Junction-strength requirements for roadway design, construction

By Barry R. Christopher

Introduction

Currently many engineers are confused about junction-strength requirements for geogrids used in roadway base reinforcement and subgrade stabilization applications, primarily because of commercialism of junction strength requirements. Some promotional efforts recommend relatively high junction strength, while others dismiss junction strength altogether.

Confusing?

At least one local public agency specifies a junction strength for one type of geogrid and states that it is not required for another type. Adding to the confusion are the methods of reporting junction strength.

Junction strength is usually defined in terms of the ultimate junction strength (i.e., the force required to rip the junction apart), as measured by the Geosynthetics Research Institute GRI GG2 procedure.

However, junction strength is also often reported in terms of force per width of the material, which is obtained by dividing the force applied to the junction by the nominal aperture opening,

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or efficiency, which is the ultimate junction strength divided by the strength of the rib.

Regardless of which definition is used, the specification of ultimate junction strength is applicable in relation to quality control and meeting minimum constructability requirements.

Pavement performance is evaluated based on serviceability (i.e., permanent deformation, a.k.a. rutting, over the life of the pavement) as opposed to a failure state and, correspondingly, the low-strain modulus of the geogrid is most important for reinforced base applications. Junctions are required to provide geogrid interaction at these low strains and, thus, junction stiffness or modulus is required for design.

The stiffness of the junction is related to the ability of the junction to transfer stress at low strains. However, the junction stiffness requirements have not been defined and a test method is not available that allows for an evaluation of junction stress-strain characteristics.

While the ultimate junction strength is not necessarily related to its junction stiffness, it is related to construction survivability (i.e., the ability to resist orthogonal ribs from being ripped off of the geogrid during construction). The key issue is: How strong

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Relatively low strength junctions are typically required to survive construction (GMA, 1998). In pavement test sections reported in the literature (e.g., see references reviewed in GMA, 1998 and Berg et.al., 2000), several of which have been observed by the authors, geogrid junction failure has not been reported during exhumation of the geogrid following traffic loading. However, there have been reports of junction failures during construction (although the conditions resulting in these problems have not been well documented) and it is still prudent to specify minimum construction survivability junction strength for quality control and to preclude junction failure during adverse construction conditions.

The correct technical approach is to base junction strength on: (1) Design requirements in terms of stiffness at working loads pertinent to the permanent strain levels expected in the reinforcement; (2) Construction requirements in terms of strength required to survive the anticipated construction conditions; and (3) Requirements that the rib transverse to the load is challenged through its junction strength.

This paper provides a review of technical literature to establish those requirements. Based on this review, recommendations

| Barry Christopher is an independent geotechnical engineering consultant specializing in reinforced soil and other ground improvement technologies. He has authored numerous technical papers including design manuals for the U.S. Federal Highway Administration (FHWA).

are provided to establish sound and reliable minimum requirements based on field trials and research, as outlined in the paper.

Junction strength for construction

Junction strength for roadway construction is essentially the minimum strength required to maintain the integrity of the geogrid during shipment and placement. During roadway construction operations, the geogrid experiences relatively high levels of localized load as aggregate material is placed, spread, and compacted on top of the reinforcement.

During placement, the aggregate pushes down on the geogrid (providing confinement) and out (developing interlock, which is key to its performance). Provided proper construction techniques are used, some level of aggregate cover will be maintained on the geogrid during construction, meaning the junctions of the geogrid are under a state of confinement due to the aggregate.

For construction, the junction strength specification is typically and appropriately based on the standard junction strength quality control test, Geosynthetics Research Institute GRI GG2. For example, the American Association of State and Transportation Officials (AASHTO) references this test in AASHTO 4E-SR "Standard of Practice Guidelines for Base Reinforcement."

The GRI-GG2 test procedure involves gripping the cross member of a geogrid rib on both sides of the junction with a clamping device and gripping the other end of the geogrid rib (i.e., in the principal loading direction) with another clamp. Load is applied to the two clamps until rupture of the junction occurs. Depending on how the gap between the clamps (i.e., over the junction) is machined, the junction may experience a restricted to small amount of out-of-plane rotation and peeling during loading.

Grab tests involving peeling of the junction (either by machine or hand) should not be performed, as these tests allow for unrestricted out-of-plane rotation without any constraint of the junction and, thus, do not represent conditions seen in the field. Recommended values for construction survivability based on performing tests using GRI-GG2 are reported in the literature. Based on a literature review of 19 geogrid studies involving installation survivability, the Geosynthetic Materials Association (GMA) recommends a minimum junction value

of only 35N (8 lbs.) for construction, as obtained from the GRI-GG2 test (GMA White Paper 1).

Conversation with several state agencies indicated that they have increased this value to 110N (25 lbs.), based on their own experience with construction that was more aggressive than anticipated. Other state and local agencies have specified even higher values, on the order of 270N (60 lbs.) or more, based on specific products and reportedly due to junction problems with other products (albeit, with anecdotal background and no reported conditions, e.g., aggregate type, truck loading, lift thickness, subgrade strength, etc., that resulted in these problems).

Considering the number of agencies specifying a junction-strength requirement and the order of magnitude range of requirements specified, it would appear that an unbiased, minimum value (similar to construction requirements for geotextiles) should be established to assure that junctions are not ripped off during construction and for quality control.

A conservative value should be developed by the industry that will allow products to be used in any application without concern. On projects where construction is not anticipated to be severe, or on projects where field trials and monitoring can be performed, leeway should be given to using products with lower junction strengths, as is currently done for geotextiles in AASHTO M288-05 (AASHTO, 2005).

