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RETAINING WALL

**Description**

This work shall consist of furnishing all designs, construction plans and specifications, working drawings, materials, labor and equipment necessary to construct retaining walls consisting of precast reinforced concrete modular units at the locations shown on the plans in accordance with 105.03, as described in this Section, as per the design/supplier's recommendations and as approved by the Engineer and Owner in writing. The work shall conform to the applicable portions of Section 700 and 910 of the INDOT Standard Specifications, except as specified herein.

The Contractor shall coordinate with the wall manufacturer to ensure retaining walls will be accommodated as proposed. The Contractor shall verify the wall and locations for fit with the proposed adjacent elements in the project.

The Contractor shall furnish a retaining wall of the following type: T-WALL® which is a product of The Reinforced Earth Company (RECO) 12001 Sunrise Valley Drive, Suite 400, Reston, VA 20191 (703)-547-8797.

**Materials**

All precast reinforced concrete modular units shall be manufactured by a Department Certified Precast Concrete Producer in accordance with ITM 813. A quality control plan shall be submitted by the precaster and approved prior to start of production. The concrete mix design shall be Self-Consolidating Concrete (SCC) with a minimum compressive strength of 5,000 psi at 28 days. The mix design shall be submitted and approved by the Engineer prior to the manufacture of any units.

#### Testing and Inspection

Acceptability of the concrete for the precast units will be determined on the basis of compression tests, certifications, and visual inspection. The concrete strength requirements for the precast units shall be considered satisfied regardless of curing age when compression test results indicate that the concrete strength conforms to 28-day specifications. The precast manufacturer shall furnish facilities and perform all necessary sampling and testing in an expeditious and satisfactory manner.

#### Casting

The units shall be cast in steel forms with dimensional tolerances that will assure the production of uniform units.

#### Curing

The curing method shall be as submitted and approved in the quality control plan.

#### Removal of Forms

The forms shall remain in place until the forms can be removed from the units without damage.

#### Marking of Precast Units

Clearly and permanently mark each precast unit on the butt end of the stem with the unit type, the date of manufacture, the lot number if applicable, and the trademark of the wall manufacture.

#### Unit Finish and Tolerances

Steel Form Finish - Unit Tolerances - all dimensions shall be within plus or minus 1/4 inch.

Surface Finish - all honeycomb or open texture shall be properly repaired.

Architectural Form Liner Finish - shall be as called for on the plans and as specified elsewhere.

Front Face Tolerance - length and height of front face shall be within plus or minus 1/4 inch.

#### Handling, Storage, and Shipping

All units shall be handled, stored, and shipped in such a manner as to avoid chipping, cracking, fracturing and excessive bending stresses.

#### Reinforcing Steel

Shall meet the requirements of AASHTO M31 (ASTM A615) Grade 60.

Reinforcing steel and all support devices shall be epoxy coated.

The minimum concrete cover for the reinforcing steel shall be in accordance with the referenced specifications.

Rebar cage fabrication by welding is not permitted and is cause for rejection

#### Joint Materials

##### Horizontal Joints

Neoprene or Rubber blocks with a minimum durometer of 60 placed as shown in the approved precast retaining wall units drawings.

**Joint Filter Fabric**

Horizontal and vertical joints shall be backed by a 12-inch wide geotextile fabric such as Mirafi 1120N or approved equal.

**Shear Keys**

Precast shear keys shall be made of the same concrete mix as the precast retaining wall units and cured in the same manner.

**Shear Key Wrap**

The shear keys are to be wrapped with a 1/4 inch closed cell polyethylene foam by AVI Astro-Foam or equal.

**Select Granular Backfill**

The general gradation requirement of this backfill material is:

Sieve Size	Percent Passing
2 inch	100
3/4 inch	20-100
No. 200	0-8

Locally produced materials with a gradation that falls between the upper and lower limits stated above would be considered satisfactory.

**General Design Parameters**

Angle of Internal Friction	34° Minimum
Unit Weight (density)	120 pcf
Compaction -	95%
	Of Standard Proctor, ASTM D-698

If the locally available material meets the gradation and angle of internal friction requirements stated above, but not the unit weight, the wall design may be modified to reflect the actual properties of the available material. Backfill between the precast retaining wall units meeting the above criteria may be one of the following locally available materials:

- Crushed or natural sand
- Crushed or uncrushed gravel
- Recycled concrete
- Old ballast

**Leveling Pad Concrete**

The leveling pad concrete shall have a nominal minimum compressive strength of 2,500 psi for placement of the precast retaining wall units.

