

ROCK DOWELING

**\*\*From Rockingham IM 091-1(57)**

- xx. DESCRIPTION. This work shall consist of furnishing, installing, and testing rock dowels at the locations indicated in the Plans and as directed by the Engineer and Agency Geologist (Geologist).

The work includes high-angle installation of rock dowels to be completed using industrial rope access methods.

- xx. GENERAL. Rock doweling shall consist of galvanized continuous thread steel bars (Grade 75 (minimum) continuous thread bar) inserted in boreholes drilled into rock. For installed bar lengths of 7 feet or less, the boreholes shall be filled with cement grout using a tremie pipe prior to insertion of the bars. For installed bar lengths of greater than 7 feet, a grout tube attached to the bar or removable tremie pipe shall be used to install the grout after the bar is installed. When installed as rock dowels, the bars are not tensioned. Installation of rock dowels shall be performed in accordance with the Plans and as directed by the Engineer and Geologist.

- xx. APPLICABLE STANDARDS AND SPECIFICATIONS. The most recent versions of the cited standards and specifications shall be used to govern the quality of work and materials.

ASTM A 36	Standard Specification for Structural Steel
ASTM A 123	Zinc (Hot-Dip Galvanized) Coatings for Iron and Steel Products
ASTM A 153	Zinc Coating (Hot-Dip Galvanized) on Iron and Steel Hardware
ASTM C 109	Standard Test Method for Compressive Strength of Hydraulic Cement Mortars
ASTM C 150	Standard Specification for Portland Cement
ASTM C 452	Standard Test Method for Potential Expansion of Portland Cement Mortars Exposed to Sulfate
ASTM E 329	Practice for Inspection and Testing Agencies for Concrete, Steel, and Bituminous Materials as Used in Construction

- xx. MATERIALS.

- (a) Rock Dowels. Rock dowels shall, at a minimum, consist of Grade 75 steel manufactured for use as rock dowels and be in the form of continuous thread bar, as manufactured by Dwyidag, SAS, Williams, or an approved equal, with a minimum diameter of 1 inch. Appurtenant bearing plates with spherical seats and spherical nuts shall be manufactured by the thread bar manufacturer for rock doweling applications.

Rock dowel steel shall be handled and stored in such a manner as to avoid damage or corrosion. Damage to the rock dowel steel as a result of abrasion, cuts, nicks, welds, or weld splatter will be cause for rejection by the Engineer and Geologist.

Rock dowel steel shall be protected from dirt, rust, and deleterious substances. All exposed parts of the rock dowel, bearing plate, and spherical nuts on the surface shall be galvanized. Dowel ends, where cut, shall be painted with a cold galvanizing compound following installation.

- (b) Cement. Portland cement for grout shall, at a minimum, comply with the requirements of ASTM C 150, Type II or III.
- (c) Mixing Water. The water used for mixing shall be potable and free from substances which might be deleterious or corrosive to concrete or steel, and shall be furnished by the Contractor. The Contractor, if requested by the Engineer and Geologist, shall submit reports of tests made by a competent laboratory on samples of the water which the Contractor proposes to use or is using.

xx. SUBMITTALS.

- (a) Qualifications. Not less than two weeks prior to beginning any rock doweling, the Contractor shall provide qualifications of Contractor's personnel in writing to the Engineer and Geologist. The supervisors and drill operators shall have a minimum of two years of demonstrated experience in the installation of rock dowels.
- (b) Work Plan. Not less than two weeks prior to beginning rock doweling, the Contractor shall submit a detailed work plan for the rock doweling. The plan shall include:
  - (1) The proposed construction sequence and schedule.
  - (2) The proposed rope access methods and safety plan.
  - (3) The proposed drilling method and equipment.
  - (4) The proposed drill hole diameter.
  - (5) The proposed steel for the rock dowel, bearing plates, and nuts, including manufacturer's certificates/mill sheets.
  - (6) The proposed corrosion protection for the rock dowel system.
  - (7) Contractor's proposed mix design for grout.

Work shall not begin until the appropriate submittals have been approved in writing by the Engineer and Geologist.

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- (c) Field Reports. The Contractor shall submit a field report on a daily basis to the Engineer and Geologist for approval. The field report shall include the location and description of dowels installed, and for each dowel, the length of dowel, installation angle and direction, number of cement bags used, and water cement ratio of grout.

xx. CONSTRUCTION REQUIREMENTS.

- (a) General. Work shall proceed according to the approved Work Plan and schedule submitted by the Contractor prior to the beginning of work.
- (b) Drilling. The orientation of the drill hole shall be determined in the field by the Engineer and Geologist. Unless otherwise specified, the angle of installation shall be, at a minimum, 10 degrees down from horizontal as shown on the Plans. The dowels shall be installed within 5 degrees of the specified angle.

The Contractor shall flush the drill hole of all drill cuttings and debris with compressed air prior to the installation of the rock dowel.

