ARKANSAS STATE HIGHWAY AND TRANSPORTATION DEPARTMENT

SPECIAL PROVISION

JOB NO. 110229

SLURRY DISPLACEMENT DRILLED SHAFT

DESCRIPTION: This work includes the furnishing of all materials and the construction of foundations consisting of reinforced concrete shafts placed within drilled excavations using a slurry displacement method. This method uses mineral or polymer slurry to maintain stability of the borehole while advancing the excavation to the final depth and placing the reinforcing cage and shaft concrete. Such foundations shall be constructed in accordance with the details and governing dimensions shown on the plans, the Standard Specifications, this special provision, and as directed by the Engineer.

MATERIALS: (a) Slurry. The slurry shall be a mineral or polymer slurry product developed for concrete shaft construction using a slurry displacement method.

The Contractor shall provide the Engineer with a copy of the Manufacturer's Specifications including the parameters for the tests required in this Special Provision for the slurry he intends to use. The approval to use this slurry shall be made by the Engineer.

(b) Concrete. All concrete shall be Class S with a minimum 28-day compressive strength of 3500 psi and shall conform to Section 802 unless modified herein.

The slump of the drilled shaft concrete, at time of placement, shall 8 inches ± 1 inch for concrete placed underwater/under slurry. The maximum water cement ratio specified in subsection 802.05 shall not be increased. Approved admixtures may be used to obtain desired workability.

TRIAL BATCH: Each concrete mix design proposed by the Contractor to be used in the drilled shafts shall be submitted to the Engineer at least 10 business days prior to preparing a trial batch. A trial batch for each concrete mix design shall be prepared using the specific materials, including admixtures, that are intended for use on the job. The Contractor shall prepare a plant batch of at least 3 cubic yards or one-third the rated capacity of the mixer, whichever is greater. This trial batch shall be accomplished by the Contractor under the observation of the Engineer. This batch shall be sampled and tested by the Engineer for compliance with the specifications for slump and compressive strength. Additionally, this batch shall be sampled and tested by the Engineer for slump loss according to the following procedure:

SP JOB NO. 110229 – SLURRY DISPLACEMENT DRILLED SHAFT

(b) Concrete. (Cont.)

TRIAL BATCH: (Cont.)

1. After initial mixing, determine the slump, concrete temperature, and ambient temperature. Ensure that the slump is within the range meeting the requirements for time of placement. The time of test is initiated at this point.
2. Mix the concrete intermittently for 30 seconds every 5 minutes at the mixing speed of the mixer.
3. Determine slump, concrete temperature, and ambient temperature at 30-minute intervals for 3 ½ hours. The concrete mix shall maintain a slump of 4 inches or greater during the test. Mix the concrete for 1 minute at the mixing speed of the mixer immediately before these slump tests are performed.
4. Submit the results of the slump loss test to the Bridge Engineer for information and record purposes.

(c) Reinforcing Steel. Reinforcing steel shall be Grade 60 conforming to the requirements of Section 804, unless noted herein.

(d) Casing. Temporary casings shall conform to ASTM A 252, Grade 2 or Grade 3. Permanent casings shall conform to ASTM A 252, Grade 2 or Grade 3, or shall be zinc coated (galvanized) corrugated steel pipe conforming to AASHTO M36 and M 218. The walls and interior surfaces of the casings shall be carefully washed and cleaned of all sand, gravel, bonded concrete, or foreign materials before use.

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CONSTRUCTION: (a) Work Plan. At least 30 days prior to the beginning of construction of the drilled shafts, the Contractor shall submit to the Engineer for information and record purposes a Work Plan for each shaft of similar type and setting. Where drilled shafts are to be constructed at multiple sites, a separate Work Plan shall be submitted for each site. The Work Plan shall include but is not limited to:

1. A thorough and complete description of the proposed drilling equipment including cranes, drills, augers, tremies, concrete pumps, slurry pumps, de-sanding equipment, casings, etc.
2. Method of drilling and achieving shaft alignment tolerances and removing obstructions.
3. Slurry management plan.
4. Method of installation for any permanent casings and the method of installation and removal for any temporary casings
5. Method of mixing, circulating and cleaning slurry.
6. Details of methods to clean and inspect the shaft excavation including the bottom of the shaft.
7. Method of supporting and centralizing the reinforcing steel.
8. Method and anticipated time required for concrete placement in each shaft.
9. Sequence of drilling and a time schedule for completion of each shaft including non-destructive testing.
10. Preventative measures for working around any railroad tracks and utilities in the immediate vicinity.
11. The location of any work roads, detours and traffic control devices.

