A SunCam online continuing education course

Accelerated Bridge Program

Intro to GRS-IBS Abutment Construction

by

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Introduction

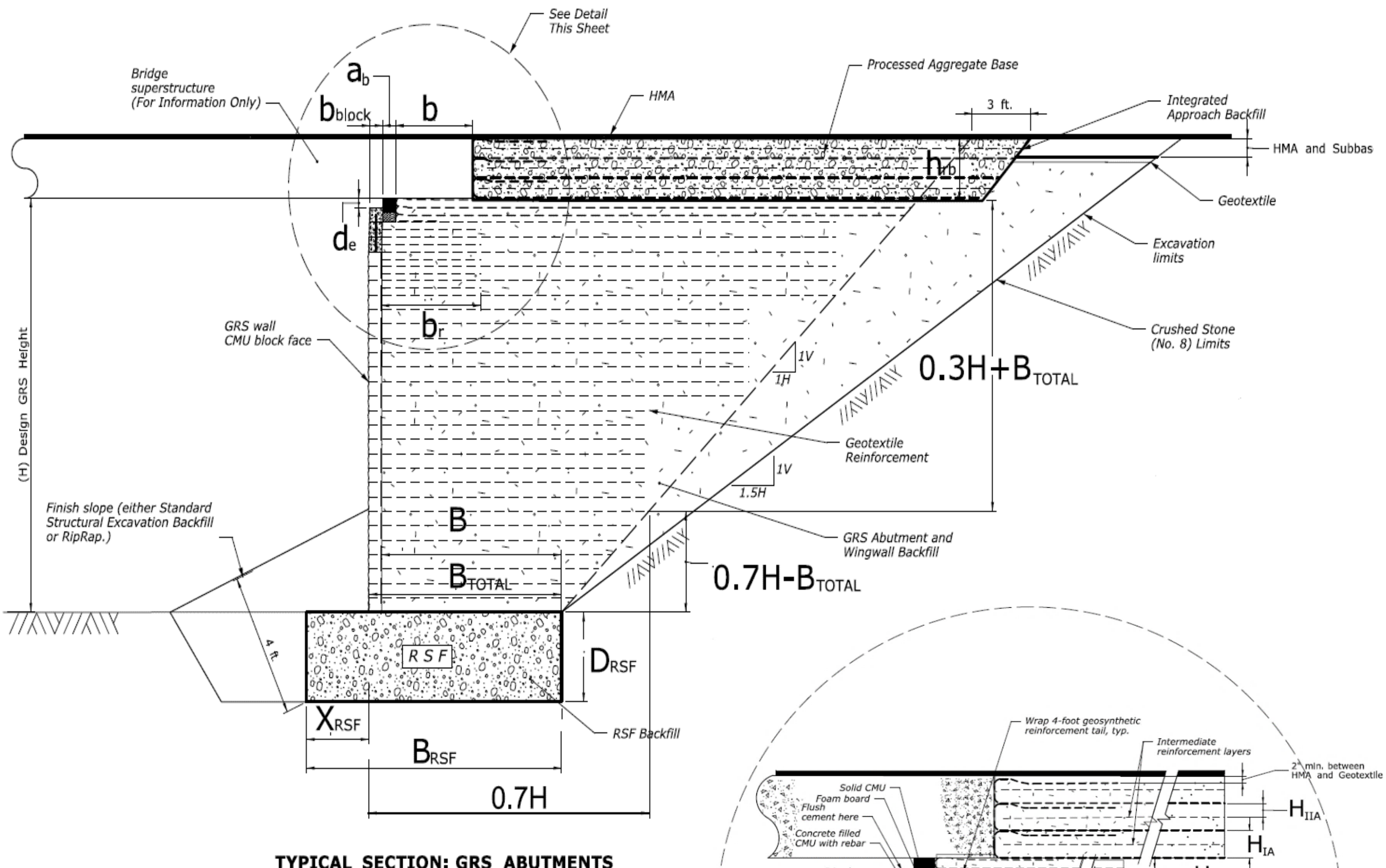
In order to meet the needs of the nation's failing infrastructure, many State Department of Transportations are instituting an accelerated bridge construction program. These programs require corrections to existing bridges in a shortened time frame with as little inconvenience to the traveling public as possible. Massachusetts Department of Transportation's Fast 14 is a great example of an accelerated bridge program that constructed 14 bridge replacements in 10 weekends of a single summer construction season. To shorten the construction time frame associated with traditional cast-in-place substructures, projects have begun utilizing Geosynthetic Reinforced Soil – Integrated Bridge Systems or GRS-IBS for short. These types of bridge substructures offer many benefits to owners like reduced costs, reduced construction time, reduced environmental impacts, and reduced maintenance of traffic. These benefits can be achieved while utilizing local labor and materials, and better means of quality control. These bridges can accommodate highways, railways, and rapid transit, in both urban and rural environments. They can be straight or curved alignments and can span difficult obstructions and terrain. However, to maximize the efficiency they are typically used for regular shaped, simple span bridges of short to medium length.

