Certified Nursery &
Landscape Professional

CNLP

New York State Certified Nursery & Landscape Professional

Training Manual

New York State Nursery & Landscape Association

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LANDSCAPE PRINCIPLES

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Introduction

Landscape Principles

Knowledge of basic landscape principles is important for knowing how to properly interpret designs, apply for permits and then transform conceptual ideas on paper to physical landscape features.

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2. Basic Principles of Hardscape Installation
3. Basic Principles of Pavements
4. Basic Principles of Retaining Walls
5. Chapter Review Questions

In chapter one, we discussed the properties and structure of soil, in the context of plant health and needs. In this section we will focus on grading and drainage principles as they apply to basic landscape development. Grading is defined as the shaping of the Earth's surface for aesthetic and functional use. Applications of sound grading and drainage principles are critical to the success of all natural and developed landscapes.

Principles of Grading and Drainage

When landscape systems fail, repairs and mitigation can be costly and time consuming. Dead plants, failed structures, and wet sites are often directly related to improper grading and drainage techniques. In most cases, corrective measure may require removal or modification of newly installed features above the soil line before corrective grading and drainage can occur.

Most landscape projects start with site and soil modifications that best accommodate proposed landscape elements. From the design phase forward, every project should include the following principles of grading and drainage:

1. Prevent moisture and structural problems by draining storm and surface water away from buildings, structures, and high traffic areas.
2. Know and understand the onsite soil conditions and characteristics.
3. Prevent damage to existing trees and shrubs that will remain as part of the finished landscape.

- Avoid grade changes within the drip line of all trees and shrubs
- Prevent compaction and excessive fill within the drip line by installing a fence around the drip line to protect roots and branches.
- Avoid grade changes to adjacent areas which may encourage excessive ponding of water or dryer soils around the base of the plant.
- Do not extend grade changes beyond the property line and avoid creation of drainage conflicts on adjacent parcels.
- Make sure the proposed grading suits the function and purpose of the landscape.
- Avoid direct contact between soil fill and structures by using vapor barriers or moisture sealants. Damp soil and excessive moisture may encourage pest insects or cause decay to the building materials.
- Uniformly slope pavement surfaces to provide adequate drainage and prevent puddling.
- “Ditch to daylight” where possible. When using drain tile, conduit or other materials to promote drainage, the end of a drain should be exposed, be lower than the inlet, or be above the surface of water runoff is being directed to.

Slope and Elevation

Grading is affected by two factors, slope and elevation. Slope is the percentage of vertical rise or fall in relation to a horizontal distance. Elevation is a vertical measurement above or below a horizontal reference point.

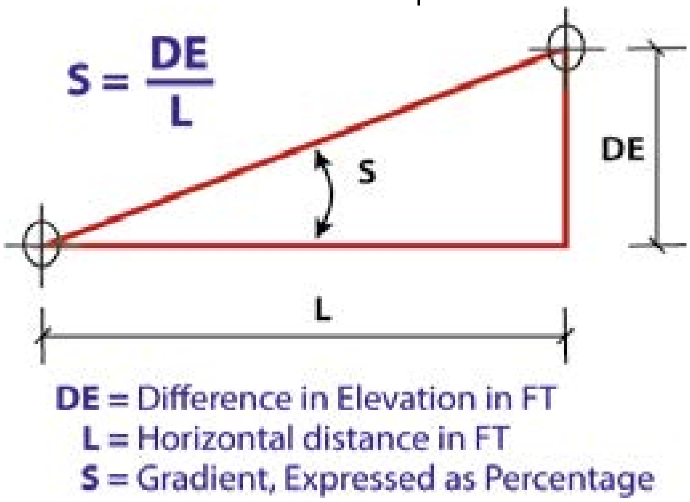


Figure 1 - Diagram of Slope Formula

L= horizontal distance (run) which a grade is projected over.

DE= vertical (rise) change in elevation from the existing grade elevation to the proposed grade elevation.

S= % of slope relative to the change in elevation relative to the distance traveled.

> *Slope can also be expressed as a ratio such as 4:1. This means that for every (4) feet of horizontal distance there is a 1-foot vertical change either up or down. The horizontal distance is always the first number in the ratio.*

Table 1 - Typical Slopes used in Landscape Applications

Type of Use	Max (%)	Min (%)	Preferred (%)
Parking areas	10	.5	1-3
Concrete terraces	2	.5	1
Concrete walks (longitudinal)	10	.5	1-5
Flagstone, slate & brick terraces	2	.75	1
Planted slopes & beds	10	.5	3-5
Lawns & grass areas	25	1	5-10
Berms & mounds	20	5	10
Planted slopes & beds	10	.5	3-5
Mowed slopes	25 (3:1)	No Minimum	20
Unmowed grass	50%	No Minimum	Up to 33
Patios	2	1.5	2
Handicap ramps	12	No Minimum	8

General notes about slopes:

- Minimum slopes should be increased based on drainage capabilities of surfacing materials or soils.
- Maximum slopes should be decreased based on local climatic conditions, such as ice and snow, and limitations of maintenance equipment.
- All standards should be checked against local building codes; Public Works/ Highway Departments and other governing agencies

Collection of vertical Measurements

Instruments used to determine elevations:

- Laser Level, Transit, Hand Level
- Tripod
- Measuring Rod

Basics of Determining Elevation

- Level the instrument. Choose a location on site that is approximately half way between the highest and lowest elevations and where most areas of the site are visible. Mount the instrument on the tripod and level the instrument by adjusting the thumbscrew adjustment(s) until the bubble(s) indicate a level position front to back and left to right.
- Identify a benchmark (BM). Elevation is the altitude relative to a given vertical benchmark. A benchmark is a vertical point of reference used to determine elevations. This should be a fixed object upon which all other elevations will be referenced from. Using the level and measuring rod, place the rod on the benchmark and record a Back Sight elevation reading. It is important to note times, choose a benchmark that is solid and will not be moved or disturbed during construction.
- Identify secondary reference points such as grading stakes and other fixed objects by taking Fore Sight readings. Once elevations have been collected, grades for drainage can be calculated using the slope formula.

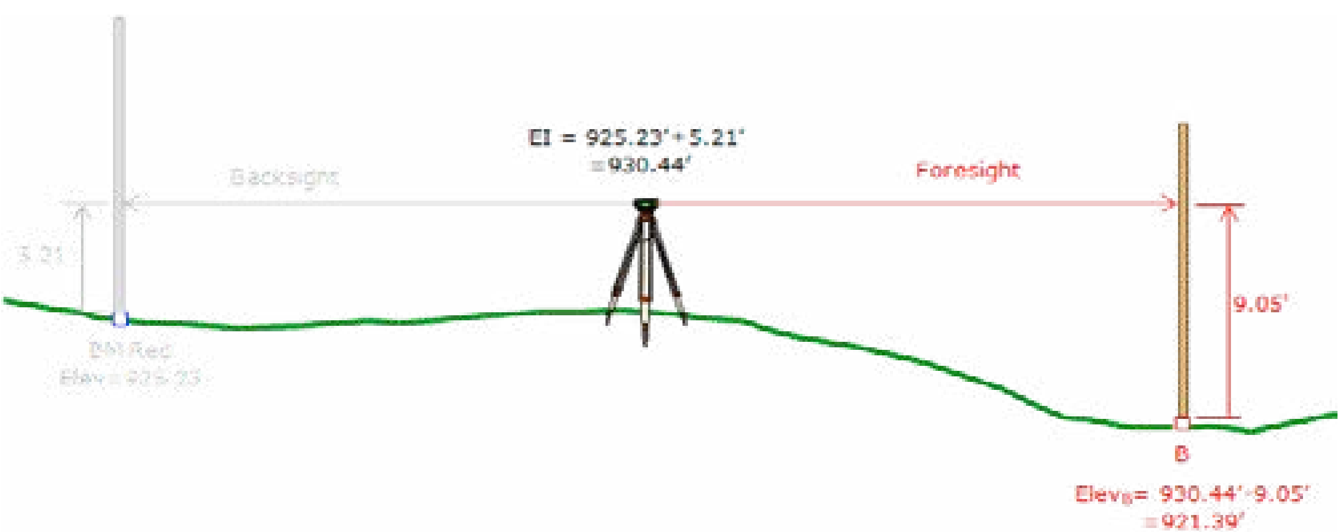


Figure 2 - Sight - Foresight

Drainage Devices and Strategies

<u>Swale:</u> A depression or channel varying in depth and intended to divert surface drainage away from locations where water has a tendency to pool or is not wanted. Vegetated (planted with vegetation) and non-vegetated (without vegetation), swales are commonly used for most landscape applications.

