HARDSCAPE CONSTRUCTION

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Hardscape Construction

The key elements of business and administrative needs for landscape contracting have been described in the chapter on Landscape Contracting. The landscape Contractor must understand management of plant selection, plant installation and plant maintenance, all of which are described in several other chapters of this manual. All of these major segments of landscape contracting are critical to the success of any landscape contract. In addition to business, administrative and plant management activity by the Landscape Contractor, knowledge of the management and installation of hardscapes and hardgoods is another major requirement of this profession. Hardscapes now play a major role in landscape projects nation wide. Difficult to use or non-functional areas can become functional parts of a landscape with the addition of hardscape elements. This includes, but it not limited to, the construction of patios, walkways, driveways, fountains, water gardens, and retaining walls.

However, hardscape elements are highly regulated for proper installation and for their impact on the landscape. Most local government building codes require approved engineered drawings for most forms of hardscaping. In addition, many local governments allow only a certain percentage of the landscape to be covered by hardscaping. Before starting any hardscaping project, always check the local government building code requirements for all engineering regulations and restrictions, and for the percent of hard cover allowed on each specific landscape.

Also prior to commencing excavation for hardscaping installation, it is essential to make the Gopher State One Call. A least forty-eight hours before any excavation, make the Gopher State One Call to have all underground utilities marked. Refer to the Gopher State One Call Bulletin enclosed with this manual.

Hardscape Construction requires professional and technical skills to accomplish the wide diversity of tasks required in this profession. It also requires specific tools and equipment. A skid steer loader, backhoe or forklift may be critical assets on some sites to move heavy blocks and rock and for excavation and backfilling. In addition, certain tools and supplies are required for constructing any type of patio, walkway, driveway or retaining wall. Some of these tools are listed below.

1. Safety equipment including safety glasses, gloves and steel-toed shoes.
2. Spades and flat shovels for excavation and backfilling pavers or walls.
3. Marking paint or other tools and supplies to draw the shape of the wall or walkway on the ground.
4. String with stakes for setting straight lines.
5. A plate tamper or vibrator and tamper bar.
6. Survey equipment and levels.
7. Chisel and one-pound hammer.
8. Rubber mallet for leveling stones and blocks.
9. Stone cutter or splitter; chain saw or circular saw.

Walkways, Driveways and Patios

Several attractive and durable surfaces are available for patios, walkways and driveways. Segmental pavers, natural stone, wood rounds and timbers are all alternatives to poured concrete and asphalt paving.

Pavers and flat stone are often used to create long-lasting paths, walks, patios and driveways. They provide a rustic and elegant look to landscapes and incorporate a texture that compliments plant materials of all kinds. In addition to the aesthetics of pavers and flat stone, these materials are relatively easy to maintain and, when installed correctly, can add significant value to a property. It is important to follow recommended guidelines when installing pavers and flat stone in order to create safe and long-lasting areas within a landscape. Types of pavers are described in Table 1.

Table 1. Descriptions of types of pavers. From: SULIS: www.sustland.umn.edu .

Types of Pavers	Appearance	Maintenance	Winter / Durability
Concrete Pavers	Wide range of textures and colors; can be positioned in a variety of patterns, symmetrical or asymmetrical.	Low; broken pavers can be removed and replaced easily; however, color of new pavers may not match due to exposure.	Small, high density pavers resist cracking; smooth surface allows for easy snow removal.
Flat Stone	Irregular shapes; various textures and colors; typically creates a rustic and organic look.	Low; broken stones can be removed and replaced easily; however, achieving the same shape and spacing may require cutting.	Rough surface makes snow removal difficult.
Clay Pavers	Limited range of colors available; limited number of shapes available.	Irregularities in surface are prone to chipping and breaking.	Salt can cause damage; rough surface on some pavers makes snow removal difficult.

The number of pavers needed for a job depends on the size of the paver and the square footage to be covered. Generally, four to five pavers are required for each square foot to be covered. Always use high quality pavers that will not crack under the intended use. When determining the finished size of the paved area, choose a size and pattern that will require as little cutting or splitting of pavers as possible.

Using non-mortared flat stone can create an informal, irregular walk or patio that is reminiscent of old-world paths. Properly designed and installed, flat stone can provide an excellent surface that is functional and maintainable. Deciding on the type of flat stone to be used in a walk or a patio will depend on the existing colors and materials available, the landscape design and style desired, and the budget for the project. The following is a description of shapes and uses, and they are further defined in Table 2.

Flagstone – Flagstone is a stone cut to form a shallow, flat slab. Flagstones are often used as an alternative to pavers for patios and paths. They are available in several different thicknesses and can have either a straight edge or a random cut or split edge. Flagstone is commonly cut from stones that are easily split such as limestone, granite, and sandstone.

Ashlar – Ashlar is stone that is cut into a straight-edged, geometric shape and used in building stone walls. Typical ashlar stones are limestone, granite and sandstone.

Rubble Stone – Rubble Stone is any uncut stone that is used for building stone walls. They are also used as stepping stones. Rubble stone is usually a hard stone such as basalt, gneiss or granite.

Fieldstone – Fieldstone can be any uncut stone that is indigenous to the area. For example, basalt and granite are typical field stones of Minnesota and Wisconsin.

Belgian Blocks – Belgian Blocks are paving units with similar dimensions to brick. Belgian blocks are typically cut from granite or other durable stone.

In addition to the pavers and stone described above, several other products are required for the construction and installation for a walkway, driveway or patio. Class 5 (¾ inch minus) or Class 2 (3/8 inch minus) crushed rock with fines is required as a solid underlying base for the area to be paved. Patios, walks and driveways each have different base requirements: walking paths require four inches of base; paths with heavier traffic such as a garden tractor, require six inches of base; and driveways require twelve inches of base (Figure 1).

Table 2. Characteristics of Flat Stone. From: SULIS: www.sustland.umn.edu . Adapted from Stonescaping by J.K. Whitner.

Characteristics of Flat stone					
Rock Type	**Texture or Grain**	**Color**	**Durability**	**Water Absorption**	**Shape and Use**
Basalt	Fine	Grey, black, brown	Strong	Resistant	Rubble; used for walls, stepping stones, natural water basins.
Gneiss	Medium to coarse	Pink-grey, black, white; banded colors	Strong	Resistant	Rubble; used for specimen stones and walls.
Granite	Fine to medium-coarse	Pale grey, pink, red	Strong	Resistant	Rubble or ashlar; used for walls, stepping stones, specimen stones.
Limestone	Varies	Grey, black, white, buff	Medium-strong to very weak	Poor resistance	Ashlar; used for walls.
Marble	Fine	Pink, white, black, yellow, brown	Strong	Resistant	Ashlar; slabs for walls and pavers.
Sandstone	Varies	Buff, brown, black, blue, pink	Strong to very weak	Somewhat resistant	Rubble or ashlar; used for walls and flagstone.
Slate	Fine	Black, green, red	Strong	Resistant	Ashlar; used for flagstones.

Construction fabric or geo-textile fabric is used to stabilize organic or recently disturbed soils. It is also used to separate soil from the compacted gravel base, especially in soils subject to moisture levels approaching, or at saturation. The geo-textile material should be placed so that the material extends up the side of the excavated area a sufficient distance to cover the base material. While geo-textile fabric does not substantially increase the bearing capacity of the soil sub-grade, it does prevent intrusion of the soil sub-grade into the bottom of the gravel base and the subsequent erosion of the base by excess moisture. This will extend the life of the base material and slow the rate of deformation resulting from repetitive vehicle loads or periodic exposure to moisture from the soil.