**Design Data**

The design of the retaining wall system shall be performed in accordance with the following:

1. AMERICAN RAILWAY ENGINEERING AND MAINTENANCE-OF-WAY ASSOCIATION "Manual for Railway Engineering" (AREMA) current edition, E90 Loading
2. CANADIAN NATIONAL RAILWAY "CN GUIDELINES FOR DESIGN OF RAILWAY STRUCTURES" (CN) REVISION JANUARY 2006
3. "Indiana Department of Transportation Design Manual," current edition.

The design shall consider the external stability of the wall including the actual applied bearing pressure, overturning, sliding, and stability of temporary construction slopes. The size of all structural elements shall be determined such that the design load stresses do not exceed the allowable stresses.

In the absence of specific test data for the embankment placed behind the wall, the maximum angle of internal friction used to determine the external stability and sliding resistance of the wall shall be 30°. Passive pressure in front of the wall will be assumed to be zero for design purposes.

The factor of safety for overturning of the wall shall not be less than 2.0, and that for sliding of the wall shall not be less than 1.5. The actual applied bearing pressures under each wall segment shall be clearly indicated on the wall plans and shall be less than the maximum allowable soil pressure shown on the contract plans.

The tops of all leveling pads shall be set a minimum of 3.0 ft below finished grade at the exposed face of wall, unless otherwise noted. The wall design height shall be measured from the top of leveling pad.

The exposed face of walls shall be vertical.

The wall segments will be designed to tolerate differential settlement as follows. Face panels shall be designed to accommodate a differential settlement of 1 linear unit in 100. Face panels of an area greater than 32 SF through 64 SF shall be designed to accommodate differential settlement of 1 linear unit in 200.

If additional information is required to complete the design, the Contractor shall be responsible for obtaining the information at his expense.

#### **Wall Drainage**

Wall face drainage system shall be detailed and installed as required by design. Drainage located at the heel of the wall for the bottom most layer of pre-cast sections is required. Details and all connections, including locations to be provided on the working drawings.

#### **Structural Requirements**

The precast retaining wall system shall be designed by the Contractor as a minimum to the design data shown above.

**Working Drawings**

## Submittals:

Prior to beginning fabrication, design calculations, supplemental geotechnical investigation (if required for design), and working drawings shall be submitted together to the Engineer for approval. Three sets of working drawings and structural design calculations, subject to the review period as indicated in the provision titled "PROTECTION OF RAILWAY INTEREST", signed and sealed by a Professional Engineer registered to practice in the State of Indiana, shall be submitted to the Engineer for CANADIAN NATIONAL RAILWAY review and approval prior to construction. Design plans and calculations shall be in English units.

Submit product data for products used in precast retaining walls fabrication and construction, including rebar, concrete, admixtures, and aggregates.

Submit working drawings showing sizes and detailing fabrication and erection of each precast retaining wall indicated. Include plans, elevations, sections, profiles, and details of fabrication, their connections, and their installation. Indicate heights, sizes and spacing of components. Include brackets for wall mounted hardware installations. Show anchorage, joinery and accessory items.

The Contractor shall submit complete design calculations, explanatory notes and detailed construction plans and specifications for the proposed wall system. The construction plans and specifications shall include all views, details, notes, quantities and cross sections necessary to construct the walls and shall include, but not be limited to, the following:

1. A plan sheet showing: index of drawings, general notes, design criteria, curve data (horizontal and vertical) and summary of quantities necessary to construct each wall.
2. A plan and elevation sheet or sheets for each wall which will contain the following:
  - a. An elevation view of the wall showing: allowable and applied bearing pressures; original and final ground lines; sub-drainage system; fencing limits including post spacing; elevations at the top of wall for all vertical and horizontal breaks; elevations at the top of finish grade along the exposed face of wall at minimum intervals of 50 feet; and elevations at the top of all leveling pads or steps.
  - b. A plan view of the wall showing: stations and offsets from the centerline of construction to the face of the wall at all changes in horizontal alignment, and to the centerline of any drainage structures on or adjacent to the wall, including any utilities or drainage pipes behind or passing through or under the wall.

