Reinforced Earth wall Construction Manual

Concrete Facing

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PART I: INTRODUCTION

Reinforced Earth is a composite material formed by the association of a frictional soil and reinforcement strips. In concept, it is like reinforcing concrete; that is, it is an economical means of improving the mechanical properties of a basic material, earth, by reinforcing that material with another, steel.

Stresses produced within the soil mass are resisted by the strips. The stresses are transferred to the strips by friction.

A Reinforced Earth structure constructed using this material is shown as the “reinforced volume” in figure 1 below. Concrete facing panels are used at the face of the reinforced volume to prevent erosion of the backfill and to provide an attractive, finished appearance.

COMPONENTS

Reinforced Earth structures consist of the following:

Concrete Levelling Pad
A 150mm deep by 350mm wide pad of unreinforced concrete that serves as a flat starting surface for placing panels.

Precast Concrete Facing Panels
- Full size or “A” panels are used for the majority of the wall. The subscript “4” in panel designations is the number of reinforcement strip connections (tie strips) per panel.
- Alternating panels in the initial course are half height or “C’” panels.

Top course panels are designated “B”, “D”, “E”, “F”, “3”, “4”, “5”, “6”, “7”, “8” panels. These panels have a flat top and vary in height to provide a smooth surface at the top of the structure.

Joint Materials
- Rubber bearing pad, 100mm x 85mm x 20mm thick for the horizontal joint.
- Filter cloth (250mm minimum width) glued to the rear face of RE panels at joints or polyester foam strips 40mm square for vertical and horizontal joint.

Reinforcement Strips - The reinforcement strips are supplied in sizes and lengths determined by the design of the structure. The strips are generally hot dip galvanised and are designed to be bolted to the tie strips embedded in the back of the facing panels.

Galvanisation may not be required for temporary structures.

Fasteners - Reinforcement strips are connected to facing panels with Grade 8.8 bolts and nuts of appropriate size.

Backfill - Backfill conforming to contract specifications must be used within the reinforced volume.

MATERIALS AND SERVICES SUPPLIED BY REINFORCED EARTH

- Engineering and design of the structure
- All facing panels
- All reinforcement strips
- All nuts, bolts and washers
- Delivery of all construction materials to the site
- On site technical assistance
- One set of lifting device (on loan)
- Two spacer bars (on loan)
- Installation of panels and reinforcement strips.

![Figure 1](image-url)
EQUIPMENT, TOOLS AND MATERIALS
SUPPLIED BY CONTRACTOR

Items to be Fabricated (figure 2)
- Kiln dried hardwood wedges, at least enough to provide 4 to 6 wedges per vertical joint for the length of wall under construction.
- Clamps, one per vertical joint for the length of wall under construction. More clamps may be used for bracing the initial course of panels.

Miscellaneous Tools and Small Items
- Nylon slings or four point cable lifts for unloading panels
- Bracing for first course of panels
- Crowbars and pinch bars
- 1200mm level
- Ratchet handle with 19mm socket
- Box or crescent wrench 19mm
- Claw hammers
- Sledge hammer
- Chalk line
- Brooms or brushes
- Plumb bob

WORK TO BE PERFORMED
BY CONTRACTOR
- Site preparation, including excavation
- Pouring of levelling pad
- Wall construction, including backfilling
- Concrete coping or traffic barrier

Basic Construction Procedure
- Pour levelling pad
- Set and brace first course of panels
- Spread and compact backfill up to lowest level of tie strips
- Bolt reinforcement strips to panels
- Backfill to top of half panels
- Set to second course of panels
- Repeat cycle of backfilling, connecting, strips, setting panels
- Set top panels
- Remove all wedges and clamps

Crew Size and Production Rates

A typical wall erection crew: average four men and a working foreman.

Construction rates for Reinforced Earth structures depend entirely on the rate at which backfill can be placed and compacted.

The daily production rate can be estimated follows:

1) Determine the average daily rate of backfill placement and compaction. Include random backfill as well as the select granular backfill within the reinforced volume.

2) Divide the backfill rate (expressed in volume per day) by the average width of backfill to be placed from the panels to the rear limit of backfilling. This determines the average area of wall that can be built in a day with the above backfill rate.

Experience has shown that a typical 5 man crew can construct 70 square metres of wall surface per 8 hour shift, providing that backfilling and compaction keep pace with panel and strip placement. If the anticipated wall erection rate is more than 70 square metres per shift, the crew can be increased by one worker per shift for each additional 15 square metres of wall erection. The maximum crew size is ten.

If the anticipated wall erection rate is less than 70 square metres per shift the crew can be reduced by one worker for every 15 square metres less than 70 square metres. The minimum crew is four.
PART II: HANDLING REINFORCED EARTH MATERIALS

FACING PANELS

Panel delivery. Before construction begins, the Contractor should establish a panel delivery schedule. This advance planning and scheduling will allow Reinforced Earth precasting operation to match the construction schedule.