Concrete sand approximately one inch thick should be laid over the entire base area. This bedding sand should be sharp, washed and free of foreign material. Limestone screenings or stone dust will not compact

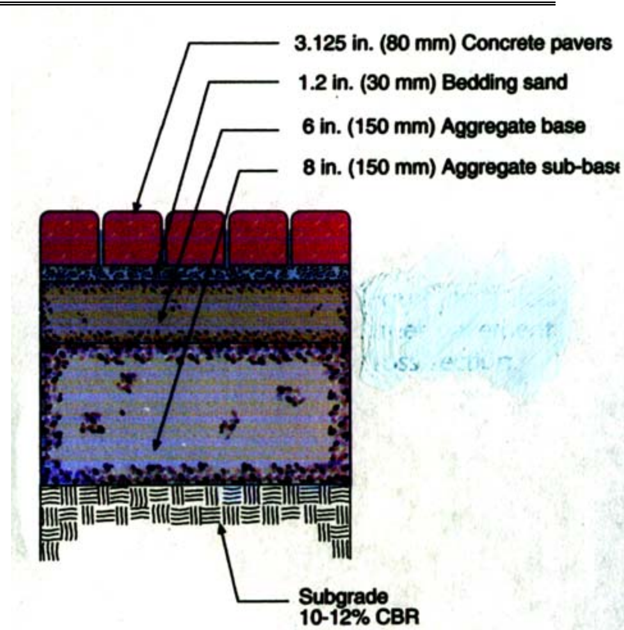


Figure 1. Typical street pavement cross section.

uniformly nor maintain an even profile over time. This is due to the elongated shape of the particles and the presence of water-soluble minerals. Concrete sand should be spread and screeded to a minimum thickness of one inch or to a maximum thickness of 1.5 inches. Frozen or water saturated sand should not be installed. Sand should not be used to compensate for uneven elevations or an improper compacted gravel base. These irregularities in elevation will reflect through to the surface over time, creating a washboard appearance. Low or high areas of base material must be brought to a smooth consistent elevation. Sand is typically screeded with a straight, true screed bar. The board is pulled across pipe laid directly on the base prior to spreading the sand. Once the sand is screeded it should not be disturbed.

Joint filler is required between the pavers or stones. Pea gravel or colored aggregates can be used for flat stone. Concrete sand is used to fill the space between individual pavers after they are laid in place. If pavers or flat stones are not installed against an immovable surface, some type of edging should be used for lateral support. A commercial poly paver edging or a product such as Snap Edge is recommended for this purpose, however two inch by six inch lumber or six inch by six inch timbers can also be used. Figure 2 and Figure 3 show the use of a commercial poly paver edging and the Snap Edge edging respectively.

Prior to excavation, the area to be excavated should be staked and grade elevations must be established to ensure proper elevation of the paved surface. The minimum recommended slope should be at least 1.5 percent for adequate drainage. Grade elevation markers should be checked periodically throughout the job to be sure they have not been inadvertently disturbed. Avoid areas where tree roots might cause damage to the paved area. Recently disturbed soils, loose soils or soils high in organic matter should be removed and replaced with compacted base. Any saturated soil must be drained of all standing water. Low wet areas can be stabilized with crushed stone after the excess water has been removed. The sub-grade soil should be properly compacted with a plate compactor.

Manipulating the finished size and shape of the paved area and choosing as appropriate paver size and pattern will reduce the amount of paver cutting and splitting. Gaps at edges should be filled with cut pavers. They can be cut with a double bladed paver splitter or a masonry saw. A masonry saw gives the cleanest appearance. Gaps less than 3/8-inch wide should be filled with sand. Spacing between the pavers or flat stone can be used to create different effects. Tight spacing is more formal; it creates a continuous surface and attracts attention to the area. Tight spacing is the best application for driveways. Loose spacing is more informal. It is used for walkways, paths, and stepping stones. Sometimes flat stones are laid directly on quality top soil with the area between the stones planted with sun or shade tolerant groundcovers.

In considering a paving pattern, ninety degree or forty-five degree herring bone patterns should be used in all street applications, as these patterns resist horizontal creep from braking and accelerating vehicles. Herringbone patterns interlock, thereby offering greater resistance to deformation. Patterns with straight seams can be maintained by snapping a chalk line directly on the sand or pulling a string line just above the surface of the pavers. Sides of buildings or opening in the pavement, such as concrete collars or inlets, should not be used as a basis for establishing lines. They generally are not straight. Natural stones do not interlock with one another and they do not have the strength to withstand higher weight loads. Therefore, natural stones should not be used for driveway surfaces or surfaces that bear greater weight loads that typical foot traffic.

Joints between pavers should be approximately 1/16 inch to 1/8 inch wide. Some pavers are made with spacer bars to create a minimum joint width. These will automatically provide the minimum joint necessary for sand to enter.

The actual step by step construction process for installing a walkway, driveway or patio is delineated below and is shown graphically in Figure l, 2 and 3.

1. Use marking paint, flags, string or garden hose to mark the area to be paved.

2. For flat stones, lay out the stones on the soil in the exact path and pattern where they will be installed to determine exact placement **prior** to excavation. Place stones so that their edges mirror the adjacent stones. Shape the stones to fit the spot with a chisel and hammer. Stepping stones can be placed 24 to 26 inches center-to-center or with ½ inch to one inch spacing between stones.

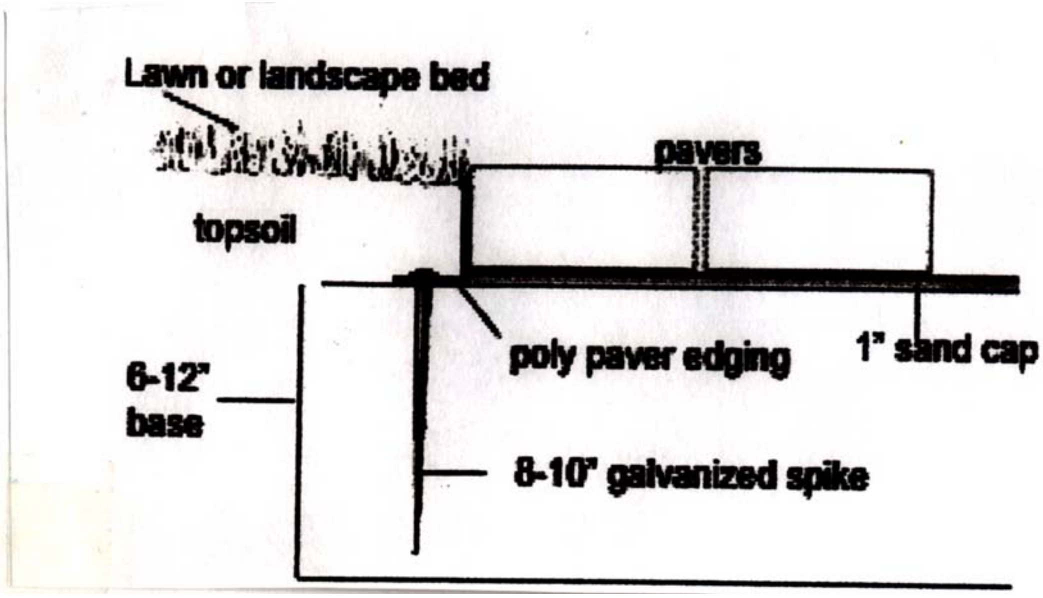


Figure 2. Cross section of a paved area using poly edging. From: SULIS: www.sustland.umn.edu.

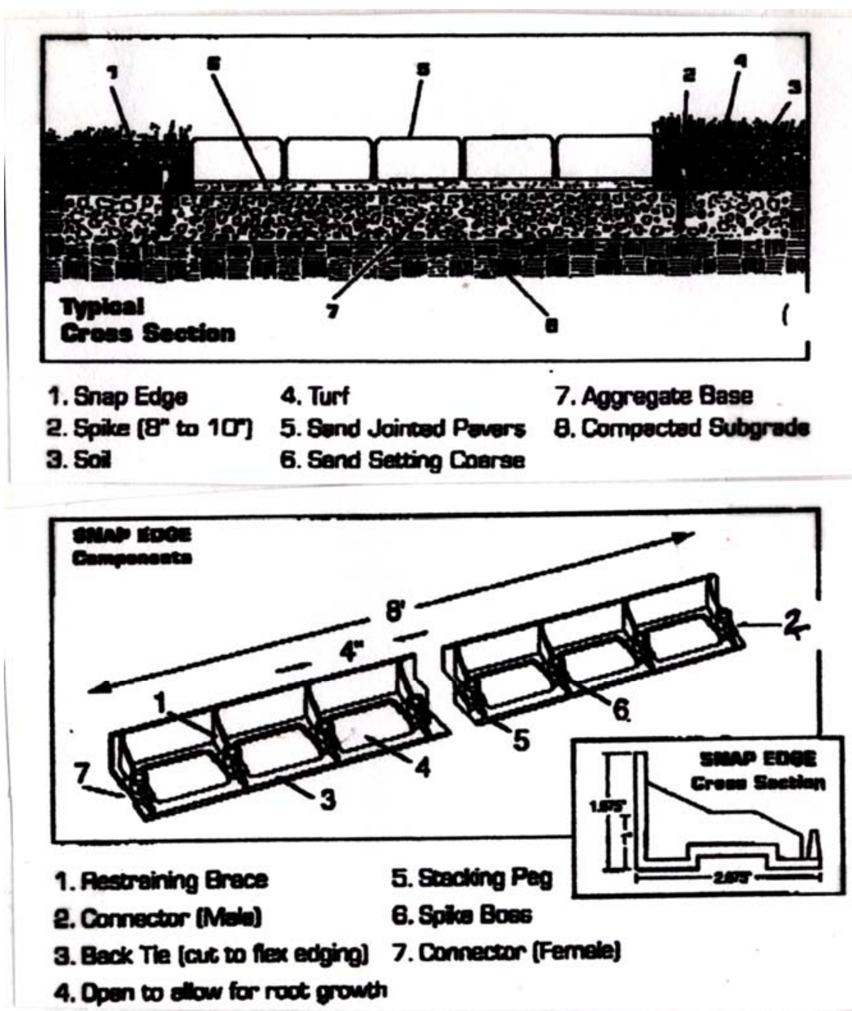


Figure 3. Cross section of a paved area using Snap Edge and a description of Snap Edge.

