Engineering Brief No. 49

INFORMATION: Engineering Brief No. 49   April 20, 1994
Geogrid Reinforced Base Course

FROM: Manager, Engineering and Specifications
Division, AAS-200

TO: All Regions
ATTN: Manager, Airports Division

Engineering Brief No. 49 provides information and guidance on geogrid reinforced base course. Recent research results indicate geogrid reinforcement will permit thickness reductions in base courses without sacrificing pavement performance. The permissible thickness reduction is shown in the Engineering Brief. An interim specification for geogrid reinforced base course, Item P-214(I) Geogrid Reinforced Base Course, is attached for your information and use.

The information in the brief is not to be construed as general approval by the Office of Airport Standards. Use of this product will be on a case-by-case basis and require prior approval by this office.

Original signed by
Richard J. Worch

ENGINEERING BRIEF NO. 49
Geogrid Reinforced Base Course

PURPOSE:
The purpose of this engineering brief is to provide guidance on the use of geogrid reinforcement in aggregate base course.

DEFINITION:
A geogrid is defined as a deformed or nondeformed regular grid structure of polymeric material formed by joined intersecting ribs used for reinforcement with foundations, soil, rock, earth, or other geotechnical engineering related material. To be effective, it must have aperture geometry, rib, and rib junction cross sections sufficient to permit significant mechanical interlock with the material being reinforced.

BACKGROUND:
The Federal Aviation Administration funded studies by the U.S. Army Corps of Engineers to evaluate the benefits of geotextiles and geogrids for reinforcement of flexible pavements intended to serve light aircraft. The results of these studies have been published in research reports DOT/FAA/RD-90/28, Geogrid Reinforced Base Courses for

Flexible Pavements for Light Aircraft: Literature Review and Test Section Design and DOT/FAA/RD-92/25, Geogrid Reinforced Base Courses for Flexible Pavements for Light Aircraft: Test Section Construction, Behavior Under Traffic, Laboratory Tests, and Design Criteria.

RESULTS:
Flexible pavements with and without geogrids were trafficked to failure under a 30,000 pound single wheel load with a 68 psi tire pressure. These studies show some geogrids are capable of increasing pavement life under traffic; while others have little or no effect on pavement life. We have attempted to capture the physical properties a geogrid must possess in order to enhance flexible pavement performance.

A relationship between unreinforced thickness and equivalent reinforced thickness was developed and is shown in Figure 1. Note that both thicknesses refer to the thickness of hot mix asphalt surfacing plus base. The curve is based on the assumption of a 2-inch surfacing course. This curve is intended to represent equal performance levels for reinforced and unreinforced base courses. This relationship (thickness reduction) is permitted for geogrid base courses constructed in accordance with this engineering brief. No adjustment to the curve is permitted for surface courses greater than 2-inches.

COST:
In order for geogrid reinforced base course to be cost effective, the cost of providing the geogrid reinforcement must be equal to or less than the cost of increasing the base course thickness to provide equal performance. The cost of providing geogrid reinforcement is highly variable and dependent on a number of considerations. Project size and location, labor cost, shipping cost, aggregate cost, etc. all influence the price of a project. As a very crude rule-of-thumb, geogrid reinforcement of the type necessary to permit a thickness reduction will cost on the order of $2.25 to $3.00 per square yard.

APPLICATION:
Geogrid reinforced base course may be substituted for Item P-209 only on pavements designed to serve aircraft with gross weights of 60,000 pounds or less. Geogrid reinforced base course does not lessen the requirements for frost or permafrost protection for pavements.

SPECIFICATION:
Attached is an interim specification for geogrid reinforced base course, Item P-214 (Interim), Geogrid Reinforced Base Course.

