Date: August 27, 2013

To: MAG Specifications and Details Committee Members

With additional proposed comments and edits after review by MAG Engineers from 8-22-2013 MAG 309 meeting.

Purpose: Update and revise MAG 309 with explanation and discussion points listed below:

309.1 Revised to define Lime Stabilization and Lime Modification.

309.2.1 Clarify test methods. Method A Referee Method is consistent with other MAG references for subgrade testing and overrides dry prep one point method in case of disputes.

309.2.2 Clarified lime types. ASTM C977 defines quicklime and hydrated lime test methods and specification requirements.

Sentence prohibiting addition of dry quicklime directly to soil has been removed. Adding quicklime directly to soil is permitted by National Lime Association, Lime-Treated Soil Construction Manual and by California Department of Transportation. Contractor is responsible for appropriate safety measures when applying and mixing lime. MAG should have all lime treatment options available.

309.2.3 Reformatted to include properties, certificate of compliance, and applied quantities to both lime slurry and hydrated lime applications.

309.3.1 Moved to 309.4 Construction Section.

309.3.2 Reformatted to 309.3.1 show untreated and treated soil test procedures for Lime Stabilization Mix Design.

Untreated soil:
(a) Sulfates result is used by designer to determine mellowing times for treated soil laboratory specimens when necessary.
(b) The untreated proctor result is used in the field to determine lime application rate. It is also used to compare untreated soil proctor versus treated soil proctor for effectiveness of lime treatment in the field.
(c and d) Results are used to classify untreated soil.

Treated soil:
(a) Do not require lime saturation of 12.4 pH because there may be soils where lime saturation occurs at 12.3 pH. Refer to pH test procedures for detailed explanations.
(b) Method A Referee Method is consistent with other MAG references for subgrade testing and overrides dry prep one point method in case of disputes.

(c) Test method clarified.
(d) Test method changed from D1633, for soil-cement, to D5102, which is for lime-soil. Deleted alternate method because there is not an alternate ASTM test method for unconfined compressive strength of lime mixtures.
(e) Mellowing time and mellowing moisture content above optimum are required for some soils to mitigate some or all of the following: Ettringite generation and subsequent heaving, reduce swell potential, and reduce plasticity index. The Thompson Procedure requires a 1 hour of mellowing period for lab specimens. Other agencies, FAA and Arizona D.O.T., require mellowing periods. Basically, the higher the sulfate content, the longer the mellowing period.
(f) 5.0% lime provides some insurance for variation in materials and application conditions. Hydrated lime content greater than 5.0% may be required and should be determined by mix design Engineer.

309.3.2 Added to separate Lime Modification.

309.3.3 Tolerance deleted. Lime content range added to 309.4.4

309.4.1 Delete extra “a”.

309.4.2 Leave unchanged. Not allowing construction below 40ºF is consistent with many agencies.

New 309.4.4.1 Quicklime application added. Adding quicklime directly to soil is permitted by National Lime Association, Lime-Treated Soil Construction Manual and by California Department of Transportation. Contractor is responsible for appropriate safety measures when applying and mixing lime. MAG should have all lime treatment options available.

309.4.4.1 Change to Section 309.4.4.2. Leave dry hydrated lime as an application option.

309.4.4.2 changed to 309.4.4.3

309.4.4.2 Traffic sentence moved to mixing section 309.4.5. Engineer sentence moved to application section 309.4.4. Thickness moved to new section 309.4.7.

309.4.5 Traffic sentence moved to this section. Mix design proctor added because field proctor will not be completed yet. Site material treated with recommended lime quantity should yield proctor results similar to mix design proctor.

309.4.6 Mellowing time and mellowing moisture content added and determined by mix design. FAA and Arizona D.O.T. require mellowing periods and can be referenced by Engineer. Failure to mellow properly and premature final compaction can result in Ettringite generation and heaving of the lime treated base. See National Lime Association Construction Manual for details.

Changed moisture density (proctor) test from D558, which is for soil-cement, to D698, which is for soil.

Composite sample moved in front of density sentence because proctor is needed first to calculate in-place density; note that “untreated” has been changed to “treated” and “wet density to “dry density”. Dry density is the standard of care for compaction determination in Arizona. Using 95% of wet density for compaction acceptance will understate dry density. In the event nuclear gauge readings are yielding low dry density compactions values, nuclear gauges are required by the test standards to be correlated with sand cone results to verify density values while correlated to oven-dry moisture results to verify moisture values.

