GRS-IBS Definition and History

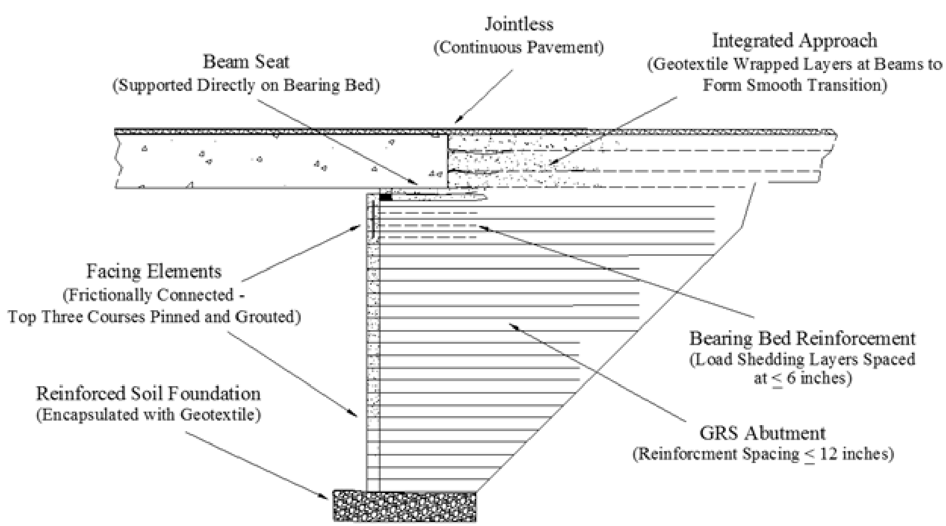
The Geosynthetic Reinforced Soil–Integrated Bridge System (GRS–IBS) is an innovation to help reduce bridge construction time and cost. The GRS acronym represents alternating layers of compacted granular fill and layers of geosynthetic reinforcement to provide support for the bridge. IBS stands for the fast, cost-effective method of bridge support that blends the roadway into the superstructure.

Although this type of methodology may be new to the bridge construction industry, it is not new to reinforced earth. Reinforced earth was used when creating the Great Wall of China as a double-sided retaining wall while reinforcing the soil with Tamarisk branches. Using this old technology with new materials allows us to create the most efficient designs available.

Soil reinforcement didn't become widely accepted for years later when Mechanically Stabilized Earth (MSE) structures used steel straps and a facing to hold back the earth in the 1960s. These structures are often referred to as tie back structures because they are doing just that, tying back the retaining wall face. In the 1970s, the US Forestry Service began using geotextiles for wrapped face walls which are still used today. In the 1980s, the Colorado Department of Transportation (DOT) began using modular block retaining walls which frictionally connected concrete blocks as the facing to a geogrid reinforced soil structure. The Federal Highway Administration (FHWA) refined what the Colorado DOT method had begun with load bearing applications. Through the 1990s and 2000s, the FHWA continuously tested the methodology in order to critique the content and get the most useful and relevant information to the industry. That testing is still used today as GRS-IBS application become more prevalent. Currently there are hundreds of GRS-IBS bridges in service across North America.

Design

The GRS-IBS technology consists of three components: the reinforced soil foundation, the abutment, and the integrated approach. Through lab and field performance, there are design considerations that need to be considered. One of those is the height of the abutment, however, according to the FHWA, the



Allan Block Corporation 7424 W. 78th St. Bloomington, MN 55439

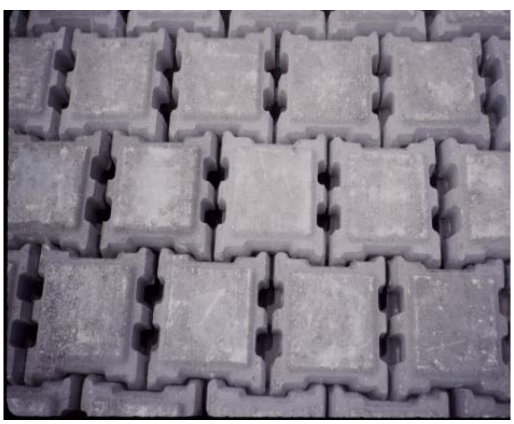
Phone: (952) 835-5309 Fax: (952) 835-0013

height limitation is based on the tallest GRS abutment to date. With the segmental retaining wall (SRW) industry dating back to the mid-1980s, the industry knows that Geosynthetic Reinforced Soil structures can exceed 30 ft (9 m) when designed properly.

