WASTE MANAGEMENT *Information*

Suggested Specifications for Solidification/Stabilization (S/S) of Waste

These suggested specifications cover the requirements for solidification/stabilization (S/S) of materials contaminated with hazardous and toxic waste. The suggested specifications are an adaptation of the U.S. Army Corps of Engineers (USACE) Guide Specification for Construction, Solidification/ Stabilization of Contaminated Material, CEGS-02160.

Part 1 General

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by basic designation only.

AMERICAN SOCIETY OF TESTING AND MATERIALS (ASTM)

ASTM D 1633	(1996) Compressive Strength of Molded Soil-Cement Cylinders
ASTM D 4832	(1995) Preparation and Testing of Controlled Low Strength Material (CLSM) Test Cylinders
ASTM D 5084	(1990; R 1997) Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter

CODE OF FEDERAL REGULATIONS (CFR)

40 CFR 268	Land Disposal Restrictions

ENVIRONMENTAL PROTECTION AGENCY (EPA)

EPA SW-846	(Rev O; updates I, II, IIA, IIB and III) Test Methods for Evaluating Solid Waste (Vol IA, IB, IC, and II)

1.2 UNIT PRICES

NOTE: *This paragraph should be deleted if the work is in one lump sum contract or there is a separate Measurement and Payment Section. Batch processing is likely to use weight as the method of measurement. Continuous and in situ processes are more likely to use volume as the method of measurement.*

Payment shall be based on the Contract unit price schedule for each [in situ] [metric ton/ton] [cubic meter/cubic yard] of contaminated material entering the S/S process. This unit price shall include the cost for materials, waste feed processing, S/S operations, stockpiles, post-treatment testing and other incidental work associated with the S/S process.

1.2.1 Reprocessing

No payment will be made for reprocessing any processed material not meeting the physical and chemical testing requirements outlined in this section. Reprocessed material shall be deducted from the daily production rate.

1.3 SYSTEM DESCRIPTION

NOTE: *The Contractor is sometimes required to provide treatability study test results prior to performing work at the site. Treatability study test results should include the proposed reagent and mix ratios to be used during full scale treatment. The test results submitted should verify that the mix design proposed meets the post-treatment criteria listed in Table 1. Consideration should also be given to the need to monitor off-gas and dust emissions during the treatability study. Detailed information on testing requirements, test methods, detection limits, and off-gas and dust emission testing requirements should be presented in the appropriate section and referenced here.*

At projects where strict testing protocols are required to adequately determine the effectiveness of the process being tested, the Contractor may be required to provide a "Treatability Study Work Plan" for approval prior to performing the treatability study.

Prior to performing any treatability study, the untreated samples should be tested to verify that they contain the

contaminants of concern at high enough concentrations. Additional testing may be needed to verify that physical properties of the samples are also representative of site conditions.

The last two sentences of this paragraph should be omitted if a specific method of treatment (in situ or ex-situ) is desired.

An [in situ] [pug mill] [ex-situ] [_____] S/S system shall be used which provides a safe, reliable method to treat contaminated material so that the treated material conforms to paragraph PERFORMANCE REQUIREMENTS. A system or procedure, other than described in this section, may be used if the approved SUBMITTALS demonstrate equivalent capabilities. Such approval does not relieve the Contractor of responsibility for meeting specified requirements for safety, reliability, and performance.

1.4 PERFORMANCE REQUIREMENTS

NOTE: *The post-treatment testing criteria listed in Table 1 are only examples. Chemical and physical test criteria should be determined on a site specific basis. Post-treatment criteria may be based on federal regulatory criteria, site-specific risk analyses, or site-specific criteria based on state and local regulations.*

The [Toxicity Characteristic Leaching Procedure as specified in EPA SW-846] [_____] shall be performed on representative samples of treated material. The extract shall meet the post-treatment chemical testing criteria listed in Table 1. Chemical testing required in this section shall be conducted in accordance with Section [_____][CHEMICAL DATA QUALITY MANAGEMENT] [_____]. The treated material shall also meet the physical testing criteria listed in Table 1. The tests listed in Table 1 shall be performed on samples that have been cured for [3] [_____] days.

