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SECTION 02261

DEEP MIX METHOD (DMM) CUTOFF WALL
12/02

PART 1 GENERAL

1.1 SCOPE

The work consists of furnishing all plant, labor, equipment, and materials and of performing all operations, including quality control and quality acceptance testing, and as-built drawing and end-of-construction summary report, in connection with the construction of a cutoff wall. An option for the cuoff wall construction method shall be the wet deep mixing method (DMM). The cut off wall shall be constructed in accordance with these Specifications and Drawings. The purpose of the cutoff wall is to provide a low permeability, permanent seepage control wall through and beneath the levee. The cutoff wall shall consist of a series of overlapping DMM columns and panels, formed underground through and beneath the levee. All work under this section shall comply with the requirements of EM 385-1-1.

1.2 APPLICABLE PUBLICATIONS/REFERENCES

The publications listed below,including any cross references cited in the individual ASTMs, form a part of this Specification to the extent referenced and cross-referenced. The publications are referred to in the text by basic designation only.

AMERICAN PETROLEUM INSTITUTE (API)

API Spec 13A	(2004, 16th ED.) Specifications for Drilling-Fluid Materials- Specifications and Tests

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)
2003 Annual Book of ASTM Standards Section 4, Construction, Volume 04.01 Cement;Lime: Gypsum, Volume 04.02 Concrete and Aggergates, Volume 04.08 Soil and Rock(I) and Volume 04.09 Soil and Rock (II).

ASTM C 117	(1995) Standard Test Method for Materials Finer than 75-um (No. 200) Sieve in Mineral Aggregates by Washing
ASTM C 136	(2001) Standard Test Method for Sieve Analysis of Fine and Course Aggregates
ASTM C 150	(2002) Standard Specification for Portland Cement
ASTM D 422	(2002) Standard Test Method for Particle Size Analysis of Soils
ASTM D 2113	(1999) Standard Practice for Rock Core and Sampling of Rock for Site Investigation

ASTM D 4380	(2001) Standard Test Method for Particle Size Analysis of Soils
ASTM D 2488	(2000) Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)
ASTM D 2487	(2000) Standard Classification of Soils for Engineering Purposes (Unified Soil Classification System)
ASTM D 3740	(2001) Standard Practice for Minimum Requirements for Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
ASTM D 4630	(2002) Standard Test Method for Determining Transmissivity and Storage Coefficent of Low Permeability Rocks by In Situ Measurements Using the constant Head Injection Test
ASTM D 4832	(2002) Standard Test method for Preparation and testing of Controlled Low Strength Material (CLSM) Test Cylinders
ASTM D 2938	(1995) Standard Test method for Unconfined Compressive Strength of Intact Rock Core
ASTM E 329	(2002) Standard Specification for Agencies Engaged in Testing and/or Inspection of Materials Used in Construction
ASTM D 5084	(1990) Standard Test Method for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter

U.S. ARMY CORPS OF ENGINEERS (USACE)

EM 385-1-1	(2003) U.S. Army Corps of Engineers Safety and Health Requirements Manual

1.3 GENERAL CONDITIONS

1.3.1 Lines and Grades

The cutoff wall shall be constructed to the lines, grades, and dimensions indicated on the drawings, unless otherwise directed in writing by the Contracting Officer. The Goverment reserves the right to increase or decrease the cutoff wall dimensions and locations in response to site conditions.

1.3.2 Conduct of Work

The Contractor shall maintain and protect the cutoff wall in a satisfactory condition at all times until final completion and acceptance of all work under the Contract.

1.3.3 Access and Ramps

Access and ramps shall be as shown on the drawings. Prior to the commencement of construction, the Contractor shall submit for approval a plan, detailing the location of all haul roads and access ways to and within the project area. The Contractor shall maintain the haul routes and access ways during construction in a safe manner and condition, as indicated in EM 385-1-1. Additional access and ramps shall only be constructed at locations approved by the Contracting Officer. If needed, ramps shall be added or improved by adding material to the levee cross section. Cuts into the levee for ramps are prohibited.

1.3.4 Protection of Existing Facilities

Construction shall be conducted in such a manner to avoid damage to existing manmade and natural features depicted on the drawings and not designated for removal. Natural and manmade features adjacent to and in the vicinity of the project area shall also be protected from construction impacts.

1.3.5 Permits

The Contractor shall obtain all local, State, and Federal permits required to accomplish the work and pay all necessary fees associated with the permits.

1.4 DEFINITIONS

1.4.1 Cutoff Wall

The cutoff wall is a soil-cement-bentonite seepage barrier installed below the prepared working surface using wet deep mixing methods (DMM). The DMM cutoff wall is also referred to as a Deep Soil Mix (DSM) wall. A panel is the portion of the wall that is formed by inserting and withdrawing the multi shaft (multi-column) mixing apparatus at one location. The wall is formed by constructing overlapping panels.

1.4.2 Cutoff Wall Cap

The cutoff wall cap is the section of impervious levee fill that is placed above the cutoff wall and extends the seepage barrier to the levee crown. The geometry of the cutoff wall cap is shown on the drawings and shall be constructed in accordance with the Section 02331A EARTHWORK.

1.4.3 Bentonite Slurry

Bentonite slurry is a colloidal mixture of bentonite (fully hydrated) and water and other suitable material prepared in accordance with API Spec 13A.

1.4.4 Cement Slurry

Cement slurry is a colloidal mixture of Portland cement Type II (per ASTM C 150) and water and other suitable material.

1.4.5 Bentonite

Bentonite is an ultra fine natural clay whose principal constituent is

sodium cation montmorillonite.

1.4.6 Grout

Grout is the mixture of cement, bentonite, water and additives that form the hardening agent (binder) injected into the soil in the DMM method to improve the in situ soil engineering properties.

1.4.7 Working Surface

The working surface is the top of the prepared surface on the levee as shown on the drawings from which the cutoff wall is constructed.

1.4.8 Admixture

Any additive used to modify the properties of the bentonite slurry, cement slurry, or the grout material.

1.4.9 DMM Cutoff Wall Specialist

A DMM specialist is an individual who has had at least five (5) years of experience in DMM cutoff wall construction and has knowledge in all aspects of DMM cutoff wall construction as indicated in Qualifications.