3. Before removing the stones for excavation, number the stones on the underside with a grease pencil to make it easy to place them after excavation.

4. Excavate the area to be paved and level the area insuring that it is free or any mounds or depressions. If construction fabric is needed, it should be laid to stabilize the existing soil before the base material is added.

5. Fill the excavated area with base material. Begin by spreading an even layer of rock approximately two to three inches deep. Use a power plate tamper to compact the rock. Continue the layering process until the desired depth of base is in place and fully compacted. Moistening the base with water will reduce air spaces, settle the base material, and make it easier to compact.

6. When using pavers, poly paver edging is frequently installed around the perimeter of the area to be paved. Secure the edging to the installed base material with 3/8 inch galvanized spikes eight to ten inches long. Add enough spikes to the curved areas in order to maintain the integrity of the curve and prevent the pavers from rolling away from the path or driveway. Check measurements for accuracy, so pavers will fit properly.

7. Add one inch of concrete sand over the crushed rock base. The sand covers the small rocks found in the base material and makes leveling easier. Using a screed bar and rails, smooth the surface of the sand so that the entire area is level. The finished height of the sand surface should allow for the pavers or flat stone to initially sit approximately ¼ inch above the finished elevation.

8. Set the pavers or flat stone on the sand in the desired pattern. Set flat stones as described in Step two. When installing natural stones, because they do not interlock, it is important to arrange bedding sand around and under each individual piece to compensate for varying thickness and irregular shapes. Sawn stones still have a very large surface area and are difficult to level even through the thickness of each stone is consistent.

9. When laying pavers in larger areas, criss-cross string to assist in aligning the pavers correctly. Pavers should be set tightly against one another. Cut pavers to a desired size by using a brick chopsaw or split them with a hammer and chisel.

10. When all pavers or flat stones have been set, spread the selected joint filler over the entire area and sweep it into sand crevices between the pavers or flat stone. Repeat as necessary until cracks remain filled.

11. Once pavers are installed, vibrate the pavers into the sand with a plate vibrator. This equipment should be capable of providing 3,000 to 5,000 pounds of centrifugal force, and operate at a frequency of 80-90 hertz. For clay pavers, use a smaller plate compactor or use plywood protection over the pavers. At least two passes with the vibrator should be made across the surface. Sweep dry sand into the joints and vibrate again until they are full. This may again take two or three passes with the plate vibrator. If the sand is moist, it can be spread on the pavers to dry before being swept and vibrated into the joints. Do not vibrate within three feet of an unrestrained edge. All work within three feet of the laying face must be fully compacted with sand-filled joints at the completion of each day. At the end of the day cover the remaining compacted edge of the laying face and sand with a waterproof covering. Sweep off excess sand when the job is complete.

Pavers and non-mortared flat stone enable a landscape designer to create areas that feature interesting patterns, shapes, textures and color. By combining these hardscapes with plant materials, the effect enhances a landscape and creates spaces that provide areas of movement, recreation and leisure. The versatility of pavers and flat stone, as well as their maintainability and durability, provide the designer with infinite design options, and add value and beauty to a landscape.

Building Retaining Walls

A retaining wall is a grading structure used to prevent soil erosion where the gradient or slope is steep enough to succumb to wind and water erosion. It is also used to create a flat surface where a steep hill once existed. The decision to use a retaining wall depends on the angle of repose. The angle of repose is the angle or slope at which a soil mound or wall will start to crumble due to gravity. If the soil is very sandy, it has a low angle of repose, meaning that it is an appropriate situation in which to build a retaining wall.

For walls more than four feet high, most building codes require a final wall design prepared by a licensed Civil Engineer (P.E.) registered by the state. Actually in all instances, **leave the Engineering to the Engineers.** It is important to recognize when walls need engineering. Those that do require engineering should be designed by a qualified engineer, whose plans should then be closely followed. **Wall failure is a genuine threat!** Whoever engineers or re-engineers the wall is liable if there is a problem.

Standard walls are designed as traditional gravity walls. For non-reinforced walls, the stabilizing weight of the battered wall units is compared to the loading on the walls to ensure stability against overturning and sliding. When the loading exceeds the stability of the units alone, a larger gravity mass is created from reinforced soil.

To ensure stability of a reinforced retaining wall, the wall engineer must design the reinforced soil mass large enough to resist loads from outside the wall system, which is known as external stability, and with enough layers of proper strength geosynthetic material to keep the reinforced soil mass together, this is known as internal stability. In addition, the design must have sufficient geosynthetic layers to keep standard units stable and properly connected to the reinforced soil mass; this is known as facial stability.

For internal stability, the geosynthetic layers must resist loads that could pull apart the reinforced soil mass. The wall design engineer must ensure the geosynthetic layers have enough anchorage length to resist pullout from the stable soils and enough strength to resist overstress or breakage. The geosynthetic layers must also be long enough to resist sliding along the lowest layer.

For external stability, the reinforced soil mass must have sufficient width to resist sliding and overturning. The wall design engineer must increase geosynthetic lengths until the reinforced soil is massive enough to provide required stability. The project geotechnical engineer should review the wall design and site soil conditions for external stability against bearing failures, settlement, or slope instability. A wall design engineer can address most global stability concerns by increasing geosynthetic lengths.

For facial stability, the wall design engineer must ensure wall units can resist loads at the face of the wall, and stay connected to the reinforced soil mass, stay interlocked between geosynthetic layers, and not overturn at the top of the wall.

Loading on segmental walls is dependent on soil conditions, surcharges, slopes, water conditions, and wall heights. Accurate knowledge of each of these properties is needed for a proper design. Soil properties required for segmental retaining wall design include the internal friction angle (Φ) and soil unit weight (γ). Generally, the cohesion (c) of any fine-grained soil is conservatively ignored to simplify the design.

Geo-grid is often used in a terraced wall or in an application where there is an excessive amount of force behind the wall. When using geo-grid, extensive excavation of soil is required to properly install the grid mat. Drain tile is most often used in tall walls or where there is a concern for excessive water run-off in the wall area. The drain tile will help alleviate water pressure against the retaining wall, thereby keeping it from blowing out.

For tiered walls that are independent from each other, the upper wall must be back of the wall twice the distance of the height of the lower wall (Figure 4). The walls can be closer if they are reinforced. This is important because slopes at the top and bottom of a wall change the wall's stability. Also, a wall places a load on a slope below. A steep slope below a wall may not be stable under the new load the wall adds to the site. This is called global instability. The engineer must add geogrid to make these slopes more stable.

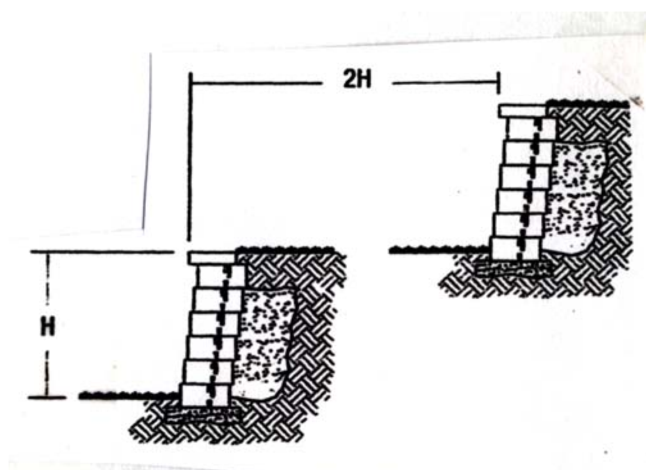


Figure 4. The upper wall of independent tiered walls must be back of the lower wall a distance equal to twice the height (2H) of the lower wall (H).

