Basic Design Approach for Geogrid Base Reinforcement

Geogrids are incorporated into standard pavement designs and construction activities to improve the long-term performance or reduce initial construction costs. Outlined below are many of the basic concepts on what makes geogrid base reinforcement a cost effective construction technique.

Geogrids are used to improve the performance of aggregate base course (ABC) materials supporting both paved and unpaved roadway surfaces. Geogrids provide confinement (lateral stability) of unbounded base courses, thus improving their vertical stress distribution characteristics. Confinement is achieved by the geogrid restraining the lateral and vertical deformation of the aggregate, which is locked into the aperture openings of the product during placement and compaction of the aggregate. The reinforcement action (strength) of the geogrid is generated by the application of vertical stress causing lateral and vertical deformations of both the aggregate and the geogrid. Some people refer to this as the "snowshoe effect", being capable of spreading a concentrated load (foot/shoe or wheel/tire) over a larger area, sufficient to preclude a "punching" shear type failure {through the snow (foot) or soft subgrade soils (wheel)}.

Since geogrids spread the concentrated wheel load more efficiently, than unbounded aggregate bases, this permits a reduction in aggregate base course thickness to achieve the same applied stress to the subgrade. This is sometimes referred to as the Base Course Reduction (BCR) percentage for a geogrid reinforced vs. unreinforced aggregate thickness. This percentage reduction, or effectiveness, varies depending on the strength of the supporting subgrade. Geogrids provide a greater benefit in stabilizing lower strength subgrades, than higher strength subgrades. Typical BCR values for Synteen geogrids are as follows:

Soil Subgrade Strength (CBR)	**Base Course Reduction (BCR) of UnReinforced Aggregate** using **Synteen SF-11**	using **Synteen SF-12**
Greater than 6	24 %	28 %
4 – 6	29 %	34 %
2 – 4	33 %	39 %
1 – 2	36 %	43 %
Less than 1.0	40 %	46 %

Subgrade strengths are qualitatively classified into five categories; ranging from, very poor to good, see attached Table 2.15 from "Designing with Geosynthetics" by Koerner, R.M. Table 2.15 is a handy reference because it places soil types (top of the chart) and subgrade strength measurements (bottom of chart) into these broad qualitative categories. The most common measure of subgrade strength for pavement design is CBR, (i.e. California Bearing Ratio) and can be determined using ASTM D-1883. There are many other measures of subgrade strength, as shown in Table 2.15, including conventional shear strength testing, CalTrans R-value, etc., allowing cross-referencing of different subgrade strength measuring techniques.

Subgrade strength is the starting point for any pavement design. Most designers utilize the lowest subgrade strength in a given length of roadway. It is rare for a pavement section to change more than once every 500 feet. Pavement sections are typically consistent for 1,000 to 5,000 ft. increments, based on the worst subgrade conditions within that stretch. However, most pavement construction specifications, include proof-rolling, to identify weak spots in the subgrade, that can be improved prior to beginning the pavement structure (layers).

Service life has the largest influence on pavement design for a given set of subgrade strength conditions. Most pavement design methods, including AASHTO 1993, utilize the number of passes of a standard axle load to define service life. The standard axle load is 18,000 lbs supported by two wheels on the traffic surface. All traffic axle loads (larger and smaller) are converted, using equivalency tables developed through empirical research, to this Equivalent Single Axle Load (ESAL). The AASHTO 1993 design guide has tables to convert cars, and different size truck (axle) loads to an ESAL. ESALs are usually calculated on a daily or weekly basis, and then multiplied by the total number of days or weeks in the design service life of the pavement. Therefore, ESALs become the measurement of pavement service life in terms of load applications, not time. That's how a pavement can fail before it's design life, should traffic volumes be larger than anticipated during design. A rural 4 lane state highway might have 18 – 20 million ESALs in 20 years, whereas an urban interstate highway with commuter traffic might be more on the order of 18-20 million ESALs per year! It's all in traffic counts, the growth of which is routinely under-estimated by designers. Some states, like CalTrans, have developed specific ESAL requirements for different roadway classifications. A designer should check the prevailing state DOT requirements prior to finalizing any pavement section.