John L. Rice
Civil Engineer

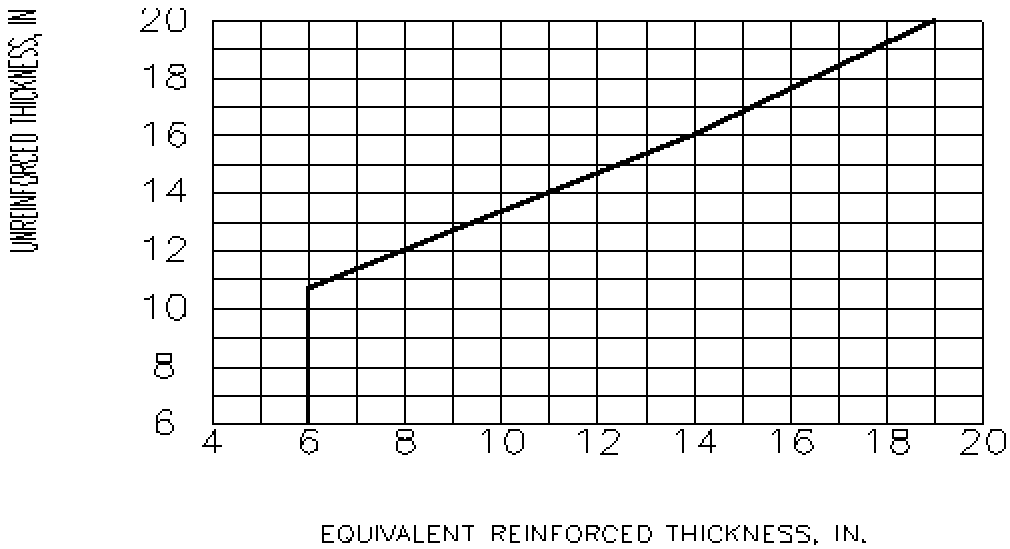

FIGURE 1. DESIGN CRITERIA FOR UNREINFORCED THICKNESS (AC SURFACE PLUS BASE) VERSUS

EQUIVALENT REINFORCED THICKNESS

ITEM P-214 (INTERIM)
GEOGRID REINFORCED BASE COURSE

DESCRIPTION

214 (I)-1.1 This item consists of a base course composed of crushed stone aggregate and a reinforcing geogrid placed on a prepared course in accordance with these specifications and in conformity to the dimensions and typical cross sections shown on the plans.

MATERIALS

214 (I)-2.1 AGGREGATE. Crushed stone aggregate for geogrid reinforced base course shall consist of clean, sound, durable particles of crushed stone, crushed gravel, or crushed slag and shall be free from coatings of clay, silt, vegetable matter, and other objectionable materials and shall contain no clay balls. Fine aggregate passing the No. 4 (4.75 mm) sieve shall consist of fines from the operation of crushing the coarse aggregate. If necessary, fine aggregate may be added to produce the correct gradation. The fine aggregate shall be produced by crushing stone, gravel, or slag that meet the requirements for wear and soundness specified for coarse aggregate.

The crushed slag shall be an air-cooled, blast furnace slag and shall have a unit weight of not less than 70 pounds per cubic foot (1.12 Mg/cubic meter) when tested in accordance with ASTM C 29.

The crushed aggregate portion which is retained on the No. 4 (4.75 mm) sieve shall contain not more than 15 percent, by weight, of flat or elongated pieces as defined in ASTM D 693 and shall have at least 90 percent by weight of particles with at least two fractured faces and 100 percent with at least one fractured face. The area of each face shall be equal to at least 75 percent of the smallest midsectional area of the piece. When two fractured faces are continuous, the angle between the planes of fractures shall be at least 30 degrees to count as two fractured faces.

The percentage of wear shall not be greater than 45 percent when tested in accordance with ASTM C 131. The sodium sulfate soundness loss shall not exceed 12 percent, after 5 cycles, when tested in accordance with ASTM C 88.

The fraction passing the No. 40 (0.42 mm) sieve shall have a liquid limit no greater than 25 and a plasticity index of not more than 4 when tested in accordance with ASTM D 4 318. The fine aggregate shall have a minimum sand equivalent value of 35 when tested in accordance with ASTM D 2419.

a. Sampling and Testing. Aggregates for preliminary testing shall be furnished by the Contractor prior to the start of production. All tests for initial aggregate submittals necessary to determine compliance with the specification requirements will be made by the Engineer at no expense to the Contractor.

Samples of aggregates shall be furnished by the Contractor at the start of production and at intervals during production. The sampling points and intervals will be designated by the Engineer. The samples will be the basis of approval of specific lots of aggregates from the standpoint of the quality requirements of this section.

In lieu of testing, the Engineer may accept certified state test results indicating that the aggregate meets specification requirements.

Samples of aggregates to check gradation shall be taken by the Engineer at least once daily. Sampling shall be in accordance with ASTM D 75, and testing shall be in accordance with ASTM C 136 and C 117.

b. Gradation Requirements. The gradation (job mix) of the final mixture shall fall within the design range indicated in Table 1, when tested in accordance with ASTM C 117 and C 136. The final gradation shall be continuously well graded from coarse to fine and shall not vary from the low limit on one sieve to the high limit on an adjacent sieve or vice versa.