1.5 SUBMITTALS

Goverment approval is required for submittals with a "G" designation; submittals having an "FIO" designation are for information only. The following shall be submitted in accordance with Section 01330 SUBMITTAL PROCEDURES:

SD-01 Data

Grout Mix; G

The Contractor shall submit the proposed grout mix design along with a laboratory test report. The report shall summarize the test results and address the suitability of the proposed mix design as it relates to site subsurface soil conditions and the specification requirements. The report shall contain mix proportions and test results for all test batches. The calibration of the mixing plant shall be documented.

Qualifications; G

In accordance with the requirements of paragraph 1.6 "QUALIFICATIONS", The Contractor shall submit evidence of qualification experience of the DMM cutoff wall operator and DMM cutoff wall equipment specialist. This information shall be submitted within twenty (20) working days after receiving the Notice to Proceed.

Pre-Construction Quality Control Reports; G

Prior to construction, the Contractor shall submit a proposed Daily Quality Control Report format for approval by the Contracting Officer. Samples of testing data sheets and sample data reduction to obtain strength and permeability of the DMM material shall be submitted.

Bentonite and Cement; G

The Contractor shall submit copies of the test reports from the manufacturer for each lot of bentonite and cement shipped to the site. Submit statements signed by an authorized official to certify on behalf of the manufacturer of the materials attesting that the products meet specified requirements. The statement shall be dated after the award of contract, shall state the Contractor's name and address, shall name the project and location, and the specific requirements which are being certified. The Contractor shall submit a statement certifying each lot of bentonite and each lot of cement, after delivery to the site and before the material is used.

Chain of Custody Form for Quality Control / Acceptance / Quality Assurance Samples; G

The Contractor shall submit a sample of the chain of custody form used to keep track of all samples taken by the Contractor. The form shall include who formed the samples, transfer of Ownership, dates, time, batch number, panel number, and stationing of the samples

SD-09 Reports

Cutoff Wall Construction; G

a. Submit for approval the methods, schedule, and sequence of operations for construction of the cutoff wall, including but not limited to site access, working surface construction, wall layout, waste management, offsite disposal locations, grout preparation, grout injection, and final grade closure. The schedule shall also include information regarding equipment mobilization, equipment setup, DMM production installation, and verification testing.

b. Submit for approval the layout of operations including working pads and associated levee excavation, if required, for the construction of the wall. Include storage areas, grout preparation and mixing areas, access corridor, and location and sizes of all stationary equipment.

Equipment and Procedures; G

a. Submit for approval a detailed description of the equipment and procedures to be used during the project including, but not limited to, construction of the cutoff wall and monitoring the quality control parameters outlined herein, and collecting samples for laboratory testing. Procedures shall include methods for locating the wall in the field and confirming that the wall is plumb. The Contractor shall also submit the proposed mix design and construction methods needed to comply with the drawings and specifications. The calibration of the mixing plant and soil mixing rig / apparatus shall be documented.

b. Include data on equipment such as mixers capable of producing a stable colloidal suspension of bentonite slurry, cement-slurry or other mix combinations; storage facilities including tanks and

methods of agitation; delivery methods and equipment; spillage, and containment facilities to control spillage

As-Built Drawings and End of Construction Summary Report; G

Submit for approval as-built drawings and end-of-construction Summary Report prepared by a Professional Engineer and a licensed surveyor indicating the width, depth, and location of the cutoff wall in terms of project coordinates, all quality control and quality acceptance test results, all pertinent submittals, mix designs used, subsurface conditions encountered, major problems, core logs, and all construction equipment. The summary report shall summarize and compare statistically all test data to the contract requirements.

SD-13 Certificates

Admixtures; G

The Contractor shall submit a certificate for each lot of admixtures, if used.

SD-14 Samples

Equipment and Procedures to Obtain Wet Bulk and Core Samples of Mixed Soil

Samples, including both fabricated and unfabricated physical samples of materials, products and units of work as complete units or portions of units of work.

SD-18 Records

Construction Records; G

Construction Records are reports, documentation, test results, logs, and material certificates. Construction records shall be submitted for the cutoff wall test section and all subsequent production work. All information shall be submitted in electronic format and hard copy. Data / test summaries shall be in Microsoft Excel files. Text reports shall be in Microsoft Word.

Construction Documentation; G

During construction of the DMM cutoff wall, records shall be maintained by the Contractor for all test results, descriptions, measurements, and inspections performed to ascertain that the cutoff wall construction meets the specifications. All data records from the mix design shall be furnished to the Contracting Officer for approval prior to construction. Data shall be in both hardcopy and electronic form as Microsoft Excel and Microsoft Word files. The data records shall include, but are not limited to: all laboratory test data, test result summaries, data acquisition from instruments, production information on amount of bentonite and cement used, volume of grout placed, and DMM production

records. The Contractor shall submit mix reports for the bentonite-cement grout including water content and mix proportions for each batch prepared. The report shall indicate where (station / panel) each batch was used. All required reports, records, and documentation shall be furnished to the Contracting Officer OR his representative by the end of the next working day.

Construction Quality Control and Quality Acceptance Test Results; G

The results of all construction control testing required in these specifications, including, coring, water tests, grout tests, permeability and strength testing of wet bulk samples and cores, shall be furnished to the Contracting Officer. The Contractor shall furnish records of all observations, measurements, and tests performed, identified with the location and time of testing. Each test report shall be properly identified. Test methods used shall be identified and test results shall be recorded. Details of laboratory test procedures for performing strength and permeability tests on wet bulk and core samples shall be provided. These records shall be furnished no later than 24 hours after the tests, measurements, and/or observations are made.

Construction Log;FIO

The Contractor shall maintain a construction log of daily activities, which shall include delays encountered during construction, causes of delays, locations of affected areas, and extent of delays. The log shall also record unusual conditions or problems encountered, and the dispositions made. The Contracting Officer shall be immediately notified of unusual conditions or problems followed by a written description. The log will also include the amount of labor, equipment and materials used.

1.6 QUALIFICATIONS

1.6.1 Specialist and Operator

The Contractor shall maintain a DMM cutoff wall specialist and equipment operator at the site on a full-time basis while the cutoff wall is being constructed.