- Vegetated swales will typically handle storm water runoff with light to moderate rainfall. Although vegetated swales may be more aesthetically pleasing, they may be susceptible to erosion if the volume and speed of water being conveyed exceeds the ability for roots of the vegetation to hold soils in place. Depending upon location and client requirements, vegetated swales may also require seasonal maintenance.
- Non-Vegetated swales incorporate the use of stones, riprap or concrete lining the bottom and side slopes of the drainage channel. Non-vegetated swales are usually designed to accommodate greater volumes of water traveling at a higher rate.
- Swales that combine the use of both vegetation and hard materials are often ideal. A combination of materials provides adequate erosion control and aesthetic quality.

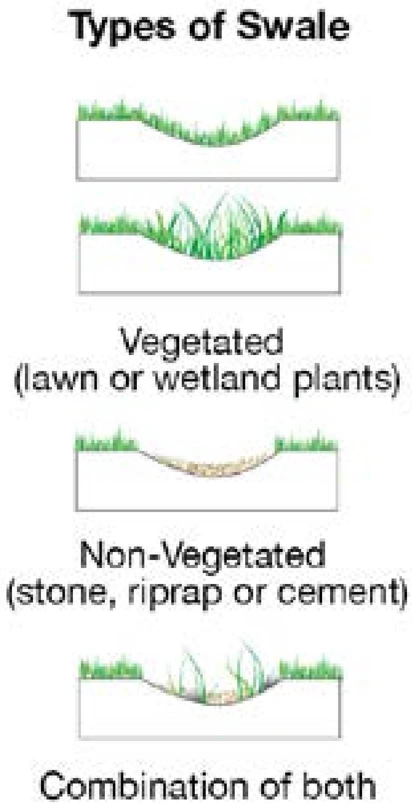


Figure 3 - Types of Swale

<u>French Drains:</u> A shallow trench filled with stone usually 12-18” deep, used to distribute water below grade. This trench is filled with angular drainage stone (ASTM 57) and sloped downward from the water source to the outlet. Perforated drainage pipe is placed 2 -3" from the bottom of the drainage stone to convey excess water. This drain type usually "daylights"at the lowest point within the landscape.

Figure 4 - French drain

Figure 5 - Ditch

Ditch: A ditch is much deeper than a swale in proportion to its width. Ditches may be vegetated but are usually not maintainable. Generally, ditches are most often found in location where excess water is conveyed over a long distance.

Crowned Drainage: Often applied to the grading of turf surfaces or roadways, crowned drainage is the intentional raising and shaping of a high point in the landscape to control and direct surface runoff to a lower point.

Sheet drain: The practice of establishing one uniform slope from a highpoint to a low point. Generally used to convey water to a secondary drainage basin, the method of sheet draining is commonly used across hard surfaces and large grassy areas.

Piping: Usage of piping for conveying excess or unwanted water usually to a designed storm water management system is commonly used to move water underground in areas where surface drainage may not be possible.

> *Appropriate pipe size, type and layout for installation should be verified by consulting with a local code enforcement officer.*

Figure 6- Crown drainage

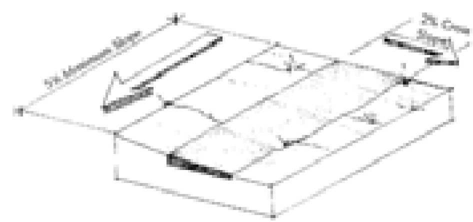


Figure 7- Sheet drainage

Figure 8- Storm water management systems

Storm Water Management Systems:

- **Municipal storm sewers** are designed to carry storm water runoff to a designated point of discharge, holding area or larger body of water. These systems are usually designed to handle calculated amounts of water from areas such as streets, parking lots and backyards.
- **Detention ponds** are a type of constructed wetland that is used to contain stormwater or rain runoff for longer periods of time. Short term "detention" of runoff helps to prevent flooding. All the water contained in a detention pond is released within a short period of time.
- **Retention ponds** are a type of constructed wetland that is used to contain stormwater or rain runoff for longer periods of time. Water remains in the local area that it was deposited in. These structures frequently act as a replacement for the natural absorption of a forest or other natural process lost when vacant areas are developed. As such, these structures are designed to blend into neighborhoods and viewed as an amenity rather than a basin without value.
- **Dry well** is a drainage pit lined with loose stonework for the leaching of liquid wastes. This technique can be used for smaller amounts of water to be dispersed into the soil on-site, hence reducing the amount of required drain tile. This can also be used if there is no outlet for water to be displaced.

Sources

Strom, S., and Nathan, K. 1993. *Site Engineering for Landscape Architects*. Von Nostrand Reinhold, New York

Harris, Charles W. and Dines, Nicholas T. 1998. *Time Saver Standards for Landscape Architecture*, 2nd edition McGraw Hill, Inc.

Introduction to Hardscapes

<u>Hardscape vs. Softscape</u>
Up until this chapter, we have been mainly discussing softscapes within the landscape. Softscapes include planting beds, perennial borders, and specimen trees or shrubs used to soften the landscape design.

Hardscapes refer to all of the hard aspects of a landscape including walkways, patios, walls, driveways etc… These features form the basic structure or backbone of the landscape design. Typically, the hardscapes are constructed first followed by the softscapes. These two entities should compliment one another creating an effective landscape design.

Types of Hardscapes

- Patios and walkways are hard pavements constructed to provide an area for entertainment or to channel people from one area to another. These surfaces can be created using pavers or natural stone arranged in a variety of patterns.
- Driveways are pavement surfaces as well, used to provide parking and a surface for traffic. Paver driveways are very common now, designed to blend into the surrounding landscape. However, these surfaces have different base requirements as discussed later in this chapter.
- Retaining walls are designed to retain soil or facilitate a sudden grade change within a landscape. These features can be constructed using natural stone, boulders or segmental retaining wall systems. Several factors discussed later in this section are important in the construction of retaining walls.
- Freestanding walls are often used as sitting walls within landscape designs. Natural stone and concrete products are used to create these walls. These walls are designed to stand by themselves and form borders around sitting areas or property barriers.
- Ornamental boulders are used to form an instant barrier, focal points or retaining walls within a landscape.
- Ornamental stone mulches consist of round or angular stone in a variety of colors that can be used to create drip edges, pathways or used as low maintenance mulch.

- Footpaths are simple hardscapes worth mentioning. Stepping-stones or simple bark mulch trails with log borders can be used to channel pedestrian traffic within a landscape.
- Timber construction such as arbors, pergolas, fencing and gazebos are other key components of a hardscape. Though not discussed in this chapter, they should be considered within a landscape plan.
- Water gardens are a popular form of hardscape in today's landscaping market. Though not discussed in this chapter, they are a growing trend within American landscapes.

Hardscape installation; Project Planning Checklist

Once you have agreed upon a landscape design with your client, plan ahead before you begin to install. For a cost effective and efficient production, make a checklist of the following factors:

Codes & Permits

☐ You must meet local codes. Check with the local building inspector or code enforcement officer to secure all necessary permits (building, landscape, tree removal, plumbing/drainage, electrical, etc.). Codes and ordinances will vary from one city or town to the next. Therefore it is important to know where to obtain information and to whom questions should be addressed. Get all required permits prior to commencement of a project.

Locate Utilities

☐ In New York State, it is the law that a contractor must contact Dig Safely New York prior to any excavation work. If a utility is damaged by a contractor who failed to have it marked, the contractor will be held responsible for the damage, could face additional fines, and may be responsible for any bodily harm inflicted upon workers or bystanders. Dig Safely New York is a free service provided by the state to locate underground utilities.

