Geosynthetic Reinforced Soil Integrated Bridge System

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compacted and encapsulated with a geotextile fabric. It provides embedment and increases the bearing width and capacity of the GRS abutment. The abutment uses alternating layers of compacted fill and closely spaced geosynthetic reinforcement to provide support for the bridge. This is placed directly on the GRS abutment without a joint and without cast-in-place concrete. GRS is also used to construct the integrated approach to transition to the superstructure. This bridge system therefore alleviates the “bump at the bridge” problem caused by differential settlement between bridge abutments and approach roadways.

Background

Reinforced soil technology is not modern. The ancients used native material such as straw, tree branches, and plant material to reinforce the earth. The reinforcement provides tensile resistance to soil that is weak in tension, but relatively strong in compression and shear.

Modern reinforced soil technology has evolved into two primary methods for the stabilization of earth: Mechanically Stabilized Earth (MSE) and GRS. Today the predominant method of building reinforced soil is MSE. MSE technology has branched off into two primary pathways: proprietary structures built with metallic (inextensible) reinforcements and proprietary structures built with geosynthetic (extensible) reinforcements.

MSE structures built with inextensible reinforcement, such as discrete metallic strips or welded wire mats, have a unique combination of precast panels, reinforcement, and connection details. The vertical spacing of the reinforcement is typically about 30 inches, and the typical size of the precast panel is about 5 feet high by 5 to 10 feet wide.

MSE structures built with extensible reinforcement such as geosynthetics were introduced in the mid-1980’s. During this time, geogrids were used to reinforce or stabilize the fill behind structures constructed with concrete modular blocks. Today, these proprietary modular block structures are typically built with a unique combination of the block, geogrids, and connection details. The vertical spacing of the reinforcement is typically 24 inches.

The first documented use of alternating layers of geosynthetic and soil, referred to as GRS technology, was by the U.S. Forest Service in the 1970’s. The Forest Service used the technology to build logging roads on steep mountain terrain. These GRS structures utilized a wrapped face – the geosynthetic was wrapped up and around the face of the individual soil layers and anchored by the overburden of the subsequent layer of soil.

Later, the Colorado Department of transportation
CDOT developed a low-cost generic wall system using lightweight concrete blocks. Rather than securing the blocks to the reinforcement with connections, as in MSE technology, the concrete facing blocks were frictionally connected to the GRS mass. The interface between the blocks and the geosynthetic provided enough friction to resist block movement. This method of connection in combination with closely spaced reinforcement layers created a facing system that adjusts to relieve stress without transferring loads to the facing. The Federal Highway Administration (FHWA) refined the CDOT method to account for vertical load-bearing applications, resulting in the development of GRS abutment, followed by GRS-IBS (see figure 1). GRS-IBS was initially developed by FHWA during the Bridge of the Future initiative to help meet the demand for the next generation of small, single span bridges in the United States. GRS-IBS can be built with lower cost, faster construction and potential improved durability and can be used to build bridges on all types of roads, on or off the National Highway System. GRS-IBS was recently used to rebuild a bridge in North Haven, Maine. This is believed to be the first use of GRS-IBS in New England.

**COMPOSITE BEHAVIOR**

**Reinforcement Spacing**

GRS abutments built with a reinforcement spacing less than or equal to 12 inches behave as a composite mass with predictable behavior. A degree of composite behavior results from close reinforcement spacing. For larger-spaced reinforced soils systems, the composite behavior diminishes with increased reinforcement spacing. It is important to note that the transition into GRS behavior is not dependent solely on reinforcement spacing; the aggregate size and friction angle are also contributing factors.

Closer reinforcement spacing creates more soil-geosynthetic interaction. In GRS, the reinforcement not only serves to resist tensile forces but also functions to restrain lateral deformation of the soil, increase lateral confinement of the soil, generate apparent cohesion in a granular soil (while maintaining all desirable characteristics of granular soil), enhance compaction-induced stresses, increase ductility of the soil mass, and reduce migration of fines, depending on the reinforcement selected. These added benefits develop because of the close reinforcement spacing.

The closeness of reinforcement spacing in GRS allows for compaction of the soil directly behind the facing, producing the capacity for load bearing at this location. The spacing of the reinforcement also has a significant impact on the strength and behavior of GRS performance. The ultimate capacity of GRS is a function of the reinforcement spacing, the reinforcement strength, and the soil conditions, including maximum particle size and friction angle. The ultimate capacity of GRS is influenced more by the reinforcement spacing than by the reinforcement strength.

**Reinforcement Strength**

In addition to calculating the required reinforcement strength, a factor of safety (or reduction factor) is necessary to reduce the ultimate strength of the reinforcement used in design. Because a GRS structure is a composite mass, the use of cumulative reduction factors for the long-term strength of the reinforcement is unnecessary. A single factor of safety of 3.5 (or resistance factor of 0.4) for ultimate reinforcement should be used, which accounts for long-term degradation (creep, durability, and installation damage). This recommended value is derived from the cumulative long-term reduction factors for a GRS mass in conjunction with an overall uncertainty factor of 2.0. This factor of safety is based on the results of several tests conducted on different reinforcement materials within soil, including accelerated creep tests.

Note that creep deformation of a GRS wall is the result of soil-geosynthetic interaction. If the backfill has a tendency to creep faster than the geosynthetic
reinforcement, the creep rate of the geosynthetic reinforcement will accelerate. Conversely, if the backfill has a tendency to creep slower than the geosynthetic reinforcement, the creep rate of the geosynthetic reinforcement will become smaller. For a GRS wall with a well-compacted granular backfill, the time-dependent deformation will be very small, and the rate of deformation will typically decrease rapidly with time (the geosynthetic cannot creep by itself). This means that creep will cease soon after construction. Moreover, the tensile forces induced in geosynthetic reinforcement at working stresses are typically very small due to stress redistribution. The very small tensile forces also contribute to very small creep deformation. GRS tests have shown that the soil and reinforcement strain together because the lower spacing confines the soil.

For granular fill, damage to the reinforcement is usually not a concern. If large aggregate particles (greater than 3 inches in diameter) are used, however, considerable damage to the reinforcement may occur. This would require reevaluation of the combined effects and may necessitate the use of a heavier reinforcement with a greater tensile strength.

**Reinforcement Length**

The base-to-height ratio can be reduced to as low as 0.3 as long as external stability is satisfied. This is because a GRS mass is freestanding and internally stable. Internally supported systems stabilize a soil mass by the inclusion of the reinforcement alone.

The facing elements of a GRS abutment are not required for structural support and do not carry any appreciable load. GRS facing blocks are primarily a construction aid to provide a form for each lift of compacted fill, a protective barrier, and a façade for aesthetic purposes. To ensure that the face is not loaded the superstructure is placed with a setback and clear space.

**Conclusion**

Geosynthetic Reinforced Soil (GRS) technology consists of closely-spaced layers of geosynthetic reinforcement and compacted granular fill material. GRS has been used for a variety of earthwork applications since the U.S. Forest Service first used it to build walls for roads in steep mountain terrain in the 1970’s. Since then, the technology has evolved into the GRS Integrated Bridge System (IBS), a fast, cost-effective method of bridge support that blends the roadway into the superstructure. GRS-IBS includes a reinforced soil foundation, a GRS abutment, and a GRS integrated approach. The application of IBS has several advantages. The system is easy to design and economically construct. It can be built in variable weather conditions with readily available labor, materials, and equipment and can be easily be modified in the field. This method has significant value when employed for small, single span structures.