SECTION 5 – PAVING AND SUBGRADE DESIGN REQUIREMENTS

5.01. General

A. The following specifies minimum standards required for the pavement and subgrade design for roadways, alleys, and fire lanes within the Town of Prosper. These minimum standards are not intended to replace the professional judgement of the Geotechnical Engineer for any specific project. The standards may need to be expanded or modified on a case by case basis as determined necessary and appropriate by the Geotechnical Engineer, and as approved by the Deputy Director of Engineering Services.

B. Table 5.1 lists the Town's minimum pavement and subgrade thicknesses and dimensions. In no case shall the pavement and subgrade be less than the minimums.

TABLE 5.1: Pavement and Subgrade Minimum Standards

Criteria	Thoroughfare Classification[1]							
	4/6LD		4LRD, 3L, 2LC		2LN/2LRN		Alley	
	Eagle Ford	Austin Chalk	Eagle Ford	Austin Chalk	Eagle Ford	Austin Chalk	Eagle Ford	Austin Chalk
Concrete[2] Thickness	9"	9"	7"	7"	6"	6"	6"	6"
Reinforcement	#4 On 18"	#4 On 18"	#4 On 18"	#4 On 18"	#4 On 24"	#4 On 24"	#4 On 24"	#4 On 24"
Lime Thickness	12"	6"	8"	6"	8"	6"	8"	6"
Lime Application Rate	8%	6%	8%	6%	8%	6%	8%	6%
MC Depth:								
Avg. Swell <2%[3]	0-48"	N/A	0-48"	N/A	0-48"	N/A	0-48"	N/A
2%≤ Avg. Swell <6%	60"	N/A	60"	N/A	60"	N/A	60"	N/A
6%≤ Avg. Swell <8%	72"	N/A	72"	N/A	72"	N/A	72"	N/A
8%≤ Avg. Swell <10%	84"	N/A	84"	N/A	84"	N/A	84"	N/A
Avg. Swell ≥10%	96"	N/A	96"	N/A	96"	N/A	96"	N/A
SG Behind BOC	2 ft	2 ft	2 ft	2 ft	2 ft	2 ft	2 ft	2 ft
MB Behind BOC	6 ft	N/A	6 ft	N/A	6 ft	N/A	6 ft	N/A

1: See Thoroughfare Design Manual for classification definitions
2: All concrete shall be Class P1 or P2
3: Geotech report must support moisture conditioning less than 48”

MC = Moisture Conditioning
SG = Subgrade
BOC = Back of Curb
MB = Moisture Barrier

C. All roadways and alleys shall have a geotechnical investigation and pavement and subgrade design performed. Results of the geotechnical investigations, engineering analysis, and recommendations shall be presented in a Geotechnical Report for Roadways (“Report”). The Report and any subsequent reevaluations or supplemental reports shall be signed and sealed by a Licensed Professional Engineer in the State of Texas trained and qualified to provide geotechnical engineering analysis and pavement and subgrade design recommendations.

D. The Report shall address all items listed in the *Geotechnical Report for Roadways Checklist* (“Checklist”). The Checklist shall be filled out completely and submitted with the Report. Any “N/A” response on the Checklist shall include a written explanation and adequate justification as deemed necessary by the Deputy Director of Engineering Services.

E. The *Summary of Geotechnical Recommendations Form* (“Form”) shall be filled out completely and submitted with the Report.

F. Town review of the Report will be conducted as a means to verify the pavement and subgrade design has been performed in general conformance with the Town’s requirements and shall not be considered a detailed technical review of the pavement and subgrade design for adequacy, accuracy, or completeness. The Geotechnical Engineer performing the pavement and subgrade design shall remain responsible for the technical adequacy, accuracy, and completeness of the pavement and subgrade design and shall not be relieved of any responsibility for such as a result of the Town’s review.

G. The information and recommendations contained in the Report and any subsequent reevaluation and/or supplemental reports shall be accepted by the Deputy Director of Engineering Services in writing prior to Release of Construction.

