

Reinforced eARTH
SUSTAINABLE TECHNOLOGY

Construction and Quality Control Procedures Manual



**Retained Earth® MSE wall system with
Two-Wire ladder soil reinforcements**

Square Panels

Version v2020.1



SAFETY BULLETIN

February 25, 2014

Re: Safety Reminder for Retained Earth® Panel Installation

Please review the Retained Earth® Construction Manual carefully and practice safety in all aspects of handling and installing Retained Earth wall materials. The following provides important safety reminders when handling and installing wall panels:

1. Panels at the levelling pad course should be externally braced as shown in the construction manual upon installation and before additional panels are installed.
2. Panels must remain attached to lifting equipment until such time as external bracing, wedges and shoulder clamps are in place and secured.
3. All subsequent panels must remain attached to the lifting equipment until alignment adjustments have been made and wedges and clamps have been installed and secured.
4. Cut panels adjacent to a cast-in-place structure require special attention. Bracing, wedging and clamping is required before releasing the panel from the lifting equipment. Timber or steel angle can be anchored to the vertical surface of the adjacent cast-in-place structure and then the cut panel can be wedged and clamped to the secured timber or angle.
5. The last panel at the free end of wall should be externally braced on the free end as well as secured with wedges and a clamp to the adjacent panel.

Please ensure your crew is aware of the above safety reminders.

CONSTRUCTION AND QUALITY CONTROL PROCEDURES MANUAL

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I. Preface

This Construction and Quality Control Procedures Manual has been prepared as a guide in building Retained Earth® structures.

Its contents should be thoroughly reviewed by the Contractor, the superintendent and the foreman responsible for construction prior to the delivery of Retained Earth materials to the job site.

The Reinforced Earth Company will provide construction advisors to assist the Contractor in the implementation of correct construction procedures. However, in the event of any conflict between the Plans, Specifications or Contract Documents and this Manual, the former will prevail. If there is any doubt with regard to any aspect of the Retained Earth construction, contact The Reinforced Earth Company before commencing or continuing work.

The handling, loading and lifting procedures referenced in Retained Earth wall plans or this construction manual, when furnished by The Reinforced Earth Company, are general in nature and do not include any analysis or assessment of site specific conditions, the nature of any equipment used by others, or means and methods utilized by any contractor, fabricator, or delivery company. All firms or entities using Retained Earth wall plans, using this construction manual or involved in the handling, transport, loading, unloading or erection of products supplied by The Reinforced Earth Company, shall make an independent review and assessment of all handling, loading, and lifting conditions and procedures and shall not solely rely on any general recommendations supplied by The Reinforced Earth Company. The Contractor shall devise and execute project specific procedures for handling, loading and lifting which comply with all federal, state, and local safety laws, regulations and requirements and all applicable contract requirements at all locations where The Reinforced Earth Company materials are loaded, unloaded, handled or erected. Any party utilizing Retained Earth wall plans or this construction manual agrees to indemnify, defend and hold harmless The Reinforced Earth Company from loss, cost, damage or claim arising from their handling, loading, lifting and erection procedures, unless proximately caused by the sole and exclusive negligence of The Reinforced Earth Company.

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II. Non-Disclosure Notice and Disclaimer

1. This Document is the property of The Reinforced Earth Company, with headquarters at 12001 Sunrise Valley Drive, Suite 400, Reston, VA 20191, and contains information, which is proprietary to The Reinforced Earth Company. This Document is being made available solely for use in connection with your interest or participation in the proposed Retained Earth project, and for no other purpose.
2. Except as specified in the paragraph above you must not, without the prior express written consent of The Reinforced Earth Company, use any of the information contained in this Document whether to construct, design, manufacture, fabricate, assemble, produce or install, or otherwise utilize - or cause the same or any of them to be done - any elements of Retained Earth (whether or not patented), or special forms of equipment unique to the production, manufacture, fabrication, assembly, installation, or utilization of Retained Earth, or for any other purpose.
3. This Document and the information contained herein must not be copied or disclosed in any manner or form, in whole or in part, to any third party without the prior express written consent of The Reinforced Earth Company.
4. Receipt of Document gives no entitlement to any property right in the Document or in the information contained therein by virtue of the temporary supply of the Document in accordance herewith.
5. Retained Earth structures designed by The Reinforced Earth Company comprise or are based solely upon:
 - (a) The internal stability of the Retained Earth structure based upon the design assumptions noted on all drawings provided by The Reinforced Earth Company relating to the structure and the external loads, surcharges and site geometries supplied by or on behalf of the Owner.
 - (b) The layout and geometry of the structure based upon survey details, plans and drawings supplied by or on behalf of the Owner; and
 - (c) The Job Specifications.

The design does not include a check of the overall stability of the foundation soils below or behind the structure, nor a check of any potential failure planes external to the structure, nor a check of the stability of any permanent or temporary slopes above or below the wall or temporary excavations. Based on the completeness and accuracy of the above information used or relied upon in designing the structure, The Reinforced Earth Company warrants the internal stability of the structure only.

6. Upon demand, the Document and all copies thereof must be immediately surrendered and returned to The Reinforced Earth Company.

III. Introduction

Retained Earth® is a composite material formed by the interaction between a frictional soil and welded wire soil reinforcements (Two-Wire ladders). In concept, it is like reinforced concrete; that is, Retained Earth is an economical means of improving the mechanical properties of basic material, earth, by reinforcing it with another, steel.

The Two-Wire ladders resist stresses produced within the soil mass; stresses are transferred to the ladders via friction.

A Retained Earth structure constructed using this technique is shown as the “reinforced volume” in Figure 1. Precast Concrete panels are used at the face of the reinforced volume to prevent erosion of the backfill and to provide an attractive, finished appearance.

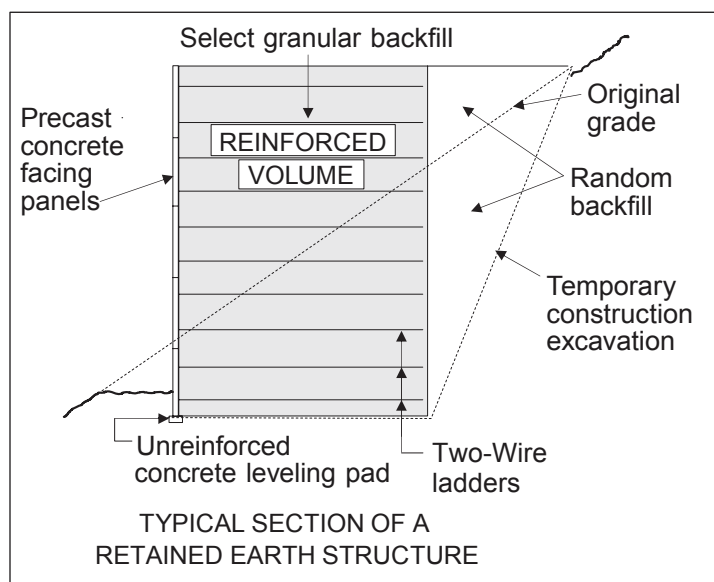


Figure 1

A. Purpose

This document is intended to provide the Owner, Contractor, Engineer and the inspection staff, those who are responsible for overall quality control and inspection during construction with the criteria necessary to monitor the erection of Retained Earth structures for compliance with the Plans, Specifications, and Contract Documents.

B. Responsibilities

It is the Contractor's responsibility to complete construction in strict accordance with the Plans, Specifications, and Contract Documents. To assist the Contractor in this regard, The Reinforced Earth Company provides recommended erection procedures in this manual. Nothing in this document is intended to relieve the Contractor of the responsibility of complying with all safety standards and construction procedures, including fall protection, at the job site.

The Contractor and Owner should verify that the Contractor's on-site erection personnel are in possession of and are familiar with the recommendations of this Procedures Manual.

Technical Advisors from The Reinforced Earth Company are available on site during initial construction and thereafter on a request basis. They may assist the Contractor with material scheduling and coordination and provide advice on recommended construction procedures for Retained Earth structures as set out in this manual.

Technical Advisors are not available on-site on a full-time basis, and are not provided with the intent of replacing the Contractor's and Owner's designated quality control and/or inspection staff.

Only the Engineer can Enforce the requirements of the Plan, Specifications, and Contract Documents.

C. Plans, Specifications, and Layout

- Prior to commencing any site work, the contractor should verify that the latest issue of the Plans, Specifications, and Contract Documents-approved for construction-are being used to build the retaining wall.
- The Contractor should also confirm that the retaining wall is being constructed at the proper location by verifying elevation, line, grade, offset, and all other location criteria.

D. Components

Retained Earth structures consist of the following:

Concrete Leveling Pad – A cast-in-place or precast unreinforced concrete leveling pad serves as a smooth, level surface for placing panels. Generally this pad is 6-in. thick and 12-in. wide. Refer to the Plans and Specifications for dimensions and requirements.

Precast Concrete Facing Panels

- Full-size – or A_n – panels are used for the majority of the structure. The subscript “n” in panel designations indicates the number of Two-Wire ladder connections or clevis loop pairs on each panel.
- Alternating full and half height panels of varying heights are typically required in the initial course.
- Top-course panels may have a flat top and vary in height to provide a stepped transition at the top of the structure.
- Specially cut, bent, or sloping panels as required by the geometry of the structure.

Facing Panel Joint Materials

- Rubber bearing pads are placed in the horizontal joints throughout the structure to prevent concrete to concrete contact. Rubber shims are used as needed to adjust for minor variations in panel height.
- Geotextile is applied with adhesive to the backfill side of the panels to cover all the horizontal and vertical panel joints.

Two-Wire Ladders

- Two-Wire ladders are supplied in various wire diameters with longitudinal bars spaced per design. The ladders are supplied in varying lengths as required by the design of the structure.
- Two-Wire ladders are galvanized for permanent applications.

Fasteners – During construction, Two-Wire ladders are fastened to clevis loop connections embedded in the back of each facing panel using W20 pins made of galvanized structural steel.