1.6.1.1 DMM Equipment Operator

The DMM Equipment Operator shall have experience using similar DMM equipment as that proposed for this project. The experience shall correspond to the technical proposal submitted for Key Personnel Experience. The projects shall be submitted to the Contracting Officer for approval. The submitted cutoff wall project experience information shall indicate the project name, date of construction, type of cutoff wall, width of cutoff wall, and depth and length of the cutoff wall.

1.6.1.2 DMM Cutoff Wall Specialist

The DMM Cutoff Wall Specialist (DMM Specialist) shall be experienced in providing supervision of mix design and field control composition and mixing and placing of the cement-bentonite grout using DMM equipment. The experience shall correspond to the technical proposal submitted for Key Personnel Experience and have successful supervision experience in all aspects of DMM cutoff wall construction, which includes, but is not limited

to: (1) controlling composition, mixing, placing, sampling, testing, cleaning, and maintaining cement-bentonite grout; (2) supervision of alignment, verticality, and depth of DMM equipment; (3) controlling blending, mixing, sampling, and testing in-situ DMM material (grout+ in-situ soil); and (4) a thorough knowledge of DMM cutoff wall construction equipment and material testing.

1.7 GEOTECHNICAL SITE CONDITIONS

1.7.1 Explorations

Subsurface cone penetrometer test probes and exploratory borings have been performed by the Goverment to evaluate the nature of seepage and the nature of materials to be excavated. Approximate locations of the explorations and boring log descriptions are shown on the drawings. The Agency assumes no responsibility for interpretations, conclusions, or deductions made by the Contractor from the logs of the explorations. Local variations in the subsurface materials are to be expected and, if encountered, will not be considered as being materially different.

1.7.2 Groundwater

Groundwater at the time of exploratory borings was encountered approximately at the elevation that corresponds to the adjacent river stage. Groundwater levels can be expected to fluctuate in response to variations in rainfall, river stage, irrigation, and tidal influence.

1.7.3 Levee Embankment and Subsurface Conditions

The levee embankment and subsurface materials are described in the drawings and in the materials referenced in Section 02020 SUBSURFACE DATA.

1.8 MEASUREMENT AND PAYMENT

1.8.1 Measurement

Measurement for DMM Cutoff Wall, shall be based on the area in square feet of wall measured in a vertical plane through the centerline of the cutoff wall as established by the working surface indicated on drawings, the bottom of the cutoff wall and vertical lines at each end of the cutoff wall. Measurement shall be based on surveys and measurements taken at the site as directed and approved by the Contracting Officer. Payment shall be made on the basis of a wall constructed to the depth indicated on the drawings unless excavation to a greater depth is directed.

1.8.2 Payment

Payment for DMM Cutoff Wall shall be made at the contract price per square foot of Bid Item, "DEEP SOIL MIX CUTOFF WALL." Such price shall include all costs of levee preparation, cutoff wall installation; stockpiling or spoiling materials generated during the cutoff wall installation, obtaining materials from commercial sources; mixing, blending, and pumping grout; surveying; quality control and quality acceptance testing; reporting; preparing as-built information; and all other items incidental to the construction and completion of the cutoff wall. No separate payment will be made for materials including bentonite, cement, additives, soil, equipment and mixing, handling and cleaning the slurry, diking around the

open trench, and overtime during continuous operations, cleanup, assistance in the collection and maintenance of records and preparation of as-built documentation reports; such items being included in the price of the cutoff wall. Final acceptance of the cutoff wall will be based on meeting all the requirements for the in situ wall dimensions, core recovery (continuity), homogeneity of the wall, and the permeability and strength requirements.

PART 2 PRODUCTS

2.1 GENERAL

The Contractor shall maintain at the job site a sufficient quantity of raw materials and other supplies such that the work can proceed uninterrupted by material shortages. The contractor shall modify the mix proportions and methods as needed to meet the required wall strength, permeability, continuity, and homogeneity. The Contractor shall undertake any additional tests necessary to assist in material selection, to verify compliance with the Specifications and to demonstrate the characteristics of the cutoff wall..

2.2 BENTONITE

The bentonite shall be sodium cation based montmorillonite powder (Premium Grade Wyoming-type bentonite) that conforms to the standards set forth in API Spec 13A. The same bentonite shall be used for both the mix design and construction of the DMM walls. No chemically treated bentonite will be allowed. No bentonite from the bentonite manufacturer shall be used prior to acceptance by the Contracting Officer. All bentonite will be subject to inspection, sampling and verification of quality by testing under the supervision of the Contracting Officer or his representative. Bentonite not meeting the specifications shall be promptly removed from the site and replaced with bentonite conforming to specification requirements at the Contractor's expense. Bentonite shall be protected from moisture during transit and storage.

2.3 WATER

The Contractor shall obtain and supply all water required for mixing with bentonite and cement to produce slurry and slurry cutoff wall backfill. The Contractor shall transport the water from the source to the project site.

2.3.1 Water Standards

The water shall be clean, fresh, and comply with the standards set below:

a) A pH equal to 7.0 plus or minus 1.0.
b) Total dissolved solids not greater than 500 parts per million.
c) Oil, organics, acids, alkali, or other deleterious not substances greater than 50 parts per million each.
d) Hardness less than or equal to 50 ppm.

2.3.2 Hydrants

If the Contractor intends to use hydrants: 1) note the locations of hydrants for use, and 2) procure appropriate permits. The Contractor shall abide by any and all regulation and other requirements governing such use. The Contractor shall include the cost of all related fees in the bid items pertinent to the work.

2.4 CEMENT

Cement shall conform to ASTM C 150 Type II. The cement shall be adequately protected from moisture and contamination while in transit to and in storage at the job site. Reclaimed cement or cement containing lumps or deleterious matter shall not be used.

2.5 ADDITIVES

Admixtures may be added to the water or the grout to permit efficient use of material and proper workability of the grout. The Contractor shall provide a written statement from the manufacturer as to the use of any such admixture, its effect on the DMM material, its long-term performance and stability, and its effect on the environment. Admixtures must be proven with the trial design mixes. No admixtures shall be used except as approved by the Contracting Officer. Retarders, fly ash or other solids containing heavy metals may not be used in the design.

