ITEM 5
STABILIZED SUBGRADE

PART 2 MECHANICALLY STABILIZED SUBGRADE

5.2.1 DESCRIPTION

Item includes mechanically stabilized subgrade of base/subbase course and/or subgrade improvement in the construction of paved or unpaved roadways. Design details for geogrid reinforcement, such as geogrid type, fill thickness, pavement cross-section and associated details, shall be as shown on the contract drawings. Work consists of:

5.2.1.1 Purpose

The purpose of the work shall be to provide a stabilized paving platform section on which paving materials can be placed. This Item shall not be used to retain moisture in subgrades unless retaining moisture in the section can be assured. This specification shall be used for a construction platform and not as a means of mitigating swell.

5.2.2 MATERIALS

5.2.2.1 Definitions

A. Mechanically Reinforced - Placement of a geogrid immediately over a soft subgrade soil in order to improve the bearing capacity and mitigate deformation of the subgrade soil. The goal of this application may be to reduce deeper excavation requirements, improve construction efficiency, reduce the amount of aggregate subbase/base material required, provide a stiff working platform for pavement construction, or combination of these.

B. Geogrid - A biaxial polymeric grid formed by a regular network of integrally connected tensile elements with apertures of sufficient size to allow interlocking with surrounding soil, rock, or earth to function primarily as reinforcement.

C. Multi-Layer Geogrid - A geogrid product consisting of multiple layers of grid which are not integrally connected throughout.

D. Extruded Geogrid – A geogrid product formed by extrusion of a polypropylene or polypropylene/polyethylene copolymer sheet followed by its perforation with a precise arrangement of holes and subsequent stretching, or drawing, into the finished product.

E. Woven Geogrid – A geogrid product formed by weaving discrete strips of polymer into a network. These geogrids usually require a protective coating to protect the polymer from pre-mature degradation.

F. Minimum Average Roll Value (MARV) - Value based on testing and determined in accordance with ASTM D4759-92.

G. True Initial Modulus in Use - The ratio of tensile strength to corresponding zero strain. The tensile strength is measured via ASTM D6637 at a strain rate of 10 percent per minute. Values shown are MARVs. For multi-layer geogrid products, rib tensile testing shall be performed on the multi-layer configurations, as prescribed by ASTM D6637

H. Junction Strength - Breaking tensile strength of junctions when tested in accordance with GRI-GG2 as modified by AASHTO Standard Specification for Highway Bridges, 1997 Interim, using a single rib having the greater of 3 junctions or a minimum 8 inch machine direction sample and tested at a strain rate of 10 percent per minute based on this gauge length. Values shown are MARVs. For multi-layer geogrid products, junction strength testing shall be performed across junctions from each layer of grid individually, and results shall not be assumed as additive from single layers to multiple layers.

I. Flexural Stiffness (also known as Flexural Rigidity) - Resistance to bending force measured via ASTM D1388-96, Option A, using specimen dimensions of 864 millimeters in length by 1 aperture in width. Values shown are MARVs. For multi-layer geogrid products, flexural stiffness testing shall be performed directly on the multi-layer configuration without using any connecting elements other than those used continuously throughout the actual product, and results shall not be assumed as additive from testing performed on a single layer of the multi-layer product.

J. Aperture Stability Modulus (also known as Torsional Rigidity or Torsional Stiffness) - Resistance to in-plane rotational movement measured by applying a 20 kg-cm (2.0 m-N) moment to the central junction of a 9-inch by 9-inch specimen restrained at its perimeter. Values shown are MARVs. For multi-layer geogrid products, torsional stiffness testing shall be performed on each layer of grid individually, and results shall not be assumed as additive from single layers to multiple layers.

K. Granular Fill Material – The preferred gradation for base reinforcement application is well-graded crushed aggregate fill with a maximum particle size (100 percent passing) of 1 ½ inches, and less than 10% fines (passing the #200 sieve). Recycled concrete may be used only with polypropylene geogrids in accordance with FHWA 2001.

5.2.3 MANUFACTURERS

All manufacturers will be considered provided they meet the submittal process as per Item 5.2.6 and per Table 5.2.4.