Select Granular Backfill – Backfill conforming to Contract Specifications **must be used within the reinforced volume.**

E. Materials and Services Provided by The Reinforced Earth Company

- Engineering and design of the Retained Earth structure
- Precast concrete facing panels
- Horizontal and vertical joint material and adhesive
- Two-Wire ladders
- Bearing pads and shims
- Pin connectors
- One set of panel lifting devices
- Delivery of The Reinforced Earth Company furnished materials to the site (F.O.B.) with two hours of time allowed for unloading
- Initial on-site technical assistance

Two-Wire ladders, pins, geotextile, adhesive, bearing pads, and other special items provided by The Reinforced Earth Company are bundled and packed to minimize damage in unloading and handling.

Materials should be thoroughly inspected upon delivery to the job site. Any damaged items should be set aside and The Reinforced Earth Company notified immediately. Materials should be handled and stored to prevent damage or theft. Geotextile must be stored in a sheltered location and protected from sunlight. Adhesive must be stored in dry location and protected from the elements.

Certificates of compliance based on project specifications for all materials are furnished by The Reinforced Earth Company. However, it is the Contractor's responsibility to verify that all materials received at the job site are in accordance with shipping documents and project requirements. Any discrepancies should be reported to The Reinforced Earth Company immediately.

To prevent construction delays, the Contractor should continuously monitor the quantity of materials on hand to ensure an adequate supply consistent with the Plans, Specifications, and Contract Documents.

F. Equipment, Materials, Tools and Work Supplied by Contractor

Materials, Equipment, and Tools supplied by the Contractor:

- **Panel lifting** – A hydraulic crane, boom truck or similar equipment is required. A standard 5½-in. thick A_n facing panels weighs 1,700 lbs; the heaviest plain finish panel weighs 2,700 lbs. Panels with architectural finish may be heavier.
- **Backfilling** – Dump trucks, scrapers, dozers, graders, front-end loaders, water trucks, etc, are used for hauling dumping and spreading backfill. (Specific equipment selection will depend on backfill, lift thickness, compaction specifications, etc).
- **Compaction** – Large smooth-drum vibratory rollers are used for mass compaction of most backfills. Fine uniform sands are compacted using a smooth-drum static roller.
- Small walk-behind vibrating rollers or flat-plate compactors are needed for compaction within 3 ft. of facing panels.
- **Tools** – 5/8-in. or 3/4-in. Wooden Spacers (Figure 2).
- Wooden wedges in a quantity at least sufficient to provide 4 to 6 wedges per vertical joint for the length of structure under construction (Figure 2).
- Clamps, one per vertical joint for the length of structure under construction. Additional clamps will be needed to brace the initial course of panels (Figure 2).
- Nylon slings for unloading panel stacks.
- Lumber for the initial panel course (Figures 18 & 19)
- Crowbars (pinch bars)
- A 4 ft. carpenter level
- Wrenches or socket sets
- Claw hammers and 16 penny (min.) duplex nails
- A Sledge Hammer
- Chalk line
- Brooms or brushes
- A plumb bob
- Equal length cables with shackles to connect to panel lifting devices
- Large Size Caulking Gun for 2lb tubes
- Survey Equipment

Summary of Work Performed by Contractor

- Site preparation including shoring, excavation and installation of drainage systems as required.
- Forming and pouring concrete leveling pad(s).
- Marking wall layout line on leveling pad(s).
- Construction of the Retained Earth structure consisting of the erection and positioning of facing panels, installation of joint materials, connection of Two-Wire ladders, placement and compaction of Select Granular Backfill.
- Placement of any concrete coping, traffic barrier, or other work as required.

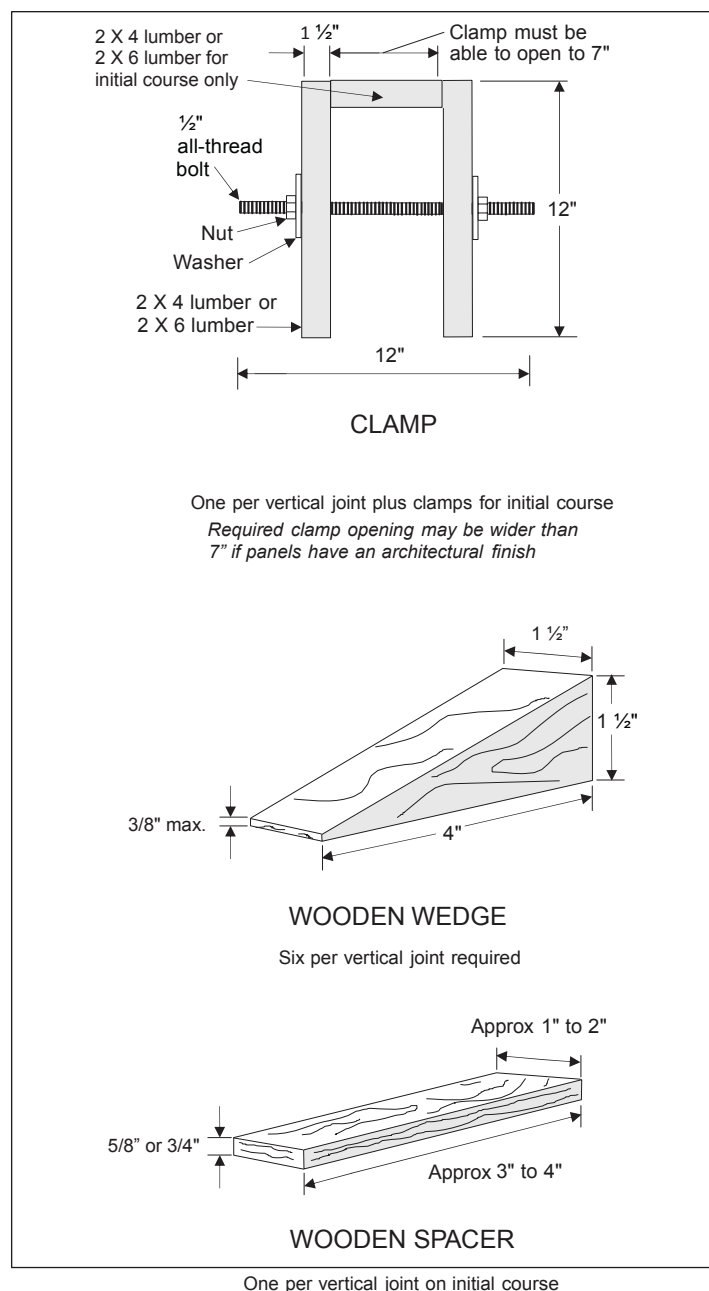


Figure 2

IV. Handling Retained Earth Materials

A. Concrete Facing Panels

Panel Delivery - Prior to the start of construction, the Contractor should establish a panel delivery schedule that will allow The Reinforced Earth Company's precaster to match their panel production and delivery to the Contractor's construction schedule.

Panels shall be inspected by the Contractor upon delivery. Contractor shall verify quantities and condition of materials received with the trucker's bill of lading upon receipt. Any damage or discrepancy shall be noted on the bill of lading and reported by the Contractor to RECo within 24 hours of delivery, in writing.

Panels are usually delivered on flatbed trailers in stacks of four or five panels high. The delivery point is made as close to the retaining walls as a truck can be safely driven under its own power.

Panels should be free of any surface defects that may occur in transportation, unloading, or storage at the construction site, including:

- Chipped or broken front corners.
- Permanent stains on exposed face.
- A crack in panel's exposed face.

These panels may be repaired before they are used in the structure.

Any repairs to panels must be completed to the satisfaction of the Engineer.

Unloading Panels - Under normal conditions, a two-hour unloading period is allowed per delivery to unload panels. In this time, panels may be placed directly into the structure being constructed or temporarily stacked following either of these methods:

1. by using lifting devices to lift and handle individual panels (Figure 3A and 3B) OR
2. by using nylon slings to lift and handle individual or stacks of panels (Figure 4)

Care must be taken to protect facing panels from damage during handling and storage.

Panels can be stored at the job site by re-stacking. Select a location with firm, level ground for both stability and to protect panels from cracking or staining. Carefully lift and place each panel face down on the nylon pads of the dunnage. Stacks should be no more than five panels high with dunnage used between each panel as illustrated in Figure 5.

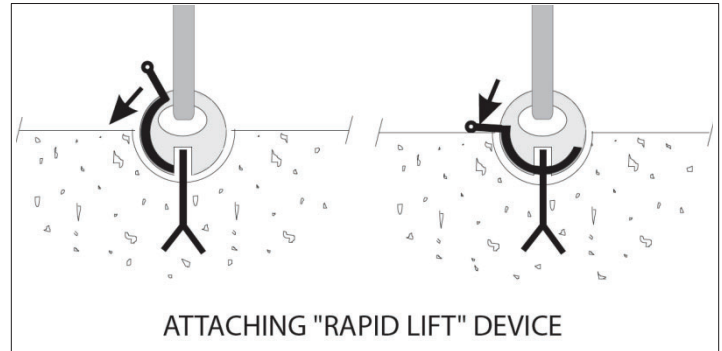


Figure 3A



Figure 3B

**Never re-stack panels without dunnage.
Never place panels face down directly on the ground. Never stand panels up on end.**



Figure 4

Panel Storage - Panels should be securely placed and blocked on firm, level ground to prevent damage and staining during storage.