With a clear majority of the bridges around the country being single span structures, the GRS-IBS methodology has centered in on these types of bridges initially. Although the methodology and testing has shown it is possible to use a Geosynthetic Reinforced Soil pier to provide intermediate support for multiple span bridges, this type of structure isn't promoted in the initial push by the FHWA.

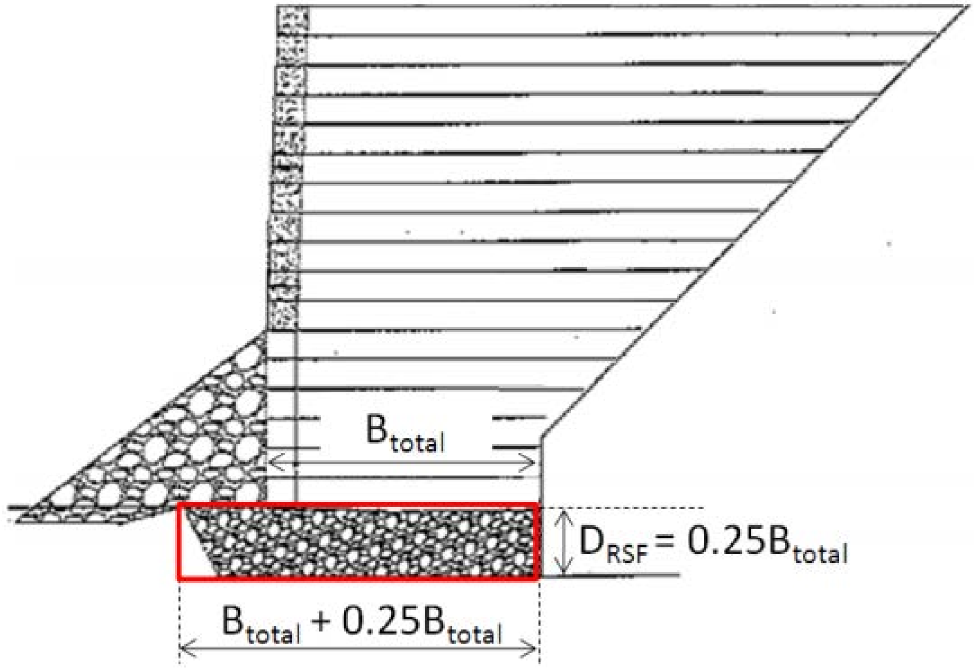
Most bridges are in place or require to be placed due to a grade change with most due to a water crossing. With any kind of water crossing, scour protection is another design consideration that cannot be overlooked.

Scour is an engineer calculation that is required in all cases due to water crossings during flood events. In most of these flood events, there will be moving water that will meet the bridge abutment. A design counter measure such as rip rap in front of the abutment is used to prevent the undermining of the abutment and will be a main consideration during the design phase. An alternative option to rip rap is using Articulated Concrete Blocks (ACBs). An ACB is a mat that uses either open celled or closed cell blocks that are bound together with a high strength steel cable. They are placed upstream or around the abutment to reduce the amount of scour that takes place at the base of the abutment.



The foundation is a granular fill encapsulated in geotextile. This is to provide the footprint on the foundation soils and may require the size to be increased depending on the site soils. The designer will need to check the bearing capacity of the system to meet or exceed the required load. The design stage for the foundation and the depth of the abutment coincide and may take an iterative approach due to the abutment width requiring to be the minimum geotextile depth and an additional 25% of that same minimum. That additional 25% is the distance in front of the abutment facing to stabilize the abutment facing.

