Synthetic Turf Council

Guidelines for Synthetic Turf Base Systems

Published February 2017

Printed February 14, 2017

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Acknowledgements

This document is the dedicated work of four individuals to whom special credit is due:

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Once written, other STC members volunteered their time, talent, and expertise to review and comment on the document. They include: Alastair Cox, Catherine Eiswerth, Jeffrey Graydon, John Kuentz, Luke McCoy, David Nardone, Greg Parker, Laith Ross, and Todd Smith.

Gratitude is also extended to Fred Stringfellow, CAE and the members of the American Sports Builders Association (ASBA) whose comments and suggestions helped shaped the end product.

Craig Honkomp of Sportworks Field Design provided the photos.

STC staffer Melanie Taylor contributed to this project, attended meetings, and proofed the draft.

The STC gratefully acknowledges these individuals and organizations for their continued support and participation in the STC.

1. BACKGROUND

1.1. INTRODUCTION

The purpose of these voluntary guidelines is to enable owners, buyers, designers, and contractors of synthetic turf to better understand the range of decisions and variables that comprise the "base" of a synthetic turf installation.

1.2. OBJECTIVES

The unseen base for synthetic turf is equally as important as the surface that is seen and used. Both the success and failure of a turf installation is as likely to be contributed to the base as the surface. If the base was poorly designed or constructed, it will reflect to the surface. It is the intent of this document to increase the awareness of all involved in the many aspects needed to create a successful synthetic turf project through a good base system. Through this increased awareness the industry will continue to improve its quality and enhance its reputation as a long term positive contributor to our built environment.

These voluntary STC Base Guidelines will help owners, designers, and contractors pause and consider how their site and project will be impacted by the following:

- The existing soil composition
- The existing drainage patterns
- The site surroundings
- The proposed drainage system
- The type of stone used in the base system
- The planarity of subgrade soils
- The planarity of the stone base

As you review this guideline, stop and consider how each principle may correlate to your project.

The intent of this document is not to prescribe a method of designing or constructing a base, as that is unique to each project and situation, but to offer guidance and concepts to consider as you plan for this investment and contribution to the spaces that our family and friends will use and enjoy well into the future.

2. TERMINOLOGY

Aggregate: A component that resists compressive stress, such as sand, gravel, or crushed stone.

Base System: A designed system of materials that provide porosity and stability such as soil, crushed aggregate, geotextiles, and drain lines.

Drainage System: A method of removing surface and subsurface moisture / water.

Infill: Loosely dispersed materials that are added to the synthetic turf system near the surface and within the turf fibers.

Geo-fabric: Typically defined as any permeable textile material used to increase soil stability, provide erosion control or aid in drainage.

Geotechnical: Of or relating to practical applications of geological science and are concerned with the analysis, design and construction of foundations, slopes, retaining structures, embankments, tunnels, levees, wharves, landfills and other systems that are made of or are supported by soil or rock.

Groundwater: Water held underground in the soil or in the pores and crevices in rock.

Hydrology: The branch of science concerned with the properties of the earth's water, especially its movement in relation to land.

Organics: The organic matter component of soil, consisting of plant and animal residues at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by soil organisms.

Permeability: The rate at which water flows through a surface or system cross-section or components of the cross-section.

Planarity: Uniformity of the surface as compared to certain fixed predetermined points or prescribed slopes.

Proof Rolling: A process where compacted soil is checked for soft areas in order to supply a balanced support system for synthetic turf.

Runoff Coefficient: A dimensionless coefficient relating the amount of runoff to the amount of precipitation received. It is a larger value for areas with low infiltration and high runoff (pavement, steep gradient), and lower for permeable, well vegetated areas (forest, flat land).

Shock Absorbing System: Component(s) that add resiliency to the system.

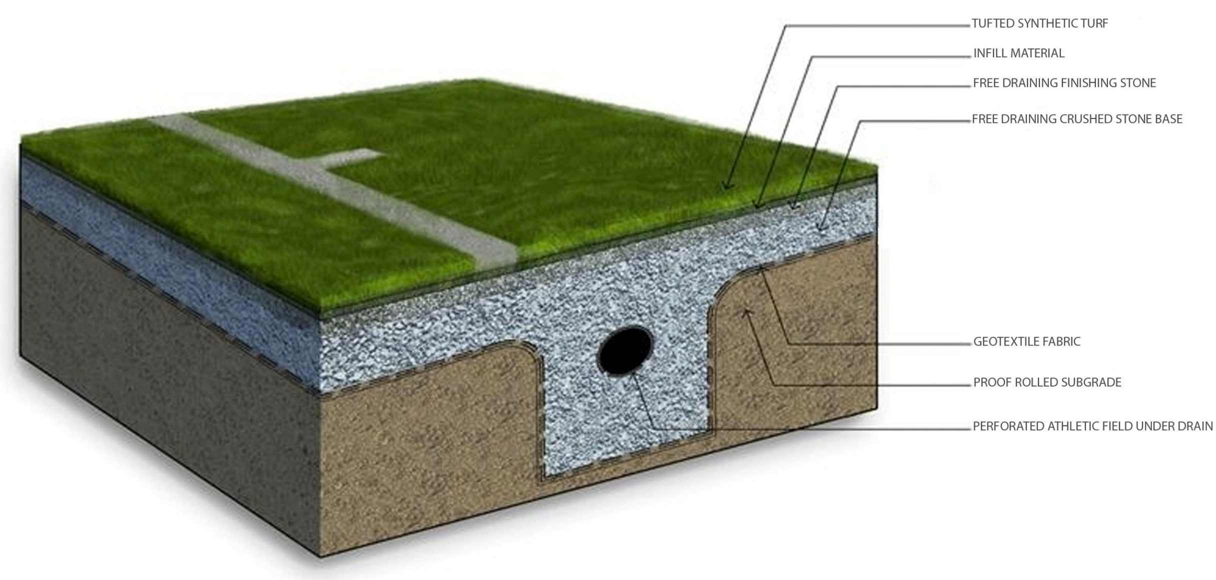
Sub-grade: A stable foundation onto which the base materials and field systems are installed.

3. FUNCTIONS AND COMPONENTS OF A STONE BASE SYSTEM

When it was first introduced, the so-called 3rd generation synthetic turf system proclaimed its ability to provide the highest quality player experience while having the ability to sustain intense levels of play in all weather conditions.

Over the years, research has allowed impressive advancements in the physical characteristics of these playing surfaces, emphasis being put on both wear resistance and an increase in the overall quality of the player's experience. And the safety of the players has been the focus of intense research and development efforts by all the major industry players.

Most of the development efforts have been afforded by turf manufacturers and those of associated system components (drainage pads and accessories, infill, etc.). But one component of the synthetic turf system that is critical to the overall performance of the resulting playing surface has long been overlooked. The stone base is an integral part of the overall system, as it ensures the integrity of some of the most essential properties of the system, such as long term surface stability and planarity. The base is also the most critical component of these system's drainage properties, which is one of their main selling points.