SP JOB NO. 110229 – SLURRY DISPLACEMENT DRILLED SHAFT

(a) Work Plan. (Cont.) The drilled shafts shall be constructed in accordance with the Work Plan and no deviation shall be allowed without the written permission of the Engineer. Any change in the Work Plan shall be submitted to the Engineer at least 3 business days before any work is begun. Acceptance of the Work Plan shall not relieve the Contractor of any other requirements in the Plans and Specifications.

(b) Protection of Existing Structures. The Contractor shall control his operations to prevent damage to any existing structures and utilities. Preventive measures shall include, but are not limited to, selecting construction methods and procedures that will prevent caving of the shaft excavation, and monitoring and controlling the vibrations from construction activities such as the driving of casing or sheeting, or drilling of the shaft. Blasting will not be permitted.

(c) Construction Tolerances. The following construction tolerances apply to drilled shafts unless otherwise shown on the plans:

1. The center of the drilled shaft shall be within three (3) inches of plan position in the horizontal plane at the plan elevation for the top of the shaft.

2. The vertical alignment of a vertical shaft excavation shall not vary from the plan alignment by more than 1/4 inch per foot of depth.

3. After all the concrete in a shaft is placed, the top of the reinforcing steel cage shall be no more than four (4) inches above and no more than two (2) inches below plan position.

4. The top elevation of the shaft shall have a tolerance of plus one (1) inch or minus three (3) inches from the plan top of shaft elevation.

5. Excavation equipment and methods shall be designed so that the completed shaft excavation will have a planar bottom. The cutting edges of the excavation equipment shall be normal to the vertical axis of the equipment within a tolerance of ± 3/8 inch per foot of diameter.

6. The finished diameter of the shaft shall be no less than the specified diameter along the entire length of the drilled shaft.

Drilled shaft excavations and completed shafts not constructed within the required tolerances are unacceptable. The Contractor shall be responsible for correcting all unacceptable shaft excavations and completed shafts to the satisfaction of the Engineer. Materials and work necessary, including engineering analysis and redesign by a Professional Engineer registered in the State of Arkansas to complete corrections for out of tolerance drilled shaft excavations shall be furnished without either cost to the Department or an extension of the completion date of the project.

SP JOB NO. 110229 – SLURRY DISPLACEMENT DRILLED SHAFT

(d) Casings.

Temporary Casing: When shown in the plans or as directed by the Engineer temporary casings may be used in conjunction with the slurry displacement method to prevent caving of the excavated shaft, to exclude ground water, or to create a positive seal into impervious material so that no piping of water or other materials occurs into or from the shaft excavation. The Contractor shall remove temporary casing before completion of concreting of the drilled shaft. Predrilling with slurry and/or overreaming to beyond the outside diameter of the casing may be required to install the casing. Temporary casings may be used in conjunction with any permanent casings. The Contractor shall maintain both alignments of the temporary casing with the permanent casing.

Before the temporary casing is withdrawn, the level of fresh concrete in the casing shall be a minimum of five feet above the hydrostatic water level in the soil or the level of drilling fluid in the annular space behind the casing, whichever is higher. As the temporary casing is withdrawn, care shall be exercised to maintain an adequate level of concrete in the casing so that fluid trapped behind the casing is displaced upward and discharged at the ground surface without contaminating or displacing the shaft concrete.

Temporary casings, which become bound or fouled during shaft construction and cannot be practically removed, shall constitute a defect in the drilled shaft. The Contractor shall be responsible to improve such defective shafts to the satisfaction of the Engineer. Such improvement may consist of, but are not limited to: removal of the shaft concrete and extending the shaft deeper to compensate for loss of frictional capacity in the cased zone, providing saddle shafts to compensate for capacity loss or providing replacement shaft. All corrective measures, including redesign of the bent caused by the defective shaft, shall be done to the satisfaction of the Engineer by the Contractor without either compensation or an extension of time shall do. In addition, no compensation will be paid for the casing remaining in place.