Since the GRS abutments are flexible structures, there is no requirement for frost depth. The abutment allows small movements due to frost heave which are not transferred to the bridge structure above. The FHWA recommends if frost does need to be accounted for, to excavate to the frost depth and use the geosynthetic reinforced foundation and non-frost susceptible soils to fill in the excavation to the bottom of the wall. They do not require or recommend the wall facing to be buried to the full frost depth.

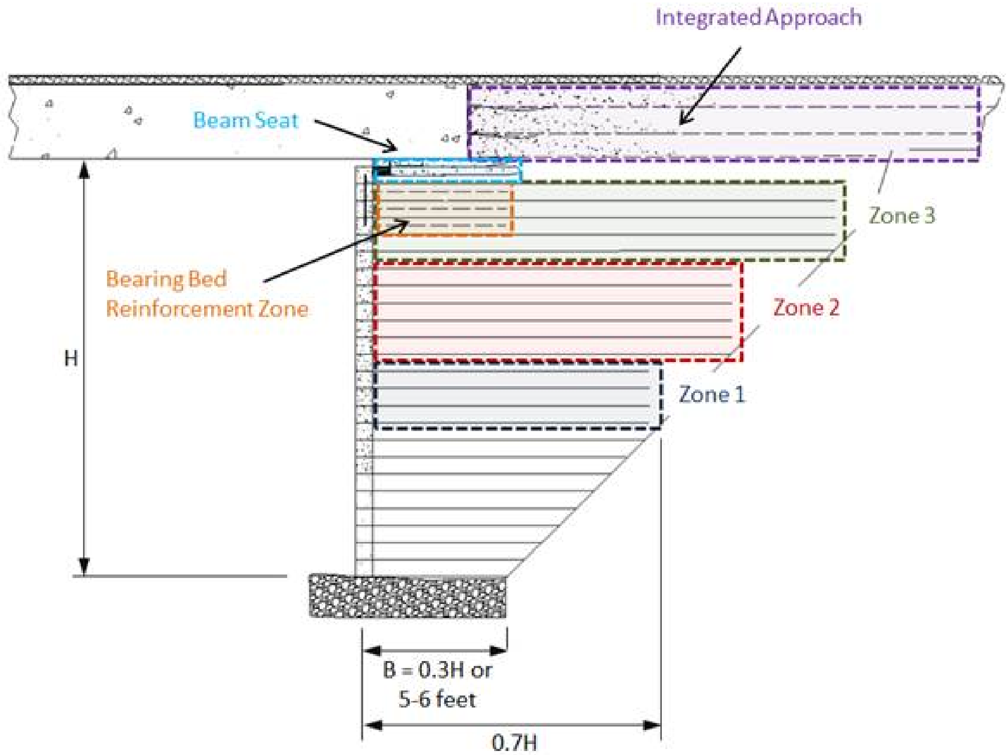


As the foundation is completed and encased within geotextile, the abutment design can begin. The FHWA recommends that the starting reinforcement depth is greater than 30% of the structure height or a minimum of 5 ft (1.5 m) span length for structures under 25 ft (7.5 m) in height. If the span is greater than 25 ft (7.5 m), then a required minimum of 6 ft (1.8 m) is used in the design. The depth of reinforcement used in the abutment is based on the site soils and vertical load to resist the required sliding, global, and internal stability calculations. The depth of the reinforcement may require multiple iterations to establish the final design depth. Once this first depth of reinforcement is established, a cut into the embankment is required at a 1:1 slope per OSHA requirements. In some cases, this may be steeper than 1:1. Many GRS-IBS applications have the geotextile follow the sloped cut, but this is left up to the designer to meet or exceed their calculations.

The superstructure will sit on the reinforced soil and that area is referred to as the bearing reinforced zone. The height of this zone is determined by the designing engineer's internal calculations to resist the superstructure load at the top of the abutment. The number of intermediate spaced layers of geotextile should not be less than 3 layers per FHWA recommendations. In this area, the spacing of geotextile is reduced to half the primary spacing which aids in distributing the load to the GRS structure.