The following questions must be asked and answered to obtain the required engineering information to develop an accurate and efficient wall design.

A. **Site Conditions**

1. What is the general site topography?
2. Is a site plan available with existing and proposed grades shown?
3. What is the layout of the wall(s) in relation to other structures, slopes, roads, etc.?
4. Will grading for a wall require excavation or fill, or both?

B. **Soil Conditions**

1. Is a soil investigation report available with boring logs?
2. What is the soil type at the site: Gravel, Sand, Silt or Clay?
3. Is the existing soil suitable for foundation soil?
4. If fill needs to be imported from off-site, what soil type will it be?
5. Are there areas of problem soils such as soft, compressible soils, sidecast fill, or non-compacted utility trench backfill?

C. Drainage and Water Conditions

1. Does the topography of site present drainage or erosion problems such as water flow hitting the back of a wall or running along side or front of a wall?
2. Does storm water flow off a building or paved area to the wall and are there any drainage outlets near the wall?
3. Is the wall along a stream, lake, drainage ditch or swale that may cause heavy current or wave action?
4. Is there a high groundwater table?
5. Does existing soil seep water when excavated?
6. Is there possible contact with ice at the face of the wall? Will ice heaving or ice flows hit the wall?

D. Wall Geometry and Conditions

1. What is the height of the wall or walls?
2. What is the profile of the wall? What does the wall look like when facing the front of the wall? Does the base of the wall step up or down along the length of the wall? Does the top of the wall step up or down?
3. Is the final grade forward of the wall base level or sloped? What is the angle and length of the slope?
4. Is the final grade behind the top of the wall level or sloped? What is the angle and length of the slope? What is the surcharge behind wall, including permanent or dead loads such as structures or stored materials, and temporary or live loads such as traffic, parked cars, construction or paving equipment?
5. If walls are tiered, what will the horizontal spacing be between each tier?

E. General Information

1. What type of geogrid is preferred?
2. Is a seal or stamped design by a registered design engineer required?
3. Is a specific design method such as: "Must be designed by AASHTO guidelines for a DOT" required?
4. Will there be a review by an agency or another engineer and do they have special requirements?
5. What are other special concerns such as site access constraints, possible vehicle impacts, salt exposure, etc.?

Once the decision has been made to build a retaining wall, several types of building materials are available. The four most popular retaining walls are constructed from boulders, concrete blocks, natural stones, and timbers. Deciding which material to use is a combination of personal taste and site considerations. In constructing a retaining wall, measure and lay out the area where the wall will be built. Use stakes and string to create a straight line. Garden hose, flags or paint can be used to lay out curves. Curve radius is very important. Follow the block manufacturer's specifications to ensure the minimum curve radius for a specific block is not exceeded. The minimum curve radius must be determined at the top of the wall, because the radius becomes smaller as each row of block is installed (Figure 5).

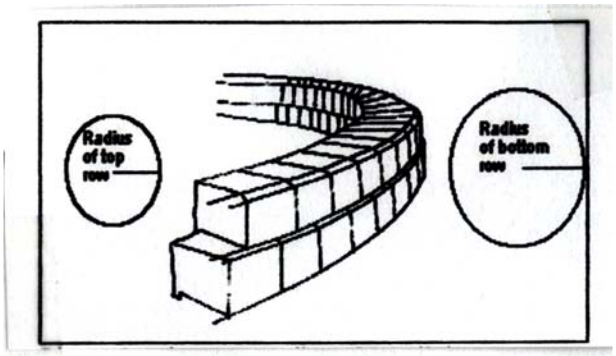


Figure 5. The curve radius of a wall decreases as height of the wall increases.
From: SULIS: www.sustland.umn.edu .

Basic guidelines for deciding what type of wall to build and materials to use are described below.

Boulder Retaining Walls – The acceptable size of a boulder retaining wall depends on the site. It is usually better to build two shorter, terraced walls than one tall wall. The size of the wall will determine the size of the boulders. Shorter walls can be built with smaller boulders, which would be less than 18 inches. Taller walls that hold back more soil should be built with larger boulders because of their weight and holding ability. Boulders are sized in supply yards by approximate overall length. Common sizes are 6 to 12 inches, 12 to 18 inches, and 18 to 24 inches for small to medium walls. Larger boulders are available for more sizable walls. A boulder wall's strength depends on good contact between the boulders, and a 30 percent setback into the area being retained (Figure 6). Heavy duty fabric should be installed between the boulders and the soil bank to prevent soil from washing out between the boulders. Boulder walls allow water to flow freely behind and through the wall, thus relieving a significant amount of pressure on the wall.

Boulder retaining wall construction includes the following procedures.

1. Measure and lay out the area where the boulder wall is to be built. Use stakes and string to create a straight level line. Paint, flags or garden hose should be used to define curves.

2. Dig a trench deep enough to accommodate 1/3 to ½ of the depth of the first row of boulders. The first row of boulders must be partially buried in the soil to provide stability and strength for the wall.

3. Set the first course of boulders into the trench. The largest boulders should be used in the first row to anchor the wall securely in place. They should be approximately equal in size so the second course is relatively level and they should fit as tightly together as possible. Position the boulders with the smoothest side up so the next course has a good contact surface.

4. Place fabric behind the boulders and then backfill soil against the back of the first course and tamp thoroughly. Pack soil up to the height of the base course to provide a level surface for the second course of boulders. Lay fabric against the backfill to allow room for the next course.

5. The second and subsequent courses should be set back into the hill to provide strength for the wall. The setback should generally be 30 percent or three inches for every one foot of elevation. Place boulders on top of the base course so that seams in the second course do not match seams of the first course. If seams match, it will create a weak spot in the wall. Select each boulder to fit as tightly as possible with the adjacent boulders. Rotate boulders until a good fit is achieved. Due to the friction that is created, the wall will be stronger with the greatest surface area contact between boulders. Mixing smaller boulders with larger ones usually weakens a wall.

6. Continue adding each course of blocks with fabric behind it. Backfill and tamp soil behind the wall after each course is in place.

Prefabricated Concrete Block Retaining Walls – There are several different brands of prefabricated concrete blocks on the market in a variety of shapes, textures and colors. These blocks can be used to create sturdy, long-lasting retaining walls. Each brand has its own method of connecting the blocks together, but the general procedures for building modular walls remain the same.