2.6 Grout

The grout shall be premixed in a grout plant, which combines dry materials and water in predetermined proportions. The grout shall assist in loosening the soils for penetration and optimum mixing, lower the permeability of the in situ soils to form a seepage cutoff wall (DMM cutoff wall), and upon setting, strengthen the in situ soils. It is the responsibility of the Contractor to assure that the grout when mixed with the in situ soil of the levee, meets the contract requirements.

2.7 DMM Material

The material created by the in-place mixing of soil and cement-bentonite grout that forms the cutoff wall seepage barrier.

PART 3 EXECUTION

3.1 GENERAL

3.1.1 General

The Contractor shall establish and maintain field quality control for the grout batching and DMM cutoff wall construction to assure compliance with contract requirements and maintain detailed records of field and laboratory quality control for all operations. The Contractor shall use only an independent established commercial laboratory approved by the Contracting Officer. The laboratory facilities and personnel shall comply with the requirements in SECTION 01451A paragraph 3.7.2.1. The Contracting Officer reserves the right to make inspections of the Contractor's designated laboratory facilities, including test equipment and procedures. All laboratory and field equipment shall be kept in proper working order and have proof of recent (within 3 months) calibration.

The Contractor shall perform sufficient testing to ensure the work is being accomplished as specified. The testing program specified herein represents the minimum level and frequency of testing. The Contractor is responsible for performing all additional tests as necessary to confirm compliance with the contract requirements.

3.1.2 SITE WORK

The Contractor shall furnish all plant, equipment, labor, and materials required to construct a cutoff wall as shown on the Drawings and specified herein, except that the Contracting Officer may at any time direct changes to the wall depth and length to accommodate conditions encountered in the field.

3.1.3 Wall Structure

The purpose of the cutoff wall is to provide permanent seepage control. The cutoff wall shall consist of a series of continuous overlapping DMM columns and panels. The minimum dimensions and layout of the cutoff wall are shown on the plans. Multi-shaft (three or more shafts) equipment shall be used to construct multiple overlapping columns simultaneously. The wall shall be constructed continuously along the wall alignment, with one auger overlap between adjacent panels.

3.1.4 Method

The cutoff wall shall be constructed by in-situ mixing of soil, cement, and bentonite. The soil-cement-bentonite columns shall be formed by at least three (3) overlapping soil mixing shafts guided by a lead mounted on a crawler base machine. The mixing shafts shall be driven by a power source sufficient to provide torque for a wide range of drilling conditions and to maintain a continuous installation of soil-cement-bentonite columns. The mixing augers shall be advanced into the soil, with grout being pumped through the hollow stem of the auger shafts and injected into the soil at the shaft tips. The auger flights and mixing blades on the shafts shall blend the soil with grout in pug mill fashion. When the design depth is reached, the mixing shafts shall be withdrawn while the grouting and mixing process is continued. The mixing shafts shall be positioned so as to overlap one another to form continuously mixed panel of three or more columns. After withdrawal, the next panel will be constructed by completely overlapping the end column, (i.e. one total column overlap is required). The process shall be repeated to form a continuous wall of overlapping panels.

3.2 EQUIPMENT

3.2.1 DMM Equipment

The DMM equipment shall meet the following requirements:

a. Multi-shaft mixing equipment (machines with at least three (3) overlapping mixing shafts) shall be used for this project. Single or double shaft mixing equipment is not allowed. The mixing shafts shall have mixing augers and blades (paddles) configured in such a manner so that they are capable of thoroughly blending the in situ soils and grout to the appropriate depths. The equipment and/or DMM column overlapping technique shall be configured so that the length of the overlapping mixing shafts extends for the full depth of the DMM cutoff wall. The deep mixing method and equipment utilized shall be sufficient to prevent soil inclusions greater than fifty (50) percent of the core diameter from occurring. The power source for driving the mixing shafts shall be sufficient to maintain

the appropriate revolutions per minute and penetration rate from a stopped position at the maximum depth required.

b. The DMM rig shall be equipped with electronic sensors built into the leads to determine vertical alignment in two orthogonal directions: fore-aft and left-right. The sensors shall have an sensitivity of at least 1 part per 1000 (0.1 percent). The location of the sensors on the rig shall be painted to be easily identified from the ground. The hardware utilized to determine panel verticality shall be capable of measuring the deviation of one panel with respect to the adjacent panel at any incremental depth. The software accompanying the "inclinometer" hardware shall be capable of graphically displaying the incremental and total accumulated deviations with depth / elevation and be coded to alert the reader to any excess deviations. The output from the sensors shall be routed to a readout and data storage device and a display on the rig console that is visible to the operator and the Contracting Officer during penetration and withdrawal. The inclination of the augers shall be continuously monitored and recorded. The recorded data shall be available in table and graphic form such that the inclination and position of the as-built panel with respect to vertical and the adjacent panel can be easily determined.

c. The DMM augers and equipment shall be adequately marked to allow the Contracting Officer to visually determine the penetration depth to within 6 inches during construction. Depth shall be continuously monitored.

d. Grout shall be pre-mixed in a mixing plant, which combines dry materials and water in predetermined proportions. The mixing plant shall consist of a grout mixer, grout agitator, grout pump, batching scales, and a computer control unit. Positive displacement pumps shall be used to transfer the grout from the mixing plant to the augers. The grout shall be delivered to each auger by an individual positive displacement pump. All aspects of the batching and pumping operations shall be continuously monitored and recorded electronically. The batching and pumping record shall be determined for each panel.

e. Installation records per panel shall include: date, location, panel ID, auger diameter, shaft spacing, rpm calibration, depth calibration, speed calibration, Batch plant calibration, pump calibrations, verticality calibration, start and finish times, top and bottom elevation, unusual circumstances and changes, depth, elapsed time, and speed, rotation, grout injection rate per shaft, grout injection volume per shaft, energy, and torque versus depth. Records shall be in table and graphic format.

f. The Contractor shall obtain and maintain at the job site a supply of spare critical replacement parts or backup equipment sufficient to allow the DMM cutoff wall construction to proceed with minimum loss of time due to mechanical breakdown or equipment failure.