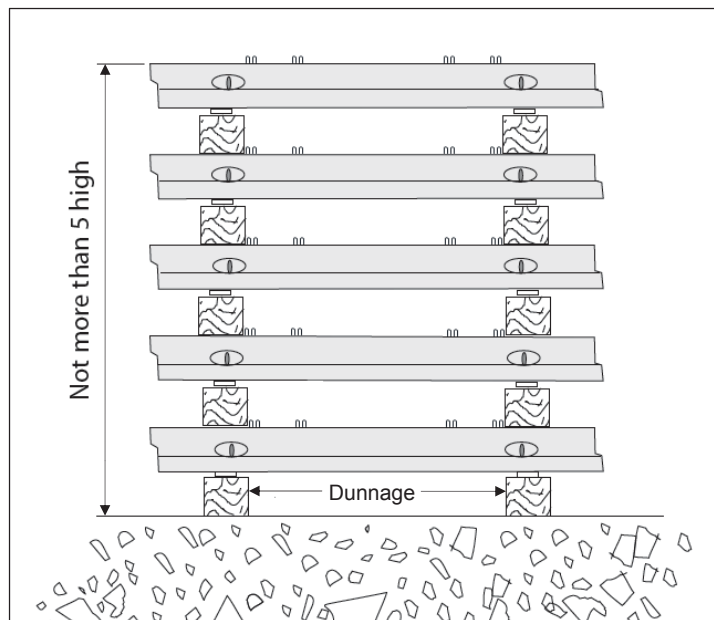


Figure 5

Note: All dunnage and pallets remain the property of The Reinforced Earth Company. They should be stacked and made available for pick-up as soon as they are no longer needed for panel storage.

B. Two-Wire Ladders, Fasteners, and Joint Materials

Two-Wire Ladders - Ladders may be up to 36 ft. long and are delivered to the site in bundles of 30 each (Figure 6). Depending on wire size, each bundle can weigh approximately 30 lbs. per linear foot to 50 lbs. per linear foot. Storage in the open is acceptable but bundles should not be placed directly on the ground.



Figure 6

Bearing Pads - Rubber bearing pads are packed in cartons each weighing 50 to 75 lbs (Figure 7).

Fasteners – Pin connectors are packed in containers, each pin weighing 0.72 lbs (Figure 8).

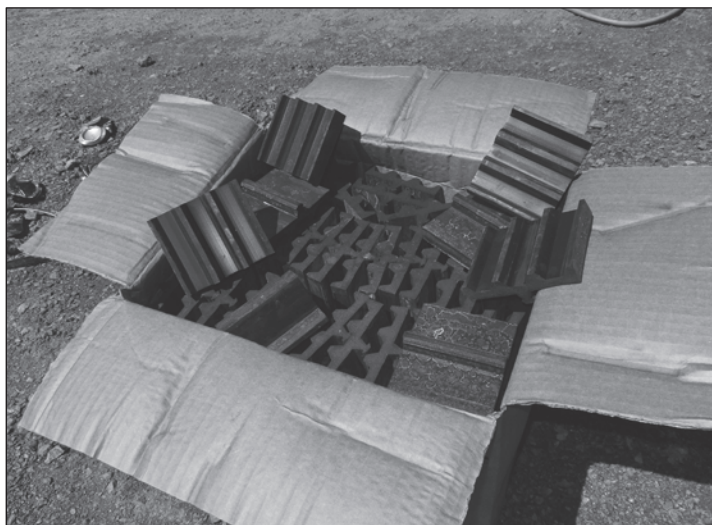


Figure 7



Figure 8

Geotextile - Geotextile is supplied in 12-in or 18- in. wide rolls. In addition to normal security, geotextile must be stored in a sheltered location, protected from the elements (Figure 9A).



Figure 9A

Adhesive - Adhesive for geotextile is supplied in appropriate containers. Adhesive tubes must be stored in a dry location and protected from the elements (Figure 9B).

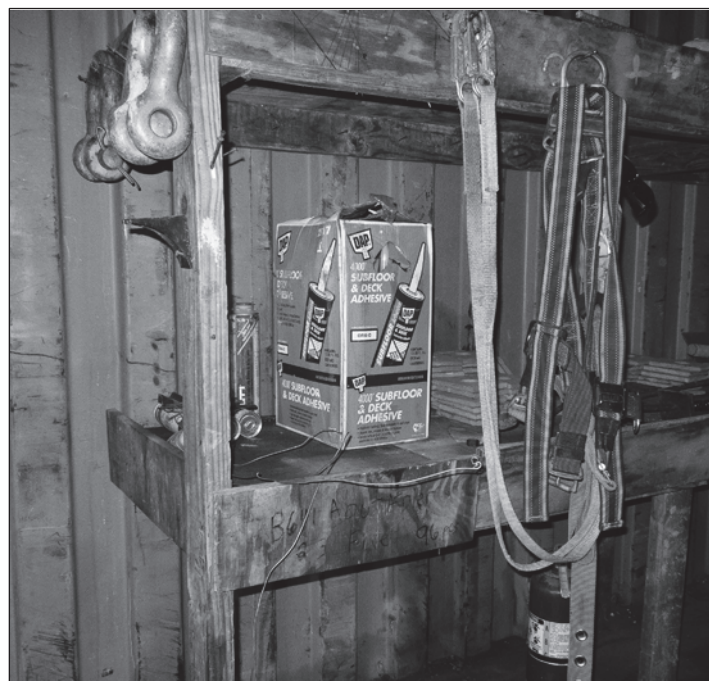


Figure 9B

V. Construction Procedures

A. Overview

The basic erection sequence for a Retained Earth structure can be summarized in these steps:

- Prepare the site including excavation and installation of drainage systems if required.
- Form and pour leveling pad (see Step B-3 for tolerances).
- Set and brace the initial course of facing panels, which consists of alternating half- and full-height panels.
- Use wood wedges and clamps to hold panels in position.
- Attach geotextile with adhesive.
- Spread and compact backfill in lifts up to 1 to 2 inches above the lowest level of panel clevis loops.
- Connect Two-Wire ladders to panel clevis loops.
- Spread and compact backfill in lifts to within 3 to 5 inches of the top of the half panels.
- Place bearing pads and set the second course of full panels
- Repeat cycle of backfilling and compacting in lifts, connecting ladders, placing geotextile and bearing pads and setting panels until design height is reached.
- As each course is completed, remove the wooden wedges from the panels in the course three levels below.
- Set top panels; connect ladders, complete backfilling and compaction.
- Remove all wedges and clamps.
- Install concrete coping, traffic barriers, or any C.I.P. concrete as required.

The finished appearance of a Retained Earth structure depends to a large extent on the care taken in erecting and positioning facing panels. For this reason, particular attention must be paid to the initial course of facing panels and to backfill placement.

Close attention to detail and accuracy at this point will help ensure trouble free and rapid construction of the remainder of the structure.

The following steps for position, alignment and procedures should be reviewed prior to the start of construction.

Lifting, Placing and Spacing Panels - Panels can be lifted from the horizontal, or stacked position, directly to a vertical position by attaching a lifting device to each of the two cast-in-place lifting inserts at the top edge of the panel (Figure 3A & 3B). Use dunnage as blocking to prevent damage as each panel rotates from horizontal to vertical (Figure 10).

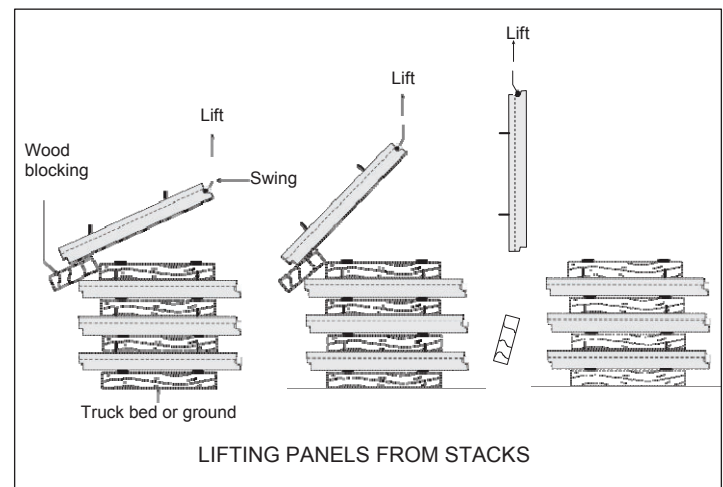


Figure 10

When placing the initial course of panels, insert a spacer to create a joint $\frac{3}{4}$ " wide between each panel at the base of the front face of the wall (Figure 11B). Note: A minimum of one spacer should remain in place until the next panel joint (in the direction of panel placement) has been established by a spacer. Subsequent courses of panels will be placed by centering the panel in its' respective opening (Figure 26).

Panels must be braced (examples shown in Figures 18 and 19) prior to releasing the crane from the panel. Bracing must remain in place until all braced panels have had their Two-Wire ladders attached and have been backfilled and compacted up to the top of the braced panels.

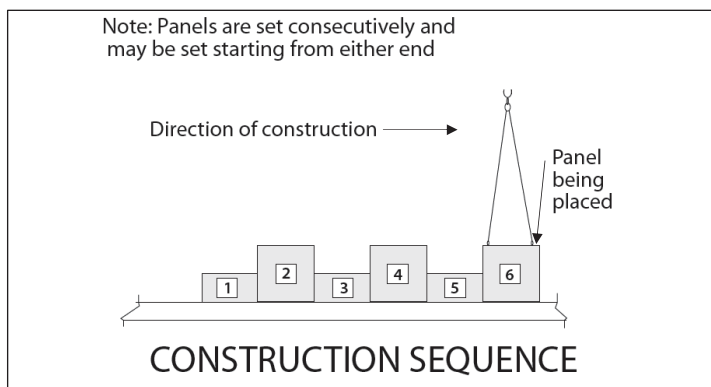


Figure 11A



Figure 11B

Care should be taken to assure that the panel remains centered and properly located until it has been aligned, battered, and clamped.

Check alignment - Visually check the alignment of each panel in relation to either the control line on the leveling pad for the initial course of panels or to the panel below in subsequent courses. Make adjustments with a crowbar on the fill sides of the panel (Figure 12) so that the structural face of successive panel courses are aligned. For panels with irregular architectural finishes, use the side edge or chamfer of the panel to help align adjacent panels. Do not attempt to adjust the panel by using the crowbar on the front side – this can result in unacceptable chipping or spalling.

