VERIFICATION TEST PLAN
EPOXYTEC INTERNATIONAL INC.
For
EPA/NSF Environmental Technology Verification Program

Water Quality Protection Center

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TEST PLAN FOR VERIFICATION OF EPOXYTEC INTERNATIONAL EPOXYTEC CPP COATING FOR WASTEWATER COLLECTION SYSTEMS

Prepared for:

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With support from the
U.S. Environmental Protection Agency

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Foreward

The U.S. Environmental Protection Agency (EPA) is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory (NRMRL) is the Agency's center for investigation of technological and management approaches for preventing and reducing risks from pollution that threaten human health and the environment. The focus of the Laboratory's research program is on methods and their cost-effectiveness for prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites, sediments, and ground water; prevention and control of indoor air pollution; and restoration of ecosystems. NRMRL collaborates with both public and private sector partners to foster technologies that reduce the cost of compliance and to anticipate emerging problems. NRMRL's research provides solutions to environmental problems by: developing and promoting technologies that protect and improve the environment; advancing scientific and engineering information to support regulatory and policy decisions; and providing the technical support and information transfer to ensure implementation of environmental regulations and strategies at the national, state, and community levels.

This publication has been produced as part of the Laboratory's strategic long-term research plan. It is published and made available by EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

Acknowledgements

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Acronyms

ASTM	ASTM International
CIGMAT	Center for Innovative Grouting Materials and Technology
EPA	United States Environmental Protection Agency
ETV	Environmental Technology Verification
NSF	NSF International
ORD	Office of Research and Development
QA	quality assurance
QAPP	quality assurance project plan
QC	quality control
UH	University of Houston
WQPC	Water Quality Protection Center

Glossary of Terms

Bonding Test - Tests performed to determine the bonding strength of coatings to selected substrates.

Coatings - Materials applied to protect substrate the substrate against corrosive environment.

Holiday Test - Testing coated materials with pinholes in the coating, which penetrate into the substrate.

1 INTRODUCTION

1.1 Background (City of Houston-University of Houston Study)

University of Houston (UH)/CIGMAT researchers have been investigating the performance of various coatings for use in the City of Houston's wastewater facilities. Performance of each coating has been studied with wet (representing rehabilitation of existing wastewater collection systems) and dry (representing new construction) concrete and clay bricks. The studies have been focused on (1) applicability and performance of the coating under hydrostatic pressure (with an evaluation period between six to nine months) (2) chemical exposure with and without holidays in the coating (initial evaluation period of six months) and (3) bonding strength (initial evaluation period of twelve months). Chemical tests and bonding tests on over twenty coating materials are being continued at UH. The long-term data collected on each coating can further help engineers and owners to better understand the durability of coated materials in wastewater environments.

1.2 Technical Approach

The overall objective of this test plan is to describe a testing program for systematically evaluate coating materials used in wastewater systems to control the deterioration of cementitious materials. Specific testing objectives are to:

- evaluate the acid resistance of coated concrete specimens and clay bricks, with and without holidays; and
- determine the bonding strength of coating materials to concrete and clay bricks.

Testing will use relevant ASTM and CIGMAT standards. Specimens made from the coating material, in addition to uncoated concrete and clay specimens will first undergo characterization testing to determine if they are suitable for use during the acid resistance and bonding strength tests. The coating manufacturer will then be responsible for coating the concrete and clay specimens, under the guidance of CIGMAT staff members. Finally, the coated specimens will be evaluated over the course of six months.

1.3 Test Plan Schedule and Milestones

The tests described herein will be completed within six months from the start date. The data will be compiled and summarized in a report to NSF International within two months of the conclusion of testing.

1.4 Roles and Responsibilities

This section defines the participants in this technology verification and their roles and responsibilities.

1.4.1 Verification Organization (NSF)

- Coordinate with CIGMAT, the Testing Organization, and the Vendor to prepare and approve a product-specific test plan using this generic test plan as a template and meeting all testing requirements included herein;
- Coordinate with the ETV Coatings Technical Panel, as needed, to review the product-specific test plan prior to the initiation of verification testing;
- Coordinate with the EPA Water Quality Protection Center Project Officer to approve the product-specific test plan prior to the initiation of verification testing;
- Review the quality systems of the testing organization and subsequently, qualify the testing organization;
- Oversee the coatings evaluations and associated laboratory testing;
- Review data generated during verification testing;
- Oversee the development of a verification report and verification statement;
- Print and distribute the verification report and verification statement; and
- Provide quality assurance oversight at all stages of the verification process.