The pavement structure is the sequence of bound (asphalt & concrete) and unbound aggregate layers placed over the subgrade to support the traffic loads and provide a safe, smooth traffic surface upon which to travel. A number of different elastic and mechanistic theories have been successfully used for pavement design, the most common of which is detailed in the 1993 AASHTO "Guide for Design of Pavement Structures." The AASHTO 1993 guide converts service life requirements (ESALs) and environmental conditions (subgrade strength, drainage (m), & freeze/thaw) to a required Structural Number (SN) that the pavement structure must meet to support the traffic loading. Through empirical testing and observation AASHTO has assigned different structural layer coefficients (a) to various materials, like; asphalt (a1 = 0.4-0.44), typical aggregate base courses (a2 or a3 = 0.11-0.14) and drainage conditions (m2 or m3 = 1.0 – 0.1). The total pavement thickness is determined directly, using these coefficients, and various layer depths (D1, D2, D3) to attain the desired Structural Number (SN), using the following equation:

$$SN = (a1)\,(D1) \;+\; (a2)\,(D2)\,(m2) \;+\; (a3)\,(D3)\,(m3) \qquad \{\text{eq } 1\}$$

Geogrid can be incorporated into the pavement design using a Layer Coefficient Ratio, representing the improvement in load carrying capabilities of the aggregate when reinforced. The design equation is altered slightly to incorporate reinforcement, as follows:

$$SN = (a1)\,(D1) \;+\; (a2)\,(D2)\,(m2)\,(LCR) \;+\; (a3)\,(D3)\,(m3)\,(LCR) \qquad \{\text{eq } 2\}$$

Typical Layer Coefficient Ration (LCR) values for Synteen geogrids are as follows. Use an LCR equal to 1.0 whenever the geogrid is not present.

Soil Subgrade Strength (CBR)	**Layer Coefficient Ratios (LCR) of Aggregate Reinforced**	
	with Synteen SF-11	**with Synteen SF-12**
Greater than 6	1.32	1.39
4 – 6	1.41	1.52
2 – 4	1.49	1.64
1 – 2	1.56	1.75
Less than 1.0	1.67	1.85

Geogrids are most efficient and cost effective when placed coincident with the proposed finished compaction lift thickness interval, typically 6", 8", or 10". Geogrids should be placed a minimum of 6" and maximum of 12" beneath bottom of asphalt/concrete (paved) layers, or traffic surface (unpaved), and at least every 12" deeper throughout the entire aggregate thickness, if applicable.

Synteen SF-11 and SF-12 geogrids are manufactured with the preferred strength direction perpendicular to the roll length, to facilitate rolling the product out parallel with the roadway centerline. Synteen geogrid roll widths should be overlapped to ensure reinforcement strength is continuous across the entire roadway width.

Soil CBR	Method of Joining
Greater than 3	300 mm (12 in) overlap
1 – 3	600 mm (24 in) overlap
0.5 – 1	900 mm (36 in) overlap or 600 mm (24") w/ mechanical ties
Less than 0.5	1000 mm (40 in) w/ Mechanical Ties or Bodkin

The minimum geogrid reinforcement layer width must be at least 2 ft. wider (1' each side) than the primary roadway / traffic surface width. Other considerations for shoulder width penetration, in order of priority are;