H. Fire lane paving shall be designed in accordance with the standards below and the current Fire Code.

- Six inches (6 in) of concrete, reinforced with No. 4 bars on 24” centers, and six inches (6 in) of lime stabilization. Or,
- Seven inches (7 in) of concrete, reinforced with No. 4 bars on 24” centers, and six inches (6 in) of flexible base subgrade.

I. The Civil Engineer shall prepare a site-specific jointing plan for any roundabout. This includes, but is not necessarily limited to, expansion and contraction/sawed joints. Refer to Chapter 4 – Thoroughfare Design Requirements for more information on roundabouts.

J. Refer to the General Notes for additional specific requirements related to pavement and subgrade.

5.02. Existing Surface/Subsurface Investigation

A. Filed Investigation elements include:

1. Borings shall be drilled on the center of the roadway at 250 ft spacing (or less), alternating between each roadway direction or on a 200' grid throughout a subdivision to a depth of at least twenty feet (20 ft) below finished subgrade.

2. Borings shall be sampled continuously to a depth of 10 feet (10 ft) in 2-foot increments, then every five feet (5 ft) thereafter. In areas of cut, sampling should be continuous to 10-foot depth below the final pavement elevation.

3. Bulk samples of each soil type encountered in the upper five feet (5 ft) shall be taken for Laboratory Investigation.

B. Laboratory Investigation elements include:

1. Moisture Content Tests (ASTM D 2216) shall be performed. Average all swell test results to determine the mean maximum swell percentage and the standard deviation.

   a. For samples taken during the months of June through September, use the mean swell percentage.

   b. For samples taken during the months of October through May, use the mean plus one standard deviation to determine the design swell percentage.

   c. Re-sample the pavement subgrade soils within one month before subgrade preparation begins to allow the findings to be incorporated into the final design.

2. Soil types in each boring shall be classified as follows:

   a. Atterberg limits (ASTM D 4318)

   b. Percent Passing the No. 200 sieve (ASTM D 1140)

   c. Moisture/Density

C. Weathered Eagle Ford shale (classified as either shale, shaley clay, or clayey shale and not rock) encountered within eight feet (8 ft) below finished subgrade shall be excavated to a depth of at least the depth of the required moisture treatment and preplaced with on-site light brown or dark brown clays or other approved material. Weathered Eagle Ford shale is not suitable for stabilization without appropriate detailed design and acceptance by the Town.

D. A geotechnical reevaluation will be required if more than two (2) months occur between the end of moisture conditioning and beginning of liming operations; when conditions have changed significantly between moisture conditioning and liming operations; when Contractor and/or Owner have not properly maintained moisture content; or as deemed necessary by the Town. The reevaluation shall include additional field and laboratory testing to confirm moisture condition in still acceptable, or how to rectify the substandard condition prior to liming operations as necessary. Borings for the reevaluation will be required on center of roadway at 500 ft spacing (or less) or on a 400 ft grid throughout a subdivision to a depth of at least then feet (10 ft) below finished grade in the Austin Chalk formation and twelve feet (12 ft) in the Eagle Ford.

5.03. Subsurface Design

A. Laboratory investigation elements for both Eagle Ford and Austin Chalk formations include determining swell characteristics and movement potential using the Swell Test AND the calculated Potential Vertical Rise (PVR) – TxDOT Tex-124-E methods for a sixteen-foot (16 ft) depth of moisture penetration. The results of both tests shall be included in the Report. The Geotechnical Engineer shall use the more conservative value in determining swell potential and depths of moisture treatment.

1. Swell Test: Test for swell potential in Austin Chalk soils using swell test (ASTM D 4546) at the anticipated final overburden pressure at the top of the sample using 125 psf per foot of soil. Test at least two (2) samples per boring at varying depths from zero feet (0 ft) to ten feet (10 ft) to determine the average swell potential of the subgrade. In the Eagle Ford, test at least three (3) samples per boring in similar fashion at varying depths from zero feet (0 ft) to twelve feet (12 ft). Use Table 5.1 to determine the minimum depth of moisture treatment based on average swell potential.