3.3 Mix Design Test Procedures

3.3.1 General

The Contractor shall develop a laboratory testing program to demonstrate the adequacy of the proposed mix design. Trial mix designs shall cover a range of percentages of bentonite and cement to correlate anticipated ranges of soil gradations using the site-specific soils. Any combination of soil, water, bentonite, cement, and additives can be used by the Contractor. The Contractor shall fabricate a sufficient number of samples and mix designs to support the basis for the proposed mix design. The

minimum number of trial mix designs shall be three (3) per each coarse grained and fine grained soil type anticipated. Refer to ASTM D 2488 and 2487 for description, identification and classification of soils.

3.3.2 Field/trial mixes

Field trial mixes shall be made using site-specific soils, which will represent the range of materials expected to be encountered along the entire extent of the project. Soil samples obtained by the Goverment for design purposes are not available to the Contractor for development of mix design. The Contractor's test results for each trial mix design, including soil gradation, moisture content; mix proportions; 3 and 7-day permeability; and 3 and 7-day compressive strength, shall be submitted to the Contracting Officer within 30 calendar days following receipt of Notice to Proceed. The Contractor's test results for 14 and 28-day permeability and 14 and 28-day compressive strength shall be submitted to the Contracting Officer within 2 days of completion of each test. Three (3) extra / reserve test specimens shall be fabricated for each trial batch. Six (6) additional representative fabricated specimens of each batch from the trial mixes shall also be submitted to the Contracting Officer for Quality Assurance testing.

3.3.3 Permeability

The proposed mix design shall be such that permeability testing performed on laboratory produced trial mix design specimens shall result in a maximum permeability of 1 x 10-7 cm/sec at 7 days. The intent is to target a mix design that achieves a permeability that is an order of magnitude lower than the permeability required for the in place cutoff wall.(Acceptance criteria for the in place cutoff wall is 1 x 10-6 cm/sec at 7 days.)

3.3.4 Strength

The proposed mix design shall be such that strength testing performed on laboratory produced trial mix design specimens shall result in a minimum unconfined strength of 45 psi at 7 days.

3.4 CUTOFF WALL TEST SECTION

3.4.1 General

Prior to full scale production of the DMM wall, Test Sections shall be prepared by the Contractor to verify that the required permeability and strength can be achieved by the Contractor's selected mix design, and that the installation methods provide adequate mixing, homogeneity, and continuity, for the existing field conditions at the project sites. The Contractor shall construct at least one Test Section per site. A Test Section can be incorporated into the permanent cutoff wall if it meets all the requirements for the production walls. In addition to determining the proportions of cement, bentonite, soil, and water to be utilized during production, the Test Section is to be used to determine the grout injection rate, auger rotation speed, auger penetration/withdraw rate, and time delay between completion of a primary panels and beginning of an overlapping secondary panel which will be used during installation of the production wall.

3.4.2 Location

The Test Section shall be installed at locations selected by the Contractor and approved by the Contracting Officer. A Test Section shall consist of at least 50 linear feet of wall constructed. The cement and bentonite dosage, and means and methods used for the approved Test Section will be required for use in the production wall construction. If procedures or equipment are changed following the Test Section, the Contracting Officer reserves the right to request a new Test Section at the Contractor's expense.

3.4.3 Quality Control

Quality control and acceptance testing for the Test Section shall be similar to the testing for the production work except at a higher frequency. In the Test Section, four (4) wet bulk samples shall be obtained every 25 linear feet and 3 core holes drilled per every 50 linear feet. The size of the wet bulk sample shall be sufficient to fabricate the numerous cylinders required for the strength and permeability tests as required for the production quality control and acceptance testing. The core and in situ testing shall also be as required for the production quality control and acceptance testing.

3.5 SAMPLE COLLECTION AND TESTING

Wet bulk sampling and testing, coring, core testing, and in situ permeability testing of the DMM cutoff wall panels / columns by the Contractor, will be required as indicated below. Sampling frequencies for the Test Section are higher and are indicated in 3.4 Cutoff Wall Test Section.

3.5.1 Sample Collection and Testing

Acceptance of the work will depend on the Contractor's work demonstrating that the in-place wall is homogeneous, continuous, and has achieved the strength and permeability requirements. Quality assurance sample collection and testing, in addition to the testing required by the Contractor, will be conducted by the Goverment. Samples shall be collected using: (1) continuous core sampling techniques, (2) discrete wet bulk sampling at frequencies described below, and (3) other sampling methods as required to obtain representative samples of construction materials. Results of in situ testing and tests performed on samples obtained during continuous coring shall take precedence over results of wet bulk sample testing and other sampling methods.

3.5.1.1 Continuous Core Sampling

Core sampling allows direct observation of the product, size and spatial distribution of the constituents, and an assessment of the thoroughness of the mixing process. Coring shall be accomplished by an experienced driller using wireline techniques and a triple-tube core barrel equipped with a fine diamond step-bit with side discharging waterways. The core sample diameter shall be 3.0 inches or greater. ***Core drilling technique shall be capable of keeping drilling deviation to a value of 1 percent or less. All core holes shall be measured for deviations once all of the samples have been extracted from the boring.*** Samples shall be retrieved after the soil-grout mixture has achieved a compressive strength of 45 psi. The continuous core samples shall extend the entire depth of the DMM column/panel. ***All core samples shall be stored in wooden boxes and in a laboratory moisture room having constant temperature, saturated environment***

meeting the requirements of ASTM C 511 until tested or until otherwise directed by the Contracting Officer. Core sections selected for permeability and strength testing shall be stored and tested in the same manner as the wet bulk samples. Each core shall be digitally photographed and logged in detail by the Contractor's Geotechnical Engineer. Any water or drilling fluid loss or gain shall be noted on the log. Coring and logging shall be in general accordance ASTM D2113. A copy of the field logs shall be attached to the daily QC log. A final core log shall be included with other as-built information. The core shall be available to the Engineer for inspection and quality assurance testing. All core holes shall be grouted with a neat cement grout after coring and in situ permeability testing.