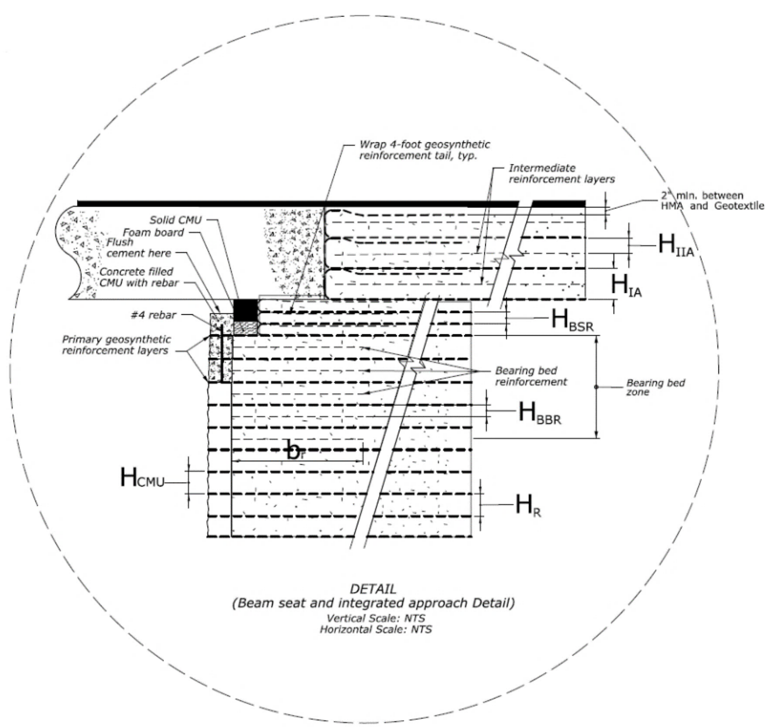
The GRS-IBS bridge substructures are versatile and perform well in almost any new bridge construction application and they are extremely adaptable to single-stage and multi-phase bridge reconstruction projects. The course will be broken down into three basic sections: GRS-IBS Materials, Construction Process, and Equipment.

DEFINITIONS

CMU: Concrete Masonry Units, Hollow-core Concrete Blocks used for the wall facing as detailed by the designer. May be wet cast or dry cast depending on owner specifications.
CMU Height: The bottom to top vertical dimension of the CMU Face.
CMU Width: The center to center horizontal dimension of the CMU Face.
CMU Thickness: The front to back perpendicular horizontal dimension of the CMU block, approximated for architectural irregular faced units.
CMU Abutment and Wingwall Wall Face: The portion of the GRS-IBS that comprises the CMU wall face.
Bearing Bed Reinforcement Zone: The portion of the system that is directly below the bridge superstructure or distribution slab (if one is required).
Reinforced Integrated Approach: The portion of the system that is placed under the roadway approach pavement behind the rear face of the superstructure and distribution slab (if one is required).
GRS Abutment and Wingwall: The portion of the system that makes up the reinforced soil portion of the system, including the CMU, crushed stone, any cast-in-place concrete, and the geotextile.
GRS Foundation: The portion of the system that is below the reinforced soil portion of the GRS Abutment. It is a foundation to properly seat the GRS-IBS on the existing soils.
Coping: A cast-in-place (CIP) concrete cap which tops the uppermost CMU course providing an architectural finish and structural protection for the uppermost wall section.

Geosynthetic Reinforced Soil – Integrated Bridge Systems





The basic building blocks for the GRS-IBS System is the geosynthetic reinforcing material, the aggregate backfill material, and the CMU block wall units. The materials are typically packaged in small lightweight bundles so they can be installed by hand or with light equipment.
Structural Concrete and Reinforcing Steel are used for cast-in-place elements

Geosynthetic Material –

Woven biaxial geotextile fabric with specified tensile strength and puncture/tear resistance used to reinforce the backfill material and distribute the bridge loading. The material used is a biaxial, polypropylene geotextile. The Geotextile requires a minimum ultimate tensile strength of 4,800 lbs/ft and the reinforcement strength shall be greater than 960 lbs/ft at 2% strain in both the cross-machine and machine directions. Tests shall be performed in compliance with ASTM 4595-11 or ASTM D 6637-11.

Delivered in rolls of standard length and width, wrapped in UV protective plastic. When ordering the quantity add a waste factor for overlap splicing of the RSF (Reinforced Soil Foundation) layers and for unusable lengths at the end of a roll. At delivery, the geosynthetic reinforcement Manufacturer will provide a quality control certificate. This should include each roll number and identification, sampling procedures, and results of control testing (including a description of test methods used). The manufacturer is responsible for establishing, maintaining, and documenting their quality control (QC) program and the certificates are provided to ensure compliance. Sampling and materials acceptance testing shall comply with ASTM D-4354, or as specified. Geotextile product acceptance shall be per ASTM D-4759.

Aggregate Backfill Material –

Aggregate backfill for the Reinforced Soil Foundation (RSF) and the Geosynthetic Reinforced Soil (GRS) should be clean ½” or 3/8” crushed stone aggregate of the AASHTO #67 or #8 stone gradation. Aggregate backfill for the Reinforced Integrated Approach System portion of the (IBS) should be a crushed stone processed aggregate base. Properties will be specified for LA Abrasion, Hardness, Fractured Face, Angularity, and Bulk Unit Weight. The aggregate material must be kept clean and uniform. Any contamination or segregation of the aggregate can be cause for rejection and rework.

CMU Block Wall Units-

Concrete Masonry Units (CMU's) are uniform in size and shape, with hollow cells and match cast faces to help with alignment and interlock. Units may have architectural coloring and/or texture. The Engineer will specify concrete strength, architectural, and durability properties. Typically, the CMU shall have a minimum 28-Day compressive strength of 4000 psi and shall have 4% to 7% air-entraining. They shall be cast from concrete comprising Portland cement, fine and coarse aggregates, admixtures, and water. Cinder Blocks and Clay Brick are unacceptable for CMU material.

Prior to the start of construction:

SHOP DRAWINGS:

The first drawing should detail general construction notes, design assumptions, tolerances, and staged construction.