Before the GRS structure is finalized, the bridge seat and approach needs to be considered. Whether the structure is to be built out of timber, steel, or concrete, the designing engineer needs to account for the length of the superstructure. To determine the overall length, they must consider the required clear distance between abutment faces, the batter of the abutment, and the required seat depth. The depth of the bridge seat is dependent on the span from abutment to abutment so they coincide in determining the final length as it is illustrated within the GRS-IBS Interim Implementation Guide by the FHWA.

The approach continues by placing geotextile layers to the height of the subbase for the roadway overlay. The length of this geotextile will become longer at the top to bridge the gap from the unreinforced soil outside to the GRS structure itself. By continuing the reinforcement layers into the integration zone, it creates a smooth transition from the unreinforced area of the road to the GRS abutment. The maximum vertical spacing of the integrated zone is 12 in. (300 mm) but typically an even increment less than 12 in. (300 mm) based on the height of the top of the abutment face to the roadway elevation.



For more complete design information, the FHWA provides additional resources and example calculations to aid in the design.

Construction

Once the GRS-IBS has been designed, the design information can now be given to the contractor for installation. An advantage that a GRS-IBS project has over traditional bridge construction is that the crew can typically be made up of 4-5 members with only 1 equipment operator and 4 laborers depending on experience. This crew doesn't require special training and a reason why the SRW contractors have provided the level of experience that most projects are looking for. There isn't a need for pile driving equipment or other specialized equipment since the abutment can be constructed with a single excavator.

The first step is to excavate the area which may require full or partial removal of existing bridge structures. Since many of these structures are placed on existing sites, portions of the existing bridge can be kept in place to reduce the design considerations illustrated above, such as scour. To fully excavate the site, this may require routing the current stream through a culvert to dewater the area for foundation prep. The final subgrade should be excavated to the required design depth so that it is smooth without protruding objects.

This is because the entire foundation will be wrapped in geotextile to keep migration of soils into the mass or vice versa.

The material used in the foundation can be open graded or well graded material and is typically regionally dependent. This material will need to be placed in 6 in. lifts (150 mm) and compacted to create a stable platform to begin construction. Within the Reinforced Soil Foundation (RSF) are layers of geotextile spaced no further than 12 in. (300 mm) vertically. Upon reaching the designed height of the RSF, the geotextile reinforcement that encases the foundation should be wrapped with a minimum of 3 ft (0.9 m) of overlap to keep water from infiltrating the RSF. That wrap should also be done by folding the overlapped geotextile in a shingled manor to keep the flow from rolling the flap onto itself and allowing water to infiltrate the mass.

Now that the foundation is completed, the first course of block is placed directly on the foundation to begin the abutment construction. For future inspection of the structure, use a different colored block for the portion of the abutment that should remain below grade.

When the FHWA began the GRS-IBS initiative, Concrete Masonry Units (CMUs) were used due to the market outreach of those systems and the cost-effective solution. For the first decade, most of the applications have used a CMU for this very reason. Since CMUs are hollow with only a web thickness of just over an inch, the FHWA required that the bottom of the bridge abutment be constructed with solid CMUs instead. This was one of the first benefits of using a SRW instead of a CMU since the face thickness of an Allan Block is closer to 4 in. (100 mm).

Since CMUs are used typically with rebar and mortar and the GRS-IBS abutments are built using mortarless technology, SRWs have been able to shine as a product that is easy to install, have much higher levels of quality control, and have trained contractors established around the world. Segmental retaining wall units also have an interlocking mechanism, like the lip/notch of an Allan Block, which takes the guessing out of installation. The contractor simply stacks the blocks and pulls the units forward to engage the lip of the block. The FHWA uses the Best Practices for SRWs in order to outline the durability requirements in all areas of the US. ASTM C1372 outlines the requirements for SRWs and provides minimum standards for dimensional tolerances. There is no mortar being placed between the blocks when constructing GRS-IBS structures. Therefore, the blocks need to have strict dimensional tolerances so they stack up and install evenly.