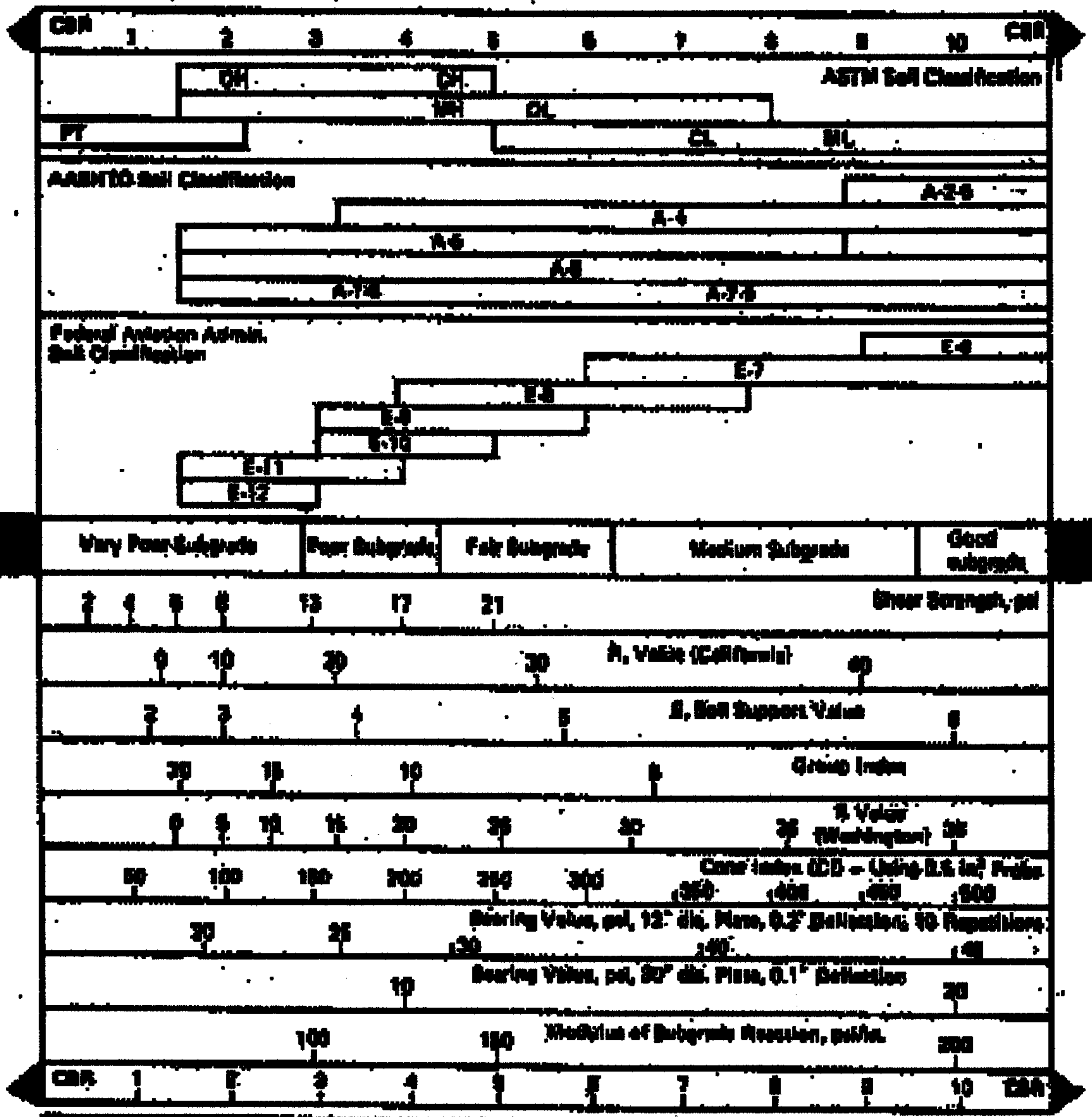
A.) Subgrade strength (CBR): Increase penetration based on subgrade strength.
(i.e. the shoulder penetration width, should be at least the overlap distance.)
B.) Roll width of product: Try to use an even number of roll widths.
(i.e. is it worth an extra or partial roll width to stabilize the shoulder that will see a very small percentage of the design ESALs for the main roadway).
C.) Drainage: Better drained pavement sections require less penetration.

The large apertures of Synteen geogrids that provide good interlock with aggregate base courses, offer little protection against subgrade intrusion. The aggregate base course gradation generally provides more protection against subgrade intrusion than the geogrid itself. Consequently, when encountering very poor subgrade conditions (CBR < 3), it is recommended that a geotextile separator be used in conjunction with geogrid reinforcement and placed directly on the subgrade, as a discreet barrier/separator between soft soils and aggregate. The purpose of the separator is to keep the soft (pumpable) fine grain soil subgrade from migrating into and fouling (reducing the strength of) the aggregate. Fouling reduces an aggregate's load carrying capacity and effective thickness. AASHTO M-288 Class 2 separator geotextiles should be used for subgrade CBRs between 1 & 3. AASHTO M-288 Class 1 stabilization geotextiles are used when CBRs fall below 1. Geotextiles at the subgrade interface can provide a savings of about 2 ins. on the structural aggregate thickness, which many designers ignore in favor of a protected or prolonged service life (ESALs) of the geogrid reinforced aggregate base course.

Finally, the designer must decide how to maximize the benefits of incorporating geogrid reinforcement into the pavement structure. There are 3 simple options:

1.) Determine the reduced aggregate thickness with geogrid reinforcement (Eq-2) that provides the same SN (performance) as unreinforced pavement (Eq-1), and take the maximum benefit as reduced aggregate thickness (initial construction costs).
2.) Add geogrid to Eq-1 pavement structure improving only SN (performance), service life.
3.) Perform a breakeven analysis using in-place aggregate costs, to determine aggregate savings necessary to offset installed geogrid costs. Any aggregate thickness between breakeven thickness and option 1 provides both cost savings and improved service life.

TABLE 2.15 CORRELATION CHART FOR ESTIMATING SOIL STRENGTH VALUES



Approximate CBR	Identification Procedure
Less than 2	Easily penetrated with thumb
2-3	Moderate effort to penetrate with thumb
3-6	Indented by thumb
6-16	Indented by thumbnail
Over 16	Difficult to indent with thumbnail

Group Symbols	Soil Group Name
ML	Silt
MH	Micaceous silt
OL	Organic silt
CL	Silty clay
CH	High plastic clay
OH	Organic clay
PT	Peat and muck

Source: After Portland Cement Association and E. I. Du Pont Company.