EVERGREEN®

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EVERGREEN MACRO MINIMUM REQUIREMENTS

Minimum Requirements for EVERGREEN WALLS

Concept

- Evergreen Requirements specify tasks and responsibilities of each activity in the team to design, produce, and erect Evergreen walls.
- Such tasks and activities are listed on separate pages, each one addressed to a specific function with the specific tasks.
- Hand out 'Evergreen Requirements' specific pages to each of the responsible persons.
- This set of 'Minimum Evergreen Requirements' summarizes decades of experiences – take advantage of it and do not try to make your own costly mistakes!

Functions and Persons	Responsible:
1. Design	Draftsman
2. Plans, Specifications and Notes	Engineer
3. Fabrication	Manufacturer
4. Site Preparation	Contractor, Site supervisor
5. Excavations and Foundations	Contractor
6. Transportation, Unloading, and Stockpiling	Trucker
7. Wall Erection	Contractor
8. Material Specifications	Engineer

1. EVERGREEN Minimum DESIGN Requirements

The following design instructions must be fulfilled for Evergreen wall projects:

MINIMUM SAFETY FACTORS	**for permanent loads** SF minimums are:		
	Code minimum	**Evergreen min.**	**Some DOT*min.**
SF sliding	= min. **1.5 - 1.6**	**min. 1.5**	min. 1.5
SF overturning	= min. **1.5 - 1.8**	**min. 1.7**	min. 2.0
SF bearing capacity (full)	= min. **2.0**	**min. 2.0**	(min. 3.0*)

Evergreen requests formally to increase minimum safety factors to levels set.
Experience shows, that the extra safety margin is of negligible additional cost.
* 3.0 is minimum for the (outdated) simple bearing capacity formula. The new AASHTO code uses set coefficients for additional issues. For this conservative approach min. is 2.0, some DOT*: 2.5.

For **exceptional surcharges** including **seismic loading** the safety factors are:

SF sliding	= min. **1.2**	(DIN = German code)
SF overturning	= min. **1.3**	
SF bearing capacity	= min. **1.3**	(DIN)

Wall friction angle delta at the back of the wall - Normally delta is 2/3 of phi for contact of soil against concrete. Since the back of an Evergreen wall is 53% concrete to soil and the remainder is soil against soil, the average wall friction theoretically is delta = 0.842 phi. For this reason the standard wall friction used is delta = 0.75 phi'**.**

Watch for rare cases –

- **Check 'Evergreen Design Table for Allowable Stresses and Moments'** for any project.
- The Evergreen software print shows for every Evergreen Macro design tray moments, **shear forces, and forces on cross legs V for the lowest Evergreen unit**, to be compared with the **allowable moments and forces** as given by this design criteria table.
- Obviously the project **design values should be well below allowable values**, which is normally the case.
- If the subsoil is deep clay, prone to long term consolidation under the load of the heavy gravity wall, the subsequent settlement of the wall itself may cause sliding of the wall along its back downward (negative wall friction!).
- Of course this effect reverses the standard wall friction and it may mean zero delta or even a negative delta value, up to delta = minus phi.
- It is easy to design for. However the wall will be much heavier and costlier.
- Thus it is **efficient and wise to remove such weak clay or provide deep foundations** not affected by consolidation settlement.

EQP - Equivalent Fluid Pressure is an American design method as found in the Navy Design Manual. The manual is specifically points out that EQP-method is for short walls only. Experience shows that too many designers are using that method and then use it even for seismic design, which ends up with extremely heavy gravity walls. EQP-method is not applicable for battered walls and is outdated and must be replaced by more rational methods such as Coulomb.

No cohesion for backfill - Professional rules and experience show that the development of cohesion in an artificial fill is not possible, except for a minimum cohesion of 0 - 0.08 ksf = 0 - 4 kN/m2. Thus using cohesion in a backfill is not quite appropriate. The exceptions are cuts in rock or firm clay, provided the gap between the back of the wall and the cut is less than 18 inches = 0.45 m. Otherwise the silo pressure build up in the gap is bigger than active earth pressure.