This document will explore the different aspects of designing and then building a proper synthetic turf stone base, with the emphasis put on their critical aspects of drainage and stability. The main intent behind this endeavor is not to propose any one type of construction design as being the ultimate goal to strive for, which would greatly limit the usefulness of such a document. Conversely, writing efforts have been focused on following a generic approach that would concentrate on basic design items and issues as well as construction guidelines that can be useful in assisting those tasked with such projects in any type of site specific conditions.

Please note that this document addresses those systems that are meant to provide high levels of drainage performance, as well as extended surface stability. There are some sports that have different needs, such as field hockey, that requires a certain level of water content in the infill to provide optimal playing conditions. This document does not address these peculiarities, which are too sport specific. The reader should keep this in mind when drainage is evoked in this document.

NOTE: The use of design professionals and builders with demonstrated expertise and success in the development of synthetic turf systems is highly recommended, and will increase the likelihood of a successful project.

3.1. FUNCTIONS OF A TYPICAL STONE BASE SYSTEM

3.1.1. Structural Stability

Critically important to the performance, usability, and durability of the playing surface, the base on which the synthetic turf is installed must provide a structurally sound foundation for the turf surface, as well as a media for drainage.

3.1.2. Drainage

Field owners often cite improved drainage of the playing surface as an important factor for choosing a synthetic turf sports field. An efficient and effective underground drainage system that will divert the water that percolates through the turf is an integral design element of a synthetic turf system. The base drainage system chosen will depend on the use of the field, climate, amount of rainfall and other factors.

3.1.3. Storm Water Management and Flow Control

Most local jurisdictions have requirements that prohibit an owner from increasing the peak rate of runoff from their property. Increasing peak flows can cause excessive soil erosion, over tax receiving storm sewers, and ultimately cause flooding and property damage to downstream owners. In rural areas, where no regulations exist, precedent court cases exist that similarly protect the downstream property owners from adverse effects caused by improvements on upstream properties. In order to avoid exposure to such risks and liabilities it is important to understand how a synthetic turf system will affect the pre-developed runoff rates. Given that most synthetic turf systems are built to quickly drain the surface rainwater, it is likely that some type of flow control (storm water detention) will be necessary to slow the peak rate of runoff before the water exits the property boundary. Where there is sufficient land, this temporary storage and release of the rainwater can be accomplished outside the perimeter of the synthetic turf playing surface. Where space is limited it may be necessary to detain and control the rate of runoff under the synthetic turf surface. This can be accomplished in a variety of ways including additional pipes, chambers, vaults, or even in the void space of additional stone aggregate.

3.2. COMPONENTS OF A TYPICAL STONE BASE SYSTEM

The components of a standard stone base system that provide structural stability and good drainage include:

3.2.1. Native sub-grade soil

Native soils vary dramatically across North America, and can even vary dramatically within a region. Each of the diverse soil conditions will affect the design and help determine the construction methodologies necessary to achieve a stable subgrade soil. Knowledge of the existing soil conditions specific to an individual project location is critical to achieving a stable sub-grade and a high performing and long-lasting synthetic turf sports field.

3.2.2. Base stone and finish stone

As with native soils, stone aggregate varies across North America. The aggregate can vary significantly in hardness, friability (ease of breaking or crumbling), and permeability. These characteristics will determine how the project will be designed and constructed, including how the aggregate must be handled, placed, and graded to insure that it maintains its desirable properties. Care must also be taken to select the stone with the proper granular distribution curve and particle shape and size to provide the desired balance of stability and free drainage. The stone should be tightly graded (similar in size), free of silts and fines that could inhibit the storage or flow of water, and have sufficient void space to allow both vertical and lateral flow of the rainwater through the stone.

3.2.3. Stone/Soil Interface

Once the storm water has flowed through the synthetic turf system, finish stone, and base stone, the water must either be absorbed into the native soil or be moved from under the field. In many areas of the country the native soils will not absorb the water from heavy or prolonged rain events. Therefore, it is common to plan for the storm water to build up and run along the surface of the native soil. One way to facilitate good and proper drainage at this interface is through the installation of manmade materials. These additions may include layers of geotextile fabric, geogrids, filter fabrics, or impermeable liners.

3.2.4. Drainage Pipes

Drainage pipes come in a wide variety of shapes, sizes, and materials, but as their name implies their singular purpose is to convey water. When properly designed and installed, the drainage system under a synthetic turf surface should operate with little maintenance for decades. Common types of pipes and materials include round pipes and flat/panel pipes, and pipes made of PVC (polyvinyl chloride) and HDPE (high density polyethylene). Important characteristics include flow area, friction factor, structural strength, and ability to be installed on a true line and grade.

3.2.5. Peripheral Drainage Elements

The drainage system should include a system outside the synthetic turf surface area to collect and convey the water that originates from the surrounding areas. Collection and conveyance can usually be accommodated in swales, drainage pipes, inlets, trench drains, french drains, and other manufactured elements.

3.2.6. Drainage and Shock Attenuation Pads

There are a variety of other layers and system components that can be utilized below the synthetic turf infill and carpet. Some can replace all or portions of the stone base and provide both shock attenuation and drainage, while others are used in combination with a traditional stone and drainage base. Such systems include *in situ* elastic layers (or e-layers), prefabricated, roll out, or panel systems. They can be permeable or impermeable and are designed in many cases to contribute to a safe g-max level throughout the life of the synthetic turf field. The use of design professionals and builders with demonstrated knowledge about the complete range of these specialty products is highly recommended.

4. DESIGNING A SYNTHETIC TURF BASE AND DRAINAGE SYSTEM

Designing a synthetic turf drainage base system should ideally follow a certain series of stages and steps in order to attain the desired properties, and for the desired performance characteristics to continue over time.

This chapter looks at different aspects of the process behind the design of a synthetic turf granular base, with more emphasis on the drainage aspect, which is the most difficult to attain. The following topics will be addressed:

* General design considerations
* Site exploration program
* Site grading strategies
* Base design strategies
* Drainage system design

4.1. GENERAL DESIGN CONSIDERATIONS

4.1.1. The synthetic turf stone base – the drainage/stability paradox

In a stone base, attaining both stability and drainage is critical to the system's ultimate success. But, unfortunately, these are set at opposite ends of the physical properties spectrum. Thus, designing and building such a structure is an exercise in balancing the material's characteristics and the system's architecture so that the base's stability is maintained at an optimal level while preserving the whole system's percolation and water transmission properties.

4.1.2. Drainage system performance

The drainage system should be designed to meet the performance requirements of the Customer and the local jurisdiction. Where no local regulations exist, the design storm frequency (and design of the entire drainage system) should be determined by a registered professional civil engineer.