Table 1. *POST-TREATMENT TEST CRITERIA SECTION*

TEST	TEST VALUE
TCLP	
Arsenic	**[_____] mg/L**
Cadmium	**[_____] mg/L**
Chromium (total)	**[_____] mg/L**
Lead	**[_____] mg/L**
Min. Unconfined Compressive Strength ASTM D 1633	**[_____] kPa**
Max. Permeability ASTM D 5084	**[_____] cm/s**
Maximum Volume Increase	**[_____] percent**

1.4.1 Disposal of Treated Material

NOTE: *Reference the appropriate section which describes requirements for disposal of treated material, including manifests for off-site disposal. Identify on-site disposal locations on the drawings.*

The treated material, upon meeting the physical and chemical testing criteria, shall be disposed of as required by Section [_____].

1.4.2 Emission Controls

NOTE: *Site-specific requirements should be added to this paragraph.*

The S/S system shall include control apparatus necessary to meet local, state, and federal regulations for air emissions and dust.

1.4.3 Noise Control

NOTE: *Different day and night noise restrictions may be appropriate.*

The S/S system shall [meet state and local noise pollution control regulations.] [not exceed [_____] decibels at any site boundary.]

1.5 SUBMITTALS

NOTE: *Submittals must be limited to those necessary for adequate quality control. The importance of an item in the project should be one of the primary factors in determining if a submittal for the item should be required.*

Indicate submittal classification in the blank space using "OA" when the submittal requires Owner approval or "FIO" when the submittal is for information only.

Owner approval is required for submittals with a "OA" designation; submittals having an "FIO" designation are for information only.

Work Plan

Work Plan; [_____].

An S/S Work Plan within [60] [_____] days after notice to proceed. No S/S of contaminated material shall be performed until the work plan is approved. A period of [30] [_____] days shall be allowed in the schedule for Owner review and approval of the work plan. The work plan shall address the technical requirements listed in this section and shall include, but is not limited to, the following:

a. Contractor Experience: Information to demonstrate that the S/S Contractor meets the qualification requirements outlined in Paragraph QUALIFICATIONS.

b. Mix Design: The proposed mix design to be used in treating the contaminated material. The proposed source of water to be used for the S/S process shall also be identified.

c. Equipment: Specifications for the proposed homogenization and mixing equipment, batching equipment, and process control instrumentation. Process flow diagrams, mixing times, and processing rates shall be included. Anticipated pretreatment of the contaminated material shall be identified.

d. Drawings: Drawings indicating dimensions and layout of the S/S system on the site. Drawings shall be to scale.

e. Emissions: Air emissions, dust, and noise from the system shall be identified and estimated. Control systems required to maintain compliance with local, state, and federal regulations shall be described as appropriate. Air emissions, dust, and noise testing protocol to be performed during the test run and full scale operations shall also be described.

f. Quality Control: A quality control plan which covers control of batch proportions, mixing time, mixing speed, sample collection, sample curing, and post-treatment testing.

g. Demobilization: A post-treatment cleanup and sampling plan for the treatment area.

h. Stockpile Design: A proposed stockpile design which meets the criteria outlined in this section.

Key Personnel; [_____].

Resumes of key personnel at least [5] [_____] working days prior to the personnel assuming duties on site.

Batch Proportions; [_____].

Daily batch proportion and mixing quality control data.

Test Results; [_____].

Results of post-treatment tests performed.

Field Demonstration; [_____].

The field demonstration report shall include pre-treatment and post-treatment test results, and shall document other relevant field demonstration data including but not limited to: batch proportions, mixing time, and mixing speed. Off-gas, dust, and noise test results shall also be included.

Reagents; [_____].

Reagent composition and certificates of analysis.

1.6 QUALIFICATIONS

1.6.1 Contractor Experience

The Contractor shall have completed at least [3] [_____] S/S projects of comparable size and scope in accordance with local, state, and federal requirements using the proposed system or a similar system.