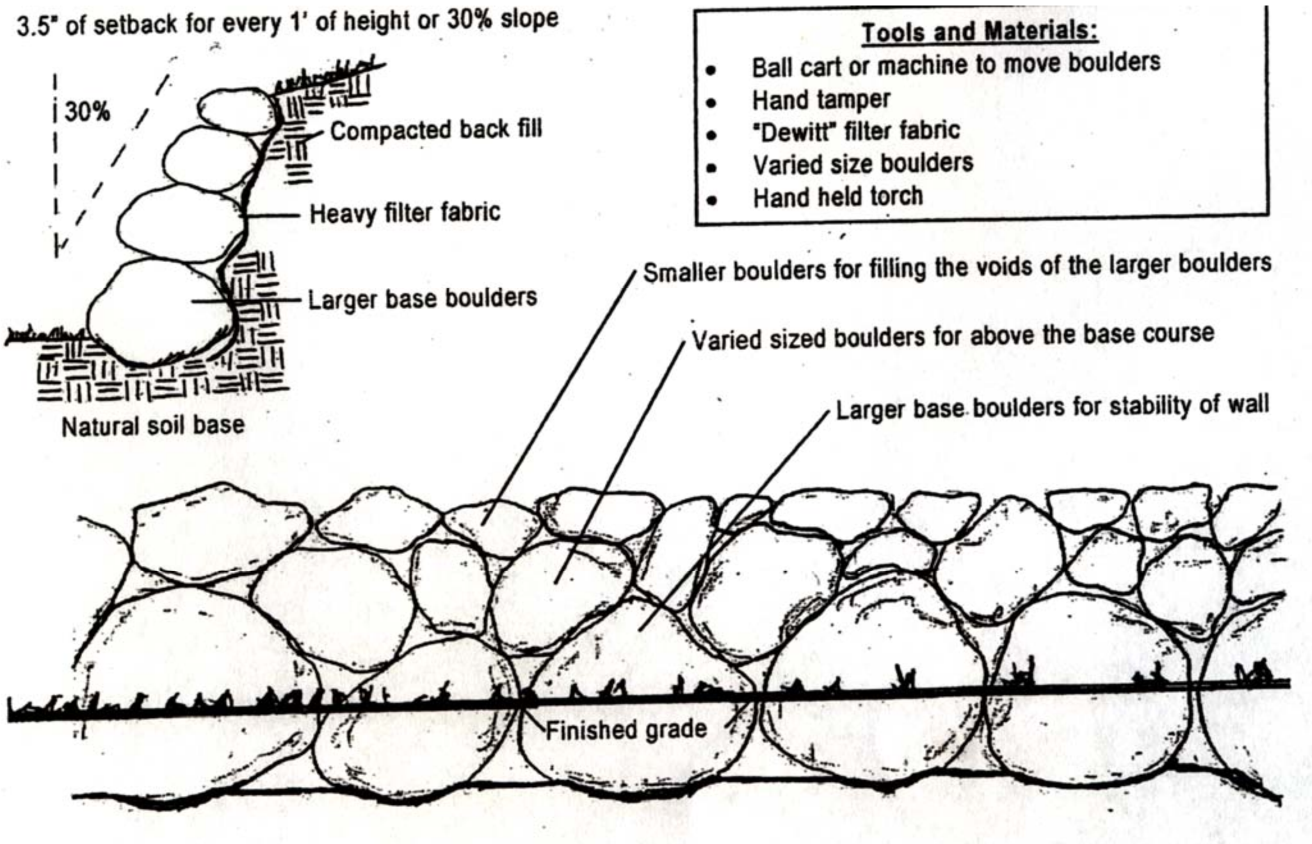


Figure 6. Illustration of a boulder wall construction including the 30 percent setback.

The size of concrete block walls depends on the site. It is usually better to build two shorter, terraced walls rather than one tall wall. The size of the wall determines the size of the blocks. Short walls, under three feet, can be built with smaller blocks, often called half-unit blocks. These half-unit blocks measure approximately 6 inches by 8 inches by 12 inches, and weigh 40 pounds. Taller walls need larger, heavier blocks, which usually measure approximately 6 inches by 18 inches by 12 inches, and weigh 80 to 90 pounds. Cap units, pin connectors and tapered blocks are also required. Larger walls require a soil retention grid mat or geo-grid to hold the wall in place. A four-inch drainage tile with a filter fabric sock is often specified behind the wall to separate drainage gravel from soil.

Construction of a prefabricated concrete block retaining wall includes the following procedures.

1. Excavation – The project site should be excavated to the lines and grades shown on construction drawings. Care should be taken not to disturb additional foundation material. The foundation should be adequately compacted. Placing wall units on non-compacted soil will result in wall settlement.

2. Leveling Pad Construction – Install and compact a leveling pad accurately to a smooth, level surface. It should consist of gravel or crushed stone. Leveling pads should be at least six inches thick and 24 inches wide. To quickly construct long pads, screeding techniques similar to forming a sidewalk may be used.

3. Base Course Installation – Starting at the lowest point of the wall, place base course units side by side on the completed leveling pad. Level units front to rear, side to side, and with adjacent units. Make sure there is complete contact between the bottom of all units and the leveling pad. After

base course units have been properly positioned, place and compact soil backfill behind and in front of the units to prevent shifting. Install entire length of base course before starting succeeding courses.

4. Place Succeeding Courses – Succeeding courses will be set back from lower courses ¾-inch. Two pins will be inserted through front holes of upper course units into receiving slots in lower course units. The hole and slot arrangement allows for a variable bond. The vertical joints should be tight-fitting and can "wander" in relation to the units above and below. Place and compact backfill after every two courses.

5. Compaction – Proper compaction of backfill is critical to the stability of a modular wall. Poorly compacted soil puts extra pressure on the wall, especially when loose backfill gets wet. Geogrid reinforcing does not work if the soil around it is not compacted. Do not use heavy, self-propelled compaction equipment within three feet of the wall face as it will push the wall units out of alignment. Once units and backfill are pushed out, it is difficult to realign them. If backfill is placed in layers no thicker than the recommended six-inch lifts, the smaller, hand-pushed equipment can easily provide the required compaction near the wall face.

6. Drainage – Granular, free-draining fill or drain rock is recommended for all walls. The drainage fill keeps water pressures from building up behind the walls. The drainage fill must be free of fine soil. Drainage fill is recommended even if sand is used for backfill. For walls over three feet high, use a perforated drain pipe to collect the water at the base of the drain rock. The pipe helps to quickly remove large amounts of water.

Geosynthetic filter fabric may be specified for a project. It is generally placed behind the drain rock. The fabric is most often used in water applications where the backfill may be saturated. The fabric keeps the fine soil and sand behind the drain rock from being "sucked" into the drain rock and the wall face units.

7. Geogrid Installation – Geogrid is used to reinforce retained soil fill. The existing site, soil, wall loading, and seismic conditions will all influence the design of geogrid reinforcement. Geogrid reinforcement is placed at wall elevations shown on construction drawings. Lay the geogrid horizontally on top of the block units approximately one inch back from the front edge and onto properly compacted backfill at the same level. Geogrids are usually stronger in one direction than the other, so it is very important to place them in the correct direction. The strongest direction of the grid must be perpendicular to the wall face. Follow the grid manufacturer's directions to orient the grid correctly.

Place and pin succeeding courses of blocks. Place granular drainage fill against the back of the units and on top of the grid. Pull geogrid taut, anchor it, and place and compact backfill material.

8. Capping – Two cap unit types may be used to finish installed walls. Cap units may be set back, flush, or set out as much as one inch from the face of the wall. Alternate Type A and Type B caps on straight wall sections (Figure 7). Use only Type A caps on convex walls and Type B caps for concave walls. Secure caps using a concrete adhesive.

9. Completed Wall Illustrations – Figure 8 and Figure 9 illustrate the proper components and construction of non-reinforced and reinforced retaining walls respectively.

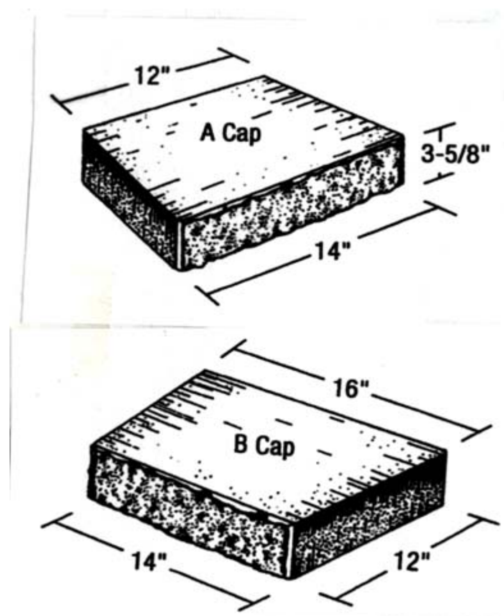


Figure 7. Type A and Type B cap units used to cap straight, convex or concave concrete block retaining walls.