ASTM C-90 (Strength and Absorption Requirements of CMU)

Compressive Strength,[A] min, psi (MPa)		Water Absorption, max, lb/ft^3 (kg/m^3) (Average of 3 Units)		
Average Net Area		Weight Classification—Oven-Dry Weight of Concrete, lb/ft^3(kg/m^3)		
Average of 3 Units	Individual Unit	Lightweight, less than 105 (1680)	Medium Weight, 105 to less than 125 (1680–2000)	Normal Weight, 125 (2000) or more
1900 (13.1)	1700 (11.7)	18 (288)	15 (240)	13 (208)

[A] Higher compressive strengths may be specified where required by design. Consult with local suppliers to determine availability of units of higher compressive strength.

ASTM C-1372 (Strength, Absorption, and Density Requirements of SRW)

Density Classification	Oven-Dry Density of Concrete lb/ft^3(kg/m^3)	Maximum Water Absorption lb/ft^3(kg/m^3)		Minimum Net A Compressive St lb/in.^{2}(MPa
	Average of Three Units	Average of Three Units	Individual Units	Average of Three Units
Lightweight	Less than 105 (1680)	18 (288)	20 (320)	3000 (20.7)
Medium Weight	105 to less than 125 (1680 to 2000)	15 (240)	17 (272)	3000 (20.7)
Normal Weight	125 (2000) or more	13 (208)	15 (240)	3000 (20.7)

[A] Consult manufacturers for available densities.

With the first course of block installed, backfilling is the next step in proper construction. Heavy compaction equipment such as large rollers are required to remain 3 ft (0.9 m) behind the wall facing which aids in keeping the facing in the designed batter. Only hand operated compaction equipment is used within the first 3 ft (0.9 m) of the abutment facing for the full height of the structure.

The abutment soils must be placed and compacted with geosynthetic not spaced more than 12 in. (300 mm) between layers. Compaction lifts cannot be greater than 8 in. (200 mm) during the placement of the fill and will need to meet the required density chosen by the designing engineer.

Now that the soil is compacted, placement of the geotextile can be placed on top of the first course of block and extending to the design depth. The geotextile should be placed so that the strongest direction is perpendicular to the abutment face and should remain flat with no wrinkles in the material. Abutment construction repeats as necessary until transitioning from the depth below grade to above grade when the selected block color is used.

Another benefit of using an SRW for the constructability is the ability for a block such as an Allan Block to perform a 90-degree corner. SRWs manufacture a corner block to be used in these areas which reduces the need to cut blocks and offsets vertical lines in the abutment. As the construction of these systems evolved, Hamilton County in Indiana transitioned from using Allan Block for the corners to curved abutments. This simple transition was estimated by the contractor to have saved 1 day of construction which amounted in cost savings for the project and increases the aesthetic of the abutment.

As the abutment is constructed to the point of the bearing reinforced zone, the construction tolerances change by including twice as much geotextile layers to support the load above. In this area, the contractor must only use walk behind compaction equipment for the full length of the bearing reinforced zone to mitigate the installation damage to the geotextile. When the bearing reinforced zone is completed, the top of wall will need to be prepped for installation of the superstructure.

The superstructure is not placed directly on the block. Instead, an area is constructed to rest the superstructure on the bearing reinforced zone which is called the beam seat. The first step is to place a 4 in. (100 mm) thick foam board on top of the bearing reinforced zone. This foam board should butt directly behind the top course of block. A 4 in. (100 mm) solid concrete block is placed on top of the foam board for the entire length of the bridge seat. Geotextile is used as a "burrito" wrap to create the first 4 in. (100 mm) compacted fill to the top of the foam board. A second wrapped layer is then placed to the top of the 4 in. (100 mm) solid block which concludes the bridge seat construction.