1.6.2 Key Personnel

Key personnel shall have a minimum of [2] [_____] years of S/S field experience. Key personnel shall include system operators, quality control personnel, and supervisory engineering and technical staff involved with the S/S system operation.

1.7 PROJECT/SITE CONDITIONS

NOTE: *Pertinent site characterization data should be placed in the appendix of the specifications or on the drawings and referenced here. Indicate the detail to which site characterization has been performed and indicate where obvious data gaps exist.*

The physical conditions indicated on the drawings and in the specifications are the result of site investigations. While the site investigation data is representative of subsurface conditions at a specific location, variations in the contaminated materials are expected to exist.

1.8 EQUIPMENT

1.8.1 Mixing Equipment

The mixing equipment shall have a minimum capacity adequate to meet performance and schedule requirements and shall be equipped with positive means for controlling the mix proportions, maintaining the time of mixing constant, and maintaining the appropriate speed of rotation of the mixer.

1.8.2 Reagent Feed Units

Satisfactory means, incorporating weighing, metering, or volumetric measurement, shall be provided to separately batch the required amount of each reagent. Silos and feeders shall be equipped and operated so that no caking of material or variation in feed occurs. Provision shall be made so that each reagent can be easily sampled.

1.8.3 Accuracy of Measurement Equipment

Scales, meters, and volumetric measuring devices used for measuring contaminated material, reagents, and water for S/S processing shall be accurate to plus or minus [0.1] [_____] percent of the quantity being measured. A check of calibration of measuring equipment shall be performed once every [5] [_____] working days.

1.9 MIX DESIGN

NOTE: *In most instances, the Owner will have conducted treatability studies prior to advertisement for bids. Results of these treatability studies will be provided to bidders and included in the contract documents.*

The Contractor shall select a mix design which meets the performance criteria listed in Table 1 for use during full scale treatment. [A preliminary treatability study has been performed on the contaminated materials. Results of this study are provided in Appendix [_____] for information only.] [No Owner treatability studies were performed.]

Part 2 Products

2.1 MATERIALS

2.1.1 Water

NOTE: *It may be appropriate to require chemical testing of the proposed water source when the water is of questionable quality.*

Water shall not contain concentrations of oil, acid, salt, alkali, organic matter, or other deleterious substances which will be detrimental to the successful execution of the S/S treatment process.

2.1.2 Reagents

The chemical composition of reagents used shall be provided to the Owner. A certificate of analysis supplied by the vendor shall accompany each shipping unit of reagent. Reagents shall be shipped in properly labeled containers with instructions for handling and storage. The instructions shall be strictly adhered to.

Part 3 Execution

3.1 STOCKPILES

NOTE: *Delete this paragraph if stockpiles are not required. More elaborate stockpile requirements may be needed based on site-specific regulatory criteria. In addition to leachate collected from stockpiles, water from other sources (decontamination water, surface runoff, etc.) is also sometimes used in the S/S process.*

Stockpiles shall be constructed for storing contaminated material [prior to] [and] [following] treatment. Stockpiles shall be constructed to include:

a. An impermeable geomembrane liner with a minimum thickness of 1.0 mm (40 mils). The liner shall be protected from vehicles by a [270] [_____] g/square m ([8] [_____] ounce/square yard) geotextile and a traffic surface layer consisting of gravel, concrete, or other material which will not damage the geomembrane. The ground surface on which the geomembrane is placed shall be free of rocks and other objects greater than 12.5 mm (0.5 inches) in diameter or any other object which could damage the membrane.

b. An impermeable geomembrane cover with a minimum thickness of 0.25 mm (10 mils) to prevent precipitation from entering the stockpile.

c. Berms surrounding the stockpile which are a minimum of 300 mm (12 inches) in height.

d. The liner shall be sloped to a low point to allow leachate to be collected. Leachate collected from the stockpile shall be analyzed and, if necessary, treated to meet applicable local, state, and federal regulations. Leachate collected from the stockpile may be used in the S/S process provided the treated material meets the physical and chemical post-treatment test criteria.

