Alternative Studies and System Engineering Methodology Guidance Manual, WSRC-IM-98-000033, Appendix A (Reference 5.3). This methodology is commonly used to select an alternative from two or more options which would be available to meet specific functions, selection criteria, and requirements.

The SEE process is shown in Figure 2-1 and is described in detail within the following sections.

Figure 2-1: Study Process



2.1 Selection of Study Team Members

The initial activity of the study was to identify SEE team members and resources. SEE Team members were selected for their experience, expertise, and history in the design, construction and operation of SDUs and the Liquid Waste Program at SRS.

The following functional areas were represented within the Team:

- Customer
- Project Management
- CH2M
- Engineering
- Design Services
- SRNL
- Construction

The list of SEE team members is shown in Table 2.1-1:

Table 2.1-1: Team Members

Name	Organization
Brent Gutierrez	DOE (non-voting)
Charles Comeau	DOE (non-member contributor)
Mark Smith	DOE (non-member contributor)
Irvin Rubin	DOE (non-member contributor)
Michelle McHenry	CH2M
Eric Skidmore	SRNL – Materials
Noel Chapman	SRR – Engineering
Steve Simner	SRR – WDA C&DA
Sergio Mazul	SRR – Design Services
Don Hayes	SRR – Construction
JP Thompson	SRR – Design Authority
Matt Maryak	SRR – Engineering Programs
Chuck Keilers	SRR – Engineering
Adeola Adediran	SRR – Design Services
Craig Carlisle	SRR – SDU 6 Project Management
Jon Lunn	SRR – SDU 6 Project Manager
Dennis Conrad	SRR – Engineering Programs
Gavin Winship	SRR - Risk Management

2.2 Problem and Mission Statement

The initial step of this SEE was to identify and succinctly state the problem and define a mission and goal for the study. To ensure these perquisites were accepted by the facilities, management and engineering, a Charter was developed and approval obtained (Reference 1). Within this Charter the problem statement was defined as:

> **"Until SDU 6 is brought back into functional compliance and has passed a leak test, it cannot become operational."**

From this the team developed the following mission statement:

> **"As part of bringing SDU 6 into functional compliance, a leak-tight floor and roof must be validated."**

2.3 Brainstorming

Prior to initiating brainstorming activities, presentations were made by subject matter experts on the current condition of SDU 6. These presentations provided the team with a detailed understanding of the problem.

The team elected to address the SDU 6 slab leak tightness first. Using the Problem and Mission statements, the team performed brainstorming to identify potential options that could bring SDU 6 into compliance through a successful hydrostatic leak test. 25 potential options were identified (see Table 2.4-1). As the team worked through the options those not feasible were removed from this initial list of options. This resulted in a list of 16 initial options carried through to screening. Brief descriptions of initial options are presented in Appendix A.

2.4 Screening

Screening criteria were developed by the team based on selected primary functions and design requirements. As with the Problem and Mission statements these screening criteria were included in the Charter (Reference 1) and approved by management, facilities and engineering. The following screening criteria were developed:

- Provide a watertight reinforced concrete SDU structure.
  NOTE: Initial design criteria required this without relying on coatings or linings to achieve water tightness, however if this is identified as an option for repair it will be considered. This is also not a requirement in documentation submitted to SCDHEC.

- Provide concrete protection from sulfate and chemical attack using an internal protective coating per ACI 350.

- Provide rain infiltration prevention and exposure to the elements including penetrations into the SDU.

- Provide long term closure as demonstrated by the Performance Assessment.

  NOTE: For purposes of evaluation, it is assumed that the current PA model will address the current configuration of the SDU without being detrimental to the long term closure.

- Design life of the SDU structure shall be a minimum of 25 years from date of construction completion.

  NOTE: It is assumed that the leak-tightness requirement is only for the period the SDU is being filled with grout (up to 6 years).

- SDU 6 shall have a minimum saltstone disposal capacity of 30 million gallons.

After applying the above screening criteria to the 16 options identified during brainstorming, two further options were screened out. The results of initial brainstorming and screening are shown below in Table 2.4-1:

Table 2.4-1: Brainstorming and Screening Results

#	Option Title	Pass/Fail	Comments
1	Epoxy Injection	Pass	
2	Routing and Sealing	Pass	
3	Surface Sealing by Gravity Filling	Pass	
4	Crystalline Waterproofing	Pass	
5	Chemical Grouting	Pass	
6	Polyurethane and methyl acrylate resins injection	Pass	
7A	Coating-Polyurea	Pass	
7B	Coating- EC 66 Flexible Epoxy	Pass	
8	Liner-Synthetic	Pass	
9	Autogenous Healing	Pass	
10	Add bentonite to floor	FAIL	Cannot install a coating
11	Bentonite (leak test with bentonite)	FAIL	Determined not viable.
12	Install concrete overlay	Pass	
13	Gunite/Shotcrete (fiber reinforced)	Pass	
14	Liner - Steel	Pass	
15	Repair Mortar	Pass	
Options Not Considered Feasible or Practical			
Near-surface reinforcing and pinning			
Additional reinforcement			
Drilling and plugging			
Portland cement grouting			
Drypacking			
Crack arrest			
Install waterproofing sheets (Bituthane)			
Seal floor with a layer of grout			
Chipping up floor and repouring			

2.4 Develop Evaluation Criteria

Evaluation criteria were developed based on those specific attributes that the team considered critical to mission success and of specific interest to stakeholders. The evaluation criteria were also considered to be discriminating between options in that each option would vary in how well they perform against each criterion. The evaluation criteria developed by the team and topics associated with the criterion were as follows:

Cost

The total cost to fully deploy the option (Dollars). The lower cost options are preferred.

Schedule
The total critical path duration change for decision to proceed to initiation of leak test. The shorter the duration, the more preferred the option.

Leak-tightness
The leak-tightness of the option relates to how successful the deployment is predicted to be in terms of passing the hydrostatic leak test. In other words, what is the confidence level that the option will be fully successful. (Technical uncertainties in the deployment will be identified as risks). The greater the confidence level, the more preferred the option.

Durability
The ability of the option to continue to support leak-tightness of the SDU (as required) during the planned ~6 years of SDU grout filling and up to the design life of 25 years. Durability assumes the SDU acts as a system with applicable influence of coatings or linings (if used). The more durable, the longer the option continues to support leak-tightness during and past the planned filling period, the more preferred the option. (Technical uncertainties in the deployment will be identified as risks).

Stakeholder Approval
Are there any changes that must be sanctioned by Stakeholders, (e.g. regulators, DOE, Codes and Standards etc.) to allow the option to be deployed, if so is approval considered difficult to achieve. Those options with no changes to be sanctioned are preferred.

Constructability
The easier the option is to construct, the more it is preferred.

Acquisition Strategy
Impacts to the current fixed price contract, e.g. forced revisions to existing contractual agreements with existing subcontractors to facilitate the deployment of the option could be significant. No changes or minimal change is preferred.

2.5 Data Development

After the development of evaluation criteria, the 14 final options that passed screening were investigated further and matured to provide an understanding of how they would perform for each of the evaluation criteria. The final options and developed data are presented in Appendix B. Cost and schedule data for all options was reviewed by the team and consistent assumptions applied to all estimates.

The assumptions applied to each option relative to cost were as follows:

- Research and Development (R&D) and testing costs are those needed prior to deployment of the option.

- Construction costs include construction equipment, in house labor and subcontract costs.
- An adjustment was made for the options which eliminated the need for EC-66 coating of the slab.
- 10,000 linear feet of floor cracks were assumed.

It must be noted that these costs are a rough order of magnitude which although acceptable for comparison purposes, should not be taken as a detailed or accurate estimate to be used in budgeting activities.

The resulting cost and schedule data are shown in Appendix C.

As the options were not always mutually exclusive, a grid was prepared for use in identifying when an option can be used as a backup, risk mitigation for another option or in combination. This grid is presented in Appendix D. In this grid, it is assumed that the options listed in the left column are performed first, with options listed within each column of that row being subsequently performed. The compatibility or viability of the option sequence was evaluated accordingly.

2.6 Evaluation

A software package specifically designed for alternative analyses was used to perform the evaluation. The software, Expert Choice Pro© provides an analytical platform capable of recording data in the form of weighted criteria and scoring and performing a synthesis of these data to arrive at rankings. Secondary features are the ability to modify criteria weights and show in real time, ranking changes. Using the data developed for each option and weighted criterion, the options were scored, ranked, and a sensitivity analysis performed. Risks were assessed for top option(s) as discussed below.

2.6.1 Criteria Weighting

The analysis hierarchy was developed using Expert Choice Pro© as shown in Figure 2.6.1-1:

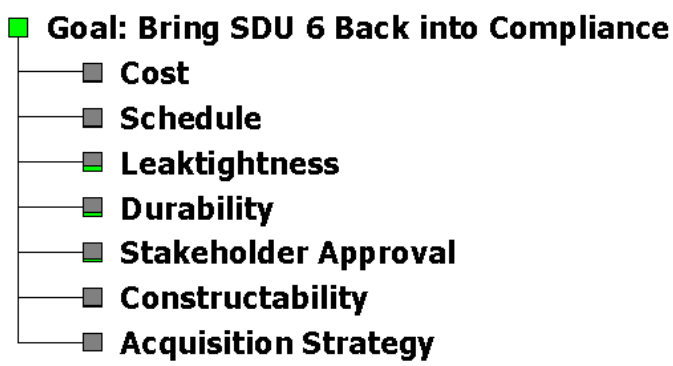


Figure 2.6.1-1: Analytical Hierarchy

A pair-wise comparison of criteria was then performed to establish weights based on preference judgements. The resulting hierarchy and criteria weights are shown in Figure 2.6.1-2:

Figure 2.6.1-2: Criteria Weights

As expected, leak-tightness, the confidence in the option to enable a successful leak-test, weighted highest as this is primary goal of the preferred option. Durability was the second highest weighted criteria due to its importance to the long term mission of being able to maintain leak-tightness during the anticipated 6 year operational phase of the SDU and beyond, up to the 25 year design life of the structure. Stakeholder approval was the third highest weighted criteria as Stakeholders (e.g. DOE and SCDHEC) may have to review and approve any changes to design, permitting etc., necessary to allow an option to be deployed. As this highly visible project has layered oversight, the Stakeholders' approval process may be complex and difficult for significant changes.

Of the remaining four criteria: cost was weighted highest, reflecting the current funding environment; constructability and schedule were essentially equally important, and acquisition strategy carried least weight knowing that necessary acquisition changes will be made, the only discriminator being the marginal level of difficulty.

The SEE team agreed (by consensus) upon subjective weighting criteria based on their experience and information provided by subject matter experts.

2.6.2 Scoring

To facilitate assigning a numerical value to the team assessment of how an option would perform relative to a specific criterion, a guide scale was developed as shown in Table 2.6.2-1:

Table 2.6.2-1: Scoring Guide Scale

Excellent	1
Very Good	
	0.75
Good	
Acceptable	0.5
Marginal	
	0.25
Poor	
Very poor	0

The team then proceeded to apply a score to each criterion for each option. The results of the scoring are shown in Appendix E.

2.6.3 Ranking

After the scoring had been completed the software program synthesized the results by multiplying the score by the weighting factor for each criterion, then totaling and normalizing the score for each option to arrive at a ranking. Figure 2.6.3-1 shows the ranking score results for all options.

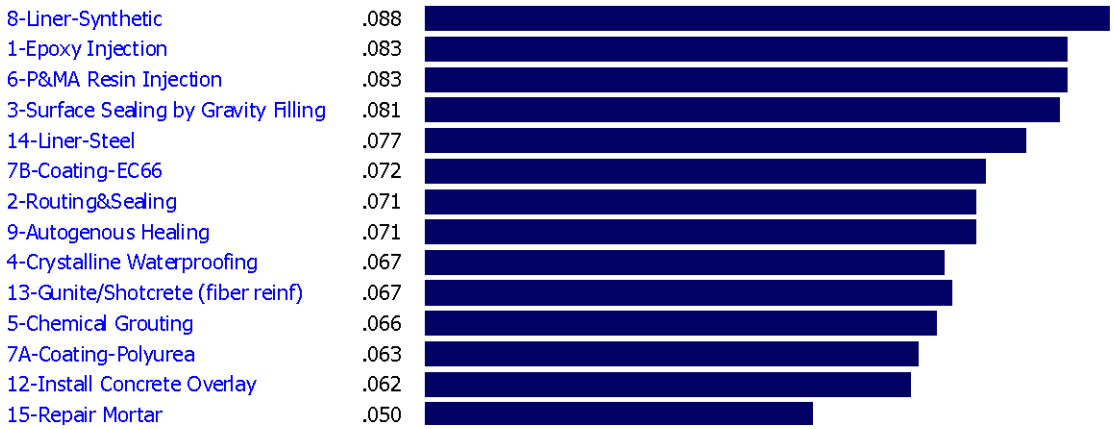


Figure 2.6.3-1: Results

As can be seen from Figure 2.6.3-1, Option 8 (Synthetic Liner) was the highest ranking option.

2.6.4 Sensitivity Analysis

A model's results are considered robust if evaluation criteria weights can be altered by ± 10% and the top ranking option is not displaced. A sensitivity analysis was performed by increasing and decreasing the weight of a particular criterion, resulting in the increase or decrease being proportionally distributed to the other criteria. This changed the scores of the options. It was observed that in no case did this degree of change displace the top two options. The criteria generally had to be changed upwards of 30% to displace the top ranked option and in many cases drastic decreases or increases in selected criteria did not displace the top option. This model and result were therefore considered robust and valid.

2.6.5 Risk Assessment

A premortem process was used to identify risks and opportunities associated with the top options from the SEE. For comparison purposes, the option of applying EC-66 flexible epoxy coating (current project baseline) was also evaluated. The risks/opportunities identified and their associated handling strategies are presented in Appendix F.

The risk assessment showed that greater risk was associated with the second ranked options (Epoxy Injection and PMMA/Urethane Resin Injection), than was associated with the top ranking option (Synthetic Liner). The EC-66 option also had greater risk, primarily associated with coating application and sensitivity to movement of existing cracks or development of new cracks during operations.

While the technical risks associated with the top ranked option (Synthetic Liner) were deemed lower than with all other options, the primary risk associated with this option is one of stakeholder approval. A level 2 Baseline Change Proposal (BCP) per the Project Execution Plan would have to be approved by DOE to allow the synthetic liner to be credited for leak-tightness rather than the SDU structure itself. This assumes that no intermediate repairs or attempts to make the structure leak-tight prior to liner installation are required.

With this option a few opportunities exist for consideration. Liner seams and joinings can be vacuum box tested or otherwise tested (vendor technique) prior to the hydrostatic leak test. In addition, use of a liner could be extended to the design of future SDUs as lessons learned, with appropriate reviews and testing as required. Also, an opportunity exists to extend the liner to cover the SDU walls which could provide a less complex wall/floor transition.

The team discussed the recovery of the Liner and Epoxy/Resin injection options, should the hydrostatic leak test fail after their individual deployment. In the case of the liner, the liner could be repaired and subsequently vacuum box tested once the leak location(s) is detected. In the case of epoxy/resin injection, further inspection for additional cracks and additional injections would be performed. This assumes the cracks can be found and adequately sealed. For both options, this could be an iterative process until a successful hydrostatic leak test is achieved.

A separate approach discussed under chemical grouting was that it may be possible to seal the primary leak path at the floor slab/HDPE interface from the exterior using a water-reactive polyurethane expanding grout or similar product. This would not be a structural repair and would be an exterior seal rather than containing liquid from within the structure. The durability of this approach is unknown. Sealing leak paths within the concrete may be possible but bonding to HDPE would be difficult.

The primary difference in these approaches is the definition of the barrier credited for leak-tightness. In the case of the liner, the liner itself is the barrier (not the SDU structure) whereas in the case of epoxy/resin, the entire structure is credited.

3.0 Discussion of Results

The evaluation results show that Option 8 (Synthetic Liner) is the highest ranking option. The sensitivity analysis demonstrated this to be a robust model and ranking. The risk assessment further showed that although risks did exist, they were considered manageable. The deployment of the top option shared the highest confidence of successfully passing a hydrostatic leak test with a steel liner (which ranked much lower based on its evaluation of other criteria).

The team also reviewed the previous evaluation of roof coatings for Vault 4 (SRR-KWP-2014-00011, Rev1) and concluded that the recommendation to use GacoFlex S-20 is appropriate for SDU 6, providing dedicated walkways can be safely established for where access is needed during operations to minimize slipping hazards.

4.0 Recommendations

Of the options reviewed and considered, it is the recommendation of the team that Option 8 (Synthetic Liner) be deployed, with additional recommendations that the risk handling strategies identified as part of the premortem process be implemented, most notably:

- Perform engineering research of vendor data & select appropriate liner material
- Perform exposure testing to qualify liner
- Design/mockup
- External SME Design Review
- Craft Training
- Quality Control
- Work Planning
- Review what surface treatment is best with liner vendor as part of the design process
- Review special features/products of liner system to cover pedestals and corners
- Determine if special order sizes can be used to minimize seams

- Develop a strategy to perform crack repair near restrained edges

The team further recommends the use of GacoFlex S-20 for the SDU 6 roof, and providing dedicated walkways with slip resistant surfaces where access is needed during operations.

5.0 References

5.1 Y-AES-Z-00001, SDU 6 Floor and Roof Repair Evaluation Team Charter, February 23, 2016.

5.2 Manual E7, Procedure 2.15, Alternative Studies.

5.3 Systems Engineering Methodology Guidance Manual, WSRC-IM-98-00033, Appendix A.

5.4 SRR-CWDA-2016-00015, Evaluation of Potential Impact Due to a Prematurely Degraded Roof and Floor in SDU 6, Revision 0, February 2016.

5.5 T-ESR-Z-00009, Structural Integrity of SDU 6, (DRAFT) March 2016.

6.0 Appendices

Appendix A – Initial Options
Appendix B – Final Options and Data
Appendix C – Cost and Schedule Data
Appendix D – Compatibility Grid
Appendix E – Option Scoring
Appendix F – Risk Assessment Premortem Results

Appendix A – Initial Options

Option #1: Title: Epoxy Injection

Author: Matthew E Maryak

Description:
Description: Cracks as small as 0.002 inches may be repaired by epoxy injection through either surface mounted ports (Fig. 1) or cross drilling (Fig 2) the crack profile. The injection of epoxy will provide a leak-tight path where it penetrates, restore some if not all of the original structural integrity and enhance the durability of the structure. The foundation is generally 12 inches thick. The port spacing should be roughly equal to the foundation thickness. However it is recommended that for cracks less than 0.010 inches the ports should be spaced at 6 inches. With roughly 8,000 lineal feet of crack at least 16,800 ports would need to be installed and sealed. Cleanliness of the crack is very important to successful injection. Surface mounted ports should have the cracks, as a minimum, flushed with compressed air. Cross drilled cracked should likewise be vacuumed and cleaned with compressed air. The installation cleanliness will be critical for the successful injection of cracks. Epoxy materials proposed to be injected should meet the requirements of ASTM C881/C881M Type I or IV Grade 1. Without sealing the back side of the crack epoxy may not flow laterally to cover the entire flow path. The injection process should be performed at low pressures for at least 10 minutes per port. The injection process alone will consume 168,000 minutes (117 days) assuming 100% successful injection at each port.

Low viscosity, insensitivity to moisture, high bond strength and compressive and tensile strengths higher than those of concrete make epoxy injection one of the most effective ways of repairing narrow cracks. Repairs are made by sealing the surface of the crack, then injecting epoxy into it through ports spaced along the crack.

Figure 1

Figure 2

Pros:

- The injection material can restore structural integrity and durability.

Cons:

- Low viscosity injection was attempted in SDU6 with little success
- Difficult to validate the travel and penetration of the epoxy.
- Fines in the concrete may inhibit epoxy flow due to tightness of cracking.
- The cracks currently are covered with epoxy and would have to be cleaned off.
- The cleaning process will potentially clog the cracks.
- The process of preparing and injecting cracks is very time consuming.
- The SDU6 may leak even after injection is completed.
- Contamination of the cracks may impact the ability to bond the concrete.

Option #: 2 Title: Routing and Sealing

Author: Sergio Mazul

Description:
Enlarge surface crack along its exposed face and fill with suitable joint sealant. This repair will require sandblasting of the floor to further expose all cracks, V groove all cracks and then apply a very flexible sealant in the V-grooves. The sealant has to be flexible enough to withstand potential movement and rigid enough to bond with the concrete.
Sealants applicable for this option are:
Sikadur 51 NS. This is a 2-component, non-sagging, solvent free, flexible epoxy control joint sealer and adhesive. Used fill vertical and overhead non-moving saw cut construction control joints and cracks.
Sika Loadflex 524 EZ. This is a 2-component quick setting, semi-rigid solvent free, control joint filler. It is also used for repairing interior concrete slabs that have experienced random cracking due to shrinkage.
Pros and Cons:

PROS	CONS
Sandblasting of the floor may help determine crack pattern and flow path(s) locations.	Labor Intensive (Sandblasting, V-grooving and filling ~ 8000 ft of cracks).
V-Grooving will provide enough area to enable proper sealant coverage.	Seals Visible Cracks Only.
	High Viscosity materials. Ok for surface filling but not for pressure injection.

Option #: 3 Title: Surface Sealing by Gravity Filling

Author: Craig Carlilse

Description:
Low viscosity urethanes, high-molecular-weight methacrylates (HMWA) and some epoxies can gravity fill cracks with widths from 0.001 to 0.080 inches. Lower viscosity materials are used to fill narrow cracks. This method is ideal for areas with multiple surface cracks that are dormant such as plastic shrinkage cracks. The area and cracks are cleaned with air or water blasting (and allowed to dry) before flooding the area with the monomer or resin. If cracks are full of dirt, moisture or other contaminants, penetration of the repair material into cracks is poor. The material is worked into the cracks with brooms, rollers or squeegees then the excessive material is removed to avoid shiny, slick areas.
Cores taken at cracks can be used to evaluate the effectiveness of the crack filling. The depth of penetration of the sealant can be measured. Shear (or tension) tests can be performed with the load applied in a direction parallel to the repaired cracks (as long as reinforcing steel is not present in the core in or near the failure area). For some polymers the failure crack will occur outside the repaired crack.
Pros and Cons:
Pros

- Installation requires limited prep work and is not intrusive

Cons:

- Did not penetrate deep into crack on first applications,
- Seal could be damaged when floor is sandblasted prior to coating application,
- All cracks are not visible and thus this method does not guarantee a leak tight tank,
- Trial test box on roof indicates the effectiveness of gravity filling for leak tightness is indeterminate.