Permanent Casing: Permanent casing shall be used when shown in the plans. The casing shall be continuous between top and bottom elevations as shown in the plans. The diameter of the permanent casing shall be sufficient to produce a finishes drilled shaft with a diameter no less than the specified diameter along the entire length of the shaft. The inside diameter of permanent casing shall not be greater than the specified diameter of the shaft plus 6 inches unless otherwise approved by the Engineer. Lengths of permanent casing shown on the plans are for estimating quantities only; actual lengths are to be determined in the field. All casings shall be steel, watertight and of ample strength to withstand handling and/or driving stresses and the pressure of both concrete and the surrounding earth materials. All casings used shall be selected by the Contractor to control the dimensions and alignment of excavations within tolerances and to execute all other construction operations.

SP JOB NO. 110229 – SLURRY DISPLACEMENT DRILLED SHAFT

(d) Casings. (Cont.)

Temporary Surface Casing: Temporary surface casing may also be required to prevent sloughing of the top of the shaft excavation for no greater than 10 feet below top of shaft. Temporary surface casings shall not be removed until after a minimum of 72 hours has elapsed since concrete placement and shall be done in a manner so as no damage will occur to a finished drilled shaft. At the Contractors option, temporary surface casing may be left in place or permanent casing may be used as the temporary surface casing. No additional payment will be made if temporary surface casing is left in place but will be included in the item "Slurry Displacement Drilled Shaft (84 " Dia.)" or "Slurry Displacement Drilled Shaft (54 " Dia.)".

(e) Excavations. The Contractor shall perform the excavation required for the shafts through whatever materials encountered, to the dimensions and elevations shown on the plans or required by the site conditions. The Contractor's methods and equipment shall be suitable for the intended purpose and materials encountered.

Bottom of shafts shall not be founded at an elevation above that shown on the plans without the approval of the Bridge Engineer. The depth that is to be drilled shall be considered to be an approximation and the Engineer may order such changes in depth as may be necessary to secure a satisfactory foundation.

The excavation will require the use of the slurry displacement. Unless obstructions are encountered, the excavation shall be completed in a continuous operation and the concrete shall be placed without undue delay. If the excavation will be subjected to vibrations from railroad tracks that are in the immediate vicinity, temporary casing may need to be advanced as drilling proceeds to prevent caving.

Material excavated from shafts and not used in the backfill around the compacted pier or abutment shall be disposed of in a manner approved by the Engineer and shall not be placed in a waterway or otherwise impair the efficiency or appearance of the bridge or other parts of the work. Any excavation for the shaft beyond the lines required by the plans shall be filled with Class S Concrete at the Contractor's expense.

When the elevation of the top of shaft is below ground level at the time of concrete placement, an oversize temporary surface casing from ground elevation to a point below the top of the shaft will be required to control caving of any substance into freshly placed concrete and facilitate construction. The oversized temporary surface casing shall be removed and shall be backfilled in accordance with subsection 801.08. When drilled shafts are to be installed in conjunction with embankment placement, the Contractor shall construct drilled shafts after the placement of fills unless otherwise approved by the Engineer.

SP JOB NO. 110229 – SLURRY DISPLACEMENT DRILLED SHAFT

(e) Excavations. (Cont.) The Contractor shall provide suitable access and equipment for checking the dimensions and alignment of each permanent shaft excavation and for inspecting the excavation.

An excavation shall not be left unattended until the concreting operations are completed for that excavation. During non-working hours excavations shall be protected by the use of solid, safe covers that are firmly fastened in place.

The Contractor shall check the dimensions and alignment of each shaft excavation under the direction of the Engineer. Final shaft depths shall be measured with suitable weighted tape or other approved methods after final cleaning of the excavation.