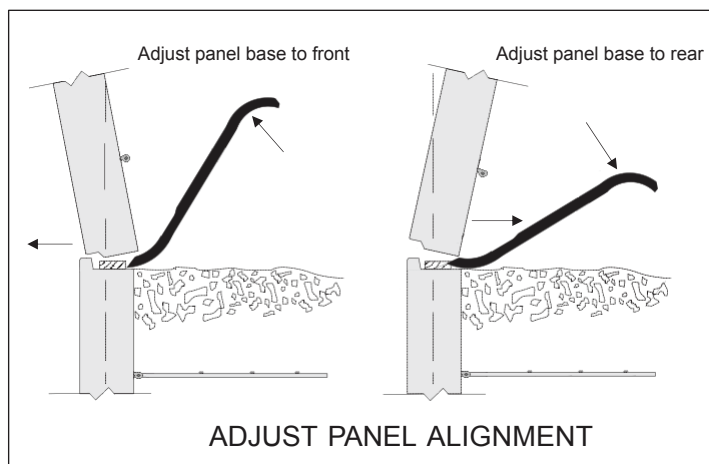


Figure 12

Check horizontal level. The horizontal level of each panel should be checked and adjusted in order to assure a uniform appearance and even joint spacing throughout the structure.

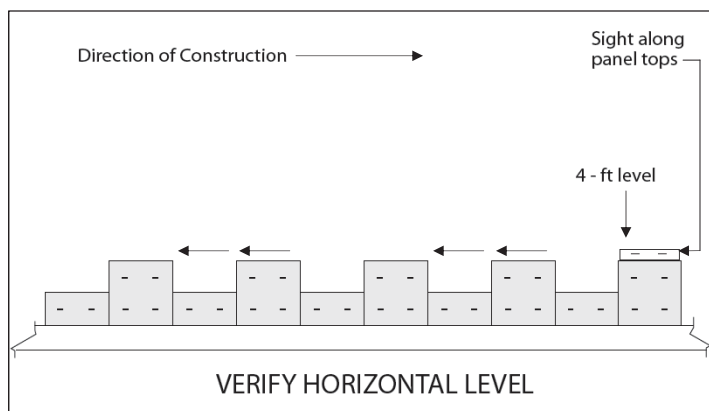


Figure 13

As shown in Figure 13, use a 4 ft. level to verify that the new panel is level. Small rubber shims are provided to aid in leveling the panels. Then sight back along the tops of the panels to ensure that the new panel is at the elevation of the others in its course.

Correct any variations by lifting the panel (with proper equipment) slightly and inserting rubber shims in the horizontal joint at the panel base. Recheck the horizontal spacing and alignment after any such adjustment.

Set Batter - Panels must be given a slight batter, or tilt, toward the backfill in order to compensate for the subsequent outward movement, which occurs during backfill placement and compaction. This movement will tend to push the panel to a true vertical position. Measure batter using a 4 ft. level (Figure 14).



Figure 14

Set the batter by adjusting the panel from the fill side. Batter of the initial course can be set with the bracing.

To maintain the batter, drive one wooden wedge from the face of the structure into each of the horizontal panel joints and/or the vertical joint and clamp the panel to the adjacent panels (Figures 16, 17 and 18).

The horizontal panel joint wooden wedges should remain in place during the erection of three subsequent courses but must be promptly removed. If wedges are left in place for more than three courses, removal will be difficult and spalling can occur. Vertical joint wooden wedges must be removed prior to placement of the next panel course.

The amount of batter varies and depends on the type and moisture content of the backfill, required compaction, type of compaction equipment, and length of the Two-Wire ladders. A batter of $\frac{1}{2}$ -in. in 4 ft. is generally used as a starting point. Coarse backfill, such as crushed stone, may require less batter, while fine backfill, such as sand, may require more.

Monitor the actual movement of panels during the placement and compaction of each lift of backfill; adjust the amount of batter according to field conditions.

Vertical Alignment Check - During construction, check the overall verticality of the structure using a plumb bob. This should be done on panels completely backfilled. Make any changes in batter necessary to assure that final verticality is within tolerances (see specifications), in subsequent lifts of panels.

Erection Tolerances

- Refer to the project specifications for Owner specified tolerances.
- The overall vertical alignment tolerance, or plumbness, from top to bottom of the structure, shall not exceed $\frac{3}{4}$ -in., per 10 ft. of height.

Vertical and horizontal alignment tolerance, and plumbness, shall not exceed $\frac{3}{4}$ -in. when measured with a 10 ft. straight edge on a selected wall section. Vertical and horizontal alignment should be checked at every course throughout the erection process.

- The maximum allowable offset between any two panels shall not exceed one inch.
- Horizontal and vertical joints should be uniform in appearance. The target joint width is $\frac{3}{4}$ " \pm $\frac{1}{4}$ ".

Corrective action should be taken immediately when any of the specified tolerances are exceeded.

B. Foundation Preparation

Step B-1: Excavation - Excavate the site to the depth and width specified on the Plans for the length of the section to be built. Remove all unsuitable material and replace it, as necessary, with compacted fill as directed by the Engineer.

If required by the Specifications and as directed by the Engineer, proof-roll the foundation to a density suitable for the bearing pressure shown on the Plans. In the event of an over-excavation of the sub-grade, the Engineer must approve the gradation, placement, and compaction of replacement material.

Evaluation and approval of foundation suitability is the responsibility of the Engineer. Any foundation soils found to be unsuitable shall be removed and replaced with material approved by the Engineer. The material shall then be compacted, as directed by the Engineer, to a density suitable for the bearing pressure as shown on the Plans, Specifications, and Contract Documents.

Foundation evaluation and control are critical; the behavior and performance of a Retained Earth structure is largely dependent upon the foundation on which the reinforced volume is placed.

Step B-2: Drainage System(s) - Install any drainage system(s) as required by the Plans and Specifications or as directed by the Engineer.

Step B-3: Leveling Pad - A smooth finish unreinforced concrete leveling pad is formed and cast at each foundation elevation. Leveling pads have nominal dimensions of 6-in. thick by 1 ft. wide and are cast using a minimum 2,000-psi, 28-day compressive strength concrete. Leveling pads should cure for a minimum of 12 hours before the setting of panels.

Leveling pads must be cast to the design elevations as shown on the Plans. The allowable elevation tolerances are +0.01 ft (1/8-in) and -0.02 ft. (1/4-in.) at design elevation.

Precast leveling pads may be utilized depending on project specific design requirements.

An improperly placed leveling pad can result in subsequent panel misalignment and decreased wall construction productivity.

If the Plans call for the structure to have a step in elevation, pour the higher leveling pad as indicated on the Plans. Leave a 6-in typical (9-in maximum) gap between the higher pad and the centerline of the joint of the last panel of the lower course (Figure 15).

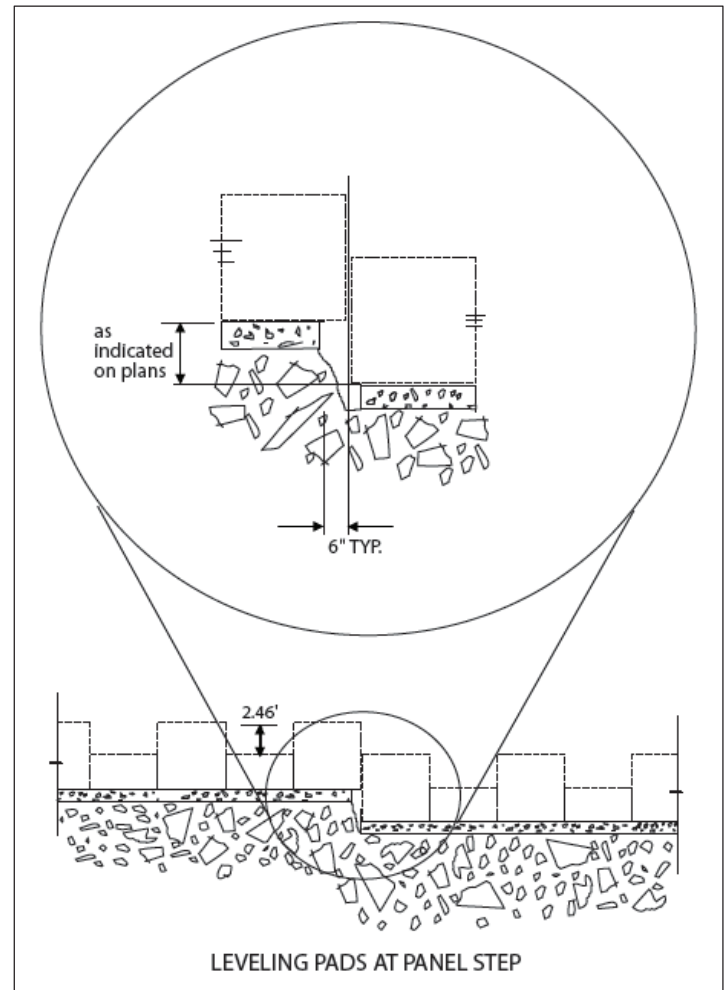


Figure 15

Step B-4: Wall Layout Line - On the leveling pad establish a layout line for the front face of the structure. This may be different than the wall's layout line given in the contract documents.

C. Erecting the Initial Panel Course

Step C-1: Panel Placement - Panel layout usually begins at the lowest leveling pad or a fixed point such as a corner or existing structure (Figure 16). Place the first panel [1], this may be a full or half height panel, on the leveling pad. Check the horizontal level and shim as needed. Align the face of the panel along the layout line; and using bracing in addition to wooden wedges at the base of the panel, set the batter for the panel.

Brace the initial course of panels by securing an adequate lumber brace to each full height bottom panel in excess of 3 ft. in height and two adequate lumber braces to each panel in excess of 6'-6" in height (Figures 18 and 19). Bracing may or may not be required on subsequent courses based on site conditions.

Throughout construction it is of utmost importance that the panel type and number of clevis loops of each panel match the requirements as shown on the approved Plans.

Bearing pads are not used under the first course of panels between the leveling pad, unless specifically shown on the Plans or separately authorized in writing by The Reinforced Earth Company. If needed, only rubber shims may be used to shim between the leveling pad and first course of panels. Permanent wood shims are not permitted at any point in the structure.

Panels must be braced as shown in Figures 18 and 19 prior to releasing the crane from the panel. Bracing must remain in place until all braced panels have had their Two-Wire ladders attached and have been backfilled and compacted up to the top of the braced panels.