Phone Number for Dig Safely New York - 1.800.962.7962

for NYC and Long Island - 1.800.272.4480

Locate Septic Fields, Irrigation, and other Private Utilities

☐ Dig Safely New York does not locate all utilities. It is important to interview the customer to find out the location of secondary utilities. For example, septic leach fields are often soft and shouldn't be traversed with heavy equipment and vehicles. Irrigation systems, low voltage lighting, and pet fencing are other utilities that should be marked. Taking the time to locate these utilities prior to excavation can eliminate unnecessary repairs to more cost effective, efficient production.

Determine Site Conditions; Soils & Grades

☐ Sites respond differently to changing weather conditions. Clay sites become difficult to work on following a rainstorm whereas gravel and sandy sites tend to dry very quickly. Slopes and low spots can affect drying times as well as create more work while moving material in and out. Soil types can also affect the depth of base used under pavements or amendments needed in planting beds. Take a soil sample and have it tested at a soil lab during the early design stages of a project. Determining these site variables prior to a project may make a difference in scheduling and the amount of estimated time needed to complete the installation.

Site Planning

☐ Every site is different, managing your site for flow of materials and equipment helps lead to more efficient production. Parking and staging areas are important to identify at your site. Some sites have ample room to park vehicles while others are very difficult. Likewise, a supplier can often stage materials near the project but not always. Placement of materials and timing of delivery are critical to efficient production.

Access

☐ Access is another critical aspect of your site. -Some projects have clear access through a side yard whereas others are more difficult. In some city sites, contractors have to carry materials through the residence in order to reach a backyard patio.

Locating Power & Water Source

☐ Locating an adequate power and water source is very important as well. Often times, electricity is required to run wet saws or skill saws during a job. At many new construction sites, power is not always available. A generator will need to be rented in these situations in order to operate tools. Likewise, a water tap should be identified for running wet saws, mixing mortar or watering newly installed plant material.

Locate Material Suppliers Nearby

☐ Finding a supplier near a job site is another key factor in creating more efficient production. Prior to starting a job, do your research in the area. Identify local suppliers such as nurseries or quarries. Time saved by cutting down on travel is critical to maintaining efficient production. Likewise, having materials delivered is often beneficial.

Locate Dump Sites

☐ Excavated excess material and unwanted debris often need to be removed from the job site. Locating a site nearby is critical to maintaining efficient production. The closer the dump site, less time is spent driving and more time is available for installation. Many people often look for free fill; finding these people near your project will also save you time and money. On the other hand, if a dump site is not readily available, factor the expenses of travel or dump fees into your costs.

Determine Equipment Requirements

☐ Different job sites and site conditions warrant the use of different equipment. For example, track loaders should be used on wet sites to prevent damage whereas wheel loaders work well on hard sites. Sometimes, small equipment will fit through fence openings and be more effective then large equipment. Renting a piece of equipment to complete a project faster is often more efficient then paying for more labor. Locating rental dealers near the job site will increase your efficiency. Consider delivery fees versus picking up rental equipment.

Site Cleanup

☐ Cleaning up the job site at the end of each day is critical for both company image and efficient production. An area should be designated for storing tools and equipment, such as an enclosed trailer. Ask clients for permission before using their sheds to store tools in. Any trash, bottles, or pallet wrappings should be removed from the site at the end of each day.

***Following these guidelines will lead to more efficient production.*

Hardscape Construction: Industry Standards

There are basic materials and installation standards in every industry. The CNLP program was originally designed to establish a series of guidelines and standards for helping nursery, and landscape professionals to make qualified decisions. Different locations have varying standards to follow due to different climates. However, the overall purpose is the same. The following pages in Chapter 6 will provide you with the basic principles of hardscape construction. Keep in mind, there is no substitute for substantial field experience when competently installing hardscape projects.

Companies looking to specialize in hardscape construction are encouraged to become certified by the following organizations:

Interlocking Concrete Pavement Institute (ICPI)
This organization provides the industry standard for paver installation in North America.
www.icpi.org

National Concrete Masonry Association (NCMA)
This organization provides the industry standard for segmental block walls in North America_
www.ncma.org

Dry Stone Conservancy (DSC)
This organization provides the .industry standard for dry stone walling in North America. It closely follows the standards of the Dry Stone Walling Association of Great Britain.
www.drvstone.org

Construction Materials

The American Society of Testing Materials (ASTM) provides the standard for certified materials. ASTM numbers have been assigned to several industry-related materials including quarried aggregate and piping.

Similar to plant nomenclature, quarried materials used in hardscapes have several common names. To eliminate confusion, ASTM specifications are standardized. Materials used on hardscape projects should be taken from certified quarries. These quarries have materials meeting these specifications nationwide.

Aggregate materials are specified based on gradation. Gradation is typically expressed in percent mass of a sample passing through particular sieve sizes. Similar to measuring soils, the amount of particles passing through a 200 sieve determines the gradation of a material. The gradation of a material affects its ability to perform under pavements. For example, too many fine particles within an aggregate material create a weak base susceptible to frost heaving. On the other hand, too few fine particles within an aggregate base allow for migration of the bedding sand.

Materials meeting the following Specifications should be used in hardscape construction projects

Table 2 - ASTM Specifications Table		
Specification	**Common Name**	**Description**
ASTM 2940	Crusher-run gravel	Aggregate material used to create the base under walls, patios and walkways.
ASTM C33	Concrete sand	Coarse, angular, multi-grained sands used as bedding sands under interlocking paver systems
ASTM C144	Mason sand	Fine sands used to sweep into the joints of interlocking paver systems
ASTM 57	57's, 3/4" drainage	¾" round drainage stone placed behind retaining walls.

Principles of Base Installation

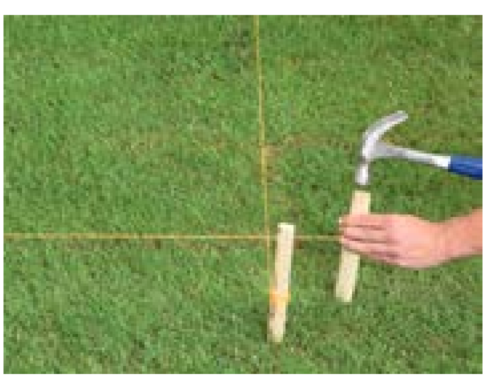
The success and longevity of a patio is dependent upon the base installed beneath it. No matter how nice a patio appears when first constructed, the quality of the base will enable it to pass the test of time. Patio failure is due to many factors that will be discussed in this section.

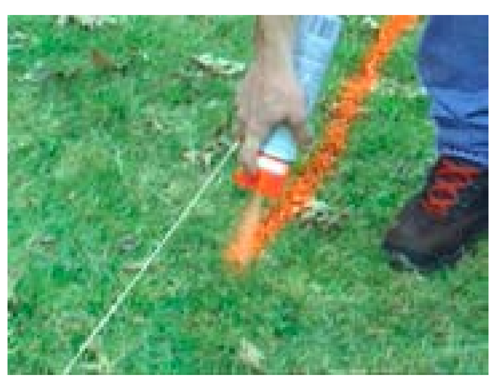
Layout

When laying out a patio or walkway it is important to mark out the entire patio first in the area prior to excavation. Usually this is performed with marking paint or string lines. This spells out the design and indicates if it works functionally and aesthetically within the given area. This also allows the client to preview the patio and make initial changes before excavation, saving you future time and money.

String lines and stakes should be at least one foot outside of excavated area. This allows you to keep them in place while excavating and use them for checking elevations. The stakes provide points of reference for both grading and drainage:

Figure 9 a & b - Layout methods





Excavation

Project excavation is a critical stage in maintaining efficient production. Under-excavation can lead to an improper base depth resulting in wall or patio failure over time. Over-excavation requires additional labor, generation of unnecessary material removal, and installation of additional base aggregate than originally required. All of these factors affect overall efficiency during construction.

When determining depth of excavation, one must consider the patio slopes, base depth, bedding sand depth, and thickness of the paving unit. By adding all of these factors and figuring in slopes, one is able to determine the proper elevations.