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1.4.2 U.S. Environmental Protection Agency (EPA)

This test plan has been developed with financial and quality assurance assistance from the ETV Program, which is overseen by the EPA's Office of Research and Development (ORD). The ETV Program's Quality Assurance Manager and the WQPC Project Officer will provide administrative, technical, and quality assurance guidance and oversight on all ETV WQPC activities, and will review and approve each phase of the verification project. The primary responsibilities of EPA personnel are to:

- Review and approve test plans, including the quality assurance project plans (QAPPs);
- Sign the test plan signoff sheet;
- Review and approve the verification report and verification statement; and
- Post the verification report and verification statement on the EPA ETV website.

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1.4.3 Technology Panel

A Technology Panel was formed to assist with the review of the coatings test plan. Input from the panel ensures that data generated during verification testing are relevant and that the method of evaluating different technologies is fair and consistent. All product-specific grout test plans are subject to review by representatives of the Technology Panel and will be approved by the WQPC Program Manager, the WQPC Project Officer, and the vendor.

1.4.4 Testing Organization (CIGMAT Laboratories at UH)

The Testing Organization for verifications conducted under this test plan is CIGMAT Laboratories at the University of Houston. The primary responsibilities of the Testing Organization are:

- Coordinate with the Verification Organization and Vendor relative to preparing and finalizing the product-specific Test Plan;
- Sign the test plan signoff sheet;
- Conduct the technology verification in accordance with the Test Plan, with oversight by the Verification Organization;
- Analyze all samples collected during the technology verification process, in accordance with the procedures outlined in the Test Plan and referenced SOPs;
- Coordinate with and report to the Verification Organization during the technology verification process;
- Provide analytical results of the technology verification to the Verification Organization; and
- If necessary, document changes in plans for testing and analysis, and notify the Verification Organization of any and all such changes before changes are executed.

CIGMAT supports faculty, research fellows, research assistants and technicians. The CIGMAT personnel will work in-groups to complete the tests described in this test plan. All the personnel report to the Group Leader and the CIGMAT Director. The CIGMAT Director is responsible for appointing Group Leaders, who, with his approval, are responsible for drawing up the schedule for testing. Additionally, a Quality Assurance (QA) Engineer, who is independent of the testing program, will be responsible for internal audits.

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1.4.5 Vendor (Epoxytec International Inc.)

- Provide the Testing Organization with coating samples for verification (this includes applying the coating materials to test specimens at the CIGMAT facilities);

- Complete a product data sheet prior to testing. (Refer to Appendix B);
- Provide start-up services and technical support as required during the period prior to the evaluation;
- Provide technical assistance to the Testing Organization during verification testing period as requested; and
- Provide funding for verification testing.

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1.4.6 Product Description

Epoxytec CPP™ is a two-component moisture sensitive, highly adhesive, chemical resistant, 100% solid strength epoxy paste with superior adhesion. It can be used as an adhesive, patching filler, or a protective high-build, stand-alone protective liner. It bonds to concrete, steel, stone, wood, brick and many other construction materials.

2 TEST FACILITY

The testing will be performed in the CIGMAT Laboratories at the University of Houston, Houston, Texas. The CIGMAT Laboratories are located in the Central Campus of UH at 4800 Calhoun Road (off interstate highway I-45 South toward Galveston).

The CIGMAT laboratories and affiliated facilities are equipped with devices that can perform all of the coatings tests in this test plan. Molds are available to prepare the specimens for testing, and all acid resistance and bonding strength test procedures are documented in standard operating procedures.

3 EXPERIMENTAL DESIGN

The test plan includes characterization of coating materials used on concrete and clay brick surfaces. In addition, holiday tests and bonding strength tests on the coated/lined materials will be performed.

3.1 Preparation of Test Specimens

Testing will be completed using both concrete and clay brick specimens. The concrete specimens will be prepared in the CIGMAT laboratory by CIGMAT personnel prior to application of the coating. The clay brick specimens will be obtained from a local brick supplier and prepared to the proper specifications by CIGMAT staff. The source of materials for all specimens will be identified in the final report.

3.1.1 Concrete Specimens

3.1.1.1 Preparation of specimens

Mix proportions for the concrete are summarized in Table 3-1. The cylindrical specimens will be cast in 3-in (diameter) × 6-in (length) plastic molds. Wooden molds will be used to cast the 1.5-in × 2-in × 6-in prism specimens. The concrete specimens will be cured for at least 28 days at room conditions.