3. Plan sheet or sheets showing the following:
  - a. Limits of all temporary sheeting, excavation, and backfill necessary to construct the walls, including leveling pads and steps. The type of sheeting and bracing details shall be shown for each location requiring temporary sheeting and bracing. All temporary sheeting and excavation plans shall be sealed by an Indiana Licensed Engineer.
  - b. All dimensions, elevations and reinforcing steel necessary to construct concrete leveling pads including steps.
  - c. All dimensions, elevations, reinforcing steel, inserts, miscellaneous hardware, anchors, sub-drains and backfill necessary to construct the wall using precast concrete modules.
  - d. All dimensions, elevations and details necessary to construct joints between retaining wall systems and/or conventional reinforced concrete retaining walls, wingwalls, or abutments.
  - e. Indicate field verified dimensions and conditions on working drawings.
  - f. All details to the wall and leveling pads necessary to support fencing, railings or coping where required by the plans.

Construction plans and specifications submitted for review shall be accompanied by a set of design calculations and explanatory notes for each wall. The calculations and notes shall be legible and shall demonstrate that the design criteria as set forth herein has been met. The factors of safety against pullout, sliding, and overturning, for which the minimums are specified hereinafter, and the actual applied bearing pressure beneath the wall shall be clearly indicated.

The plans shall be prepared on reproducible sheets 11 by 17 inches including borders. Each sheet shall have a title block in the lower right-hand corner. The title block shall include the sheet number of the drawing, name or designation of the wall, the project designation, the system designer/supplier, and the Contractor. Calculations and notes shall be on 8½ by 11 inches sheets, shall contain the project designation, date of preparation, initials of designer and checker, and page number at the top of the page. Calculations and plans shall be signed and stamped by a Professional Engineer registered in the State of Indiana. No work shall be done or material ordered by the Contractor until the submittal has been approved by the Engineer and the Owner.

The precast retaining wall plans must completely identify the site geometry and installation of the system. The specific requirements of the plan submittals are as follows:

1. General plan view should show:
  - a. Railroad right-of-way and North arrow.
  - b. Spacing between all existing elements.
  - c. Footprint of proposed structure, and any existing structures if applicable.
  - d. Proposed horizontal clearances.
  - e. Location of existing and proposed utilities.
  - f. Railroad and other "CALL BEFORE YOU DIG" numbers.
  - g. Detailed view of railing along with controlling elevations and dimensions.
  
2. Typical section and elevation should show:
  - a. Top of wall elevations for all walls.
  - b. Offset from the baseline to the face of leveling pad (supporting foundation) and to the front face of all wall at all changes in horizontal alignment.
  - c. All structural components, controlling elevations and dimensions of walls.
  - d. All controlling dimensions.
  - e. All slopes, existing structures and other facilities which may impact the walls
  - f. Location of all existing and proposed utilities.
  - g. Total depth of wall stems and backfill.
  
3. General criteria
  - a. Design loads to be based on the design data referred to above
  - b. ASTM designation and yield strength for each material.
  - c. Maximum allowable bending stress for all materials.
  - d. Temporary overstress allowances are not acceptable.
  - e. Shoring deflection to be calculated and meet the design data referred to above
  
4. Miscellaneous:
  - a. Project name, location, GPS coordinates, track owner, Railroad line segment, milepost and subdivision in the title block.
  - b. Procedure outlining the installation of walls.
  - c. General notes specifying material requirements, design data, details, dimensions, cross sections, sequence of construction etc.
  - d. Drawings must be signed and stamped by a Licensed Professional Engineer, registered to practice in the State of Indiana.
  - e. Call Before You Dig number.
  - f. Construction clearance diagram.

Submit samples representative of materials and finished products as may be requested by the Owner.

Submit fabricator certificates signed by Contractor certifying that the fabricator complies with requirements specified under "Quality Assurance" article.

Manufacturer of precast concrete units shall provide a guarantee for no less than ten (10) years from the date of installation against, failing, settling, spalling, cracking or color fading of this product. Any such units that fail during the stipulated guarantee period shall be replaced with new units or suitably repaired existing units at no additional cost to the owner.