4.1.3. Project Specific Drainage Considerations

How a synthetic turf system experiences a rain event is project specific. It is impacted most dramatically by local climatic conditions. Rainfall duration intensity curves can be developed from the National Weather Service Technical Paper *TP-40 Rainfall Frequency Atlas for the United States* or coordinated with the local weather statistics at the project site location. The subgrade soil type also affects total storm water outflow volumes and peak rates. For example, a porous sandy soil may soak up a significant portion of the rainfall volume, while a clay soil may fill like a bathtub and all the collected water will need to be managed by the system. Knowledge of the local soil conditions is thus very important to obtain a peak performing synthetic turf surface and to keep the drainage system's scale and associated costs within optimal limits. A geotechnical survey is critical to the design process.

4.1.4. Water runoff coefficient / volume of runoff

An early step to designing a proper base system is understanding and applying the correct runoff coefficient for the proposed synthetic turf system. Knowing how the existing subgrade will react to the design rainfall event will allow the designer to establish the type and size of the below grade drainage system so that it will protect the integrity of the synthetic turf surface from the anticipated volume of runoff.

4.1.5. Water Flow Time

Simultaneous to determining the runoff coefficient the designer will need to calculate the time it will take for the water to permeate the surface and base layers, and to reach the collector drainage system. The time of travel for the rainwater to reach and flow through the pipes is an important variable in determining how much water, and how quickly the water will need to be accommodated by the base system to mitigate any impacts on the turf surface.

4.2. SITE EXPLORATION PROGRAM

Site conditions, soil type, hydrology and other such factors will have a big impact on a synthetic turf system's longevity and performance, and on the design of the base and the drainage system.

The design of a synthetic turf sports surface should be preceded by a thorough inventory and analysis of the site it is to be built on. A comprehensive geotechnical study should be conducted in order to develop a detailed understanding of the site's geotechnical conditions, including its general soil and groundwater characteristics by means of test borings made at representative locations throughout the site.

4.2.1. Physical exploration strategy

Before starting off on a site analysis program, one must define an exploration strategy. This is important so that all the field work is done in a single operation, as it can be costly to have to remobilize an exploration team.

4.2.1.1. Site's human and environmental history

Exploring past human occupation of a site can provide useful information as to what materials may be found on the site and need to be dealt with. This can help in identifying possible problems and guide in determining a site exploration strategy and project costs.

4.2.1.2. Study of existing site conditions

Local geological maps should be collected and studied to better anticipate general soil types and approximate depth to bedrock. A general idea of soil types can be obtained from the U. S. Geological Survey (www.usgs.gov).

Local soil laboratories will often have developed an intimate knowledge of site specific geological conditions. This is why it is often better to consult local professionals who will be able to better orient site exploration.

This information is necessary to decide the types of equipment that will be needed for the exploration work and its scope.

4.2.1.3. Identify projected work types – Preliminary design

Different projects call for different work types. Some, such as grading and shaping, can require the movement of great volumes of materials, which may have to be disposed of or be redistributed on the site in such a way that the resulting profile will be stable. This requires certain information that will help determine disposal or manipulation methods.

Other work types call on other geotechnical properties. For instance, the setting of light standards or football goal posts requires deep excavations and structural foundations that provide axial or lateral loading resistance. Also, the type of foundation backfill must be compatible with the existing soil conditions in order to ensure optimal stability.

The drainage system will require the setting of pipes and the digging of sloped trenches that can reach considerable depths. These trenches can cut through a profile composed of different soil types, which can react differently to an inflow of water. This must be properly understood in order to design a site condition specific system.

Also, the intense circulation of machinery over an exposed soil surface during construction work can disrupt its structure and cause stability problems that can have long-term repercussions. Construction specifications will often include specific instructions to the Contractor on working techniques designed to reduce these types of impacts.

For these reasons, it is important to conduct a preliminary design of the overall project in order to identify and locate the different types of work that will be conducted on the site and the needed geotechnical explorations these may require.

4.2.1.4. Site hydrology

In order to devise an efficient base design strategy, it is essential to gain a clear understanding of the project's site hydrology. This includes mapping existing surface drainage (grading), peripheral drainage, surface and underground water flow from outside of the perimeter of the project as well as problems associated with managing water flowing towards and through the projected synthetic surface's location.

The site's ground water levels and fluctuations are also important to consider since, in some instances, they can conflict with the projected synthetic surface's drainage system. The designer will want to avoid draining the existing water table if you do not have to.

Finally, gaining a clear understanding of the site's hydrology is essential for the designer to address storm water management design, which is required of new constructions in most locations.

4.2.2. Site geotechnical sampling program

The geotechnical sampling program is intended to provide the designers with the most comprehensive and precise information possible to guide them in their work. The exploration team must be equipped with the necessary machinery and equipment to conduct all the required tests and explorations. Samples are collected and a detailed log is maintained in order to thoroughly document all stages of the process.

Ideally, the exploration team is provided with a geo-referenced site plan that will allow it to precisely position its different interventions and to record the elevations of the different horizons it encounters in the soil profiles it samples.

4.2.2.1. Soil borings

The designer will work with a soil lab to determine the best locations for the different types of soil exploration work that will be needed. This is why it is important to define as precisely as possible the types of systems and equipment that must be integrated in the project program, such as lighting standards, score board and goal post support structures, drainage and water detention works. This way, the exploration program can be tailored to the specific design needs of the program elements.

4.2.2.2. Load-bearing capacity

Once the stone base is put in place, it does not really exert much more pressure than the original soil did. The density is similar and the resulting load is evenly distributed over a large surface.

A base with poor load bearing capacity can suffer problems when machinery and construction equipment circulate during the actual construction of the project. It is important that the sub base be able to support this traffic which exerts much more localized pressure than the finished base will.

Localized soft spots must sometimes be addressed when they are identified. At the soil test stage, these can appear in the overall tests as areas where particularly problematic soils are encountered. In these instances, remedial actions will be incorporated in the project's work schedule. If they are not detected at this early stage, they must be identified and dealt with during the construction phase.

4.2.2.3. Geotechnical properties of disturbed soils

Many projects involve the redistribution of existing soils over the site in cut and fill grading operations.

Although it may be determined that the existing soil has certain geotechnical properties, these can be affected when the soil is moved and manipulated on site, and then compacted to increase its stability. Once it has been decompacted, it will be very difficult to return a soil to its original state (density). The soil can lose some of its load bearing capacity and will probably become more porous, thus affecting the uniformity of the resulting sub-base's properties. These changes must be anticipated in the design process and proper measures must be implemented in the earth work specs to counteract the potential problems these could cause.

4.2.2.4. Organics, debris, contaminants

Organic soils are to be avoided in a synthetic field sub-base. These soils are unstable, are sensitive to water and have a low load-bearing capacity. Sometimes, in the sub-grade, there are pockets of peat or other highly organic soils. Unless they are buried at such great depth that they cannot interact with the surface, especially during the construction phase when there is intense vehicle circulation, these pockets must be eliminated and replaced with a fill material that is stable and compatible with the surrounding materials.

Certain soils are very sensitive to wet conditions and identifying such site-specific problems can prevent having to deal with them later on. This information will help determine the proper drainage network configuration and appropriate work techniques that will be detailed in the bid documents as specific requirements.