Table 3.1 Mix Proportions for Concrete

Materials	Amount
Cement	6 bags
Sand	1400 -1500 lbs
Coarse Aggregate	1600 -1700 lbs
Water	320 – 330 lbs

The materials used for making the specimens shall meet the following specifications:

Cement – ASTM C150 Type 1, purchase in 94 lb bags
Sand – ASTM C33
Coarse aggregate – ASTM C33, ranging in size from No.4 to 1.5 in sieves

The concrete shall be prepared by combining proportional amounts of cement, sand, and coarse aggregate in a container and mixing the materials with a standard concrete mixer until the mixture is uniform in appearance. The specimen molds shall be filled with the mixture and shall be mechanically vibrated until the concrete in the molds is the appropriate consistency.

3.1.1.2 Number of specimens to be prepared

A total of 20 concrete cylinders and 36 concrete prisms shall be prepared. This number of specimens is sufficient for testing replicate and control samples.

3.1.2 Clay Brick Specimens

3.1.2.1 Preparation of Specimens

Clay bricks will be purchased new from a brick supplier. The bricks shall be standard sewer bricks. The source and characteristics of the bricks shall be recorded and the information included in the final report. The bricks shall be cut at the CIGMAT laboratory into 1.5-in × 2-in

× 6-in prism specimens using a diamond-tipped saw blade. The prepared specimens shall be stored at room conditions.

3.1.2.2 Number of specimens to be prepared

A total of 56 clay brick prisms shall be prepared. This number of specimens is sufficient for testing replicate and control samples.

3.1.3 Coating Specimens

3.1.3.1 Preparation of Specimens

Specimens made only of the coating material shall also be prepared in 1.5-in (diameter) × 3-in (length) plastic molds. This information is retained and reported to verify the coating in any future applications. It can be used to determine if the coating material tested through the ETV WQPC is the same as that is being applied.

3.1.3.2 Number of specimens to be prepared

A total of 6 coating specimens shall be prepared for characterization testing.

3.2 Evaluation of specimens

The concrete cylinders and prisms, clay brick prisms, and raw coating material cylinders shall be evaluated as described in this section to determine if they meet the required properties for use in the verification testing. The specimens shall be characterized using the following tests, as specified in Table 3-2:

Table 3-2. Test Names / Methods

Test Name	Test Method
Pulse Velocity	ASTM C 597
Holiday Test (Chemical Resistance)	ASTM G20 / CIGMAT CT-1-99
Bonding Strength	ASTM C 321/ CIGMAT CT3 (Sandwich Method) ASTM D 4541/CIGMAT CT2 (Pull-Off Strength)

The pulse velocity and unit weight of all the specimens will be determined for quality control purposes. Additional specimens will be used to determine the compressive (3 specimens) and flexural strength (3 specimens) of concrete and flexural strength of clay bricks (3 specimens) (Table 3-3). The average values of the strengths will be reported in the final report. Note that the strength tests are done for completeness and not for quality control.

Table 3-3. Number of Specimens Used for Each Characterization Test

Material	Number of Specimens Used in Test				
	Unit weight	Pulse velocity*	Water absorption**	Flexure***	Compression***
Coating	6	6	6	None	None
Concrete Cylinders	20	20	10	None	3
Concrete Prisms	36	36	None	3	None
Clay Prisms	56	56	10	3	None

*Unit weight measurement taken on specimens prior to this test.

** Specimens used after the Pulse Velocity test.

*** Flexure and compression tests are performed for informational purposes only.

The unit weight of concrete and clay brick will be in the range of 140-160 pcf and 120-140 pcf, respectively. The pulse velocity of concrete and clay brick will be in the range of 15000-16000 ft/sec and 7500-8500 ft/sec, respectively. The water absorption of concrete and clay brick will be in the range of 0.5-2 % and 18-30% respectively. The flexural strength of concrete and clay brick will be in the range of 900-1300 psi and 700 -1100 psi, respectively. The compressive strength of concrete and clay brick will be in the range of 4000-5000 psi.