Holes drilled for rock doweling in which dowel installation is considered by the Engineer and Geologist to be unacceptable or impractical shall be re-drilled at the Contractor's expense.

The Contractor's drillers shall keep and provide a borehole log for each borehole drilled for rock dowels. The log shall include, but not be limited to, the following:

- (1) Hole location, diameter, length, and angle from horizontal.
- (2) Date/time of drilling, drilling equipment used, encountered subsurface conditions (groundwater, joints, voids, soil/weak rock, etc.), and name of driller.

The Contractor shall submit the logs to the Engineer and Geologist on a daily basis.

- (c) Grout Mixing. Cement grout shall consist of a maximum of five gallons of clean potable water per sack consisting of 94 pounds of Type II or III Portland cement. The grout shall be mixed for a minimum of five minutes in a paddle-type grout mixer and passed through a #4 size sieve before being used. Grout may be pumped or fed by gravity into the tremmie pipe or grout tube. Grout containing lumps or that has been in the grout mixer for more than 30 minutes shall not be used. No chemical additives shall be used unless approved in writing by the Engineer and Geologist. The use of epoxy grout will not be permitted.

The Contractor shall flush the drill hole of all drill cuttings and debris with compressed air prior to grout installation.

- (d) Dowel Installation. For installed bar lengths of 7 feet or less, tremmie neat cement grout into hole with tremmie pipe at the toe of the hole. Fill hole with grout while withdrawing tremmie pipe at a rate such that the bottom of the tremmie pipe remains at or below the rising grout surface.

For installed bar lengths of greater than 7 feet, leave hole full of fluid grout for five minutes. If grout level drops by less than 1 inch, insert bar with centralizers into hole. If grout level drops by more than 1 inch in five minutes, re-fill hole with grout. If grout level continues to drop for more than 15 minutes, thicken grout mix as directed by the Engineer and Geologist. Insert bar with centralizers once the level stabilizes.

For all dowel bar installations, the annular space between the dowel and the drill hole perimeter in the completed installation shall be completely filled with cement grout over the full depth of the hole. Sufficient grout shall be used such that, at a minimum, a small amount of grout extrudes from the collar of the hole when the dowel is inserted to ensure that no voids are left around the bar. The quantity of grout that is required to fill each dowel hole will vary, and is highly dependent on geological conditions.

The "birds beak" annulus between the dowel and the hole shall be filled with hand-packed grout as shown on the Plans, and the face plates and nuts should be attached and tightened with a wrench as directed by the Engineer and Geologist.

- (e) Dowel Grout Testing. The strength of the grout for the dowels shall be tested at least every 10 dowels. The testing shall be performed by the Contractor in accordance with ASTM C 109. Acceptable grout shall have a minimum compressive strength of 4500 psi at 28 days.
- (f) Rock Dowel Testing. For each different method of dowel installation, two successful verification pullout tests shall be performed to verify the Contractor's installation methods, anchor pullout capacity, and design assumptions. The tests shall be performed prior to installation of production dowels at locations within the limits of work specified by the Engineer and Geologist. The dowels used for the verification tests shall be sacrificial and shall not be incorporated as production dowels. Dowel testing shall not be performed until the dowel grout has attained at least 50 percent of its specified 28-day compressive strength. All test data shall be recorded by the Contractor and submitted to the Engineer and Geologist.

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Testing equipment shall include two dial gauges, a dial gauge support, jack and pressure gauge, a load cell, and a reaction frame as shown in the Plans. A minimum of two dial gauges capable of measuring to 0.001 inch shall be available at the site to measure the anchor movement. The dial gauges shall have a minimum travel sufficient to allow the test to be performed without re-setting the dial gauge. The dial gauges shall be aligned within 5° of the axis of the dowel and shall be supported independent of the jacking setup and the rock surface. A hydraulic jack, pressure gauge, and pump shall be used to apply and measure the test load. Test setup shall be as approved by the Engineer and Geologist.

The jack and pressure gauge shall be calibrated by an independent test laboratory as a unit. The Contractor shall submit calibration reports for the jack and pressure gauge indicating calibration within 180 days prior to use. Rock dowel testing will not be allowed until approval of the calibration report by the Engineer and Geologist. The pressure gauge shall be graduated in 100 psi increments or less. The jack shall be capable of tensioning dowel bars to 80 percent of the guaranteed ultimate tensile strength of the bars within the rated pressure capacity of the pumping units, unless approved otherwise by the Engineer and Geologist.

The jack shall be independently supported and centered over the rock dowel so that the dowel does not carry the weight of the jack. The stressing equipment shall be placed over the dowel in such a manner that the jack, bearing plates, and stressing anchorage are in alignment. The jack shall be positioned at the beginning of the test such that unloading and repositioning of the jack will not be required during the test. The Contractor will be required to provide a reaction bearing pad for each test. The bearing pad shall be constructed to a size and thickness that will prevent failure of the pad or movement of the test jack or bearing plate.