Option #: 4 Title: Crystalline Waterproofing

Author: Keilers
Description:
Crystalline waterproofing involves using commercial proprietary products that essentially diffuse with water through concrete, react with water and cement hydration products (e.g., free lime), and precipitate nonsoluble crystals capable of plugging pores and bridging small cracks. The chemical process is similar to autogenous (self) healing.

The Xypex product is similar to several that are on the market. The Xypex specification[1,2] indicates their product is nontoxic; effectively seals hairline cracks up to 0.4 mm (10 mils); and highly resistant to pH 3 - 11 for constant exposure. The crystalline structure has pores that allow passage of vapors but not water. It is composed of portland cement, very fine silica sand, and various "active proprietary chemicals" that catalyze the precipitation.

Variants of the products can be applied by brush, spray equipment, dry shake material on new surfaces, or as an admixture. Surfaces need to be clean, free of dirt and oil, and have an open-pure structure that permits capillary action and waterborne diffusion. If the surface is too smooth, it should be acid-etched, or lightly sandblasted or water blasted. Larger cracks should be routed out and repaired per Xypex repair procedures. The surface needs to be thoroughly wetted prior to application. Coverage is about 1.5 lb to 2 lb per yd^2 (i.e., about 12 tons for SDU-6). Water-fog misting is needed during curing, typically three times per day for 2 - 3 days. Allow 12 days before filling with liquid.

The Kryton product specification[3] discusses effectiveness at self-sealing hairline cracks up to 0.5 mm (0.02 in). The Tremco product specification discusses 2 inch penetration.[4]

There is trade journal information on applications, such as a repair to the Georgia Raccoon Creek water treatment facility, which used about 150 tons of a Xypex product at a cost of about $1.5M.

Pros and Cons:

- Pros:
  - Multiple vendors; easy of application; non-toxic – used for potable water tanks.
  - Some demonstrated experience at sealing hairline cracks of up to 5 – 10 mil width.
- Cons:
  - Requires careful surface preparation and repair of larger cracks.
  - Requires careful maintenance of the wet-cure conditions.
  - Besides water, requires the presence of the hydration reaction products.
  - Proprietary products; no consensus installation standards.
  - May be ineffective alone for this application, depending on actual crack size distribution.

References

1. Xypex datasheet for Cementitious Crystalline Waterproofing 07160
   http://www.xypex.com/technical/spec-data
2. Xypex Training Material, May 2015.
   http://continuingeducation.bnpmedia.com/article.php?upgrade=new&L=49&C=850
3. Kryton Krystol Specification
   http://www.kryton.com/products/krystol-t1-t2/attachment/technical-data-sheet-krystol-t1-t2/
4. Tremco Permaquik Crystalline Waterproofing, Capillary Waterproofing formulation.
   http://www.tremcosealants.com/products/permaquik-crystalline-waterproofing.aspx
5. Waterproof Magazine
   http://www.waterproofmag.com/back_issues/201301/Watertanks.php
6. Waterworld
   http://www.waterworld.com/articles/wwi/print/volume-19/issue-5/regulars/keep-water-in-and-out-ofconcrete-water-tanks.html

Option #: 5 Title: Chemical Grouting

Author: Keilers
Description:
ACI 224.1R-07 states: "Chemical grouts, such as urethanes and acrylomides, are activated by catalysts or water to form a gel, a solid precipitate, or foam that will fill void space within concrete. The materials are primarily used for sealing cracks from water penetration. Bond strengths are typically low, so structural repairs are not made with chemical grouts. Cracks in concrete as narrow as 0.002 in. (0.05 mm) have been filled with chemical grout."
Polyurethane chemical grouting, activated by water, has been used since the 1950's to repair sewers, tanks, vaults, etc., primarily to prevent groundwater infiltration2 It is usually injected under pressure near the leak site and chemically reacts upon contact with water to create a foam, gel, or solid. Formulations can be hydrophylic (water-wetted) or hydrophobic (water-repelled). The latter is mixed with a non-water catalyst. Reaction time is in the tens of seconds, and volume expansion can be large, making these techniques suitable for gushing types of leaks.
The U.S. Bureau of Reclamation report discusses testing of pressure-injected polyisocyanate that reacts with water, releasing carbon dioxide, forming foams, gels, or solids. For water-activated formulations, room-temperature viscosities ranged from 1 - 500 cps, with the foam and gel applications at the lower end. Two-component formulations typically form solids, have viscosities of 50 to 500 cps, tend to be rubber to hard, and have less effectiveness with water. They report cracks are sealed down to about 1 mm (30 mils) by injection.
Some of the challenges are the wide variety of materials and the lack of consensus standards. Application can be low pressure (e.g., a caulking gun) or high pressure (e.g., modified paint sprayer or rocker pump). In some cases, plastic tapered fittings can be hammered into an injection port. Ports are often drilled above or below the crack and angled to intercept the crack. Jute caulking is hammered into a crack if grout appears too quickly..
Pros and Cons:

- Pros:
  - Reported effective for larger cracks (30 mils or greater).
- Cons:
  - Difficult or impractical to use for smaller cracks.
  - No consensus standards.
  - Uses pressure injection, which may be more labor intensive than other techniques.
  - Quick setup time (tens of seconds), which may be undesirable for SDU-6 application.
  - Possible large volume expansion for some formulations, which could damage concrete.
  - May be ineffective alone for this application, depending on actual crack size distribution.

References

1. ACI 224.1R-07, *Causes, Evaluation, and Repair of Cracks in Concrete Structures*
2. Concrete Monthly, March 2008
   http://primeresins.com/wp-content/uploads/2013/07/Concrete-Monthly-TechTalk-Polyurethane-Chemical-Grouting.pdf
3. U.S. Bureau of Reclamation, Leaking Crack Repair Using Chemical Grouts, Sep 2005
   https://www.usbr.gov/research/projects/download_product.cfm?id=317

Option #: 6, 7, 8 Title: SDU 6 Coatings/Linings/Polymer Resin Injection Options

Author: Eric Skidmore/SRNL-Materials Science& Technology
Description:
Tank is currently required to be leak-tight without coatings or linings. Current SDU6 protective coating (EC-66 flexible epoxy) is specified to protect concrete, principally from sulfate attack. Relying on coatings/linings for leak-tightness requires TRAC change. Existing tank condition (floor/roof cracks, dye test failure) involves multiple through-slab cracks. Development of new floor cracks during later hydrotesting or grout placement assumed not likely but may be possible (concrete SME input?). Crack movement, if it occurs, should be minimal. However, crack-bridging ability of coatings/linings is arguably more important for leak-tightness than concrete protection.
Coatings and linings are generally divided into two main groups: a) liquid or spray-applied and b) membrane/sheet linings. Liquid-applied systems for chemical/corrosion protection of steel/concrete generally fall into the following classes, each with pros/cons:

- Epoxies (bis-A or bis-F types, novolacs, epoxy-phenolics, flexibilized, zinc-rich, FRP resins)
- Polyurethanes (aliphatic, aromatic types, rigid or elastomeric, moisture-cured)
- Polyureas (reaction of isocyanate and amine, rapid cure, aliphatic, aromatic, polyaspartic)
- Polyurea/urethane hybrids (truck bed linings)
- Polysiloxanes (epoxy or acrylic + silicone) – typically exterior only, weathering
- Vinyl esters (high chemical resistance, rigid, high VOC/styrene hazards, FRP resins)
- Polyesters (different types, all relatively rigid types, FRP resins)
- Phenolics (steel only, rigid, baked finishes)
- Some types can be installed with reinforcement filler or fabric (glass or synthetic) to improve crack-bridging ability. Joint sealants also needed (polysulfide, polyurea, polyurethane, etc.).
- Bituminuous – typical for waterproofing/below-grade, not for chemical/high heat exposure

Membrane/sheet linings generally fall into the following classes:

- Rubber linings (butyls, EPDM, natural rubber, neoprene, FKM/Viton®, Hypalon®/CSPE)
- Thermoplastics (HDPE, PP, plasticized PVC)
- Bituthene or similar – asphaltic/HDPE waterproofing, typically below-grade
- Fluoropolymer – extreme chemical resistance/high temp, less commonly needed, expensive
- EVA (ethylene-vinyl acetate) or EVA blends
- Blends/tradenames (Marseal®/Blair Rubber /DuPont Elvaloy® copolymers/EPDM)
- Some can be loose laid or mastic/adhesive-backed, joints sealed via hot-air (HDPE), heat-sealing, adhesives, etc. Some are fabric-reinforced for integrity.

Initial coating selected for SDU2 was mat-reinforced epoxy novolac (Blome TL-45S or similar) to resist Saltstone bleedwater at design temperature (68°C). Other coatings (aggregate-filled, trowel-applied mortar systems) were also considered/recommended (different PA/technical requirements) but more costly and labor intensive. Primary limitation of this coating type is rigidity, also installation issues (mat saturation, vendor experience, substrate levelness, etc.). Mat-reinforcement provides some crack-bridging capability but limited.

Elastomeric coatings (polyurethanes, polyureas, flexible epoxies (including EC-66) were initially considered by SRNL for SDU2 but were not initially recommended by vendors (including Blome) due to concerns/unknowns with bleedwater chemistry at bounding design temps. EC-66 later used on SDU2 as an overlay system, now specified as a standalone coating option in SDU6 specification. In hindsight, a preferred system might have been EC-66 as a flexible basecoat with TL-45S as a more chemical-resistant topcoat (more typical). Recent VSL and other testing of EC-66 may show this to be satisfactory for SDU6 requirements. Lower actual service temperatures reduces concerns over chemical/thermal degradation of all coatings/linings.

Membrane or sheet linings (Marseal series or similar) were also initially considered for SDU2 for higher flexibility and crack-bridging capability with sufficient chemical/heat resistance, but could not be used due to SDU sheet drain attachments. Such systems offer some advantages in terms of surface preparation and sensitivity to environmental conditions during installation.

Options to consider/further evaluate:

- Base case: EC-66 has been used and some testing has been performed. EC-66 is likely sufficient for walls (no leakage) and possibly floors. Reinforcement fabric is recommended for floor application, use maximum system thickness per vendor. Consider additional EC-66 flexible, non-reinforced basecoat to reduce crack-bridging concerns (consult vendor). SRNL has some concerns on 25-year longevity of EC-66 as the sole coating (primarily chemical resistance at bounding temp). Test data, actual temperatures and time at temperature may be acceptable.

- Use Envirolastic AR425 polyurea (with or without geotextile fabric) for walls or floors only (with fabric), with vendor consultation. AR425 likely provides higher tensile strength, elongation and tear strength, possibly superior chemical resistance, abrasion resistance and crack-bridging ability compared to EC-66. Mutual compatibility of different systems, if used?

- Recommend formal evaluation of EC-66 and AR425 data and document basis for EC-66 vs. AR425 selection for SDU6, accounting for current condition and addressing all relevant aspects (durability, 25-year longevity, installed costs, etc.). Polyurea/geotextile systems now commonly used in wastewater systems, secondary containments, tank linings. Suggest discussing application with Dudley Primeaux (principal developer of

polyurea coatings , now at Versaline, developed/formulated many polyurea coatings on the market).

- Regardless of coating/lining selected, experienced applicator is needed. If polyurea system is used, applicator must have specific polyurea experience (heated plural component equipment, rapid cure, geotextile systems). Not all coatings applicators have polyurea experience. Experience with such systems for tank linings should be verified (case references, etc.). On or off-site demos with the system may be warranted prior to in-tank installation.

- Suggest waiting on current SREL coating test results with EC-66 and AR425 coatings for final determination, if schedule allows. Current testing may not address all critical aspects, particularly crack-bridging capability, but direct comparison in applicable conditions is desirable. Longer chemical/thermal exposures are always desirable, particularly for longer service life. Longer exposures often needed for degradation mechanisms to manifest.

- Relying solely on coating systems for leak-tightness may work but is not recommended, particularly given current condition. Fabric-reinforced systems may be sufficient without crack repair but not recommended. Cracks should be sealed/injected to the extent practical to minimize leak paths prior to coating application. Such effort alone may be sufficient for leak-tightness, with additional protection provided by the coating/lining.

- Must consider surface preparation requirements for any coating system over previous crack repairs or sealing methods. Widespread use of sealers or resins can inhibit adhesion of liquid-applied coatings and surface preparation for coating may damage crack repair (likely surface only). Epoxy or urethane grout injections are likely of less concern. Adhesion may be less critical if coating integrity is sufficient.

- Elastomeric sheet linings (EPDM, Marseal 8000, other) likely have superior chemical/temperature resistance and crack-bridging ability than flexible epoxy and/or polyurea coating systems. Could not be used in earlier SDU designs due to sheet drain attachment penetrations. Such linings tend to be less dependent on substrate conditions for performance.

- Recommend documenting actual bounding service conditions in SDU6 (thermal modeling, etc.). Lower service temperatures reduce chemical resistance concerns for practically all polymeric systems.

Pros /Cons/Questions:

- SME consensus on further or new crack development? Can sub-surface cracks exist that can later open to the surface after initial repairs or coating?

- Does the tank (and coating/lining if credited for containment) have to remain leak-tight during or after a seismic event? If so, how much movement/displacement is expected (or bounded by hydrostatic test)? Lining durability and flexibility may be more critical in such cases.

- Sheet linings likely reduce surface preparation efforts (abrasive blasting, etc.). Adhesive-backed systems likely recommended over loose-laid (more typical for secondary containment). Loose-laid systems must be affixed at top and likely other locations (stainless steel termination strips are typically used). Difficulty working coatings/linings around roof pedestal bases, but used in secondary containment/diked areas (consult vendors).

- Sheet linings likely reduce if not eliminate concerns over bridging existing or future cracks, particularly if any significant movement. If sheet linings are given further consideration, suggest bringing in an experienced vendor (Blair Rubber/Marseal or similar) for detailed consultation.

- Crack-bridging capability of coatings is a subject of much debate in the coatings industry. The relationship between tensile/elongation properties, modulus, adhesion, reinforcements and performance is not well-established. Variation in test methods, laboratory results vs. field performance, etc. complicate the issue.

- PVC-based membranes not recommended due to concerns over plasticizer migration (modified thermoplastic), particularly at elevated temperature. Thermal/radiolytic degradation of PVC also generates HCl gas (corrosive).

- HDPE liners not recommended at this time due to possible concerns over stress-cracking in high pH chemistry at bounding temperatures. Chemical resistance is generally excellent but some literature suggests possible ESC issues at certain conditions. HDPE also not as flexible as elastomeric liners.

- EPDM-based liners likely have excellent resistance to bleedwater chemistry at bounding SDU6 service temperatures and beyond. EPDM is well-suited for high pH salt solutions. All constituents should be considered, including any organics in the system, if any. Even minor organics in a process can influence polymer degradation, often more than pH or

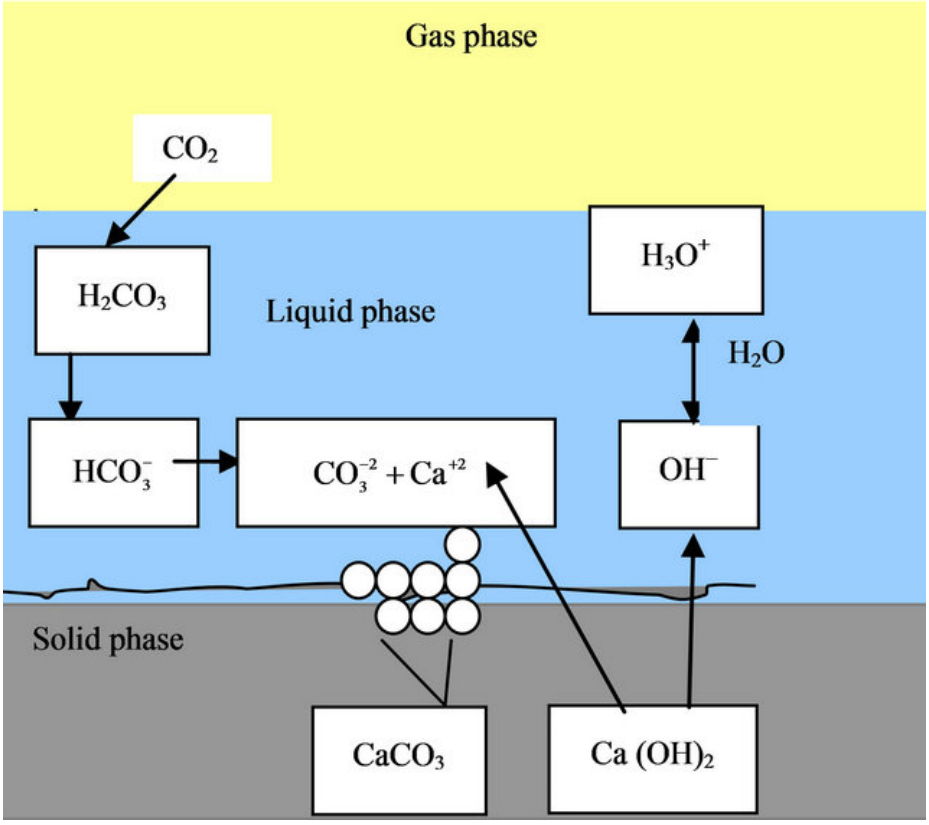
aqueous species, particularly if there is a specific sensitivity. Any testing performed should include such species, if present.

- Global or isolated use of low-viscosity monomer or resin injection (acrylate/urethane sealants) may improve leak-tightness for duration of leak testing. However, resin selection is complex (which product) and success depends significantly on the degree of penetration, crack dimensions, potential for movement, etc. Long-term durability is more questionable, particularly for bleedwater chemistry at temperature. The use of such systems could also affect later application of protective coatings/linings, or be impacted by necessary surface preparation.

Option #: 9 Title: AUTOGENOUS CRACK HEALING
Author: S. SIMNER
Description:
Autogenous (self-produced) crack healing in concrete occurs in the presence of water via two primary mechanisms.
1. Concrete containing unreacted cementitious materials – infiltrating water may result in the hydration of unreacted cement and the formation of calcium silicate hydrate (CSH)) on opposing crack surfaces. Concrete may also contain unreacted, supplementary cementitious materials (SCMs), such as blast furnace slag (BFS) and fly ash; these materials exhibit limited hydration in the presence of water (pH 7) but will react (especially BFS) in the presence of alkali hydroxide solutions to form CSH-like materials. When utilized in concrete the reactivity of SCMs is initiated by the cement hydration product calcium hydroxide ($Ca(OH)_2$).
SDU concrete has the following solids composition:

Ingredient	Material Quantity (lbs/yd^3)
Type V cement (Lehigh T-V #2 ; ASTM C 150)	213
Grade 100 Blast furnace slag (Holcim Grade 100 Slag; ASTM C 989)	284
Silica Fume (W. R. Grace Silica Fume; ASTM C 1240)	47.3
Type F Fly ash (SEFA Group, Class "F" Fly Ash; ASTM C 618)	165.7
Sand (Natural Washed Sand; ASTM C 33)	911
Aggregate (#67 Granite; ASTM C 33)	1850

While unreacted cement may have been depleted at crack surfaces (as a result of previous leak testing) unreacted BFS likely still exists and infiltrating the cracks with a caustic solution (e.g., 0.01 – 0.1M $Ca(OH)_2$) may initiate the hydration of BFS and to a lesser degree the fly ash and silica fume also.
2. $Ca(OH)_2$ (aq) that has leached from the concrete pores to the crack surface may convert to calcium carbonate ($CaCO_3$) (s) in the presence of water with dissolved carbon dioxide (CO_2) – carbonation.



Pros

- Relatively simple and economical approach – flood floor with mildly caustic solution and let it flow through cracks.
- If the predominant mechanism is via alkali-activation of BFS crack healing could be fairly rapid (days to a few weeks).
- Approach could be initiated and given a set time frame for success after which an alternate method (e.g., coating) could be deployed. Note success = visual determination of leak cessation on SDU exterior.
- Approach could be first evaluated on individual cracks on SDU roof.

Cons

- Crack widths that can be healed may be limited to 1 mm or less; mechanism may not seal all cracks.
- Approach may be time prohibitive – while hydration reactions would be expected to occur in a matter of days/weeks, carbonation phenomenon will probably take much longer.
- Not sure of SRS environmental limitations with respect to allowing caustic solution to flow from SDU into environment (may be some way to absorb liquid at leak sites).

Option #: 10 Title: Add bentonite to floor

Author: Noel F. Chapman
Description:
Sodium bentonite swells 15-18 times its dry size when wetted by water. The fact that sodium bentonite swells many times its mass, then forms a strong water and chemical proof seal makes it an ideal, inexpensive, permanent, and easy to install a liner. Sodium bentonite is environmentally friendly and safe to use.

Sodium Bentonite has a natural swelling ability and will maintain its swelling ability throughout its use. Calcium bentonite is a non-swelling bentonite. It will not swell without additives or chemicals. Calcium bentonite enhanced with additives will quickly lose its swell and is short lived. It is the swelling ability of the sodium bentonite that enables this clay to bond with the soil to create an impenetrable liner in the soil. The preferred method for sealing ponds and earthen dams is to drain the pond and till in the appropriate amount of bentonite into the soil. It is the swelling of the bentonite when exposed to water that creates the impermeable liner.

A blanket of bentonite can be installed on the floor slab using covered layers of Geogrid which is ultimately covered by non-sealed joints of HDPE sheets. This bentonite system will provide a "reservoir of material" across the slab surface that would be available wherever it is needed to seal any future cracks. It will remain active for sealing over again, even after its initial sealing task is completed. There would be no need to initially put a concrete cover over the Bentonite system to keep it from being dislodged or damaged by the Product Grout discharge. A three to four foot water head should be enough to cause the Bentonite to move and close off any joints it comes in contact with prior to doing the final acceptance hydro. The blanket method is preferred over the sprinkle method per Sturgis.
CETCO provides bentonite under the Volclay product name and CETCO suggests two grades may be applicable (CP-200 or CG-50). Volclay application use and description can be found on the CETCO web site CETCO.com.
Pros and Cons:
Pros:
Relatively simple to install.
Cons:
Would require testing to demonstrate long term effectiveness and compatibility with the environment inside SDU 6.
No data on width of crack that bentonite will seal.
Prevents installation of coating system to protect concrete from corrosion
Consumes 4 to 6 inches of grout storage volume
No data found supporting use of a Volclay slurry to seal leaks in a leaking structure from an interior application.
Bentonite will not swell in water containing large quantities of mineral salts or acids - Sturgis

Bentonite will not stop the leak immediately. Some seepage is to be expected after the bentonite is applied - Sturgis

Option #: 11 Title: Bentonite Slurry (leak test with bentonite)

Author: Noel F. Chapman
Description:
Sodium bentonite swells 15-18 times its dry size when wetted by water. The fact that sodium bentonite swells many times its mass, then forms a strong water and chemical proof seal makes it an ideal, inexpensive, permanent, and easy to install a liner. Sodium bentonite is environmentally friendly and safe to use.