Step C-2: Second Panel Placement - Place the second panel [2] on the leveling pad and place a spacer to create a joint $\frac{3}{4}$ -in. wide between it and panel [1] (Figure 16). Spacers must be used during panel erection. Spacers are supplied by the Contractor and may be fabricated from any available material.

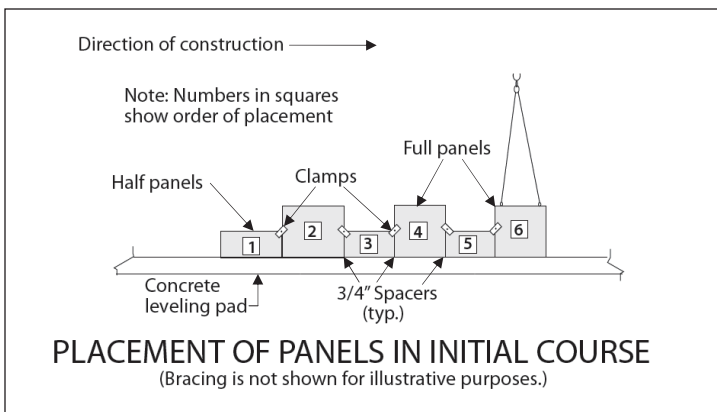


Figure 16

Step C-3: Setting Panel Batter - Set the panel's batter as before. Clamp the panel to panel [1] as shown in Figure 17. Tighten clamps sufficiently to hold the panel in position without movement.

Wooden wedges may be used at the base of the panels to temporarily set batter in the initial course of panels. These wedges must be removed during subsequent construction.



Figure 17



Figure 18

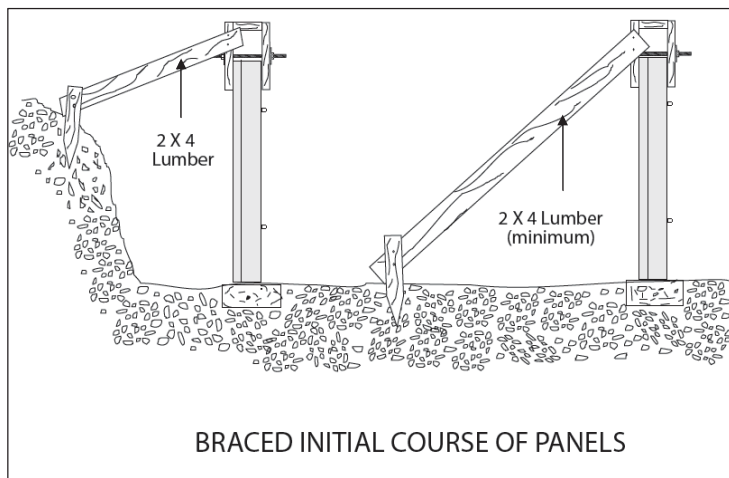


Figure 19

Step C-4: Place a third panel [3], aligning the panel with the control line and use a spacer to ensure 3/4-in. spacing. Check the horizontal level of the panel and shim as necessary. Set the panel's batter.

Step C-5: Continue setting the panels in this manner and site back along the tops of the full height panels to assure that each new panel is at the elevation of the others in that course (Figure 13). After ten panels have been set, recheck the wall's alignment by sighting along the wall face. Adjust panels if needed to obtain a true line.

D. Joint Materials

Joint materials are installed from the backfill side of the structure only. Geotextile prevents the loss of fine backfill particles while allowing the structure to be free draining. Bearing pads prevent concrete-to-concrete contact between facing elements vertically.

- Geotextile is affixed to the backfill side of both the vertical and the horizontal panel joints (Figure 20) using several dabs of a contact adhesive.

The adhesive provides a temporary attachment for the geotextile and should be used sparingly. It is not recommended that the geotextile be glued solid to the back of the panel. Geotextile is not generally required at the base of the wall where the panel rests on the leveling pad.

- Bearing pads are placed on top of each panel. Thickness and/or quantity at various levels within the structure may differ and must be in strict accordance with the Plans. Bearing pads should be placed a 1/4" back (clear) from the panel lip.

Bearing pads are designed to compress during the construction process. The initial joint created by the bearing pads may decrease in size when the wall is completely constructed.

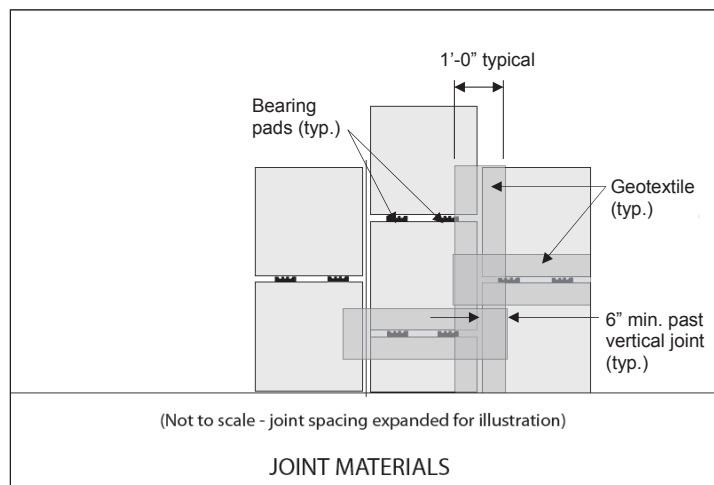


Figure 20

E. Backfilling

The constructability and performance of a Retained Earth structure directly relates to the quality of the Select Granular Backfill and to the manner in which it is installed.

Prior to placing the Select Granular Backfill, the Contractor shall certify to the Engineer that the material conforms to the requirements stated in the Plans, Specifications, and Contract Documents for Retained Earth structures.

Select Granular Backfill material to be used in the reinforced volume must be tested and shown to strictly conform to the Specifications. Material which does not conform to the specifications cannot be used as Select Granular Backfill.

The gradation of the Select Granular Backfill should be tested periodically during construction to assure compliance with the Specifications. This gradation testing should be performed for every 2,000 cubic yards of material placed and/or whenever the appearance or behavior of the material noticeably changes.

Immediate gradation and moisture testing is required if either excessive panel movement or backfill pumping occurs during construction.

Step E-1: Place and compact initial lifts of Select Granular Backfill up to bottom row of panel clevis loops. In order to avoid pushing the braced panels out of alignment, initial lifts of backfill are neither placed nor compacted against the back of the panels (Figure 21). Note that the loose thickness of each lift of backfill material must not exceed 1 ft. The level of the compacted backfill should be 2+ inches above the clevis loops as shown in Figure 22.

Connect the first layer of Two-Wire ladders to the clevis loops on the panel as detailed in Section F, place a lift of backfill, and compact over the ladders. Only then can backfill then be placed and compacted against the back of the panels illustrated in Figure 23.

After compaction has taken place, check wall alignment visually and with a level. If required, adjust panels as necessary. Depending on site conditions, realigning panels may require reconnection to the lifting equipment.

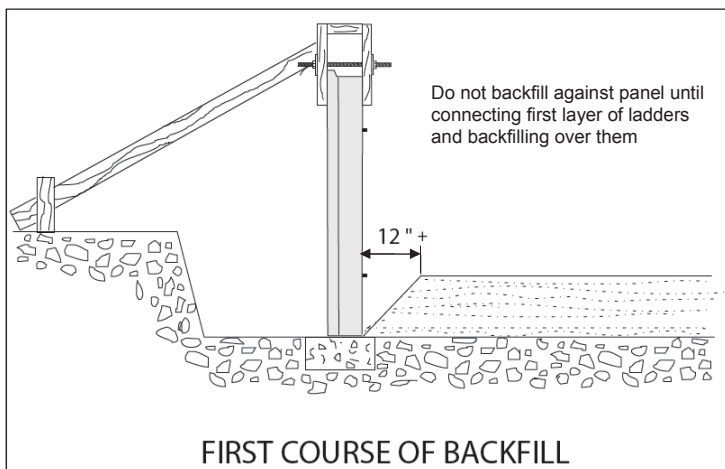


Figure 21

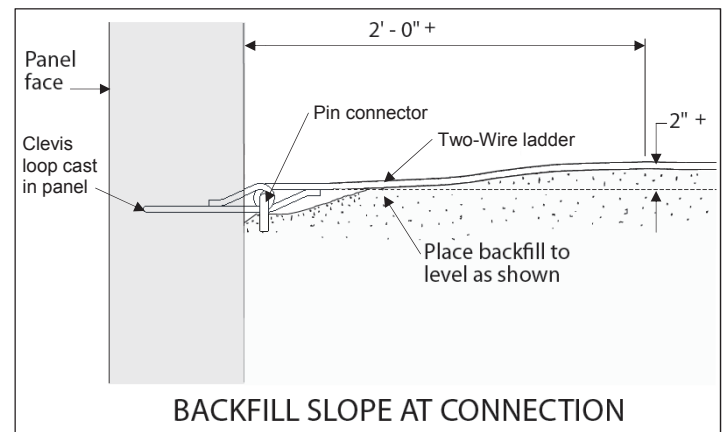


Figure 22

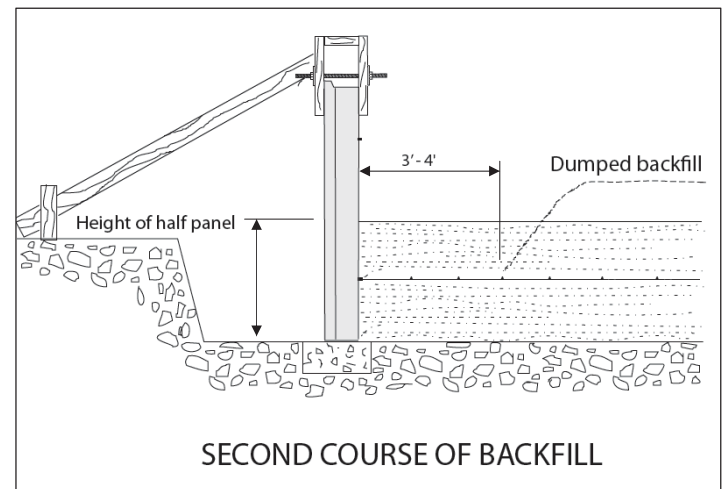


Figure 23

Step E-2: Compaction - Large smooth-drum vibratory rollers are used to accomplish mass compaction of Select Granular Backfill materials, except for fine uniform sands.