3.3 Coating Application

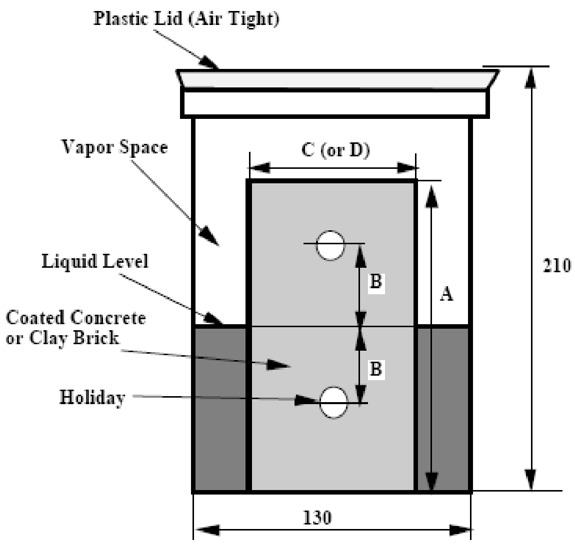
The concrete and clay specimens shall be coated by Epoxytec or their representative in the CIGMAT laboratory at the UH. Wet specimens are immersed in water for at least 7 days before coating the specimens. The manufacturer of the coating will select the method to prepare the specimens. The details will be summarized in the final report.

3.4 Evaluation of coated specimens

Coated concrete and clay brick specimens will be tested for chemical resistance and bonding strength after the coating is cured in accordance with the coating manufacturer's specifications.

3.4.1 Preparation of Exposure Vessels

Typical sizes of the clean vessels that will be used in the holiday tests are shown in Fig. 3-1. In each bottle there will be only one coated specimen. Once the vessels are closed, they shall be airtight. No venting of the vessels is required.



A ----- 152 mm (6.0 in.) height concrete specimen or clay brick
B ----- 38 mm (1.5 in.) holiday location
C ----- 76 mm (3 in.) diameter concrete cylinder
D ----- 152 x 64 x 45 mm cross section of clay brick

Figure 3-1. Test configuration for the Holiday Test.

3.4.2 Placement of specimens in vessels

The specimens will be placed in water or 1% sulfuric acid solution as shown in Fig. 3-1. Half the specimen will be submerged in the test liquid (CIGMAT CT 1).

3.4.3 Conditions for storage of vessels

The specimens will be stored at room temperature (72^{o}F).

3.5 Analytical Procedures

3.5.1 Holiday Test

In this test (CIGMAT CT 1-99), the changes in (1) diameter/dimension at the holiday level (2) weight of specimen and (3) appearance of specimen will be monitored at regular intervals. The test reagents selected for this study are (1) deionized (DI) water (pH = 5 to 6) and (2) 1% sulfuric acid solution (a pH of 1 represents a long-term, worst-case condition in a wastewater collection system, arising from formation of hydrogen sulfide). Control tests will be performed with no holidays.

Dry and wet concrete and clay brick specimens will be coated. Dry specimens are dried at room condition for at least seven days before coating the specimens.

Specimens will be prepared by stripping the molds from the concrete cylinders completely. Clay bricks will be cut to a size of 2-in. × 1.5-in. × 6-in. for this test. Dry and wet specimens shall be coated on all sides. For the test, two radial holidays of different diameters will be drilled into each specimen approximately 0.5-in. deep (Fig. 3-1). The diameter of the drill bits used shall not be less than three times the coating thickness, and they shall be selected from the following standard diameters: 3 mm (1/8”), 6 mm (1/4”), and 13 mm (1/2”). Both holidays shall lie in the same axis.

In order to study the chemical resistance of coated concrete and clay brick materials, as shown in Fig. 3-1, the specimens will be immersed in a selected test reagent to half the specimen height in a closed vessel so that the specimens are exposed to both the liquid phase and vapor phase. This method is intended for use as a relatively rapid test to evaluate the acid resistance of coated specimens under anticipated service conditions.

The specimens shall be inspected after 1 and 6 months to determine if there are blisters, cracking of the coating, and /or erosion of the coating in the immersed solution. The results will be summarized as shown in Table 3-4.

All observations shall be recorded at the time of observation and reported in the final report.

Table 3-4. Sample of Holiday Test Results (Liquid Phase) for Coated Concrete (Dry) After One (1) Month of Immersion

Concrete	Holiday	Medium (No. of Specimens)		Total No.	Remarks
		DI Water	1% H_2SO_4	%(N/B/C)	
Dry	No Holiday	N(2)	N(2)	4 (100/0/0)	None
	1/8 inch	N(2)	N(2)	3 (100/0/0)	None
	1/2 inch	---	N(2)	2 (100/0/0)	None
Total No. %(P/B/F)		4 (100/0/0)	6 (100/0/0)	10 (100/0/0)	Total of 10 specimens tested
Remarks	After one (1) month of immersion	None	None	None	No damage

N=No blister or crack; B=Blister; C=Cracks.