Sodium Bentonite has a natural swelling ability and will maintain its swelling ability throughout its use. Calcium bentonite is a non-swelling bentonite. It will not swell without additives or chemicals. Calcium bentonite enhanced with additives will quickly lose its swell and is short lived. It is the swelling ability of the sodium bentonite that enables this clay to bond with the soil to create an impenetrable liner in the soil. The preferred method for sealing ponds and earthen dams is to drain the pond and till in the appropriate amount of bentonite into the soil. It is the swelling of the bentonite when exposed to water that creates the impermeable liner.

Bentonite can be used to seal a leaking body of water by sprinkling it uniformly over the surfaced of the water. Bentonite sinks to the bottom where it swells. The bentonite gel that is created is drawn into the leaky seams and closes them. CETCO provides bentonite under the Volclay product name and CETCO suggests use of CC-8 when a body of water is not drained to install a bentonite layer. Application rate using a sprinkle method is 1 to 2 pounds of Volclay CC-8 per square foot of bottom surface area per CETCO Technical Data Sheet for Volclay CC-8. Additional Volclay application use and description can be found on the CETCO web site CETCO.com.

In all methods of bentonite application, it's the swelling of the particles that stop the leak. Bentonite will not stop the leak immediately. Some seepage is to be expected for up to a week after the bentonite is applied. Bentonite will not swell in water containing large quantities of mineral salts or acids.

Pros and Cons:
Pros:
Relatively easy to create a bentonite slurry.
Cons:
Would require testing to demonstrate long term effectiveness and compatibility with the environment inside SDU 6.
No data on width of crack that bentonite will seal.
Volclay CC-8 is stated as being 50% effective in sealing pond leaks by its manufacturer CETCO using the sprinkle method - Volclay
No data found supporting use of a Volclay slurry to seal leaks in a leaking structure.
Sprinkle method is not as successful as the mixed or pure blanket methods but will generally work if the location of the leak is known and enough bentonite is used - Sturgis

Bentonite will not swell in water containing large quantities of mineral salts or acids - Sturgis
Bentonite will not stop the leak immediately. Some seepage is to be expected after the bentonite is applied - Sturgis
May require additional cleaning to prepare walls and floor for installation of the coating system to protect concrete from corrosion.

Note: The CETCO web site contains numerous products they manufacture to prevent water intrusion into structures. These products typically contain an engineered geotextile fabric with bentonite included in the design. As these products are preventing ground water intrusion the only chemical compatibility data readily available is for water with

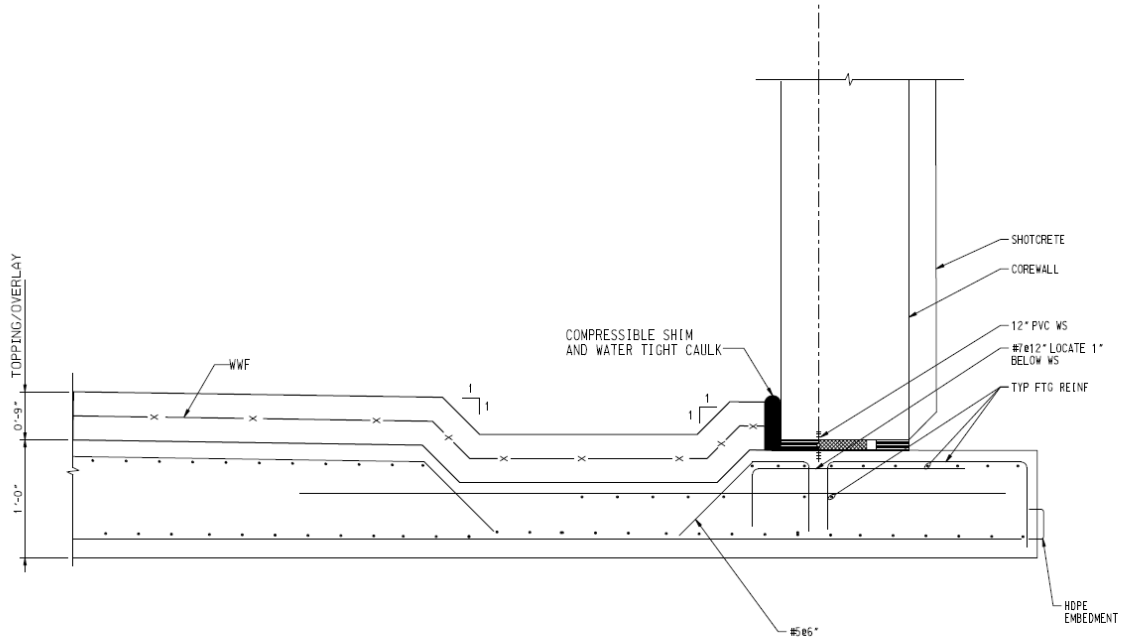
Option #: 12 Title: Install Concrete Overlay

Author: Adeola Adediran

Description:
A Concrete Overlay is essentially a new slab over an old one. It is designed as a topping over the existing slab, meaning that the existing slab is still the structural slab and the main lateral force resisting diaphragm. The new slab is then an added weight on the existing slab and the slab needs to be designed to resist this new weight as well as the mass of this new slab needs to be added to the existing slab in the seismic response of the slab.
Overlays may be designed using regular concrete from an approved hydraulic cement concrete design mix or may include polymers, epoxies and/or polyesters. Asphaltic concrete overlays are deemed not included in this option since they have been previous ruled out in the SEE process and also because they are very porous and will only work in concert with a liner. Depending on the thickness of the Overlay, the overlay would need to be reinforced with one layer at mid height or two layers at opposite faces of the overlay. The overlay could be reinforced with regular reinforcement or by welded wire fabric. Furthermore the mix used in the overlay could contain concrete fibers and other additives to prevent plastic shrinkage that could crack the overlay.
Constraints of Solution:
Concrete Overlays will also not prevent propagation of cracks from an active crack. So in some cases the cracking in the old slab need to be fixed and a crack bond breaker used across to prevent propagation of cracks.
Polymer concrete overlays have been very effective at preventing the penetration of moisture through the overlay but if moisture can get behind the overlay to between the new and old concrete slab then the path for moisture thru the old cracks in the old slab may still be accessible.
Pros:
Polymer –Portland cement concrete overlays have exhibited excellent long term performance. They are highly resistant to corrosive environment (Chlorides) and do well under high temperature. They have been used most frequently over bridges in repairs of bridge decks.
Concrete Overlays can be made with low-slumps such that they are sloped and can maintain the current drainage profile of either the floor slab and or the roof. The low slumps also make they more durable and more resistant to sulfate attacks.
The polymer concrete typically bonds well to the prepared substrate becoming very wear resistant
Polymer-concrete overlays can be installed without expensive equipment.

Cons:

Polymer-concrete overlays have to be installed over a dry surface though bonded Portland cement concrete overlay is more tolerant of moisture on the interface to the substrate and a damp surface is preferable for that installation.
The surface prep for overlays include abrasive blasting of the surface of the substrate which will undo some of the substrate repair that have previous been done.
The overlay may interrupt or interfere with the ability for the tank walls to move with the expected thermal growth.
The reference for this write up has been ACI 546.5R Guide for Polymer Concrete Overlays and ACI 546R-14 Guide to Concrete Repair.



PROPOSED OVERLAY
SCALE: NONE

Option #: 13 Title: Gunite / Shotcrete (Fiber Reinforced)

Author: J.P. Thompson

History:
Shotcrete is defined as concrete conveyed through a hose and pneumatically projected at high velocity onto a surface. Shotcrete is an all-inclusive term that describes spraying concrete with either a dry-mix or wet-mix process. Gunite was a registered trademark name that specifically referred to the dry-mix process. Other manufacturers used different terminology to describe their process such as shotcrete, pneumatic concrete, guncrete, etc. The current acceptance is that the term "shotcrete" is used in the United States and "sprayed concrete" is used throughout Europe.
Description:
The dry-mix shotcrete method has pre-blended dry materials (cement, sand, aggregates, etc.) placed into the hopper. Compressed air conveys the dry materials through a hose at a high velocity to a nozzle, where water is added. The nozzle man controls the addition of water at the nozzle. The materials are consolidated on the receiving surface by the high-impact velocity. The dry-mix process is recommended when the job involves frequent stops during the application process.
The wet-mix shotcrete method is where all ingredients, including water, are thoroughly mixed and introduced into the delivery equipment. Wet materials are pumped to the nozzle where compressed air is added to provide high velocity for placement and consolidation. The greatest advantage of the wet-mix process is that larger volumes can be placed in less time.
The basic concrete mix contains cement, aggregates (< ½ inch) and water. Properties of both dry and wet process shotcrete can be further enhanced through the addition of other ingredients, such as:

- Silica Fume – Provides reduced permeability, increased compressive and flexural strength, increased resistance to alkali and chemical attack, improved resistance to water washout, reduced rebound levels, and allows for thicker single-pass applications.
- Air-Entraining Admixtures – Improve pumpability and adhesion in wet-process shotcrete and freeze-thaw durability in both processes.
- Accelerators – Increase the stiffening rate, provide early strength development, improve the placement characteristics in adverse conditions and allow for thicker single-pass applications.
- Plasticizers – With the wet-mix process the water / cement ratio can be accurately controlled and with water-reducing plasticizers, water / cement ratios below 0.45 can easily be achieved.
- Fiber Reinforcement – Added to shotcrete to control plastic shrinkage cracking, control thermal cracking, improve abrasion and impact resistance, improve fire resistance, improve ductility and toughness, and enhanced tensile and flexural strength.

Pros and Cons:
Properties and Advantages – Shotcrete exhibits certain properties that in some respects make it superior to poured concrete. However, it should be remembered that these properties are largely as a result of the different methods of mixing, transporting and placing rather than fundamental differences in component materials.

- Low Water / Cement Ratio – Shotcrete generally has a lower water / cement ratio than poured concrete. This is particularly true in the dry-mix process where a low slump mix capable of supporting itself without sagging is quite normal. Wet-mix process achieves a similar result using a plasticizer.
- High Strengths with Rapid Strength Gain – Shotcrete can be expected to attain high compressive strengths particularly with a low water / cement ratio and the dense compaction achieved with the high velocity of application. Compressive strengths 30 percent higher than conventionally placed concretes can be expected.
- High Density / Low Permeability – The high velocity of placement ensures good compaction and high density coupled with low permeability and water absorption. This results in a durable homogeneous material with excellent freeze / thaw resistance, low surface cracking and a high degree of abrasion resistance. These properties may be further enhanced by the use of fiber reinforcement in the mix.
- Enhanced Adhesion and Bond Strength – Presuming that the substrate is properly prepared, the bond strength with shotcrete is generally excellent. Furthermore, the use of bonding agents is usually unnecessary and, under certain conditions, damaging to the bond. Shotcrete can be applied to horizontal, vertical and overhead surfaces.

According to the American Shotcrete Association, thousands of shotcrete tanks have been built since the process was pioneered. These watertight, durable, and economical tanks, which range from 50,000 to 20 million gallons, can be used to store a variety of liquids, including wastewater, industrial wastes and chilled water.
Shotcrete General Tips – Construction joints should be designed as with placing regular concrete. Moist curing is the preferred method of curing shotcrete. Shotcrete success depends largely on the skill and actions of the nozzle man. For this reason, it is important to require that the nozzle man be ACI certified for the application.

Option #: 14 Title: Liner - Steel

Author: Don Hayes

Description:
Line the tank floor with ¼" steel plate. Join plates with full thickness fillet welds using GMAW process and ¼" backing bar. Modify expansion joint/reglet design from coating system to use at floor and wall interface. Seal interfaces between column pedestal and liner plate with epoxy filler. Weld liner to embeds for drain wells and thermocouple trees. Vacuum box test all welds and wall/column/plate interface points.
Evaluate use of stainless versus un-coated carbon steel. Grout pipe is carbon steel and drainwater pipe is stainless.
Pros and Cons:
Pros:

- Use of liner will allow deletion of the floor coating.
- Vacuum box testing of liner will allow deletion of water leak test of floor slab. Walls have already passed water leak test therefore no additional water leak test required.
- Very high confidence level for providing leak free tank.

Cons:

- Cost and schedule impacts may exceed other options.
- Requires revision to design requirements.
- Requires stake holder buy in.

Option 15 – Repair
Mortar

Construction

Product Data Sheet
Edition 11.20.2015
SikaTop® Seal 107

SikaTop® Seal 107

Flexible, waterproofing and protective slurry mortar

Description	SikaTop® Seal 107 is a two-component, polymer-modified, cementitious waterproofing and protective slurry mortar for concrete. It is slightly flexible to tolerate fine cracks and suitable in both interior and exterior applications.
Advantages	SikaTop® Seal 107 provides the following beneficial properties: ■ Improves the watertightness of water-containing concrete tanks, reservoirs, and clearwells. ■ Protects against water penetration, yet water vapor permeable (breathable). ■ Excellent freeze/thaw resistance. ■ Good adhesion to sound, prepared substrates. ■ Easy and fast mixing and application. ■ Good abrasion resistance. ■ Protects against concrete carbonation (80 mils SikaTop® Seal 107 is equivalent to 6 inches of concrete). ■ Can be mixed to slurry or trowelable consistency. ■ Improves concrete/masonry appearance. ■ Available in concrete gray and off-white. ■ SikaTop® Seal 107 is ANSI/NSF 61 potable water compliant.
Where to use	■ Horizontal surfaces subjected to light foot traffic (balconies). ■ For waterproofing of drinking water, tanks, reservoirs, and clear wells. ■ For internal and external waterproofing and damp-proofing concrete, mortar blockwork and brickwork. ■ For protection of concrete structures against the deleterious effects of deicing salts and freeze/thaw cycles. ■ For sealing "hairline" cracks in concrete structures not subject to movement surfaces. ■ For interior and exterior waterproofing of basements. ■ Vertical surfaces.
Coverage	■ For damp-proofing: apply one coat at 40 mils. ■ For waterproofing: apply two coats at 40 mils per coat. Theoretical thickness (wet film) on smooth substrates: 40 ft.^{2}/gal. = 40 mils (2 kg./m^2 = 1 mm). The above figures are theoretical and do not allow for substrate profile and wastage. Three coats may be required in areas of extremely high water infiltration.
Packaging	44 lb. unit - when mixed yields 2.65 gallons (10 l) Component 'A' - 1 gal. plastic jug; 4/carton. Component 'B' - 35.5 lb. multi-wall bag.

Typical Data ***(Material and curing conditions @ 73°F (23°C) and 50% R.H.)***

RESULTS MAY DIFFER BASED UPON STATISTICAL VARIATIONS DEPENDING UPON MIXING METHODS AND EQUIPMENT, TEMPERATURE, APPLICATION METHODS, TEST METHODS, ACTUAL SITE CONDITIONS AND CURING CONDITIONS.

Shelf Life 1 year when unopened.

Storage Protect Component 'A' from freezing and Component 'B' from moisture.
Store dry at 40°- 95°F (4°- 35°C). Condition material to 65°-75°F conditions before using.

Colors Concrete gray and off white.

Mixing Ratio Component 'A': Component 'B'. Slurry consistency 1:4.1 by weight (full unit)
Trowelable consistency 1:4.5 by weight (90% liquid to full bag)

Density (wet mix) 125 lbs./ft.^{3} (2.0 kg./l.) = 16.6 lbs./gal.

Working Time Approximately 60 minutes at 68°F; Approximately 30 minutes at 86°F

Compressive Strength (ASTM D-695) @ 28 days
Type White 3,000 psi (20.7 MPa)
Type Gray 3,400 psi (23.4 MPa)

Tensile Strength (ASTM C-307) 28 days
White 870 psi (6.0 MPa)
Gray 990 psi (6.8 MPa)

Bond Strength (ACI 503R-30 Modified): Pull-off Test 28 days 180 psi (1.25 N/mm^2)

Flexibility (ASTM D522 modified) Approximately 25%

Watertightness under hydrostatic pressure (DIN 1048 mod.)

Water Pressure		Penetrated Water		Water Absorption	
feet	(bar)	grains	(grams)	grains ft^2 • hours	(grams) (m^2 • hours)
16	(0.5)	0	(0)	0	(0)
33	(1)	15	(1)	3	(2)
99	(3)	31	(2)	10	(7)

Rendering mortars absorbing less than 91 grains/ft.^{2} • h (64 grams/m^2• h) are considered watertight.

Vapor Permeability (ASTM E-96) U.S. perms: 28 days 18 (not a vapor barrier)

Carbon Dioxide Diffusion Coefficient (μCO_2) Approximately 35,000, equivalent to 6 inches of concrete

Water Vapor Diffusion Coefficient (μH_2O) Approximately 500 ("breathable")

PRIOR TO EACH USE OF ANY SIKA PRODUCT, THE USER MUST ALWAYS READ AND FOLLOW THE WARNINGS AND INSTRUCTIONS ON THE PRODUCT'S MOST CURRENT PRODUCT DATA SHEET, PRODUCT LABEL AND SAFETY DATA SHEET WHICH ARE AVAILABLE ONLINE AT HTTP://USA.SIKA.COM/ OR BY CALLING SIKA'S TECHNICAL SERVICE DEPARTMENT AT 800.933.7452 NOTHING CONTAINED IN ANY SIKA MATERIALS RELIEVES THE USER OF THE OBLIGATION TO READ AND FOLLOW THE WARNINGS AND INSTRUCTIONS FOR EACH SIKA PRODUCT AS SET FORTH IN THE CURRENT PRODUCT DATA SHEET, PRODUCT LABEL AND SAFETY DATA SHEET PRIOR TO PRODUCT USE.

Construction

How to Use

Substrate Preparation

Concrete, mortar and masonry surfaces must be clean, free from grease, oil and loosely adhering particles. All surfaces must be as true and flat as possible. An open-textured, sandpaper-like substrate is ideal (CSP-3). All surfaces must be saturated surface dry (SSD), with no standing water at time of application. It is necessary to stop water ingress prior to the application of SikaTop® Seal 107. Use a quick setting, waterproof slurry (SikaSet®) to seal water leaks.

Mixing

The consistency of the mix can be altered by reducing the amount of Component 'A' (liquid) to be used. Under normal circumstances, when the full quantities of both components are mixed together, a slurry consistency will result. For a trowel-able consistency use only 90% of component 'A'. Mix in a clean container by slowly adding the powder component to the liquid component and mixing with slow speed drill and mixing paddle.

Application

SikaTop® Seal 107 can be applied by trowel, notched trowel, stiff bristle, or spray equipment. Work the material well into the prepared substrate, filling all pores and voids.

For brush consistency: Apply the first coat of SikaTop® Seal 107 with horizontal brush strokes and leave to harden (4 to 8 hours). Apply the second coat with vertical brush strokes.

For trowel consistency: Apply the first coat with a notched trowel and leave to harden (4 to 8 hours). Apply the second coat with a flat trowel.

For spray application: Use a hopper gun spray equipment, textured sprayer (e.g. Texspray E110c), or a rotor/stator pump equipment. Allow the first coat to harden (4 to 8 hours) prior to the application of the second coat. As soon as the mortar layer starts to set, a uniform surface texture can be obtained by rubbing the surface with a fine sponge or a plastic trowel. Do not overwork SikaTop® Seal 107 during finishing and avoid the use of additional water. [Where required, a third coat of SikaTop® Seal 107 may be applied no later than 24 hours after the second coat (in this case, do not trowel or sponge finish the second coat). If intercoat period exceeds 24 hours, light grit blasting is required prior to further application].

Balcony Waterproofing Layer: Fill in any spalled areas in the existing substrate with the appropriate Sika repair mortar as required. Apply an appropriately sized closed cell backer rod along transition (wall-slab) to prevent three-sided adhesion. Apply a continuous cant bead of Sikaflex® 11-FC or Sikaflex® 2C, to a depth of 1/8" minimum and 1/2 inch thickness. Allow sealant to cure sufficiently. Substrate must be SSD with no standing water at time of application. Apply a 1/16" thick layer of SikaTop® Seal 107 over the entire balcony. While the material is still wet apply a "360 degree pull" non-alkaline, woven fiberglass mesh to reinforce the 107 layer along static hairline cracks, wall to slab transitions and patched areas. Using trowels remove any wrinkles in the mesh by forcing down into the SikaTop® Seal 107. Ensure the mesh is completely embedded and covered with SikaTop® Seal 107. If any areas are not covered apply additional SikaTop® Seal 107 over top of mesh to cover. Trowel to a smooth uniform finish. Allow curing so that surface can take foot traffic without harming the coating.

Tooling & Finishing

Curing: As with all cement based products, curing is important. Protect newly applied product against direct sunlight, wind, rain and frost.

Limitations

- If rain is anticipated within 1-2 days after application, the surface should be protected in order to prevent streaking.
- Not an aesthetic coating.
- Minimum ambient and substrate temperatures are 45°F (7°C) and rising at the time of application.
- Maximum application thickness per coat = 80 mils (2 mm). Do not apply less than 20 ft.²/gal. = 1 m²/liter.
- As with all cement based materials, avoid contact with aluminum to prevent adverse chemical reaction and possible product failure. Insulate potential areas of contact by coating aluminum bars, rails, posts etc. with an appropriate epoxy such as Sikadur® Hi-Mod 32.
- Allow 2 days of air curing before subjecting SikaTop® Seal 107 to submersion.