Sheep foot Rollers are never to be used for compaction of Select Granular Backfill.

Fine uniform sands, which contain more than 60 percent passing a No. 40 sieve used for Select Granular Backfill, must be compacted using a smooth-drum static roller.

Vibratory compaction equipment should not be used to compact fine uniform sands.

Compact each backfill lift using a large smooth-drum vibratory roller except within a 3 ft. zone directly behind the panels. In this area, a small hand-operated vibratory compactor must be used to avoid undue panel movement.

Compaction within 3 feet of the back face of the panels shall be achieved by at least three passes using a lightweight mechanical tamper, roller or vibratory compactor. Compaction testing should not be performed in this 3 foot zone.

At a minimum, Select Granular Backfill material must be compacted to 95% of maximum density, per AASHTO T-99, methods C or D (with oversize correction as outlined in Note 7 in AASHTO).

The minimum frequency of compaction testing shall be one test per lift of Select Granular Backfill material placed. Test locations are determined by the Engineer.

If 30% of the Select granular Backfill material is greater than $\frac{3}{4}$ -in. in size, AASHTO T-99 is not applicable. For such material, the acceptance criterion for compacting is either a minimum of 70% of the Relative Density of the material as determined by ASTM D-4253 and D-4254, or a Method Specification based on a test compaction section which defines the type of equipment, lift thickness, number of passes of the specified equipment and placement moisture content.

Moisture content of Select Granular Backfill material during placement should be approximately 1% to 2% less than its optimum moisture content.

Step E-3: Grading - At the end of each day's work, backfill must be graded to slope away from the back of the panels in order to divert water runoff from the structure area.

Failure to properly grade the backfill can result in erosion or excessive water in the Select Granular Backfill and cause subsequent movement of the panels beyond alignment tolerances.

F. Two-Wire Ladders

Step F-1: Place Two-Wire ladders on the compacted backfill. Position ladders perpendicular to the facing panels, unless otherwise shown on the Plans. Two-Wire ladders are supplied in standard lengths as shown on plans.

Connect each Two-Wire ladder to two embedded clevis loops by inserting both ends of the Two-Wire ladder into the gap between the two exposed ends of the clevis loop. Align the loops, push the pin through both sets of loops, and then bend the straight end of the pin to secure. To remove slack from the system install a small wedge between the panel and the ends of the Two-Wire ladder within the clevis loop (Figure 24).

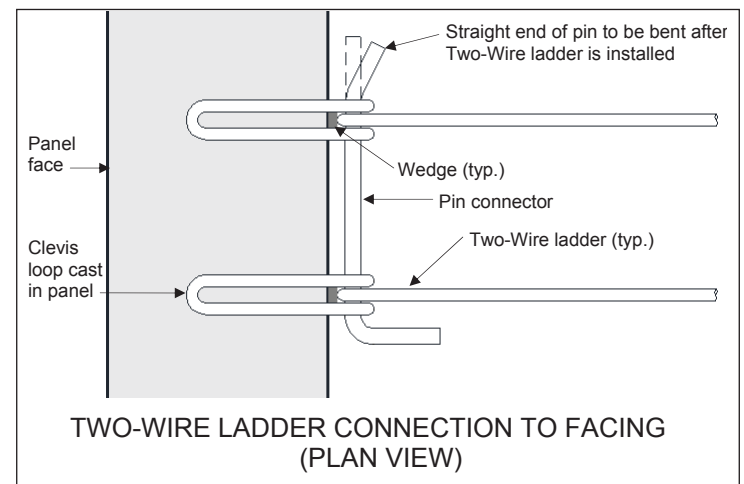


Figure 24

Two-Wire ladders are designed to be placed perpendicular to the back of facing panels. However, in specific, limited situations, it may be necessary to skew a Two-Wire ladder in either the horizontal or vertical plane. Refer to specific wall plans for details.

Design of the Retained Earth structure is based on the perpendicular placement and connection of Two-Wire ladders (unless otherwise detailed on the Plans) along with installation of the correct density and length of ladders to each panel.

The placement of any Two-Wire ladder in a skewed manner, unless detailed on the Plans, Specifications, and Contract Documents, must be authorized in writing by The Reinforced Earth Company prior to placement in the field.

Step F-2: Dump backfill onto the Two-Wire ladders so that the toe of the backfill pile is 3-4 ft. from the panels. Spread the backfill by pushing the pile parallel to the panels and windrowing it toward the panels and toward the free end of the ladders. If ladders are long, a second load may be required to backfill to the ends. If so, dump and spread this load only after spreading the first. Continue to backfill to the full height of the half panels (Figure 23).

Earthmoving equipment should not come in direct contact with the Two-Wire ladders.

Step F-3: Step: If required to make a step in elevation of the wall, use the following procedure.

Transfer the wall layout line from one leveling pad to the next to establish a wall-face control line. Place the next required panel along the control line, space $\frac{3}{4}$ -in., set its batter and brace if necessary. Then continue construction of the upper course using the procedure used on the lower level.

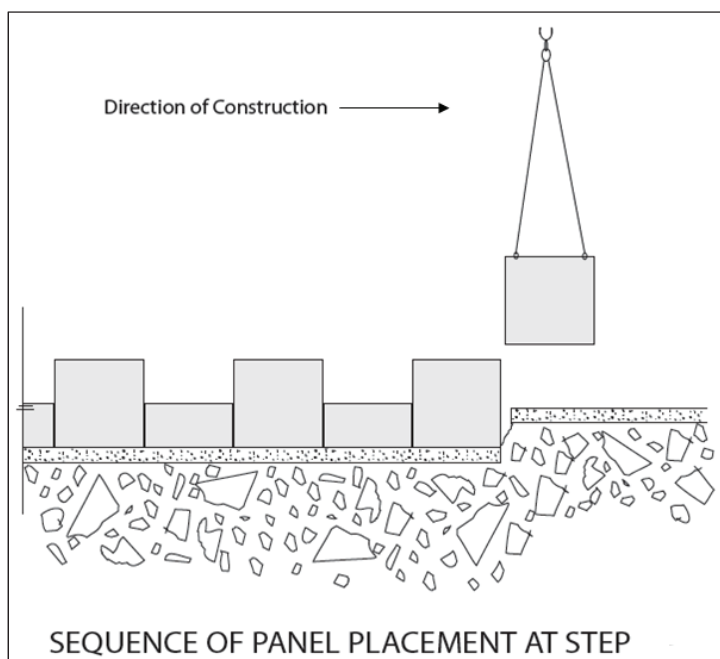


Figure 25

G. Constructing Second and Subsequent Courses

Step G-1: Only after compacted backfill has reached just below the top of the half panels can construction of the second course begin. Throughout construction, panels should only be set after backfilling and compaction to grade has been completed.

Removing the clamps from a panel or placing any panel atop a panel, which has not been completely backfilled can create an unstable situation, can lead to misalignment of panels, and is strictly prohibited.

Begin the second and subsequent courses of panels at the end of the wall where construction began (Figure 26).

Step G-2: Remove the clamps holding the full height panels [1] and [3] to the half-height panel [2]. (As each course proceeds, remove only two clamps at a time to allow for setting of each new panel. Clamps should not be removed prior to complete backfilling of the affected panels.) To prevent concrete-to-concrete contact at horizontal joints, set bearing pads onto the top edge of panel [2]. Allow for $\frac{1}{4}$ " clearance between bearing pad and back of panel lip.

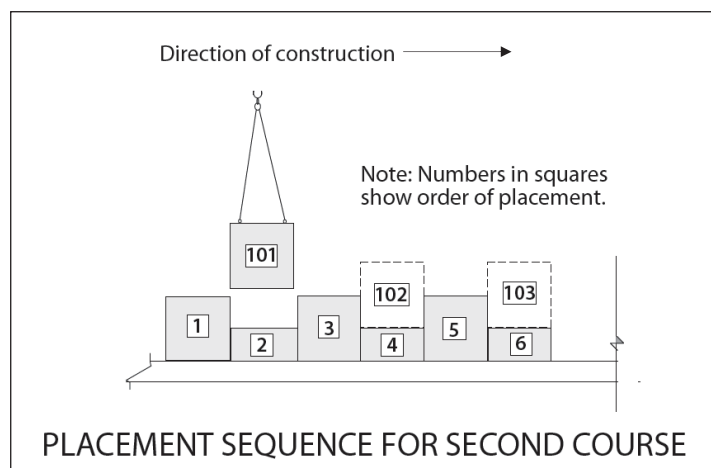


Figure 26

Step G-3: Set the full height panel [101] onto the half height panel [2] (Figure 26), center the panel to ensure equal vertical joints and match the panel's front face to that of panel [2]. Set the batter of the panel as described for the panels of the first course and clamp the full height panel [101] to the initial course panels [1] and [3].

Don't over-tighten the clamps as they may remove the batter just set in the panel.

Step G-4: Remove the next pair of clamps; place bearing pads onto the half panel [4]; and set the full height panel [102] onto it. Center the panel to assure equal vertical joints. Match the face of the panel just placed to that of the panel below, and set its' batter. Clamp the panel [102] to adjacent panels [3] and [5].

Continue to set full height panels in the same sequence. As work proceeds, check the wall's alignment frequently. Install joint material as in Step D-1.

Step G-5: When the course of panels is complete and after vertical and horizontal geotextile has been installed, place backfill in compacted lifts according to the Plans, Specification, and Contract Documents to 2-in. above the clevis loop level. Figure 27 illustrates the sequence for backfilling the second and subsequent courses.

Step G-6: After backfilling, recheck the batter and alignment of the wall, then place and connect the next layer of Two-Wire ladders as in step F-1.