2. PVR-TxDOT Tex-124-E: The procedure to calculate PVR shall consider materials to a depth of ten feet (10 ft) in the Austin Chalk formation and to twelve feet (12 ft) in the Eagle Ford. In extreme situations (e.g., recently cleared heavily wooded areas) PVR shall be calculated to sixteen feet (16 ft) depth as stated in Tex-124-E. The PVR shall be calculated and the design shall provide recommendations for moisture treatment depth based on the more conservative of either Tex-124-E or swell testing that is sufficient to limit PVR to 4.5 inches.

B. The Geotechnical Engineer shall address transitions between zones of varying depths of moisture treatment. Zones shall remain at the most conservative depth 150 feet from the location of the boring resulting in the greatest depth, prior to transitioning to a zone with less moisture conditioning depth. In no case shall the transitions be greater than 1H:1V.

C. If street trees are proposed and within the limits of the moisture treated subgrade and moisture barriers, the Geotechnical Engineer shall address this condition in the Report and propose an alternate moisture barrier for the Town's review.

D. All subsurface improvement shall be in accordance with the Town of Prosper technical specifications unless otherwise approved by the Deputy Director of Engineering Services.

5.04. Subgrade Design

A. Laboratory Investigation elements for both Eagle Ford and Austin Chalk formations include:

1. Lime stabilization series for each soil type expected to be in the uppermost twelve inches (12 in) of the final subgrade elevation. The Eades-Grimm method of pH testing (ASTM D 2976) may be used to obtain a beginning point. Additional testing shall be performed for each soil type to determine lime content (either Lime-PI or Lime-pH methods). Minimum acceptable design criteria are below:

   - Lime -PI performed in 1% increments of lime content. Design lime content shall be the content where the Plasticity Index (PI) first becomes ≤ 15; or

   - Lime-pH series performed in 1% increments of lime content. Design lime content shall be the content where the pH after mellowing ≥ 12.4; or point where pH after mellowing becomes nearly constant with increasing lime content. If this method is used for design, the Plasticity Index (PI) of the 12.4 pH or constant pH mixture shall be determined and shall be ≤ 15.

   - Swell potential < 1% under the anticipated overburden stress test using an overburden pressure of 125 psf per foot of overburden at the top of the sample (ASTM D 4546). As noted in our review document, accuracy and repeatability of this test will be a challenge. If this requirement is to remain, then the remolding should be explicitly stated and should conform to the compaction and moisture requirements set forth in the project plans and specifications (e.g.; ≥ 95% density at a moisture content between zero and plus 3 percentage points of Optimum (0% to +3%)). Please note that higher compaction and lower moisture contents both produce higher swells, whereas wetter and less compacted specimens will produce the least.

   - The minimum lime content shall be the percentage, by weight, of the hydrated lime as determined by lime stabilization series plus 1%, and in no case be less than the Town's minimum requirements listed in Table 5.1.

2. Test for sulfates in the upper three feet (3 ft) of the subgrade in each boring using Tex-124-E with 10:1 dilution ratio. Provide testing to determine the levels of sulfate present in all soil types in the upper three feet (3 ft).

B. Eagle Ford or Austin Chalk formations having over 5,000 ppm (0.5%) sulfates shall be lime stabilized using a split application method. The application of lime shall follow the below method.

   The design percentage by weight or pounds per square yard of lime to be added will be as shown on the plans and may be varied by the Engineer if conditions warrant. Slurried hydrate lime shall be the only method acceptable in the Town. The rate of application shall be verified using the methods provided in ASTM D 3155.

   Slurried quick lime shall be spread and mixed within one hour (1 hr). Slurry exposed to the air over one hour (1 hr) shall not be accepted for payment.