PRIOR TO EACH USE OF ANY SIKA PRODUCT, THE USER MUST ALWAYS READ AND FOLLOW THE WARNINGS AND INSTRUCTIONS ON THE PRODUCT'S MOST CURRENT PRODUCT DATA SHEET, PRODUCT LABEL AND SAFETY DATA SHEET WHICH ARE AVAILABLE ONLINE AT HTTP://USA.SIKA.COM/ OR BY CALLING SIKA'S TECHNICAL SERVICE DEPARTMENT AT 800.933.7452 NOTHING CONTAINED IN ANY SIKA MATERIALS RELIEVES THE USER OF THE OBLIGATION TO READ AND FOLLOW THE WARNINGS AND INSTRUCTIONS FOR EACH SIKA PRODUCT AS SET FORTH IN THE CURRENT PRODUCT DATA SHEET, PRODUCT LABEL AND SAFETY DATA SHEET PRIOR TO PRODUCT USE.

KEEP CONTAINER TIGHTLY CLOSED. KEEP OUT OF REACH OF CHILDREN. NOT FOR INTERNAL CONSUMPTION. FOR INDUSTRIAL USE ONLY. FOR PROFESSIONAL USE ONLY.

For further information and advice regarding transportation, handling, storage and disposal of chemical products, users should refer to the actual Safety Data Sheets containing physical, ecological, toxicological and other safety related data. Read the current actual Safety Data Sheet before using the product. In case of emergency, call CHEMTREC at 1-800-424-9300, International 703-527-3887.

Prior to each use of any Sika product, the user must always read and follow the warnings and instructions on the product's most current Product Data Sheet, product label and Safety Data Sheet which are available online at http://usa.sika.com/ or by calling Sika's Technical Service Department at 800-933-7452. Nothing contained in any Sika materials relieves the user of the obligation to read and follow the warnings and instruction for each Sika product as set forth in the current Product Data Sheet, product label and Safety Data Sheet prior to product use.

SIKA warrants this product for one year from date of installation to be free from manufacturing defects and to meet the technical properties on the current Product Data Sheet if used as directed within shelf life. User determines suitability of product for intended use and assumes all risks. Buyer's sole remedy shall be limited to the purchase price or replacement of product exclusive of labor or cost of labor. NO OTHER WARRANTIES EXPRESS OR IMPLIED SHALL APPLY INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. SIKA SHALL NOT BE LIABLE UNDER ANY LEGAL THEORY FOR SPECIAL OR CONSEQUENTIAL DAMAGES. SIKA SHALL NOT BE RESPONSIBLE FOR THE USE OF THIS PRODUCT IN A MANNER TO INFRINGE ON ANY PATENT OR ANY OTHER INTELLECTUAL PROPERTY RIGHTS HELD BY OTHERS. SALE OF SIKA PRODUCTS ARE SUBJECT SIKA'S TERMS AND CONDITIONS OF SALE AVAILABLE AT HTTP://USA.SIKA.COM/ OR BY CALLING 201-933-8800.

Visit our website at usa.sika.com **1-800-933-SIKA NATIONWIDE**

Regional Information and Sales Centers. For the location of your nearest Sika sales office, contact your regional center.

Sika Corporation
201 Polito Avenue
Lyndhurst, NJ 07071
Phone: 800-933-7452
Fax: 201-933-6225

Sika Canada Inc.
601 Delmar Avenue
Pointe Claire
Quebec H9R 4A9
Phone: 514-697-2610
Fax: 514-694-2792

Sika Mexicana S.A. de C.V.
Carretera Libre Celaya Km. 8.5
Fracc. Industrial Balvanera
Corregidora, Queretaro
C.P. 76920
Phone: 52 442 2385800
Fax: 52 442 2250537

Sika and SikaTop® are registered trademarks.
Printed in Canada.

Appendix B – Final Options and Data

Option #1: Title: Epoxy Injection

Author: Matthew E Maryak

Description:

Description: Cracks as small as 0.002 inches may be repaired by epoxy injection through either surface mounted ports (Fig. 1) or cross drilling (Fig 2) the crack profile. The injection of epoxy will provide a leak-tight path where it penetrates, restore some if not all of the original structural integrity and enhance the durability of the structure. The foundation is generally 12 inches thick. The port spacing should be roughly equal to the foundation thickness. However it is recommended that for cracks less than 0.010 inches the ports should be spaced at 6 inches. With roughly10,000 lineal feet of crack at least 20,800 ports would need to be installed and sealed. Cleanliness of the crack is very important to successful injection. Surface mounted ports should have the cracks, as a minimum, flushed with compressed air. Cross drilled cracked should likewise be vacuumed and cleaned with compressed air. The installation cleanliness will be critical for the successful injection of cracks. Epoxy materials proposed to be injected should meet the requirements of ASTM C881/C881M Type I or IV Grade 1. Without sealing the back side of the crack epoxy may not flow laterally to cover the entire flow path. The injection process should be performed at low pressures for at least 10 minutes per port. The injection process alone will consume 208,000 minutes (144 days) assuming 100% successful injection at each port.

Low viscosity, insensitivity to moisture, high bond strength and compressive and tensile strengths higher than those of concrete make epoxy injection one of the most effective ways of repairing narrow cracks. Repairs are made by sealing the surface of the crack, then injecting epoxy into it through ports spaced along the crack.

Figure 1

Figure 2

Pros:

- The injection material can restore structural integrity and durability.

Cons:

- Low viscosity injection was attempted in SDU6 with little success
- Difficult to validate the travel and penetration of the epoxy.
- Fines in the concrete may inhibit epoxy flow due to tightness of cracking.
- The cracks currently are covered with epoxy and would have to be cleaned off.
- The cleaning process will potentially clog the cracks.
- The process of preparing and injecting cracks is very time consuming.
- The SDU6 may leak even after injection is completed.
- Contamination of the cracks may impact the ability to bond the concrete.

Cost

The cost of fully implementing epoxy injection for all floor cracks will be very high. Based upon the description section above it will take 144 days of injection time. Those are 24 hour days. An injection crew consists of two laborers and a supervisor. Preparation time would take approximately 6.7, 50 hour work weeks based upon the existing floor joint work. The staffing would be 4 laborers and a supervisor. Test validation of some injection would take 14 days. This is roughly 10,000 man-hours to complete the work with no rework. Material needs would be 70 gallons of Sikadur 55 SLV and 70 gallons of Sikadur 32.

Schedule

From the above discussion, the duration would be somewhere in the range of 4 months using multiple crews ,7 days a week, 12 hours per day.

Leak tightness

The epoxy injection process has been proven to be a difficult one to get quality results. If you were to achieve leak-tightness it would require significantly more effort and quality checking of the work performed. If ports refused to take epoxy, modifications to installation or technique would be required along with validation coring. This adds significant time to the schedule, to gain some reliability. There is no guarantee that the injection will be 100% reliable.

Durability

The epoxy injection is certainly one that can claim significant durability to both the drain water and thermal gradients. It not only seals the crack it structurally bonds the concrete back together and meets the structural performance needs of 25 years. However there is no guarantee that all of the crack will be penetrated. See attached data sheet for physical properties.

Stakeholder approval

Stakeholders would have to accept that the epoxy may not have penetrated the full depth and length of all cracks.

Constructability

Epoxy injection could prove to be a very difficult and time consuming task. Significant time must be spent in preparation and application of the injection to assure leak-tightness.

Contract

There would be little impact to the contract, if DNTanks was tasked to perform the work.

Construction

Product Data Sheet
Edition 9.23.2014
Sikadur® 55 SLV

Sikadur® 55 SLV

Super low-viscosity, moisture-tolerant epoxy resin, crack healer/penetrating sealer

Description	Sikadur® 55 SLV is a 2-component, 100% solids, moisture-tolerant, epoxy crack healer / penetrating sealer, having a fast tack-free time to minimize downtime. It is a super low-viscosity, high-strength adhesive formulated specifically for sealing both dry and damp, existing, non-dynamic cracks. It conforms to the current ASTM C-881, Types I and II, Grade-1, Class-C* and AASHTO M-235 specifications. * except for gel time
Where to Use	■ Sikadur® 55 SLV seals cracked concrete. ■ For interior slabs and exterior above-grade slabs. ■ For elevated horizontal decks, parking garages and other structures exposed to foot and pneumatic tire traffic.
Advantages	■ Super low viscosity/low surface tension for excellent penetration into existing cracks. ■ Seals existing cracks by gravity down to 2 mils (0.002" / 0.05 mm) in width. ■ Prolongs life of cracked concrete. ■ Penetrates and seals surface from water absorption, chloride-ion intrusion, and chemical attack (patent pending technology). ■ Improves concrete surface by reducing water and chloride intrusion. ■ Can be open to traffic in 6 hours at 73°F (23°C). ■ High bond strength, even in damp cracks. ■ **U.S. Patent No. (pending)** for ultra low viscosity healer/sealer to strengthen cracked concrete.
Coverage	1 gal. (3.8 liters) yields 231 cu. in. (3,785 cm^3) Typical coverage is 150-175 ft^2/gal. (3.7-4.3 m^2/L) for surface sealing. Coverage varies with porosity and surface profile of substrate. Higher porosity concrete will reduce coverage. For crack healing, follow Application instructions and allow to pond over cracks.
Packaging	3 gal. (11.35 l) unit = 'A' = 2 gal. (7.6 l) + 'B' = 1 gal. (3.8 l)

Typical Data *[Material and curing conditions @ 73°F (23°C) and 50% R.H.]*

RESULTS MAY DIFFER BASED UPON STATISTICAL VARIATIONS DEPENDING UPON MIXING METHODS AND EQUIPMENT, TEMPERATURE, APPLICATION METHODS, TEST METHODS, ACTUAL SITE CONDITIONS AND CURING CONDITIONS.

Shelf Life	2 years in original, unopened containers			
Storage Conditions	Store dry at 40°-95°F (4°-35°C). Condition material to 65°-75°F (18°-24°C) before using.			
Color	Clear, amber			
Mixing Ratio	Component 'A' : Component 'B' = 2:1 by volume			
Viscosity (Mixed)	Approximately 105 cps			
Pot Life	Approximately 20 minutes			
Tack-Free Time	**40°F (4°C)***	**60°F (15°C)***	**73°F (23°C)***	**90°F (32°C)***
	> 11 hrs.	11 hrs.	6 hrs.	2.5 hrs.

Tensile Properties (ASTM D-638)	**73°F (23°C)**		
7 day	Tensile Strength	7,100 psi (48.9 MPa)	
	Elongation at break	10%	
Bond Strength (ASTM C-882)			
Hardened Concrete to Hardened Concrete		**2 day (moist cure)**	2,500 psi (17.2 MPa)
		14 day (moist cure)	2,500 psi (17.2 MPa)
Hardened Concrete to Steel		**2 day (moist cure)**	1,500 psi (10.3 MPa)
		14 day (moist cure)	1,600 psi (11.0 MPa)
Flexural Properties (ASTM D-790)			
7 day	Flexural Strength	8,500 psi (58.6 MPa)	
	Tangent Modulus of Elasticity	3.2 x 10^5 psi (2,206 MPa)	
Shear Strength (ASTM D-732)	**7 day**	5,800 psi (40.0 MPa)	
Heat Deflection Temperature (ASTM D-648)	**7 day**		
[fiber stress loading = 264 psi (1.8 MPa)		110°F (43°C)	
Water Absorption (ASTM D-570)	**7 day**	(24 hour immersion)	0.60%

PRIOR TO EACH USE OF ANY SIKA PRODUCT, THE USER MUST ALWAYS READ AND FOLLOW THE WARNINGS AND INSTRUCTIONS ON THE PRODUCT'S MOST CURRENT PRODUCT DATA SHEET, PRODUCT LABEL AND SAFETY DATA SHEET WHICH ARE AVAILABLE ONLINE AT HTTP://USA.SIKA.COM/ OR BY CALLING SIKA'S TECHNICAL SERVICE DEPARTMENT AT 800.933.7452 NOTHING CONTAINED IN ANY SIKA MATERIALS RELIEVES THE USER OF THE OBLIGATION TO READ AND FOLLOW THE WARNINGS AND INSTRUCTIONS FOR EACH SIKA PRODUCT AS SET FORTH IN THE CURRENT PRODUCT DATA SHEET, PRODUCT LABEL AND SAFETY DATA SHEET PRIOR TO PRODUCT USE.

Construction

Compressive Properties (ASTM D-695)

Compressive Strength, psi (MPa)

	40°F (4°C)*	60°F (15°C)*	73°F (23°C)*	90°F (32°C)*
1 day	-	320 (2.2)	1,100 (7.6)	4,800 (33.1)
3 day	2,000 (13.8)	6,500 (44.8)	8,300 (57.2)	8,000 (55.2)
7 day	7,800 (53.8)	10,400 (71.7)	10,900 (75.1)	8,300 (57.2)
14 day	9,600 (66.2)	11,000 (75.8)	11,800 (81.4)	10,000 (68.9)
28 day	11,700 (80.7)	12,000 (82.7)	12,000 (82.7)	10,000 (68.9)

Compressive Modulus **7 day** 3.0×10^5 psi (2,068 MPa)

How to Use

Surface Preparation

Substrate must be clean, sound and free of surface moisture. Remove dust, laitance, grease, oils, curing compounds, waxes, impregnations, foreign particles, coatings and disintegrated materials by mechanical means (i.e. shot blasting, sandblasting, etc.). For best results, substrate should be dry. Surfaces prepared by Low Pressure Water Cleaning or High Pressure Water Jetting methods should be allowed to dry for 24 hrs. minimum [at 73°F (23°C)].

Mixing

Mix 1 part Component 'B' to 2 parts Component 'A' by volume into a clean pail. Mix thoroughly for 3 minutes with Sika paddle or jiffy mixer on a low-speed (400-600 rpm) drill until uniformly blended. Mix only that quantity which can be used within its pot life.

Application

To gravity feed cracks: Sikadur® 55 SLV is applied to horizontal surfaces by flat squeegee or broom. Spread material over area and allow to pond over cracks. Let material penetrate into cracks and substrate. Remove excess epoxy with roller leaving no visible surface film. For cracks greater than 1/8 in. (3 mm) wide, fill crack with oven-dried sand before applying Sikadur® 55 SLV. Seal cracks from underside, when accessible, to prevent leakage.

A second treatment may be required on very porous substrates. Apply second treatment before broadcasting After treatment, wait a minimum of 20-30 minutes at 73°F (23°C) before broadcasting sand. Cover with broadcast of an oven-dried 20/40 silica sand or similar sand. Distribute evenly over the surface to excess at a rate of 30-40 lbs./100 sq. ft.. Allow to cure 6 hours minimum at 73°F (23°C). Remove any loose sand and open to traffic once epoxy has cured. Consult Sika Technical Service at 1-800-933-SIKA for additional information.

To pressure inject cracks: Use automated injection equipment. Set appropriate injection ports. Seal ports and cracks with Sikadur® 31, Hi-Mod Gel, Sikadur® Injection Gel or Sikadur® AnchorFix 2/Sikadur® AnchorFix 500. When the epoxy adhesive has cured, inject Sikadur® 55 SLV with steady pressure. Consult Technical Service at 1-800-933- SIKA for additional information. Mock ups to ascertain penetration on job site conditions is strongly recommended. Actual penetration should be verified by core testing.

Limitations

- Do not thin. Addition of solvents will prevent proper cure.
- Material is a vapor barrier after cure.
- Do not apply if rain is imminent. Water exposure or humidity will affect surface appearance and may cause surface whitening.
- Not an aesthetic product. Color may alter due to variations in lighting and/or UV exposure.
- Sealed concrete surface may appear blotchy due to differential absorption.
- Allow sufficient time for the substrate to dry after rain or other inclement conditions.
- Application temperature of substrate must be minimum 5°F (3°C) above the dew point.
- Minimum ambient and substrate temperature 40°F (4°C). Maximum application temperature 95°F (35°C).
- Do not inject cracks greater than 1/4 in. (6 mm) Consult Technical Service at 1-800-933-SIKA.
- Minimum age of concrete is 21-28 days, depending on curing and drying conditions.
- Not designed to seal or inject cracks under hydrostatic pressure during application.
- Penetration results will vary. Factors that may impede penetration include, but are not limited to, temperature (ambient and material), geometry of crack, concrete porosity, and dirt inside cracks.
- Product is not appropriate for use in dynamic cracks.

PRIOR TO EACH USE OF ANY SIKA PRODUCT, THE USER MUST ALWAYS READ AND FOLLOW THE WARNINGS AND INSTRUCTIONS ON THE PRODUCT'S MOST CURRENT PRODUCT DATA SHEET, PRODUCT LABEL AND SAFETY DATA SHEET WHICH ARE AVAILABLE ONLINE AT HTTP://USA.SIKA.COM/ OR BY CALLING SIKA'S TECHNICAL SERVICE DEPARTMENT AT 800.933.7452 NOTHING CONTAINED IN ANY SIKA MATERIALS RELIEVES THE USER OF THE OBLIGATION TO READ AND FOLLOW THE WARNINGS AND INSTRUCTIONS FOR EACH SIKA PRODUCT AS SET FORTH IN THE CURRENT PRODUCT DATA SHEET, PRODUCT LABEL AND SAFETY DATA SHEET PRIOR TO PRODUCT USE.

KEEP CONTAINER TIGHTLY CLOSED. KEEP OUT OF REACH OF CHILDREN. NOT FOR INTERNAL CONSUMPTION. FOR INDUSTRIAL USE ONLY. FOR PROFESSIONAL USE ONLY.

For further information and advice regarding transportation, handling, storage and disposal of chemical products, users should refer to the actual Safety Data Sheets containing physical, ecological, toxicological and other safety related data. Read the current actual Safety Data Sheet before using the product. In case of emergency, call CHEMTREC at 1-800-424-9300, International 703-527-3887.

Prior to each use of any Sika product, the user must always read and follow the warnings and instructions on the product's most current Product Data Sheet, product label and Safety Data Sheet which are available online at http://usa.sika.com/ or by calling Sika's Technical Service Department at 800-933-7452. Nothing contained in any Sika materials relieves the user of the obligation to read and follow the warnings and instruction for each Sika product as set forth in the current Product Data Sheet, product label and Safety Data Sheet prior to product use.

SIKA warrants this product for one year from date of installation to be free from manufacturing defects and to meet the technical properties on the current Product Data Sheet if used as directed within shelf life. User determines suitability of product for intended use and assumes all risks. Buyer's sole remedy shall be limited to the purchase price or replacement of product exclusive of labor or cost of labor. NO OTHER WARRANTIES EXPRESS OR IMPLIED SHALL APPLY INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. SIKA SHALL NOT BE LIABLE UNDER ANY LEGAL THEORY FOR SPECIAL OR CONSEQUENTIAL DAMAGES. SIKA SHALL NOT BE RESPONSIBLE FOR THE USE OF THIS PRODUCT IN A MANNER TO INFRINGE ON ANY PATENT OR ANY OTHER INTELLECTUAL PROPERTY RIGHTS HELD BY OTHERS. SALE OF SIKA PRODUCTS ARE SUBJECT SIKA'S TERMS AND CONDITIONS OF SALE AVAILABLE AT HTTP://USA.SIKA.COM/ OR BY CALLING 201-933-8800.

Visit our website at usa.sika.com **1-800-933-SIKA NATIONWIDE**

Regional Information and Sales Centers. For the location of your nearest Sika sales office, contact your regional center.

Sika Corporation
201 Polito Avenue
Lyndhurst, NJ 07071
Phone: 800-933-7452
Fax: 201-933-6225

Sika Canada Inc.
601 Delmar Avenue
Pointe Claire
Quebec H9R 4A9
Phone: 514-697-2610
Fax: 514-694-2792

Sika Mexicana S.A. de C.V.
Carretera Libre Celaya Km. 8.5
Fracc. Industrial Balvanera
Corregidora, Queretaro
C.P. 76920
Phone: 52 442 2385800
Fax: 52 442 2250537

Sika and Sikadur are registered trademarks.
Printed in Canada.

Option #: 2 Rev 1 Title: Routing and Sealing

Author: Sergio Mazul

Description:
Enlarge surface crack along its exposed face and fill with suitable joint sealant. This repair will require sandblasting of the floor to further expose all cracks, V groove all cracks and then apply a very flexible sealant in the V-grooves. The sealant has to be flexible enough to withstand potential movement and rigid enough to bond with the concrete.
Sealants applicable for this option are:
Sikadur 51 NS. This is a 2-component, non-sagging, solvent free, flexible epoxy control joint sealer and adhesive. Used fill vertical and overhead non-moving saw cut construction control joints and cracks.
Sika Loadflex 524 EZ. This is a 2-component quick setting, semi-rigid solvent free, control joint filler. It is also used for repairing interior concrete slabs that have experienced random cracking due to shrinkage.
Pros and Cons:

PROS	CONS
Sandblasting of the floor may help determine crack pattern and flow path(s) locations.	*Labor Intensive (Sandblasting, V-grooving and filling ~ 8000 ft of cracks).*
V-Grooving will provide enough area to enable proper sealant coverage.	*Seals Visible Cracks Only.*
	High Viscosity materials. Ok for surface filling but not for pressure injection.