5.2.4 GEOGRID MATERIAL PROPERTIES

A. Structural Soil Reinforcement Geogrid – The geogrid shall be integrally formed and deployed as a single layer having the following characteristics according to Table 5.2.4 (ALL VALUES ARE MINUMUM AVERAGE ROLL VALUES UNLESS A RANGE OR CHARACTERISTIC IS INDICATED):

TABLE 5.2.4 – GEOGRID STRUCTURAL PROPERTIES

Property	Test Method	Units	Type 1	Type 2
Aperture Stability Modulus at 20 cm-kg (2.0 m-N)	Kinney (2001)	m-N/deg	0.32	0.65
Rib Shape	Observation	N/A	Rectangular or Square	Rectangular or Square
Rib Thickness	Calipered	In	0.03	0.05
Nominal Aperture Size	I.D. Calipered	In	1.0 to 1.5	1.0 to 1.5
Junction Strength	GRI-GG2-2000 [1]	ratio	NOTE 1	NOTE 1
Flexural Rigidity	ASTM D1388-96 [2]	Mg-cm	250,000	750,000
Minimum Tensile Strength @ 2% Strain:	ASTM D6637-01 [4]			
- MD[3]		Lb/ft	280	410
- CMD[3]		Lb/ft	450	620
Minimum Tensile Strength @ 5% Strain:	ASTM D6637-01 [4]			
- MD[3]		Lb/ft	580	810
- CMD[3]		Lb/ft	920	1,340

NOTES:

1. The ratio of Junction Strength/Ultimate Tensile Strength must meet or exceed 75%.
2. Resistance to bending force measured via ASTM D-5732-95, using specimens of width two ribs wide, with transverse ribs cut flush with exterior edges of longitudinal ribs (as a “ladder”), and of length sufficiently long to enable measurement of the overhang dimension.
3. MD = machine direction (along roll length); CMD = cross-machine direction (across roll width).
4. True resistance to elongation when initially subjected to a load determined in accordance with ASTM D6637 without deforming test materials under load before measuring such resistance or employing “secant” or “offset” tangent methods of measurement so as to overstate tensile properties.

B. Geotextile materials shall not be considered as an alternate to geogrid materials for subgrade improvement or base/sub-base reinforcement applications. A geotextile may be used in the cross-section to provide separation, filtration or drainage; however, no structural contribution shall be attributed to the geotextile.

5.2.5 EXECUTION

5.2.5.1 Examination

A. The **CONTRACTOR** shall check the geogrid upon delivery to verify that the proper material has been received. The geogrid shall be inspected by the **CONTRACTOR** to be free of flaws or damage occurring during manufacturing, shipping, or handling.

5.2.6 DELIVERY, STORAGE, AND HANDLING

5.2.6.1 Storage and Protection

A. Prevent excessive mud, wet concrete, epoxy, or other deleterious materials from coming in contact with and affixing to the geogrid materials.

B. Store at temperatures above -20 degrees F (-29 degrees C).

C. Rolled materials may be laid flat or stood on end.

D. Geogrid materials should not be left directly exposed to sunlight for a period longer than the period recommended by the manufacturer (as per ASTM D4355).

5.2.6.2 Preparation

A. The subgrade soil elevation shall be prepared at the proper elevation and alignment as directed by the **ENGINEER** or as indicated on the construction drawings.

5.2.6.3 Installation

A. The geogrid shall be installed in accordance with the installation guidelines provided by the manufacturer or as directed by the **ENGINEER**.

B. The geogrid may be temporarily secured in place with ties, staples, pins, sand bags or backfill as required by fill properties, fill placement procedures or weather conditions or as directed by the **ENGINEER**.

5.2.6.4 Granular Fill

A. Compaction – Standard compaction methods may be used unless the soils are very soft. In these cases, static instead of vibratory compaction is prudent, particularly over silty subgrades. Compaction is then achieved using a light roller. Keeping fill moisture content near optimum will make compaction more efficient. Water spray is most effective with sand fill. Compact aggregate fill to project specifications, after it has been graded smooth and before it is subject to accumulated traffic.

B. Vehicle Operation Over Geogrids- A minimum loose fill thickness of 6 inches is required prior to operation of tracked vehicles over the geogrid. Turning of tracked vehicles should be kept to a minimum to prevent tracks from displacing the fill and damaging the geogrid. When underlying substrate is trafficable with minimal rutting, rubber-tired equipment may pass over the geogrid reinforcement at slow speeds (less than 10 mph) when integrally-formed geogrids are used. This shall not be allowed with coated geogrids and sharp turning movements shall be avoided.