3.5.2 Bonding Strength Tests (Sandwich Method and Pull-Off Method)

These tests will be performed to determine the bonding strength between concrete/clay brick specimens and the coating material over a period of six months. The number of specimens to be used for testing is summarized in Tables A-1 and A-2. A total of twelve sandwich and twelve pull-off tests shall be performed on coated concrete samples. The same number of tests shall be conducted with coated clay bricks.

3.5.2.1 Sandwich Method

In this test (CIGMAT CT 3-00), the coating will be sandwiched between a pair of rectangular concrete block and clay brick specimens and then tested for bonding strength (Fig. 3-2). The bonding strength of the coating will be the failure load divided by the bonded area. Also the failure type (see Table 3-5) will be identified.

In the sandwich method test, the coating will be sandwiched between a pair of rectangular concrete block and clay brick specimens and then tested for bonding strength (Fig. 3-2). Both dry and wet specimens will be used to represent the extreme coating conditions. Dry specimens are dried at room conditions for at least seven days before coating the specimens. Wet specimens are immersed in water for at least seven days before coating the specimens. The manufacturer of the coating will select the method to prepare the specimens and also coat them. The details will be summarized in the final report. All the bonded specimens will be cured under water up to the point of testing. A total of twenty-four concrete and twenty-four clay brick prisms will be used in this test.

The sandwich method bonding strength tests will be performed to determine the bonding strength between the concrete/clay brick and the coating material over a period of six months. A total of 12 tests with concrete and 12 tests with clay bricks are planned.

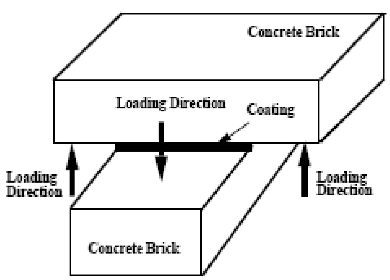
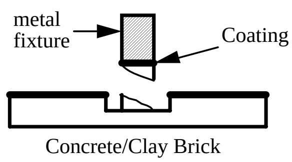
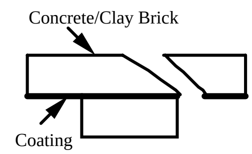
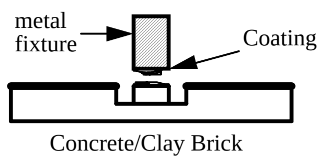
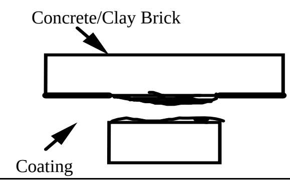
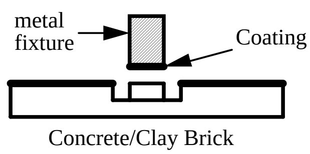
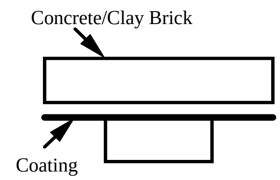
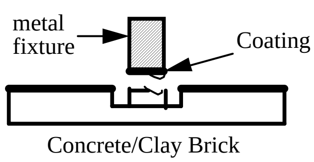
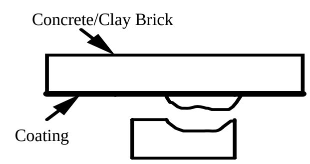
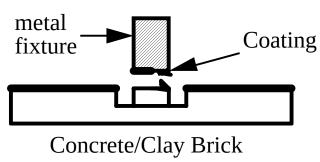
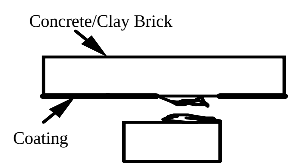


Figure 3-2. Sandwich Test configuration.

Table 3-5. Failure Types in CIGMAT CT 2 Test and CIGMAT CT 3 Tests

Failure Type	Description	CIGMAT CT 2 Test (Modified ASTM D4541)	CIGMAT CT 3 (ASTM C321 Test)
Type B1	Substrate Failure		
Type B2	Coating Failure		
Type B3	Bonding Failure		
Type B4	Bonding and Substrate Failure		
Type B5	Bonding and Coating Failure		

3.5.2.2 Pull-Off Method

In this test (CIGMAT CT 2-00), a 2-in. diameter circular area will be used for testing (Fig. 3-3). Coated concrete prisms and clay bricks will be cored using a diamond core drill bit to a predetermined depth to isolate the coating and a metal fixture will be glued to the isolated coating section using a rapid setting epoxy.