Cost *Both the Sikadur 51 NS and the Sika Loadflex 524 EZ are readily available. Dimensions for the V-groove for the 8K to 10K linear ft of cracking is 3/8" Wide by 1/2" Deep. Sealant application is via low pressure extrusion equipment. No modifications required to enable material access into the tank. PPE and ventilation will be necessary.*

Schedule *Sealant application to the 8,000 to 10,000 linear ft of cracking will require sandblasting of the floor to further expose all cracks, V groove all cracks and then the application of a sealant. Based upon a 1 month duration for the pressure injection of 1,500 linear ft of joints, this repair may take 5 to 6 months. Recommended curing time is 60 to 90 days.*

Effectiveness	*Sandblasting and V-grooving the cracks will expose all the cracks. Based upon preliminary information from the petrography examination, it appears that the gravity fed epoxy in-filled the cracks. That result indicates that V-grooving and sealing the cracks may prove to be effective in sealing the cracks and thus enable a successful leak test.*
Durability	*Because these sealants are flexible enough to withstand potential movement and rigid enough to bond with concrete, they are used to seal cracks where heavy traffic is expected. Based upon these characteristics, sealed cracks should be able to maintain leak tightness during the planned 6 years of SDU grout filling.*
Stakeholder Approval	*The project will not be able to claim a 100% crack repair. The extent of this repair is limited to surface cracks and should there be cracks below the surface, these will not be covered by this repair as the application is essentially a gravity fed application. Therefore, given a successful leak test, the Stakeholders acceptance of an unquantified repair will be necessary.*
Constructability	*The quality of this repair will be a function of the skill of the craft. Sandblasting of the floor, visual identification of all the cracks and sealant placement will be labor and QC intensive.*
Contract	*The contract CSI specification requires the subcontractor to build a tank with a zero leakage. This repair should not require any revision to the contractual agreements.*

Option #: 3 Title: Surface Sealing by Gravity Filling

Author: Craig Carlilse

Description:
Low viscosity urethanes, high-molecular-weight methacrylates (HMWA) and some epoxies can gravity fill cracks with widths from 0.001 to 0.080 inches. Lower viscosity materials are used to fill narrow cracks. This method is ideal for areas with multiple surface cracks that are dormant such as plastic shrinkage cracks. The area and cracks are cleaned with air or water blasting (and allowed to dry) before flooding the area with the monomer or resin. If cracks are full of dirt, moisture or other contaminants, penetration of the repair material into cracks is poor. The material is worked into the cracks with brooms, rollers or squeegees then the excessive material is removed to avoid shiny, slick areas.
Cores taken at cracks can be used to evaluate the effectiveness of the crack filling. The depth of penetration of the sealant can be measured. Shear (or tension) tests can be performed with the load applied in a direction parallel to the repaired cracks (as long as reinforcing steel is not present in the core in or near the failure area). For some polymers the failure crack will occur outside the repaired crack.
Pros and Cons:
Pros

- Installation requires limited prep work and is not intrusive

Cons:

- Did not penetrate deep into crack on first applications,
- Seal could be damaged when floor is sandblasted prior to coating application,
- All cracks are not visible and thus this method does not guarantee a leak tight tank,
- Trial test box on roof indicates the effectiveness of gravity filling for leak tightness is indeterminate.

Potential Products:
Low viscosity, gravity fill epoxy such as Sikadur 52 LVMY or Sikadur 35 Hi-Mod LV
Cost:
Since the majority of the cracks were previously repaired with this technique and the tank is not leak tight, assume that all existing cap seals will be removed via V-grooving. Costs include v-groove & surface prep/cleaning, material & labor.
Productivity and Rate assumptions are outlined below:

- V-Groove using 10 machines @ $750 per week @ 100LF /day
- Materials Epoxy, assume Sikadur 55 @ 17 cf (127 gal) @ $327/gallon
- Applicators Assume 10 Operators @ 25 LF per hour each

Schedule:
Mobilization + v-groove @ 100LF/hour @10,000LF & surface prep + 3 weeks repair + 3 days cure for a total duration 6-7 weeks.

Effectiveness:
Assuming existing cap seals are removed, the technique is effective for cracks from 0.001 to 0.080 inches and USCOE petrography analysis indicates the penetration of the epoxy into the cracks. Surface prep, identification of all cracks, and workmanship / QC will contribute to the effectiveness.
Durability:
Surface sealing is a current approved repair technique and should meet the durability requirements.
Stakeholder approval:
Since this is an approved repair technique, stakeholder approval should not be an issue.
Constructability:
This is a proven technology with simple installation methods used in industry.
Contract:
Technique is within capability and scope of awarded subcontracts. Could experience cost claims if Interior Coating subcontractor is mobilized and demobilized and is required to sandblast floor again prior to installing coating system.

Option #: 4 Title: Crystalline Waterproofing

Author: Keilers
Description:
Crystalline waterproofing involves using commercial proprietary products that essentially diffuse with water through concrete, react with water and cement hydration products (e.g., free lime), and precipitate nonsoluble crystals capable of plugging pores and bridging small cracks. The chemical process is similar to autogenous (self) healing.

The Xypex product is similar to several that are on the market. The Xypex specification[1,2] indicates their product is nontoxic; effectively seals hairline cracks up to 0.4 mm (10 mils); and highly resistant to pH 3 - 11 for constant exposure. The crystalline structure has pores that allow passage of vapors but not water. It is composed of portland cement, very fine silica sand, and various "active proprietary chemicals" that catalyze the precipitation. Vendor specifications claim high chemical resistance (i.e., Xypex: pH 3 – 11 constant contact / pH 2-12 periodic contact).

Variants of the products can be applied by brush, spray equipment, dry shake material on new surfaces, or as an admixture. Surfaces need to be clean, free of dirt and oil, and have an open-pure structure that permits capillary action and waterborne diffusion. If the surface is too smooth, it should be acid-etched, or lightly sandblasted or water blasted. Larger cracks should be routed out and repaired per Xypex repair procedures. The surface needs to be thoroughly wetted prior to application. Coverage is about 1.5 lb to 2 lb per yd^2 (i.e., about 12 tons for SDU-6). Water-fog misting is needed during curing, typically three times per day for 2 - 3 days. Allow 12 days before filling with liquid.

The Kryton product specification[3] discusses effectiveness at self-sealing hairline cracks up to 0.5 mm (0.02 in). The Tremco product specification discusses 2 inch penetration.[4]

There is trade journal information on applications, such as a repair to the Georgia Raccoon Creek water treatment facility, which used about 150 tons of a Xypex product at a cost of about $1.5M.

Pros and Cons:

- Pros:
  - Multiple vendors; ease of application; non-toxic – used for potable water tanks.
  - Some demonstrated experience at sealing hairline cracks of up to 5 – 10 mil width.
- Cons:
  - Requires careful surface preparation and repair of larger cracks. This could require sand or water blasting the surface, excavating prior epoxy repairs, and route and seal larger cracks.
  - Requires careful maintenance of the wet-cure conditions.
  - Besides water, requires the presence of the hydration reaction products.
  - Proprietary products; no consensus installation standards.
  - Similar to the concrete, chemical compatibility with the waste may be an issue.

- May be ineffective alone for this application, depending on actual crack size distribution.
- Requires addressing larger cracks before application. Once applied, visually obscures cracks, limiting effectiveness of any follow-on techniques.

Cost

- Crystalline waterproofing would need to be used with:
  - a technique that addresses larger crack sizes, such as route and seal
  - a technique that addresses the high pH waste form, such as coating.
- Requires careful surface preparation such as sand or water-blasting.
- Requires careful attention to ensure moist cure.
- However, it can be applied by a brush or spray equipment to address multiple cracks over a large area. This is less labor intensive than some of the other techniques.
- Ball-park costs, estimated $10,000 for research on compatibility with coating and waste form; $0.5 /ft^2 material cost for 100,000 sq ft; $250,000 for surface preparation; $50,000 for application; $360,000 total.

Schedule

Judgment is that installation would require several months. Ball-park estimate: 6 weeks for preparation and 6 weeks for application (ie., 90 days).

Effectiveness

Effectiveness depends on: the presence of moisture and hydration reaction products; careful surface preparation, and curing; controls to ensure protection from highly caustic waste form. If these are present, then crystalline waterproofing could be effective for smaller crack sizes, but would require some other technique to address larger crack sizes.

Durability

Crystalline waterproofing will require a coating for protection from high pH waste. As intended, it is highly durable, since it precipitates to a crystalline form that bridges cracks and is integral to the concrete matrix. This requires careful installation and free lime within the concrete matrix.

Stakeholder Approval

Crystalline waterproofing is not a coating and has the potential to improve leak tightness.

Constructability

Installation requires careful surface preparation and maintaining a moist cure for several days. However, brush or spray application is less labor intensive than some of the other techniques.

Contract

Judgment is that this is not a discriminator for this technique.

References

7. Xypex datasheet for Cementitious Crystalline Waterproofing 07160
http://www.xypex.com/technical/spec-data

8. Xypex Training Material, May 2015.
http://continuingeducation.bnpmedia.com/article.php?upgrade=new&L=49&C=850
9. Kryton Krystol Specification
http://www.kryton.com/products/krystol-t1-t2/attachment/technical-data-sheet-krystol-t1-t2/
10. Tremco Permaquik Crystalline Waterproofing, Capillary Waterproofing formulation.
http://www.tremcosealants.com/products/permaquik-crystalline-waterproofing.aspx
11. Waterproof Magazine
http://www.waterproofmag.com/back_issues/201301/Watertanks.php
12. Waterworld
http://www.waterworld.com/articles/wwi/print/volume-19/issue-5/regulars/keep-water-in-and-out-ofconcrete-water-tanks.html

Option #: 5 Title: Chemical Grouting

Author: Keilers
Description:
ACI 224.1R-07 states: "Chemical grouts, such as urethanes and acrylomides, are activated by catalysts or water to form a gel, a solid precipitate, or foam that will fill void space within concrete. The materials are primarily used for sealing cracks from water penetration. Bond strengths are typically low, so structural repairs are not made with chemical grouts. Cracks in concrete as narrow as 0.002 in. (0.05 mm) have been filled with chemical grout."
Polyurethane chemical grouting, activated by water, has been used since the 1950's to repair sewers, tanks, vaults, etc., primarily to prevent groundwater infiltration.[2] It is usually injected under pressure near the leak site and chemically reacts upon contact with water to create a foam, gel, or solid. Formulations can be hydrophylic (water-wetted) or hydrophobic (water-repelled). The latter is mixed with a non-water catalyst. Reaction time is in the tens of seconds, and volume expansion can be large, making these techniques suitable for gushing types of leaks.
The U.S. Bureau of Reclamation report discusses testing of pressure-injected polyisocyanate that reacts with water, releasing carbon dioxide, and forming foams, gels, or solids. For water-activated formulations, room-temperature viscosities ranged from 1 - 500 cps, with the foam and gel applications at the lower end. Two-component formulations typically form solids, have viscosities of 50 to 500 cps, tend to be hard, and have less effectiveness with water. They report cracks are sealed down to about 1 mm (30 mils) by injection.
Some of the challenges are the wide variety of materials and the lack of consensus standards. Application can be low pressure (e.g., a caulking gun) or high pressure (e.g., modified paint sprayer or rocker pump). In some cases, plastic tapered fittings can be hammered into an injection port. Ports are often drilled above or below the crack and angled to intercept the crack. Jute caulking is hammered into a crack if grout appears too quickly.
Pros and Cons:

- Pros:
  - Reported effective for larger cracks (30 mils or greater).
  - May be effective if injected through the base slab or around the perimeter (e.g., fill the gap between the base slab and the mud mat with SikaFixHH or similar).
  - May be possible to groom repair during leak tightness testing by injecting around perimeter.
- Cons:
  - In general, difficult or impractical to use for smaller cracks.
  - May be ineffective alone for this application, depending on actual crack size distribution.
  - No consensus standards.
  - Uses pressure injection, which may be more labor intensive than other techniques.
  - Quick setup time (tens of seconds), which may be undesirable for SDU-6 application.

- May shrink with time, reducing longer term effectiveness

Cost

- Option 5.1 – Chemical grouting of individual cracks would be labor intensive and costly. It is only as effective as the ability to find and inject the cracks that are the source of leakage. Since it would not seal smaller cracks, it may have to be used with another technique. Compatibility with the waste is not clear; there is a reliance on coating.

- Option 5.2 - Chemical grouting through the slab and around the periphery from tank outside would require less effort and cost, but would be difficult to ensure adequate coverage for effectiveness. Scope estimated based on requiring 3,000 gal ($60/gal) and 2,000 injection points (no more than 10 ft spacing internally, with additional peripheral injection sites).

- Ball-park costs, focused on Option 5.2 – estimated $50,000 for design; $200,000 for material cost; $100,000 for application (based on comparison to estimate for epoxy-injection option); $350,000 total.

Schedule

Judgment is that installation would require a few months to many months, respectively. Ball park estimate: 12 weeks.

Effectiveness

Effectiveness would depend on coverage and depth of penetration. One metric of coverage would be to monitor the amount injected. However, there are few visual indicators of effectiveness until the leak test is performed. It may be possible to repair concurrent with the leak tightness testing (i.e., inject around the periphery where leakage is visible); however, this may just push the leak site to another area; therefore, interior injection would improve performance.

Durability

Long-term compatibility with the waste form would need to be determined. The material may also shrink with time.

Stakeholder Approval

Use of chemical grout would need to be negotiated with the customer. Judgment is that agreement would not be difficult.

Constructability

The technique has been used in industry. While labor intensive, it is proven technology.

Contract

This is not a discriminator for this technique.

References

4. ACI 224.1R-07, *Causes, Evaluation, and Repair of Cracks in Concrete Structures*
5. Concrete Monthly, March 2008 http://primeresins.com/wp-content/uploads/2013/07/Concrete-Monthly-TechTalk-Polyurethane-Chemical-Grouting.pdf
6. U.S. Bureau of Reclamation, Leaking Crack Repair Using Chemical Grouts, Sep 2005 https://www.usbr.gov/research/projects/download_product.cfm?id=317
7. http://www.pwmag.com/inflow-and-infiltration/get-to-know-your-grout.aspx

Option #6: Title: Polyurethane/Acrylate Resin Injection

Author: T. Eric Skidmore
Description:
Per ACI 224.1 R-07 and U.S. Bureau of Reclamation Guide to Concrete Repair, the use of polymer resins for crack injection (other than epoxy) is an approved or recommended method for sealing cracks. However, as with epoxy injection, the success of this option strongly depends on the resin/product selected and salient properties. In particular, viscosity is important. Polymer impregnation has not been successfully used to repair fine cracks, but has mainly been used to provide a more durable, impermeable surface such as for vehicular traffic. Cracks to be injected with polyurethane resin should not be less than 0.005 inch in width, though smaller cracks can be injected with methacrylic acrylates.
A possible concern with either polyurethane and acrylate resins is resistance to chemical degradation, particularly to the high pH Saltstone bleedwater and elevated temperature expected. Urethanes are likely more resistant than acrylates. Once filled, if the cracks are then overcoated with the EC-66 flexible epoxy or other coating/lining materials, the concern over chemical/thermal resistance is mitigated.
Typical products used for this approach would be Sika Injection 29, Sika Injection 304 and Sika Injection 305 low-viscosity acrylate gels/resins or Sika Injection 201/203 polyurethane resins. An advantage of the Injection 201/203 resins and the Injection 29 resin is that they are single-component products, so pumping time and pot life is longer than for most plural-component systems. Manufacturer recommendations needed for specific resins. No obvious advantage over epoxy resins, particularly for structural repair. Product descriptions are provided here for information. Specific recommendations needed from Sika or similar manufacturers if deemed viable.
Sika® Injection-304
Flexible, very low viscous and very quick gelling polyacrylic injection gel for permanent watertight sealing of leaking surfaces. The material reacts to form a waterproof, flexible but solid gel with good adhesion to both dry and wet substrates.
Sika® Injection-305
Flexible, very low viscous and quick gelling polyacrylic injection gel for permanent watertight sealing of damaged membranes (single and double layer systems). The material reacts to form a waterproof, flexible but solid gel with good adhesion to both dry and wet substrates.

Sika® Injection-29
Low viscous, flexible and solvent-free polyacrylic injection resin with a high solids content. It is used for the injection of the Sika® Injectoflex Hose System.
Sika Injection 201 CE/RC
Low viscous, flexible and solvent-free polyurethane injection resin for permanent waterproof sealing of cracks and construction joints. It forms, in contact with water, a

uniform, closed and therefore watertight pore structure. The reaction time of Sika® Injection-201 RC/CE can be accelerated with Sika® Injection-AC20.

Sika® Injection-203

A low viscosity, elastic and solvent-free polyurethane injection resin, which cures in both dry and wet conditions to form an elastic, watertight filling and sealing material.

Cons:

- Urethane/acrylate resin injection is not considered a structural repair, but for sealing/leak-tightness only (may not be a concern)
- Low viscosity epoxy injection was attempted in SDU6 with little success (need to compare product viscosity)
- Difficult to validate the travel and penetration of the resin(s).
- Fines in the concrete may inhibit resin flow due to tightness of cracking.
- The cracks currently are covered with epoxy that would have to be cleaned/removed.
- The cleaning process will potentially clog the cracks.
- The process of preparing and injecting cracks is very time consuming.
- The SDU6 may leak even after injection is completed.
- Contamination of the cracks may impact the ability to bond the concrete.

Cost

Similar to epoxy injection, option #1

Schedule

Similar to epoxy injection, option #1

Leak tightness

Similar to epoxy injection, option #1. The resin injection process has been proven to be a difficult one to get quality results. Achieving leak-tightness soley by this method will require significantly more effort and quality checking of the work performed. If ports refused to take resin, modifications to installation or technique would be required along with validation coring. This adds additional time to the schedule to gain some reliability. There is no guarantee that resin injection alone will achieve 100% leak-tightness.

Durability

The polyurethane/acrylate resins injection used for sealing cracks are considered generally durable. However, in comparison to epoxy injection, these resins cannot be claimed for any structural integrity (sealing only). Durability (chemical resistance in particular) will depend on the resin selected. Covering the resin/repairs with coating or lining would likely be needed (planned anyway) to protect the repairs. There is no guarantee that all of the cracks or the full depth of any particular crack will be penetrated.

Stakeholder approval

Stakeholders would have to accept that resin injection may not penetrated the full depth and length of all cracks.

Constructability

Resin injection could prove to be a very difficult and time consuming task. Significant time must be spent in preparation and application and verification of the injection to assure leak-tightness.

Contract

There would be little impact to the contract, if DNTanks was tasked to perform the work.

Coating Option 7A – Envirolastic AR425 Polyurea System (SW) as specified in C-SPP-Z-00013, Revision 3:

- Surfacer: Kem Cati-Coat or equivalent, as needed
- Base Coat: Corobond HS High Solids Primer
- Putty: Steel Seam FT910, as needed
- Top Coat: Envirolastic AR425 Polyurea (1-2 coats)
- Option: Embed geotextile fabric (floors only)

Pros

- Faster cure of polyurea systems (seconds/minutes vs. days, immersion cure)
- Less sensitive to environmental conditions during application (still must follow vendor instructions)
- Commonly used for secondary containment linings, wastewater, chemical containment
- Generally superior mechanical properties/abrasion resistance compared to flexible epoxy
- Possibly superior chemical/heat resistance than flexible epoxy (testing in progress)

Cons

- Not initially recommended by vendor or SRNL for SDU2 due to concerns/unknowns over long-term durability (mainly at peak temp of 68C). Lower temps reduce risk.
- Long-term durability in service environment not fully demonstrated (testing in progress).
- Requires applicator experienced with polyurea systems (vendor recommendations).
- Relying on coatings/linings for leak-tightness requires TRAC change

Cost Basis for EC-66 vs. polyurea decision and documented? (cost, schedule, technical, etc.). Polyurea quoted at $41.25/gal. EC-66 flexible epoxy assumed at $150.00/gal in SRR estimate. Variation in coverage per gallon, depends on thickness applied.

Schedule No significant impact compared to flexible epoxy, material procurement/delivery

Effectiveness Likely to be effective in meeting leak tightness requirement, assuming proper installation and inspection. Minor damage/leakage possible at joints/interfaces due to movement (same with all coating options).

Durability Very likely sufficient for duration of grout operations (6 yrs). Potentially more durable than flexible epoxy, testing in progress (recommend evaluating results prior to deployment)

Stakeholder Approval Relying on coatings/linings for leak-tightness requires TRAC change

Constructability No issues, time required for application, curing, inspection

Contract Different coating than already selected/purchased. Possibly new subcontractor/applicator required.

Coating Option 7B – Blome/Hempel EC-66 Flexible Epoxy
System proposed per C-SPP-Z-00013, Revision 3:

- Surfacer: Blome CP-83MP Epoxy Adhesive/Mortar as needed
- Primer: Blome Primer 75
- EC-66 High Performance Flexible Epoxy Coating (2 coats, 20-30 mils/coat)
- EC-60 Blome EC-60 Engineering Fabric – optional (EC-125 also)

Pros

- Used in previous SDUs (overcoat for TL-45S and sole coating)
- Previous/current test data in bleedwater simulants, no significant degradation (500 hrs)
- Common coating type used for secondary containment linings, wastewater
- Currently specified for concrete protection, material already purchased, current contractor experienced
- EC-60 fabric/mat recommended for additional integrity (floors) – consult vendor

Cons

- Not initially recommended by Blome or SRNL for SDU2 due to concerns/unknowns over long-term durability (mainly at peak temp of 68C). Lower temps reduce risk.
- Long-term durability in service environment not fully demonstrated (testing in progress).
- Lower mechanical properties/abrasion resistance than polyurea systems
- Sensitive to environmental conditions during application (similar to other coatings, not unique)
- Relying on coatings/linings for leak-tightness requires TRAC change

Cost (Floor Only):	2 coats (40 mil/coat), no fabric = $1.6M W/fabric = $2.02M (adds $431K)
Schedule:	With fabric, labor hrs/$ essentially double (33, 303 hrs vs. 16, 217 hrs)
Effectiveness	Likely to be effective in meeting leak tightness requirement, assuming proper installation and inspection. Minor damage/leakage possible at joints/interfaces due to movement (true for any coating option)
Durability	Likely sufficient for duration of grout operations (6 yrs).
Stakeholder Approval	Relying on coatings/linings for leak-tightness requires TRAC change
Constructability	Already planned, time required for application, curing, inspection
Contract	No issues with current contract, increases labor hrs/$

Option 8 - Membrane/Sheet Linings (floor only, many options) – Marseal M-4000 (Elvaloy) or M-8000 (EPDM)

Pros

- Improved crack-bridging ability (essentially independent of substrate behavior)
- Commonly used for secondary containment linings, wastewater, chemical containment
- Reduce if not eliminate surface preparation (abrasive blasting), surfaces to be clean/dry
- No dependency on installation environmental conditions, cure time, etc.
- Likely more resistant than flexible epoxy or polyurea coatings, particularly at peak chemistry/temperature conditions. Marseal M-4000 max temp is 65C, M-8000 is 150C.

Cons

- Long-term durability in service environment not fully demonstrated (but likely more resistant than flexible epoxy or polyurea, particularly at peak temperatures)
- Likely requires certified/trained installation crew (or possibly vendor oversight of site or contractor personnel)
- Seam/joint inspections (vacuum box) – less area than holiday testing in coatings.
- More often used for secondary containment than primary containment
- Relying on coatings/linings for leak-tightness requires TRAC change

Cost M-4000 = $257, 075 (700 rolls, 38" x 50', plus 125 5-gallon kits of primer at $6452.50)

M-8000 = 3X M-4000 (700 rolls, $602, 805 plus 125 5-gallon kits of primer at $6452.50)

Tooling: $623.68 (hot air welder, rollers) – may need more kits for productivity.