Depth of Base

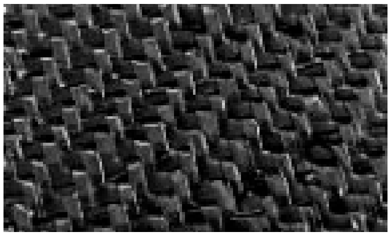
The thickness of the base (after compaction) is determined by traffic loads, soil strength, subgrade soil drainage, and climate. Base depth continues to be the center of debate among contractors. Different site conditions require different depths of base material. For example, sandy sites provide excellent drainage and therefore moisture is less apt to remain at the earth's surface. These sites require less of a base. However, clay soils retain water and are very susceptible to frost heaving. These soil conditions require a deeper base beneath patios. The ICPI standard, minimum base depth for any walkway or patio regardless of soil type is four inches. Residential driveways on well drained soils require a 1CPI minimum of six inches. Areas such as upstate New York have very active freeze-thaw cycles and mixed soil conditions. Much deeper bases are recommended in these areas.

The base should extend at least six inches beyond the outside of the patio to prevent pavement failure along edges.

Installation of Geotextiles

Geotextiles contain and preserve the base, separating it from the subsoil. These synthetic fabrics are especially useful in clay and silt conditions. These are conditions which tend to retain moisture and are very susceptible to freeze - thaw movements. Geotextiles will help preserve the load bearing capacity of the base under wails and pavements for a longer period of time.

- Woven Geotextites - These fabrics allow for drainage but retain and separate the material above to prevent sub-grade from contaminating the base. Woven fabrics have bilateral tension ability which helps to prevent settling. These fabrics are perfect under patios, especially in poor draining clay situations. These geotextiles are often used to dry up the subgrade allowing construction projects to continue. (Example: Mirafi 500x: Product created for interlocking concrete paver stabilization.)
- Non-Woven Geotextites - These geotextiles act as a filter fabric. They can be used as a soil separator or within several drainage system applications. (Example: Mirafi 140N Products created for subsurface drainage applications.)



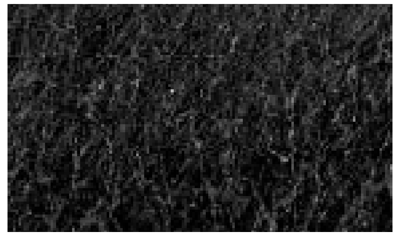


Figure 10 & 11 - Woven & Non-woven Geotextiles

Installation of Aggregate
Once the geotextile has been placed within the excavated area, the aggregate installation process can begin. ASTM 2940 is the standard aggregate that should be used to create the base. This specified material has the proper gradation and will not fail when compacted properly. Please see the diagram below showing the importance of using base material with the proper gradation. Fines are important within an aggregate base; however, too many fines can be detrimental.

Compaction of Base
Install the base material in small increments or "lifts" to ensure proper compaction. Each lift should be graded out to the proper pitch and compacted. Lifts have an average thickness of 2 - 6" depending on the type of compaction equipment used. Different soil conditions require different methods and amounts of compaction.
Compaction is the process of mechanically increasing soil density or unit weight. Compaction removes air and moisture from soil, moving like particles together, and increasing density. Increased soil density allows soil to support a load without settling.

Figure 12 & 13 - Loose / Compacted base material

The Mechanics of Base Compaction

3 Factors Affecting Compaction of a Material:

- Type of material or sub-grade
- Moisture content of material
- Type of compaction method used (pressing, ramming, or vibratory equipment).

3 Types of Compaction Machines:
Compaction machines are designed to compact based on frequency and amplitude. Frequency measures the speed, while amplitude is a measure of the height of the plate above the ground.

- Ramming Compactors - Have a low frequency and high amplitude. Excellent for clay soils in confined areas. Compacts soil by forcing out air and water, rearranging particles.
- Vibratory Compactors or Vibratory Rollers - Have a high frequency and low amplitude. These compactors are commonly used for most residential walkway

and patio applications. These machines compact soils by sending frequent vibratory waves through soils, rearranging the particles.

- Static Rollers - These machines rely on their weight alone to achieve compaction. These machines are usually used-on asphalt.

Figure 14 - Compactor Machine Selection

<u>Achieving Compaction</u>

Compaction of a material is measured by its proctor density. Although beyond the scope of this course, large paver applications require field tests during installation.
98% standard proctor density is the minimum allowable density rating for surfaces wider vehicular traffic.

Methods for Measuring Compaction;

- Nuclear Density Gauge
- Dynamic cone penetrometer

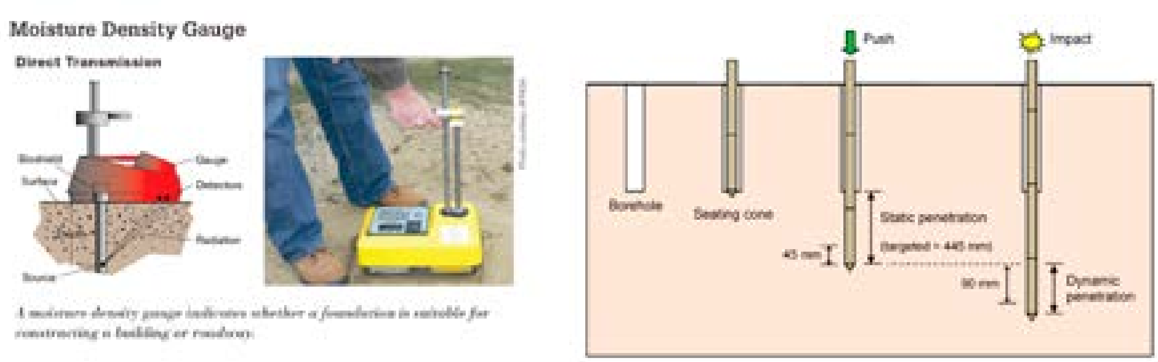


Figure 15 - Measuring Compaction

Final Base Preparation

The consistency and slope of the final base layer of aggregate is crucial for a successful patio. This is especially true in paver patios. Many contractors prepare the base and any errors are made up within the bedding medium. It is common to see the bedding course two inches deep in some areas and very thin in others. The problem with doing this is that once compacted, the bedding medium will form to the base. Therefore, the final pavement surface will have the same inconsistencies as the base. The following tolerances are the CPI standard for paver patio construction.

Allowable Tolerances for Base Materials:

- The tolerance for the base elevations for the preliminary elevations should not vary more than +3/4" to -1/2" from the specified thickness.
- The tolerance for the final surface elevation should not exceed +/-3/8" over a 10' span.
- The base should be sloped the same as the final paver elevation.

Pavement Slopes

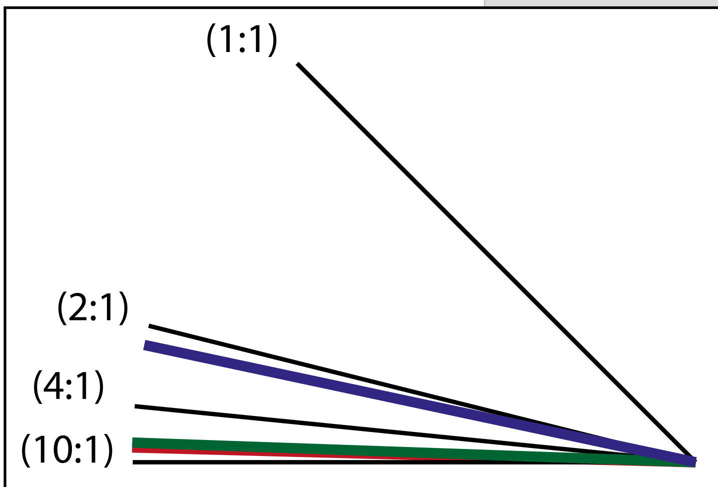
Laws and design standards implemented by the American with Disabilities Act (ADA) must be adhered to and should be further reviewed by the landscape designer. For example, such standards will dictate slopes on handicap access ramps, walkways, heights and applications for hand rails, etc.

The minimum amount of slope on a paving surface is 1.5% or a drop of 3/16" for every foot of pavement.

Most residential patios have a 2% slope or .25" for every foot of pavement. This allows for better drainage away from the structure. These patios usually run level along the foundation.

The maximum amount of slope on a paving surface for comfortable walking is 12%.

Figure 16 - Grades and Slopes (next page)
Is a good reference guide for relations of slope, gradient, percent slope, and the number of inches of drop per foot.