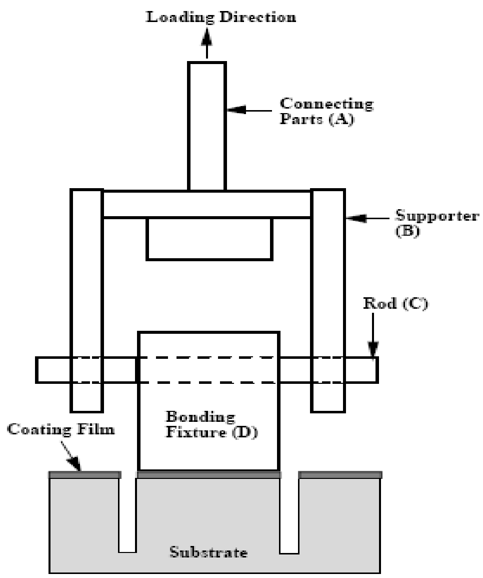


Figure 3-3. Pull-Off Test Method Configuration.

Dry and wet concrete and clay brick specimens will be coated. Dry specimens shall be dried at room conditions for at least seven days before coating the specimens. Wet specimens shall be immersed in water for at least seven days before coating the specimens. The manufacturer of the coating will select the method to prepare the specimens and also coat them. The details will be summarized in the final report.

A 2-in. diameter circular area will be used for testing (Fig. 3-3). Coated concrete prisms and clay bricks will be cored using a diamond core drill to predetermined depth to isolate the coating and a metal fixture shall be glued to the isolated coating section using a rapid setting epoxy. A total of 24 tests with coated concrete and coated bricks shall be performed.

The failure strength will be equal to the failure force divided by the area. Also the failure type will be identified as shown in Table 3-6.

Table 3-6. Sample of Test Results for Bonding Strength of Coating with Dry Concrete

Concrete	Curing Time (days)	Failure Modes					Failure Strength (psi)
		Type 1	Type 2	Type 3	Type 4	Type 5	
Dry	10				X		192
	10				X		260
	90			X			174
	90			X			217
	180			X			156
	180			X			267
Total No. (% Failure)		0%	0%	67%	33%	0%	Total no. of successful lab. tests is 6
Remarks	Up to twelve (12) months	None	None	Dominant failure mode		None	Average strength is 211 psi.

Type 1 = Concrete failure
Type 2 = Coating failure
Type 3 = Bonding failure
Type 4 = Combined concrete and bonding failure
Type 5 = Combined coating and bonding failure

3.3 Sampling Events

3.3.1 General Description

Tables A1 and A2 summarize the samples needed for each test condition (dry versus wet; concrete and clay bricks). Bonding tests are planned after two weeks (or at the earliest time specified by the coating manufacturer), 3 months and 6 months after coating. The planned tests with coated concrete are summarized in Table 3.7.

Table 3.7. Total Number of Tests with Coated Concrete

Exposure Time	Holiday Test*		Bonding Strength Test	
	DI Water	1% H_2SO_4	Sandwich	Pull-Off
2 Weeks			4	4
1 Month	8	12		
3 Months			4	4
6 Months	8	12	4	4

* The same specimens are monitored for 6 months.

4 DATA EVALUATION AND REPORTING

CIGMAT is responsible for managing all the data and information generated during the testing program. To maintain good quality data, specific procedures shall be followed during data reduction, validation, and reporting. These procedures are discussed below.

4.1 Data Reporting

All the data collected during the testing will be processed and analyzed as outlined in Section 5. All data will be processed and reported in hard copy. The report will include the main text with summary of the test results. The appendix will include sections on material tests, hydrostatic test, chemical-holiday test and bonding test. Photographs on the coated surfaces and bonding test specimens will be included in the report. Also the information provided by the coating/lining manufacturer will be included in the appendix.

After discussions with NSF and EPA, appropriate information will be posted on their web sites.

4.2 Data Reduction

Data reduction refers to the process of converting the raw results from the equipment into data that of use in selecting the material for wastewater system maintenance and rehabilitation. The data will be obtained from logbooks, data sheets, and computer outputs.