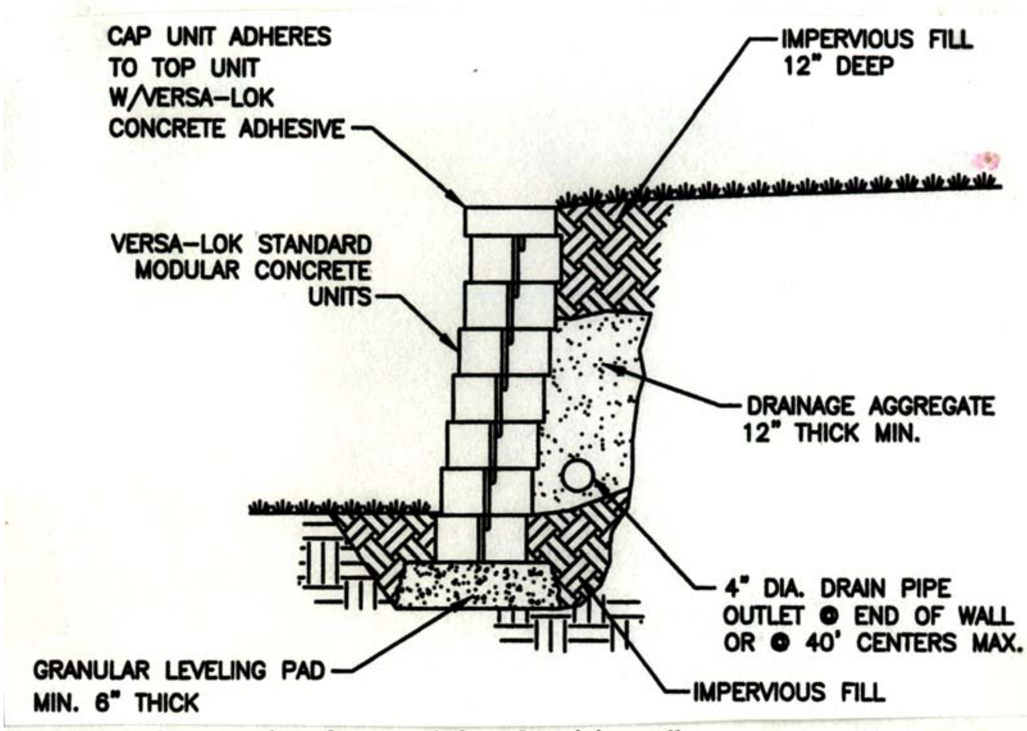


Figure 8. Components and construction of a **non-reinforced** retaining wall.

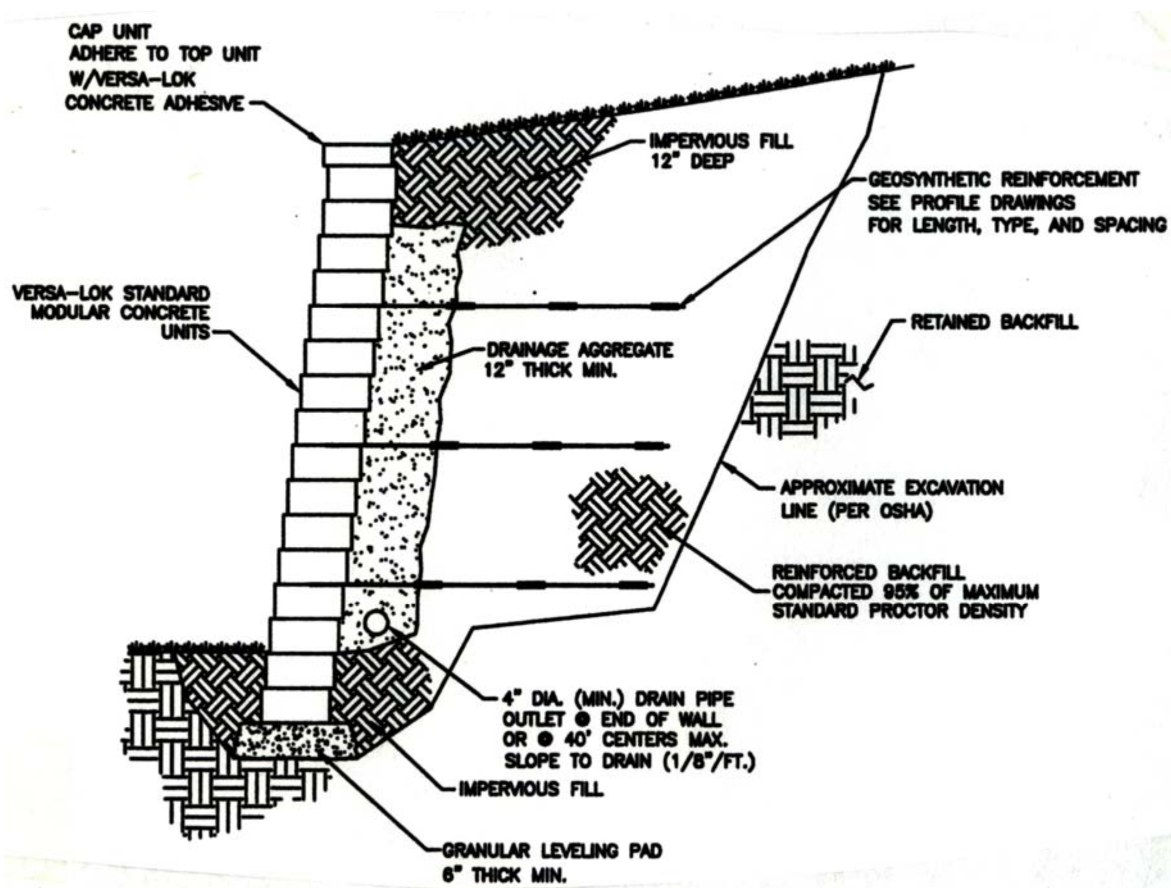


Figure 9. Components and construction of a **reinforced** retaining wall.

Modular Freestanding Walls and Pillars – Freestanding walls bring definition and elegance to a landscape. They can create beautiful borders along patios and walkways. The height and sturdy construction of these freestanding walls also make them ideal for perimeter seating.

Freestanding units are simply stacked on a compacted granular base and secured using flexible concrete adhesive and/or pins. No mortar or frost footings are required. Solid concrete characteristics make units extremely durable, long lasting and virtually maintenance free. Units are integrally colored so color cannot chip off or peel. These walls are built without mortar, therefore, they remain flexible to tolerate freezing and thawing earth movement.

Construction of freestanding walls and pillars includes the following procedures.

1. Determine Wall Layout – Prior to excavating, lay the first course of units in the desired configuration to help determine the path of the wall. Mark an area six inches out from all sides of the wall which is approximately a 20-inch width. This is the area that will be excavated.

2. Excavate Trench – Excavate the marked area to a depth of seven inches. This depth will allow room for a four-inch high compacted granular leveling pad and a three-inch embedment of the first course. If necessary, over excavate soft foundation soil and replace it with properly compacted backfill. Use a hand tamper or vibratory plate compactor to compact the base of the trench.

3. Build Leveling Pad – Place granular leveling pad material in the trench and compact it to a smooth, level surface approximately four inches deep. Place and compact no more than a two-inch thicknesses at one time if using a hand tamper or four-inch thicknesses if using a vibratory plate compactor. Leveling pad material should consist of coarse-grained sand, gravel, crushed stone or Class 5 road base. Spread a thin ½ to 1 inch layer of sand on top of the leveling pad material to help with block leveling.

4. Place, Level and Backfill First Course – Place the first course of units on the leveling pad. Level each unit front to back, side to side, and with adjacent units. Adjust the sand layer or use a rubber mallet to help with unit leveling. Where 12-inch high vertical units are placed next to six-inch-high units in the base course, it is helpful to temporarily set additional six-inch-high units for the next course so it can be leveled across the vertical unit. After the first course of units is installed, backfill the open trench areas with desired soil and compact. Take care not to displace units during compaction.

5. Place and Glue or Pin Succeeding Courses – Prior to pinning and before applying adhesive, test position the next course. Align units to create a vertical wall and stagger unit joints from course to course for improved wall strength. When satisfied with unit arrangement, set aside temporarily placed units in an ordered fashion. Sweep off any debris on the installed units. Spread a ¼-inch bead of concrete adhesive in a wavy pattern on the top surface of installed units. Replace the previously selected units on the adhesive. Pins may now be used to further secure each course to the course below it. Repeat this process with remaining courses. **Remember, the exposed height of a freestanding wall, including the height of cap units should not exceed 24 inches.**

6. Place and Glue Cap Units – Cap units may be used to finish the top of the wall. To create the proper ten-inch depth, split the rear two inches off using a masonry chisel and heavy mallet or rented mechanical splitter. Caps are tapered on both sides. Caps may be arranged to create straight and curved configurations. Glue cap units to the wall using a concrete adhesive.

Natural Stone Retaining Walls **–** Natural stone is a generic term for any quarried and cut stone that is used for construction purposes. The actual types of stone include granite and various kinds of limestone which all have slightly different aesthetic differences. Granite is heavier, splits more evenly, and is stronger for use in larger walls. Limestone is less expensive than granite and comes in a variety of types. Natural stone walls are constructed without the use of mortar or other adhesives to hold the wall in place. Instead, the wall is held together by friction and the weight of the stacked stones and setback. Natural stone can be packaged and delivered in a specific range of sizes. Common heights of the stones would be two to three inches, three to four inches or four to six inches. The width of the stone, from the face to the back, is sold at eight-inch, 12-inch, 18-inch and random sizes. Larger stones should be used for taller walls. Walls that are under 18 or 20 inches could be constructed with stone as small as two inches by eight inches. For walls over 20 inches, stones four inches by eight inches or larger are required The number of square feet of wall space obtained per ton of specific stone relative to width is shown in Table 3.