Reccomendations	Slope	Degrees	Percent	Inches Drop per Foot
	1:1	45.0	100.0	12
	1.5:1	33.7	66.7	8
	2:1	26.6	50.0	6
	2.3:1	21.8	40.0	4.75
	3:1	18.3	33.3	4
	3.5:1	15.9	28.6	
	4:1	14.0	25.0	3
	4.5:1	12.5	22.2	
	5:1	11.3	20.0	2.50
	6:1	9.5	16.7	2
	7:1	8.1	14.3	
Max. Slope for Walking	8:1	7.1	12.5	
	9:1	6.3	11.1	
	10:1	5.7	10.0	1.25
	11:1	5.1	9.0	
	12:1	4.7	8.3	1
	13:1	4.3	7.7	
	14:1	3.9	7.1	
	15:1	3.6	6.6	
	16:1	3.4	6.3	.75
	17:1	3.2	5.8	
	18:1	3.0	5.5	
	19:1	2.8	5.2	
	20:1	2.7	5.0	.635
	25:1	2.1	4.0	.50
	33:1	1.5	3.0	.375
Recommended for Patios	50:1	0.9	2.0	.25
Min. Slope on Paved Surfaces	65:1	0.06	1.5	.1875
			1.0	.125

Figure 16 - Grades and Slopes

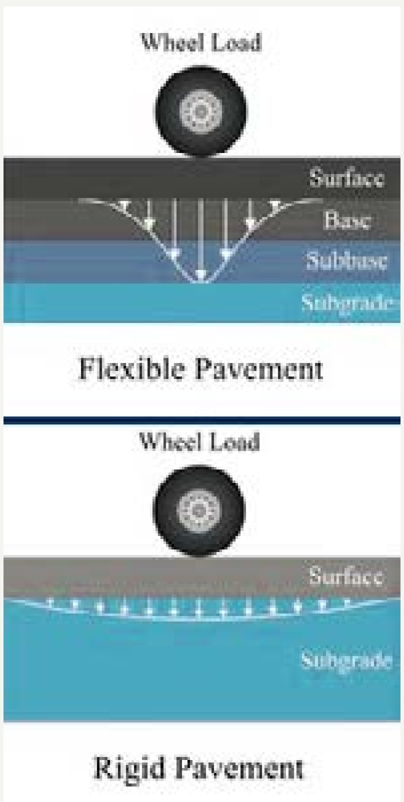


Figure 17 - Load Distribution of Pavements

Crowns are often placed in pavement systems because they cause greater interlock known as progressive stiffening.

Principles of Pavements

Pavers

Brief History of Flexible Pavers - The revival of interlocking concrete pavements in North America occurred in the early 1970's. The concept was brought down from Canada and originated in Europe. Today paver installation is the fastest growing segment of the construction industry.
This is referred to as a revival because segmental paving systems have been used for centuries throughout the world. In fact, the earliest presence of segmental roads dates back to the Minoans over 7,000 years ago. The Romans had extensive interstates over 2,000 years ago. Brick streets in the older portions of American cities during the 1800's are our earliest form of paving.

Concept of Interlocking Pavements - Interlocking concrete pavers are designed to spread loads across the base. These pavement systems are referred to as flexible because loads are distributed through-the base, through point to point contact and interlock between the aggregate. Energy is distributed from the paver to the sand, to the base, and finally to the undisturbed soil below. Unlike asphalt or poured concrete, pavers can handle movement within the base without cracking.
3 Types of Interlock:

- **Vertical Interlock** is the shear transfer of loads in horizontal paths to surrounding units.
- **Rotational Interlock** is due to uniform thickness, equal joint spacing and being restrained.
- **Horizontal Interlock** is due to the patterns and being restrained.

Installation of Bedding Medium - Many contractors will improperly use stone dust as bedding medium for laying pavers. This is not recommended because stone dust contains a mixture of particle sizes. Continuous pressure will eventually break down the larger particles causing settlement within the bedding medium. On the other hand, mason's sand (ASTM C144) shouldn't be used either because the particles are too fine. Patios constructed with mason's sand often have a wavy appearance.
ASTM C33 is the ICPI standard for bedding sand under interlocking pavements.

Screeding is the process of grading bedding sand prior to laying pavers. This is typically done with one inch outside diameter pipes placed at the proper pitches. As mentioned earlier, the bedding medium should be spread consistently across the base. If some areas of the base do not meet the desired tolerances, this will be reflected in the final pavement surface.

** 3/8" is usually lost during compaction. This is important to remember when figuring elevations.
** The ICPI recommends only compacting bedding medium after pavers have been laid. Pre-compacting reduces the amount of interlock achieved, affecting the long-term integrity of pavements.

Figure 18 - Screeding with pipes

Choosing Pavers - The ASTM standard for pavers is C936. The minimum thickness is 2 3/8" for pedestrian use and 3 1/8" for vehicular use.

When selecting pavers one must consider the following factors:

- **Application;** walkway vs. driveway. Driveways require a thicker paver, more cost associated.
- **Pattern;** herringbone, running bond, woven, basket weave. Herringbone patterns are often recommended for driveways due to exceptional interlock. Woven and herringbone patterns take longer to lay then a straight running bond or basket weave.
- **Soldier Course;** Often a row of uniform pavers is cut and placed along the outside of a patio or walkway to create a definitive border.
- **Tumbled pavers;** are more durable and have an attractive texture but are considerably more expensive then aggregate pavers.
- **Slabs;** Some pavers are actually considered to be slabs. If the length of a paver divided by its thickness (known as aspect ratio) is greater than 4 then it is considered a slab. Knowing the difference is important when determining compaction methods and the amount of traffic load that they will accept.
- **Color Blends;** Some products have colors already blended while others require buying separate pallets and mixing.
- **Salt tolerance;** Most modem tumbled pavers are tolerant to de-icing chemicals. This should be checked though with the supplier depending on the application.

Laying Pavers - The general method to follow is to "click and drop" the pavers.
Click the bottom of the paver in your band against the top of the paver(s) already installed. Let go of paver, tightly pushing it directly downward. This results in uniform paver joints no greater than 3/16".

Figure 19 -Click & Drop Method

When laying pavers on a large patio it is important to draw from multiple pallets to maintain consistency of colors throughout.

Cutting Pavers - Almost every paver job requires cutting. Usually the outsides of a walkway need to be cut or curves need to be cut on more detailed projects.
3 Methods of Cutting Pavers;

Paver Splitter; non-motorized tool which is quiet and dust free but lacks accuracy.
Wet Saw; requires water and adequate electricity, very accurate and dust free but takes time to set up. Use only electric saws approved for use with water.
Cutoff saw; motorized, fast and accurate but loud and dusty. Use of water where possible is recommended to reduce dust and minimize blade wear.

Figure 20 - Cutting Equipment

* Proper safety equipment should be used including eye and ear protection as well as a mask.

Dust particles given off while cutting any concrete or stone product are very toxic. Silicosis is a preventable occupational lung disease caused by the inhalation of respirable crystalline silica dust. (health.ny.gov). It is important that you comply with state, federal and local laws regarding while constructing hardscapes. Saws are available that will minimize exposure to this silica dust and are well worth the investment.

Edging Restraints - Interlocking pavement systems need to be restrained along the outside edges to maintain interlock. If not, a situation known as "creep" will occur among the pavers opening up the joints and weakening the system. Restraints are sometimes already existing (against buildings) in which case pavers are installed right up tight to them. Curved walkways usually require cutting. Edging is placed along these edges following cutting.

Types of Edging Restraints:

- Buildings or walls; act as restraints against pavers
- Precast concrete curbing or stone curbing; Belgian blocks
- Aluminum or steel edging
- Plastic edging; this is the most cost effective form of edging. It is secured with 10" steel spikes.
- Troweled concrete and submerged curbs are not recommended in freezing climates as they may crack and cause on-going maintenance problems.

Paver Compaction - Once the patio has been cut and edged to meet the design, it is ready for compaction. It is important to compact the patio prior to sweeping in any joint sand. The process of compaction draws sand from beneath the pavers up between the pavers creating interlock.