One (1) full depth core shall be obtained for every 75 linear feet of cutoff wall constructed. Full depth means that the length/depth of the core hole is equal to the panel length /depth at the cored location. The core holes shall be located with at least 50 percent of the tests being located at the intersection of overlapped section of adjacent columns and panels. A minimum recovery of ***85*** percent for the total cored depth shall be achieved at each core hole / panel location. The core shall be visually inspected for defects, inclusions, and adequacy of mixing. Representative core samples shall be jointly selected by the Contractor and the Contracting Officer. Six core samples shall be selected per location; three (3) for laboratory permeability tests and three (3) for laboratory strength tests. The core testing shall begin within 24 hours of coring.

3.5.1.2 Wet Bulk Sampling

Wet bulk material shall be sampled and test cylinders prepared per ASTM D 4832, with the following exceptions. Each cylinder shall be 3 inches in diameter and 6 inches in length. The wet bulk sample shall be taken using a bailer-type device that allows for complete retrieval of the mixed material without additional mixing or segregation. The retrieved sample shall be passed through a 3/4-inch sieve prior to cylinder fabrication; no other sieving is allowed. After the sample is retrieved from the wall additional mixing is prohibited. Unconfined compressive strength testing shall be performed on cylinders at 7, 14, and 28 days for the production wall. Laboratory permeability testing shall be performed on cylinders at 7, 14, and 28 days for the production wall. For each wet bulk sample collected, the Contractor shall fabricate and retain a minimum of two (2) extra cylinders for possible additional "backup" testing. Approximately 20 percent of the tested locations will be selected for quality assurance testing by the Goverment. At these selected locations, the Contractor shall obtain and provide to the Contracting Officer a duplicate set of six (6) representative samples / cylinders for quality assurance testing.

One (1) wet bulk sample shall be obtained for every 50 linear feet of cutoff wall constructed. The sample depth shall vary. One third of the total number of samples shall come from the upper one third of the wall. One third of the total number of samples shall come from the middle third of the wall. One third of the total number of samples shall come from the bottom third of the wall. Normally, a minimum of 8 test cylinders shall be prepared from each wet bulk sample of in situ mixed material taken at the locations and depths selected by Contractor and approved by the Contracting Officer. At locations selected for Agency Quality Assurance testing, a minimum of fourteen (14 = 8 + 6) test cylinders shall be prepared from each wet bulk sample.

3.5.2 Wet Bulk Sample and Core Permeability Testing

Laboratory permeability testing shall be in accordance with ASTM D 5084. For permeability testing, the cell and backpressure states to be applied during the initial application to achieve 10 psi effective confining pressure which produce a B coefficient equal to or greater than 0.9. In no case shall the cell pressure exceed 100 psi.

Stage	Cell Pressure (psi)	Back Pressure (psi)	Effective Confining Pressure (psi)
1	5	3	2
2	10	8	2
3	20	15	5
4	30	20	10
5	40	30	10
6	60	50	10

Saturation shall be confirmed by measuring the B coefficient. The initial gradient used during permeation shall be 20. Plots of the ratio inflow to outflow, gradient, and hydraulic conductivity versus time shall be required for each test. Lines describing the boundary limits for the listed termination criteria shall be included on the plots. The permeate liquid shall be clean water. The specimen top cap, bottom cap, and porous end pieces shall have a diameter equal to the diameter of the test specimen ± 2%. The diameter of the core samples will be a nominal diameter 3 inches and approximate length of 6 inches. Head shall be increased on the inflow end at the bottom of the specimen to a pressure which will develop the gradient of 20.

3.5.3 Wet Bulk Sample and Core Strength Testing

Laboratory strength tests of the wet bulk sample cylinders shall be in accordance with ASTM D 4832, except that loading shall continue on all specimens until the cylinder breaks enough to examine the appearance of the interior of the specimen. Photograph the broken specimen and note any apparent segregation, lenses, pockets, and the like in the specimen. Laboratory strength tests of the core samples shall be in accordance with ASTM D 2938. The rate of loading for the fabricated specimens shall be the same as for the cores. Photograph the broken specimen and note any apparent segregation, lenses, pockets, and the like in the specimen.

3.5.4 Continuity

Continuity of the cutoff wall shall be confirmed by a) constructing the panels with an overlap, b) measuring and recording the verticality of the deep soil mix augers / leads during the forming of the wall, and c) the results of the coring. Core recovery shall be at least ninety five (95) percent over the full depth of the wall. The maximum incremental deviation at any depth shall not be greater than twenty (20) percent of the specified minimum wall thickness. The accumulated total deviation of any single panel from vertical shall not exceed one (1) percent of the panel depth. The coring rig shall be equipped with the same type of equipment used on the DMM rig to assure verticality. The core hole shall be vertical and terminate just below the bottom of the cutoff wall. If the core hole exits the wall before the as-constructed wall depth is reached, a core hole deviation measurement shall be performed by the Contractor. If the core

hole deviation measurement and the recorded cored depth indicate the panel exceeds the allowable deviation, corrective action will be required to bring the panel and wall into compliance with the contract requirements.

3.5.5 Homogeneity

Homogeneity refers to how well the soil-cement-bentonite materials are mixed. Homogeneity will be judged by the visual inspection of the core by the Contractor's Geotechnical Engineer and the Contracting Officer's representative. Portions of the core that appear to be insufficiently mixed will be selected for quality control permeability and strength testing. Core recovery shall also be used as an indication how well the material is mixed. Core recovery shall be at least ninety five (95) percent over the full depth of the wall.

3.5.6 In situ Permeability Testing

In situ permeability shall be determined in accordance with ASTM D 4630. Each core hole shall have three (3) field permeability tests performed, one each in the top, middle, and lower third of the hole. Exact locations will be selected by the joint agreement of the Contractor's Geotechnical Engineer and the Contracting Officer based on the visible inspection of the core and description of water loss or gain noted on the Geotechnical Engineer's log.

3.5.7 Wet Bulk Sample Gradation

Representative grain size distribution (gradation) shall be determined for all wet bulk samples retrieved. Gradations shall be obtained in accordance with ASTM D 422 or ASTM C 117 and ASTM C 136. Hydrometer analyses used to determine grain size distribution of the fines are not required.