Panels are usually delivered in stacks of four on flatbed trailers. The delivery point is made as near to the structure as the truck can be driven under its own power.

Unloading panels. Under normal conditions, one hour unloading limit is allowed for each delivery. In this time panels may be placed directly in the structure or stacked on the ground using any of the following methods.

1) by using lifting bracket and cast-in pin to handle the panels individually (figure 3a)
2) by using lifting device to handle the panels individually (figure 3a, 3b)
3) by using a four point cable lift (figure 4) to handle the panels individually, or
4) by using cloth or nylon slings to handle panels individually or in stacks (figure 5)

Care must be taken to protect the panels from damage during handling.

Panels can be stored by re-stacking on dunnage. Place the panels face down in line with the dunnage (figure 6). Panels should be stacked no more than six (6) high on firm level ground.
PART III: CONSTRUCTION PROCEDURES

SETTING AND POSITIONING PANELS

The finished appearance of a Reinforced Earth structure depends largely on the care taken in erecting and positioning facing panels. For this reason, particular attention must be given 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, rapid construction for the remainder of the structure.

Lift panels from the horizontal (stacked) position directly to the vertical position by attaching a lifting device the panel (figure 7). Use dunnage as blocking to prevent damage when rotating panels from horizontal to vertical. When placing panels, match the plastic dowel of one panel to the corresponding tube in the adjacent panel (figure 8).

Once a panel is lowered into place, gauge the correct distance between the new panel and the existing adjacent panel of the same course by setting a spacer bar into position between the panels (figure 9). The bar remains in place as the new panel is positioned.

A series of simple steps ensures proper panel position and alignment.

**Check alignment.** Visually check the alignment of the panel in relation to the control line on the levelling pad for the initial course of panels or to the panel below for subsequent courses. Make adjustment with a crowbar on the fill side of the panel (figure 10) so that the surfaces of successive panel are aligned. Do not attempt to adjust the panel by using the crowbar on the front side became unacceptable chipping or spalling may result.
**Check horizontal levels.** The horizontal level of the panels should be checked and adjusted to ensure uniform appearance and even joints throughout the structure.

As shown in figure 11, use a 1200mm level to verify that the panel is level. Then sight back along the tops of the panels to ensure that the panel is at the elevation of the others in the course.

Correct any variations by lifting the new panel and inserting wedges (initial course only) or adjusting the thickness of the horizontal joint material below. Recheck the horizontal spacing after any such adjustment.

**Set batter.** As shown in figure 12, panels must be given a slight batter toward the backfill to compensate for outward movement caused by backfill placement and compaction.

To maintain desired batter, drive the hardwood wedges into the short horizontal panel joints at the face of the wall (figure 13). Wedges for each course of panels should remain in place during the construction of three subsequent courses, then promptly removed. If wedges remain in place for more than three courses, they will be very difficult to be removed.

The amount of batter will vary and will depend on the type of backfill, required compaction, type of equipment, and length of the reinforcing strips. However, a batter of 10mm in 1500 mm is generally used as a starting point:

Monitor the actual movement of panels during the initial and early courses, and adjust the amount of batter to produce verticality.

During construction, check the overall verticality of the structure daily using a plumb bob. By adjusting wedges, make any adjustment to batter necessary to ensure that final verticality is within specified tolerances.
A. SITE PREPARATION

Step A-1: For the length of the wall section to be built, excavate to the depth and width specified on the contract drawings, remove all unsuitable material and replace it with compacted fill, where necessary.

Step A-2: Proof roll the foundation in accordance with project specifications.

Step A-3: Install drainage systems as required.

Step A-4: Pour concrete levelling pad. The pad should be cured for 12 hours, or longer if required by the contract specifications, prior to use. The concrete finish must be smooth and flat and must not vary from the design elevation by more than 5 mm in any 3000 mm in length.

When a step-up is required at the wall, pour the higher levelling pad to the required level and leave a 230mm gap between the new pad and the centreline of the dowel of the last panel of the lower course (figure 14).

Step A-5: Snap a chalk line on the surface of the levelling pad to establish a control line for the wall.

B. CONSTRUCTING INITIAL COURSE

Panel layout begins at the lowest levelling pad.

Step B-1: Place the first “C” (half) panel (1) on the levelling pad (figure 15). Align the face of the panel along the control line. Use 1200 mm level to set vertical and horizontal levels.

Step B-2: Place the second “C” panel (2) on the levelling pad. Align it with the control line, and set it the correct distance from panel (1) using the spacer bar. Leave the spacer bar in place. Check levels.

Step B-3: Place a third “C” panel (3) aligning the panel with the control line and using the spacer bar to ensure spacing. Check levels.

