**Revision of Section 307
Cement Treated Subgrade**

**Revise Section 307 of the Standard Specifications for this project to add the following:**

# Description

**307.01** This work consists of treating the earth subgrade by combining Portland cement and water with a mixture of imported subgrade soil to the specified depth and compaction requirements as shown on the plans.

# Materials

**307.02 Portland Cement.** Portland cement for cement treated subgrade shall be applied in dry application. Portland cement for cement treated subgrade shall conform to the requirements of ASTM Cl 14.

**307.03 Water.** Water used for mixing or curing shall be per subsection 712.01, with the additional requirement that the sulfate content shall be less than 200 ppm.

**307.04 Soil.** The Soil shall be free from roots, sods, weeds, and shall not contain gravel or stone retained on a 1-inch sieve and shall have between 12 and 35 percent fines (material passing the U.S. No. 200 sieve) as determined by CP-31. The plasticity index of the material shall be between 0 and 10 percent as determined by AASHTO T-89 and T-90. The material shall have a minimum Sand Equivalency value of 35.

# Construction Requirements

**307.05 General.** The Contractor shall construct one compacted course 12-inches inthickness of treated material. The treated material shall be a uniform blend of soil, cement, and water, free from loose or segregated areas. It shall have uniform density and moisture content and be void of all vegetation and other organic or man-made material. The subgrade shall be well bound for its full depth and width with a smooth surface suitable for placing pavement. The Contractor shall regulate the sequence of the work to accurately apply and uniformly blend the cement at the designated rate and rework the courses with additional concentrations of cement as necessary to meet the above requirements.

At least 7 days before commencing the stabilization work, the Contractor shall submit a mix design and Process Control Plan to CDOT for Approval.

The Contractor shall mix Portland cement with water to produce a uniform mixture at the job site with equipment specifically manufactured for this purpose.

Excessive aeration of the cement treated soil layer will not be permitted.

**307.06 Typical Weather Operations.** The cement-treated subgrade (CTS) shall not be mixed when the subgrade material is frozen or raining to the extent that moisture content cannot be controlled. The CTS shall not be mixed or compacted if the temperature of the cement or soil is below 35 °F measured 3-inches below the surface of the CTS. Remove and replace or rework at the sole risk of the Contactor all CTS that is permitted to freeze within the first 24 hours, whether frozen on the surface or full depth. When materials are exposed to freezing ambient air temperatures after the first 24 hours but before the 7 day field cure period is complete, demonstrate that the 7 day design strength has been achieved.

Failure to demonstrate the 7 day design strength has been achieved shall require removal and replacement or rework at the sole risk of the Contactor at Contractor's expense.

When wind causes cement to blow across roadway, production shall cease as determined by the ICQC or CDOT. Suspend application when the ICQC or CDOT determines that weather conditions are unsuitable.

**307.07 Cold Weather Operations.** The CTS may proceed when the subgrade material falls below 35 °F measured 3-inches below the surface of the CTS. The CTS shall not be mixed or compacted if the ambient air temperature is not 35 °F and rising. During cold weather operations, a frost check will be completed on each day of production. The frost check can be a probe into the ground or observation of excavation in the area to be treated. CTS operations shall not proceed if the frost depth exceeds 10-inches in the area to be treated. Once the air temperature has reached the allowable temperature of 35 °F and rising and a frost check has been completed, mixing can commence. CTS should not be placed if forecasted weather temperatures indicate extreme low temperatures during the cure period. Soil temperature checks shall be taken behind the mixing operation immediately when mixing commences and every 100-feet or as directed by ICQC or CDOT and must meet or exceed a minimum temperature of 35 °F and should not contain frozen soil. If the resultant Soil/Cement/Water mixture is not above 35 °F or contains frozen soil, operations shall cease. If proven, through the use of recording thermometers, that the CTS froze before obtaining the required design strength as determined by PC field cured cylinders, the affected area shall be removed and replaced or reworked at the sole risk of the Contractor. Failure to demonstrate the 5 day design strength has been achieved shall require removal and replacement or rework of the CTS section at the sole risk of the Contractor at Contractor’s expense.