Unless otherwise approved by the Engineer, the lime operation shall not be started with the air temperature is below 40° F and falling but may be started when the air temperature is above 35° F and rising. The temperature will be taken in the shade and away from artificial heat. Lime shall not be placed during periods of rain or when either conditions, in the opinion of the Engineer, are not suitable.

Slurry Placement – Lime Slurry shall be delivered to the project in the slurry form at or above the minimum lime concentration as listed in the approved mix design. The residue or "stones" remaining in the tank from the slurring procedure shall be spread uniformly over the length of the roadway currently being processed, or wasted, unless otherwise approved by the Engineer. Slurry shall be of such consistency that it can be applied uniformly without difficulty.

C. Alternative subgrade options may be proposed by the Geotechnical Engineer and may be approved by the Deputy Director of Engineering Services in writing.

D. If lime stabilization is not a feasible option, a flexible base alternative subgrade shall have a minimum depth equal to the lime thickness as listed in Table 5.1 and shall extend a minimum of two feet (2 ft) behind the back of curb. Flexible base shall be TxDOT Specifications, Item 247, Type D, Grade 1 or 2 with Triax TX 140 Geogrid (or approved equal) under the flexible base.

E. All subgrade improvements shall be in accordance with the following Technical Specifications and the General Notes unless otherwise approved by the Deputy Director of Engineering Services.

1. Lime – The lime shall meet the requirements of ASTM C977 / AASHTO M216; contain at least 92% calcium and magnesium oxide, and the rate of slaking test for moderate reactivity per ASTM C100 / AASHTO T 232. All lime shall come from a single source, shall be the same source as used in the design, and shall be subject to periodic testing to confirm properties. Each shipment of lime shall be accompanied by a Certificate of Compliance stating the conformance of the product to these specifications. Certificates shall be provided to the Engineer.

   In the event the Contractor changes lime sources, no work shall be done until the Engineer accepts, in writing, a new lime-soil mix design using the new lime source.

2. Water – Water used for slaking, mixing or curing shall be free of oil, salts, acid, alkali, sugar, vegetable, or other deleterious substances which may cause damage to the finished product. All water shall meet the material requirements in AASHTO T 26. Known potable water may be used without testing.

3. Soil – Subgrade soils used in the stabilization shall be the same AASHTO or ASTM classification and Plasticity Index range as used in the approved mix design. All organics, roots and deleterious materials shall be removed from the area to be stabilized and shall be wasted. The condition of the subgrade soils must be approved by the Engineer prior to beginning work. All imported soils shall be tested using all appropriate methods as listed in previous sections.

4. Asphalt – Asphalt used to seal the surface of the lime stabilized subgrade shall be CSS1h or other approved asphalt as approved by the Engineer and shall conform to the requirements of TXDOT Item 300, "Asphalts, Oils and Emulsions". Each shipment shall be accompanied by a Certificate of Compliance stating the conformance of the product to these specifications which shall be provided to the Engineer.

5.05. Pavement Design

A. All street, alley, and fire lane pavement design shall be in accordance with the following technical specifications unless otherwise approved by the Deputy Director of Engineering Services.

- Minimum compressive strength of 3500 psi at twenty-eight (28) days with a minimum of 5.5 sacks of cement as verified by an approved laboratory.
- Finish will be with a baker broom.
- All batch designs must be signed by the testing laboratory and include all documentation, such as results of field trial testing.
- A fly ash batch design may be submitted for approval on a specific job basis; fly ash up to twenty percent (20%) by weight of cement replacement may be used in machine pours.
- If applicable, all batch designs shall specify an appropriate sulfate resistant cement or equivalent.
- Slump shall be 1-3 inches for all machine work and 2-4 inches for all hand work.
- Streets (depending on classification) and fire lanes shall have a minimum thickness of six inches (6 in); alleys shall have a minimum thickness of 8"-5"-8".
- Upon completion of construction, all streets and fire lanes shall be cored for thickness (2-inch diameter cores) at a spacing of 300 ft maximum, alternating from left quarter point to center line to right quarter point. Alleys shall be cored for thickness (2-inch diameter cores) in an alternating pattern at spacing of 300 ft maximum.
- Pavement of a thickness less than the thickness shown on the plans by more than one-quarter inch (1/4 in) but less than three-quarter inch (3/4 in) will be considered deficient. The Contractor shall pay to the Town two (2) times the unity bid price per square yard for the area determined to be deficient in thickness as defined above. Pavement deficient in thickness by more than three-quarter inch (3/4 in) shall be removed and replaced completely. The deficient area shall be cored immediately on ten-foot (10 ft) centers or two (2) per panel to be proved out.