Maximum of 3 B -units - Any Evergreen wall should use **not more than 3 B-units**. The reasons are simple: (a) Filling and compacting inside of B-units is difficult; (b) Much of the fill is topsoil, with a weight much less; (c) Voids in B-units are very bad and affect stability more in bigger ones.

* DOT = Departments of Transportation, Highway Departments

2. EVERGREEN MINIMUM REQUIREMENTS for Plans, Specifications and Notes

These are minimum requirements for plans, specifications, and notes for Evergreen wall projects:

Typical Section - Each offer, bid, or wall design including set of drawings for final projects. Each one must include:

- A typical section showing the main features of an Evergreen wall and
- Notes explaining specifications and
- Erection instructions. (That is what engineers and contractors look at).

Soil Parameters - Final drawings must show soil parameters used for design calculations, for backfill, and for subsoil.

Only with the relevant soil parameters at hand the site supervisor can evaluate whether the materials seen on site are within design or worse.

Should he be unable to evaluate soil parameters (for friction angle, cohesion) he is and should feel obliged to call the soil engineer. That is a professional approach, which is encouraged by giving full design information to the site engineer.

Geology - A note on the drawings should say: **'Soil properties as found on site must be conveyed to design engineer for checking final design calculations.'**

Stamps for Preliminary - Wall designs based on assumed soil parameters use the following sticker or stamp: **'For preliminary use, not for construction, pending confirmation of soil properties'.**

This note clearly indicates that natural variations of soil properties are not within the risk of the engineer. It also means that in case of subsoil changes the wall design has to be revised and a change order entitles for extra payment.

Drainage: Remember the three most important issues in retaining wall design and construction are:

- Drainage of runoff water on the back slope,
- Drainage on the excavation face and
- Drainage pipe at the heal of the wall.

Drawings have to show drainage facilities, such as

- water diversion at the top of the wall,
- geotextile cover over the excavation face,
- a drainage pipe at the heal of the wall and
- Free draining material within one foot of the first unit.

Drawings:

1. Prepare Evergreen wall elevation and plan view showing **stack numbers.**
2. **Start with number one at the lowest foundation elevation.**
3. Arrow to indicate **'start erection here'** for lowest foundation or corner.
4. Prepare typical section and various wall sections **showing each unit.**
5. Each stack must be numbered and **each unit must be specified by a letter.**
6. Custom made units are to be numbered: **stack #, unit type and layer #.**
7. Prepare **foundation plan view** with dimensioning for layout.
8. Prepare **foundation reinforcing drawing**.
9. Prepare foundation drawing with measuring lines and or coordinates of meeting points of stacks at joints to neighboring units.

3. EVERGREEN MINIMUM REQUIREMENTS

For Manufacturing Evergreen Units

Minimum Requirements for Fabrication of Evergreen Units are:

CONCRETE QUALITY - Concrete quality requirement for Evergreen walls is **5000 psi = 35 MN/m2** = 350 kg/cm2 compressive strength of concrete after 28 days. Walls along highways where road salts are used must be made using **air entrainment** for salt resistant concrete.

SPACERS - A very large number of spacers are necessary to ensure **proper concrete cover** of steel reinforcing, **minimum 1"1/4 = 30 mm.** Experience showed, that along the **front trays 8 spacers** are needed. Similarly **min. 3 spacers** are needed on the **front of the legs** and several along the sides of the legs. Walls erected a long time ago indicate that this is the most crucial point for long term quality performance of Evergreen walls.

STRIPPING OF UNITS FROM MOULDS - Stripping of the units is the hardest moment in the lifetime of Evergreen units. Special care must be taken to avoid any torsion stresses on the unit by having one corner still sticking. The efficient and safe method of stripping units from molds without fissuring is by means of **hydraulic jacks** operated simultaneously. Lift units with special lifting gear or long belts, steeper than 45° is required. Chains or steel cables around arms are not permitted.

STOCKPILING - The green units should be cured by keeping them away from cold temperature, from wind, and from direct sunshine for at least one day by keeping them **inside the fabrication hall or covered with plastic covers**. Units must be stored on a solid yard, leveled and firm, using wooden blocks at two (2) points (at corners) under one leg and at one (1) point (at center) under the other leg. This shimming prevents twist and distorted units after curing. Evergreen units are not designed for twist at all.