4.3 Data Validation

The person performing the test shall verify the completeness of the appropriate data forms. The CIGMAT Director will review laboratory logbooks and data sheets on a regular basis to verify completeness. The CIGMAT technical staff will inspect the testing equipment and keep them in working condition.

5 QUALITY ASSURANCE PROJECT PLAN (QAPP)

The QAPP for this testing plan specifies procedures that shall be used to ensure quality and integrity. Careful adherence to these procedures will ensure that the data generated from the verification testing will provide sound analytical results that can serve as the basis for performance testing.

The qualified testing organization, Center for Innovative Grouting Materials and Technology (CIGMAT), with oversight from NSF, should ensure the QAPP is implemented during all the testing activities. For each batch of concrete and clay brick purchased to perform the laboratory tests, 5% of the specimens will be tested to ensure the quality. The testing will include unit weight, pulse velocity and water absorption of the specimens. If the maximum or minimum value of the batch exceeded $\pm$20% of the mean value the batch will be rejected.

CIGMAT researchers and technical personnel will perform the tests. Primary responsibility for ensuring that the sampling and testing activities comply with the accepted QA/QC requirements shall rest with the Director of CIGMAT with oversight by NSF. If problem arises or any test data appear unusual, they shall be thoroughly documented.

5.1 Quality Control Indicators

5.1.1 Representativeness

As specified by NSF, representativeness of samples for the ETV will be ensured by executing consistent sample collection procedures, including sample locations, timing of sample collection, sampling procedures, sample preservation, sample packaging, and sample transport.

5.1.2 Completeness

Completeness refers to the amount of data collected from a measurement process compared to the amount that was expected. For this ETV test plan, completeness refers to the proportion of valid, acceptable data generated using each method. The completeness objective for data generated through this test plan is 85 percent.

$$Completeness = \left(\frac{n_{valid\ and\ acceptable}}{n_{total}}\right) \times 100 \qquad \text{(Equation 1)}$$

5.1.3 Precision

As specified in Standard Methods (Method 1030 C), precision is specified by the standard deviation of the results of replicate analyses. The overall precision of a study includes the random errors involved in sampling as well as the errors in sample preparation and analysis.

$$\int S\tan dard\ Deviation = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-1}} \qquad \text{(Equation 2)}$$

Where:

$\bar{x}$ = sample mean
x_i = ith data point
n = number of data points

6 ASSESSMENTS

6.1 Audit Reports

Any QA inspections will be formally documented in an Audit Report and submitted to the EPA Center Manager, EPA Center Quality Manager, and NSF Partner Manager for review. The NSF Partner Manager, Project Coordinator, Manager, QA and Safety, or other qualified NSF designee will conduct a technical system audit and a performance evaluation audit of measurement systems used in testing at least once during the verification testing period for a given technology.

6.2 Corrective Action Plan

This test plan shall include the predetermined acceptance limits, the corrective action to be initiated whenever such acceptance criteria are not met, and the names of the individuals responsible for implementation. Routine corrective action may result from common monitoring activities, such as:

Performance evaluation audits
Technical systems audits

Ultimately, responsibility for project quality assurance/quality control (QA/QC) during implementation of this Test Plan rests with the Verification Organization, specifically the Verification Organization Project Manager, with appropriate input from the Verification Organization QA/QC Manager. However, immediate QA/QC for individual tasks (e.g. sample collection, handling, preparation, and analysis) rests with the individuals and organization performing the task at hand, as described this Test Plan. The Verification Organization Project Manager will coordinate oversight and/or audits of these tasks with the Testing Organization

Project Manager to ensure that the Test Plan is being executed as written, and that nonconformances are appropriately reported and documented.

Corrective action shall be taken whenever a nonconformance with the Test Plan occurs. Nonconformances can occur within the realm of sampling procedures, sample receipt, sample storage, sample analysis, data reporting, and computations.

7 SAFETY CONSIDERATIONS

Coating the specimens for the tests will be done at the covered test CIGMAT facility at UH, which as adequate ventilation. The research personnel and technicians on-site will take all necessary precautions to ensure safety and compliance with local and federal regulations.

CIGMAT maintains a health and safety plan, which shall be made available to personnel involved in this project. Adherence to health and safety plan shall be ensured throughout the duration of the project.