3.5.8 Rejected DMM Cutoff Wall Sections

If the specified dimensions, continuity, homogeneity, strength or permeability are not achieved, the deficient section of the DMM cutoff wall will be rejected. The deficient section limits will be determined by the Engineer. The deficient section shall be no less than the entire rig-shift's placement from which the representative core or wet bulk samples were obtained. If tests fail to meet the specified requirements, the Engineer reserves the right to require additional sampling and testing at the Contractor's expense. For failed/rejected sections, the Contractor shall construct and retest a second parallel backup wall at no additional cost to the Agency.

3.6 LEVEE PREPARATION

3.6.1 Levee Surface

The Contractor shall prepare the working surface of the levee section to a firm and essentially level condition for passage of the Contractor's machinery and equipment. This may require the excavation and lowering of the levee crown to a width that will accommodate the Contractor's equipment. A berm or other appropriate type of barrier shall be constructed within the construction limits to prevent off-site movement of waste materials, grout spills, etc..

3.6.2 Construction Staking

The Contractor shall provide, install, and maintain all temporary benchmarks, layout staking and necessary construction staking to locate the centerline of the wall. Survey construction control staking shall be performed by a licensed surveyor or registered professional engineer authorized to perform surveying in California. All survey data shall be stamped by the surveyor.

3.6.3 Working Surface

The working surface, from which the cutoff wall is constructed, shall constitute the top of the DMM cutoff wall for the purpose of measurement for payment. The Contractor shall not construct a working surface to a level lower than the limits shown on the drawings without the Contracting Officer's approval. There will be no payment for any additional excavation, fill, relocation, or cutoff wall required as the result of constructing a lower working surface than the defined working surface. Upon completion of the cutoff wall installation, the levee shall be restored to final alignment and grade in accordance with Section 02332 LEVEE RESTORATION AND EARTHWORK.

3.7 CUTOFF WALL CONSTRUCTION

3.7.1 General

The cutoff wall shall be constructed to the elevations, lines, grades, and cross-sections indicated on the plans and in accordance with these specifications, unless otherwise directed. The wall shall have essentially vertical columns with a minimum diameter of 36 inches, a minimum thickness of 30 inches, and shall extend to the depths indicated on the Drawings. The completed wall shall be a homogeneous mixture of grout and the in situ soils.

3.7.2 DMM Production

Prior to beginning production cutoff wall installation, the Contractor shall prove that the Contractor's proposed equipment, procedures, and mix design can meet the acceptance criteria. The Contractor may proceed with production cutoff wall work at his/her own risk, until the test sections have been approved by the Contracting Officer.

3.7.3 Horizontal Alignment

The Contractor shall accurately stake the proposed and actual as-constructed location of the cutoff wall. The surveyor shall be available during all production work. The cutoff wall centerline shall be constructed within 1.0 ft. of the locations shown on the plans. The Contractor shall provide adequate methods and permanent in field markers and bench marks to allow the Goverment to verify the as-built location of the wall during and after construction. The centerline of each panel for the production wall shall be surveyed and staked.

3.7.4 Construction Methods

Movement of the crawler base machine shall provide the preliminary alignment of the augers and the final alignment shall be adjusted by hydraulic manipulation of the leads. One stroke of the machine shall construct a DMM panel of 3 or more columns. The wall shall be advanced in

a continuous manner by installing a primary panel of 3 or more columns followed by a secondary panel of 3 or more columns with 1 full column of overlap to create a continuous wall. The minimum and maximum time allowed between the completion of a primary panel and the beginning of an overlapping secondary panel shall be determined by the Contractor. However, if the time between adjacent panel construction exceeds 48 hours, a special "cold joint" panel overlap / joint shall be constructed providing one full panel overlap as directed by the Contracting Officer.

3.7.5 Grout Preparation

3.7.5.1 Material Handling

Dry material shall be stored in silos and fed to mixers for agitation and shearing. The air evacuated/displaced from the storage silos during the loading process shall be filtered before being discharged to the atmosphere. In order to accurately control the mixing ratio of grout, the addition of water and cement shall be determined by weight using the automatic batch scales in the mixing plant. Representative samples of the cement and bentonite shall be obtained for each lot or truck load of material delivered to the site. These samples stored in air tight containers until the contract is complete, and shall be used if needed, for testing to confirm material quality. Water shall be tested once every two weeks.

3.7.5.2 Material Mixing

Minimum mixing time shall be three minutes; maximum holding time shall be three hours. The specific gravity of the grout shall be determined during the design mix program for confirmation of grout proportions.

3.7.5.3 Specific Gravity

Contractor shall check the specific gravity of the slurry at least twice per 8-hour shift per rig using the methods outlined in ASTM D4380. The specific gravity measurements shall be indicated on the Daily Quality Control Report.

3.7.6 Soil-Grout Mixing

3.7.6.1 Mixing Technique

The completed panel shall be a homogeneous, macro-uniform mixture of the grout and the in situ soils. Soil and grout shall be mixed together in-place by mechanical mixing of the overlapping augers and blades for the full width of the panel. Jetting may not be used to facilitate mixing or auger advancement. Grout ports in the augers shall direct the flow to the side and not downward. The mixing action shall blend, circulate and knead the soil over the vertical height of the panel.

3.7.6.2 Construction Progress

Installation of each column shall be continuous without interruption. If an interruption of more than 1 hour occurs, the column shall be remixed for the entire height of the element using the correct dosage of fresh grout.

3.7.7 Grout Shaft Rotation Speed and Penetration/Withdrawal Rate

The mixing shaft rotational speed and penetration/withdrawal rates shall be as established by the Contractor during the test section, and shall be adjusted as needed to achieve adequate mixing. If the rotation speed and penetration and withdrawal rates vary by more than ten (10)percent from the parameter established in the test section, the Contracting Officer may require additional testing to verify acceptable results at no additional cost to the Goverment.

3.7.8 Grout Injection Rate

3.7.8.1 General

The quantity of grout injected shall be in accordance with the mix design established during the test section. The grout injection rate shall be constantly monitored, calculated, and controlled. For production quality control, the real time monitoring of the slurry injection rate shall be performed. If the injection rate varies by more than ten (10) percent from the parameter established in the test section, the Contracting Officer may require additional testing to verify acceptable results at no additional cost to the Agency.

3.7.8.2 Grout Injection Modifications

The Contractor may request to modify the established mix design and injection ratio. All modifications are subject to Contracting Officer approval, and the Contracting Officer may request additional Quality Control testing to verify acceptable results at no additional cost to the Goverment.