Remove moisture content at time of compaction requirement. Optimum to plus 4% above optimum will result in pumping and unstable conditions.

Remove ASTM D-2167, Rubber Balloon Method.

Change rock correction from ARIZ 227 to ASTM Method D-1556 to be consistent with other MAG procedures.

309.4.7 Thickness moved to end section because this is the last step to verify after final compaction.

309.4.7 MAG Section 333 in blue font as received from MAG. No proposed changes for section 309.4.7.

SECTION 309

LIME STABILIZATION OR MODIFICATION OF SUBGRADE

309.1 DESCRIPTION:

This section shall consist of constructing a mixture of soil, lime and water for the stabilization or modification of subgrade soils. The work shall be performed in conformity with the lines, grades thickness, and typical cross sections shown on the plans.

According to the National Lime Association, "Stabilization: When adequate quantities of lime and water are added, the pH of the soil quickly increases to above 10.5, which enables the clay particles to break down. Determining the amount of lime necessary is part of the design process and is approximated by tests such as the Eades and Grim test (ASTM D3276). Silica and alumina are released to react with calcium from the lime to form calcium-silicate-hydrates (CSH) and calcium-aluminate-hydrates (CAH). CSH and CAH are cementitious products similar to those formed in Portland cement. They form the matrix that contributes to strength of lime-stabilized soil layers. As this matrix forms, the soil is transformed from a sandy, granular material to a hard, relatively impermeable layer with significant load bearing capacity. The process begins within hours and can continue for years in a properly designed system. The matrix formed is permanent, durable, and significantly impermeable, producing a structural layer that is both strong and flexible."

Lime modification may be used to "Dry-up of wet soil at a construction sites" or "include treating fine-grained soils or granular base materials to construct temporary haul roads or construction platforms."

309.2 MATERIALS:

309.2.1 Soil or Subgrade: For lime stabilization applications, the soil or subgrade material used for this work shall consist of materials on the site or imported, and shall be free of roots, sod, weeds and stones larger than 3 inches and have a plasticity index (PI) greater than 10, when tested in accordance with AASHTO T-146 Method A, AASHTO T-89 Method A, and T-90. For lime modification applications, the allowable soil or subgrade properties will be determined by the Engineer.

309.2.2 Quicklime and Hydrated Lime: Lime used shall be either quicklime or hydrated lime and shall conform to the requirements of ASTM C977. All lime shall come from a single source. If a source change is requested, a new mix design shall be submitted using lime from the proposed new source. The new design must be approved by the Engineer prior to use.

309.2.3 Lime Slurry: Lime slurry shall be a pumpable suspension of solids in water. The solids portion of the mixture, when considered on the basis of solids content, shall consist principally of hydrated lime of a quality and fineness sufficient to meet Section 309.2.2 requirements. A certificate of compliance shall be provided to the Engineer for each load of lime applied at the project.

309.2.4 Water: Water used for mixing or curing shall be reasonably clean and free of oil, salt, acid, alkali, sugar, vegetable, or other substances injurious to the finished product. Water shall be tested in accordance with and shall meet the suggested requirements of AASHTO T-26. Water known to be of potable quality may be used without test.

309.3 COMPOSITION:

309.3.1 Lime Stabilization Mix Design: Before commencing lime treatment work, the Contractor shall submit for approval by the Engineer, a proposed mix design. The proposed mix design shall be prepared by a testing laboratory under the direction and control of a registered professional engineer. The mix design shall be determined using the soils or subgrade material to be stabilized and lime from the proposed supplier, and shall determine the following:

For soil stabilization applications, the mix design shall report and comply with the following requirements:

Untreated Soil:
(a) Sulfates: Tested per ARIZ 733, AASHTO T-290, or ASTM C1580.
(b) Moisture-Density Relationship (Proctor): Tested per ASTM D698A.

(c) Plasticity Index: Test method AASHTO T-146 Method A, AASHTO T-89 Method A, and T-90.
(d) Sieve Analysis and Minus No. 200 Wash: Test methods ASTM C136 and ASTM D1140.