Schedule Slightly impacted by material availability (700 rolls not in stock, few weeks delay). Installation relatively straightforward

Effectiveness Very likely to be effective in meeting leak tightness requirement, assuming proper installation and inspection. Interfaces around pedestal bases most sensitive to leakage. Seams to be inspected.

Durability Very likely sufficient for duration of grout operations (6 yrs) and likely 25 years

Stakeholder Approval Relying on coatings/linings for leak-tightness requires TRAC change

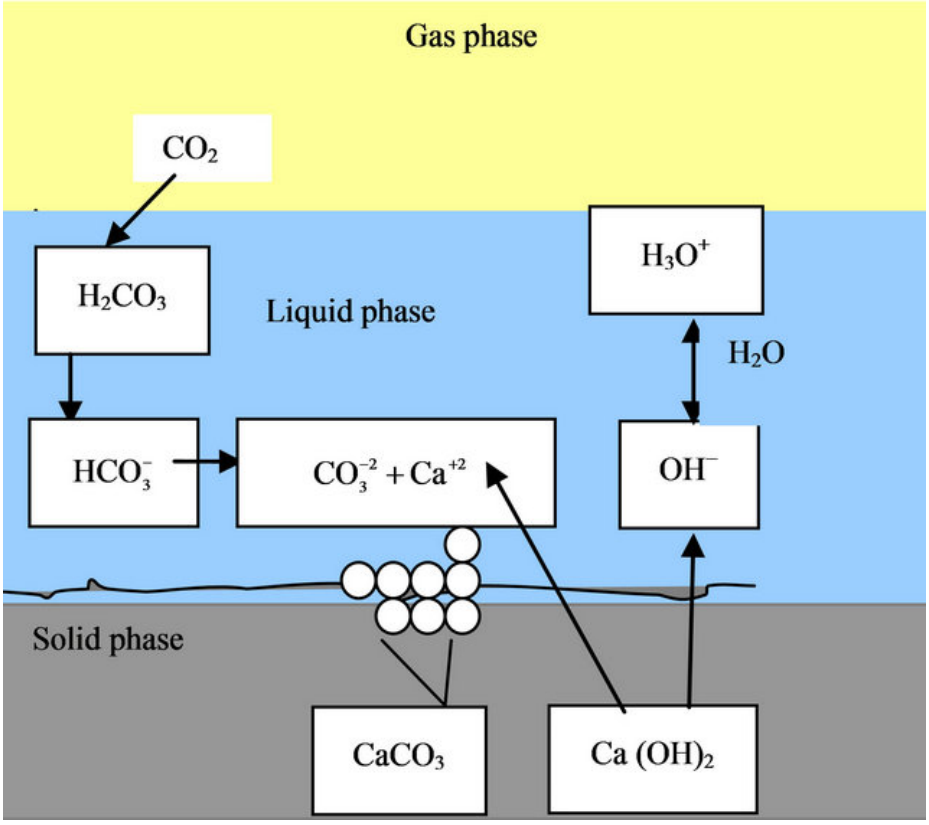
Constructability Sheet linings in 38" x 50' rolls. Work around pedestal bases, interface with wall/base joint. 700 rolls of material + primer.

Contract Not currently specified, design change, possibly new installation contractor or on-site training and oversight by vendor (daily rate = $530.00 day)

Option #: 9 Title: AUTOGENOUS CRACK HEALING
Author: S. SIMNER
Description:
Autogenous (self-produced) crack healing in concrete occurs in the presence of water via two primary mechanisms.
1. Concrete containing unreacted cementitious materials – infiltrating water may result in the hydration of unreacted cement and the formation of calcium silicate hydrate (CSH)) on opposing crack surfaces. Concrete may also contain unreacted, supplementary cementitious materials (SCMs), such as blast furnace slag (BFS) and fly ash; these materials exhibit limited hydration in the presence of water (pH 7) but will react (especially BFS) in the presence of alkali hydroxide solutions to form CSH-like materials. When utilized in concrete the reactivity of SCMs is initiated by the cement hydration product calcium hydroxide ($Ca(OH)_2$).
SDU concrete has the following solids composition:

Ingredient	Material Quantity (lbs/yd^3)
Type V cement (Lehigh T-V #2 ; ASTM C 150)	213
Grade 100 Blast furnace slag (Holcim Grade 100 Slag; ASTM C 989)	284
Silica Fume (W. R. Grace Silica Fume; ASTM C 1240)	47.3
Type F Fly ash (SEFA Group, Class "F" Fly Ash; ASTM C 618)	165.7
Sand (Natural Washed Sand; ASTM C 33)	911
Aggregate (#67 Granite; ASTM C 33)	1850

While unreacted cement may have been depleted at crack surfaces (as a result of previous leak testing) unreacted BFS may still exist and infiltrating the cracks with a caustic solution (e.g., 0.01 – 0.1M [OH-]; pH 12-13) may initiate the hydration of BFS and to a lesser degree the fly ash and silica fume also.
2. $Ca(OH)_2$ (aq) that has leached from the concrete pores to the crack surface may convert to calcium carbonate ($CaCO_3$) (s) in the presence of water with dissolved carbon dioxide (CO_2) – carbonation.



Pros

- Relatively simple and economical approach – flood floor with caustic solution and let it flow through cracks.
- If the predominant mechanism is via alkali-activation of BFS crack healing could be fairly rapid (days to a few weeks).
- Approach could be initiated and given a set time frame for success after which an alternate method (e.g., coating) could be deployed. Note success = visual determination of leak cessation on SDU exterior.
- Approach could be first evaluated on individual cracks on SDU roof.

Cons

- Reliant on the presence of unreacted BFS at the surfaces of cracks.
- Crack widths that can be healed may be limited to 1 mm or less; mechanism may not seal all cracks.
- Approach may be time prohibitive – while hydration reactions would be expected to occur in a matter of days/weeks, carbonation phenomenon will probably take much longer.
- Not sure of SRS environmental limitations with respect to allowing caustic solution to flow from SDU into environment (may be some way to absorb liquid at leak sites).

- Reaction is enhanced with higher [OH-] concentrations and pH 12-14; high pH may be prohibited from standpoints of handling safety, environmental impact, and neutralization/disposition of solution from SDU. To achieve pH 12 will require a minimum $Ca(OH)_2$ concentration of 0.005 M (higher concentration may be required to initially neutralize acidity of well water).
- Potential for caustic solution to react with agglomerated silica fume at SDU surface; however, agglomeration of silica fume unlikely based on adequate presumed dispersion by mixing with aggregate.
- May require the use of high purity $Ca(OH)_2$ if potential impurities considered deleterious to concrete.

COST

- Cost associated with filling tank with approximately 2 million gallons of caustic water – pumping water from well to SDU; addition of $Ca(OH)_2$; periodic leak inspection; limit spread of caustic to environment; neutralize/drain water.
- Example material requirements;

  0.01 M [OH-] (~pH 12) = 0.005M $Ca(OH)_2$ = 0.371 g per L; therefore, 2 million gallons (7.6 million liters) = 2,820 kg $Ca(OH)_2$.

  5 kg (95% purity) = $160; (estimate $100K for 0.005 M $Ca(OH)_2$)); bulk purchase expected to be less.

SCHEDULE

- Allow approximately 1 month for autogenous healing to indicate impact to leak rate; in parallel prepare to employ other option (most obvious would be to coat with EC-66).

LEAK TIGHTNESS

- Dependent on width of remaining cracks, the presence of unreacted BFS at the crack surfaces, and the pH utilized.

DURABILITY

- Results in the formation of BFS reaction product already present in bulk material; predominantly calcium (aluminum) silicate hydrate gel.

REGULATORY

- No regulatory impacts; the caustic water would be neutralized and removed, and the polymeric coating subsequently applied as initially proposed

CONSTRUCTABILITY

- Primary concern is handling of large quantity of $Ca(OH)_2$ and how it is incorporated into the water being fed into the SDU.

IMPACT TO CONTRACT

- No impact to contract; he caustic water would be neutralized and removed, and the polymeric coating subsequently applied as initially proposed.

Option #: 12 Title: Install Concrete Overlay

Author: Adeola Adediran

Description:

A Concrete Overlay is essentially a new slab over an old one. It is designed as a topping over the existing slab, meaning that the existing slab is still the structural slab and the main lateral force resisting diaphragm. The new slab is then an added weight on the existing slab and the slab needs to be designed to resist this new weight as well as the mass of this new slab needs to be added to the existing slab in the seismic response of the slab.

Overlays may be designed using regular concrete from an approved hydraulic cement concrete design mix or may include polymers, epoxies and/or polyesters. Asphaltic concrete overlays are deemed not included in this option since they have been previous ruled out in the SEE process and also because they are very porous and will only work in concert with a liner. Depending on the thickness of the Overlay, the overlay would need to be reinforced with one layer at mid height or two layers at opposite faces of the overlay. The overlay could be reinforced with regular reinforcement or by welded wire fabric. Furthermore the mix used in the overlay could contain concrete fibers and other additives to prevent plastic shrinkage that could crack the overlay.

Constraints of Solution:

Concrete Overlays will also not prevent propagation of cracks from an active crack. So in some cases the cracking in the old slab need to be fixed and a crack bond breaker used across to prevent propagation of cracks.

Polymer concrete overlays have been very effective at preventing the penetration of moisture through the overlay but if moisture can get behind the overlay to between the new and old concrete slab then the path for moisture thru the old cracks in the old slab may still be accessible.

Pros:

Polymer –Portland cement concrete overlays have exhibited excellent long term performance. They are highly resistant to corrosive environment (Chlorides) and do well under high temperature. They have been used most frequently over bridges in repairs of bridge decks.

Concrete Overlays can be made with low-slumps such that they are sloped and can maintain the current drainage profile of either the floor slab and or the roof. The low slumps also make they more durable and more resistant to sulfate attacks.

The polymer concrete typically bonds well to the prepared substrate becoming very wear resistant

Polymer-concrete overlays can be installed without expensive equipment.

Cons:

Polymer-concrete overlays have to be installed over a dry surface though bonded Portland cement concrete overlay is more tolerant of moisture on the interface to the substrate and a damp surface is preferable for that installation.

The surface prep for overlays include abrasive blasting of the surface of the substrate which will undo some of the substrate repair that have previous been done.

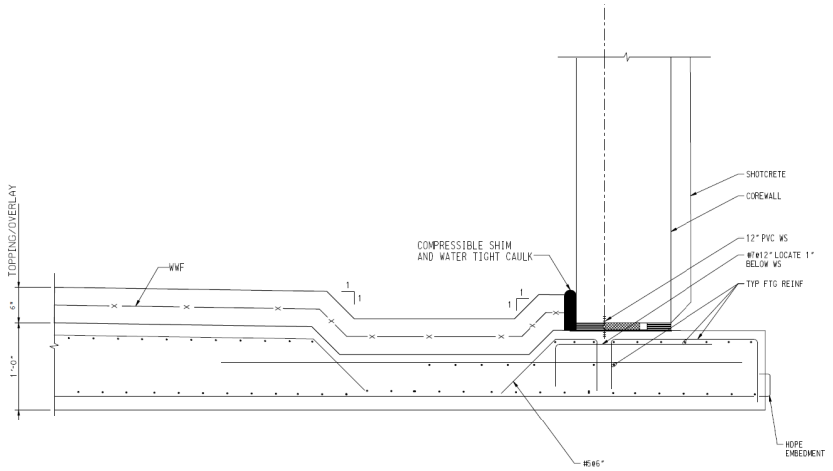
The overlay may interrupt or interfere with the ability for the tank walls to move with the expected thermal growth.

The reference for this write up has been ACI 548.5R Guide for Polymer Concrete Overlays and ACI 546R-14 Guide to Concrete Repair.

Takes up volume in the tank and add mass to the diaphragm.

Details will be required at the interface with wall and columns and any penetration.

There is still a risk that the engineered PCC overlay could still crack either by itself due to its own shrinkage or may be reflective of a moving crack in the existing slab. The one mitigation strategy for the reflective crack is to provide an isolation layer which would prevent the cracks currently in the existing slab from being reflected in the overlay. But the overlay could be bonded at the interface with columns and walls to prevent a path for water to migrate behind the overlay.



PROPOSED OVERLAY
SCALE: NONE

Description of the Concrete Overlay to be engineered.

6" of polymer concrete reinforced with welded wire fabric using MasterEmaco S 466CI or a pre-engineered Portland concrete cement overlay. Note that using the MasterEmaco does not currently meet the shrinkage requirement in the specification of 0.04% but an approved equal meeting this shrinkage requirement may be used.

To prevent reflective cracks we need to use an isolator layer which is to be designed later.

Since the surface area to place is 110500 sq. ft. assume 5 placements with at 10 FTE working the placement.

Wet curing is recommended and the product is cured till strength reaches 2500 psi in 7 days.

Cost:

Cost Breakdown	Unit rate ($/ft^2)	Quantity (ft^2)	Total ($)
Engineered PCC	13.06	110500	1443130
Labor	4.5	110500	497250
Misc materials and supplies	0.11	110500	12155
Equipment cost	-	-	9,500
Welded wire mesh	0.2	110500	22,100
Design	1% of installation cost	1984135	19841.35
QA/QC	0.25% of installation cost	1984135	496033.8
Total			2,500,010

Installation Schedule is 5000 hours to install. Duration is 60 days placement with 7 days between placements and 30 days engineering for concrete mix design. Total schedule duration is 90 days for this option.

Leak tightness:

With good engineered details and quality placement, there is 97% confidence leak tightness can be achieved.

Durability:

Since this is concrete, it is usually durable for 40 years and be engineered to be sulfate resistant as well as resistant to corrosive environment.

Stakeholders:

There are two items that stakeholders will need to be notified of but none require a formal approval. The first is the change in available tank volume for grout. The current volume of SDU6 is 32 million gallons of grout accounting for the head space. The minimum volume contractually is 30 million gallons. The overlay with take up ½ million gallons space so the space left for grout is 31.5 million gallons of grout which is still greater than the 30 million gallons minimum required. The second would be that the new concrete mix design would require DOE buy-in. Other than these no stakeholder approval will be required.

Constructablity:

The only challenge to this placement is joint design and batch plant supply. But this technology is regular and not equipment intensive and the concrete polymer mix can be pumped.

Contract:

No issues recognized at the moment.

BASF
We create chemistry

Technical Data Guide

3 | 03 01 00
Maintenance of Concrete

MasterEmaco® S 466CI

Flowable structural-repair concrete with integral corrosion inhibitor

FORMERLY EMACO® S66 CI

PACKAGING
55 lb (25 kg) polyethylene-lined bags
3,300 lb (1,500 kg) bulk bags

YIELD
0.43 ft³ (0.012 m³) per 55 lb bag (25 kg)

STORAGE
Store in unopened containers in a cool, clean, dry area

SHELF LIFE
55 LB BAGS: 12 months when properly stored
3,300 LB BAGS: 3 months when properly stored

VOC CONTENT
0 g/L less water and exempt solvents

DESCRIPTION
MasterEmaco S 466CI is a flowable, shrinkage-compensated repair concrete. It is designed for large volume repairs, including structural elements in applications from 1" (50 mm) to full depth. It has a unique formulation that provides excellent bond, resistance to sulfates and chlorides, high electrical resistivity, low permeability, high-compressive strengths, and protection from corrosion.

PRODUCT HIGHLIGHTS
- Very low chloride permeability and an integral corrosion inhibitor protects reinforcing steel
- Only requires the addition of potable water
- High compressive strength
- Excellent freeze/thaw resistance for durability in cold, wet environments
- Abrasion resistant for repairs requiring protection from vehicular traffic
- Flowability makes it ideal for placement by pumping or pouring into congested locations
- Shrinkage compensated, minimizing cracking from drying shrinkage reducing stress at the bond line

APPLICATIONS
- Interior and exterior
- Large volume structural repairs
- Repair or replacement of concrete elements

SUBSTRATES
- Concrete

HOW TO APPLY
SURFACE PREPARATION

CONCRETE
1. Substrate must be structurally sound and fully cured (28 days).
2. Saw cut the perimeter of the area being repaired into a square with a minimum depth of 1" (25 mm).
3. Refer to current ICRI Guideline no. 310.2R for surface prep requirements to permit proper bond.

REINFORCING STEEL
1. Remove all oxidation and scale from the exposed reinforcing steel in accordance with ICRI Technical Guideline No. 310.1R.
2. For additional protection from future corrosion, coat the prepared reinforcing steel with MasterProtect P 8100 AP.

Technical Data Guide
MasterEmaco® S 466CI

Technical Data

Composition

MasterEmaco S 466CI is a rheoplastic cement-based silica-fume-modified flowable repair concrete.

Typical Properties

PROPERTY	VALUE
Unit weight, lb/ft³ (kg/m³)	142 (2,275)
Working time, min	90
Set times, hours (ASTM C 266)	
Initial set	4
Final set	6

Test Data

PROPERTY	RESULTS			TEST METHODS
	1 Day Psi (MPa)	**7 Day Psi (MPa)**	**28 Day Psi (MPa)**	
Splitting tensile strength	300 (2.1)	550 (3.8)	700 (4.8)	ASTM C 496
Flexural strength	– –	– –	770 (5.3)	ASTM C 348
Compressive strength	2,500 (17.2)	6,000 (41.4)	8,000 (55.2)	ASTM C 109
Direct tensile bond strength	– –	260 (1.8)	340 (2.3)	ACI 503R, Appendix A
Direct shear bond strength	350 (2.4)	500 (3.4)	600 (4.1)	Michigan DOT
Slant shear bond strength	– –	2,150 (14.8)	3,300 (22.8)	ASTM C 882, modified[1]
Drying shrinkage, %, at 28 days	0.067	does not meet current specification		ASTM C 157, modified2
Modulus of elasticity, psi (GPa), at 28 days	5.90×10^6 (40.7)			ASTM C 469
Rapid chloride permeability, coulombs, at 28 days	650			ASTM C 1202 / AASHTO T 277
Freeze/thaw resistance, % RDM, at 300 cycles	97.0			ASTM C 666, Procedure A
Scaling resistance, 50 cycles	2; slight to moderate			ASTM C 672
Sulfate resistance, %, length change at 6 months	+0.006			ASTM C 1012

[1]No epoxy-bonding agent used
[2]CRI Guideline No. 03733, 3 by 3 by 10" (75 by 75 by 250 mm) prism, air cured
Results were obtained when material was mixed with 0.6 gallons (2.3 L) of water per bag and cured at 70° F (21° C).
Expect reasonable variations depending upon application methods, test methods, and curing conditions.

MIXING

1. Precondition material to 70° F ±5° (21° C ±3°) before mixing.
2. Add 0.40–0.60 gallons (1.5–2.3 L) of potable water for each 55 lb (25 kg) bag of MasterEmaco S 466CI. Mix mechanically using a slow-speed drill (400–600 rpm) and a Jiffy paddle or mix in an appropriately sized mortar mixer.
3. Pour approximately 90% of the mix water into the mixing container, and then charge the mixer with the MasterEmaco S 466CI. Add the remaining mix water as required to obtain desired consistency. Add enough water to the mixing container to obtain a slump of 4–6" (102–152 mm), approximately 0.6 gallons (2.3 L) per bag. Maximum recommended slump is 7" (175 mm).
4. Mix until a homogeneous consistency is achieved, approximately 3–5 minutes. Do not mix longer than 5 minutes.
5. For applications greater than 8" (203 mm), add up to 25 lbs (11.3 kg) of ½–¾" rounded, high-density, washed, SSD coarse aggregate for each 55 lbs (25 kg) of MasterEmaco S 466CI.
6. Aggregate must comply with the requirements of ASTM C 33.

APPLICATION

FORMED APPLICATIONS

1. Build forms in accordance with ACI 347R. Keep the unrestrained surface area of the repair to a minimum.
2. Saturate the prepared concrete substrate by filling the prepared formwork with clean water 24 hours before placement.
3. Immediately before the placement of MasterEmaco S 466CI, completely drain this water and seal the drainage outlets, leaving the substrate saturated surface-dry (SSD) with no ponded water remaining.
4. In jobsite circumstances where the formwork cannot be filled with water to achieve an SSD surface, the prepared concrete substrates must be thoroughly hosed down with clean water to achieve an equal level of saturation. Apply the repair material with sufficient pressure to ensure intimate contact with the substrate.
5. A long open-time bonding agent such as MasterEmaco P 124 may be used in place of a saturated substrate. In such a case, place the MasterEmaco S 466CI before the bonding agent becomes tack free.
6. Immediately after mixing, pump or pour the MasterEmaco S 466CI into the formed area. The material does not require vibrating.
7. The recommended application range of MasterEmaco S 466CI is from 45 to 85° F (7 to 29° C). Follow ACI 305 and 306 for hot or cold weather guidelines.

HORIZONTAL APPLICATIONS

1. After removing all standing water, thoroughly scrub a thin layer of bond coat into the saturated surface with a stiff-bristled broom or brush. Do not dilute the bond coat with water. Do not apply more of this bond coat than can be covered with mortar before the bond coat dries. Do not retemper the bond coat.
2. Immediately place the repair mortar from one side of the prepared area to the other. Work the material firmly into the bottom and sides of the patch to ensure good bond. Level the MasterEmaco S 466CI and screed it to the elevation of the existing concrete. Apply the appropriate finish.
3. Finish the completed repair, as required, taking care not to overwork the surface.
4. The recommended application range of MasterEmaco S 466CI is from 45 to 85° F (7 to 29° C). Follow ACI 305 and 306 for hot or cold weather.
5. A maximum of 90 minutes should be allowed to mix, place, and finish MasterEmaco S 466CI at 70° F (21° C).

CURING

1. Leave the formwork in place until the compressive strength reaches 2,500 psi (17.2 MPa) or a strength specified by the engineer.
2. Cure with an approved curing compound compliant with ASTM C 309 or preferably ASTM C 1315. If the repair area will receive a coating, wet curing is recommended.

CLEAN UP

Clean tools and equipment with clean water immediately after use. Cured material must be removed mechanically.

FOR BEST PERFORMANCE

- Do not mix partial bags.
- Do not add plasticizers, accelerators, retarders, or other additives.
- For professional use only; not for sale to or use by the general public.
- Make certain the most current versions of product data sheet and SDS are being used; visit www.master-builders-solutions.BASF.us to verify the most current versions.
- Proper application is the responsibility of the user. Field visits by BASF personnel are for the purpose of making technical recommendations only and not for supervising or providing quality control on the jobsite.