**Quality Assurance:**

**Fabricator Qualifications:** Firm experienced in successfully producing precast retaining walls similar to that indicated for this Project, with sufficient production capacity to produce required units without causing delay in the Work.

**Regulatory Requirements:** Comply with applicable requirements of all governing codes, ordinances and regulations.

**Construction Requirements**

**Manufacturer Oversight:**

The pre-cast wall manufacturer will provide a representative, qualified and skilled in the design and construction this pre-cast unit system to conduct a pre-activity meeting. Additionally, the representative will observe and review the installation of at least 20% of the total pre-cast units installed which are governed by this provision. The representative will guide the installation procedures to the extent necessary to achieve a quality, in-place and complete pre-cast wall system. The representative will document these observations, review and guidance in daily reports when on-site, which will be submitted for inclusion into the project record.

**Manufacture Procedure:**

Manufacturing of precast members shall be in accordance with applicable portions of Sections 702, 703, and 707 of the Standard Specifications except as modified herein.

The forms shall be constructed and the members shall be manufactured so that the completed concrete members conform to the shape, line and dimension as shown on the plans.

The Contractor shall correct all imperfections on the concrete surfaces to the satisfaction of the Engineer, as specified in the Standard Specifications.

Prior to delivery to the jobsite, the Engineer shall visually inspect and approve the pre-cast units for delivery to the job-site. Damaged units will not be approved for shipment.

**Delivery and Storage:**

Precast members shall be lifted and supported at the lifting and supporting points indicated on the working drawings. Precast members are to be stored off the ground. Stacked precast members shall be separated by battens across the full width of each bearing point. Precast members shall be protected from weather, marring, damage, and overload.

Precast structural members shall not be subjected to excessive abuse which produces crushing or undue marring of the concrete. All structural members damaged during handling, storing, transporting, or erecting shall be replaced. Unless otherwise approved, precast structural members shall be handled with a suitable hoisting device provided with a spreader sling. The spreader shall be of sufficient length to prevent horizontal forces being produced in the structural member due to lifting and shall be equipped with leads and hooks at each end. The structural members shall be lifted by the devices shown on the plans. Proposed alternate lifting devices and procedures shall be approved prior to use and shown on the working drawings. If any other method of handling is used, it shall be shown on the working drawings and approved prior to use. If the method produces horizontal forces in the precast structural member, sufficient reinforcement shall be added to compensate for them.

The structural members shall remain in an upright position at all times and shall be supported as indicated in the plans when in storage and during transportation to the construction site.

When the concrete has attained a compressive strength of not less than 4,500 pounds per square inch, but not prior to 7 days after casting, the members may be loaded, shipped and erected.

Contractor shall verify material compatibility e.g. form liners, form oil, coatings, sealer, curing compound.

#### Installation:

##### Surface Drainage

Contractor shall be responsible for the stability of all excavated slopes and shall assure that surface runoff is diverted away from the wall. The Contractor is responsible for providing dewatering of excavated areas in order to maintain dry working conditions during construction of the wall. A site drainage analysis must be performed to ensure that the surface runoff for the entire site is controlled or directed away from the walls.

##### Pre-Cast Units

Prior to incorporation into the wall, the Engineer shall visually inspect and approve the pre-cast units for use. Damaged units will not be approved for incorporation into the wall system.

##### Foundation Preparation

The foundation soil shall be evaluated by a Geotechnical Engineer, retained by the Contractor, to ensure that the bearing soils meet or exceed the design conditions, the assumptions in the geotechnical report and the approved precast retaining wall manufacturer's design. Compact the graded area with an appropriate roller weighing a minimum of 8 tons by at least 3 passes or as directed by the Engineer. Remove and replace any soft or loose foundation soils to insure that there is adequate bearing capacity as directed by the Geotechnical Engineer or the Engineer. The soil foundation shall be approved, by the owner and certified by the Contractor's Geotechnical engineer, prior to installation of the precast retaining wall units. Any foundation soils found to be unsuitable shall be removed and replaced as directed by the Engineer.

The Contractor shall verify all locations of underground utilities before construction. Any damage to existing utilities caused by the Contractors operations shall be repaired by the Contractor in a manner satisfactory to the Engineer and at no cost to the owner.