Table 3. Square feet of wall face per ton of stone, relative to stone width. From: Buechel Stone Corp. 1998. SULIS: www.sustland.umn.edu .

Stone Width	Square Feet of Wall per Ton
8 Inches	20 Square Feet
12 Inches	15 Square Feet
18 Inches	8 Square Feet
Random Sizes	15 Square Feet

Like boulder walls, natural stone walls also allow water to flow freely behind and through the wall. However, Class-5 rock for the base, plus angular, clear stone, or other aggregate for drainage, plus geo-textile fabric with filter fabric sock, plus drain tiles for collection and transport of water, may also be required in the construction of a natural stone wall.

Natural stone walls should not be taller than four feet including the base course. If a taller wall is required, the wall should be terraced into two or more, smaller walls, or a different type of wall material, such as cast concrete block walls should be used.

Natural stone retaining wall construction includes the following procedures.

1. Use a string line and stakes to lay out straight portions of the wall and the marking paint, flags or garden hose to draw out curves. When curved walls are desired, it is important that the curves be as large as possible to eliminate irregular curves. As curves become tighter, smaller stones will be needed. Larger pieces will create flat spots on the curve and the set backs from one course to the next will not be even.

2. Dig a trench that follows the string line or marking paint. The trench should be one foot deep and two times the width of the stone. For instance, if the stone selected is eight inches wide, the trench should be 16 inches wide and 12 inches deep.

3. Place four to six inches of Class 5 rock in the trench. Roughly level it and compact it thoroughly in two-inch layers with a plate compactor.

4. Begin leveling the base course of stone by placing a stone on the coarse rock. Check for level front to back and side to side and adjust accordingly with a large mallet. Due to the nature of the material, the stone will not be perfectly level, but it is possible to be very close using shims if necessary (Figure 10). Once the first stone is level, continue along the trench and make sure each new stone is level with the preceding stone. Use the string line again to make sure that the straight sections are straight.

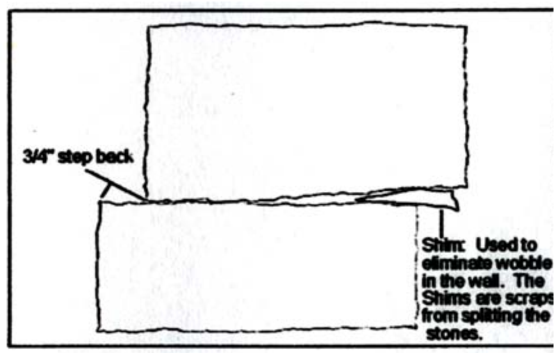


Figure 10. Use shims to level natural stone walls. (Illustration by Chris Matson).

5. If the wall is going to be taller than three feet, perforated drain tile should be placed behind the base course and then covered with drainage aggregate (Figures 8 and 9).

6. Stack the second course of stone on top of the base course. Make sure the seams between the stones do **not** line up from one course to the other. Also, pick stones that fit well with those on either side. If there are large gaps, it may be necessary to use a stone splitter to get a more snug fit. Each course should be set back at least 3/4 inch to allow the wall to lean back into the ground that it will be retaining. Often, the stones will not lay perfectly level on the preceding course. In this case, it is necessary to shim the backs of the stones to eliminate wobbling. Shims are small flat stone chips that break off the stone when they are split (Figure 10).

7. After two or three courses of stone are stacked, backfill the wall with drainage aggregate. To do this, lay the geo-textile fabric on the soil behind the wall, and place the drainage aggregate between the wall and the fabric (Figures 8 and 9). The aggregate should be at least eight inches from the wall to the fabric. Compact the aggregate thoroughly. It may be necessary to fill soil in behind the fabric as the stone is added.

8. Continue to alternate the rock seams in each course, and after every two or three courses backfill with aggregate. Repeat this process until the wall is complete.

Landscape Timber Retaining Walls – Pressure-treated timbers are recommended for timber retaining walls. They usually come in five-inch by six-inch by eight-foot sections or six-inch by six-inch by eight-foot sections. Untreated wood will not hold up when exposed to constant moisture and weather and should not be used for retaining walls. The specific construction detail is dependent on the size of the wall and existing site conditions. Timber walls should be professionally designed because of the complexity of their construction. Approximately 25 percent of the timbers required will be hidden behind the wall to tie back or hold the wall in place. A minimum of four 3/8 inch galvanized spikes per eight-foot timber is recommended to tie the timbers together. Two spikes at each tieback connection points are required. Holes for all spikes should be pre-drilled. The size of the wall will depend on the site. It is usually better to build two shorter, terraced walls than one tall wall. The tiebacks are composed of timbers called headers and deadmen. The number of headers and deadmen needed for the wall are determined by the size of the wall, soil conditions, drainage, topography and anticipated loads or surcharge, above the wall. If soil is not well drained, a drainage aggregate such as pea gravel, sand or an angular clear stone, should be placed directly behind the wall to reduce water pressure on the wall. A four-inch perforated drain tile should be installed in the aggregate to move water away from the base of the wall. Also install a geo-fabric between the aggregate and the soil.

Timber retaining wall construction includes the following procedures.

1. Measure and lay out the area where the timber wall is to be built. Use stakes and string to create a perfectly straight line, and to determine the elevation for the base course of timbers. Timbers do not work well for curved walls, but can be used to develop angular or straight walls.

2. Dig a trench eight inches wide or 14 inches wide if a drain tile is used, and one to two inches deeper than the height of the timber being used. Add one to two inches of sand to the base of the trench. The sand makes leveling of the base timbers much easier.

3. Tiebacks, headers and deadmen are portions of timbers placed into the soil behind the wall to strengthen the wall. Excavate for headers and deadmen into the hill. The size, length and location of headers and deadmen will be design specific (Figure 11). Headers can extend 1½ to two inches past the wall face to add strength and to prevent splitting (Figure 12). In some cases this is also considered a decorative feature

4. Place and level the first course of timbers on the sand in the trench. This first course must be perfectly level and must be completely buried in the ground. When timber ends fit together poorly, use a chain saw or large circular saw and run down the seam between the timbers. This will make the timbers match up better and will avoid gaps, however, this does remove some of the treated lumber.

5. Lay the second course of timbers over the base course, staggering the seams. This staggering should continue throughout the wall so the seams of two adjoining courses are never in the same place. Each course should also be set back approximately ½ inch from the course below. This is called battering. Leaning the wall into the slope in this way adds strength to the wall.

6. As each course is added, drive 3/8-inch galvanized spikes through to the course below. Spikes should be placed six to twelve inches from each end with one to two additional spikes in the center of the timber. Pre-drilling the spike holes prevents the timbers from splitting.

7. Soil should be backfilled behind each course and tamped thoroughly. If the soil is not well drained, or the wall is over three feet tall, place drainage aggregate eight to twelve inches wide against the wall to collect surface water and reduce water pressure on the wall. Install a four-inch perforated tile at the bottom of the wall to disperse water as it moves through the aggregate. Place fabric between the aggregate and the soil.