Process Control will install recording thermometers at the beginning of the section and end of the section to monitor and record cure temperatures during the curing period. Cure temperatures will be monitored until Unconfined Compressive Strength test provide evidence cure has been achieved or until the completion of the 5 day cure period. If strength or temperature specifications are not met, removal and replacement or rework at the sole risk of the Contractor is required at the Contractor’s expense.

As directed by the Engineer of Record or CDOT, repair or replace cured materials exposed to ambient air temperatures below freezing or repeated freeze/thaw cycles that result in loosening or fluffing of the surface. Removal and replacement are at the Contractor’s expense.

**307.08 Preparation of Subgrade**. Before beginning any cement treatment, the subgrade shall be constructed and finished to smooth and uniform surfaces conforming to the grades and typical sections specified by importing material specified in 307.04. The material shall be compacted to at least 93 percent relative compaction. Variation from the subgrade plan elevations specified between the moisture treated subgrade zone and the CTS zone shall not be more than ±0.10 foot.

It is the Contractors option to place the subgrade material with low water content. Material that is placed dry shall be mixed with water at the time of cement application per subsection 307.10. Material placed dry shall be uniformly distributed and compacted to an elevation that will provide the minimum required 12-inches of treated material following processing, compaction, finishing, curing, and trimming. The Contractor shall verify dry placed subgrade is not oversaturated, frozen or contaminated before mixing with cement and water. Rework or removal and replacement of material due to contamination, saturation, or freezing shall be at the Contractor’s expense.

Process Control will perform a Total Station survey of the area to obtain the elevation of the moisture treated subgrade before placing the CTS material. The logged survey information shall be maintained by the contractor.

The maximum subgrade compacted thickness of a single lift shall be 6-inches. If the thickness of the final subgrade lift is greater than 6-inches, spread and compact the subgrade in multiple lifts of equal thickness with a maximum lift thickness of 6-inches. If the subgrade is spread in multiple lifts, offset the longitudinal and transverse joints by at least 6-inches.

**307.09a Test Section.** Before full-scale production, the Contractor shall construct a test section to demonstrate subgrade stabilization using the materials, equipment, and methods to be used in full-scale production. The test section shall be at least 100-feet long, one spreading and mixing lane wide, and the same depth as the course represented in the plans. The test section shall be tested per the same test requirements for the cement and soil design mix. If the test section is unsatisfactory, the Contractor shall adjust the materials, equipment, and methods or combinations thereof as necessary to conform to the specifications. Additional test sections shall be constructed as required to produce a satisfactory test section before full-scale production. Unsatisfactory test sections shall be removed and replaced or reworked at the sole risk of the Contractor. Full production shall not begin until a satisfactory test section is completed. Before start of work, the Contractor shall determine the cement application rate, and the maximum dry density and optimum moisture content of the material after it has been treated with cement.

**307.09b Cold Weather Test Section.** Before full-scale cold weather production, the Contractor shall construct a test section to demonstrate subgrade stabilization using the materials, equipment, and methods to be used in full scale cold weather production. The test section shall be at least 100-feet long, one spreading and mixing lane wide, and the same depth as the course represented in the plans. The test section shall be tested by ICQC and PC per Table 307-1 and soil mix design. If the test section is unsatisfactory, the Contractor shall adjust the materials, equipment, and methods or combinations thereof as necessary to conform to the specifications. Additional test sections shall be constructed as required to produce a satisfactory test section before full-scale cold weather production. Unsatisfactory test sections shall be removed and replaced or reworked at the sole risk of the Contractor. Full cold weather production shall not begin until a satisfactory test section is completed. Before start of work, the Contractor shall determine the cement application rate, maximum dry density and optimum moisture content of the material after it has been treated with cement. A cold weather test section shall follow the below list:

1. A Hold Point and frost check shall take place as soon as ambient air temperature reaches 35°F and is rising.
2. Start test section mixing once ambient air temperature is 35 °F and rising. CTS should not be placed if forecasted weather temperatures indicate extreme low temperatures during the cure period.
3. Record the beginning ground temperature measured 3-inches below the surface of the CTS.
4. Before mixing record the frost depth, mixing water temperature, and ground temperature measured 6-inches, 9-inches and 11-inches below the surface of the CTS for informational purposes.
5. Record temperature of the mixed soil and air immediately when mixing commences and continuously until the required field cure strength is achieved.
6. Nine PC field cure compressive strength specimens shall be obtained from the test section length.
7. Field cure cylinders shall be cured under the same conditions and protection as the in place treated material. If cylinders are buried within the CTS layer, they shall be located a minimum of 2-feet from edges of CTS section. PC cylinders shall be taken in each third of the test section and cured at the test sample location.
8. Thermo-couplers shall be placed 1-inch below the surface of the soil at the beginning area and the end area of the test section and a minimum of 2-feet from edges of CTS section.
9. Additional thermo-coupler(s) will be left above the blanket to continuously record the ambient air temperature during the curing period.
10. After the 5 days of curing in the field, the field cure specimens will be tested to determine the in-situ strength and to validate the test section and confirm cold weather production plan.
11. The test section establishes the minimum allowable temperature of the soil for CTS mixing. Additional test sections are required to establish a new minimum soil temperature.
12. The Contractor shall submit a summary of the test section results to CDOT for Acceptance before continuing with full scale production in cold weather. The report shall include confirmation from ICQC and PC representatives that the test section achieved the required specifications. CDOT reserves the right to revert back to the original typical weather operation specifications and CDOT may stop the work if the requirements are not being met to the satisfaction of the Department, due to field conditions during placement or during cure period that are not conducive to a quality product, or other reasons as determined by CDOT.

**307.10 Processing Materials.** After the subgrade has been finished and approved as specified, the subgrade shall then be processed and pulverized by a self-propelled rotary type mixing machine to the depth and width shown on the plans. Precautions shall be taken to avoid forming furrows of loosened material below the depth specified for the cement-stabilized soil mixture. The machine shall uniformly process and pulverize the loosened material to a thickness of the cement-treated layer as specified in the Contract and shall have cutters that plane the base of the cut and pulverize zone to a smooth surface over the entire width. The machine must give visible indication at all times that it is processing to the proper depth.

1. *Cement Application*. Cement shall be applied in the form of a dry application, on that area where the mixing and final compaction operations can be completed during the same working day. Equipment for spreading dry cement shall be of an approved screw-type spreader box, mixer, or other semi-enclosed equipment which is equipped with a metering device. Spreading of cement by aggregate spreaders or motor-graders will not be allowed.

Contractor to provide an example field calculation sheet attached to method statement for reference. Process Control will perform measurement and ICQC to witness and verify.

1. *Mixing.* Mixing shall take place immediately after cement application. The cement, soil, and water shall be thoroughly mixed and blended by a self-propelled rotary type mixing machine, until a uniform mixture and color is obtained throughout the required depth and width.

The mixing machine shall make a sufficient number of passes to uniformly mix the cement, water, and soil to the full depth of the pulverized layer. Streaks and pockets of cement will be considered evidence of inadequate mixing and shall require additional mixing to correct.

The moisture content of the mixture immediately following the blending of water, cement, and soil shall not be less than optimum as determined by ASTM D 558, plus necessary hydration moisture.

**307.11 Compaction**

1. Compaction of the cement and soil mixture shall be completed within 90 minutes of the time cement or water is applied. The field density for the compacted mixture shall be at least 95 percent of the maximum density of laboratory specimens prepared from samples taken from the cement soil material in place before compacting. The specimens will be compacted and tested per ASTM D 558, and the in-place field density will be determined per Colorado Procedure (CP) 80. The moisture content of the mixture at the start of compaction shall be between optimum and to 3 percent above the optimum moisture content. The optimum moisture content will be determined per ASTM D 558, as specified in the subgrade stabilization design.

Moisture content and density measurements will be determined per CP 80, In-Place Density and Moisture Content of Soil and Soil-Aggregate by the Nuclear Method. Per Section 8.4.1 of CP 80, if gauge’s moisture content is off by 1 percent, the moisture content will be determined per AASHTO T265, Standard Method of Test for Laboratory Determination of Moisture Content of Soils.

Maintain moisture content of the surface material at not less than optimum during finishing operations. If material becomes oversaturated, it must be remediated or replaced.