Paver Compaction Tips

- A vibratory compactor with a minimum force of 4,000 psi is what should be used to compact the paver surface.
- When compacting irregular surfaces, a pad should be installed on the compactor to prevent scuffing. Geotextile fabric can be used to cover the surface if a pad is not available.
- Start compaction around the outside perimeter of the pavement and work toward the center.
- Maintain an overlap of one paver width or 4 - 6 inches when compacting the patio.
- If not finished with the entire patio, it should be compacted at the end of each day. Compact out to within 6 feet from the edge of the patio. Cover the uncompacted section with tarps until the next work day.

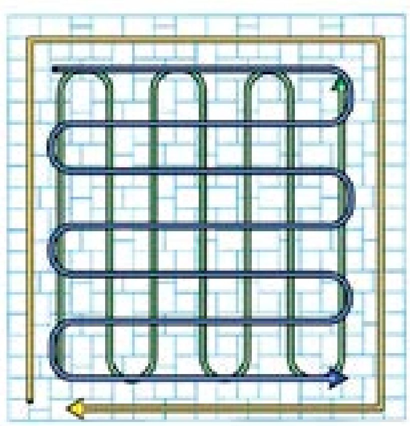


Figure 21 - Compaction Sequence

Sweeping in Joints and Patio Completion - After the pavement has been passed over twice with the compactor, it is ready to be "Swept in". Polymeric joint stabilizing sand is commonly used for this process. This sand has a polymer adhesive within the sand that stiffens the sand once water is applied.

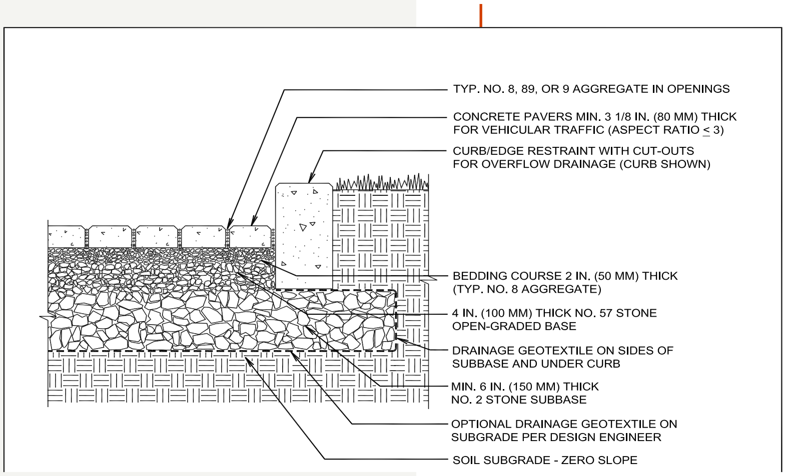
As an alternative, a liquid sealer or joint sand stabilizer can be used in place of joint sand. In this process, the entire surface is cleaned and all excess joint sand is removed prior to adding the sealant. Contact your suppliers for more information on these products.

Backfilling the Patio - Once completed, it is very important that the patio or walkway is backfilled. Though the edging provides the bulk of the restraint, the mass of the surrounding beds is also important to maintaining interlock. If the edging is not backfilled, pavers will have a tendency to lift up in freeze-thaw conditions. This will have an adverse effect on the integrity of the pavement.

Permeable Pavers

Permeable Interlocking Concrete Pavement (PICP) has become a popular option for both residential and commercial applications. This type of interlocking paver system exaggerates the joint spacing which enables infiltration of surface runoff and pollutants. The efficiency and environmental benefits of these systems have made them an attractive alternative to standard asphalt and concrete for parking areas, driveways, streets and even walkways.

Permeable pavers require a different type of base and setting bed from standard interlocking pavers and are designed to absorb water rather than sheet it away.



Be sure to consult and follow recommended permeable paver installation procedures which can be obtained through the I.C.P.I. Available HERE.

Figure 22 - Permeable pavement cross-section detail

Principles of Pavements; Natural Stone

Stone is the oldest construction material known to mankind. The rigidity and simple elegance of a natural stone patio is tough to compare to. Good stone masons are rare in today's fast paced society. Few contractors are willing to spend the time and energy required to complete this type of craft. Average stone masons can lay approximately 75 square feet of stone in an eight hour day. This rate compared to paver installation is exactly why natural stone is less common. Pavers are now being produced to capture the same look of stone at a much more affordable price. These pavers are effective but still are no match to the real thing!

<u>Types of Stone -</u> There are different types of stone all around New York State. Bluestone is the most prevalent stone used in pavements in our state. However, limerock, granite, marble and several other types of stone are found and used here and throughout the country.
Each type of stone has unique characteristics. Some stone such as bluestone is soft, while granite is very hard to work with. Experienced stone masons are able to differentiate the types of material and know how it reacts to chiseling.

<u>Stone Pavements</u>
Irregular Stone Patios - These patios are composed of completely irregular sized and shaped stones woven together like a large puzzle. 1/2" inch joints are the maximum joints tolerable in this form of patio, 1/4" joints are preferred. Not one piece in the patio matches another one. The patio is formed as the stones come off the pallets. This form of stone patio is the most difficult type of paving surface to construct.

Random Flagstone Patios - These patios are composed of random sized pieces of stone. All of the pieces are in the shape of squares or rectangles. 1/4" joints are maintained within these patios. The general idea is to prevent parallel lines and not to allow lines to extend too far. The corners of four stones should not come together at one point. This form of patio is often used in more formal settings.

Figure 23 -Irregular stone patio

Figure 24 -Random flagstone patio

Setting Stone - Stone can be set on a variety of media depending on the style of patio being created. Concrete sand and stone screenings are commonly used for random flagstone patios. Pea gravel is commonly used as a bedding medium for irregular stone patios. Pea gravel is effective in that it doesn't hold moisture and is less apt to wash out the sand or stone dust.

Most stone has to be individually placed due to the inconsistency in thickness. Therefore, heights are determined and each stone is brought to level based on the one laid prior to it. Checking levels by bridging a long straight edge over several pieces can prevent low spots. Completed patios are usually swept in with the bedding medium, joint stabilizing sand, or a light mix of mortar and mason's sand.

In non-freeze climates, stone can be bedded on mortar. This technique is not recommended for New York State unless it is an overlay project on a concrete slab. The joints of these projects are usually “pointed" with a mortar mix or grout, creating one solid patio.

Stone Tools - The advantage to stone work is that very few tools are needed to create long lasting structures. 3# stone hammers, chipping hammers, and chisels are all that is needed for stone projects. Having the skills to complete the project is another story!

Cutoff saws are often used to increase efficiency while constructing stone patios. They prevent accidental splitting of stone surfaces while chiseling. However, it is important to work the stone in all cases to mask the saw cuts

Principals of Retaining Walls

Segmental Walls

Retaining walls are used in several different applications ranging from residential settings to shopping malls to large roadside construction projects. Retaining walls enable you to rapidly change an elevation by cutting out a slope and making a solid retaining edge. When properly constructed, a retaining wall can provide an attractive, long lasting, and functional structure within the natural landscape.

The mortar-less artificial block wails used to retain the earth are known as segmental retaining walls. These walls became popular during the 1980's and have grown into a multimillion-dollar industry in the United States. Several companies produce wall systems, each have different engineering behind their construction. However, all wall systems are alike in that they consist of segmental units (blocks composed of concrete) that are placed together to retain the soil behind them. The main benefit of these wall systems is that they do not require a frost footing. Therefore, segmental retaining walls provide a cost effective alternative to poured walls in addition to allowing greater design flexibility.