Soil borings can also uncover various debris and contaminants that may need to be disposed of in a prescribed manner. Local regulations may sometimes allow for the on-site burial of some contaminants, which is always a more economical disposal method than trucking these materials to regulated facilities. The soil tests will allow the designer to prescribe the proper disposal method and to allow for this work in his work schedule and budget.

4.2.2.5. Presence of rocks (in frost situations)

The presence of big rocks or boulders in a synthetic turf surface's sub base can be annoying when important grading work needs to be done. They can also present obstacles when laying drainage collectors, which are typically deeper than the rest of the system.

Rocks and boulders do become a potentially important problem in cold climates where, in winter, the soil freezes at great depths. Freeze-thaw cycles typically cause rocks to migrate towards the surface. This is a natural phenomenon that cannot be stopped. Small rocks do not pose a problem because the stone base that is laid over the surface will stop their upward progression. But big rocks and boulders can present a threat to the base's integrity over time.

It is most often cost prohibitive to try to remove great amounts of rock from a project's sub-base. It can also be counter-productive because it can disturb the sub base's integrity and cause settling in the spots where the boulders have been removed and replaced by fill. But it is important to be aware of this potential problem and design the grade work and the stone base accordingly.

4.2.2.6 Groundwater

When boring or digging to gather soil samples, the soil lab may encounter water at certain depths below the surface. This water may come from many sources and its depth can fluctuate with the seasons and the atmospheric conditions.
The presence of groundwater below a synthetic field's stone base is not a problem in itself as long as the situation is controlled. Groundwater can be found at great depths and in these cases, it does not create a problem. But in some instances, the groundwater can be closer to the surface with its level fluctuating up and down. It can interfere with the base's drainage system, and in some extreme cases, it can saturate the field's stone base, threatening its stability. It can also alter the sub base's load bearing capacity.

This is why it is important to examine a site's groundwater dynamics in order to design the necessary drainage structures and systems. Soil borings will allow the mapping of groundwater presence and its level. Varying water table levels on a site can signal problematic soil conditions that will need to be identified and addressed. Interpretation of the collected data can allow the identification of the origin of the sub surface water. It may be sometimes necessary to monitor over a certain length of time the fluctuations of these levels in order to determine if these can cause problems and, if required, to integrate the required control measures in the drainage system design.

4.2.3 Regional climatic considerations

A synthetic turf stone base has two main functions: ensure the surface's structural integrity and planarity and provide the efficient evacuation of rain water. The structural performance of the system relies on a combination of factors and parameters closely related to the geotechnical parameters mentioned above, the materials used for the base and the way it is built. The effectiveness of its drainage function is in great part dependent on the design of the system and its compatibility with the local climate and meteorological regimen.

The design of a drainage system for a hot dry climate will be different than the design for a temperate region with regular rains and an annual 4 four-season cycle. The design must plan for projected storm events, typically over 20 to 50 year occurrences, so that the system can manage regular rain events without being over designed. But the design must assure that the field does not flood every time there is a storm.

Local weather data is invaluable in this respect since it allows the designer to determine the performance objectives he is aiming for. Municipalities often determine for themselves what occurrences they want used in the design of the drainage system, and the designer can then turn to the local weather bureau to collect the relevant data.

4.2.4. Engineering guidelines

Once all the different tests and assessments are done, the geotechnical laboratory will provide a detailed report of its findings. Based on the interpretation of this information, engineering guidelines are provided on the geological aspects of the project, including construction considerations that can affect design decisions.

4.3. SITE GRADING STRATEGIES

Surface grading is critical in the design of a synthetic turf surface. Typically, on a synthetic turf sports field, surface slopes can be kept at a minimum because drainage relies more on percolation than it does on surface runoff, which may not be the case with natural turf surfaces. Also, it is preferable to maintain relatively weak slopes so that there is as little lateral displacement as possible of the synthetic turf infill during intense rain events.

Considering the depth occupied by the stone base, and because of the large areas that a sports field usually covers, most projects require some quantity of grading work to attain a suitable plane. This type of large scale grading needs to be carefully planned.

4.3.1. Working through soil horizons

Typically, a site's soil profile is comprised of a series of different soil layers, or horizons. The top layer is usually more organic than the others and the sub-soil is usually more mineral. The organic horizon is usually eliminated when preparing for a stone base because it is unsuitable for such use. The lower layers have varying properties depending on the soil type. The soil lab will recommend how these are to be dealt with when the base and the drainage system are built into them.

When grading the sub base, it is often necessary to excavate through one or more sub-soil horizons. This is especially true when the site is sloped and a proper plane must be reestablished for the base. In these cases, great care must be taken to maintain a homogenous sub-base composition throughout the whole area so that it reacts evenly throughout.

This is why leveling work must take into account the sub-base composition. The soil moving strategy must be carefully determined and compatible with local soil conditions. This is essential in order to ensure stability of the whole surface over time.

4.3.2. Balancing cut & fill

Balancing cut and fill on a site is the optimal goal of a grading scheme in order to save on material transportation and disposal costs, which can be considerable.

For instance, an inch (2,54 cm) of eliminated material on a 100,000 sq. ft. area equals 308 cu. yds., or the equivalent of around 20 dump trucks. When excavating to prepare the site for a turf field's granular base, this can add up very quickly.

On flat sites, there is often very little possibility for balanced grading, unless the base and drainage infrastructure are superimposed over the existing grade. On a sloped site, balancing cut and fill can be an attractive option. The danger in striving for this at all costs is displacing and superimposing soil layers that are not compatible or are inappropriate for the intended use. However desirable balanced cut and fill may be, it should never be attempted at the expense of the surface's ultimate stability.

4.3.3. Surface shaping

There exist many different surface-grading patterns. Some are extremely simple, while others are quite complex. Complexity, however attractive it may be on a grading plan, does not necessarily guarantee effectiveness.

As mentioned above, surface grading in a synthetic turf system may be necessary to ensure some runoff in extreme rain events, when the turf and drainage system cannot keep up with the influx of water. There are also instances when drainage through a porous base is not possible and drainage is assured by surface runoff alone. Whatever the case, the rule of thumb in surface drainage is to try to limit runoff distance to a minimum. Some surface shaping patterns are more effective at this than others.

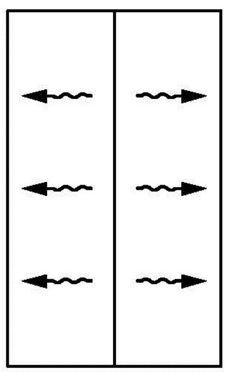
It is also important to maintain some surface slope in regions where winter freezing causes a drop in the stone base percolation. The surface slope will allow for the evacuation of melt water until the base and sub-surface drainage system thaw and resume their normal drainage action.