Elevation View: The Elevation view drawing should provide critical dimensions for the wall construction, wall lengths, heights, elevations, thickness of layers (ie. the reinforced soil foundation), and locations for specific call-out items like utilities, steps in foundations, changes in grade for the wingwall or bridge seat slopes, etc…. It is also helpful for the plan view to show the individual CMU courses as a visual aid, but this may give a cluttered look to the drawings utilizing a small scale.

Plan View: The Plan view drawing should also provide critical dimensions like wall length, should show the stations and offsets, survey coordinates for critical points on the wall, angles for corners and alignment to baseline, and widths of wall portions (ie. the reinforced soil foundation). Similar to the elevation view, specific call-out items for utilities and other roadside development items.

Cross-Section View: A Cross-Section view should be provided for each major section of the wall. Wingwall sections, Regular wall sections, and Bridge seat sections may have different requirements for detailing. Each section should show the limits of excavation and backfill, the reinforced fabric lengths, the component heights and widths, and any specific call-out items like cast-in-place coping locations.

A table of reinforced geotextile lengths should be provided correlating each fabric layer with a CMU course. It is helpful to have this table detailed alongside its corresponding cross-section view.

Lastly, Individual details should be provided for corner treatments, bearing bed and integrated soil approach sections, cast-in-place concrete details for coping or slope capping, control and expansion joints, and architectural treatments.

SAMPLES, CERTIFICATIONS & PRODUCT DATA: Samples of CMU's, especially if architectural specifications are given, should be given to the owner for evaluation of each size and type required. For architectural walls, a mock-up of the wall face may be required. Product data and materials certifications for the geosynthetic material and the aggregate base should be provided to ensure compliance with contract requirements.

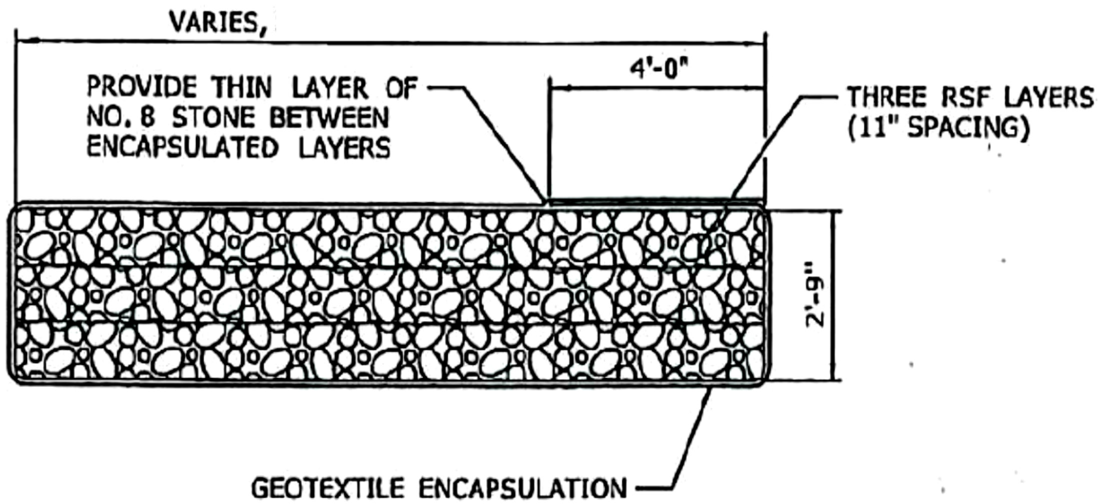
PRE-INSTALLATION FIELD MEETING: Prior to construction, a pre-installation meeting should be scheduled. Suggested attendants include: General Contractor field management – Project Manager, Superintendent, Project Engineer, and Quality Control, also if self-performing, Foremen, Lead personnel, and Surveyor or Subcontractor Critical personnel if not self-performing. Representatives from the GRS-IBS materials supplier and their engineer. Owner's field management, inspectors, and Quality Assurance Department. Project Design Team Lead Engineer, Geotechnical Engineer, and Structural Engineer, with Architect if necessary. Items to discuss include: Existing site conditions, schedule, communication, and responsibilities, as well as, specific details and construction requirements of the GRS-IBS components. This technology is relatively new, lessons learned discussions from the experts will help avoid typical errors made by inexperienced crews.

CONSTRUCTION METHODS

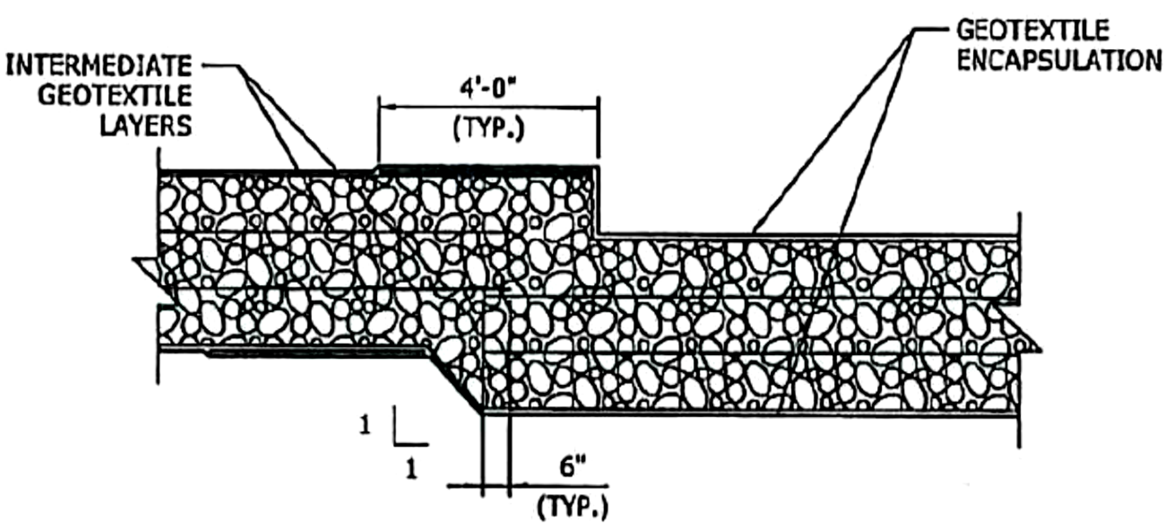
Excavation & Grading: During the excavation for the GRS-IBS substructure, the contractor shall be responsible for the global stability of all existing structures and may need temporary earth retaining systems. This is especially true for bridge reconstruction projects under live traffic. After excavating for the RSF, the grade shall be checked within survey tolerances. Soil bearing tests will be performed to confirm the existing soils are suitable and that settlement below the RSF will be negligible with no differential settlements.