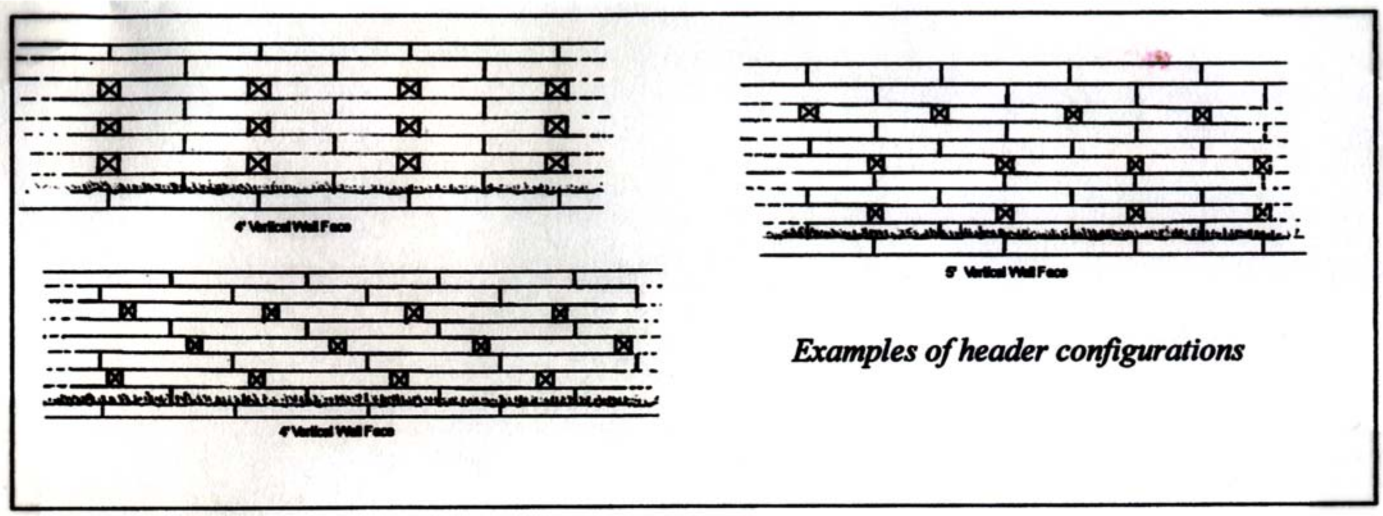


Figure 11. Examples of header placement and configuration. From: SULIS: www.sustland.umn.edu .

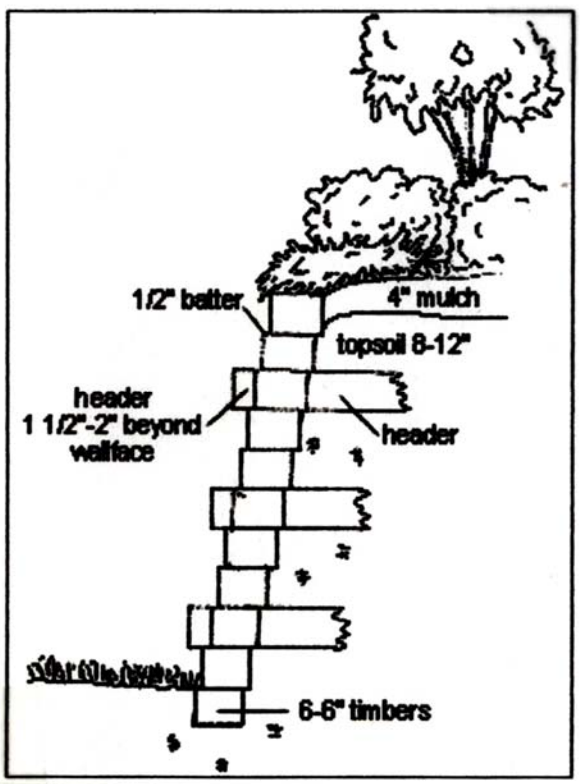
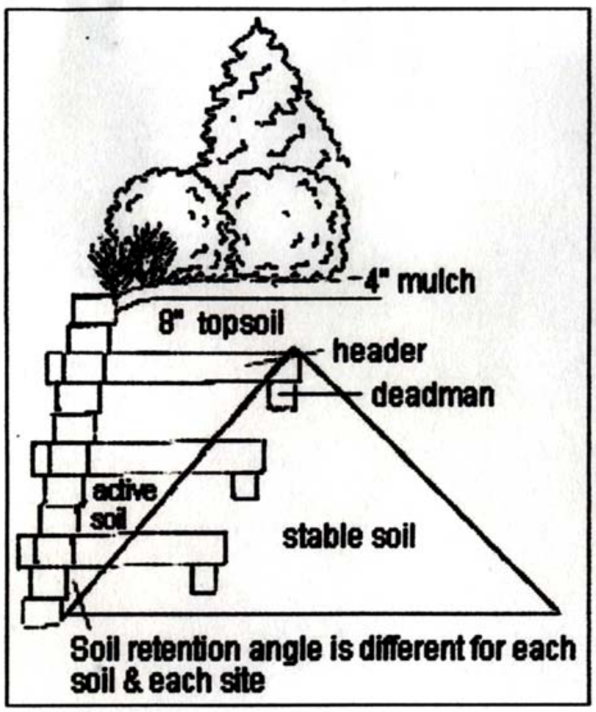


Figure 12. Illustration of ½-inch batter in timber placement (top) and 1½-inch to 2-inch extension of header beyond the wall face. From: SULIS: www.sustland.umn.edu.

8. The third and subsequent courses of timbers will require headers and deadmen. For an average small wall less than five feet, headers and deadmen should be placed after each eight-foot timber in every third course of the wall face. If enough headers and deadmen are not used, the wall will fail, a very common occurrence for walls not professionally designed. Headers should be secured to timbers with two spikes in the face of the wall as well as to the deadman in the soil behind the wall. The length of the header depends on its placement in the wall, the height of the wall, the soil type, the soil and surface water movement, and any surcharge at the top of the wall. Surcharges can be roads, homes, parking lots and other walls. The stable soil being retained behind the wall is similar to the cone-shaped pile that is formed when soil comes off a high elevator or conveyer into one pile (Figure 13). The headers need to be long enough to anchor the wall into that cone shaped pile because the area inside the cone is stable soil. The area outside the cone is active or unstable soil. Headers at the bottom of the wall will be shorter than those near the top of the wall. Deadmen are placed perpendicular to the header making a "T." While deadmen length is design specific, they are usually not less than 60 percent of the header length. The top two courses of timbers can be set and spiked without tiebacks to headers and deadmen. This avoids interference with planting above the wall (Figure 14).



9. Backfill soil after each course of timbers is secured and tamp thoroughly.

It is essential that all the rules be followed in the construction of a retaining wall. There is no tolerance for poor quality work as a failed wall is very costly to all concerned and can be hazardous as well. It is better to error on being too safe than to be sorry.

Refer to chapters on Landscape Contracting, Soils for Nursery and Landscape Management, Irrigation Management, Landscape Management and other related chapters for additional information.

Figure 13. Location of headers and deadmen into stable soil behind a retaining wall. From: SULIS: www.sustland.umn.edu.

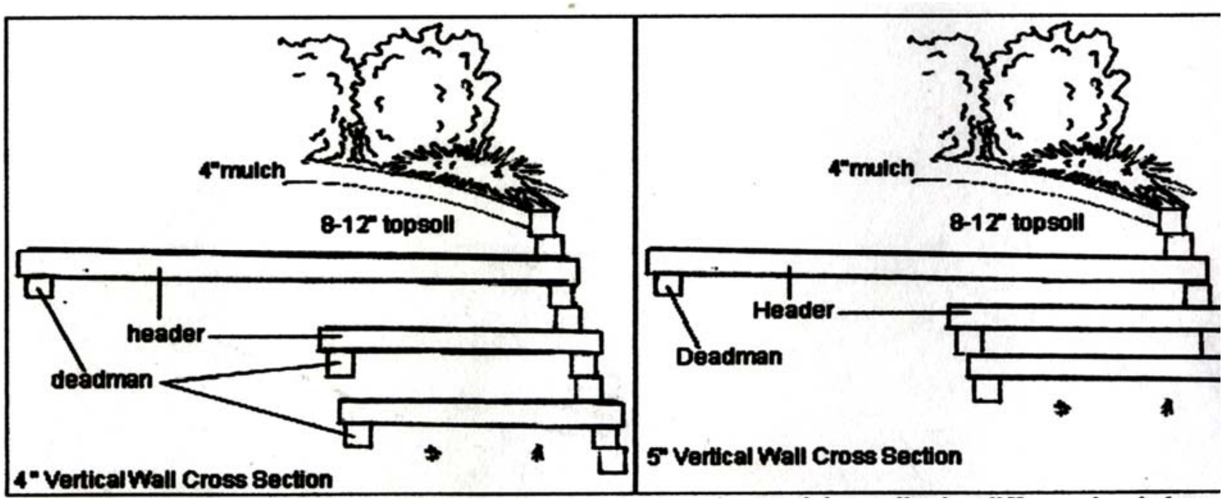


Figure 14. Location and relative lengths of headers and deadmen in a retaining wall using different size timbers. From: SULIS: www.sustland.umn.edu.