#### Structure Excavation

Contractor shall excavate to the lines and grades shown on the plans. The foundation for the precast retaining wall structure shall be excavated and graded level for a width equal to or exceeding the length of the precast retaining wall stem using the top of the leveling pad as the grade elevation. The Contractor shall be careful not to disturb base beyond the lines indicated and shall be responsible for slope stability and protection of the open excavation.

Over-excavated areas shall be filled with suitable base or backfill material and compacted to 95% modified Proctor.

#### Backfill Placement:

Granular backfill placement shall closely follow the erection of each course of units. The backfill lifts should be uniform in thickness, not to exceed 8 inches. Each lift shall be compacted to at least 95% standard proctor in accordance with ASTM D698. Placement and compaction of the backfill shall be accomplished without displacement of the wall units.

Tolerance and alignment shall be as follows:

Horizontal joint openings between precast units and between adjacent CIP Walls shall be  $3/4$  inch (plus  $1/4$  inch or minus  $1/2$  inch)

Vertical joint openings between precast units and between adjacent CIP Walls shall be  $1/2$  inch plus or minus  $3/8$  inch

Vertical tolerance (plumbness) as the wall is constructed shall not exceed plus or minus  $3/4$  inch when measured with a 10-foot straight edge. Horizontal alignment tolerance as the wall is constructed shall not exceed plus or minus  $3/4$  inch when measured with a 15 foot straight edge and shall not exceed  $3/4$  inch overall.

The overall vertical tolerance of the wall (plumbness from top to bottom) shall not exceed plus or minus  $3/4$  inch per 10 feet of wall height.

The thickness of the concrete leveling pads shall be no less than 6 inches.

Any disturbance or damage to existing structures, utilities or other property, caused by the Contractor's operation, shall be repaired by the Contractor in a manner satisfactory to the Engineer and shall be included in the cost of Retaining Wall.

A. After completion of wall installation, remove construction debris and restore any adjacent finished areas affected by wall construction to their preconstruction state or as required by the contract documents.

#### Field Quality Control

The contractor shall employ the services of an independent engineering firm to monitor soil testing and perform daily quality assurance and inspection for wall construction and soils work. Contractor shall provide quality control testing or inspection. Contractor shall be responsible for proper installation and quality control of all wall components and appurtenant materials. Quality Assurance shall include but not be limited to foundation soil inspection, backfill compaction testing, verification of geotechnical design parameters and compliance with approved working drawings, retaining wall system construction Manual and Project Specifications. Contractor shall submit all testing and quality control documents to the owner as part of the final as built plans to be submitted upon completion of the walls

Material certifications and test reports for the backfill shall be maintained by the Contractor and provided to the owner.

Testing at a minimum frequency listed below:

Compaction Test: Each course of units at 50-foot intervals and at the beginning and end of each day units are installed.

Gradation Test: Prior to construction and Weekly thereafter.

In no event shall the quality control of backfill placement be tested less than similar backfill placed under 731.11.

#### **Safety**

The Contractor shall be responsible for meeting all federal, state, and local safety code requirements to include OSHA and Department requirements. Also the Contractor is required to meet minimum safety standards as defined by the Railroad

#### **Monitoring Program**

The monitoring program is the responsibility of the pre-cast wall manufacturer. The Contractor is required to coordinate activities with the pre-cast wall manufacturer in order to facilitate a complete and in-place monitoring system as described below. During construction the Contractor is required to coordinate and allow access to the site and instruments for purposes of monitoring, Cone Penetrometer Testing (CPT) and data collection. Regarding CPT Testing, the contractor will give 3 weeks advance notice to the Engineer regarding the availability of the finished subgrade for testing and allowance for 3 days of CPT. The contractor shall install the required instrumentation devices described below. The instrumentation devices will be provided to the contractor by the pre-cast wall manufacturer.

### Program Requirements

The program will include geotechnical instrumentation whereby data is collected, reduced and submitted to INDOT for review. The instrumentation will include: inclinometers for monitoring lateral deflection; settlement monitoring devices; devices to monitor horizontal and vertical movement of panel joint openings, pressure cells including automatic data logger to monitor horizontal pressure on the segments, access to the site for CPT testing by INDOT forces and bag samples of the placed backfill. Data is to be collected in accordance with the below table. All data collected requires submission to INDOT within three (3) business days following collection.