The junction integrity can, and should, be evaluated through installation damage assessment tests, using the procedure in ASTM D 5818 "Standard Practice for Obtaining Samples of Geosynthetics from a Test Section for Assessment of Installation Damage" and performed by an independent laboratory (as routinely performed for other geosynthetic reinforcement applications). Installation damage assessment tests are field trials conducted with simulated field conditions (e.g., granular base materials placed over the geogrid and trafficked by placement and compaction equipment).

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A concise sampling and testing regime is used to obtain reduction factors for design properties of interest (e.g., design strength and, in this case, junction strength and integrity). Both strength reduction factors and any junction failures that occur during the test should be reported, such that the design engineer can assess the suitability of the geogrid for the specific application conditions.

An alternative to relying on tests is to have the contractor construct a "test pad" to demonstrate that the placement technique does not damage the geosynthetics as recommended by the FHWA Geosynthetic Design and Construction Guidelines (Holtz et. al., 1998).

Junction strength design requirements

Junction requirements for actual performance of the geogrid in roadways are currently under evaluation by a number of researchers, and, as of today, standard requirements have not been clearly established (other than through product specific empirical based designs). During the operational life of the roadway, the geogrid experiences relatively small levels of dynamic load from traffic. These loads result in dynamic strains, which accumulate and thus result in a permanent strain in the geogrid with increasing traffic levels.

The accumulated in-service tensile strain in the geogrid has been measured in laboratory and full-scale model studies at a maximum of approximately 2% (Berg et.al., 2000), and is consistent with field measurements in roads. The strength of the reinforcement at 2% strain (i.e., the 2% secant modulus) is also often specified as a design strength value for the geogrid (Berg et.al., 2000 and AASHTO 4E). Therefore, Kupec et. al. (2004) argued that the strength at 2% strain should also be the basis for the junction strength.

Considering that the soil interaction with the junction results in the stress in the geogrid, this would appear to be a logical argument. But a standardized test to evaluate the junction modulus does not exist. The current junction-strength test (GRI GG2) does not provide a method to evaluate the stress-strain characteristics of a junction.

In addition, the conventional test does not provide confinement on the junction and, to the contrary, allows the junction to rotate and thus sets up a peeling type failure in biplanar products (e.g., woven and welded geogrids). In the application, the roadway layers (aggregate and asphalt concrete) above the geogrid provide a level of confinement to the geogrid junctions as these loads are applied and the failure is more of a shear mode.

Kupec et.al. (2004) modified the existing GRI GG2 test with a special set of clamps that did not allow rotation of the junction and compared the strength obtained at the failure of the junction to the strength at the 2% strain value in the geogrid. However, it could be argued

that the junction strength value should be based on junction strength required to achieve a 2% strain in the geogrid.

Indeed, if the junction must transfer the load to the geogrid, the junction strength at 2% strain may also be an appropriate value for design. This assumes that the junction is more flexible than the geogrid and, thus, eliminates the influence that the junction itself has on the strain in the geosynthetic. Therefore, the influence of the junction on the geogrid modulus should also be evaluated.

Optimally, a test should measure the strain in the junction and the rib, to obtain a 2% strain value resulting from both deformation of the junction and strain in the rib to which the stress is being transferred. Rotational stiffness is often quoted as a method to demonstrate the stiffness of the junction. While in-plane stiffness may be important, the test method does not provide a direct junction strength or modulus value.

A test is required that will evaluate the stress that can be transferred by the junction to the ribs in the geogrid at a design strain value (e.g., 2%). The test should simulate field conditions and either minimize out-of-plane rotation or even evaluate direct shear of the junction. To modify the existing junction strength tests or develop a new test, the in-soil performance of the junctions should be evaluated for direct comparison or even be directly used for the design value if correlations with a simple lab index test cannot be established.

A pullout test has been suggested as a method to simulate the ultimate shear that develops when a wheel pulls on the restraining geogrid (located adjacent to the wheel, Perkins et.al., 2004). By using the modified pullout procedure recommended by Perkins et.al.(2004) for pavement applications and instrument the geogrid to evaluate the characteristics of the junction, this method could be used to determine the in-soil response of the junction to in-plane loading and provide the basis for comparison with simplified lab tests. This procedure is currently under evaluation by ASTM Committee D35.

Recommendations

In the interim, the following approach is recommended:

1. Use a conservative minimum junction strength that should be established industry-wide through data from full-scale installation damage tests in accordance with ASTM D 5818 and documenting the integrity of junctions. For soft-soil applications, a minimum of 150mm (6 in.) of cover aggregate shall be placed over the geogrid and a loaded dump truck used to traverse the section a minimum number of passes to achieve 100mm (4 in.) of rutting. A photographic record of the geogrid after exhumation shall be provided, which clearly shows that junctions have not been displaced or otherwise damaged during the installation process. This information will allow the establishment of junction survivability requirements in the future for the range of geogrid materials. (This was essentially the method used to establish the minimum survivability requirements for geotextiles in AASHTO M288-05.

2. For empirical methods, junction strength is not related to design but only to the characteristics of the geogrid(s) used in the laboratory or field trials to establish the traffic benefit ratio. Alternatively, continue the proprietary practice based on field trials, experience and product-specific data.

3. For mechanistic-empirical design, see Perkins et. al. (2004) for a discussion of design input values and support research to calibrate these input requirements.

4. Continue to use geogrids with confidence that most any geogrid will provide some level of improved performance; albeit not necessarily the optimum.

But a standardized test to evaluate the junction modulus does not exist.

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