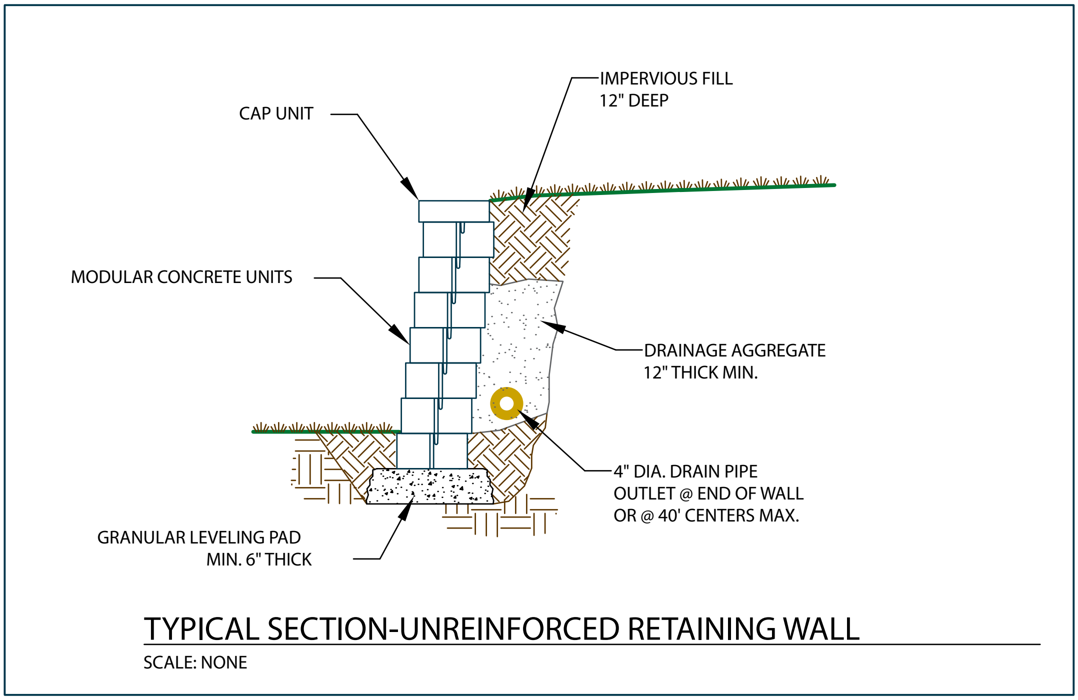
> *Note: Depending on the application, the installation of retaining walls can be very risky business. If not properly constructed, wall failure can occur in a very short amount of time. Replacing or repairing failed walls is very expensive and can often cost more than the entire project originally brought in. This section merely provides a basic overview of wall construction. If considering installing retaining walls as a profession, it is strongly recommended that you receive NCMA certification.*

<u>Base Requirements -</u> Rigid concrete footings extending below frost level are not required for segmental retaining wall systems. Because standard units are installed without mortar, they are free to move slightly in relation to each other. Flexibility of both the base and wall units accommodates freeze/thaw cycles without damage to the overall structure.
The base, which also serves as a leveling pad, should be constructed using well graded, angular gravel. ASTM 2940,

which is used in interlocking concrete paver systems, is also recommended for wall base construction.
Granular leveling pads provide stiff, yet somewhat flexible, bases to distribute wall weights. Base depth varies depending on the location and soil type but a minimum base depth of six inches is recommended in any application. Similar to interlocking paver construction, a woven geotextile fabric is recommended below the gravel to stabilize the system.

Wall Embedment - Embedment-provides enhanced wall stability and long term protection for the base. As a rule, one tenth of overall exposed wall heights should be embedded below grade. For example, a wall with ten feet of height exposed above grade should have a minimum of one foot buried below grade; making total wall height eleven feet. Likewise, when excavating for the wall base, both embedment and base depth should be considered when determining elevations. Some situations require greater embedment such as soft foundation soils, shoreline applications and certain slopes.

Soils & Compaction - With proper design, segmental retaining walls can be constructed within a wide variety of soil conditions. Problem materials like expansive clays, compressible soils, or highly organic soils (top soil) should be avoided or amended. Usually, coarse soils require less soil reinforcement and are easier to compact then fine soils. These soils are usually recommended as backfill behind segmental wall systems.
Proper compaction of the base and backfill soil is critical to the longevity and success of a segmental retaining wall system. 95% standard proctor density is the minimum allowable compaction rate. If not compacted properly, loose backfill will collect water, which will cause hydrostatic pressure against the wall, leading to settlement and blowouts. Properly compacted free draining backfill materials will eliminate hydrostatic pressure behind walls.



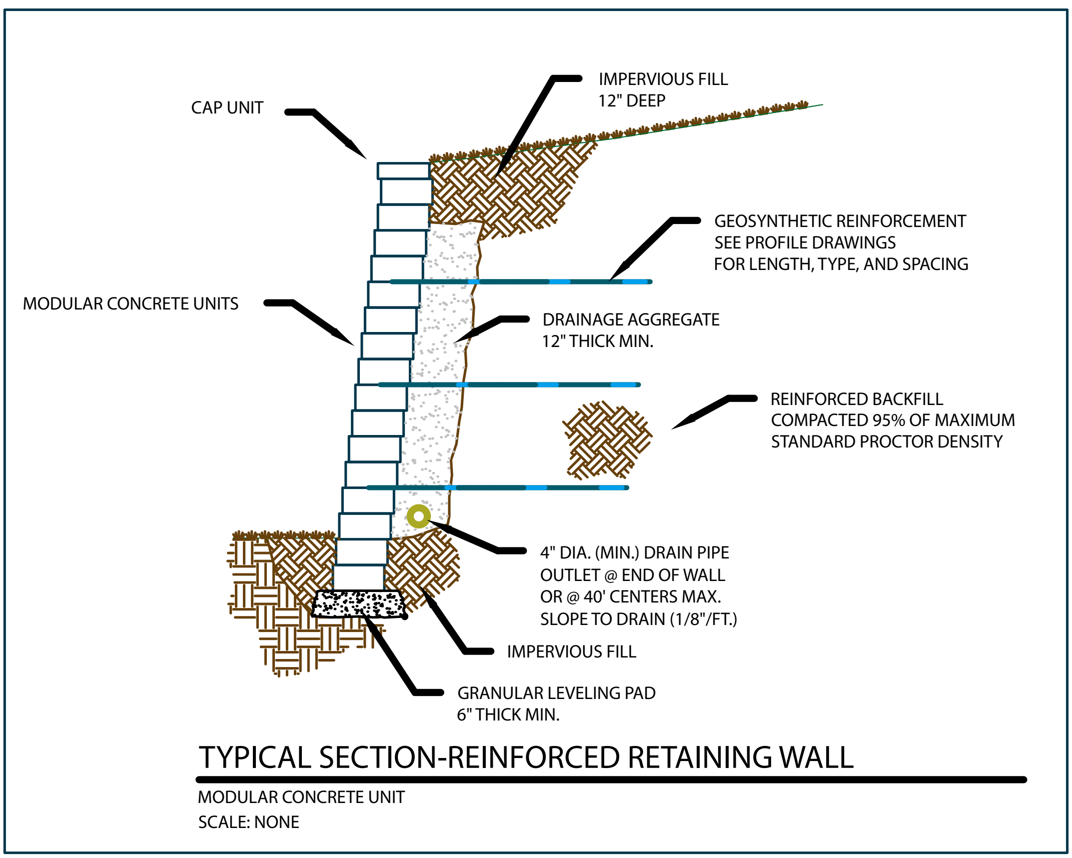


Figure 25 - Typical Section - Un-reinforced
Figure 26 - Typical Section - Reinforced

For walls greater than three feet in height, perforated drain pipe is recommended at the base of the drainage aggregate to quickly remove large amounts of water. The pipe should be day-lighted (by providing an opening to the outside to let water escape.) at least once for every fifty lineal feet of wall to ensure proper drainage.

Geotextiles provide Tensile Strength to backfilled soils

Geogrid is designed to interact with the soil for anchorage

Importance of Drainage - Segmental retaining walls are designed assuming that there is no hydrostatic pressure behind walls. To achieve this, place clean angular 3/4" drainage aggregate (ASTM 57) behind the walls to eliminate water accumulation. Because no mortar is used in these wall systems, water is free to weep though the joints of the individual wall units.

Surface drainage is also important to the integrity of segmental retaining wall systems. Wall sites should be graded to avoid water flows or pools behind retaining walls. The less water allowed to enter a wall system, the less hydrostatic pressure created. Non-woven geotextile fabrics are often placed behind retaining walls to prevent fine soil particles from migrating into the drainage aggregate, helping to keep the system intact.

Geosynthetic Reinforcement - Geosynthetics or geotextiles are high strength polymer products designed for use as soil reinforcement. Geotextiles are made from several types of polymers that are resistant to installation damage and long-term degradation. Geogrid is the most common geotextile used for wall reinforcement; it has an open grid-like formation. Geogrid is designed to interact with the soil for anchorage against pullout and resistance to sliding, similar to a "dead man" in a timber-constructed wall.