HEALTH, SAFETY AND ENVIRONMENTAL

Read, understand and follow all Safety Data Sheets and product label information for this product prior to use. The SDS can be obtained by visiting www.master-builders-solutions.basf.us, e-mailing your request to basfbscst@basf.com or calling 1(800)433-9517. Use only as directed.
For medical emergencies only, call ChemTrec® 1(800)424-9300.

LIMITED WARRANTY NOTICE

BASF warrants this product to be free from manufacturing defects and to meet the technical properties on the current Technical Data Guide, if used as directed within shelf life. Satisfactory results depend not only on quality products but also upon many factors beyond our control. BASF MAKES NO OTHER WARRANTY OR GUARANTEE, EXPRESS OR IMPLIED, INCLUDING WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE WITH RESPECT TO ITS PRODUCTS. The sole and exclusive remedy of Purchaser for any claim concerning this product, including but not limited to, claims alleging breach of warranty, negligence, strict liability or otherwise, is the replacement of product or refund of the purchase price, at the sole option of BASF. Any claims concerning this product must be received in writing within one (1) year from the date of shipment and any claims not presented within that period are waived by Purchaser. BASF WILL NOT BE RESPONSIBLE FOR ANY SPECIAL, INCIDENTAL, CONSEQUENTIAL (INCLUDING LOST PROFITS) OR PUNITIVE DAMAGES OF ANY KIND.

Purchaser must determine the suitability of the products for the intended use and assumes all risks and liabilities in connection therewith. This information and all further technical advice are based on BASF's present knowledge and experience. However, BASF assumes no liability for providing such information and advice including the extent to which such information and advice may relate to existing third party intellectual property rights, especially patent rights, nor shall any legal relationship be created by or arise from the provision of such information and advice. BASF reserves the right to make any changes according to technological progress or further developments. The Purchaser of the Product(s) must test the product(s) for suitability for the intended application and purpose before proceeding with a full application of the product(s). Performance of the product described herein should be verified by testing and carried out by qualified experts.

BASF Corporation
Construction Systems

889 Valley Park Drive, Shakopee, MN 55379
www.master-builders-solutions.basf.us

Customer Service 1(800)433.9517
Technical Service 1(800)243.6739

© 2015 BASF Corporation Form No.1019945 rev 06/15

Option #: 13 Title: Gunite / Shotcrete (Fiber Reinforced)

Author: J.P. Thompson

History:
Shotcrete is defined as concrete conveyed through a hose and pneumatically projected at high velocity onto a surface. Shotcrete is an all-inclusive term that describes spraying concrete with either a dry-mix or wet-mix process. Gunite was a registered trademark name that specifically referred to the dry-mix process. Other manufacturers used different terminology to describe their process such as shotcrete, pneumatic concrete, guncrete, etc. The current acceptance is that the term "shotcrete" is used in the United States and "sprayed concrete" is used throughout Europe.
Description:
The dry-mix shotcrete method has pre-blended dry materials (cement, sand, aggregates, etc.) placed into the hopper. Compressed air conveys the dry materials through a hose at a high velocity to a nozzle, where water is added. The nozzle man controls the addition of water at the nozzle. The materials are consolidated on the receiving surface by the high-impact velocity. The dry-mix process is recommended when the job involves frequent stops during the application process.
The wet-mix shotcrete method is where all ingredients, including water, are thoroughly mixed and introduced into the delivery equipment. Wet materials are pumped to the nozzle where compressed air is added to provide high velocity for placement and consolidation. The greatest advantage of the wet-mix process is that larger volumes can be placed in less time.
The basic concrete mix contains cement, aggregates (< ½ inch) and water. Properties of both dry and wet process shotcrete can be further enhanced through the addition of other ingredients, such as:

- Silica Fume – Provides reduced permeability, increased compressive and flexural strength, increased resistance to alkali and chemical attack, improved resistance to water washout, reduced rebound levels, and allows for thicker single-pass applications.
- Air-Entraining Admixtures – Improve pumpability and adhesion in wet-process shotcrete and freeze-thaw durability in both processes.
- Accelerators – Increase the stiffening rate, provide early strength development, improve the placement characteristics in adverse conditions and allow for thicker single-pass applications.
- Plasticizers – With the wet-mix process the water / cement ratio can be accurately controlled and with water-reducing plasticizers, water / cement ratios below 0.45 can easily be achieved.
- Fiber Reinforcement – Added to shotcrete to control plastic shrinkage cracking, control thermal cracking, improve abrasion and impact resistance, improve fire resistance, improve ductility and toughness, and enhanced tensile and flexural strength.

Pros and Cons:
Pros – Shotcrete exhibits certain properties that in some respects make it superior to poured concrete. However, it should be remembered that these properties are largely as a result of the different methods of mixing, transporting and placing rather than fundamental differences in component materials.

- Low Water / Cement Ratio – Shotcrete generally has a lower water / cement ratio than poured concrete. This is particularly true in the dry-mix process where a low slump mix capable of supporting itself without sagging is quite normal. Wet-mix process achieves a similar result using a plasticizer.
- High Strengths with Rapid Strength Gain – Shotcrete can be expected to attain high compressive strengths particularly with a low water / cement ratio and the dense compaction achieved with the high velocity of application. Compressive strengths 30 percent higher than conventionally placed concretes can be expected.
- High Density / Low Permeability – The high velocity of placement ensures good compaction and high density coupled with low permeability and water absorption. This results in a durable homogeneous material with excellent freeze / thaw resistance, low surface cracking and a high degree of abrasion resistance. These properties may be further enhanced by the use of fiber reinforcement in the mix.
- Enhanced Adhesion and Bond Strength – Presuming that the substrate is properly prepared, the bond strength with shotcrete is generally excellent. Furthermore, the use of bonding agents is usually unnecessary and, under certain conditions, damaging to the bond. Shotcrete can be applied to horizontal, vertical and overhead surfaces.

According to the American Shotcrete Association, thousands of shotcrete tanks have been built since the process was pioneered. These watertight, durable, and economical tanks, which range from 50,000 to 20 million gallons, can be used to store a variety of liquids, including wastewater, industrial wastes and chilled water.
Cons – Construction joints should be designed as with placing regular concrete, but waterstops may not be possible. Moist curing is the preferred method of curing shotcrete. Shotcrete success depends largely on the skill and actions of the nozzle man. For this reason, it is important to require that the nozzle man be ACI certified for the application.

Cost	Uses same Concrete Mix Design as SDU-6 (except smaller aggregate, added waterproofing and fiber reinforcement). Need to determine if waterproofing and fiber reinforcing is compatible with liner. The quality of a completed shotcrete application results from the combined skills and knowledge of the shotcrete crew. The nozzle operator should be certified (ref: ACI CP-60). Experience with installing shotcrete perpendicular to a horizontal surface. Presume DN Tanks is certified for this application.

	Logistics: Install wet-mix process equipment (e.g. concrete pump, air compressor, etc.). Install elevated working platform (e.g. JLG). Pump wet-mix 43 feet up and 43 feet down (or investigate reuse of grout entry pipes through foundation). Investigate PPE and ventilation requirements inside cell.
Schedule	R&D to determine if waterproofing and fiber reinforcing is compatible with liner = 7 days. Design engineering calculations, specifications, drawings, etc. = 21 days. Surface preparation (e.g. hydromilling, sandblasting, etc.) = 7 days. Shotcrete 30,000 cu ft = 1,100 cu yd. At 10 cu yd / hr and 10 hrs / day + delays = 14 days. Wet cure or Natural curing (humidity $\geq$ 85 %) = 7 days.
Effectiveness	Shrinkage is an important parameter with respect to potential cracking and boundary durability. Drying shrinkage of shotcrete generally falls within the 0.06 and 0.10 percent range at 3 months (versus concrete at 0.046 percent (maximum) with 4 inch prisms at 28 days).
Durability	Since the concrete and shotcrete are the same materials, they should both have the same 25 year life.
Stakeholder Approval	The addition of 3 inches of shotcrete reduces the storage volume by 225,000 gallons. Need to determine if waterproofing and fiber reinforcing is compatible with liner.
Constructability	Construction joints should coincide with existing joints. Contraction / expansion joints (e.g. tooling, saw cut, etc.) at 23 feet on center each way (i.e. between columns) can be paths for leakage. Possible need for epoxy injection or epoxy gravity filling of construction joints and contraction / expansion joints.
Contract	While DN Tanks did the exterior shotcrete (i.e. machine applied), they may not be experienced (i.e. certified nozzle man) in the hand application of shotcrete. Presume DN Tanks is certified for this application.

Option #: 14 Title: Liner - Steel

Author: Don Hayes

Description:
Line the tank floor with ¼" steel plate. Join plates with full thickness fillet welds using GMAW process and ¼" backing bar. Modify expansion joint/reglet design from coating system to use at floor and wall interface. Seal interfaces between column pedestal and liner plate with epoxy filler. Weld liner to embeds for drain wells and thermocouple trees. Vacuum box test all welds and wall/column/plate interface points.
Evaluate use of stainless versus un-coated carbon steel. Grout pipe is carbon steel and drainwater pipe is stainless.
Pros and Cons:
Pros:

- Use of liner will allow deletion of the floor coating.
- Vacuum box testing of liner will allow deletion of water leak test of floor slab. Walls have already passed water leak test therefore no additional water leak test required.
- Very high confidence level for providing leak free tank.

Cons:

- Cost and schedule impacts may exceed other options.
- Requires revision to design requirements.
- Requires stake holder buy in.

Cost	Salient items relating to cost: • No R&D testing • Design cost to percent of construction cost low or average. • $5.2M includes material, equipment, direct craft labor, and 21% non-manual support (field engineers, supervision, safety, etc.)
Schedule	Design issue details and layout drawings – 6 weeks, procure material, equipment, and labor – 8 weeks, fab/install liner and test – 29 weeks. Overall duration – 39 weeks or 8.5 months
Effectiveness	Welded steel liner is highly effective for passing leak test and leaks easily identified and repaired during vacuum box testing.
Durability	Carbon steel liner can maintain leak tightness during the planned ~6years of SDU grout filling.
Stakeholder Approval	Liner will provide a leak tight floor however does not provide a watertight concrete structure without relying on a lining. Will require DOE approval
Constructability	Welded liner utilizes proven means and methods. No constructability issues are expected.
Contract	Welded liner option is not within expertise of existing subcontractor and would require letting of new contract or self-performing.

Option #: 15 Title: REPAIR MORTAR
Author: S. SIMNER
Description:
Attached product datasheet provides relevant information for a repair mortar used for improving the water tightness of concrete tanks.

Pros

- Commercial product with specific purpose of enhancing water tightness in concrete tanks.
- Amenable to bulk application (e.g., spray)
- Seals hairline cracks
- Could potentially be used in lieu of EC-66 on floor though chemical resistance testing would be required.
- Can be applied to horizontal and vertical surfaces.
- Literature would suggest that repair mortars can be subsequently coated with polymeric coating.

Cons

- Only seals hairline cracks in concrete structures not subject to movement surfaces.
- Not sure about application to larger, continuous surface areas; product is only available online in 2.5 gallon quantities which would suggest that it is typically utilized for small area repairs – waiting to hear back from company on this.
- May require specialized application and pre-demonstration that product is applicable to large area application
- Still considered a coating that will require a TRAC change.
- Not as flexible as proposed EC-66 coating.

COST

- Approximately 6,000 gallons of material required to coat at 80 mils thickness for enhanced water tightness.
- Single Unit Price: 1 unit = 2.65 gal = $104; > 24 units = $70 per unit; approx. material cost $200,000. Likely cheaper for larger bulk purchases.
- Install cost probably similar to EC-66 but may have to factor in cost to demonstrate spraying of large areas prior to SDU installation.

SCHEDULE

- Install time probably similar to EC-66 but may have to factor in time spent demonstrating spraying of large areas prior to SDU installation.

LEAK TIGHTNESS

- Product designed to enhance water tightness of concrete tanks but potential coating anomalies with large surface area application. Bulk material would not be expected to be as watertight as bulk polymeric materials.
- Datasheet indicates okay for coating hairline cracks with minimal movement; may not be sufficient for cracks in SDU.

REGULATORY

- Would require a TRAC change and agreement from stakeholders to demonstrate leak tightness with a coating installed.

CONSTRUCTABILITY

- Sufficient product to mix 6,000 gallons (2 component system) and spray equipment required.
- Expertise in applying coating to large areas required.

IMPACT TO CONTRACT

- Potential impact to contract if current contractor cannot demonstrate expertise in handling/application of mortar repair coating.

Construction

Product Data Sheet
Edition 11.20.2015
SikaTop® Seal 107

SikaTop® Seal 107

Flexible, waterproofing and protective slurry mortar

Description	SikaTop® Seal 107 is a two-component, polymer-modified, cementitious waterproofing and protective slurry mortar for concrete. It is slightly flexible to tolerate fine cracks and suitable in both interior and exterior applications.
Advantages	SikaTop® Seal 107 provides the following beneficial properties: ■ Improves the watertightness of water-containing concrete tanks, reservoirs, and clearwells. ■ Protects against water penetration, yet water vapor permeable (breathable). ■ Excellent freeze/thaw resistance. ■ Good adhesion to sound, prepared substrates. ■ Easy and fast mixing and application. ■ Good abrasion resistance. ■ Protects against concrete carbonation (80 mils SikaTop® Seal 107 is equivalent to 6 inches of concrete). ■ Can be mixed to slurry or trowelable consistency. ■ Improves concrete/masonry appearance. ■ Available in concrete gray and off-white. ■ SikaTop® Seal 107 is ANSI/NSF 61 potable water compliant.
Where to use	■ Horizontal surfaces subjected to light foot traffic (balconies). ■ For waterproofing of drinking water, tanks, reservoirs, and clear wells. ■ For internal and external waterproofing and damp-proofing concrete, mortar blockwork and brickwork. ■ For protection of concrete structures against the deleterious effects of deicing salts and freeze/thaw cycles. ■ For sealing "hairline" cracks in concrete structures not subject to movement surfaces. ■ For interior and exterior waterproofing of basements. ■ Vertical surfaces.
Coverage	■ For damp-proofing: apply one coat at 40 mils. ■ For waterproofing: apply two coats at 40 mils per coat. Theoretical thickness (wet film) on smooth substrates: 40 ft.^{2}/gal. = 40 mils (2 kg./m^2 = 1 mm). The above figures are theoretical and do not allow for substrate profile and wastage. Three coats may be required in areas of extremely high water infiltration.
Packaging	44 lb. unit - when mixed yields 2.65 gallons (10 l) Component 'A' - 1 gal. plastic jug; 4/carton. Component 'B' - 35.5 lb. multi-wall bag.

Typical Data ***(Material and curing conditions @ 73°F (23°C) and 50% R.H.)***

RESULTS MAY DIFFER BASED UPON STATISTICAL VARIATIONS DEPENDING UPON MIXING METHODS AND EQUIPMENT, TEMPERATURE, APPLICATION METHODS, TEST METHODS, ACTUAL SITE CONDITIONS AND CURING CONDITIONS.

Shelf Life 1 year when unopened.

Storage Protect Component 'A' from freezing and Component 'B' from moisture.
Store dry at 40°- 95°F (4°- 35°C). Condition material to 65°-75°F conditions before using.

Colors Concrete gray and off white.

Mixing Ratio Component 'A': Component 'B'. Slurry consistency 1:4.1 by weight (full unit)
Trowelable consistency 1:4.5 by weight (90% liquid to full bag)

Density (wet mix) 125 lbs./ft.^{3} (2.0 kg./l.) = 16.6 lbs./gal.

Working Time Approximately 60 minutes at 68°F; Approximately 30 minutes at 86°F

Compressive Strength (ASTM D-695) @ 28 days
Type White 3,000 psi (20.7 MPa)
Type Gray 3,400 psi (23.4 MPa)

Tensile Strength (ASTM C-307) 28 days
White 870 psi (6.0 MPa)
Gray 990 psi (6.8 MPa)

Bond Strength (ACI 503R-30 Modified): Pull-off Test 28 days 180 psi (1.25 N/mm^2)

Flexibility (ASTM D522 modified) Approximately 25%

Watertightness under hydrostatic pressure (DIN 1048 mod.)

Water Pressure feet	(bar)	Penetrated Water grains	(grams)	Water Absorption grains ft^2 • hours	(grams) (m^2 • hours)
16	(0.5)	0	(0)	0	(0)
33	(1)	15	(1)	3	(2)
99	(3)	31	(2)	10	(7)

Rendering mortars absorbing less than 91 grains/ft.^{2} • h (64 grams/m^2• h) are considered watertight.

Vapor Permeability (ASTM E-96) U.S. perms: 28 days 18 (not a vapor barrier)

Carbon Dioxide Diffusion Coefficient (μCO_2) Approximately 35,000, equivalent to 6 inches of concrete

Water Vapor Diffusion Coefficient (μH_2O) Approximately 500 ("breathable")

PRIOR TO EACH USE OF ANY SIKA PRODUCT, THE USER MUST ALWAYS READ AND FOLLOW THE WARNINGS AND INSTRUCTIONS ON THE PRODUCT'S MOST CURRENT PRODUCT DATA SHEET, PRODUCT LABEL AND SAFETY DATA SHEET WHICH ARE AVAILABLE ONLINE AT HTTP://USA.SIKA.COM/ OR BY CALLING SIKA'S TECHNICAL SERVICE DEPARTMENT AT 800.933.7452 NOTHING CONTAINED IN ANY SIKA MATERIALS RELIEVES THE USER OF THE OBLIGATION TO READ AND FOLLOW THE WARNINGS AND INSTRUCTIONS FOR EACH SIKA PRODUCT AS SET FORTH IN THE CURRENT PRODUCT DATA SHEET, PRODUCT LABEL AND SAFETY DATA SHEET PRIOR TO PRODUCT USE.

Construction

How to Use

Substrate Preparation

Concrete, mortar and masonry surfaces must be clean, free from grease, oil and loosely adhering particles. All surfaces must be as true and flat as possible. An open-textured, sandpaper-like substrate is ideal (CSP-3). All surfaces must be saturated surface dry (SSD), with no standing water at time of application. It is necessary to stop water ingress prior to the application of SikaTop® Seal 107. Use a quick setting, waterproof slurry (SikaSet®) to seal water leaks.

Mixing

The consistency of the mix can be altered by reducing the amount of Component 'A' (liquid) to be used. Under normal circumstances, when the full quantities of both components are mixed together, a slurry consistency will result. For a trowel-able consistency use only 90% of component 'A'. Mix in a clean container by slowly adding the powder component to the liquid component and mixing with slow speed drill and mixing paddle.

Application

SikaTop® Seal 107 can be applied by trowel, notched trowel, stiff bristle, or spray equipment. Work the material well into the prepared substrate, filling all pores and voids.

For brush consistency: Apply the first coat of SikaTop® Seal 107 with horizontal brush strokes and leave to harden (4 to 8 hours). Apply the second coat with vertical brush strokes.

For trowel consistency: Apply the first coat with a notched trowel and leave to harden (4 to 8 hours). Apply the second coat with a flat trowel.

For spray application: Use a hopper gun spray equipment, textured sprayer (e.g. Texspray E110c), or a rotor/stator pump equipment. Allow the first coat to harden (4 to 8 hours) prior to the application of the second coat. As soon as the mortar layer starts to set, a uniform surface texture can be obtained by rubbing the surface with a fine sponge or a plastic trowel. Do not overwork SikaTop® Seal 107 during finishing and avoid the use of additional water. [Where required, a third coat of SikaTop® Seal 107 may be applied no later than 24 hours after the second coat (in this case, do not trowel or sponge finish the second coat). If intercoat period exceeds 24 hours, light grit blasting is required prior to further application].

Balcony Waterproofing Layer: Fill in any spalled areas in the existing substrate with the appropriate Sika repair mortar as required. Apply an appropriately sized closed cell backer rod along transition (wall-slab) to prevent three-sided adhesion. Apply a continuous cant bead of Sikaflex® 11-FC or Sikaflex® 2C, to a depth of 1/8" minimum and 1/2 inch thickness. Allow sealant to cure sufficiently. Substrate must be SSD with no standing water at time of application. Apply a 1/16" thick layer of SikaTop® Seal 107 over the entire balcony. While the material is still wet apply a "360 degree pull" non-alkaline, woven fiberglass mesh to reinforce the 107 layer along static hairline cracks, wall to slab transitions and patched areas. Using trowels remove any wrinkles in the mesh by forcing down into the SikaTop® Seal 107. Ensure the mesh is completely embedded and covered with SikaTop® Seal 107. If any areas are not covered apply additional SikaTop® Seal 107 over top of mesh to cover. Trowel to a smooth uniform finish. Allow curing so that surface can take foot traffic without harming the coating.

Tooling & Finishing

Curing: As with all cement based products, curing is important. Protect newly applied product against direct sunlight, wind, rain and frost.

Limitations

- If rain is anticipated within 1-2 days after application, the surface should be protected in order to prevent streaking.
- Not an aesthetic coating.
- Minimum ambient and substrate temperatures are 45°F (7°C) and rising at the time of application.
- Maximum application thickness per coat = 80 mils (2 mm). Do not apply less than 20 ft.²/gal. = 1 m²/liter.
- As with all cement based materials, avoid contact with aluminum to prevent adverse chemical reaction and possible product failure. Insulate potential areas of contact by coating aluminum bars, rails, posts etc. with an appropriate epoxy such as Sikadur® Hi-Mod 32.
- Allow 2 days of air curing before subjecting SikaTop® Seal 107 to submersion.

PRIOR TO EACH USE OF ANY SIKA PRODUCT, THE USER MUST ALWAYS READ AND FOLLOW THE WARNINGS AND INSTRUCTIONS ON THE PRODUCT'S MOST CURRENT PRODUCT DATA SHEET, PRODUCT LABEL AND SAFETY DATA SHEET WHICH ARE AVAILABLE ONLINE AT HTTP://USA.SIKA.COM/ OR BY CALLING SIKA'S TECHNICAL SERVICE DEPARTMENT AT 800.933.7452 NOTHING CONTAINED IN ANY SIKA MATERIALS RELIEVES THE USER OF THE OBLIGATION TO READ AND FOLLOW THE WARNINGS AND INSTRUCTIONS FOR EACH SIKA PRODUCT AS SET FORTH IN THE CURRENT PRODUCT DATA SHEET, PRODUCT LABEL AND SAFETY DATA SHEET PRIOR TO PRODUCT USE.