### Required Instrumentation

To monitor the lateral deflections, two (2) inclinometers will be installed. Each inclinometer will consist of a casing with vertical slots used as a guide for a probe that measures horizontal deflection in two directions. Inclinometer readings will be collected by manually lowering the probe into the inclinometer casing and collecting readings at 1.6 ft (0.5 m) intervals along the length of the casing. Data will be reduced to allow for comparisons with baseline measurements.

For settlement monitoring, two (2) settlement plates will be installed. Each plate will consist of a 0.5 in. by 3 ft by 3 ft (13 mm by 1.0 m by 1.0 m) steel plate equipped with sections of 3/4 in. (19 mm) pipe and 2 in. (50 mm) galvanized threaded pipe and couplings to act as a cover or guard. Settlement readings will be collected by a surveyor by taking shots on top of a steel rod extension attached to the plate and located within a pipe (i.e., to allow for the rod to move independently of the fill). Surface settlement readings will also be obtained to understand the relative movement of the fill and foundation soil.

For monitoring panel joint openings, eight (8) crack monitoring gauges will be installed to allow for measurements across the panel joints. The crack monitoring measurements will be made and compared to previously recorded readings.

For monitoring horizontal earth pressure on the segments, sixteen (16) pressure cells with an accompanying automatic data recorder will be installed on the pre-cast segments.

### Location of Instrumentation

All instrumentation will be installed as approved by the Engineer during project delivery in coordination with INDOT, the Contractor and The Reinforced Earth Company.

## Frequency of Measurements

Monitoring will be performed in accordance with the following frequencies:

Measurement	Method	Frequency During Construction	Frequency Post Construction
Vertical Settlement - Soil	Settlement Plate with Survey points	Daily	Weekly for 12 Weeks then Monthly for 2 Years (or less if approved by INDOT Engineer)
Vertical Settlement - Wall	Survey Points	Daily	Weekly for 12 Weeks then Monthly for 2 Years (or less if approved by INDOT Engineer)
Horizontal Displacement	Inclinometers	N/A	Baseline After Constructed, Weekly for 12 Weeks then Monthly for 2 Years (or less if approved by INDOT Engineer)
Panel Joint Opening	Survey Points & Crack Monitoring Devices	Daily	Weekly for 12 Weeks then Monthly for 2 Years (or less if approved by INDOT Engineer)
Wall Horizontal Pressure	Pressure Cells and Automatic Data Recorder/Logger	N/A	Beginning at completion of wall construction, Weekly for 12 Weeks

## Backfill Material Samples

For each course of pre-cast segments in the wall, a representative sample of the backfill material placed behind the face of the wall and within the same segment height, shall be collected and delivered to the Engineer for use by INDOT. The representative samples will be at least 30 pounds in weight each and be secured in an appropriate bag or container labeled with the sample date and location.

## Data Presentation

Data will be presented in graphical form and provided to INDOT by RECO within a three (3) business day period following collection. Settlement survey data will be presented in a plot of elevation versus time, and data from the crack monitoring devices will be presented in accordance with the attached form. Data from the inclinometers will be plotted illustrating cumulative lateral displacement versus depth for each successive measurement.

**Method of Measurement**

Retaining wall will be measured by the square foot of exposed face area of wall above finished grade as shown on the plans. No measurement will be made for design and construction of Railing or Fence connections to top of wall. No measurement and payment will be made for the monitoring program.

**Basis of Payment**

This work will be measured and paid for at the contract unit price per square foot for retaining wall which price shall include all labor, materials, equipment, tools and incidentals necessary to complete this item as specified except that the monitoring program will be at the sole expense of the retaining wall manufacturer (The Reinforced Earth Company).

Payment will be made under:

<b>Pay Item</b>	<b>Pay Unit Symbol</b>
Retaining Wall.....	SFT

The pay item shall include payment for all portions of wall complete in place including, but not limited to, engineering design, analysis, working drawing preparation, drainage, connections, testing, reports, quality control, as-builts, and all related materials, labor, equipment, inspection, construction, and installation except for the monitoring program.