No concrete shall be placed until the Engineer approves the condition of the excavation. Prior to placing concrete, the shaft excavation shall be cleaned so that a minimum of 50 percent of the base will have less than 1/2 inch of sediment and at no place on the base more than 1-1/2 inches of sediment. The Contractor shall be responsible for showing that the excessive loose material has been removed from the excavation. All expenses for inspection shall be included in the price bid for "Slurry Displacement Drilled Shaft (84 " Dia.)" or "Slurry Displacement Drilled Shaft (54 " Dia.)".

(f) Slurry. The slurry shall be mixed thoroughly with clean fresh water according to the manufacturer's recommendations. Check and adjust the pH of the water prior to mixing. Acidic water and soils may reduce the effectiveness of the slurry. Also, water and soil temperature lower than 40^{o} F may reduce the effectiveness of the slurry.

The slurry shall have sufficient viscosity and gel characteristics to transport excavated material out of the shaft. The specific gravity of the slurry shall be sufficient to maintain the stability of the shaft. The level of the slurry shall be maintained at the height sufficient to prevent caving of the hole.

Sidewall overreaming shall be required when the sidewall of the hole is determined by the Engineer to have either softened due to excavation methods, swelling due to delays in concreting, or degrading because of slurry cake buildup. Overreaming thickness shall be a minimum of ½ inch and a maximum of 3 inches. The thickness and elevation of sidewall overreaming shall be as directed by the Engineer. All expenses for overreaming shall be included in the price bid for "Slurry Displacement Drilled Shaft (84 " Dia.)" or "Slurry Displacement Drilled Shaft (54 " Dia.)".

Adequate slurry tanks will be required. No excavated slurry pits will be allowed without written permission of the Engineer. Recycling of the slurry is permitted provided the recycled slurry's properties satisfy the required range of values given in Tables 1 or 2.

Since cement contamination is very harmful to the slurry, the top four feet of slurry directly above the shaft concrete shall be disposed of and not reused. Certain types of soil may require cleaning of the recycled the slurry.

SP JOB NO. 110229 – SLURRY DISPLACEMENT DRILLED SHAFT

(f) Slurry (Cont.)

Slurry and material removed during shaft excavation shall not be allowed to enter a waterbody or wetland, shall be disposed of properly, and handled in accordance with Section 110 of the Standard Specifications. Unless the neutralized slurry is discharged into a sewer system under permission from the operator, the National Pollutant Discharge Elimination System requires a permit for this type of discharge associated with industrial activity. The Arkansas Department of Environmental Quality issues these permits. The Contractor shall be responsible for obtaining and complying with all requirements of the permit if he desires to discharge the slurry material, either on or off site.

Tests. Tests to determine density, viscosity, pH, and sand content shall be performed on the slurry by the Contractor during the shaft excavation to establish a consistent working pattern. The testing apparatus must be approved by the Engineer. The tests should be performed when the slurry temperature is above 40^{o} F.

A minimum of four sets of tests shall be made during the first eight hours of slurry use. When the results show a consistent behavior, the testing frequency may be decreased to one set every four hours of slurry use.

For shafts less than 50 feet in depth, tests shall be conducted on slurry samples taken from 1 foot above the base of the shaft and at midpoint of the shaft. For shafts greater than 50 feet in depth, tests shall be conducted on the slurry samples taken from 1 foot above the base of the shaft and the third points of the shaft.

When any slurry samples are found to be unacceptable, the Contractor shall take whatever action is necessary to bring the slurry within specification requirements, before advancing the shaft excavation. An acceptable range of values for the physical properties of the slurry is shown in Tables 1 or 2. Slurry Properties shall be adjusted for the site conditions as recommended by the manufacturer and approved by the Engineer.