3.2 OPERATION

3.2.1 Weather Conditions

NOTE: *Site-specific conditions should be considered when determining allowable temperatures at which S/S and curing may take place. Treatability studies can be used to address this issue.*

S/S shall not take place in an ambient temperature below [4] [_____] degrees C ([40] [_____] degrees F) without approval. Provisions shall be made to maintain the temperature of the treated material above freezing while curing. Contaminated material shall not be treated if it contains any frozen material. The temperature of the S/S material immediately after treatment shall not exceed [32] [_____] degrees C ([90] [_____] degrees F) without approval. S/S shall not be performed during periods of heavy rainfall if this will result in the addition of excess water to the mixture.

3.2.2 Dissimilar Materials

Dissimilar materials for which testing has indicated the need of different mix ratios shall not be mixed together.

3.2.3 Oversize Material

NOTE: *Indicate the method and location of disposal of treated oversize material.*

Contaminated material that exceeds the maximum allowable particle size of the S/S mixing unit and that is amenable to treatment shall be reduced to a size that the mixing unit can accept. Oversize material that cannot be reduced to an allowable size for the S/S unit shall be treated in accordance with [40 CFR 268] [_____]. After treatment, the material shall be disposed of [_____]. Hazardous residual produced in treating the oversize material shall be disposed of in accordance with applicable local, state and federal regulations.

3.3 FIELD DEMONSTRATION

Prior to full-scale operations, a field demonstration shall be performed. At least [100] [_____] cubic meters (cubic yards) of contaminated material shall be processed and the tests listed in Table 2 shall be performed on [4] [_____] representative samples of the treated material. A field demonstration shall be performed on each distinctive type of material or contaminant to be treated.

3.3.1 Full-Scale Processing Equipment

The full-scale processing equipment shall be used for the field demonstration. Reagents, mix ratios, and mixing procedures used during the field demonstration shall be the same as those used for the remainder of the work.

3.3.2 Sampling Locations

NOTE: *Sampling protocols for the field demonstration should be the same as the sampling protocols used for full scale treatment. Specify the method, location, and depth at which samples for the field demonstration will be obtained. Chemical testing should generally be performed to verify the materials to be used for the test run contain the contaminants of concern at high enough concentrations to adequately test the system. Additional testing may be warranted to verify that the physical properties of the materials are also representative of site conditions.*

Contaminated material used for the field demonstration shall be obtained from [_____]. Prior to performing the field demonstration, contaminated material to be used for the field demonstration shall be tested to verify it contains the following minimum levels of contamination: [_____].

3.3.3 Testing

NOTE: *Consideration should be given to the need for monitoring off-gas, dust, and noise generation during the field demonstration to ensure compliance with local, state, and federal regulations.*

Testing shall be performed to verify that the treated material from the field demonstration meets the specified physical and chemical criteria. If the treated material produced during the field demonstration does not pass the testing requirements, an equal quantity of the same type of material which failed shall be treated using a new mix design.

3.3.4 Volume Increase

NOTE: *Monitoring of volume increase due to treatment is recommended during the field demonstration and full-scale treatment if the treated material is to be placed in an on-site landfill. This is done to ensure adequate onsite landfill space is available to store the treated material.*

The estimated increase in volume resulting from treatment shall be determined and reported with the field demonstration test results. Volume increase shall be determined by comparing the volume of in situ contaminated material to be treated to the volume of treated material using the following formula:

$$B = 100 \times [(1+R) \times (D_{in\ situ}/D_{treated}) - 1]$$

B= Volume increase in percent.
R= Dry weight ratio of solidifying agent to waste.
D in situ= Dry unit weight of in situ waste.
D treated= Dry unit weight of compacted treated material.

3.3.5 Field Demonstration Test Results

NOTE: *While two options of the field demonstration test results paragraph are provided, it is preferable to require the Contractor to stop processing contaminated material until results from the field demonstration indicate that the Contractor's proposed mix design can successfully treat the contaminated material.*

[After completion of the field demonstration, no additional contaminated material shall be processed until test results from the field demonstration verify that the treated material meets the physical and chemical criteria listed in Table 1.]
[After completion of the field demonstration, contaminated material may continue to be processed. However, if test results from the field demonstration do not pass the criteria listed in Table 1, the contaminated material treated with the failing mix design shall be reprocessed with a working mix design at no additional cost to the Owner.]