Step G-7: Backfill to just below the top of the full height panels of the initial course. Only now can the bracing be removed. After backfilling to just below the top of the full height panels, the panels should be almost vertical. If not, adjust the amount of batter in the second course so that the third row will become vertical after backfilling.

At this point, it is possible to begin placement and compaction of part or all of a berm or embedment at the lower front surface of the structure (Figure 28). The spacers and wedges at the base of the wall must be removed prior to placing this material.

Retained Earth structures with a leveling pad at or above existing grade requires placement of an earth berm as toe protection along the face. Structures with a leveling pad below existing grade require the placement of an embedment in front of the wall. The height of the berm or depth of embedment is shown on the Plans.

The berm or embedment must be placed immediately to prevent erosion before the wall reaches 50% of its height or 20ft, whichever is less.

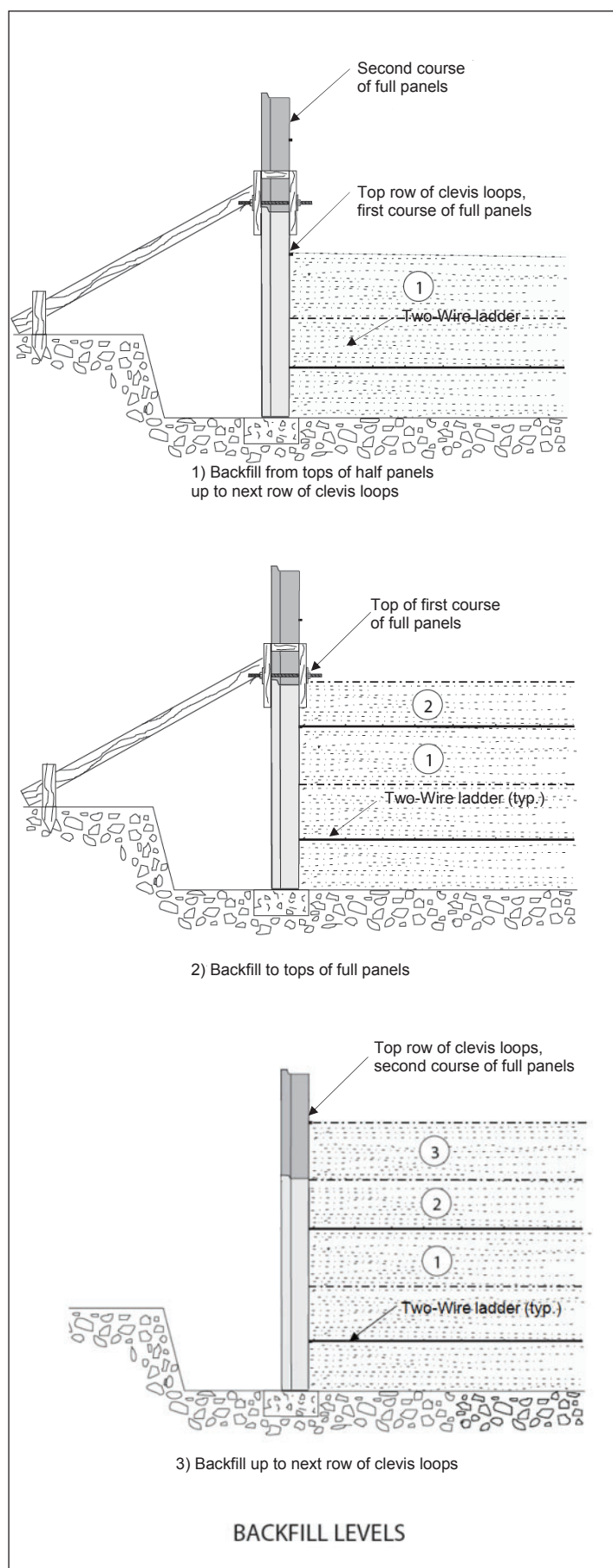


Figure 27

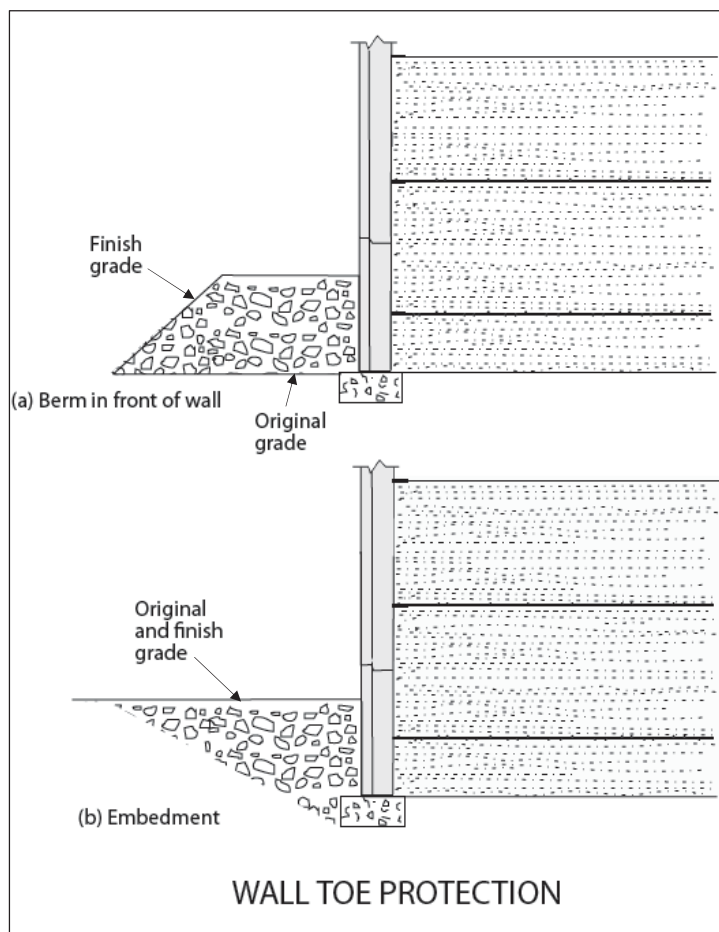


Figure 28

Step G-8: When backfill reaches just below the top of the initial course of full panels (which is halfway up the second course), begin placing the next course of panels.

Repeat steps G-1 through G-5 for panel installation; backfill placement and compaction, Two-Wire ladder installation, bearing pad placement, and horizontal/vertical geotextile placement. Follow these same procedures for the second and subsequent panel courses until the structure is ready to be topped off. Bracing may be used on all subsequent courses, if practical, to assist with maintaining batter and wall alignment as well as providing additional stability to the structure during the construction process.

Quality control requirements for Select Granular Backfilling, including density and placement moisture, are the same for the second and subsequent courses as for the first course, unless otherwise indicated in the Plans or Specifications.

Panel batter should be checked after backfilling each course with necessary adjustments made in subsequent courses to ensure plumbness.

After the erection of each course of panels, the wooden wedges of that course and the two courses below it should be checked to ensure that they are securely seated.

At least two, but no more than three rows of panel wedges should remain in place at all times during erection. When construction is complete, all wedges must be removed.

H. Completion of the Wall

Step H-1: In placing top course panels, the construction sequence continues as previously outlined. Note that, top course panels have either a level or a sloping top and will be supplied in varying heights to meet finished-elevation requirements. They may also have special geometry details or rebar sticking out for cast-in-place items.

Special care should be exercised in placement of top panels exceeding 6 ft. in height. Depending on site conditions, it may be necessary to brace top panels, particularly in high wind and inclement weather conditions. Refer to the Plans for the location of specific top panels.

Step H-2: After backfilling is complete, remove all clamps and wooden wedges from the structure.

Step H-3: Install top wall treatment. If required. Several types are commonly used:

- **Cast-in-Place** - If required, rebar for connection will protrude from top panels. All necessary attachment details for a barrier, coping, parapet, or paved ditch will be shown in the plans.
- **Precast Coping** - If required, rebar for connection will protrude from top panels. Any attachment details will be shown in the Plans.
- **Plain** - The top of panels will remain exposed. Lifting insert locations should be filled with non-shrink grout.

VI. Condition-Cause Relationships

Retained Earth structures are to be erected in strict compliance with the structural and aesthetic requirements of the Plans, Specifications, and Contract Documents. The desired results can be achieved through the use of quality materials, correct construction procedures, and proper inspection. However, considering the nature of construction work, there may be occasions when dimensional and construction tolerances and/or aesthetic limits are exceeded. Corrective measures must be taken immediately to return the structure to acceptable tolerances.

CONDITION

CAUSE

| | |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1. Distortion in Wall - During Panel Placement <ul style="list-style-type: none"> • First course difficult to set and/or maintain level. • Panel-to-panel contact, possible spalling/chipping. | <ul style="list-style-type: none"> a) Leveling pad not within tolerance. b) Backfill saturated (heavy rain or improper grading of backfill after each day's operation). |
| 2. Distortion in Wall - After Panel Placement <ul style="list-style-type: none"> • Differential settlement or low spot in wall • Overall wall leaning • Panel-to-panel contact, possible spalling/chipping. | <ul style="list-style-type: none"> a) Foundation (subgrade) material too weak or wet for proper bearing. If fill material, poor quality or improper compaction. b) Backfill saturated (heavy rain or improper grading of backfill after each day's operation). |
| 3. Wall Leaning Out | <ul style="list-style-type: none"> a) Panels not battered sufficiently. b) Large backfill placing and/or compaction equipment working within 3-ft. zone of back of wall. c) Backfill material placed wet of optimum moisture content. d) Backfill contains excessive fine materials (beyond the Specifications for percent of materials passing a No. 200 sieve). e) Backfill material pushed against back of wall before being compacted on Two-Wire ladders. f) Excessive or vibratory compaction on uniform fine sand (more than 60 percent passing a No. 40 sieve). g) Backfill material dumped close to free end of Two-Wire ladders, then spread towards back of wall, causing bulge in ladders and pushing panel out. h) Wedges not seated securely. i) Clamps not tight. j) Excessive compactive effort. k) Excessive backfill lift thickness. l) Plasticity index of backfill material in excess of specifications limits. m) Subgrade settlement. |
| 4. Wall Leaning In | <ul style="list-style-type: none"> a) Excessive batter set in panels for Select Granular Backfill material being used. b) Inadequate compaction of backfill. c) Subgrade settlement. |
| 5. Panels Do Not Fit Properly in Intended Locations Resulting In Possible Panels Spalling or Chipping | <ul style="list-style-type: none"> a) Panels are not level. a) Differential settlement (see Condition 2). b) Failure to space the panels properly. c) Leveling pad incorrect. |