Lime Treated Soil:
(a) pH: Lime saturation content per ASTM C977 APPENDIX or ASTM D6276.
(b) Plasticity Index: Less than 3, per AASHTO T-146 Method A, AASHTO T-89 Method A, and T-90.
(c) Swell Potential: Maximum expansive potential of 1.0 per ARIZ 249 using passing No. 4 sieve material. The maximum expansive potential shall be determined on a sample compacted to approximately 95 percent of the ASTM D698A maximum dry density at approximately 2% below optimum moisture content. The sample should be confined under a 100 psf surcharge and inundated.
(d) Unconfined Compressive Strength: Minimum 160 psi per ASTM D5102 Procedure A, after five days curing at 100°F, sealed in air-tight condition.
(e) Mellowing time and mellowing moisture content for treated soil sections b and c to be determined by design engineer. Mellowing time and mellowing moisture content for treated soil section d determined by ASTM D5102.
(f) Hydrated Lime Content: The design engineer shall designate the minimum percentage of lime by dry weight of the dry soil to satisfy the criteria for Section 309.3.2 requirements. The percentage of lime specified shall be sufficient to allow for expected variations during the mixing process. A minimum of 5.0% hydrated lime by dry weight of the dry soil is required for all mix designs.

309.3.2 Lime Modification: For soil modification purposes only, the Engineer shall specify the minimum amount of hydrated lime or lime slurry required to meet the desired improved soil properties.

309.4 CONSTRUCTION:

309.4.1 General: It is the primary requirement of this specification to secure a completed subgrade containing a uniform lime mixture free from loose segregated areas, of uniform density and moisture content, well bound for its full depth, and with a smooth surface suitable for placing subsequent courses.

Prior to beginning any lime stabilization or modification, the subgrade shall be constructed and brought to grade and shall be shaped to conform to the typical sections, lines and grades as shown on the plans.

Lime shall be applied at the mix design rate for the depth of subgrade stabilization or modification shown on the plans or requested by the Engineer.

When the design requires treatment to a depth greater than 12 inches, the subgrade soil shall be treated in equal layers. The top layer(s) of soil shall be removed and stockpiled. The lower layer of soil to be treated shall then be treated and allowed to cure in place. After final mixing, the lower layer shall be compacted in maximum 12 inch thick compacted lifts. The stockpiled soil shall then be placed, treated, mixed and compacted in successive maximum 12 inch thick compacted lifts.

309.4.2 Weather Limitation: Lime treated subgrade shall not be constructed if the ambient temperature is below 40° F or when conditions indicate that temperatures may fall below 40° F within 24 hours.

309.4.3 Equipment: Contractor shall provide all equipment necessary to complete the work including grading and scarifying equipment, a spreader of the lime, mixing and pulverizing equipment, sheepsfoot and pneumatic rollers, sprinkling equipment and trucks. Gravity feed or tailgate spreading, defined as not having automatic controls, will not be permitted. The spreader shall demonstrate the ability to maintain a consistent spread rate over variable travel speeds. All equipment used for this work is subject to approval by the Engineer.

309.4.4 Application: Lime shall be spread only on that area where the mixing operation can be completed during the same working day. The lime application rate shall be at the design content to +0.5%, based on weight of dry soil. The Engineer reserves the right to vary the rate of application of lime from the mix design during the progress of construction as necessary to maintain a pH of the lime/soil mixture above 12.0 and the desired characteristics of the treated subgrade.

For all lime applications, the Contractor shall provide the Engineer with daily application quantities.

309.4.4.1 Quicklime Application: Quicklime shall only be applied by approved spreader trucks equipped with operating dust collectors to minimize dust issues while loading. Additionally, dust control measures must be utilized during the spreading and soil mixing of quicklime. Contractor shall exercise safety measures when mixing quicklime with water.

309.4.4.2 Dry Hydrated Lime Application: Hydrated lime shall only be applied by approved spreader trucks equipped with operating dust collectors to minimize dust issues while loading. Additionally, dust control measures must be utilized during the spreading and soil mixing of dry lime.

309.4.4.3 Lime Slurry Application: Lime slurry shall be mixed in a portable mixing unit and spread with trucks equipped with an approved distribution system. Lime slurry shall be applied at a rate that will yield the required lime percentage determined by the mix design.

309.4.5 Mixing: The full depth of the treated subgrade shall be mixed with an approved mixing machine. The use of disc plows or blades are strictly prohibited except in areas specified by the Engineer. To insure a complete chemical reaction of the lime and soil or subgrade, water shall be used as required to maintain moisture content at optimum to +4% above the optimum of the lime treated mix design proctor, prior to beginning compaction. During the interval of time between application and mixing, lime that has been applied, unmixed and exposed to the open air for 10 hours or more will not be accepted. No traffic other than the mixing equipment will be allowed to pass over the spread of lime until after completion of mixing.