3.4 TESTS

NOTE: *Leaching and hydraulic conductivity tests are not amenable to real time quality control because of the time required to perform the tests; therefore, it is preferable to minimize the number of leaching and hydraulic conductivity tests performed and to maintain quality control of the S/S process by verifying that the mix design works during the field demonstration and maintaining quality control by monitoring batch proportions and mixing time. Real time indicator tests such as pH, specific conductance, mix temperature, and water content can also be used as quality control tools.*

3.4.1 Batch Proportions

Mixing time, mixing speed, and amounts of contaminated material, reagents, and water added to each batch shall be recorded. Mixing time, mixing speed, and batch proportions shall be maintained within the limits specified in the approved Work Plan and as modified during the field demonstration.

3.4.2 Segregation

NOTE: *It is preferable to place treated material directly into the permanent storage area rather than stockpiling it until post-treatment testing is completed.*

[Treated material shall be separated into units (stockpiles) for post-treatment testing. Table 2 lists the frequency at which post-treatment testing shall be performed. Unit size shall be equal to or less than the quantity pertaining to the most frequent quality control test.] [Treated material shall be placed directly into the permanent storage site after treatment. Treated material shall be placed such that the material from specific batches/runs can be defined and removed if it fails post-treatment testing.]

3.4.3 Test Results

NOTE: *Samples for post-treatment testing should generally be collected immediately after treatment. This would eliminate the need to remove samples from the treated mass after it has cured.*

If the treated material exhibits soil-like properties, moisture content and density criteria may also need to be specified for the post-treatment test samples.

The values shown in Table 2 for frequency of testing are only examples and need to be determined on a site-specific basis. Site-specific testing requirements for off-gas emissions, dust, and noise should also be included in the table.

The tests listed in Table 2 shall be performed on representative samples of treated material. Samples for quality control and quality assurance testing shall be collected immediately after treatment and allowed to cure as specified in ASTM D 4832 or by another approved method. Samples shall meet the post-treatment testing criteria listed in Table 1.

Table 2. POST-TREATMENT QUALITYCONTROL TESTING FREQUENCY

Standard Test Procedure	Frequency/Cubic [Meters][Yards]
TCLP (EPA SW-846)	**1 per [500][_____]**
Unconfined Compressive Strength (ASTM D 1633)	**1 per [500][_____]**
Permeability (ASTM D 5084)	**1 per [500][_____]**
Volume Increase	**1 per [500][_____]**

3.4.4 Retesting and Reprocessing

Retesting and reprocessing shall be performed at no additional cost to the Owner for treated material that does not meet the physical and chemical requirements listed in Table 1.

3.4.4.1 Retesting

Any unit that fails post-treatment quality control or quality assurance testing shall be retested or reprocessed. If the Contractor elects to retest the unit, two additional samples shall be collected and tested for the failed parameter. If both tests pass, reprocessing of the unit will not be required. If either sample fails, the unit shall be reprocessed and samples shall be tested as described in paragraph 3.4.3 Test Results.

3.4.4.2 Reprocessing

If the Contractor elects to reprocess a unit without retesting, the unit shall be sampled and tested as described in paragraph 3.4 TESTS after reprocessing.

3.4.5 Adjustments to Mix Design

Subject to approval, the mix design may be changed based on the characteristics of the material being treated. An additional field demonstration may be required by the Owner Representative prior to implementation of the new mix design.

3.4.6 Quality Assurance Testing

Duplicate samples shall be submitted to the Owner's quality assurance laboratory at a frequency of one set of samples per [10] [_____] sets of quality control tests performed. Quality assurance samples will be tested for the parameters listed in Table 2. The Owner may require additional quality assurance tests as a result of failed quality assurance or quality control tests. The Owner may also require additional quality assurance tests due to changes in the mix design or physical appearance of the contaminated material.