Figure 14

LEVELLING PADS AT STEP-UP

Figure 15

PANEL PLACEMENT
FOR INITIAL COURSE

Figure 16
Step B-4: Remove the spacer bar and set the first “A” panel (4) between the two half panels (1) and (2). Centre the panel to ensure equal vertical joints. Check horizontal level and prop vertical. Clamp the panel to panels (1) and (2) as shown in figure 16. Tighten clamps sufficiently to hold the panel in position without movement. The panel shall remain attached to the crane until it has been adequately braced or clamped to adjacent panels.

Step B-5: Place a fourth “C” panel (5) aligning the panel within the control line and using the spacer bar to ensure spacing. Check levels.

Step B-6: Remove the spacer bar and set the second “A” panel (6) between the two half panels (2) and (3), using the spacer bar to ensure the correct distance between the new “A” panel the previous “A” panel. Check horizontal level and prop vertical. Clamp the panel to the two adjacent half panels (2) and (3).

Step B-7: Continue along the wall alternating between placing half panels and full panels. Always remember to use the spacer bars to place panels and to always check that the panels are level. Bracing of the panels shall be as shown in Figures 17 and 18.

Step B-8: Install vertical joint material. Vertical joint material prevents the loss of fine backfill particles, while still allowing water to drain freely through the structure. To determine which material is used on a particular project, refer to project drawings and specifications. Always install joint materials from the backfill side of the structure. Either of the following materials is commonly used:

* Polyester foam supplied in 40mm square strips 2000 mm long, is used for all applications. Push the foam into the running vertical joints (including the short horizontal section) with a hardwood wedge or similar implement. Twisting the foam while pushing it into the joint can facilitate this process. No gluing is required.

* Geotextile cloth supplied in 250mm minimum width. Glue the cloth to rear face of the panels at horizontal and vertical joints (figure 19 and 20).

Step B-9: Begin backfilling. Place approved backfill up to the bottom row of panels tie strips (figure 21a) at 375mm per layer.

Backfilling can be compacted to within 1500mm of the panels by a large vibratory roller. A small hand operated compactor must be used within 1500mm of the panels to avoid undue panel movement.

Check wall alignment visually and with a level: adjust panels as necessary.
Step B-10: Place reinforcement strips on the compacted backfill. Position strip end into the tie strip gap, matching the holes (figure 22). Push a bolt through the holes from below; put a washer on top; and thread on a nut. Tighten the nut with a socket wrench to complete the connection.

Step B-11: Backfill to the full height of the half panels (figure 21b). Dump backfill onto the reinforcement strips so that the toe of the backfill pile is 1500 mm from the panels. Spread backfill by pushing the pile parallel to the panels and windrowing it toward the panels and toward the free ends of the strips (see figure 23). If strips are long, a second load may be required to backfill to the ends of the strips. If so, dump and spread this load only after spreading the first.

Metal tracks of earth moving equipment must never be in contact with the reinforcement strips. Rubber-tyred vehicles, however, can operate directly on the exposed strips.

Where because of the location of return walls, the reinforcing strips overlap at the same level, ensure that the strips are separated by at least 150 mm of select backfill.

If required, make a step-up in elevation at this point, using the following procedure:

Snap a chalk-line on the upper levelling pad to establish a wall face control line and ramset 100 mm x 50 mm x 200 mm timbers at each joint position.

Place a half panel on the control line, using the spacer bar to establish the proper distance from the last panel of the lower course.

Then set a full panel between the half panel and the last full panel of the lower course, placing it along the control line. Check the horizontal level and prop in vertical position (figure 24). Always make step-ups between a full panel of the lower course and a full panel of the upper course.
C. CONSTRUCTING SECOND AND SUBSEQUENT COURSES

Only after backfill has reached the top of the “C” (half) panels can construction of the second course begin.

Throughout construction always set panels at grade; never set a panel onto one that has not been completely backfilled. Begin the second and subsequent courses of panels at the end of the wall where construction began (figure 25).

**Step C-1:** Remove the two clamps holding “A” panels (4) and (6) to “C” panel (2). (As each course proceed, remove only two clamps at a time to allow for setting a new panel). To prevent concrete to concrete contact at horizontal joints, place 100mm x 85mm x 20mm thick rubber pad onto the top edge of the half panel (2) (figure 26).

**Step C-2:** Set “A” panel (101) onto “C” panels (2) (Figure 25) centering the panel to ensure equal vertical joints and matching panel’s front face to that of panel (2). Check the horizontal level and adjust if necessary.

**Step C-3:** Remove the next pair of clamps; place the rubber pad onto the half panel (3) and set “A” panel (102) onto it.

Check the horizontal level and adjust if necessary. Use the spacer bar to obtain the correct spacing between “A” panels (101) and (102). Leave the bar in place. 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 (6) and (8).