After mixing and prior to compaction, clay lumps shall meet the following criteria:

	Percent
Minimum of clay lumps passing 1-1/2 inch sieve	100
Minimum of clay lumps passing No. 4 sieve	60

309.4.6 Compaction: Compaction of the mixture shall begin after final mixing and shall be accomplished in accordance with the design specifications. Areas inaccessible to conventional rolling equipment shall be compacted to the required density by methods approved by the Engineer. Mellowing time and mellowing moisture content shall be specified by the mix design and performed prior to final compaction.

The material shall be aerated or watered as necessary to provide and maintain required moisture content. A composite of treated soil or subgrade materials from a minimum of five (5) random locations, per soil type, within the area to be stabilized shall be used to determine the maximum dry density and optimum moisture content in accordance with ASTM D698. The field density of the compacted mixture shall be at least 95 percent of the maximum dry density of the field sampled proctor. The in-place compacted field density shall be determined in accordance with ASTM D1556, sand cone, or ASTM D6938, nuclear gauge. In the event of disputed results, the nuclear gauge density shall be correlated to the referee sand cone density while the nuclear water content shall be correlated to the referee ASTM D2216 water content. The adjustment for rock larger than the no. 4 sieve shall be performed in accordance with ASTM D4718.

After each section is completed, tests will be made by the Engineer. If the material fails to meet the density requirements and finished requirements, it shall be reworked to meet requirements at no additional cost to the Contracting Agency.

309.4.7 Thickness: The thickness of the lime treated subgrade shall be determined by visual inspection and/or by depth tests taken at intervals so that each test shall represent no more than 1000 square yards per layer. If more than one layer, the method used to remove material to determine the depth of lime treatment may be by shovel and/or pick, coring or other method approved by the Engineer. Phenolphthalein solution shall be used to detect the presence of lime. When the grade deficiency is more than 1 inch, the Contractor shall correct such areas in a manner satisfactory to the Engineer. Contractor shall replace, at no cost to the Contracting Agency, the material where depth tests are taken.

All irregularities, depressions, or weak spots which develop shall be corrected immediately by scarifying the areas affected, adding or removing material as required, and reshaping and recompacting. The surface of the course shall

be maintained in a smooth condition, free from undulations and ruts, until other work is placed thereupon or the work is accepted. Compaction and finishing shall be done in such a manner as to produce a smooth dense surface free of compaction planes, cracks, ridges or loose materials.

Throughout this entire operation, the shape of the course shall be maintained by blading, and the surface upon completion, shall be smooth and shall conform with the typical section shown on the plans and to the established lines and grades. Should the material, due to any reason or cause, lose the required stability, density, and finish before the next course is placed or the work is accepted, it shall be recompacted and refinished at no cost to the Agency.

309.4.8 Finishing and Curing: After the final layer or course of lime treated subgrade has been compacted, it shall be brought to the required lines and grades in accordance with the plans. The completed section shall then be finished by rolling with a pneumatic or other suitable roller.

Each layer of lime treated subgrade shall be maintained in a moist condition until the next layer of pavement structure is placed. If required, a fog seal for curing, in compliance with Section 333, shall be furnished and applied to the surface of the final layer of the lime stabilized material as soon as possible after the completion of final rolling and before the temperature falls below 40° F. Curing seal shall be applied at a rate between 0.10 and 0.20 gallons per square yard of surface. The exact rate will be determined by the Engineer.

After curing begins, all traffic, except necessary construction equipment shall be kept off the lime stabilized subgrade for a minimum of 7 days or until the final pavement structure layer(s) are placed. As an alternative, the Contractor may place a loose lift of aggregate base course over the curing subgrade. The aggregate base course should be kept moist during the curing process.

309.4.9 Maintenance: The Contractor shall maintain, at his/her own expense, the entire lime treated subgrade in good condition from the start of work until all the work has been completed, cured and accepted by the Engineer.

309.5 MEASUREMENT:

The quantity of lime slurry treated soils shall be measured by the square yard, measured in place, treated, compacted, to the proper depth, and accepted.

The quantity of curing seal shall be measured by the ton.

309.6 PAYMENT:

The lime treated soils measured as provided above, will be paid for at the contract price per square yard, which price shall be full compensation for the item complete, as herein described and specified.

The Owner or Engineer reserves the option to pay for the lime separately. Should this option be chosen, the lime treated soils measured as provided above will be paid for at the contract price per square yard which shall include full compensation for the item less lime, as herein described and specified. The lime materials will be paid for by the contract price per ton based on hydrated lime. If quicklime in slurry form is used there will be an additional pay factor of 1.3 applied to determine the actual amount of hydrated lime placed.