TABLE 1. REQUIREMENTS FOR GRADATION OF AGGREGATE (see Note 1)

Sieve Size	Design Range Percentage by Weight Passing Sieves	Job Mix Tolerances, (plus or minus)Percent
2 in (50.0 mm)	100	
1 1/2 in (37.0 mm)	95-100	+/-5
1 in (25.0 mm)	70-95	+/-8
3/4 in (19.0 mm)	55-85	+/-8
No. 4 (4.75 mm)	30-60	+/-8
No. 30 (0.60 mm)	12-30	+/-5
No. 200 (0.075 mm)	0-8	+/-3

Note 1: Where environmental conditions (temperature and availability of free moisture) indicate potential damage due to frost action, the maximum percent of material, by weight, of particles smaller than 0.02 mm shall be 3 percent. It may be necessary to have a lower percentage of material passing the No. 200 sieve to help control the percentage of particles smaller than 0.02 mm.

The job mix tolerances in Table 1 shall be applied to the job mix gradation to establish a job control grading band. The full tolerance still will apply if application of the tolerances results in a job control grading band outside the design range.

The fraction of the final mixture that passes the No. 200 (0.075 mm) sieve shall not exceed 60 percent of the fraction passing the No. 30 (0.60 mm) sieve.

214(I)-2.2 GEOGRID. Geogrid reinforcement shall conform to the properties specified below.

TABLE 2
STRUCTURAL GEOGRID PROPERTIES

Property	Test Method	Units	Value
Aperture Size	I. D. Calipered	inches	3/4 - 1 1/2
Open Area	Corps of Engineers CW-02215	%	70 min
Rib Thickness	ASTM D 1777	inch	0.05 nom
Junction Thickness	ASTM D 1777	inch	0.16 nom

Secant Aperture Stability Modulius @20 cm-kg	Draft Test	cm-kg/deg	6.50 min
Flexural Rigidity Machine Direction	ASTM D 1388	mg-cm	750,000 min
Tensile Modulus	GRI GG1-87	lb/ft	18,500 min Machine Direction 30,000 min Cross Machine Direction
Junction Strength	GRI GG2-87	lb/ft	1080 min
Junction Efficiency	GRI GG2-87	%	90 min

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Alternate geogrid materials will be considered. Such materials must be pre-approved in writing by the Engineer prior to bid date. Alternate material packages must be submitted to the Engineer a minimum of 15 days prior to bid date. Submittal packages must include, as a minimum, the following:

1. Full-scale laboratory testing and in-ground testing of pavement structures reinforced with the specific geogrid which quantifies the structural contribution of the geogrid to the pavement structure. The increase in the structural layer coefficient of the base course must meet or exceed that of the design geogrid.

2. Independent certified test results stating that the alternate geogrid has a secant aperture stability modulus at 20 cm-kg, when tested in accordance with the "Grid Aperture Stability by In-Plane Rotation" test of 6.50 or greater.

3. A list of 5 comparable projects, in terms of size and applications, in the United States, where the results of the specific alternate geogrid's use can be verified after a minimum of 1 year of service life.

4. A sample of the geogrid and certified specification sheets.

Recommended installation instructions.

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CONSTRUCTION METHODS

214 (I)-3.1 PREPARING UNDERLYING COURSE. The underlying course shall be checked and accepted by the Engineer before placing and spreading operations are started. Any ruts or soft yielding places caused by improper drainage conditions, hauling, or any other cause shall be corrected at the Contractor's expense before the base course is placed thereon. Material shall not be placed on frozen subgrade.

214 (I)-3.2 GEOGRID POSITIONING. Geogrid reinforced base course shall be constructed such that the geogrid is located at the bottom of the base course layer. The geogrid shall be placed in such a fashion that the materials strongest direction (machine direction or counter machine direction) is perpendicular to the primary direction of traffic flow. Geogrid layout, tie down, and lap splicing shall be in accordance with the manufacturers recommendations.

214 (I)-3.3 AGGREGATE MIXING. The aggregate shall be uniformly blended during crushing operations or mixed in a plant, The plant shall blend and mix the materials to meet the specifications and to secure the proper moisture content for compaction.

214 (I)-3.4 AGGREGATE PLACEMENT. The crushed aggregate base material shall be placed so as to preclude damage to the geogrid. In no instance should construction equipment be allowed to operate directly on the geogrid. The first lift of aggregate over the geogrid shall be at least 4 inches (100 mm) thick. The underlying layer shall be moistened prior to placement. Layers of crushed aggregate base material shall be of uniform thickness.