Set the batter of the panel by driving kiln dried hardwood wedges into the short horizontal panel joints at the face of the wall. A batter of 10mm in 1500mm is generally used as a starting point.

Clamp the new “A” panel (101) to the initial course panels (4) and (6) before detaching the panel from the lifting device.

**Note:** Numbers in squares show order of placement.

![Diagram](Figure 25)

**PLACEMENT SEQUENCE FOR SECOND PANEL COURSE**

![Diagram](Figure 26)

![Diagram](Figure 27)

**BACKFILL LEVELS**
Step C-4: Remove the next pair of clamps; place the 100mm x 85mm x 20mm thick rubber pad onto the half panel (5) and set “A” panel (103) onto it.

Check the horizontal level and adjust if necessary. Use the spacer bar to obtain the correct spacing between “A” panels (102) and (103). Leave the bar in place. Match the face of the panel just placed to that of the panel below and set its batter. Clamp the panel (103) to adjacent panels (8) and (10). Continue to set “A” panels in the same sequence using all three spacer bars supplied in a “leap-frogging pattern”. As the work proceeds, check the wall’s alignment frequently. Install vertical joint material, as in step B-8.

Step C-5: When the course of panels is complete and vertical joint material installed, backfill up to the tie strip level. Figure 27 shows the sequence for backfilling the second and subsequent courses.

Step C-6: After backfilling re-check the batter and alignment of the wall, then place and connect the next layer of reinforcement strips, as in Step B-10.

Step C-7: Backfill up to the top of the “A”(full) panels of the initial course. Remove the bracing from the initial course. At this point, construction of part or all of a berm, or backfilling in front of the wall, can begin (figures 28 and 29).

Reinforced Earth structures with a levelling pad at or above grade require placement of an earth berm as toe protection along the face. Structures with a levelling pad below grade require the backfilling of an embedment in front of the wall. The height of the berm or the depth of the embedment depends on the design height of the structure and is shown on the contract drawings. The berm or embedment must be placed either before the wall reaches 50% of its height or when it has reached a height of 5000mm whichever is less.

Step C-8: When backfill reaches the tops of the initial course of full panels (halfway up the second course), begin construction of the next course of full panels. Repeat steps C-1 through C-8, placing panels, spreading and compacting backfill and connecting reinforcement strips, for each additional course until the wall is ready to be topped off.

Note: When backfilling has reached the level of the top of the second row of “A” panel, check that the panels have become almost vertical. If they have not adjust the amount of batter so that the third row will be vertical after backfilling.

D. COMPLETION OF WALL

Step D-1: In placing the last or top course of panels the construction sequence continues as previously outlined. However, top course panels have a flat or a sloping top edge and may be supplied in varying heights to meet finished elevation requirements. The location of specific top panels is shown on the contract drawings.

Step D-2: After backfilling is complete, remove all clamps and hardwood wedges.

Step D-3: Install capping units if required.
PART IV: SUMMARY OF CONSTRUCTION PROCEDURES

A. PREPARE SITE
Step A-1 : Excavate site to depth and width specified on contract drawings
Step A-2 : Proof roll foundation
Step A-3 : Install drainage systems, as required
Step A-4 : Pour levelling pad
Step A-5 : Establish wall control line on levelling pad
Step A-6 : Place safety barrier or tape or safety cone near excavation site where appropriate

B. CONSTRUCT INITIAL COURSE
Step B-1 : Place first half panel
Step B-2 : Place second half panel
Step B-3 : Place third half panel
Step B-4 : Set full panel between half panels
Step B-5 : Place fourth half panel
Step B-6 : Set full panel between second and third half panels
Step B-7 : Brace bottom panels
Step B-8 : Install vertical joint material
Step B-9 : When course is complete, backfill to bottom row to tie strips
Step B-10 : Install first layer of reinforcement strips
Step B-11 : Backfill up to top of half panels

C. CONSTRUCT SECOND AND SUBSEQUENT COURSES
Step C-1 : Remove the first two clamps, place horizontal joint material
Step C-2 : Set full panel onto half panel
Step C-3 : Set second full panel onto half panel
Step C-4 : Set third and subsequent full panels onto half panel
Step C-5 : When course is complete, backfill up to next row of tie strips
Step C-6 : Check wall alignment and batter, then place next layer of reinforcement strips
Step C-7 : Backfill to top of full panels in initial course, remove bracing from initial course
Step C-8 : Repeat Steps C-1 through C-7 for each additional course

D. COMPLETE WALL
Step D-1 : Construct top course
Step D-2 : Remove all clamps and wedges from wall
Step D-3 : Install capping units, if necessary

E. APPENDIX 1
Machine, labour and equipment required
- 15T – 20T Vibratory roller
- Plate compactor 1 “baby” roller for compacting strips zone within 1500 mm from the rear face of the panel.
- 2 general works for trimming granular backfill around the rear face of the RE panel.