There are different shaping patterns that are common for sports surfaces. Here are a few of the most common:

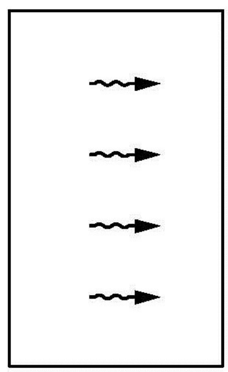
- Ridge drainage pattern (Traditional crown)
- Longitudinal ridge: Center crown across the center axis, from end to end,

sloping towards the sides. This pattern ensures the shortest runoff distance.

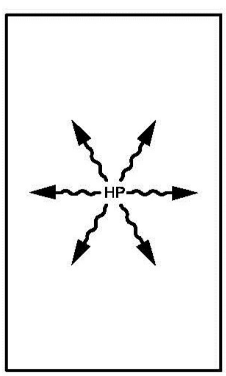
* Lateral ridge: Center crown across the center axis, from side to side, sloping towards the ends. A lateral ridge is typically avoided as for many sports this configuration is undesirable.
* High point (Diamond): High point in the center, sloping radially on all sides. This pattern is relatively difficult to grade because there is no continuous plane to guide the grading machinery.
* Single plane
    - To side: Surface water flowing from one side to the other
    - To end: Surface water flowing from one end to the other. Water trajectory is the longest, which can lead to water accumulation at the lower end during high rain events. This also creates an elevation differential between the two ends (goals). In such situations, water flow should be intercepted and collected at regular intervals in order to reduce water buildup at the lower end.
    - Diagonal plane: Water flows from one corner to the opposite. This generates the most runoff at the lower point since the runoff distance is the greatest.



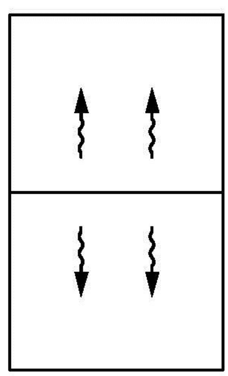
Longitudinal Ridge



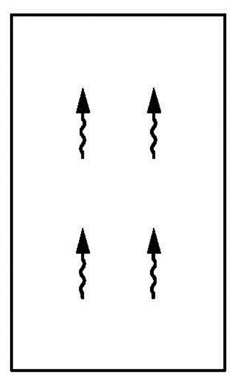
Single Plane
Side-to-Side



High Point



Lateral Ridge



Single Plane
End-to-End

It is important to remember that, ideally, the most effective surface drainage strategy is the one that provides the shortest route out for the water running off the surface. This ensures that less water will accumulate at the lower end of the system. Also, it is important that transition areas between surface planes (such as the center crown) be clearly defined and that there is not a flat area running along the center length of the surface.

4.4. BASE DESIGN STRATEGIES

The granular base is meant to fill two main functions.

The base must act as structural support for the synthetic turf surface, as well as-support the vehicular traffic generated by the weight of maintenance vehicles and occasionally emergency or service vehicles. The base must be designed accordingly.

The base is also an integral component of the drainage system. It must allow for the percolation of rainwater at a rate sufficient to ensure that the surface is usable at all times. It must also allow sufficient lateral water movement for the drainage system to keep up with the predicted precipitation rates.

4.4.1. The stone base complex

4.4.1.1. Sub-grade

The sub-grade plays an important role in the drainage strategy since it directs any water that percolates through the granular base towards the drainage system's evacuation pipe network. Usually, the sub-grade will have a certain slope built into it so that it allows the drainage water to move towards these pipes. A flat sub-grade should be used with caution because it can allow water to collect below the stone base, saturate the underlying soil and cause stability problems over time. The planarity of the sub-grade is a critical element of the overall system's performance and particular attention must be paid to this during construction to prevent low areas that will collect water. A base that does not drain completely has a higher potential for frost heaving related problems.

Some systems call for an impervious layer to be laid over the sub-grade. This is called for when the underlying soil is sensitive to the presence of water. In these cases, it is preferable that system design be entrusted to a registered professional civil engineer.

Working with an impervious layer, it is important to design the system so that there are no openings where the drainage water can penetrate into the underlying soil, causing possible stability problems. It is thus important to take special care at all points where the impervious layer comes in contact with any structures (such as the goal post bases), drainage system connection points or the perimeter of the surface.

If the soils present no particular water related problems and are of an homogenous nature, it might be better to let some of the drainage water percolate through the sub-base. This will reduce some of the volume of water that must be managed by the drainage system and it will contribute to the replenishment of the water table.

4.4.1.2. Geo-fabrics—Soil separation/filtration

Geo-fabrics are commonly used to prevent the migration of fine particles from one stone layer into a coarser underlying one. It is important to note that, as it acts to separate the two layers, it must also act as a filter that allows the movement of water from one layer to the next. Geo-fabric characteristics must be checked for their compatibility with the stone that is being used. If the fabric's pores are too small, it will retain fine particles and can clog up over time causing base drainage breakdown.

Geo-fabrics are also used as a barrier between the sub-grade and the base and drainage system. Water will be flowing through and at the bottom of the base system and an underlying geo-fabric layer laid over the sub-grade will prevent any soil particles from being transported into the drainage system, potentially compromising its performance over time.

There are many different types of geo-fabrics and all are not suitable for filtration. Also, it is important that the geo-fabric's porosity allows for the passage of some of the smaller particles that could otherwise clog the fabric and affect drainage over time. Therefore, geo-fabrics should be chosen for their specific drainage characteristics and their compatibility with the stone that will be used in the system.

4.4.1.3. Clean aggregate base layer

A clean aggregate layer allows the free flow of drainage water that has percolated through the base towards the drainage network. It will also provide better drainage of the structural layer and avoid its saturation during heavy rain events, which can affect its stability.

4.4.1.4. Structural stone layer

The stone mix must have enough fine particles to ensure stability but not so much as to affect drainage. This should be conducted beforehand in testing labs. There is very little room for error, and 1 or 2 extra percentage points of fines in the installed stone mix can mean the difference between success and a disastrous situation.

It is important to consider the erosion of the stone that will occur because of the manipulation of the stone during trucking, laying, and compaction. A stone mix will invariably change from the moment it leaves the quarry until it has been compacted -- its fine particle content will increase and affect the mix's final composition and performance.

Therefore, it is important to take into consideration the nature and hardness of the stone that will be used when defining the desired granular curve and to specify the fine content required AFTER compaction, and not just at the quarry or on a theoretical spec sheet.

4.4.1.5. Stone dust grading layer

A thin layer of a stone dust mixed with sand is sometimes used on the surface in order to attain near perfect planarity, which is difficult to reach when using coarser materials. However, if not carefully graded, this layer can "seal" the surface and disrupt the system's drainage performance.

When using this technique, the stone dust mix be perfectly graded and tested before it is used to ensure that the content of the finer particles is minimal and doesn't alter the downward flow of water, while providing a stable layer that will not shift during turf placement or, subsequently, during play.

There is also the risk that a perched water table can be created, just under the turf, which will disrupt water movement downward through the stone base and towards the drainage system. This can happen when a finely graded material is laid over a coarser one.

For the above given reasons, the use of a dust surface layer must be done with extreme caution and attention to quality materials and workmanship.