The maximum depth of a compacted layer shall be 6 inches (150 mm). If the total depth of the compacted material is more than 6 inches (150 mm), it shall be constructed in two or more layers. In multi-layer construction, the base course shall be placed in approximately equal-depth layers.

The previously constructed layer should be cleaned of loose and foreign material prior to placing the next layer. The surface of the compacted material shall be kept moist until covered with the next layer.

214 (I)-3.5 COMPACTION. Immediately upon completion of the spreading operations, the crushed aggregate shall be thoroughly compacted. The number, type, and weight of rollers shall be sufficient to compact the material to the required density.

The moisture content of the material during placing operations shall not be below, nor more than 1- 1/2 percentage points above, the optimum moisture content as determined by ASTM [ ].

214 (I)-3.6 ACCEPTANCE SAMPLING AND TESTING FOR DENSITY. Geogrid reinforced base course shall be accepted for density on a lot basis. A lot will consist of one day's production where it is not expected to exceed 2400 square yards (2000 square meters). A lot will consist of one-half day's production where a day's production is expected to consist of between 2400 and 4800 square yards (2000 and 4000 square meters).

Each lot shall be divided into two equal sublots. One test shall be made for each sublot. Sampling locations will be determined by the Engineer on a random basis in accordance with statistical procedures contained in ASTM D 3665.

Each lot will be accepted for density when the field density is at least 100 percent of the maximum density of laboratory specimens prepared from samples of the base course material delivered to the job site. Laboratory specimens shall be compacted and tested in accordance with ASTM D 698.

The in-place field density shall be determined in accordance with [ASTM D 1556 or D 2167 or ASTM D 2922, using the Direct Transmission method].

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Field density tests, ASTM D 1556 and ASTM D 2167, should be performed with extreme caution so as not to damage the underlying geogrid layer during excavation of the sample.
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If ASTM D 2922 is used, evidence shall be furnished that the gauge has been calibrated in accordance with ASTM D 2922, Annex A1. The gauge shall be operated by a certified technician in accordance with the requirements of the manufacturer. It shall be standardized daily in accordance with ASTM D 2922, paragraph 8.

Use of ASTM D 2922 results in a wet unit weight, and when using this method, ASTM D 3017 shall be used to determine the moisture content of the material. The moisture gauge shall be standardized daily in accordance with ASTM D 3017, paragraph 7. If the specified density is not attained, the entire lot shall be reworked and/or recompacted and two additional random tests made. This procedure shall be followed until the specified density is reached.

If ASTM D 2922 is used for density determination, two random readings shall be made for each sublot.

214 (I)-3.7 FINISHING. The surface of the aggregate base course shall be finished by blading or with automated equipment especially designed for this purpose,

In no case will the addition of thin layers of material be added to the top layer of base course to meet grade. If the elevation of the top layer is 1/2 inch (12 mm) or more below grade, the top layer of base shall be scarified to a depth of at least 3 inches (75 mm), new material added, and the layer shall be blended and recompacted to bring it to grade. If the finished surface is above plan grade, it shall be cut back to grade and rerolled.

214 (I)-3.8 SURFACE TOLERANCES. The finished surface shall not vary more than 3/8 inch (9mm) when tested with a 16-foot (4.8 m) straightedge applied parallel with or at right angles to the centerline. Any deviation in excess of this

amount shall be corrected by the Contractor at the Contractor's expense.

214 (I)-3.9 THICKNESS CONTROL. The completed thickness of the geogrid reinforced base course shall be within 1/2 inch (12 mm) of the design thickness. Thickness shall be determined by surveying each lot on a 25 foot-by-25 foot (7.6 m-by-7.6 m) grid system. The lot size shall be consistent with that specified in paragraph 3.5. Where the thickness is deficient by more than 1/2 inch (12 mm), the Contractor shall correct such areas at no additional cost by excavating to the required depth and replacing with new material.

214 (I)-3.10 MAINTENANCE. The geogrid reinforced base course shall be maintained in a condition that will meet all specification requirements until the work is accepted. Equipment used in the construction of an adjoining section may be routed over completed portions of the base course, provided no damage results and provided that the equipment is routed over the full width of the base course to avoid rutting or uneven compaction.