- All streets alleys, and fire lanes will require cylinders to be made for strength tests by the approved laboratory. Samples for strength tests of each class of concrete placed each day shall be taken by an approved laboratory not less than once per day, nor less than once for each 100-150 cu yd of concrete. Four (4) cylinders shall be made; one shall be broken at 7 days, two (2) shall be broken at twenty-eight (28) days, and one shall be held in case of damage to any of the other three. The average strength of the two cylinders tested from the same sample, at twenty-eight (28) days is required for each strength test; any strength test beyond twenty-eight days is unacceptable. If the twenty-eight-day design strength is not reached upon strength testing the cylinders, the deficient area shall be cored immediately on ten-foot (10 ft) centers or one per panel to be proved out. Cores shall be extracted according to ASTM C 42, latest version, and conditioned in a moisture condition most representative of the in-place service condition. For any areas deficient in strength by not more than 500 psi, the Contractor shall bay to the Town one (1) times the unit bid price per square yard for the area determined to be deficient in strength. For any areas deficient in strength by more than 500 psi shall be removed and replaced completely. No more than three – four-inch (4 in) diameter cores shall be extracted per panel without prior Town approval. A rebar detector shall be used to ensure that the cored areas are clear of any rebar. All coring and additional laboratory testing shall be at the expense of the Contractor. The width to be considered for any deficiencies shall be the full width of the pavement.

B. All sidewalks shall be concrete and designed to have a minimum compressive strength of 3000 psi at twenty-eight (28) days. Concrete finish shall be with a camel hair broom. Minimum cementitious material shall be five (5) sacks equivalent. If applicable, all batch designs shall specify an appropriate sulfate resistant cement or equivalent based on local soil conditions.

C. The minimum pavement sections listed in Table 5.1 are based on the Pavement Design Input Values contained in Table 5.2. it is the Geotechnical Engineer's responsibility to ensure those input values are applicable. In no case shall the pavement sections be less than the Town's minimum. A pavement design shall be required when any of the input values deviate from the Town's input values listed in Table 5.2. When a pavement design is required, it shall be based on the AASHTO Guide for Design of Pavement Structures, current edition, utilizing WinPAS, Pavement Analysis Software. A printout from the software program will be required.

TABLE 5.2: Pavement Design Input Values

Input	Thoroughfare Classification			
	6LD	4LD	4LRD, 3L, 2LC	2LN/2LRN, Alley
Design Period	20 years	20 years	20 years	20 years
Initial Serviceability	4.5	4.5	4.5	4.5
Terminal Serviceability	2.5	2.3	2.3	2.0
Concrete MOR @ 28 days	620 psi	620 psi	620 psi	620 psi
Concrete E @ 28 days	5,000,000 psi	5,000,000 psi	5,000,000 psi	5,000,000 psi
Modulus of Subgrade Reaction (Eagle Ford)	300 psi/in	300 psi/in	300 psi/in	300 psi/in
Modulus of Subgrade Reaction (Austin Chalk)	420 psi/in	420 psi/in	420 psi/in	420 psi/in
Reliability	90%	90%	85%	85%
Standard Deviation	0.35	0.35	0.35	0.35
Load Transfer Coefficient	2.9	2.9	2.9	2.9
Drainage Coefficient	1.0	1.0	1.0	1.0
Design Average Daily Traffic (ADT)	60,000	30,000	20,000	12,000
Traffic Growth Rate	2%	2%	2%	2%
Percent Trucks	2%	2%	1%	1%
Lanes	6	4	2/3	2
Lane Distribution Factor	0.7	1	1	1