4.4.1.6. Percolation through the stone layer

Percolation through the turf and stone base is the most common drainage strategy for a synthetic turf surface. Industry standards cover this type of drainage and most turf products are specifically designed to allow rapid passage of water into the underlying stone base.

4.4.1.6.1 Drainage in a structural drainage stone layer

Many base construction systems call for a simple structural draining stone layer laid directly over the sub base.

Since the density of these stone bases is relatively high, their hydraulic conductivity is relatively low. It is important to note that lateral water movement will only occur once the stone mass has reached a state of saturation. If the water movement is too slow to keep up with the influx of precipitation, there is a danger of ponding and other problems.

Many systems call for the incorporation of drainage pipes, flat or circular, at or near the bottom of the base to help increase the rate at which this drainage water is conveyed towards the evacuation systems. These pipes can be laid directly over the sub-base, where they are encased in the stone base itself. Flat drainage pipes are usually used for this. The pipes can also be placed in trenches dug in the sub-base. This helps lower the water level in the stone while facilitating stone placement. Circular drainage pipes are well suited for this application.

While the water movement in the stone base is somewhat influenced by the surface slope of the sub-base, most of it is due to the accumulated weight of the water, or hydraulic head, which pushes down and forces water to move to lower areas or areas where the level of water is lower, such as over the drainage pipes. This is why it is important to provide a deep enough stone layer for this action to take place and be effective.

4.4.1.6.2. Drainage in a clean aggregate layer laid below the structural base

It is commonly accepted that clean stone can provide in excess of 30% of void space. This will provide free volume for the accumulation of water. Also, clean stone provides a relatively free flowing environment for the drainage water to flow over the sub-soil towards lower lying drainage structures that will then convey it towards an outlet structure. This is the basis of the design of a two-layer base, where a clean stone layer is laid between the structural draining base and the sub grade.

This approach has the advantage of allowing the overlying structural stone layer to drain freely, avoiding accumulations of water in this layer, which can affect its structural integrity if vehicular traffic circulates over it while it is saturated, or when it is thawing out in the spring.

Although this approach is more costly because of the need for extra excavation work and extra stone, it is quite effective, especially in areas where high rain events occur.

4.4.1.7. The stone base as a support structure

A synthetic turf surface requires as much structural support as any other surface subjected to vehicular or other types of traffic. It must be noted that this traffic can occur in any weather -- wet or dry, frozen or thawed. The base must be designed accordingly.

The base must also be stable enough to retain its shape. Synthetic turf surfaces are subject to exacting planarity standards, and this property depends directly on the long term stability of the stone mass.

Traditionally, a stone base's structural soundness is determined by its depth, the type of stone that is used as well as its level of compaction. The challenge in this type of design is to find the fine line between stability and the high level of permeability the base must also possess.

4.4.2. Field surface runoff

Infilled synthetic turf is not particularly well adapted to drainage by surface runoff. The loose nature of the infill and the open configuration of the fiber tufts, especially in the case of monofilament turfs, leave the surface sensitive to flowing surface water, especially in high intensity rain events. In these instances, runoff can displace the infill and cause it to migrate towards the lower lying areas, which can become a maintenance challenge.

While some surface slope is advisable, especially in colder or wetter climates, surface slopes for a synthetic turf surface should not exceed 1% and less is acceptable. A surface slope of 0.5% is found on many, if not most professional sports fields.

4.4.3. Drainage pipes and other accessories

4.4.3.1. Round drainage pipe

Round drainage pipe is commonly used in most landscaping and civil engineering projects. This pipe is relatively inexpensive and readily available.

This pipe comes in different sizes and forms. The smaller diameters can come in both rigid and flexible form. There are different densities and rigidities available. One common form of round drainage pipe is made of polyethylene and the surface is corrugated. In most applications these corrugations create no difficulties. But in situations where the pipe is laid with very little slope, these corrugations can collect sediments that can accumulate and eventually cause flow problems. In these cases, smooth interior pipe can be used. In some jurisdictions, corrugated pipe is not permitted and drainage pipe must be rigid. The designer should be aware of the local regulations and design the system accordingly.
Round pipe is usually laid in trenches below the surface that is to be drained. This allows better drainage performance and also protects the pipe during construction as it keeps it out of the way of machinery traffic.

When designing with round pipe, it is important to consider that friction losses are generally at their least at ± 60% of the cross sectional area (varies based on the pipe diameter). Above this level, the flow is reduced and system performance can be affected . This should be considered when sizing a round drainage pipe drainage system.

Ideally, when design conditions allow it, pipe should be laid with sufficient fall to allow for water flow to maintain a self-cleaning velocity, which means that any small debris or contaminants infiltrating the system will be washed away.

4.4.3.2. Flat drains

Flat drains will facilitate water movement through the stone base. Another advantage of these drains is that they do not need to be encased in trenches, as do traditional round drainage pipes. The stone can thus be laid directly over them. This shortens installation time as well as requiring fewer installation steps and operations, which results in time and cost saving.

4.4.3.3. Drainage pads

Drainage pads, which are laid directly under the turf, are increasingly used in turf systems. These are meant to allow free lateral movement of the water that has percolated through the turf.

It is important to distinguish between the pads that provide drainage alone and those that contribute to the system's shock absorption properties.

4.4.3.3.1. Pads for drainage alone

Some pads are rigid and provide no resiliency at all. These pads only allow water to travel laterally, either to reach drainage structures installed at the lower points of the surface or to simply better distribute the water over the granular base, thus providing more even and effective drainage.

Whatever the objective, it is important that these pads provide relative freedom for this water movement. One should make sure that the products that are considered allow such easy movement. It is important to determine what are the minimal surface slopes these pads need to be effective.

If the pads are meant to allow the movement of the drainage water downwards towards peripheral drainage collectors, it is essential that these be designed to be able to evacuate this water at a sufficient rate so that there is no water accumulation at the surface's edges.

4.4.3.3.2. Resilient drainage pads

Many drainage pads are designed to provide some degree of resiliency. They add to the shock absorbing properties of the turf system as well as providing horizontal drainage.

It is important to remember that turf systems are designed to provide specific performance characteristics. Resilient drainage pads will affect the system's performance characteristics, which the designer must consider.

4.4.3.3.3. Surface drainage collection systems

The advent of different types of drainage pads and panels allows the designer to devise a system that does not rely on a stone base as the drainage medium. This approach is particularly attractive in areas where sophisticated stone mixes are not readily available. The base can thus be built using conventional road base mixes that would otherwise not be appropriate. These mixes are readily available and may be less expensive.

Drainage pads require the use of a collector system -- there a many different types -- that ties in at the periphery, and is designed to eliminate the amount of water that is likely to flow out of the drainage pads or panels during the specified rainfall intensity and duration.

4.4.4. Outside field drainage – Interception of peripheral surface and sub-surface drainage water

When designing a turf project, it is important to plan for a drainage strategy to intercept water coming from outside the turf perimeter. The turf systems are designed to evacuate water falling directly on them. This water is clean and washes out the infill. But, surface runoff coming from the outside often carries sediments and other contaminants that can accumulate in the infill or within the stone layer and eventually affect its drainage performance.