5.2.6.5 Inspection

A. The **OWNER** or **OWNER'S** representative may randomly inspect geogrid before, during and after (using test pits) installation.

B. Any damaged or defective geogrid (i.e. frayed coating, separated junctions, separated layers, tears, etc.) will be repaired/replaced in accordance with Item 5.2.5.6.

5.2.6.6 Repair

A. Any roll of geogrid damaged before, during and after installation shall be replaced by the **CONTRACTOR** at no additional cost to the **OWNER.**

B. Proper replacement shall consist of replacing the affected area adding 3ft (1m) of geogrid to either side of the affected area.

5.2.7 SUBMITTALS

5.2.7.1 Submittal Procedure – 15 days prior to bid letting.

A. Submit geogrid product sample approximately 4 inches by 7 inches or larger three days prior to installation.

B. Submit geogrid product data sheet, certification, and/or independent full scale laboratory testing from the manufacturer that the geogrid product supplied meets the requirements of Table 5.2.4

C. Submit manufacturer's installation instructions and general recommendations.

D. A list of 5 comparable projects that are similar in terms of size and application, within the state of Colorado, and where the results of using the specific geogrid material can be verified after a minimum of 1 year of service life.

E. Additional information as requested by the **ENGINEER** to fully evaluate the product.

5.2.7.2 Quality Assurance

A. Pre-Construction Conference - Prior to the installation of the geogrid, the **CONTRACTOR** shall arrange a meeting at the site with the geogrid material supplier and, where applicable, the geogrid installer. The **OWNER** and the **ENGINEER** shall be notified at least 3 days in advance

of the time of the meeting. A representative of the geogrid supplier shall be available on an “as needed” basis during construction.

5.2.8 CONSTRUCTION PLATFORM DESIGN

Construction platform design shall be performed under supervision of and signed by a Professional Engineer registered in the State of Colorado. The recommended procedure shall be derived by the Giroud-Han, Method (ASCE, August 2004).

Appropriate partial safety factors shall be applied to results obtained using geogrids having properties or characteristics outside the range of rigorous model validation (Giroud and Han, 2004). This method has been endorsed by numerous Department of Transportations and Government Agencies such as the Federal Highway Administration and Army Corps of Engineers.

For general guidance purposes only, Table 5.2.7.1 and 5.2.7.2 present a guide for estimating subgrade soil strength and minimum construction platform recommendations based on a range of subgrade strengths, respectively. A piping ratio analysis ($D15_{fill}/D85_{subgrade}$) shall be performed to determine the need of a separation fabric. If the piping ratio is less than 5 then no separation fabric is required. If the piping ratio is greater than 5 then a separation fabric is required below the geogrid. Final determination of construction platform shall be approved by the **ENGINEER**.

TABLE 5.2.8.1

Guide for Estimating Subgrade Soil Strengths (Fine Grained Soils)

Estimate Consistency by:		Test by:				Correlates to:			
Feel	Equipment/Visual	Standard Penetration Test (blows/ft)	Dynamic Cone Penetrometer (mm/blow)			Shear Strength c_u		R Value	CBR
			SC, SM, SP	CL	CH	(kPa)	(tsf)		
Very Soft	Man standing sinks > 3"	< 2	—	—	—	< 12	< 0.125	—	< 0.4
Soft	Man walking sinks ≈ 2 - 3"	2 - 4	—	—	—	12 - 24	0.125 - 0.25	< 0.36	0.4 - 0.8
Medium	Man walking sinks ≈ 1"	4 - 8	—	> 66	—	24 - 48	0.25 - 0.50	0.36 - 2.5	0.8 - 1.6
Stiff	Pickup truck ruts ≈ 1/2 - 1"	8 - 15	> 100	66 - 46	—	48 - 96	0.50 - 1.0	2.5 - 6.8	1.6 - 3.2
Very Stiff	Loaded dump truck ruts ≈ 1 - 3"	15 - 30	100 - 56	46 - 33	> 109	96 - 193	1.0 - 2.0	6.8 - 15.5	3.2 - 6.4
Hard	Insignificant rutting by loaded dump truck	> 30	56 - 27	33 - 23	109 - 54	> 193	> 2.0	> 15.5	> 6.4

References: After Portland Cement Association, E.I. Dupont Literature and McCarthy, David F., "Essentials of Soil Mechanics and Foundations," 1977, and Tensar 1998. Webster, Personal Communication 2001, "DCP vrs. CBR Correlations".
AASHTO, "1993 Guide for Design of Pavement Structures," Van Till et. al. NCHRP 128.