KEEP CONTAINER TIGHTLY CLOSED. KEEP OUT OF REACH OF CHILDREN. NOT FOR INTERNAL CONSUMPTION. FOR INDUSTRIAL USE ONLY. FOR PROFESSIONAL USE ONLY.

For further information and advice regarding transportation, handling, storage and disposal of chemical products, users should refer to the actual Safety Data Sheets containing physical, ecological, toxicological and other safety related data. Read the current actual Safety Data Sheet before using the product. In case of emergency, call CHEMTREC at 1-800-424-9300, International 703-527-3887.

Prior to each use of any Sika product, the user must always read and follow the warnings and instructions on the product's most current Product Data Sheet, product label and Safety Data Sheet which are available online at http://usa.sika.com/ or by calling Sika's Technical Service Department at 800-933-7452. Nothing contained in any Sika materials relieves the user of the obligation to read and follow the warnings and instruction for each Sika product as set forth in the current Product Data Sheet, product label and Safety Data Sheet prior to product use.

SIKA warrants this product for one year from date of installation to be free from manufacturing defects and to meet the technical properties on the current Product Data Sheet if used as directed within shelf life. User determines suitability of product for intended use and assumes all risks. Buyer's sole remedy shall be limited to the purchase price or replacement of product exclusive of labor or cost of labor. NO OTHER WARRANTIES EXPRESS OR IMPLIED SHALL APPLY INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. SIKA SHALL NOT BE LIABLE UNDER ANY LEGAL THEORY FOR SPECIAL OR CONSEQUENTIAL DAMAGES. SIKA SHALL NOT BE RESPONSIBLE FOR THE USE OF THIS PRODUCT IN A MANNER TO INFRINGE ON ANY PATENT OR ANY OTHER INTELLECTUAL PROPERTY RIGHTS HELD BY OTHERS. SALE OF SIKA PRODUCTS ARE SUBJECT SIKA'S TERMS AND CONDITIONS OF SALE AVAILABLE AT HTTP://USA.SIKA.COM/ OR BY CALLING 201-933-8800.

Visit our website at usa.sika.com 1-800-933-SIKA NATIONWIDE

Regional Information and Sales Centers. For the location of your nearest Sika sales office, contact your regional center.

Sika Corporation
201 Polito Avenue
Lyndhurst, NJ 07071
Phone: 800-933-7452
Fax: 201-933-6225

Sika Canada Inc.
601 Delmar Avenue
Pointe Claire
Quebec H9R 4A9
Phone: 514-697-2610
Fax: 514-694-2792

Sika Mexicana S.A. de C.V.
Carretera Libre Celaya Km. 8.5
Fracc. Industrial Balvanera
Corregidora, Queretaro
C.P. 76920
Phone: 52 442 2385800
Fax: 52 442 2250537

Sika and SikaTop® are registered trademarks.
Printed in Canada

Appendix C – Cost and Schedule Data

#	Option	R&D	Design	Materials	Constr.	Adjust for EC-66	Total (Dollars)	Schedule (Days)	Notes
1	Epoxy Injection	0	0	see Constr.	312,000	0	312,000	100	Assuming $39/linear ft(incl Mhrs)($40k materials); 4 crews = 25 linft/day/crew
2	Routing and Sealing	0	0	see Constr.	201,000	0	201,000	90	assuming $12/linear ft (incl Mhrs);
3	Surface Sealing by Gravity Filling	0	0	42,000	254,000	0	296,000	90	
4	Crystalline Waterproofing	10,000	0	50,000	300,000	0	360,000	90	50K for application and 250K for sandblasting
5	Chemical grouting	0	50,000	200,000	100,000	0	350,000	90	QC/QA Prcs/Delivery design/Mockup DIAPER
6	P and MA resins injection	0	0	see Constr.	350,000	0	350,000	100	assuming $35/linear ft(incl Mhrs)
7A	Coating-Polyurea	in TPC	50,000		1,150,000	0	1,200,000	120	cost to redo spec and secure a subcontractor 800K; 3 Mths (difference between baseline and new approach) Fabric cost of $400K
7B	Coating- EC 66 Flexible Epoxy	in TPC	0	In TPC	400,000	0	400,000	60	4 Mths (3 Mths in project to apply coatings)Fabric cost of $400K
8	Liner-Synthetic (M4000)	10,000	50,000	see Constr.	1,100,000	1,700,000	-540,000	60	4 Mths (3 Mths in project to apply coatings) Avoids cost of sandblasting (Adjusted to account for savings&sunk costs of EC-66)

#	Option	R&D	Design	Materials	Constr.	Adjust for EC-66	Total (Dollars)	Schedule (Days)	Notes
9	Autogenous healing	0	0	100,000	50,000	0	150,000	30	Assuming ph 12 (3000 kg of Ca(OH)2 ~ $100,000; cost based on ACS Reagent Grade 95% purity $161 per 5kg)
12	Install concrete overlay	see Constr.	see Constr.	see Constr.	2,500,000	0	2,500,000	120	R&D, construction, curing
13	Gunite/shotcrete (fiber reinforced)	10,000	50,000	200,000	540,000	0	800,000	60	$290K for application and 250K for sandblasting
14	Liner - Steel	NA	see Constr.	see Constr.	5,200,000	1,700,000	3,500,000	255	Subtracted cost of coating w/mat (5.2-1.7M=3.5). Opportunity: Substitute vacuum box for water leak test would further reduce cost. 30 days reduction due to no coating required.
15	Repair Mortar	10,000	50,000	see Constr.	940,000		1,000,000	120	Subcontractor is required

Appendix D – Compatibility Grid

Option Title	1-Epoxy Injection	2-Routing and Sealing	3-Surface Sealing by Gravity Filling	4-Crystalline Waterproofing	5-Chemical grouting	6-P and M A resins injection	7A - Coating-Polyurea	7B - Coating- EC 66 Flexible Epoxy	8-Liner-Synthetic	9-Autogenous healing	12-Intstall concrete overlay	13-Gunite/shotcrete (fiber reinforced)	14-Liner - Steel	15-Repair Mortar
1-Epoxy Injection		Y	N	N	N	N	Y	Y	Y	N	Y	Y	Y	Y
2-Routing and Sealing	Y		N	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y
3-Surface Sealing by Gravity Filling	Y	N		N	Y	Y	Y	Y	Y	N	Y	Y	Y	Y
4-Crystalline Waterproofing	Y	N	N		Y	Y	Y	Y	Y	N	Y	Y	Y	Y
5-Chemical grouting	N	Y	N	N		Y	Y	Y	Y	N	Y	Y	Y	Y
6-P and M A resins injection	N	Y	N	N	N		Y	Y	Y	N	Y	Y	Y	Y
7A - Coating-Polyurea	N	N	N	N	N	N		Y	Y	N	N	N	Y	N
7B - Coating- EC 66 Flexible Epoxy	N	N	N	N	N	N	Y		Y	N	N	N	Y	N
8-Liner-Synthetic	N	N	N	N	N	N	N	N		N	N	N	Y	N
9-Autogenous healing	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y
12-Intstall concrete overlay	N	N	N	N	N	N	Y	Y	Y	N		Y	Y	Y
13-Gunite/shotcrete (fiber reinforced)	N	N	N	N	N	N	Y	Y	Y	N	N		Y	Y
14-Liner - Steel	N	N	N	N	N	N	N	N	N	N	N	N		N
15- Repair Mortar	N	N	N	N	N	N	N	N	Y	N	N	N	Y	

Row - First Sequence	Y	Compatible
Column - Second Sequence	N	Not compatible

Appendix E – Option Scoring

Alternative	Total	DIRECT Cost (L: .078)	DIRECT Schedule (L: .052)	DIRECT Leaktightness (L: .325)	DIRECT Durability (L: .271)	DIRECT Stakeholder Approval (L: .192)	DIRECT Constructability (L: .054)	DIRECT Acquisition Strategy (L: .028)
1-Epoxy Injection	.083	.7	.4	.6	.9	1	.9	1
2-Routing&Sealing	.071	.85	.6	.3	.75	1	.9	1
3-Surface Sealing by Gravity Filling	.081	.8	.6	.5	.9	1	.9	1
4-Crystalline Waterproofing	.067	.7	.6	.1	.9	1	.9	1
5-Chemical Grouting	.066	.7	.6	.4	.5	1	.9	1
6-P&MA Resin Injection	.083	.7	.4	.6	.9	1	.9	1
7A-Coating-Polyurea	.063	.3	.2	.75	.65	.5	.75	.25
7B-Coating-EC66	.072	.7	.8	.75	.65	.5	.75	1
8-Liner-Synthetic	.088	1	.8	.9	.8	.75	.8	.5
9-Autogenous Healing	.071	.9	1	.1	.9	1	1	1
12-Install Concrete Overlay	.062	.2	.2	.35	.8	.9	.5	1
13-Gunite/Shotcrete (fiber reinf)	.067	.5	.8	.35	.8	.9	.4	1
14-Liner-Steel	.077	.1	.1	.9	.8	.8	.75	.5
15-Repair Mortar	.050	.4	.2	.2	.75	.5	.75	1

Appendix F – Risk Assessment Premortem Results

Option 1 Epoxy Injection – Pre-Mortem Results

ID	Event Title	Handling Strategy	Handling Strategy Description
1	Contaminated Crack (lubricants, debris, etc.) Does Not Allow Bond	Accept	
2	Injection Pressure Propagates Crack	Mitigate	– Craft Training – Quality Control – Work Planning
3	Damage During Installation	Mitigate	– Craft Training – Quality Control – Work Planning – Procedures that meet vendor Requirements – Observers – Lighting
4	Manufacturer Defect	Mitigate	– Pre-installation Inspection of "Salient" properties – Shipping, Handling, Storage Controls – Review vendor QA/QC Program – Review Vendor Reputation – Review Vendor Production Variation (e.g. porosity) – Request Batch Qualification from Production Run
5	Epoxy Continues To Drain After Injection	Avoid	– Control Pressure/Time/Cylinder Travel/Refusal – Craft Training – Quality Control – Work Planning
6	Not All Cracks Originate in Floor	Mitigate	– Secondary Injection System for Wall – QC Wall Coating System
7	Environmental Conditions Impact Ability to Bond (e.g. Humidity/Temperature)	Mitigate	– Condition Space – Craft Training – Quality Control – Work Planning
8	Port Injection Misses Crack (Misaligned)	Mitigate	– Craft Training – Quality Control – Work Planning

9	Test Water Chemistry Degrades Epoxy	Mitigate	– Condition Water as Needed
10	Cracks Under Pedestal Remain Hidden & Not Accessible	Mitigate	– Caulk around every pedestal
11	QC Missed Quality Defects (Program Failure)	Mitigate	– Train QC by Manufacturer – Use Manufacturer's QC Inspectors – Audit QC Program
12	Customer Challenges Leak Test Acceptance	Mitigate	– "Buy –In" Up Front
13	Epoxy Cannot be Injected (using a port) Into the Crack. Crack is Assumed to be Filled but is Not	Mitigate	– Mark Area and Remediate – Test & Validate Remediation
14	Assumed Port Spacing Is Not Adequate	Mitigate	– Test and Mock-Up
15	Pressure Is Not Adequate	Mitigate	– Test and Mock-Up
16	Time is Inadequate	Mitigate	– Test and Mock-Up
17	Viscosity is Inadequate	Mitigate	– Test and Mock-Up
18	Do Not Allow For Secondary Repair Method During Leak Test	Mitigate	– Buy in from customer – Strategy for Repair – Involve SME's to ID Repair Systems
19	QC Records Challenged After Construction	Mitigate	– Concurrence Leak Test is Accepted – QC Records Reviewed Prior to Leak Test
20	Poor Equipment	Mitigate	– M&TE Program – Use Best Available Equipment – Test and Validate Use – Provide Adequate Storage
21	Machine Produces Inadequate Hardener/Bonding Ratio and Epoxy Does Not Harden	Mitigate	– Test and Mock-Up – Craft Training
22	Epoxy Does Not Cure Sufficiently	Mitigate	– Craft Training – Quality Control – Mix Ratio
23	Incorrect Epoxy Material Selected	Mitigate	– Engineering Research of Vendor Data & Select Appropriate material
24	New Cracks Develop During Hydro (see #18)	Accept	

25	Improper Repair of Cores used To Verify Epoxy Placement	Mitigate	– Minimize Coring – Craft Training – Quality Control – Work Planning
26	Miss Injecting Existing Cracks	Mitigate	– Program to ID and Mark Cracks – Program to verify Marked Cracks are Injected – Craft Training – Quality Control – Work Planning
27	Construction Joints Leak	Accept	
28	Injection Does Not Fill Narrow Cracks	Mitigate	– Optimize Penetration by Selection of Low Viscosity Epoxy and Different Techniques For Narrow Cracks
29	Insufficient Prep Work (fines Prohibit Flow)	Mitigate	– Craft Training – Quality Control verifies Prep/Cleaning – Work Planning
Opportunities			
ID	**Event Title**	**Handling Strategy**	**Handling Strategy Description**
30	Meets Definition of Structural Repair	Accept	– Include in documentation.
31	Does Not Preclude the Use of Other Options if Fails Hydro	Accept	

Option 7B Coating (EC66)– Pre-Mortem Results

ID	Event Title	Handling Strategy	Handling Strategy Description
1	Osmotic pressure during hydro fails concrete and liner	Mitigate	– Test coating in similar mockup conditions (static head)
2	Damaged Material (Damaged on-site)	Mitigate	– Quality Control (Inspections that meet vendor requirements) – Access Limitations – Protective Cover – Work Sequencing – Lighting
3	Damage During Installation (pin holes occur)	Mitigate	– Craft Training – Quality Control – Work Planning – Work Processes (no sharp objects) – Procedures that meet vendor Requirements – Observers – Lighting – Color
4	Manufacturer Defect	Mitigate	– Pre-installation Inspection of "Salient" properties – Shipping, Handling, Storage Controls – Review vendor QA/QC Program – Review Vendor Reputation – Review Vendor Production Variation
5	Operating Pressure Exceeds Design/Experience Threshold (e.g. Coating cannot qualify "zero" leakage for head based on previous data and normal usage)	Mitigate	– Mock-up & Test
6	Not All Cracks Originate in Floor	Mitigate	– Wall Coating System

7	Environmental Conditions Impact Ability to Bond (e.g. Humidity/Temperature)	Mitigate	– Condition Space – Craft Training – Quality Control – Work Planning
8	Pedestal/Embed Interface Seals Fail	Mitigate	– Perform additional sealing (epoxy) of cracks around pedestals – Design seams to minimize the number that are placed over cracks – Design/mockup – External SME Design Review – Craft Training – Quality Control – Work Planning
9	Test Water Chemistry Degrades Liner	Mitigate	– Condition Water as Needed
10	Failure at Wall-Floor Transition (Wall Movement)	Mitigate	– Design/mockup – External SME Design Review – Craft Training – Quality Control – Work Planning
11	QC Missed Quality Defects (Program Failure)	Mitigate	– Train QC by Manufacturer – Use Manufacturer's QC Inspectors – Audit QC Program
12	Customer Challenges Leak Test Acceptance	Mitigate	– "Buy –In" Up Front
13	Failure at Wall/Floor Transition (Design/Construction)	Mitigate	– Craft Training – Quality Control – Work Planning – External (SME) Review
14	Poor Adhesion Due to Poor Surface Preparation	Mitigate	– Craft Training – Quality Control – Work Planning
15	Excessive Tears and Pinholes	Mitigate	– Repair – Craft Training – Quality Control – Work Planning

16	An interpretation of code is made and the coating is determined not approved for use other than concrete protection	Mitigate	– Evaluate and issue white paper (CSE)
17	FHA Issues	Accept	– Has been evaluated and meets requirement (risk has been managed)
18	Do Not Allow For Secondary Repair Method During Leak Test	Mitigate	– Buy in from customer – Strategy for Repair – Involve SME's to ID Repair Systems
19	QC Records Challenged After Construction	Mitigate	– Concurrence Leak Test is Accepted – QC Records Reviewed Prior to Leak Test
20	Poor Equipment	Mitigate	– M&TE Program – Use Best Available Equipment – Test and Validate Use – Storage to be Adequate
21	Undetected Lightning Strike of Drain Well	Accept	
22	Coating material is tested as a barrier material, and evaluated for withstanding a static head, but it fails to perform both functions.	Mitigate	– Evaluate and issue white paper with manufacturer input
23	Incorrect Coating Material Selected	Mitigate	– Engineering Research of Vendor Data & Select Appropriate material – Perform exposure testing to qualify coating material
24	New Cracks Develop During Hydro (see #18)	Accept	
25	TR&C change is not Approved by DOE	Avoid	– Obtain DOE concurrence before proceeding
26	Holiday test is ineffective and misses pin holes	Mitigate	– Craft Training – Quality Control – Work Planning
27	Cracking occurs between layers (alligatoring)	Mitigate	– Craft Training – Quality Control – Work Planning

28	Surface preparation too rough/too smooth	Mitigate	– Craft Training – Quality Control – Work Planning
29	Installation is inferior quality	Mitigate	– Craft Training – Quality Control – Work Planning
30	Coating not completely cured before leak test	Avoid	– Review curing times with manufacturer
31	Bridged cracks move under weight of hydro and tear coating	Mitigate	– Add fabric to coating installation in floor – Change coating system
32	Coating fails (shear) over bridged cracks	Mitigate	– Review with manufacturer to validate application
33	Industrial hazards are found with application	Mitigate	– Review MSDS – Perform AHA – Provide lighting
34	Amine blushing (top layer peels) during leak test	Mitigate	– Inspect immediately prior to leak test
35	Erosion of coating by introduction of water	Mitigate	– Use baffle/deflection plate – Control flow
36	Coating material is tested as a barrier material, and evaluated for withstanding a static head, but it fails to perform both functions.	Mitigate	– Evaluate and issue white paper with manufacturer input
Opportunities			
ID	**Event Title**	**Handling Strategy**	**Handling Strategy Description**
	No opportunities identified		

Option 8 Synthetic Liner – Pre-Mortem Results

ID	Event Title	Handling Strategy	Handling Strategy Description
1	Poor Extrusion Welds/Welding of Seams	Mitigate	– Qualified Personnel – Mock-up & Test – Qualified Equipment – Craft Training – Quality Control – Work Planning – Daily Samples/Testing – Environmental Condition Space as needed
2	Damaged Material (Damaged on-site)	Mitigate	– Quality Control (Inspections that meet vendor requirements) – Access Limitations – Protective Cover – Work Sequencing – Lighting
3	Damage During Installation	Mitigate	– Craft Training – Quality Control – Work Planning – Work Processes (control sharp objects) – Procedures that meet vendor Requirements – Observers – Lighting – Color selection if available
4	Manufacturer Defect	Mitigate	– Pre-installation Inspection of "Salient" properties – Shipping, Handling, Storage Controls – Review vendor QA/QC Program – Review Vendor Reputation – Review Vendor Production Variation (e.g. porosity)
5	Operating Pressure Exceeds Design/Experience Threshold (e.g. Liner cannot qualify "zero" leakage for head based on previous data and normal usage)	Mitigate	– Mock-up & Test

6	Not All Cracks Originate in Floor	Mitigate	– Secondary Injection System for Wall – QC Wall Coating System – Evaluate Wall/Liner Connection – Evaluate use of liner on interior wall
7	Irregularity On Floor Creates Puncture During Hydro-Test	Mitigate	– Floor Cleaning, Inspection & Repair as required to achieve a smooth surface – Use filler (e.g. mortar, epoxy) as needed
8	Pedestal/Embed Interface Seals Fail	Mitigate	– Perform engineering research of vendor data & select appropriate liner material – Perform exposure testing to qualify liner – Design/mockup – External SME Design Review – Craft Training – Quality Control – Work Planning – Review what surface treatment is best with liner vendor as part of the design process – Review special features/products of liner system to cover pedestals and corners – Determine if special order sizes can be used to minimize seams.
9	Test Water Chemistry Degrades Liner	Mitigate	– Condition Water as Needed
10	Failure at Wall-Floor Transition (Wall Movement)	Mitigate	– Design/mockup – External SME Design Review – Craft Training – Quality Control – Work Planning – Do Not connect liner to wall
11	QC Missed Quality Defects (Program Failure)	Mitigate	– Train QC by Manufacturer – Use Manufacturer's QC Inspectors – Audit QC Program
12	Customer Challenges Leak Test Acceptance	Mitigate	– "Buy –In" Up Front

13	Failure at Wall/Floor Transition (Design/Construction)	Mitigate	– Craft Training – Quality Control – Work Planning – Do Not connect Liner to Wall – External (SME) Review
14	Poor Adhesion Due to Poor Surface Preparation	Mitigate	– Craft Training – Quality Control – Work Planning
15	Excessive Tears and Repairs	Mitigate	– Replace in Lieu of Repair – Craft Training – Quality Control – Work Planning
16	Wall of Pedestal (Concrete) Delamination During Installation	Mitigate	– Craft Training – Quality Control – Work Planning – Pre-approved Repair Techniques
17	Liner Catches On Fire (FHA Issues)	Mitigate	– Select Liner Material (engineering Evaluation process) – Fire Protection (as needed) – Controls
18	Do Not Allow For Secondary Repair Method During Leak Test	Mitigate	– Buy in from customer – Strategy for Repair – Involve SME's to ID Repair Systems
19	QC Records Challenged After Construction	Mitigate	– Concurrence Leak Test is Accepted – QC Records Reviewed Prior to Leak Test
20	Poor Equipment	Mitigate	– M&TE Program – Use Best Available Equipment – Test and Validate Use – Provide adequate storage
21	Undetected Lightning Strike of Drain Well	Accept	
22	Elevated Ground Water Table De-bonds Liner	N/A	
23	Incorrect Liner Material Selected	Mitigate	– Perform engineering research of vendor data & select appropriate material – Perform exposure testing to qualify liner
24	TR&C change is not approved by DOE	Mitigate	– Obtain DOE concurrence before proceeding – Develop a strategy to perform crack repair near restrained edges

Opportunities			
ID	**Event Title**	**Handling Strategy**	**Handling Strategy Description**
24	Vacuum Box Tests can be performed prior to leak test	Exploit	
25	Eliminate Coating on Floor (No Coating Required)	Exploit	
26	Using a liner for SDU 6 will serve to evaluate the use of liners for future SDUs	Exploit	
27	An opportunity exists to extend the liner to cover the SDU walls	Enhance	– Evaluate this as a potential benefit and if so, install liner up SDU 6 walls.