Payment for curing seal will be by the ton, based on the rate of application as requested by the Engineer.

- End of Section -

SECTION 309

LIME STABILIZATION OR MODIFICATION OF SUBGRADE

309.1 DESCRIPTION:

This section shall consist of constructing a mixture of soil, lime and water for the stabilization or modification of subgrade soils. The work shall be performed in conformity with the lines, grades thickness, and typical cross sections shown on the plans.

According to the National Lime Association, "Stabilization: When adequate quantities of lime and water are added, the pH of the soil quickly increases to above 10.5, which enables the clay particles to break down. Determining the amount of lime necessary is part of the design process and is approximated by tests such as the Eades and Grim test (ASTM D3276). Silica and alumina are released to react with calcium from the lime to form calcium-silicate-hydrates (CSH) and calcium-aluminate-hydrates (CAH). CSH and CAH are cementitious products similar to those formed in Portland cement. They form the matrix that contributes to strength of lime-stabilized soil layers. As this matrix forms, the soil is transformed from a sandy, granular material to a hard, relatively impermeable layer with significant load bearing capacity. The process begins within hours and can continue for years in a properly designed system. The matrix formed is permanent, durable, and significantly impermeable, producing a structural layer that is both strong and flexible."

Lime Modification may be used to "Dry-up of wet soil at a construction sites" or "include treating fine-grained soils or granular base materials to construct temporary haul roads or construction platforms."
~~Lime Stabilization involves improving soil conditions as defined within this specification. Lime Modification can be allowed by the Engineer in the event only limited soil improvement is required.~~

309.2 MATERIALS:

309.2.1 Soil or Subgrade: For lime stabilization applications, the soil or subgrade material used for this work shall consist of materials on the site or imported and shall be free of roots, sod, weeds and stones larger than 3 inches and have a plasticity index (PI) greater than 10, when tested in accordance with AASHTO T-146, Method A, AASHTO T-89, Method A, and T-90. For lime modification applications, the allowable soil or subgrade properties will be determined by the Engineer.

309.2.2 Quicklime and Hydrated Lime: Lime used ~~to manufacture the commercial lime slurry specified herein,~~ shall be either ~~quick lime~~ quicklime or hydrated lime and shall conform to the requirements of ASTM C977. ~~The direct use of dry quicklime to the soil material is strictly prohibited.~~ All lime shall come from a single source. If a source change is requested, a new mix design shall be submitted using lime from the proposed new source. The new design must be approved by the Engineer prior to use.

309.2.3 ~~Commercial~~ Lime Slurry: ~~Commercial l~~ Lime slurry shall be a pumpable suspension of solids in water. ~~The water or liquid portion of the slurry shall not contain dissolved material in sufficient quantity naturally injurious or objectionable for the purpose intended.~~ The solids portion of the mixture, when considered on the basis of solids content, shall consist principally of hydrated lime of a quality and fineness sufficient to meet Section 309.2.2 ~~the following~~ requirements. ~~as to chemical composition and residue.~~ A certificate of compliance shall be provided to the Engineer for each load of lime applied at the project.

~~(A) Chemical Composition: The solids content of the lime slurry shall consist of a minimum of 90% by weight, of calcium and magnesium oxides (CaO and MgO), as determined by ASTM C25.~~

~~(B) Residue: The percent by weight of residue retained in the solids content of lime slurry shall conform to the following requirements:~~

~~Residue retained on a No. 6 sieve Max. 0.2%~~
~~Residue retained on a No. 30 sieve Max 4.0%~~

~~(C) Grade: Commercial lime slurry shall conform to a dry solids content as approved by the Engineer.~~

~~A certificate of compliance and a field summary of lime slurry produced shall be provided to the Engineer for each load of slurry.~~

309.2.4 Water: Water used for mixing or curing shall be reasonable clean and free of oil, salt, acid, alkali, sugar, vegetable, or other substances injurious to the finished product. Water shall be tested in accordance with and shall meet the suggested requirements of AASHTO T-26. Water known to be of potable quality may be used without test.