GRS Foundation: The foundation of the GRS-IBS substructure is constructed from a layered aggregate pad, reinforced with geotextile fabric. This foundation is referred to as the Reinforced Soil Foundation (RSF). Typical to all foundations, its function is to distribute the bridge load from the substructure to the underlying; in-place or constructed, bridge embankment at the soil/bridge interface. The RSF consists of several layers (typically two to three) of open-graded aggregate fully wrapped with geotextile fabric and separated by the same fabric material. The geotextile must wrap the RSF fully encapsulating the aggregate material on all six sides in what's commonly referred to as the "burrito." The fabric shall be pulled taught and aggregate shall be placed carefully so there are no tears or wrinkles. Each lift of aggregate shall be uniformly placed, leveled, and compacted by a minimum of 4 passes with the approved mechanical compacting equipment. At geotextile splices, a minimum lap of 3 feet is needed to seal the RSF watertight. Excess geotextile in corners shall be trimmed as neat as possible and folded tightly similar to wrapping paper on a present. Any infiltration or contamination of the aggregate will compromise the RSF and will be a reason for rejection, rework, or if uncaught, possible failure.

Prior to final encapsulation, grade and level the top of the RSF aggregate. This will serve as the leveling pad for the CMU blocks of the GRS substructure. (see below details of RSF "burrito")



REINFORCED SOIL FOUNDATION (RSF)



GRS Abutment and Wingwalls: The reinforced backfill of the GRS-IBS abutment and wingwalls is constructed with layers of aggregate (open-graded self-compacting lifts of #8 or #67 stone for the soil mass area) and geotextile fabric. The engineer will design a lift thickness between each layer of fabric reinforcement which will typically align with the height of the chosen CMU block. Compaction equipment will be selected for the appropriate level of compaction, typically 4 passes of a vibratory roller are specified. To avoid damaging the blocks of the wall face, hand-operated compactors, such as plate tampers, are used within 3 feet of the CMU's. QC representatives will visually inspect the aggregate lift for any segregation or contamination of the material and for achieving a uniform the overall compaction for each lift prior to placing the reinforcing fabric cover.

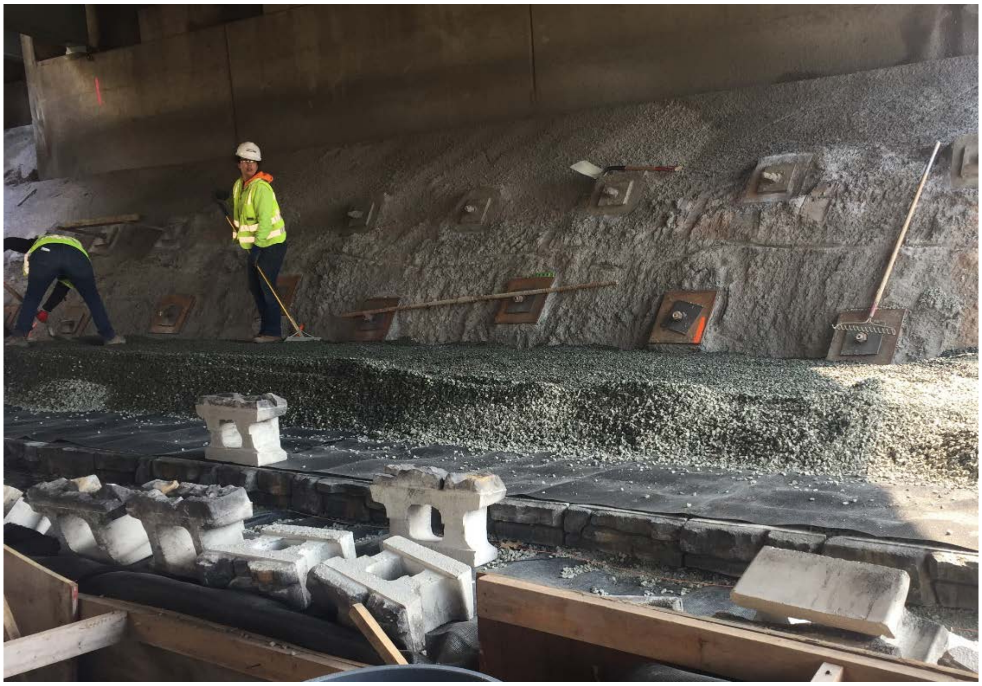
Geotextile step by step placement to cover an accepted lift of aggregate: Roll out and cut the geotextile fabric to the specified length. Starting at the CMU, place the fabric to cover 85% of the CMU block and stretch the full length of fabric to the back of the reinforced backfill limits, perpendicular to the wall face. Trim any excess material that may extend beyond the front face of the wall. Continue in this manner for the length of the wall. Adjacent sections of geotextile shall not be overlapped, trim materials to butt sections together wherever possible, even in wall corners. If layers must pass over each other, provide a minimum of 1 inch of backfill material between the layers.