SP JOB NO. 110229 – SLURRY DISPLACEMENT DRILLED SHAFT

Table 1 – Mineral Slurry Properties

ITEM TO BE MEASURED	RANGE OF RESULTS AT 60° F (20°C)	TEST METHODS
1. Density (pcf)	64 - 75 lb/ft^3 (fresh water applications)	(Mud Balance) ASTM D4380
2. Marsh Funnel Viscosity, (seconds/qt.)	28 to 45 (See Table 2 for application)	API RP13B-1 Sect. 2 (Marsh Funnel & Cup)
3. Sand Content by volume, percent, before concreting	4% maximum	(Sand Screen Set) ASTM D4381
4. pH	8 to 11	ASTM D4972

SP JOB NO. 110229 – SLURRY DISPLACEMENT DRILLED SHAFT

Table 2 – Polymer Slurry Properties

ITEM TO BE MEASURED	RANGE OF RESULTS AT 60° F (20°C)	TEST METHODS
1. Density (pcf)	64 lb/ft^3 Maximum (fresh water applications)	(Mud Balance) ASTM D4380
2. Marsh Funnel Viscosity, (seconds/qt.)	40 to 90 (or as approved by the Engineer)	API RP13B-1 Sect. 2 (Marsh Funnel & Cup)
3. Sand Content by volume, percent, before concreting	1% maximum	(Sand Screen Set) ASTM D4381
4. pH	8 to 10	ASTM D4972

SP JOB NO. 110229 – SLURRY DISPLACEMENT DRILLED SHAFT

(g) Reinforcing Steel. The drilled shaft reinforcing steel cage shall be completely assembled and shall be placed as a unit immediately after the shaft excavation is inspected and accepted, and prior to concrete placement. The cage will consist of the reinforcing shown in the plans, cage stiffener bars as needed, spacing devices, nondestructive testing pipes and any other appurtenances required to maintain alignment, shape, and clearances. Any internal stiffeners shall be removed as the cage is placed in the borehole.

The minimum clearance between the edge of the drilled shaft and the reinforcing steel shall be as shown in the plans.

The Contractor shall be responsible for the proper bracing of the reinforcing cage. This bracing shall be sufficient to permit assembly above ground and placing in the shaft as a unit without inducing deforming, twisting, or bending stress. Welding of reinforcing bars will not be permitted. Bars in the shaft shall be tied at all intersections regardless of spacing.

Concrete spacers or other approved non-corrosive spacing devices shall be used, and properly positioned at a maximum of 30" around the circumference of the steel cage and not exceeding 5 feet along the shaft to ensure concentric spacing of the cage inside the shaft. When the diameter of the longitudinal reinforcing steel exceeds 1 inch, such spacing along the shaft shall not exceed 10 feet. The spacer sizes shall be varied as necessary along the length of the shaft to maintain a concentric spacing within the cased and uncased portions of the shaft.

The cage shall be supported from the top by some positive method to minimize uplift or downward slump during concrete placement and/or extraction of casing. A minimum of ½ of the vertical bars shall be supported from the top. The supports shall be concentric with the cage to prevent racking and distortion of the steel. Bottom supports of noncorrosive material shall be provided to insure that the bottom of the cage maintains the proper clearance from the bottom.

The elevation of the top of the steel cage shall be carefully checked before and after the concrete is placed. Displacement of the steel beyond the specified tolerances will be cause for rejection.

(h) Concrete. The work shall be performed in accordance with the provisions of Section 802 and in conformance with the requirements herein.

Concrete shall be placed as soon as possible after all excavation is complete and reinforcing steel placed. The elapsed time from the beginning of concrete placement in the shaft to the completion of placement shall not exceed 2 hours. The Contractor may request a longer placement time provided a concrete mix is supplied that will meet the slump requirements at the time of placement and maintain a slump of 4 inches or greater over the requested placement time as demonstrated by trial batch and slump loss tests. Admixtures such as retarders and plasticizers may be used if included in the trial batch and approved by the Engineer.

SP JOB NO. 110229 – SLURRY DISPLACEMENT DRILLED SHAFT

(h) Concrete. (Cont.) After the concrete level has reached the required top elevation, it shall be forced to overflow until only fresh uncontaminated concrete is left in the shaft. The concrete waste shall not enter the waterway as required by Special Provision Job 110229 Section 404 Nationwide Permit 23 requirements. The top 10 feet of each drilled shaft shall be vibrated except when more than 10 feet is to be exposed above the ground line or the channel bottom. When more that 10 feet is exposed the entire exposed portion shall be vibrated. Exposed portions of each drilled shaft shall be cured and any construction joint area shall be treated as prescribed in Section 802.