MAXIMUM NUMBER OF CRACKS - The Evergreen license agreement allows for a maximum of 5 fissures on 100 units installed on site. Many precasters demonstrated that this requirement is fulfilled regularly.

ERECTION INSTRUCTIONS - Each offer, bid, set of final drawings and each first delivery of units to site must also include **Evergreen Erection Instructions**. This requirement is to reduce product liability and to help the others involved to understand the special requirements from the very beginning. First delivery of Evergreen units without Erection Instructions is not permitted.

SITE INSTRUCTIONS AND SUPERVISION - The Evergreen representative must visit the site at the moment of first delivery of units for bringing an extra set of erection instructions as a legal requirement and for teaching the crew the handling of Evergreen units for stockpiling, erection, adjusting, filling and backfiring. This is to have the field crew know about Evergreen, learn about the tricks and hints and feel comfortable working with the big units and produce a lot at quality standards.

PREFABRICATORS RESPONSIBILITY - Many of these activities seem outside of the standard duties of the prefabricator. However the correct handling of the units in all phases brings the precaster and the Evergreen wall system the success needed. The clients do not order concrete units, **they order a 'system' and with that they mean help to make sure all goes well.**

4. EVERGREEN MINIMUM REQUIREMENTS for Site Preparation

The following **site preparations** are necessary before shipping Evergreen units to site:

1 - Confirm soil properties to design engineer for final checking of safety factors

2 - Have final erection drawings approved by authority as appropriate

3 - Have engineer confirm adequate safety factors for sliding, overturning and bearing capacity

4 - Possibly have engineer provide slip circle analysis

5 - Check foundation drawing for layout and space available

6 - Determine excavation sequence and drainage with soil engineer

7 - Erect foundations and drainage

8 - Discuss tentative site schedule and Evergreen transportation plan with precaster and transport

9 - Have excavator on site good for handling units for size and reach

10 - Order Evergreen units as needed on site, preferably 2 or 3 days in advance.

5. EVERGREEN MINIMUM REQUIREMENTS

for Excavations and Foundations

The following minimum requirements apply for excavations and foundations:

Excavation:

- The excavation slope and the size of excavation is to be determined by or together with the soil engineer depending on the geology and local soil conditions, the size of the excavation needed and the season of the year: How much rain would you expect during the construction of the wall?

- In case of unstable soil conditions the excavation can be limited to a minimum of 20 to 40 feet = 6 to 12 m, for just one or two stacks of Evergreen units. Thus excavation, foundation, and wall erection takes only a few days during which the excavation must be able to remain open.

- Prepare necessary precautions to prevent slope failures, such as drain surface water away from the top of the excavation and wall area, drain foundation water away.

- Have the soil engineer approve the foundation subsoil and clean excavation.

Foundations

- Check foundation subsoil and back slope material for accordance with design parameters.

- If conditions are worse than anticipated new design calculations and changes of certain foundations and wall sections are needed.

- Prepare formwork (as necessary) and reinforcing for concrete foundations.

- Concrete foundations with help of wooden stakes indication elevation at front and at rear and use a wooden triangle for measuring foundation slant.

- Tolerance for top of foundation is **plus zero, minus 1/2" to 1"**= minus 10 to 30 mm. This means ample tolerance below, **no concrete too high**.

- Place stirrup in front of leg before concrete has hardened to provide sliding resistance.

Dokument1

6. EVERGREEN MINIMUM REQUIREMENTS

For Transportation, Unloading, and Stockpiling

The following are the minimum transportation requirements for Evergreen units:

- Evergreen units are delivered on truck accessible sites by tractor-trailer.

- Wood pieces nailed onto the trailer avoid shifting of load during transport.

- Units must be put on **three** pieces of wood and be tied down firmly to avoid bouncing and damaging. Three points loading is good for avoiding twist in units, yet possible over-topping must be kept in mind.

- Before unloading units must be checked and approved for fabrication and or transportation damages.