4.4.4.1. Controlling groundwater

Groundwater can be found at varying depths across a given site, depending on localized sub-soil conditions. On a flat site, there will usually be less variation than on a sloped site, where the groundwater tends to follow the general slope and be influenced by the obstacles and soil texture changes it can encounter in its movement.

Groundwater can be more of a problem when a flat surface meets the bottom of a steep slope. The water flows downwards until it reaches the flat plane. This movement is powered by gravity. The water is thus under pressure. As the moving water comes in contact with the standing water table under the flat plane, there is a pressure buildup. In extreme situations, the groundwater can be seen seeping out of the slope. It can also pop out of the ground at some distance from the bottom of the slope.

If this water is not managed, it can disrupt the stone base and drainage system. In such situations, it is essential to intercept the groundwater and keep it from getting under the base. This means that a secondary drainage system must be designed and installed to divert the water to an outside evacuation point.

4.5. DRAINAGE SYSTEM DESIGN

4.5.1. Drainage system design parameters

A turf drainage system encompasses the turf and infill, the base, the drainage water evacuation system and, ultimately, the municipality's stormwater/runoff collection points. In some instances, it can be designed to contribute to the recharge of the water table. Given the complexity of the system, there is naturally some confusion as to the performance requirements applied when designing such a system.

Typically, the primary design criteria will be the storm sewer's evacuation capacity, which municipalities enforce by strict regulations. A municipality will determine what inflow it allows into its system, restricting it to set flows, usually measured in gallons/second/acre (l/s/ha). The drainage system's outflow point will then need to be fitted with some type of control mechanism and pipe sizing will be adjusted to meet this performance standard. Some kind of detention structure will need to be provided in order to manage and store the accumulating backflow as the system is slowly emptying out.

4.5.1.1 The rainfall event

The whole drainage system's design is based primarily on this one parameter, though other parameters must be considered.

Typically, a rainfall event occurs in two distinct phases: there is the start of the rainfall, which slowly builds up to a peak, which will typically last for a limited time. But, during this time, the intensity can be extreme and large volumes of water can flow through the system and accumulate at the outflow point.

After the peak, the rain tapers off and the flow decreases in intensity and volume. The system should be able to handle the peak downpour volume and ultimately store the accumulating water while the evacuation system slowly feeds it into the Municipality's system at the prescribed rate.

The design of a system expected to perform under these parameters is the field of expertise of certified civil engineers. They should be consulted in order to apply the principles of drainage through porous mediums and related design issues.

In this context, it is perilous to apply pre-established base and drainage system designs without adapting them to a site and region's specific characteristics and the project's individual design parameters.

4.5.2 Storm water management

Most administrations require that measures be taken to manage storm water collected or generated in most types of new civil engineering projects. Specific regulations are set at most state and local levels. Any project affecting natural surface runoff is subject to these regulations and appropriate management measures must be implemented in the design.

These measures are meant to control the transport of sediments, pollutants and other undesirable elements into stream, lakes or the potable water system. They are also intended to limit the strain on existing storm water systems caused by any addition of impervious surfaces in the environment. A synthetic turf surface acts just like an impervious surface, since the rain water it collects is most often redirected directly into the rain sewer system instead of being left to percolate into the soil.

Synthetic turf systems must integrate storm water management considerations and must be designed to reduce runoff on site and ultimately downstream by providing storage capacity and limiting the rate at which drainage water is released.

Synthetic turf systems take into account storm water management and are designed to reduce runoff both directly onsite and indirectly downstream by providing storage capacity within the stone base and by limiting the rate at which water is discharged from the field. Some fields provide efficient means for ground water discharge.

4.5.2.1 Storm water management (Flow control and water detention)

The huge volumes of water collected by synthetic sports field drainage systems can very rarely be fed into a municipality's storm water system without some kind of flow control measure being put into place. This implies that the flow of water coming out of the system is restricted so that it will not exceed a rate that is determined by the authorities. This evacuation rate is most often less than the rate at which water accumulates in the drainage system. The system must be designed to store the excess water while it is being evacuated. Therefore, most, if not at all, modern turf drainage systems must be designed with flow control mechanisms and water detention structures.

Some jurisdictions will allow the base's inherent storage properties (through pore space of the stone mass) to be considered in the detention calculations. This implies sophisticated calculation approaches and methods. Unfortunately, some others do not recognize the permeable stone base's specific water flow properties and require that drainage design be approached in a more simple and traditional manner, which results in detention when it may not be necessary.

The project civil engineer should check whether there is an increase in the post development flow, and provide for flow reduction or storage measures in accordance with the local regulatory requirements.

Where the available space is sufficient, the storage can be done in ponds or other such outside structures. In such cases, the detention pond's optimal surface level must be below the sports field drainage system's lowest point, so that the accumulated water remains below the stone base.

But, in most cases, this is not possible. Sports fields are often built in tight spaces and there is little or no space to build these storage ponds. In such cases, the storage must be done below ground, close to or even under the playing surface, in closed tanks or stone filled trenches. The storage structure must be constructed very carefully so that there is no movement or settling that can affect the surface's planarity.

This aspect of a project's design is best left up to engineers or other competent experts. Although the calculations may seem simple, they involve the integration of many different parameters and the demonstration must be made to authorities of the accuracy of the calculation process and its results.

4.5.3. Drainage pipe network

Most, if not all, turf construction systems rely on some kind of pipe drainage network to move water through, under and out of the stone base. There are many different approaches to this.

4.5.3.1. Lateral Drainage network

The lateral drainage network is directly in contact with the stone base, either encased in it of laid under it. The lateral drainage network allows the free passage of the drainage water without the restriction created by the stone particles and its tight network of air space.

As mentioned above, some prefer to use a clean stone layer below the stone base to allow free movement of water out of the base. But this approach entails more excavation work and volumes, more granular material, and greater expense than would a lateral drainage pipe network below the base.

When designing such a system, it is important to ensure that the pipes are set with a minimum of slope if the water is to be evacuated at acceptable rates. Bigger diameter pipes will also provide more flow volume.

It is important to take into consideration that with herringbone installation patterns laid over the sub base's slope, the resulting slope at which the pipes are laid can be such that little or no water movement is obtained, other than that which is generated by the water head that is building up in the stone.

Pipe manufacturers and civil engineers can help in determining the minimal slopes that must be maintained in order to obtain desired drainage rates.

4.5.3.2. Collector drainage network

The lateral pipe network is usually connected to a collector drainage network, which moves the collected water into the outlying storm water system. The collector network consists of bigger pipes that will carry water from the lateral network or the clean stone drainage layer. These pipes are perforated and laid in a stone filled trench, or non-perforated and buried in fill. When the pipe is non-perforated, it is important that the connections be done with manufactured fittings in order to limit water loss that can cause erosion and eventually settling. Also, soil can penetrate the pipe connections and eventually contaminate the system.