309.3 COMPOSITION:

~~**309.3.1 Lime:** Lime shall be applied at the mix design rate for the depth of subgrade stabilization or modification shown on the plans or requested by the Engineer.~~

309.3.~~1~~21 Lime Stabilization Mix Design: Before commencing lime treatment work, the Contractor shall submit for approval by the Engineer, a proposed mix design. The proposed mix design shall be prepared by a testing laboratory under the direction and control of a registered professional engineer. The mix design shall be determined using the soils or subgrade material to be stabilized ~~or modified~~ and lime from the proposed supplier and shall determine the following:

~~(a) Percent of lime and rate of application of hydrated lime or lime slurry in the treated soil or subgrade material to meet the design specifications.~~
~~(b) Optimum water content during mixing, curing and compaction.~~
~~(c) Gradation of in-situ mixture after treatment.~~
~~(d) Additional mixing or equipment requirements.~~
~~(e) Sulfate content. The sulfate content of the subgrade soil shall be determined by ARIZ 733, AASHTO T-290, or ASTM C1580. This result will be reported in the design. The sulfate content will allow the mix designer to recommend the appropriate mellowing time.~~
~~(f) Mellowing time requirements to provide the contractor with the appropriate time frames for the lime reaction with the soil to be effective.~~

For soil stabilization applications, the mix design shall report and comply with the following requirements:

Untreated Soil:
(a) Sulfates: Tested per ARIZ 733, AASHTO T-290, or ASTM C1580.
(b) Moisture-Density Relationship (Proctor): Tested per ASTM D698A.
(c) Plasticity Index: Test method AASHTO T-146, Method A, AASHTO T-89, Method A, and T-90.
(d) Sieve Analysis and Minus No. 200 Wash: Test methods ASTM C136 and ASTM D1140.

Lime Treated Soil:
(a) pH: Lime saturation content per ~~Minimum 12 after compaction of initial mixing with lime at ambient temperature, in accordance with Eades Grimm pH test method (~~ ASTM C977 APPENDIX or ASTM D6276~~)~~.
(b) Plasticity Index: Less than 3, per AASHTO T-146, Method A, AASHTO T-89, Method A, and T-90.
(c) Swell Potential: Maximum expansive potential ~~(%)~~ of 1.0 per ARIZ 249 using passing No. 4 sieve material. The maximum expansive potential shall be determined on a sample compacted to approximately 95 percent of the ASTM D698A maximum dry density at approximately 2% below optimum moisture content. The sample should be confined under a 100 psf surcharge and ~~submerged/~~inundated.
(d) Unconfined Compressive Strength: Minimum 160 psi ~~in~~ per ASTM ~~D 1633, Method A,~~ D5102, Procedure A, after five days curing at 100°F, sealed in air-tight condition. ~~when tested in accordance with ASTM D1633 Method A or an alternate compressive strength method approved by the Engineer~~
(e) Mellowing time and mellowing moisture content for treated soil sections b and c to be determined by design Engineer. Mellowing time and mellowing moisture content for treated soil section d determined by ASTM D5102.
(f) Hydrated Lime Content: The design ~~e~~Engineer shall designate the minimum percentage of lime by dry weight of the dry soil~~combined lime/soil mixture~~ to satisfy the criteria ~~above~~ for Section 309.3.2 requirements. The percentage of lime specified shall be sufficient to allow for expected variations during the mixing process. A minimum of 5.0% hydrated lime by dry weight of the dry soil is required for all mix designs.

309.3.2 Lime Modification: For soil modification purposes only, the ~~mix design~~ Engineer shall specify the minimum amount of hydrated lime or lime slurry required to meet the desired improved soil properties.

~~**309.3.3 Tolerance:** At final Compaction, the lime and water content for each course of subgrade treatment shall conform to the approved mix design with the following tolerance:~~

~~**Material**~~	~~**Tolerance**~~
~~Lime~~	~~+0.5% of design~~
~~Water~~	~~Optimum to optimum +4%, (ASTM D698)~~

309.4 CONSTRUCTION:

309.4.1 General: It is the primary requirement of this specification to secure a completed subgrade containing a uniform lime mixture free from loose segregated ~~a~~ areas, of uniform density and moisture content, well bound for its full depth, and with a smooth surface suitable for placing subsequent courses.

Prior to beginning any lime stabilization or modification, the subgrade shall be constructed and brought to grade and shall be shaped to conform to the typical sections, lines and grades as shown on the plans.

Lime shall be applied at the mix design rate for the depth of subgrade stabilization or modification shown on the plans or requested by the Engineer.

When the design requires treatment to a depth greater than 12 inches, the subgrade soil shall be treated in equal layers. The top layer(s) of soil shall be removed and stockpiled. The lower layer of soil to be treated shall then be treated and allowed to cure in place. After final mixing, the lower layer shall be compacted in maximum 12 inch thick compacted lifts. The stockpiled soil shall then be placed, treated, mixed and compacted in successive maximum 12 inch thick compacted lifts.