Concrete Placed Under Slurry. All drilled shaft concrete placed using the slurry displacement method shall be placed through a suitable rigid tremie or by pumping through a suitable rigid tube to prevent segregation of materials. In the presence of the Engineer the Contractor shall provide equipment and personnel to sound the top of the concrete in order to verify the location of the concrete surface and the discharge orifice at all times.

Placement by Tremie. The tremie shall consist of a suitable rigid tube with a diameter of no more than 14 inches nor less than 10 inches. The tremie shall be watertight and shall be constructed so that the bottom can be sealed and then opened after it is in place and fully charged with concrete. If a plug is used it shall be removed from the excavation after concrete placement has begun. The tremie shall be constructed and supported so that it can be moved horizontally to cover the work area and moved vertically to control the concrete flow as the level of the concrete in the shaft is raised. The bottom of the tremie shall be near the bottom of the shaft at the beginning of the concrete placement but shall not remain at the bottom of the shaft during the entire pour. The tremie discharge end shall be immersed at least 5 feet in concrete at all times after starting flow of concrete. **At no time shall concrete be discharged above the surface of deposited concrete.**

Placement by Pump. Placing of concrete by pumping will require that the portion of the tube inside the excavation meets all the requirements above, but only that portion of the pumping tube in contact with the concrete will be required to be rigid.

All pump lines shall have a minimum four (4) inch diameter and be constructed with watertight joints. All pump equipment shall be clean and in good operating condition. Concrete placement shall not begin until the pump line discharge orifice is at the bottom of the shaft excavation. A plug or diaphragm shall be used to separate the concrete from the fluid in the hole until pumping begins. The plug shall be removed from the excavation after placement has begun. Concrete placement shall be done in one continuous operation. The discharge orifice shall be near the bottom of the shaft at the beginning of the concrete placement but shall not remain at the bottom of the shaft during the entire pour. The discharge orifice shall remain at least five (5) feet below the top surface of the fluid concrete. When lifting the pump line during concreting, the Contractor shall temporarily reduce line pressure until the orifice has been repositioned at a higher elevation in the excavation. **At no time shall concrete be discharged above the surface of deposited concrete.**

SP JOB NO. 110229 – SLURRY DISPLACEMENT DRILLED SHAFT

METHOD OF MEASUREMENT: Acceptable drilled shafts complete in place and of the specified diameter, will be measured by the linear foot as constructed to the dimensions shown on the plans or approved by the Engineer from bottom to top of shaft. No additional payment will be made for any excavation or concrete provided beyond the lines required by the plans.

Temporary steel casing will not be measured for separate payment, but shall be included in the unit price for "Slurry Displacement Drilled Shaft (84" Dia.)" or "Slurry Displacement Drilled Shaft (54" Dia.)"

BASIS OF PAYMENT: Drilled shafts, measured as provided above, will be paid for at the contract unit price bid per linear foot for "Slurry Displacement Drilled Shaft (84" Dia.)" or "Slurry Displacement Drilled Shaft (54" Dia.)" which shall be full compensation for making and inspecting shaft excavations; for furnishing, placing, and removing temporary casing; for furnishing and placing all concrete and reinforcing steel; for performing mix designs, preparing trial batches, and quality control and acceptance sampling and testing; and for furnishing all tools, labor, equipment and incidentals necessary to complete the work. Pipes for CSL testing including installation, water removal, grouting, removal of excess pipe, and other responsibilities related to testing and inspection assistance are to be paid for under the Special Provision for "Nondestructive Testing of Drilled Shafts".

When drilled shafts are carried below elevations shown on the plans at the direction of the Engineer, the additional length of drilled shaft will be measured as provided above and will be paid for in accordance with the following price schedule:

Depth Below Planned Elevation	**Price**
Not more than 5 feet	Contract Price
Excess of 5 feet and not more than 15 feet	Contract Price + 15%
More than 15 feet	Contract Price + 25%

Payment will be made under:

Pay Item	**Pay Unit**
Slurry Displacement Drilled Shaft (84" Dia.)	Linear Foot
Slurry Displacement Drilled Shaft (54" Dia.)	Linear Foot