- Any units not fit for erection must be reported immediately for shipping back. Later claims are not acceptable. Even minor fissures must be reported.

- For unloading a hydraulic excavator is used, the same used for earthwork and erection of wall. A truck waiting time of two hours is included in the delivery price. Additional waiting is charged on the standard hourly fee.

- Normally the units are unloaded directly onto foundations or onto the wall without intermediate stockpiling. The efficient way is to advance the truck and excavator one stack at the time.

- The Evergreen units are handled using long slings or using a beam with chains and pins to be inserted into the side of the Evergreen legs or cables and threaded loops to be screwed into the threaded sockets on top of the units. The Evergreen manufacturer rents out slings or other appropriate hanging equipment. The slings have reinforced sections for reducing damage to the units and to the slings. Chains or cables are not allowed.

- Intermediate stockpiling and on site is to be eliminated as much as possible for reducing cost and for avoiding damages to the units.

- Any stockpiling must be on level and firm ground.

- If such stockpiling should be necessary special care is needed to avoid twisting of units. Thus units cannot be placed on soft soil; they must always be placed on three (3) wooden blocks to avoid twist. Place two pieces under the corners of one leg and one piece exactly at center of the other leg to avoid twist. Use similar blocks on each level of stockpile.

- Maximum height of stockpiling is 5 units in any case. Dokument1

7. EVERGREEN MINIMUM REQUIREMENTS

Erection Instructions

Minimum Requirements for Evergreen wall erection are (Erection Instructions):

Erection procedures:

- Wall erection cannot start without having Evergreen wall erection instructions on site and having oral instructions by the Evergreen representative, except for contractors with a foreman on site with prior experience with erection of Evergreen walls.

- Before unloading and or starting erection all units must be checked for possible fabrication or transportation damages.

- Any units not fit for erection must be reported immediately for shipping back. Later claims are not acceptable. Even minor fissures must be reported.

- For unloading a hydraulic excavator is used, the same as used for earthwork and erection of wall. Normally a truck waiting time of two hours is included in the delivery price. Additional waiting is charged on the standard hourly fee.

- Before starting erection foundations must be totally completed including stirrups placed in front of the units and including marks placed on top of concrete foundations to indicate 'toe point P' of wall.

- Tolerances for accepting foundations are plus zero and minus 10 to 30 mm = 1/2" to 1". Thus ample tolerance, yet no foundation concrete above specified foundation elevation.

- Tolerance for placing Evergreen units is $\pm$ 1/8" = 3 mm for the first range of units and $\pm$ 1/4" to 1/2" = 5 to 10 mm for upper units.

- The first layer of Evergreen units is placed onto foundations, and then shim: use four (4) small wooden wedges placed on the side of the legs near the front and near the end. Simultaneously the units are adjusted with each other for straight alignment.

- Do NOT use metal plates or plastic shims, since they are much more slippery than mortar and the contact pressure remains permanently on them.

- Check proper wall batter using a plywood triangle with side length 1.0 m and 0.25m = 4 ft. and 1 ft. for 4:1 wall batter.

- Then use relatively dry mix of fast set, non shrinkage mortar. Push it under the legs using a tool such as a handle or piece of wood. Additional mortar is placed in front of the lowest leg to cover the stirrup placed into the foundation to ensure additional sliding resistance and provide corrosion resistance for stir-up.

- For walls with vertical foundation steps at certain joints of stacks, erection must **start at lowest foundation level**. This allows for adjustment of neighboring stacks.

- **For walls with corners erection must start at the corner** for adjusting custom made units.

- For walls with several such constraints all first units must be placed, shimmed, adjusted temporarily.

- At foundation steps a second unit must be placed temporarily. Then all units are adjusted to wall batter to alignment and to each other, and then underpinned with mortar. The second units must then be removed for filling and backfilling of first units.

- All joints between Evergreen stacks are covered using a piece of geotextile, about 18" by 18" = 0.5 x 0.5 m for erosion protection. Should joints be open wider than 25mm = 1 in. then use galvanized metal to bridge the gap under the geotextile.