Regardless, any overlap at the CMU must be trimmed to avoid varying fabric thickness under the blocks which will cause instability. Place aggregate backfill in a constant direction making sure not to shift the geotextile fabric and cause wrinkles or tears. Stagger seams by a minimum of 2 feet with each successive lift of aggregate/geotextile backfill.

The aggregate should be placed in one direction so the equipment used for delivery, spreading, and compacting can drive over the areas of geotextile that is already covered by a lift of stone. Equipment is not allowed to operate directly on the geotextile. Even while traversing on the stone, the operators should use their machines with care in order to avoid damage to the underlying fabric. Equipment shall move at speeds no greater than 5 miles per hour with no sudden braking or sharp turning.

Abutment and Wingwall CMU Wall Face: After completion in the RSF, the first course of CMU blocks shall be placed. Even though these blocks will probably be below finished grade and not visible in the final product, as with any masonry construction, care must be taken when setting the first course of block because any error will be carried through each successive course and can affect the wall structurally and aesthetically. This is especially true for GRS-IBS walls because the blocks are "dry-set" without a mortar separation. Surveyors should establish the exact line and grade on the RSF for setting the first course. If the RSF grade varies, up to ½" of stone dust may be spread across the surface as a leveling layer to compensate for the minor deviations. For larger gaps, a mortar or grout leveling bed shall be cast on top of the RSF prior to setting the first blocks. Imperfections in the casting of the CMU's can affect the line and grade of the wall. Trim off any "over-pour" grout or concrete from every block used in the wall to minimize this effect and it is recommended to select the most uniform units for this first course. Any overly misshapen blocks should be rejected or saved for corners or top row blocks if they can be cut to the correct shape.

If the RSF has steps, begin block placement at the lowest portion of the RSF and complete each level course entirely before proceeding to the next level. Place each successive block tightly against the preceding block without any gap. Due to casting irregularities, some blocks won't fit snugly together, swap positions for any large misfits so the running bond will be maintained. Check blocks with a stringline and level to ensure the placement is level and plumb and periodically have surveyors spot check the wall for trueness to plan position. Once the blocks are in place, fill the voids from the hollow core cells with aggregate and begin backfilling the reinforced aggregate per the previous section. Since the CMU's are dry-set, they can dislocate during the construction process. For the same reason, they can also be carefully moved back into tolerance without damage. Any damaged blocks are required to be removed and replaced.

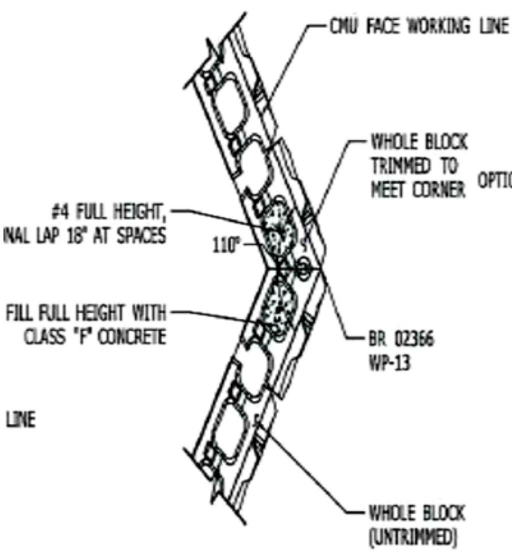



VOLVO

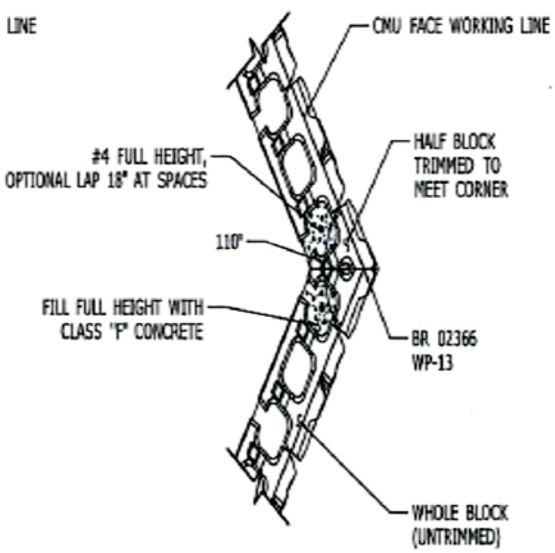

CAT

As the walls get taller, fall protection barricades and harness lines will be needed.

Coordinate the survey layout with the plan and profile shop drawings for the location of any wall corners. The shop drawings should include details of each corner specifying the miter angles needed to make the corners. A jig should be made for cutting each miter, so a tight and uniform vertical joint is constructed. If the wall is built with care, the corners can be pre-cut and available for placement ahead of time but remember every other course of block is staggered, so to maintain the running bond block placement, the location of the joint on the block will vary every other row. Concrete and reinforcing steel may be added to stabilize corners. (see below details for corner construction)