309.4.2 Weather Limitation: Lime treated subgrade shall not be constructed if the ambient temperature is below 40° F. or when conditions indicate that temperatures may fall below 40° F. within 24 hours.

309.4.3 Equipment: Contractor shall provide all equipment necessary to complete the work including grading and scarifying equipment, a spreader of the lime, mixing and pulverizing equipment, sheepsfoot and pneumatic rollers, sprinkling equipment and trucks. Gravity feed or tailgate spreading, defined as not having automatic controls, will not be permitted. The spreader shall demonstrate the ability to maintain a consistent spread rate over variable travel speeds. All equipment used for this work is subject to approval by the Engineer.

309.4.4 Application: Lime shall be spread only on that area where the mixing operation can be completed during the same working day. The lime application rate shall be at the design content to +0.5%, based on weight of dry soil. The Engineer reserves the right to vary the rate of application of lime from the mix design during the progress of construction as necessary to maintain a pH of the lime/soil mixture above 12.0 and the desired characteristics of the treated subgrade.

For all lime applications, the Contractor shall provide the Engineer with daily application quantities.

309.4.4.1 Quicklime Application: Quicklime shall only be applied by approved spreader trucks equipped with operating dust collectors to minimize dust issues while loading. Additionally, dust control measures must be utilized during the spreading and soil mixing of quicklime. Contractor shall exercise safety measures when mixing quicklime with water.

309.4.4.~~1~~ 2 Dry Hydrated Lime Application: Hydrated lime shall only be applied by approved spreader trucks equipped with operating dust collectors to minimize dust issues while loading. Additionally, dust control measures must be ~~observed~~ used during the spreading and soil mixing of dry lime.

309.4.4.~~2~~3 Lime Slurry Application: Lime slurry shall be mixed in a portable mixing unit and spread with trucks equipped with an approved distribution system. ~~as a slurry.~~ ~~Commercial~~ ~~l~~Lime slurry shall be applied at a rate that will yield the required lime percentage determined by the mix design. ~~The contractor shall provide the Engineer with the daily production quantities for the lime slurry.~~

~~Thickness: The thickness of the lime treated subgrade shall be determined by visual inspection and/or by depth tests taken at intervals so that each test shall represent no more than 1000 square yards per layer. If more than one layer, the method used to remove material to determine the depth of lime treatment may be by shovel and/or pick, coring or other method approved by the Engineer. Phenolphthalein solution shall be used to detect the presence of lime. When the grade deficiency is more than 1 inch, the Contractor shall correct such areas in a manner satisfactory to the Engineer. Contractor shall replace, at no cost to the Agency, the material where depth tests are taken.~~

~~No traffic other than the mixing equipment will be allowed to pass over the spread of lime until after completion of mixing.~~

~~The Engineer reserves the right to vary the rate of application of lime from the specified application rates during the progress of construction as necessary to maintain a pH of the lime/soil mixture above 12.0 and the desired characteristics of the treated subgrade.~~

309.4.5 Mixing: The full depth of the treated subgrade shall be mixed with an approved mixing machine. The use of disc plows or blades are strictly prohibited except in areas specified by the ~~e~~Engineer. To insure a complete chemical reaction of the lime and soil or subgrade, water shall be used as required to maintain ~~a minimum~~ moisture content at optimum to +4% above the optimum of the lime treated mix design proctor, prior to beginning compaction. ~~and held at optimum to +4% of optimum during compaction.~~ During the interval of time between application and mixing, lime that has been applied, unmixed and exposed to the open air for 10 hours or more will not be accepted. No traffic other than the mixing equipment will be allowed to pass over the spread of lime until after completion of mixing.

After mixing and prior to compaction, clay lumps shall meet the following criteria:

	Percent
Minimum of clay lumps passing 1-1/2 inch sieve	100
Minimum of clay lumps passing No. 4 sieve	60

309.4.6 Compaction: Compaction of the mixture shall begin after final mixing and shall be accomplished in accordance with the design specifications. Areas inaccessible to conventional rolling equipment shall be compacted to the required density by methods approved by the Engineer. Mellowing time and mellowing moisture content shall be specified by the mix design and performed prior to final compaction.