Geotechnical Report for Roadways Checklist

Project Name: _____

Geotechnical Engineer/Firm: _____

Report Date: _____ Date Received: _____

Note: Any N/A response shall include a written explanation with adequate justification, as deemed necessary by the Deputy Director of Engineering Services.

COMPLETE	N/A	5.01 GENERAL
☐	☐	Include the *Summary of Recommendations Form*
☐	☐	Description of Project
☐	☐	Location of Project
☐	☐	Roadway type and classification
☐	☐	Grading plan and summary
☐	☐	Discussion of underground utilities within the Project Limits
COMPLETE	N/A	5.02 EXISTING SURFACE/SUBSURFACE
☐	☐	Discussion of existing surface/subsurface conditions that may affect subgrade and pavement design or performance (i.e. vegetation, terrain, existing structures, existing pavement, etc.)
☐	☐	Discussion of geological conditions that may impact subgrade and pavement design or performance. Specify formation.
☐	☐	Surface/subsurface conditions with logs - Sampling techniques - Description of soil and rock encountered, including lab test details - Discussion of water and groundwater conditions - Discussion of seasonal variations in moisture content - Atterberg limits (ASTM D 4318) - Percent Passing the No. 200 sieve (ASTM 1140)
☐	☐	All standards used in field and laboratory testing shall be identified. Any deviations to standard procedures shall be discussed.

COMPLETE	N/A	5.03 SUBSURFACE RECOMMENDATIONS
☐	☐	Expansive Soils Evaluation - Percent swell calculation and test results - Effect of cut/fills (i.e. long-term soil uplift in cut areas; settlement overburden pressure effects in fill areas) - Identify soil movement estimates at each boring location - Explanation of anomalous variations within the soil profile and between borings (i.e. Atterberg limits, PI, sulfates, clay to rock, etc.)
☐	☐	Soil Moisture Conditioning - Discussion of swell test results summary - Recommended depth of moisture conditioning - Address transition between zones of varying depth - Discussion of possible variations during construction and mitigation thereof - Discussion of techniques to maintain moisture in soil - Discussion of methods to test soil moisture conditioning during construction (i.e. a second geotechnical investigation/re-evaluation may be required to specifically address soil moisture prior to lime operations) - Address street trees
COMPLETE	N/A	5.04 SUBGRADE RECOMMENDATIONS
☐	☐	Subgrade Stabilization - Typical subgrade type - Explanation of anomalous soil conditions anticipated and discussion of potential variations to consider - Construction techniques to implement - Effects of rock/rock fragments encountered during construction and recommendations to abate
☐	☐	Soluble Sulfates - Identify soluble sulfate test results; summarize results and discuss variations - Discussion of techniques during construction to mitigate sulfate induced heaving - Sulfate retesting during construction
COMPLETE	N/A	5.05 PAVEMENT RECOMMENDATIONS
☐	☐	Identify roadway type(s) and classification(s)
☐	☐	Identify deviations from Pavement Design Input Values (Table 5.2)
☐	☐	Identify recommended pavement section

COMPLETE	N/A	APPENDIX
☐	☐	Geological Map
☐	☐	Boring Locations
☐	☐	Boring Logs
☐	☐	Grading Plan (for non-linear projects)
☐	☐	Cut vs. fill by station number (for linear projects)
☐	☐	Printout from WinPAS pavement design software program
☐	☐	Proposed typical section with dimensions showing pavement thickness, subgrade type and thickness, moisture conditioning depth, and location of moisture barrier. If applicable, location of proposed trees and root barriers shall be shown.

Geotechnical Engineer Signature: _____ Date: _____