8 REFERENCES

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ATTACHMENT I

Tables A1 & A2

Laboratory Tests for Coating Materials with Concrete & Clay Bricks

Table A1. Planned Laboratory Tests for Coating Materials with Concrete

ASTM /CIGMAT Standard	Name of test	Number of specimens (Dry)	Number of specimens (Dry)	Number of specimens (Wet)	Number of specimens (Wet)	Type of specimens	Remarks
		WITH HOLIDAYS	*WITHOUT HOLIDAYS*	*WITH HOLIDAYS*	*WITHOUT HOLIDAYS*		
ASTM G20/ CIGMAT CT 1	Chemical Resistance of Pipeline Coatings					Concrete Cylinder 3 in. diameter and 6 in. height	20 specimens must be coated and tested over a period of six months
	3 % H_2SO_4	4	2	4	2		
	D.I. Water	2	2	2	2		
ASTM C321/ CIGMAT CT 3	Bond Strength of Coating/ Mortars	---	6	-----	6	Concrete Rectangular Blocks 2 1/4 in. X 3 3/4 in. X 8 in.	12 pairs of bonding specimens
ASTM D4541/ CIGMAT CT 2	Pull-Off Strength of Coatings Using Portable Adhesion Testers	---	6	----	6	Concrete Rectangular Blocks 2 1/4 in. X 3 3/4 in. X 8 in.	12 blocks must be coated

Table A2. Planned Laboratory Tests for Coating Materials with Clay Bricks

ASTM / CIGMAT Standard	Name of test	Number of specimens (Dry)	Number of specimens (Dry)	Number of specimens (Wet)	Number of specimens (Wet)	Type of specimens	Remarks
ASTM G20/ CIGMAT CT 1	Chemical Resistance of Pipeline Coatings	*WITH HOLIDAYS*	*WITHOUT HOLIDAYS*	*WITH HOLIDAYS*	*WITHOUT HOLIDAYS*	Clay bricks	20 specimens must be coated and tested over a period of one year
	1 % H_2SO_4	4	2	4	2		
	D.I. Water	2	2	2	2		
ASTM C321/ CIGMAT CT 3	Bond Strength of Coatings/ Mortars	---	6	-----	6	Clay bricks	12 pairs of bonding specimens
ASTM D4541/ CIGMAT CT 2	Pull-Off Strength of Coatings Using Adhesion Testers	---	6	----	6	Clay bricks	12 blocks must be coated

APPENDIX A

CIGMAT Test Methods

CIGMAT CT 1-99 *Standard Test Method of Coated or Lined Concrete and Clay Bricks*

CIGMAT CT 2 – 00 *Standard Test Method for Pull-Off Strength of Coatings or Linings: Laboratory Test and Field Test*

CIGMAT CT 3-00 *Standard Test Method for Bonding Strength of Coatings and Mortars: Sandwich Method*

APPENDIX B

Vendor Data Sheet

VENDOR DATA SHEET
PHYSICAL PROPERTIES OF COATING

Coating Product Name:

Coating Product Vendor Name and Address:

Coating Type:

Testing Method	Vendor Results
Tensile Adhesion to Concrete (ASTM D 4541)	Substrate Failure
Chemical Resistance (ASTM D 543) (3 % $H_2 SO_4$)	Hydrogen Sulfide, mild Acids
Water Vapor Transmission (ASTM D 1653/E 1907)	0
Bending Strength or Tensile Strength (ASTM D 790)	8,900 PSI
Hardness- Shore D (ASTM D 2240)	82
Impact Resistance (ASTM G 14)	
Volatile Organic Compounds - VOC's (ASTM D 2832)	0

Worker Safety	Result/Requirement
Flammability Rating	Unknown
Known Carcinogenic Content	None
Other hazards (corrosive)	Corrosive in uncured state (B component only)

Environmental Characteristics	Result/Requirement
Heavy Metal Content (w/w)	None
Leaching of Cured Coating (TCLP)	None
Disposal of Cured Coating	Non-hazardous solid waste

Application Characteristics	Result/Requirement
Primer Requirement	None
Number of Coats and Thickness	1 coat maximum ¾”
Minimum Application Temperature	40F
Minimum Cure Time Before Handling	2 hrs @ 25C or 77F
Maximum Application Temperature	115F
Minimum Cure Time before Immersion into Service	3 hrs @ 25C or 77F
Type of Surface Preparation Before Coating	Clean substrate, water pressure 3000 psi

Vendor Experience	Comments
Length of time the Coating in Use	20 years
Applicator Training & Qualification Program	Certified Applicators
QA/QC Program for Coating/Lining	Certified Applicators