Details of the verification testing arrangement, including the method of distributing test load pressures to the rock surface or reaction frame, test dowel bar size, grouted hole diameter and reaction plate dimensioning shall be developed by the Contractor and submitted to the Engineer and Geologist for approval. The test dowels shall be constructed using the same equipment, methods, and hole diameter as planned for the production dowels. Changes in the drilling or installation method may require additional dowel testing as determined by the Engineer and Geologist; such testing shall be provided at no additional cost to the Agency.

Test dowels shall have both bonded and unbonded lengths. Prior to testing, only the bonded length of the test dowel shall be grouted. The unbonded length of the test dowel shall be at least 3 feet unless approved otherwise by the

Engineer and Geologist. The bond length shall be determined by the Engineer and Geologist. The test load (TL) shall not exceed 1.33 times the design load (DL) and shall not exceed 80 percent of the guaranteed ultimate tensile strength for the bar. The DL for a 1¼ inch diameter steel threadbar grouted in a 3½ inch diameter borehole in rock is 7900 pounds (7.9 kips) per foot of bond.

Test dowels shall be cyclically and incrementally loaded and unloaded in accordance with the schedule shown below. The load shall be decreased to the alignment load (AL) after each cycle maximum, and the movement of each successive alignment load step shall be recorded. At each load increment, the total movement of the pulling head shall be recorded to the nearest 0.001 inch with respect to an independent fixed reference point. The load shall be held at each increment just long enough to obtain the movement reading, but no longer than 1 minute. Movement readings at the maximum test load (1.33 DL) shall be taken at 1, 2, 3, 4, 5, 6, and 10 minutes to measure creep rate. If the total creep movement between 1 and 10 minutes exceeds 0.04 inch, the test load shall be maintained for an additional 50 minutes. Total movements shall then be recorded at 20, 30, 40, 50, and 60 minutes from the start of the test load hold time.

Cycle	Increment	1	2	3	4	5	6
1	AL	0.25DL					
2	AL	0.25DL	0.5DL				
3	AL	0.25DL	0.5DL	0.75DL			
4	AL	0.25DL	0.5DL	0.75DL	1.0DL		
5	AL	0.25DL	0.5DL	0.75DL	1.0DL	1.25DL	
6	AL	0.25DL	0.5DL	0.75DL	1.0DL	1.25DL	1.33DL

The AL should be the minimum load required to align the testing apparatus and should not exceed 0.25 DL. During load hold periods, the dowel load shall not be allowed to deviate from the test pressure by more than 50 psi. The load should be returned to the load at the cycle maximum load prior to taking the movement reading at the cycle interval.

A test dowel shall be considered acceptable when:

- (1) A creep rate is observed to be less than 0.04 inches per log cycle of time between the 1 and 10 minute reading or, if exceeded, less than 0.08 inches per log cycle of time between the 6 and 60 minute readings, and the creep rate is linear or decreasing at the end of the creep test load hold period.

- (2) The total movement at the test load exceeds 80 percent of the theoretical elongation of the unbonded length (including the jack length), and is less than 100 percent of the theoretical elongation of the unbonded length (including the jack length) plus 50 percent of the bonded length.
- (3) A pullout failure does not occur during testing. Pullout failure is defined as the load at which attempts to increase the test load simply result in continued pullout movement of the test dowel.

The Contractor shall evaluate the results of each rock dowel test and submit a summary of the test results to the Engineer and Geologist. Dowel installation methods that do not satisfy the dowel testing requirements shall be considered inadequate. The Contractor shall propose alternative methods and install replacement test dowels at no additional cost to the Agency.

- xx. METHOD OF MEASUREMENT. The quantity of Special Provision (Rock Doweling) to be measured for payment will be the number of meters (linear feet) of dowels installed in the complete and accepted work, as obtained from the Contractor's daily field reports approved by the Engineer and Geologist.

The quantity of Special Provision (Rock Dowel Testing) to be measured for payment will be on a lump sum basis in the complete and accepted work.

- xx. BASIS FOR PAYMENT. The accepted quantity of Special Provision (Rock Doweling) will be paid for at the Contract unit price per meter (linear foot). Payment will be full compensation for furnishing, drilling, installing, and grouting the rock dowels and for furnishing all labor, tools, equipment, and incidentals to complete the work.

The accepted quantity of Special Provision (Rock Dowel Testing) will be paid for at the Contract lump sum price. Payment will be full compensation for testing the rock dowels, obtaining acceptable test results, and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

Payment for preparing and making required submittals will not be made separately, but will considered incidental to the work under this Section.

Payment will be made under:

<u>Pay Item</u>	<u>Pay Unit</u>
900.640 Special Provision (Rock Doweling)	Meter (Linear Foot)
900.645 Special Provision (Rock Dowel Testing)	Lump Sum