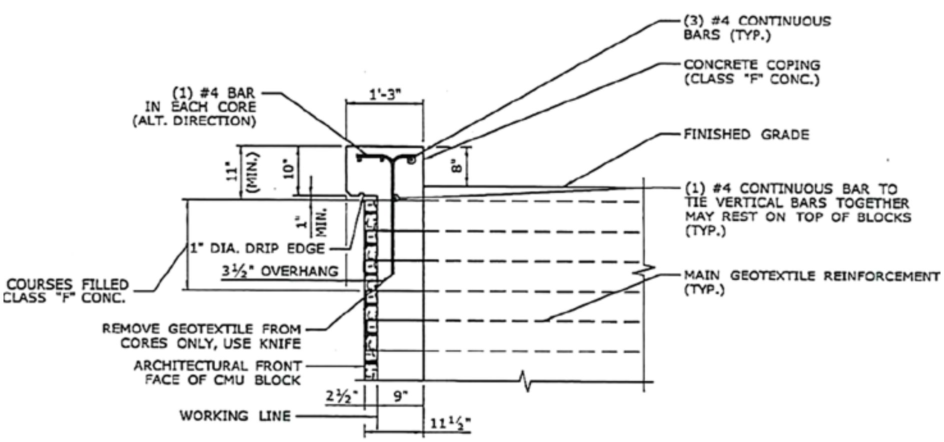
WW1B CORNER CMU COURSE 1
SCALE: 3/4" = 1'-0"



CORNER CMU COURSE 2
SCALE: 3/4" = 1'-0"

CONCRETE COPING NOTES:

1. CONCRETE COPING SHALL HAVE EXPANSION JOINTS AT INTERVALS NOT EXCEEEDING 90 FEET. CONCRETE COPING SHALL HAVE CONTRACTION JOINTS AT INTERVALS NOT EXCEEDING 30 FEET.
2. REINFORCEMENT IN CONCRETE COPING TO BE DISCONTINUOUS THROUGH VERTICAL CONTROL JOINTS, EXPANSION AND CONTRACTION JOINTS. REINFORCEMENT OVER CORNER COPING DETAILS (ANGLE POINT) SHALL BE CONTINOUS.
3. DEPTH OF CONCRETE COPING SHALL BE AS REQUIRED TO MAINTAIN TOP OF COPING ELEVATION AS SHOWN ON DEVELOPED ABUTMENT ELEVATION VIEWS. ELEVATION OF THE TOP COURSE OF CMU'S WILL VARY DUE TO CONSTRUCTION TOLERANCES.



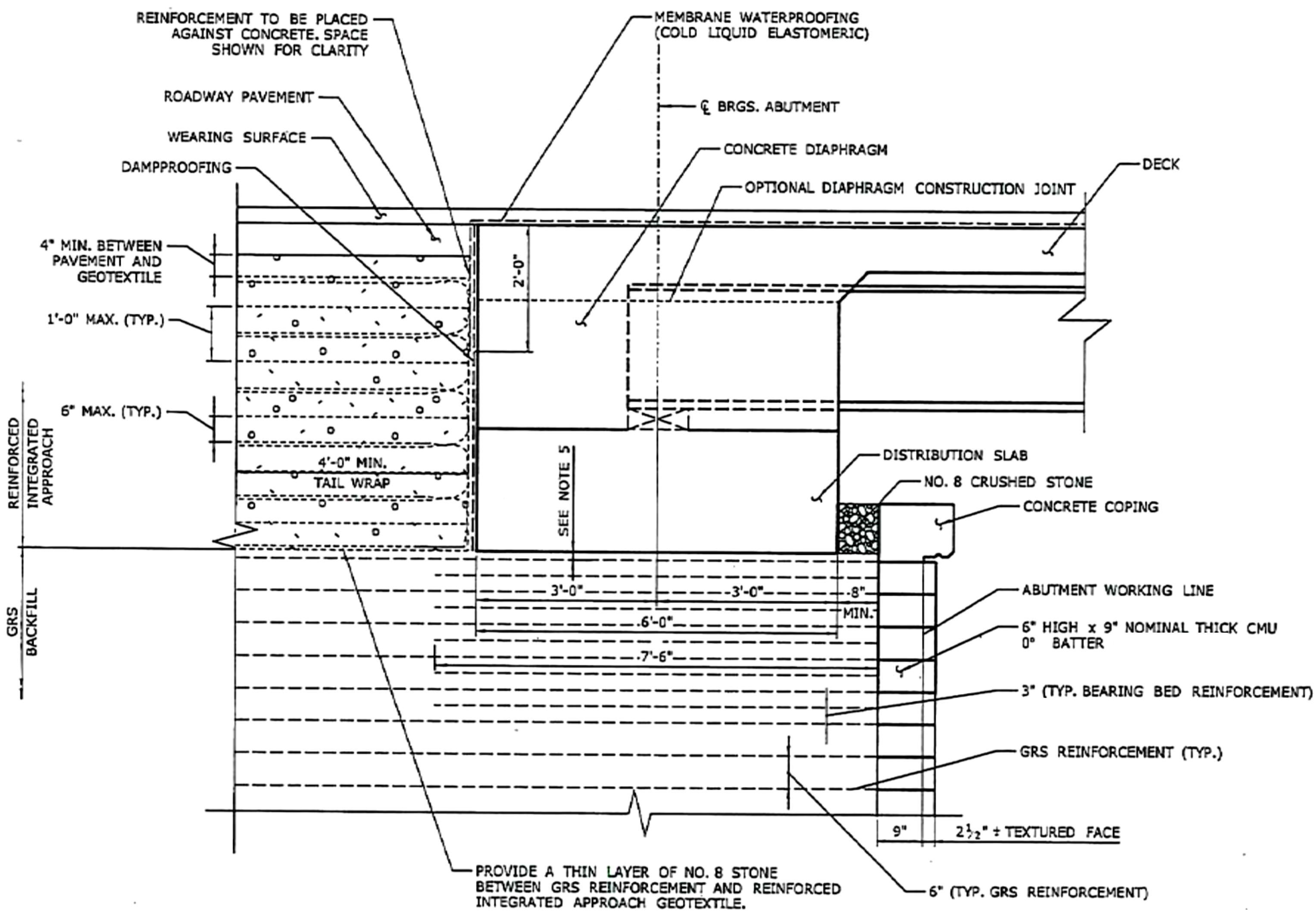
CONCRETE COPING

NOTES:

1. GEOSYNTHETIC REINFORCEMENT SHALL EXTEND BETWEEN BLOCK COURSES TO THE FACE OF BLOCK BUT SHALL NOT BE VISIBLE AT THE FRONT FACE.
2. THE CONCRETE BLOCK AND GEOSYNTHETIC REINFORCEMENT AT THE TOP OF THE BLOCK MAKE UP ONE BLOCK COURSE.
3. THE TOP THREE COURSES OF ALL GRS-IBS ABUTMENTS AND WINGWALLS SHALL BE FILLED WITH REINFORCED CLASS "F" CONCRETE.

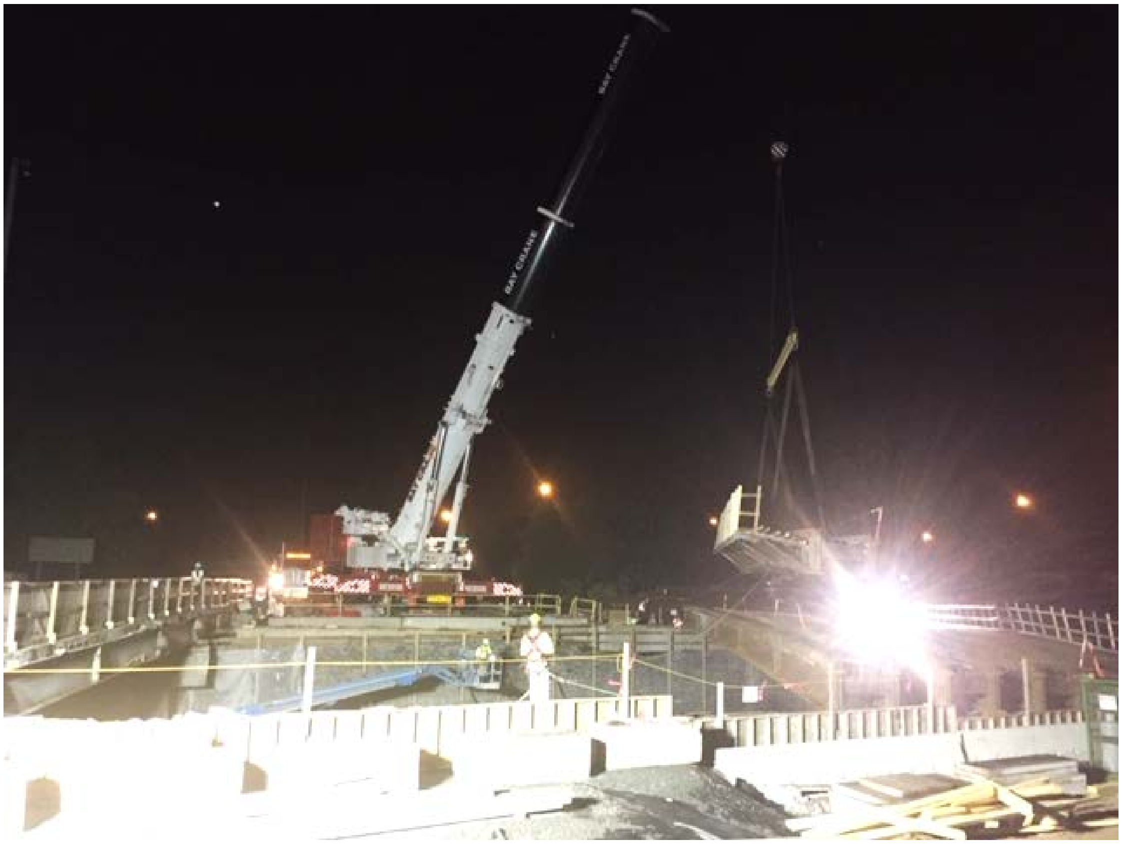
Since the CMU blocks are placed level horizontally, in order to avoid a sawtooth appearance to the top course, the blocks will need to be trimmed for any sloped portions needed for superelevated superstuctures or tapered wingwalls. A cast-in-place reinforced concrete coping shall be formed and placed on the trimmed top block course of the CMU wall. The coping serves as an architectural finish and also structurally seats and seals the uppermost courses. (see detail of coping left)

Bearing Bed Reinforcement: For GRS-IBS substructures, the bridge superstructure elements (integral end bent – beams and deck) can rest directly on the reinforced soil mass or can be cast upon a cast-in-place reinforced concrete distribution slab which similarly rests directly on the reinforced soil mass. The bearing zone directly below these superstructure elements supports the entire superstructure live and dead loads, requiring additional geotextile layers. Intermediate reinforcement layers spaced vertically by 3” are placed as a Bearing Bed Reinforcement Zone to better distribute the loads. The aggregate of this area also requires an additional 2 passes (totaling 6) of the compaction equipment before placing a subsequent layer and since the entire zone is usually within 3 feet of the wall face, lightweight plate tampers or other hand-operated compaction devices must be used to avoid damaging or displacing the CMU blocks.



Bearing Bed Reinforcing Detail

Superstructure Placement: For superstructure erection and other heavy lifts, cranes can be positioned on the GRS-IBS soil mass. Outrigger pads should be sized to limit the soil pressure loading near the wall face to a maximum of 4,000 psf. Loads can be increased as the distance from the wall increases.