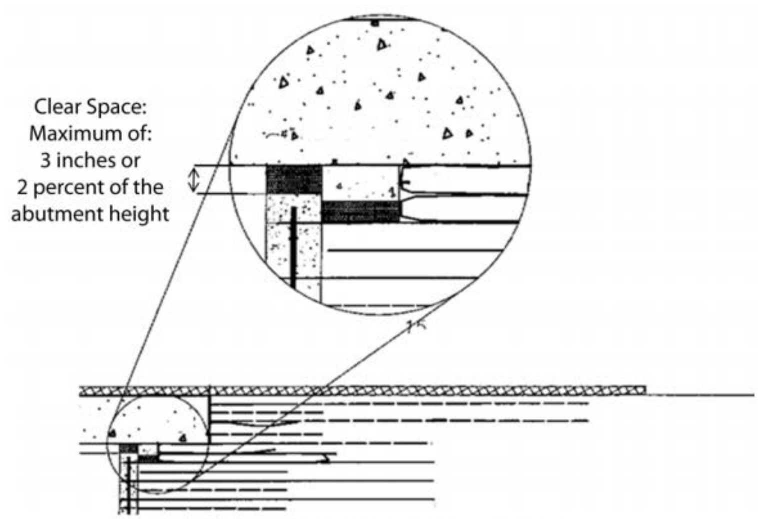


Figure 11. Illustration. Clear space distance.

Depending on the span and design of the IBS, the superstructure can be placed using a crane for prefabricated pieces, or formed up to be poured on site. Whichever route is chosen for this phase of the project, the geotextile should be taken care of to mitigate any additional installation damage during placement.

Now that the superstructure has been placed, the approach is the next step. Immediately behind the end of the beam will be a geotextile wrap which will span the entire width of the beam seat and to the designed length. The fabric is prepped and placed so that 6 in. (150 mm) of fill can be placed and compacted before folding back the layer of geotextile to encase the 6 in. (150 mm) of granular material. The approach will use the same procedure to construct the entire area to a height of 2 in. (50 mm) below the top of the beam. These 2 in. (50 mm) of backfill material provides enough spacing for the hot mix asphalt to not damage the geotextile.

As stated previously, these bridge structures have been designed and installed since 2005, but every aspect of the design and construction provides a cost savings to the owner over traditional bridge designs. Some of those advantages are:

Advantages

- Accelerated construction. GRS-IBS bridges can be built in weeks rather than months due to the simple machinery and tools.
- Reduced cost. GRS-IBS have saved up to 60 percent in cost compared to a standard DOT bridge, and the system potentially requires less or simpler life-cycle maintenance.
- Flexible design. GRS-IBS bridges employ a simple design that can be adapted to suit environmental or other needs, and the design can be easily modified in the field to adjust to unexpected site conditions.
- Construction is less dependent on weather conditions.
- QA/QC Advantages by using Allan Block which meets local and regional requirements.
- Non-specialized labor.
- No deep foundation, no approach slab, no sleeper slab, no parapets/CIP walls, no bridge bearings, and no expansion joints.
- Eliminates the “bump” when transitioning to the bridge structure.

Benefits of eliminating the bump at the bridge

- Decreases the impact loads the bump normally causes, reducing structure and vehicle maintenance.
- Improves safety for the traveling public by minimizing the potential for vehicles to lose control.
- Reduces the cost of re-leveling the transition from the bridge to the roadway.
- Eliminates the need for additional lane closures to repair the bump, decreasing exposure of workers to traffic.

Although this list may not show every benefit of GRS-IBS, it does give a quick snapshot of how these opportunities can keep projects on track and within budget. As our country continues to have an aging infrastructure and limited budgets/funding, these types of systems can easily become a solution for a majority of deteriorating bridges or new construction.

Resources

https://www.fhwa.dot.gov/innovation/everydaycounts/edc-3/grs-ibs.cfm

Geosynthetic Reinforced Soil Integrated Bridge System Interim Implementation Guide Publication No. FHWA-HRT-17-080

Allan Block Corporation 7424 W. 78th St. Bloomington, MN 55439

Phone: (952) 835-5309   Fax: (952) 835-0013