Geogrid is placed in horizontal layers to provide tensile strength to hold the reinforced soil mass together. The soil itself then in effect becomes the retaining wall taking the load off of the segmental block system.

Geogrid is generally stronger in one direction; it is clearly marked on the roll. It is important that the high strength direction be placed perpendicular to the wall face, in one continuous sheet. There should be 100% coverage without overlapping. If overlapped, the tensile strength is lost. The required type, length, vertical spacing and strength of geosynthetic vary with each project depending on wall height, loading, slopes and conditions. Many segmental retaining wall companies provide civil engineers who will come out to a project and design a wall system suitable for a given site. Contact your local dealer for more information.

Retaining Wall Construction Basics

- 1/10" of final wall height should be embedded beneath grade.
- Embedded units should be backfilled both in front and behind with soil and compacted; do not use drainage stone.
- It is critical that the base course is level in both directions. Any errors in the base course will be reflected throughout the entire wall. Make sure to triple check the base, it is easier then realizing there is an error when you have half of the wall completed.
- For long stretches of wall use a string line along the back of the wall to maintain a straight edge. The face of the wall is often tumbled or textured making it difficult to make an accurate edge.
- Most segmental retaining walls are designed with a set back or "batter" to further stabilize the wall from rolling forward. Make sure the batter is correct on the wall and that you are using the correct modules for the given application.
- The retaining wall should be backfilled with clean ¾” stone and compacted following every course of block. This will ensure maximum compaction, reducing the chance of settlement.
- If using geogrid, make sure that the tensile strength (marked on roll) is placed perpendicular to the face of the wall. Do not overlap geogrid, tensile strength is lost.
- Drain pipe placed behind walls should be day-lighted at least once for every fifty lineal feet of wall.
- It is recommended that an impervious soil be used for the top 1' of backfill. This layer sheds water, reducing the amount of load on the wall.
- Cutoff saws or block breakers are used to cut blocks to fit a design. Make sure to wear the appropriate safety equipment when making cuts.

Natural Stone Walls

History and Significance - Stone walling has been used for centuries throughout the world. Many people don't realize the role that stone walls have had within our local culture. Stone walls have been used to separate properties, divide fields, and retain banks extensively throughout the North East for centuries. It has been estimated that over 250,000 miles of dry stone walls have been constructed in New York and New England alone. (This is an impressive number especially in comparison with Great Britain. Although stone walling began there and has been used much longer, Great Britain has only 70,000 miles of stone walls.)

Figure 27 -Natural stone wall

Unfortunately, the craft of stone walling is fast becoming a thing of the past in North America. Segmental retaining wall systems have provided a much faster, much more economical solution to handling elevation changes. Yet the construction of natural stone walls is truly an art. Good stone masons are hard to find, but the beauty of a hand-crafted natural stone wall is incomparable. With minimal hand tools, one can construct features that will serve the same purpose as any segmental retaining wall. The main difference is the time, training, and artistry required!

The basics of wall construction are similar to those of segmental retaining walls. Base, embedment, drainage, backfill are all-important to a successful wall. The difference is that the units (stones) used to construct the walls are completely different in size, weight and shape from one another. All of these different units are pieced together to create a wall. All of the pieces are independent of one another and therefore are able to move slightly without damaging the integrity of the entire structure.

If interested in learning more about the art of dry stone walling please consult with the Dry Stone Conservancy listed at the beginning of this chapter.

Natural stone walling is a difficult trade to teach. Along with stone patios, different regions provide a huge variety in types of stone available. Different types of stone have different densities, making them a challenge to work with. For some apprentices it may take a year in the field to develop the basic skills required to construct stone walls. Speed and efficiency come with experience; it is primarily a self-taught trade.

Boulder Walls - Angular, round, and flat natural stone boulders are often used to create economical retaining walls at residential and commercial sites. The installation of these walls follows the same process as natural and segmental walls but at a much larger scale. Boulders can range from a couple hundred pounds to several ton and are placed with heavy equipment such as loaders and excavators. As with all retaining walls, it is important to imbed the first course of boulders (10% of total wall height) and provide adequate drainage.

Figure 28 - Boulder wall

Review Questions

Grading & Drainage

1. What is the importance of grading and drainage?
2. Name three problems that result from improper grading and drainage.
3. What effect can heavy grading equipment have on surrounding trees and shrubs within a landscape?
4. Identify the importance of vapor barriers, filter fabrics, and moisture sealants within drainage systems.

Slope and Elevation

1. What two factor effect Grading? Define both of these factors.
2. Perform an example slope calculation.
3. If a site has a 4:1 slope, describe what this means.
4. Identify the importance of minimum and maximum slope standards.

Collection of Vertical Measurements

1. What three instruments are commonly used to measure elevations? List the advantages of each.
2. List the 3 steps involved in determining elevations.

Methods of Collecting and Conveying Surface Drainage

1. List the 3 types of swales and provide an example of each.
2. What is an example of a sheet drain?
3. When is a French drain used?
4. What is the difference between a detention pond and a retention pond? Provide an example of each.
5. What is a dry well used for?

Introduction to Hardscapes

1. Describe the difference between softscapes and hardscapes.
2. List some examples of hardscapes.

Hardscape Installation; Project Planning Checklist

1. What is the importance of developing a project planning checklist?
2. What is the importance of locating utilities before entering a project?
3. Identify the importance of checking local codes before entering a project?
4. List a few factors that should be considered within a project planning checklist.

Industry Standards

1. Name the organization that provides the industry standard for interlocking paver installation.
2. Name the organization that provides the industry standard for segmental retaining wall installation.
3. Name the organization that provides the industry standard for dry stone walling.

Construction Materials

1. Define gradation? What is its importance within hardscape construction materials?
2. What organization provides the standard for certified construction materials used in hardscape construction projects?
3. What is the ASTM specification for the base material used in an interlocking paver patio?

Principles of Base Installation

1. What is the importance of site layout?
2. What is the recommended minimum base depth for an interlocking paver system?
3. Why is over-excavation costly?
4. What is the difference between woven and nonwoven geotextiles. Provide an example of where each is used.

Compaction

1. Define compaction. What 3 factors affect compaction of base material?
2. What is the importance of compacting in lifts?
3. List 3 types of compactors and provide an example of where each is used.
4. What methods can be used to measure compaction?
5. What are the allowable tolerances for final base elevations?
6. What is the standard slope on most residential paver applications?

Principles of Pavements; Pavers

1. Where did interlocking paver systems originate in North America?
2. Describe how interlocking paver systems distribute loads across the base.
3. List 3 types and interlock and explain the significance of each.
4. What is the difference between a paver and a slab and explain why this is important when planning a hardscape installation project?
5. What type of interlocking pavement system allows water to infiltrate rather than sheet away?
6. What process is used to spread and level the bedding medium in an interlocking paver system?
7. List a few types of paver patterns commonly used in walkways and patios.
8. What is the importance of salt tolerance within pavers?
9. What is the "Click and drop" method used for?
10. List 3 methods used to cut pavers and provide the advantages of each.
11. What disease can be caused by the lack of protective gear while cutting pavers and other masonry material?
12. Describe the importance of edge restraints in paver systems and give a few examples.
13. What type of compaction equipment should be used to compact a paver patio once it has been laid?
14. When compacting a paver patio where should you start? How much overlap should one maintain while compacting a patio?
15. What is the importance of backfilling a completed paver patio?

Principles of Pavements; Natural Stone

1. What is the difference between an irregular stone patio and a random flagstone patio?
2. Why should one be concerned about using mortar in the northeast?
3. What is the main difference when setting stone compared to laying pavers?

Retaining Wall Construction

1. Define a segmental retaining wall? What makes a segmental retaining wall different than other walls?
2. What is the importance of wall embedment? What is the general rule for wall embedment?
3. What is the importance of geogrid within segmental retaining walls?
4. What is the importance of drainage stone within segmental retaining walls?
5. How often should drain pipe be daylighted within a wall system?
6. What direction should the tensile strength indicators be placed in relation to the face of a wall?

Natural Stone Walls

1. Define a dry-laid natural stone wall.
2. What are some differences in the construction of a natural wall compared to a segmental block wall?
3. What are the advantages of each type of wall when compared to another?
4. Provide examples of the ways that boulders can be used within a landscape?

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