The material shall be aerated or watered as necessary to provide and maintain required moisture content. A composite of treated soil or subgrade materials from a minimum of five (5) random locations, per soil type, within the area to be stabilized shall be used to determine the maximum dry density and optimum moisture content in accordance with ASTM D698. The field density of the compacted mixture shall be at least 95 percent of the maximum dry ~~wet~~ density ~~at optimum to +4% of optimum moisture content~~ of the field sampled proctor. ~~A composite of untreated soil or subgrade materials from a minimum of five (5) random locations, per soil type, within the area to be stabilized shall be used to determine the maximum wet density and optimum moisture content in accordance with ASTM D 558.~~ The in-place compacted field density shall be determined in accordance with ASTM D1556, sand cone, ~~ASTM D 2167~~ or ASTM D6938, nuclear gauge. In the event of disputed results, the nuclear gauge density shall be correlated to the referee sand cone density while the nuclear water content shall be correlated to the referee ASTM D2216 water content. The adjustment for rock larger than the no. 4 sieve shall be performed in accordance with ASTM D4718. ~~ARIZ 227c.~~

After each section is completed, tests will be made by the Engineer. If the material fails to meet the density requirements and finished requirements, it shall be reworked to meet requirements at no additional cost to the Contracting Agency.

~~If pumping subgrade should become evident at any time prior to paving, the Engineer may require proof rolling with a pneumatic tire roller or other approved equipment in order to identify the limits of the unacceptable area. The proof rolling will be performed at no additional cost to the Contracting Agency.~~

309.4.7 Thickness: The thickness of the lime treated subgrade shall be determined by visual inspection and/or by depth tests taken at intervals so that each test shall represent no more than 1000 square yards per layer. If more than one layer, the method used to remove material to determine the depth of lime treatment may be by shovel and/or pick, coring or other method approved by the Engineer. Phenolphthalein solution shall be used to detect the presence of lime. When the grade deficiency is more than 1 inch, the Contractor shall correct such areas in a manner satisfactory to the Engineer. Contractor shall replace, at no cost to the Contracting Agency, the material where depth tests are taken.

All irregularities, depressions, or weak spots which develop shall be corrected immediately by scarifying the areas affected, adding or removing material as required, and reshaping and recompacting. The surface of the course shall be maintained in a smooth condition, free from undulations and ruts, until other work is placed thereupon or the work is accepted. Compaction and finishing shall be done in such a manner as to produce a smooth dense surface free of compaction planes, cracks, ridges or loose materials.

Throughout this entire operation, the shape of the course shall be maintained by blading, and the surface upon completion, shall be smooth and shall conform with the typical section shown on the plans and to the established lines and grades. Should the material, due to any reason or cause, lose the required stability, density, and finish before the next course is placed or the work is accepted, it shall be recompacted and refinished at no cost to the Agency.

309.4.8 Finishing and Curing: After the final layer or course of lime treated subgrade has been compacted, it shall be brought to the required lines and grades in accordance with the plans. The completed section shall then be finished by rolling with a pneumatic or other suitable roller.

Each layer of lime treated subgrade shall be maintained in a moist condition until the next layer of pavement structure is placed. If required, a fog seal for curing, in compliance with Section 333, shall be furnished and applied to the surface of the final layer of the lime stabilized material as soon as possible after the completion of final rolling and before the temperature falls below 40° F. Curing seal shall be applied at a rate between 0.10 and 0.20 gallons per square yard of surface. The exact rate will be determined by the Engineer.

After curing begins, all traffic, except necessary construction equipment shall be kept off the lime stabilized subgrade for a minimum of 7 days or until the final pavement structure layer(s) are placed. As an alternative, the Contractor may place a loose lift of aggregate base course over the curing subgrade. The aggregate base course should be kept moist during the curing process.

309.4.9 Maintenance: The Contractor shall maintain, at his/her own expense, the entire lime treated subgrade in good condition from the start of work until all the work has been completed, cured and accepted by the Engineer.

309.5 MEASUREMENT:

The quantity of lime slurry treated soils shall be measured by the square yard, measured in place, treated, compacted, to the proper depth, and accepted.

The quantity of curing seal shall be measured by the ton.

309.6 PAYMENT:

The lime treated soils measured as provided above, will be paid for at the contract price per square yard, which price shall be full compensation for the item complete, as herein described and specified.

The Owner or Engineer reserves the option to pay for the lime separately. Should this option be chosen, the lime

treated soils measured as provided above will be paid for at the contract price per square yard which shall include full compensation for the item less lime, as herein described and specified. The lime materials will be paid for by the contract price per ton based on hydrated lime. If quicklime in slurry form is used there will be an additional pay factor of 1.3 applied to determine the actual amount of hydrated lime placed.

Payment for curing seal will be by the ton, based on the rate of application as requested by the Engineer.

- End of Section -