END

The suggested specifications are an adaptation of *Guide Specification For Construction, Solidification/Stabilization (S/S) of Contaminated Material, CEGS-02160* from the U.S. Army Corps of Engineers. Large sections of the USACE guide specifications are reprinted here with the permission of the USACE. Persons working on government S/S treatment projects may wish to refer to the original USACE specification. Suggested procedures for treatability studies are described in the USACE Technical Letter entitled *Treatability Studies For Solidification/Stabilization of Contaminated Material* ETL 1110-1-158. These specifications and procedures can be found at the USACE TechInfo Web Page <http://w2.hnd.usace.army.mil/techinfo/>.

Publications on Solidification/Stabilization

Solidification and Stabilization of Waste Using Portland Cement
State-of-the-art report on the characteristics of portland cement and how it can be used effectively to solidify/stabilize various types of wastes. Discusses waste compounds that may interfere with cement hydration reactions. Includes information on several additives that may be used with portland cement to enhance solidification/stabilization reactions.
EB071S 16 pages 1991 $12

Solidification/Stabilization of Contaminated Soil
This special report describes a completed Superfund clean-up project. The project used portland cement to treat metals-contaminated soil. Five full-color photographs showing the method of treatment are included.
SR341S 4 pages 1994 $2

Cement-Based Solidification/Stabilization of Lead-Contaminated Soil at a Utah Highway Construction Site
Reprint of a technical article on the use of cement to solidify and stabilize lead-contaminated soils at a Superfund emergency response site. Provides detailed information on design and construction aspects of the cleanup. Published by Remediation, The Journal of Environmental Cleanup Costs, Technologies & Techniques.
RP332S 8 pages 1995 $4

Potential Solidification/Stabilization Projects Under the Superfund Program
Contains descriptions of 166 solidification/stabilization projects that are completed, under construction, or planned by the Federal Superfund program, the contaminants involved, selected remedies, record of decision dates, and estimated project costs. Projects are listed alphabetically by state. Addresses and telephone numbers of the USEPA Regional Offices are given to assist readers when additional project information is sought.
IS500S 112 pages 1994 $40

Potential Solidification/Stabilization Superfund Projects - 1995 Update
Contains descriptions of solidification/stabilization projects that are completed, under construction, or planned by the Federal Superfund program. Descriptions include the contaminants involved, selected remedies, record of decision dates, volumes of waste and estimated project costs. This publication describes 42 remedies recently selected by the USEPA and is an update of IS500.
IS501S 48 pages 1995 $20

PCA Membership Directory
A valuable reference for contractors seeking supplies of bulk cement for solidification/stabilization treatment projects and other large projects. The Directory lists cement sales offices grouped by U.S. state and Canadian province served in order to identify cement suppliers in a project area. This information is also available on PCA's Web Site <www.portcement.org>
MS123S Free

Guide To Improving the Effectiveness of Cement-based Solidification/Stabilization
Provides information on field techniques and additives that can be used to improve the effectiveness of cement-based solidification/stabilization treatment of wastes. The Guide includes lists of commonly occurring hazardous constituents in wastes and suggests techniques and additives that can be used to successfully stabilize these constituents.
EB211S 47 pages 1997 $18

Stabilization of Heavy Metals with Portland Cement: Research Synopsis
Highlights results of PCA-sponsored research in establishing the mechanisms of heavy metals immobilization by portland cement-based solidification/stabilization treatment. Complete results are reported in RP348S.
IS007S 6 pages 1997 $3

Stabilization of Heavy Metals in Portland Cement, Silica Fume/ Portland Cement and Masonry Cement Matrices
Reports PCA-sponsored research in establishing the mechanisms of heavy metals immobilization by portland cement-based solidification/stabilization treatment. This research found that the effectiveness of stabilization is better than could be expected based on the pH effects of cement addition alone. This suggests that certain metals may actually be bound within cement hydration products.
RP348S AVAILABLE 1999

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IS 525S