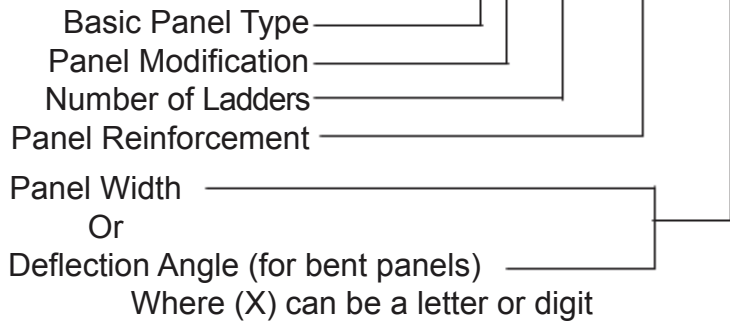
VII. Appendix

A. Facing Panel Types and Nomenclature

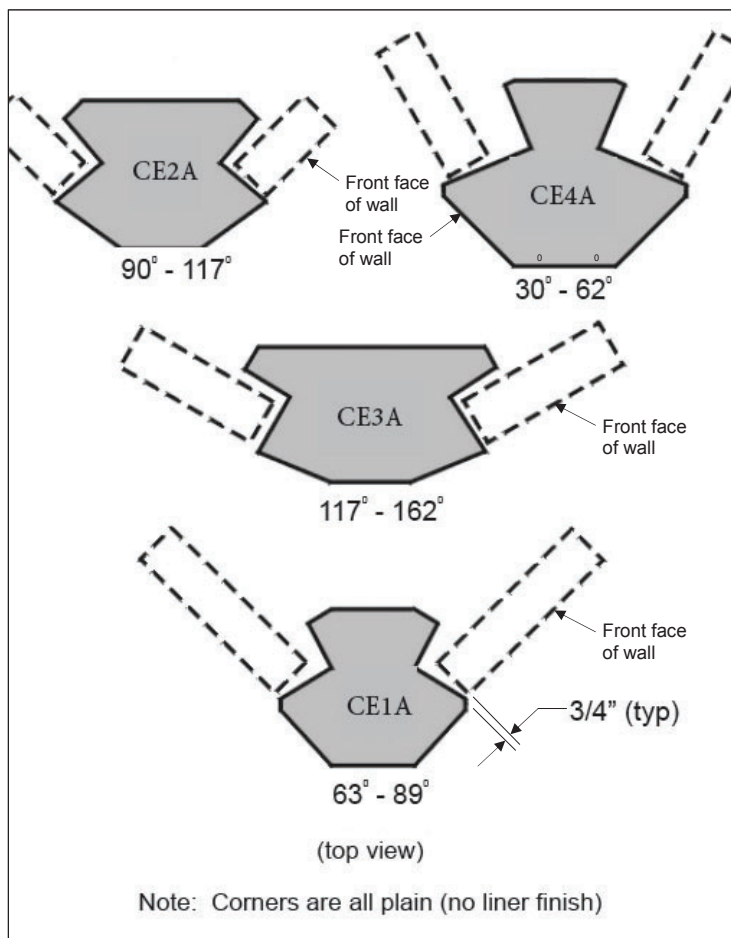
A. Panel Designations: All design and/or shop drawings, and precast panels, are designed as follows:

Key to Panel Designation:

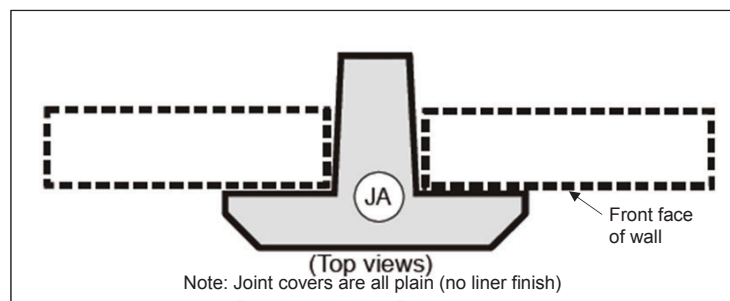
XX – X – RX – X.XX



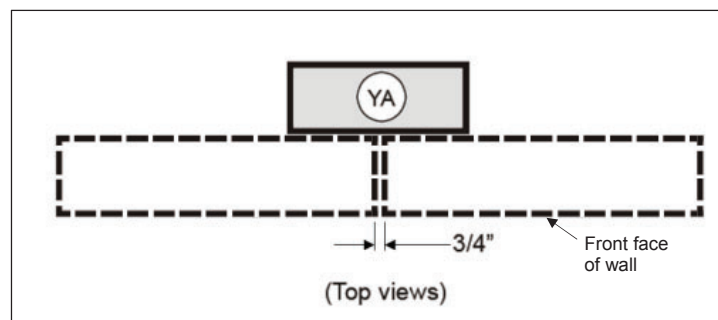
B. Corner Elements: Corner elements are designed to accept vertical cut panels and cover a range of angles. The corner element designations are CE1A, CE2A, CE3A, and CE4A for a standard 'A' height panel (other panel heights are available). Corner element details and shape may vary. Refer to the Plans and Specifications.



C. Slip Joint Cover: Slip joints are designed to accept vertical cut panels, provide system flexibility, and/or accommodate rapid changes in elevation. The slip joint cover designation is JA for a standard 'A' height panel (other panel heights are available).



D. Back-Up Panel: The back-up panel is also designed to accept vertical cut panels, provide system flexibility, and/or accommodate rapid changes in elevation. The cut panels are assembled with a 3/4-in. butt joint. The back-up panel designation is YA for a standard 'A' height panel (other panel heights are available).



B. Glossary of Terms

| | |
|---------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Agency | The person(s), firm, or corporation acting as Agent for the Owner. |
| Contract Documents | The Owner-Contract agreement, including the conditions of the Contract (general, supplementary, and other conditions), the drawings, Specifications and the provisions of the agreement between the Contractor and The Reinforced Earth Company; and also including all addenda issued prior to execution of the Contract, all modifications thereto and any other items specifically stipulated as being included in the Contract Documents. |
| Contractor | The individual, firm or corporation undertaking the execution of the Work under the terms of the Contract, and acting directly through its Agents or employees. |
| Engineer | The person(s) designated by the Owner, as having authoritative charge over certain specific engineering operations and duties. |
| Inspector | The authorized representative assigned to make a detailed inspection of any or all portions of the Work or materials thereof in the Owner's behalf. |
| Owner | The Owner of a project. The agency, person, firm or corporation with which a Contract has been made for the payment of the Work performed under the Contract. |
| Plans | The official approved plans, profiles, typical cross sections, working drawings and supplemental drawings, or exact reproductions thereof, which show the locations, character, dimensions and details of the Work to be performed. |
| Specifications | A description, for contract purposes, of the materials and workmanship required in a structure(s), as also shown on the related working drawings. The written material containing the standard provisions and special provisions, as may be necessary, pertaining to the quantities and qualities of materials to be furnished under the Contract. |
| Technical Advisor | Representative of The Reinforced Earth Company who may be available to assist the Contractor with material scheduling and coordination, and give advice on the recommended construction procedures applicable to Retained Earth structures as set out in this manual. |
| Work | The entire scope of the Work to be performed at the site of the construction project including labor, materials, equipment, transportation and such other facilities as are necessary to fulfill all obligations under the Contract. |

C. Safety Tips for Unloading Reinforced Earth Products

1. Upon arrival of truck, examine the load for any shifting or unstable conditions prior to removing tie downs.
2. The truck should be on level ground when unloading. Unloading on unlevel ground could result in shifting of panels/materials or possibly panels/materials falling from trailer.
3. Lifting equipment (straps, cables, ring clutches, etc.) should be checked for excessive wear or cracking prior to unloading truck.
4. Do not move the tractor while product is not tied down.
5. If drivers are required to remove tie downs next to lane of moving traffic, cones and flagman should be used to direct traffic away from the trailer and driver.
6. Drivers are not trained as riggers or swampers and should stay in cab or clear away from unloading operations. The drivers are acting in a delivery capacity only.
7. Personal protective equipment required by the general contractor on site should also be available and required to be worn by the delivery drivers.
8. Personnel should not be allowed under a suspended load.
9. Once removed from the trailer, panels/materials not placed directly in the wall should be stacked or secured on flat ground to prevent tipping or falling.
10. Areas between the truck and crane should be restricted to personnel required to unload trailer.
11. If any unsafe situations exist while loading or unloading RECo products, contact The Reinforced Earth Company immediately to eliminate any hazards or exposure to illness or injury.

D. The Reinforced Earth Company Offices

The Reinforced Earth Company maintains full-service offices throughout the United States. Contact the office serving your area for technical service:

| | | |
|--------------------------------------------|-----------------|----------------|
| Southeast Region | Atlanta, GA | (770) 242-9415 |
| Northeast Region | Boston, MA | (978) 664-2830 |
| Central Region | Dallas, TX | (817) 283-5503 |
| Midwest & Great Plains Region | Chicago, IL | (630) 898-3334 |
| Southwest Region | Los Angeles, CA | (949) 427-3601 |
| Western Region | Denver, CO | (303) 790-1481 |
| Central-Northeast & Mid-Atlantic Region | Sterling, VA | (703) 547-8797 |
| Florida Region | Orlando, FL | (407) 226-2840 |

Corporate Headquarters
The Reinforced Earth Company
45610 Woodland Road, Suite 200
Sterling, VA 20166

Telephone: (703) 547-8797 or (800) 446-5700

www.reinforcedearth.com