TABLE 5.2.8.2

Recommended Aggregate Fill Thickness Feel / CBR Value with Geogrid Mechanical Reinforcement				
Soil Strength [1]	CBR	Aggregate Fill Thickness (in.) [2]		
Feel	approx.	Type 1 Geogrid [3]	Type 2 Geogrid [3]	*Unreinforced*
Very Soft	< 0.4	37"	34"	52"
Soft	0.6	30"	26"	42"
Medium	1.2	20"	16"	29"
Stiff	2.5	14"	9"	22"
Very Stiff	4	12"	6"	20"

Notes:

1. Soil Strength is based in Table 5.2.8.1. The soil strength used is general for these purposes.
2. Results of aggregate fill thickness were derived using the published Giroud-Han (2004) Methodology. Average values for fill thickness are used. Aggregate fill was assumed to have a minimum R-value of 30.
3. Type 1 and Type 2 geogrid structural properties used were a minimum as derived from Table 5.2.4

5.2.9 PAYMENT

Payment shall be made at the contract unit price per square yard based upon plan quantities for the stabilization. The price shall be full compensation for furnishing all material and for all preparation of the subgrade, delivering, installation, and incidentals necessary to complete this item. Paving platform found deficient shall be removed and replaced. At the option of the **AGENCY,** the pavement structural section shall be adjusted to compensate for any deficiency in the paving platform thickness and strength at the **CONTRACTOR'**s expense as noted in Item 5.2.6.6. Granular fill will be paid for at the contract unit price per ton. Unit price will be held constant regardless of deviation from actual quantities.

Item	Description	Payment
5.3	Geogrid	$/yd^2
5.4	Separation fabric	$/yd^2
5.5	Granular fill	$/ton

5.2.10 REFERENCES

A. American Association of State Highway and Transportation Officials (AASHTO)

1. AASHTO Recommended Practice for Geosynthetic Reinforcement of the Aggregate Base Course of Flexible Pavement Structures, AASHTO PP46-01, April 2001 Interim Edition of the AASHTO Provisional Standards.
2. Standard Specification for Highway Bridges (1997 Interim)
3. AASHTO Guide for Design of Pavement Structures (1993)

B. American Society for Testing and Materials (ASTM)

1. D1388-96 - Standard Test Method for Stiffness of Fabrics, Option A
2. D6637-01- Standard Test Method for Determining Tensile Properties of Geogrids by the Single or Multi-rib Tensile Method
3. D4354-96 - Practice for Sampling of Geosynthetics for Testing
4. D4759-92 - Practice for Determining the Specification Conformance of Geosynthetics
5. D5818-95 - Practice for Obtaining Samples of Geosynthetics from a Test Section for Assessment of Installation Damage

C. Geosynthetic Research Institute (GRI)

1. GRI-GG2 - Standard Test Method for Geogrid Junction Strength

D. U.S. Department of Transportation – Federal Aviation Administration (FAA)

1. Specification for Geogrid Reinforced Base Courses, Engineering Brief No. 49 (1994).

E. U.S. Department of Transportation – Federal Highway Administration (FHWA)

1. Corrosion/Degradation of Soil Reinforcements for Mechanically Stabilized Earthen Walls and Reinforced Soil Slopes, Publication No. FHWA-NHI-00-044, March 2001, pages 59-60.

F. U.S. Environmental Protection Agency (U.S. EPA)

1. EPA 9090 - Compatibility Test for Wastes and Membrane Liners

G. U.S. Army Corps of Engineers (U.S. CoE)

1. Draft Specification for Grid Aperture Stability by In-Plane Rotation
2. CW-02215 Determination of Percent Open Area.

H. American Society of Civil Engineers (ASCE)

1. Giroud, J.P., and Han, J. (2004). “Design Method for Geogrid-Reinforced Unpaved Roads. Part I – Development of Design Method.” Journal of Geotechnical and Geoenvironmental Engineering, 130 (8), 775-786.
2. Giroud, J.P., and Han, J. (2004). “Design Method for Geogrid-Reinforced Unpaved Roads. Part II – Calibration and Applications.” Journal of Geotechnical and Geoenvironmental Engineering, 130 (8), 787-797.

I. Thomas C. Kinney, P.E., PhD

1. Determining the Aperture Stability Modulus of a Geogrid (2001).