1. The finished surface shall be smooth and uniform conforming to the typical sections specified. All irregularities, depressions, or weak spots, which develop, shall be corrected immediately by scarifying the areas affected, adding or removing material as required, adding additional cement, and reshaping and re-compacting by sprinkling and rolling. The surface of the course shall be maintained in a smooth condition, free from undulations and ruts, until other work is placed thereon, or the work is accepted.

In addition to the requirements specified for density, the full depth of the materials shown on the plans shall be compacted to the extent necessary to remain firm and stable under construction equipment. After each section is completed, ICQC will conduct tests. If the material fails to meet the density and strength requirements per the cement and soil design mix, it shall be reworked to meet these requirements at the Contractor’s expense. Throughout this entire operation, the shape of the course shall be maintained by blading. The surface shall be smooth and conform to the required lines, sections and grades, per the plans and thoroughly cured, or to within a minimum of 0.1 foot above the finished subgrade elevation to allow for trimming to final grade before placement of the surface course. Variation from the subgrade plan elevations specified shall not exceed 0.04 foot. Process Control will immediately perform a Total Station survey on the compacted material to obtain elevation of the compacted CTS and the data given to the Contractor for entry into the logged data of moisture treated subgrade elevations per subsection 307.08 to calculate and verify the minimum thickness of CTS is obtained. The logged data shall be maintained by the contractor and made available to the Engineer upon request.

**307.12 Finishing and Curing.** When initial compaction of the top layer of the cement-stabilized soil mixture is nearing completion, the surface shall be shaped to the required lines, grades, and cross section, and compaction continued until uniform and adequate compaction is obtained. The treated material shall be maintained at a moisture content satisfactory for proper curing by one of the following:

1. Sprinkling for a minimum period of five days or until further Courses are added.
2. Sprinkling for a period less than five days until emulsified asphalt prime coat (diluted 1 to 1) is applied per subsection 307.12, item (3) below.
3. Applying a protective film of emulsified asphalt prime coat (diluted 1 to 1 with water) immediately after the cement-treated subgrade has been finished. One application shall be made consisting of 0.20 gallon diluted mixture per square yard. Contractor to submit asphalt type to be used as prime coat to CDOT for approval.
4. During cold weather curing, the soil will be covered with insulating blankets with a minimum R-Value of 0.5 continuously for a minimum of 5 days or until field cure specimens indicate that the subgrade has met or exceed required strength, whichever is longer. No watering or sprinkling will be necessary during this period.

The completed section shall be cured for a minimum of five days or until it has reached the minimum compressive strength as determined by Unconfined Compressive Strength ASTM D 1633, before further courses are added or any traffic is permitted, unless otherwise directed by the Engineer of Record or CDOT. Acceptable compressive strength test results shall be a minimum of 160 pounds per square-inch to a maximum of 500 pounds per square-inch.

The Contractor is required to maintain the Subgrade in good condition until all work has been completed. Maintenance shall include immediate repairs to any defects that may occur. A repair procedure shall be submitted to CDOT for approval in advance of the repair work. If Subgrade deterioration exists, the back scatter nuclear density testing may be used to determine acceptability of the Subgrade area.

**307.13 Proof Rolling.** The Contractor shall perform proof rolling per subsection 203.08 with the exception of the requirement that proof rolling must be conducted within 48 hours of when initial pavement course is placed. Once an area has passed a proof roll another proof roll is not required unless directed by the Engineer. Proof rolling shall be performed a minimum of five days after cement treatment or when minimum compressive strengths have been attained, unless otherwise approved by the Engineer.

**307.14 Construction Joints**. Transverse and longitudinal daily construction joints shall be addressed by an overlap of 12-inches at the beginning of each workday. Daily construction joints will be formed by reprocessing material previously installed a minimum of 12-inches horizontally.

**307.15 Thickness Measurement.** CTS will be accepted for minimum thickness on a lot basis. A lot will consist of 1,500 square yards. One core shall be taken at random by ICQC at the rate of 1/3,000 square yards. When the ICQC measurement of the core from a lot is not deficient by more than 0.5-inch from the minimum plan thickness, the tested lot will be accepted. When such measurement is deficient by more than 0.5-inch and not more than 1.0-inch from the plan thickness, two additional cores shall be taken at random and used in determining the average thickness for that lot. The thickness of the core shall be determined by average caliper measurement of cores tested per ASTM C 174. When the average measurement of the three cores is not deficient by more than 0.5-inch from the plan thickness, the tested lot will be accepted.