Reinforced Integrated Approach: In lieu of the traditional cast-in-place concrete bridge approach slab, The Reinforced Integrated Approach serves as a transition for the roadway approach pavement to the bridge superstructure deck and it completes the reinforced soil mass of the GRS-IBS. The aggregate of the approach is a processed crushed aggregate base that is placed after the bridge superstructure and integral end bents are complete. The aggregate is placed in similar 6" lifts but the geotextile wraps the aggregate in 12" layers at the bridge concrete interface and has an intermediate geotextile separation layer splitting the 12" wrap at the 6" lift. The fabric extends for the full length of the integrated approach with successive 6" layers until it is within 2" below the roadway pavement structure. (see Bearing Bed Details on page 20)

Site Drainage: The aggregate of the GRS-IBS must be protected from contamination and the entire reinforced structure must be protected from erosion or washouts, so a method of controlling surface runoff must be implemented. The site should be graded to drain away from the excavation and the construction should be protected by erosion control devices. Measures should also be taken to prevent flooding by placing perimeter ditches and diversions, especially along riverbanks. Onsite stockpiled materials need to be protected from rainfall and the processed aggregate needs to be placed at optimum moisture content.

Miscellaneous: If handrail, sign, or guardrail posts are located within the GRS-IBS reinforced zone, sleeves should be carefully placed in the aggregate and the fabric should be neatly cut around the sleeves for the impacted layers. The posts can be set into the sleeves with concrete after completion of the system. Cutting or drilling into the zone after completion is unacceptable. Trees and landscaping are not permitted within the GRS-IBS and should be set back far enough to prevent the roots from growing within the area.

For bridge reconstruction projects, a series of survey benchmarks should be installed and periodically monitored to report any movement in the existing structure while the GRS-IBS is under construction. A geotechnical engineer should establish limits for horizontal and vertical movement. These limits should delineate an acceptable band for positive and negative movement, a threshold limit for geotechnical evaluation with possible changes to construction methods, and a maximum limit for movement requiring a stoppage of work and an engineering evaluation prior to work resuming.

EQUIPMENT NEEDS

Rubber Tracked Skid Steer: Low clearance and maneuverable. For delivery of materials and spreading and grading aggregates. The low profile is helpful on bridge reconstruction projects. Rubber Tracks allow for load distribution on and movement on loose graded No. 8 & 67 aggregate.

Walk Behind Rubber Tracked Loaders: With even lower profiles provide even more clearance than the skid steers and gain more access under existing bridges for reconstruction projects. Rubber Tracks allow for load distribution on and movement on loose graded No. 8 & 67 aggregate.

Mini-Rubber Tracked Excavators and Mini-Mini-Rubber Tracked Excavators: Low clearance and maneuverable. For spreading and grading aggregates. The low profile is helpful on bridge reconstruction projects. Rubber Tracks allow for load distribution on and movement on loose graded No. 8 & 67 aggregate.

Low Profile Rollers and Mechanical Plate Tampers: Low Clearance for Bridge Reconstruction Projects, The lightweight doesn't displace the CMU facing blocks while compacting the backfill lifts.

Tracked 360-degree Rotating Dumps: For restricted access bridge reconstruction projects, the 360-degree operation eliminates backing on long distances. Faster hauling and disposing of excavated material and delivery of backfill material. Tracks allow better load distribution and maneuverability in tight quarters.

Conclusion

This introduction is a brief overview of the operations for an Accelerated Bridge Program – Geosynthetic Reinforced Soil – Integrated Bridge System construction. The information provided comes directly from my design/build experience with GRS-IBS structures for the CTDOT. Much of the knowledge was gained from the CTDOT Special Provisions and Standard Details:
ITEM #0712021A – GRS ABUTMENT AND WINGWALL;
ITEM #0712022A – ABUTMENT AND WINGWALL CMU WALL FACE;
ITEM #0712023A – REINFORCED SOIL FOUNDATION (RSF);
ITEM #0712024A – REINFORCED INTEGRATED APPROACH.
State of Connecticut Department of Transportation-Office of Engineering-Guide Detail 1

Even more was gained from the FHWA publication:
Design and Construction Guidelines for Geosynthetic Reinforced Soil Abutments and Integrated Bridge Systems, PUBLICATION NO. FHWA-HRT-17-080 JUNE 2018:
U.S. Department of Transportation, Federal Highway Administration, Research, Development, and Technology, Turner-Fairbank Highway Research Center, 6300 Georgetown Pike, McLean, VA. 22101.

This publication provides a much more in-depth reference for the Design and Construction of the GRS-IBS structures.

Accelerated Bridge Construction is very specialized and no matter how in-depth the courses are written there is no substitute for experience. Many specialty subcontractors and suppliers offer onsite consulting services as a supplement to the construction staffing. To organize a new construction project, managers should strongly consider these additions as well as the support of an experienced construction engineering firm. The consulting experience will help train the project personnel, troubleshoot problems, and give confidence to the owner. Additionally, a well-structured quality control program is a must. From design to erection, unaccounted errors can have significant impacts on cost, schedule, and **SAFETY**.

Lastly, safety must be the constant and most important focus of every operation. Because of the accelerated nature of these bridges (mostly described in the opening paragraphs of the course), they are often chosen to be constructed in some of the most adverse and congested areas imaginable. Working with extreme weights, at excessive heights, and around pedestrian and vehicle traffic requires safety diligence from every

stakeholder. From Demolition to the final surface, an accelerated bridge project can be completed in less than a month. Even at this pace, with constant planning, they are often completed with zero OSHA recordable or lost time accidents. Please be safe.