- At places with resets of exterior trays a joint unit is to be placed to keep the topsoil in.

- Before stacking the next Evergreen unit, one dowel # 5 bar = dia. 16 mm in each leg is to be placed to ensure additional sliding resistance between units for taking lateral forces during filling and compaction.

- Before stacking next Evergreen unit a continuous layer of rather liquid mortar is placed on top of each leg. This eliminates load concentrations and subsequent spalling.

- For keeping the liquid mortar rather up front than in the back, the units are suspended using a longer hanger on one side for a slanted position slightly more than the wall batter.

Fill materials: **(inside the Evergreen units)**

- The Evergreen units are filled layer by two separate layers, directly after erection of each unit. Never stack more than one unit before filling (except for adjusting neighboring units across vertical foundation steps, see above).

- Fill material within precast concrete units to be ordinary borrow material, provided friction angle after compaction is phi' = min. 32° for not exceeding design silo pressures.

- Such fill must be at a moisture content max. $\pm$ 2% off optimum.

- Fill material shall have max. 10 to 25% fines passing sieve # 200 = 0.074 mm; if fill contains 15 to 25% fines, then PL plastic limit must be below 6 and fraction below 15 microns = 0.015 mm shall not exceed 15%. (This means: eliminate clay and clayey materials; preferably use material with less than 15% fines, clay and sand).

- Impervious material, such as loam, clay, and peat cannot be used.

- Big blocks must be eliminated separately; maximum size of fill materials is 5" =125 mm and weight of stones of 3" = 75 mm should not exceed 15% for reasons of acceptable compaction.

- Maximum cohesion within compacted fill material should not exceed 0.04 to 0.17 ksf = 2 to 7 kN/m2, which again excludes organic material, loam, and clay. Do not calculate with cohesion in new fill.

- Filling of voids behind legs and under trays is essential to achieve the required design weight of the gravity retaining wall.

- Fill front pockets of L-shape trays with min. of 10" = 0.25 m plantable topsoil for better plant growth with min. or 1" = 25 mm freeboard. Fill topsoil and finish final grade on each tray as wall goes up, seed for erosion protection.

- Fill compaction must reach minimum density of 122 pcf = 18 kN/m3. This minimum average density including possible voids is crucial to ensure the weight for the gravity wall effect. This requires quality fill of all voids and quality compaction using Wacker jumpers or Rammax vibratory rollers or equivalent proven tools.

- Compaction must reach a minimum of 90% relative density (Proctor standard density) and not more than 95% to avoid over-stress. Note: inside fill in a Cribwall is different to a highway base. Proctor relative density requirements are not applicable and are outdated. Use minimum moist density requirement as mentioned above and as needed for the required gravity effect to stabilize the retaining wall.

- Measure compaction on top of compacted layer, within center and or on mountain side of cells.

- Do not over compact to avoid over stress and damages to units.

- Maximum thickness of compacted layers should not exceed 15" = 0.4 m. Thus filling operation proceeds in two layers per unit in any case.

- The internal friction angle of fill material after compaction must be phi' = min. 32° to limit silo pressures to design values.

Backfill Material: **(behind wall)**

- provide drainage before backfilling:
  - provide sand drains, French drains or a geotextile on the excavation face to intercept mountain side seepage,
  - provide a drainage pipe min. schedule 80 = dia. 100 mm at the heal of the wall using min. grade of 0.5%
  - provide free draining fill material within 8" = 0.2 m of the first Evergreen unit.
  - collect and divert runoff water on the back slope,

- fill and backfill shall follow erection of each course of elements with a berm behind the wall of minimum 10 ft. = 3 m wide and adjacent slope of max 2:1 if fill goes up faster or if wall goes up faster than backfill.

- remove debris and topsoil before backfilling.

- Backfill behind the wall follows after filling of units to avoid shifting of empty units. This backfill and compaction is made in lifts not exceeding 12" = 0.3 m

- Backfill must be compacted to min. 95% relative density (= standard Proctor density) at optimum water content $\pm$ 2% to min. 125 pcf = 20 kN/m3 at maximum lifts of 16" = 0.4 m.