If the average measurement of the three cores is deficient by more than 0.5-inch but less than 1.0-inch from the plan thickness, the entire lot may be left in place and a 10 percent price reduction to the contract unit price will be made. If the average measurement of the three cores is deficient more than 1.0-inch but less than 2.0-inches from the plan thickness, the entire lot may be left in place and a 50 percent price reduction to the contract unit price will be made. When the average thickness is deficient by more than 2.0-inches, the entire lot shall be replaced at the Contractor’s expense. If three consecutive thickness tests fail (> 2-inches deficient), work shall cease. No additional work shall occur until corrective action(s) by Contractor is submitted and Approved by the Engineer of Record and CDOT.

Refer to CDOT Standard Specifications section 412.21 for pavement thickness test values PT +1 requirements.

**Table 307-1
Schedule for Minimum Sampling and Testing**

| Element and Procedure | Process Control | ICQC(Acceptance) | Remarks |
| --- | --- | --- | --- |
| UnconfinedCompressiveStrength ASTM D1633 | 1/5,000 sq. yds.or fraction thereof | 1/10,000 sq. yds. or fraction thereof | Determined by design plan criteria. The tests shall be conducted on samples cured in a moist environment for 5 days @ 100°F. When material is found to be < 25% deficient of the required strength the engineer will evaluate the roadway design section. When material is found to be > 25% deficient of the required strength the section will be removed and replaced. |
| Cold WeatherUnconfinedCompressiveStrength ASTM D1633 | 1/1,500 sq. yds. or fraction of thereof. At least one set per production area.Field cured. | 1/10,000 sq. yds. or fraction thereof, at least one set per production area | PC field cure cylinders shall be cured under the same conditions and protection as the in place treated material. PC cylinders shall be cured at the test sample location. Based on test results, expected current/future conditions, the frequency of testing may be reduced at the sole discretion of CDOT. |
| ThicknessAcceptance ASTMC 174 | Survey verification per 307.08 and307.11 | 1/3,000 sq.yds. Or fraction thereof | Refer to Revision of Section 307.08, 307.11, and 307.15 |
| Gradation CP 31 | 1/5,000 sq. yds.or fraction thereof | 1/10,000 sq. yds. or fraction thereof | 1-inch - 100% passing;#200 - 12% to 35% Passing |
| Determining PercentRelative CompactionSoil-Aggregate by Nuclear MethodCP 80 | 1/5,000 sq. yds.or fraction thereof | 1/10,000 sq. yds. or fraction thereof | Minimum 95% of maximum dry density as per ASTM D 558. Moisture content of mixture at the start of compaction shall be at optimum to 3% above optimum moisture content. |
| Moisture Density Curve ASTM D 558 | 1/soil type | 1/soil type |  |
| Water SolubleSulfateCP-L 2103 | N/A | 1/2,000cy | Water Soluble sulfate content in soil shall be less than 0.2% by dry soil weight. May propose reduction after 5 consecutive passing tests |
| LA Abrasion | N/A | 1/source |  |
| Unit Weight and Voids | N/A | 1/source |  |
| Plasticity Index | N/A | 1/2,000cy | Shall be between 0 and 10 percent as determined by AASHTO T-89 and T-90. May propose reduction after 5 consecutive passing tests |
| Cement Application Measurement | 1/shift | Witness | Refer to section 307.10 (a) |
| Sand Equivalency | N/A | 1/source | Test for deleterious materials in pit run material. Minimum SE value of 35 |

# Method of Measurement

**307.16** Cement will not be measured separately but shall be included in the work. Processing cement-treated subgrade will not be measured separately but shall be included in the work. Overlap mixing will not be measured and paid for separately but shall be included in the work.

Emulsified asphalt prime coat will not be measured and paid for separately but shall be included in the work.

Test sections and coring will not be measured and paid for separately but shall be included in the work.

Proof rolling will not be measured separately but shall be included in the work.