3.7.9 Cutoff Wall Cap

The cutoff wall cap shall consist of impervious fill material placed to the lines and grades shown on the drawings. After the cutoff wall has been topped off and has set, the cutoff wall shall be capped with impervious fill in accordance with the details shown on the drawings. Any settlement of impervious fill over the cutoff wall shall be backfilled with additional impervious fill. The cutoff wall cap material shall consist of impervious fill material as defined in Section 02331A EARTHWORK. Subgrade preparation, placement, compaction and testing shall be in accordance with Section 02331A EARTHWORK. After the impervious fill has been properly placed and compacted at the top of the cutoff wall, the levee crown shall be restored in accordance with Section 02731 AGGREGATE SURFACE COURSE.

3.8 CLEANUP & DISPOSAL

The Contractor shall clean up grout waste, debris, and leftover materials resulting from the construction process. After completion of the work, the site shall be cleared of all debris, which may have accumulated in the execution of the work. Waste materials shall become the property of the Contractor and shall be disposed of off site in a legal manner.

3.9 QUALITY CONTROL PROGRAM

3.9.1 General

3.9.1.1 Quality Control Program

The Contractor shall develop a DMM Cutoff Wall Quality Control Program that shall be in conformance with Section 01451 CONTRACTOR QUALITY CONTROL and shall include, as a minimum, the following components:

(1) Continuous real time monitoring and recording of the following soil mixing parameters:
a) Drilling and mixing depth
b) Auger penetration and withdrawal rates versus depth
c) Auger rotation speed versus depth
d) Grout injection rate and pressure for each auger shaft versus depth
e) Auger torque, amperage, or other energy related parameters
f) Verticality
g) Grout plant batching and mixing for each panel constructed
h) Confirmation of penetration into target stratum

(2) Testing of selected samples recovered.

3.9.1.2 Report Monitoring

The Contractor shall provide all personnel and equipment necessary to implement the Quality Control Program. The Contractor shall include a Registered Geotechnical Engineer and Licensed Land Surveyor or Registered Professional Engineer (authorized to perform surveying in California) as a part of the QC organization. The Contracting Officer will observe construction and will review the Contractor's Daily Quality Control Reports and test results in order to verify that the Quality Control Program is being properly implemented.

3.9.1.3 Program Duration

The established Quality Control Program shall be in effect for the full duration of the Contract.

3.9.2 Rig-Shift Quality Control Report

3.9.2.1 General

Contractor shall submit Rig-Shift Quality Control Reports for each rig per shift to the Contracting Officer by the end of the following shift. The Rig-Shift Quality Control Report shall document the progress on the DMM wall construction, present the results of the Quality Control parameter monitoring, and present the results of coring, and the strength and permeability testing on cured samples.

3.9.2.2 Data Documentation

The Rig-Shift Quality Control Reports shall include at a minimum the results of the following real time Quality Control parameters monitoring:

(1) Identification of Area of Work
(2) Rig number

(3) Date and time (start and finish) of panel installation
(4) Column number and reference drawing number
(5) Column top and bottom depths or elevations
(6) Grout injection volume
(7) Slurry specific gravity measurements
(8) Test methods and results
(9) Description of obstructions, interruptions, or other difficulties encountered during installation and how they were resolved
(10) Auger rotation speed per 3-foot vertical interval versus depth
(11) Penetration and withdrawal rates in feet per minute versus depth
(12) Grout injection rate of each auger at every 3-foot vertical interval versus depth
(13) Logs of cored exploration holes.

3.9.2.3 Reports

The Daily Quality Control Reports shall include the Rig-Shift Quality Control Reports.

3.9.3 Coordination of Testing Laboratories

The Contractor's Quality Control laboratory representative shall meet weekly with the Goverment's Quality Assurance laboratory representative to coordinate all aspects of their work. Differences in sampling, handling, transporting, storing and testing methods shall be eliminated. If discrepancies in the test results from the two labs are noted, the Chief of the Quality Control Laboratory and the Chief of the Quality Assurance Laboratory shall visit and inspect each other's laboratory facilities for the purpose of eliminating the differences and discrepancies. The Chief of the Quality Control Laboratory shall report the findings to the Goverment with recommendations for corrective action.

3.10 CUTOFF WALL ACCEPTANCE

3.10.1 General

Final acceptance of the DMM cutoff wall will be based on the Contractor's Quality Control Records as identified in the Rig-Shift Reports, Contractor's Quality Control test results, and Goverment's Quality Assurance test results. Both the Contractor's and the Agency's testing shall demonstrate that the contract requirements are met prior to acceptance of the work. If during the course of construction the Contractor's QC testing indicates noncompliance with the specifications, the Contractor shall immediately notify the Contracting Officer in writing. Notification shall include the remedial action to be taken by the Contractor to bring the work / products back into compliance.

3.10.2 Acceptance Criteria Synopsis

The following is a summarization of acceptance criteria for part but not all of the testing and procedural requirements. Refer to the entire specification and drawings for all the contract requirements.

a. Wall depth - as shown on the drawings and as directed by the Contracting Officer
b. Wall thickness - minimum 30 inches (minimum 36-inch diameter augers shall be used)
c. Wall continuity - A minimum core recovery of ***85*** percent shall be

achieved at each total core hole / panel location. The maximum incremental deviation between two adjacent panels at any depth shall not be greater than twenty (20) percent of the specified minimum wall thickness. The accumulated total deviation of any single panel from vertical shall not exceed one (1) percent of the panel depth.

d. Wall homogeneity - Mixing shall be sufficient to prevent soil inclusions greater than fifty (50) percent of the core diameter from occurring and total core recovery shall be at least ninety five (95) percent over the full depth of the wall.

e. Bulk sample strength - minimum 45 psi at 7 days

f. Bulk sample permeability - maximum 1x10-6 cm/s at 7 days

g. Core strength - minimum 45 psi at 7 ***to 21*** days

h. Core permeability - maximum 1x10-6 cm/s at 7 ***to 21*** days

i. In situ permeability - maximum 1x10-6 cm/s at 7 ***to 21*** days

-- End of Section --