METHOD OF MEASUREMENT

214 (I)-4.1 The quantity of geogrid reinforced base course to be paid for will be determined by measurement of the number of square yards (square meters) of material actually constructed and accepted by the Engineer as complying with the plans and specifications.

BASIS OF PAYMENT

214 (I)-5.1 Payment shall be made at the contract unit price per square yard (square meter) for geogrid reinforced base course. This price shall be full compensation for furnishing all materials, for preparing and placing these materials, and for all labor, equipment tools, and incidentals necessary to complete the item.

Payment will be made under:

Item P-214 (I) 5.1 Geogrid Reinforced Base Course - per square yard (square meter)l.

TESTING REQUIREMENTS

ASTM C 29	Unit Weight of Aggregate
ASTM C 88	Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate
ASTM C 117	Materials Finer than 75 um (No.200) Sieve in Mineral Aggregates by Washing
ASTM C 131	Resistance to Abrasion of Small Size

	Coarse Aggregate by Use of the Las Angeles Machine
ASTM C 136	Sieve or Screen Analysis of Fine and Coarse Aggregate
ASTM D 75	Sampling Aggregate
ASTM D 693	Crushed Stone, Crushed Slag, and Crushed Gravel for Dry or Water-Bound Macadam Base Courses and Bituminous Macadam Base and Surface Courses of Pavements.
ASTM D 698	Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 5lb (2.49kg) Rammer and 12in (305mm) Drop
ASTM D 1388	Flexural Rigidity
ASTM D 1777	Standard Method for Measuring Thickness of Textile Materials
ASTM D 1556	Density of Soil in Place by the Sand Cone Method
ASTM D 2167	Density of Soil in Place by the Rubber Balloon Method
ASTM D 2419	Sand Equivalent Value of Soils and Fine Aggregate
ASTM D 2922	Density of Soil and Soil-Aggregate in Place by Nuclear Methods
ASTM D 3017	Moisture Content of Soil and Soil-Aggregate in Place by Nuclear Methods
ASTM D 3665	Random Sampling of Paving Materials
ASTM D 4318	Liquid Limit, Plastic Limit, and Plasticity Index of Soils
U.S. Army Corps of Engineers, Civil Works Construction CW-02215	Guide Specification for Geotextiles Used as Filters
GRI GG1-87	Geosynthetic Research Institute test method, Geogrid Tensile Modulus
GRI GG2-87	Geosynthetic Research Institute test method, Geogrid Junction Strength
Draft Test (see Appendix A)	Grid Aperture Stability

APPENDIX A

Draft

GRID APERTURE STABILITY

BY

IN-PLANE ROTATION

Prepared by Dr. Thomas C Kinney
Geosynthetic Services of Alaska

Purpose:
1. This is an index test to measure the stability of a grid structure.

Significance:
The secant modulus seems to be significant in determining the performance characteristics when grid is placed in a paved airport runway between a CBR 3 to 8 clay subgrade and 6 to 18 inches of base course.

Apparatus:
See figure A1.

Method:

1. Lay grid on lower portions of clamps without stretching it. Put one node in the center.
2. Place upper portion of clamp on grid and bolt into place being careful not to move the grid.
3. Clamp post over center node.
4. Apply moment in approximately 5 cm-kg increments to 25 cm-kg or until the rotation will not drop below limits in 5 minutes.
5. Leave each load on until the rotation of the pulley is less than 1 degree per minute. Record the times.
6. Unload in same increments as loaded.
7. Repeat steps 4 through 6 for a total of four load-unload cycles.
8. Repeat setups 1 through 7 on three different samples.

Analysis:

1. Plot all load cycles to detect any anomalies.
2. If there are any obvious anomalies or if the rotation at a given load from any one test is over 20 percent different from the other two then discard it and repeat that test with a new sample.
3. Average all of the data for the first and forth curves to get a single composite set of data for these two curves.
4. Determine a best fit quadratic curve through the composite initial and fourth loading curves.
5. Calculate the secant and tangent stability moduli at 5, 10, 15, 20, and 25 cm-kg torque increments for both the first and fourth fitted loading curves. Note: The stability modulus is the moment divided by the rotation if degrees expressed in units of cm-kg/deg.

Report:

1. Define the grid, polymer, construction process, aperture size and rib dimensions.
2. Show a table of the first and fourth loading secant and tangent aperture stability moduli. A plotted curve would be desirable also.
3. Show the longest length of time required for the final load in the first and fourth load sequences.

Accuracy:

Verified under limited conditions.