- Proctor relative density requirements are applicable for backfill, yet not for fill inside of narrow bins inside of Cribwalls.

- Heavy compaction equipment is not allowed within 3 ft. = 1.0 m of back of wall, to avoid excessive compaction pressures and deformations within fill and subsequent wall deformations and possible shifting of units.

- Friction angle of fill material must reach at least values as used for design of wall, see typical section and notes. The 32° minimum friction angle as required for fill inside of units may be lowered as foreseen in the wall design.

8. EVERGREEN MINIMUM REQUIREMENTS

For Material Specifications

Fill Materials: **(inside the Evergreen units)**

- The Evergreen units are filled layer by layer, directly after erection of each unit. Never stack more than one unit before filling (except for adjusting neighboring units across vertical foundation steps, as outlined above).

- Fill material within precast concrete units to be ordinary borrow material, provided friction angle after compaction is phi' = min. 32° for not exceeding design silo pressures and it is filled in at a moisture content max. ± 2% off optimum. Fill material shall have max. 10 to 25% fines passing sieve # 200 = 0.074 mm; if fill contains 15 to 25% fines, then PL plastic limit must be below 6 and fraction below 15 microns = 0.015 mm shall not exceed 15%. (This eliminates clay and clayey materials).

- Impervious material, such as loam, clay, and peat cannot be used. Big blocks must be eliminated separately; maximum size of fill materials is 5" =125 mm and amount of stones of 3" = 75 mm should not exceed 15% for reasons of acceptable compaction. Maximum cohesion within compacted fill material should not exceed 0.04 to 0.17 ksf = 2 to 7 kN/m2, which again excludes organic material, loam, and clay.

- Filling of voids behind legs and under trays is essential.

- Fill front pockets of L-shape trays with min. of 10" = 0.25 m plantable topsoil for better plant growth with min. or 1" = 25 mm freeboard. Fill topsoil and finish final grade on each tray as wall goes up, seed for erosion protection.

- Fill compaction must reach minimum density of 122 pcf = 18 kN/m3. This minimum average density including possible voids is crucial to ensure the weight for the gravity wall effect. This requires quality fill of all voids and quality compaction using Wacker jumpers or Rammax vibratory rollers or equivalent proven tools.

- Compaction must be minimum of 90% relative density (Proctor density) and not more than 95% to avoid over-stress, measured on top of compacted layer, within center and on mountain side of cells. This Proctor relative compaction requirements, such as 90 or 92 or 95% relative minimum density are NOT applicable inside of Cribwall cells. Do NOT over-compact to prevent damages to Cribwall structure.

- Maximum thickness of compacted layers should not exceed 15"=0.4m, or two layers per unit.

- The internal friction angle of fill material after compaction must be phi' = min. 32° to limit silo pressures to design values.

Backfill Material: **(behind wall)**

- provide drainage before backfilling:
  - provide sand drains, French drains or a geotextile on the excavation face to intercept mountain side seepage,
  - provide a drainage pipe min. schedule 80 = dia. 100 mm at the heal of the wall using min. grade of 0.5%
  - provide free draining fill material within 8" = 0.2 m of the first Evergreen unit.
  - collect and divert runoff water on the back slope,

- fill and backfill shall follow erection of each course of elements with a berm behind the wall of minimum 10 ft. = 3 m wide and adjacent slope of max 2 :1 if fill goes up faster or if wall goes up faster than backfill.

- Remove debris and topsoil before backfilling.

- Backfill behind the wall follows after filling of units to avoid shifting of empty units. This backfill and compaction is made is made in lifts not exceeding 12" = 0.3 m

- Backfill must be compacted to min. 95% relative density (= standard Proctor density) at optimum water content, tolerance $\pm$ 2%, to a moist density min. 125 pcf = 20 kN/m3 at maximum lifts of 16" = 0.4 m

- Heavy compaction equipment is not allowed within 3 ft. = 1.00 m of back of wall, to avoid excessive compaction pressures and deformations within fill and subsequent wall deformations and possible shifting of units.

- Friction angle of fill material must reach at least values as used for design of wall, see typical section and notes.

End.