In the case of perforated pipe laid in a stone trench, it is good practice to lay the pipe over a layer of clean stone. This will allow any contamination of the trench from the surrounding soil to pass through the perforations and to settle in the stone and not in the pipe, which would obstruct the flow of water and possibly plug the pipe.

4.5.4. Drainage pipe network sizing and layout

Drainage layout is determined by many factors, such as available inverts, the types of pipes or the availability of pipe laying machinery.

The pipe diameter, the internal pipe friction factor and the slope at which the pipe is laid determine the velocity of the water flow. Optimal velocity and flow is attained when the level of water is at 60% of the pipe's diameter. Below that is not optimal, and above that level, the flow starts to drop because of flow restriction due to friction, turbulence and other factors. Pipe sizing is thus an important factor to consider when designing a system.

Just as important is the slope at which the pipe is laid. This parameter is most often set by invert levels at the outlet, which are a determining factor that sometimes dictates the whole system design.

Ideally, it is best to design the pipe system so that the flow velocity is maintained above 2 feet per second. This is particularly important when corrugated drainage pipes are used. The corrugations can trap sediments and cause the pipes to fill up over time, which further reduces flow. Maintaining high enough velocity ensures that the sediments are washed away by the flow. When this is not possible, it is better to use smooth interior pipe, which allows more efficient water flow with less friction.

There are different layout patterns. The most commonly used is what is called the herringbone pattern. This pattern is appropriate when there is some concern about the local contractor's ability to precisely control trenching slope and depth, especially if the slope is small and requires great precision. With the herringbone pattern, the pipe can be laid at a constant depth or right on the surface, cutting at an angle across the surface slope.

In situations where laser guided or other high precision laying techniques are available, it is possible to intercept the water as it flows down the slope, laying the pipe at a right angle with the slope. This is the most effective layout strategy because it reduces to a minimum the distance the water has to flow before it reaches the pipe. Of course, the trencher or other drainage machine will only be able to operate up to a certain depth. This limitation must be factored into the design.

When designing a system, it is important to make sure that there are the necessary resources available to implement the designed system.

4.5.4.1. Pipes in or below drainage layer

Some systems will be installed with the drainage pipes laid below the sub grade level, under the granular base. Others have the drainage pipe network laid on the sub-base and inserted at the bottom of the granular base.
Having the drainage network dug below the granular base helps the water to be totally eliminated from the stone. The water will flow out of the stone into the drainage trenches. When the pipes are buried into the base's granular

stone, some of the pressure created by the water accumulated in the profile is lost and possibly more water will remain in the profile. Of course, in either scenario, the granular base will inevitably retain a minor amount of this water because of capillary forces. But direct vertical gravitational pressure is more effective to drain out the profile.

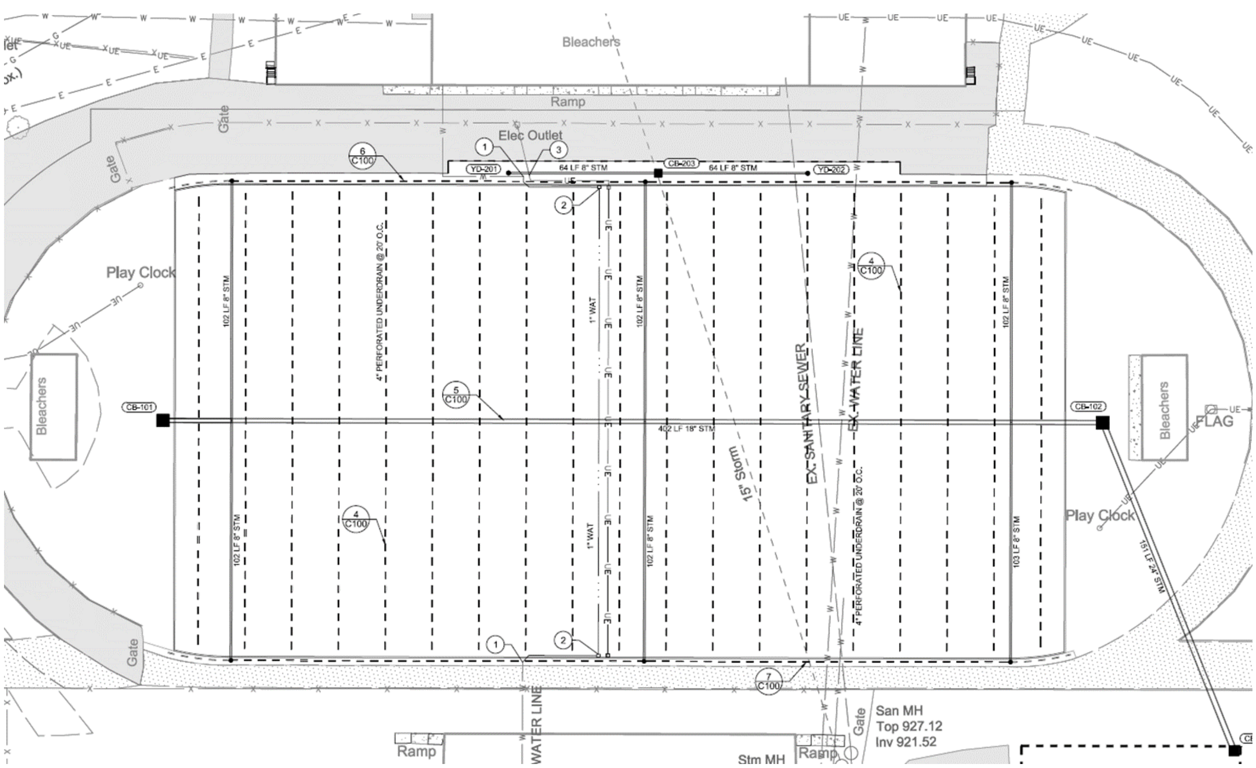
4.5.5. Sloping and grading

Sloping and grading are intricate parts of a base drainage scheme. Although a level surface will allow some level of water movement towards a drainage system due to the hydraulic head built up by the accumulated water, the objective when designing a synthetic sports surface is for the surface water to be evacuated as quickly as possible. On the opposite end of the equation, players prefer the playing surface to be as flat as possible.

The designer is thus confronted with very tight limits within which to work. Added to this are the great distances that drainage pipes must sometimes reach and the excavation depths associated with providing sufficient slope in such conditions. In designing the system, it is always important never to lose sight of the fact that the system must be built and that equipment and working condition constraints must be considered.

4.5.5.1. Sloping drainage surfaces

There is a direct correlation between the permeability of the base and the surface slope. In some cases, where the base properties are optimal, the surface could be flat. But it is customary to provide a minimal surface slope.



The standard in most high-end construction is a maximum surface slope of 0.5%, subject to the base's drainage properties. In cases where a precisely graded stone supply is not available, it is quite acceptable to slope beyond this level. FIFA allows 1% surface slope in its standards.

4.5.5.2. Sloping drainage pipes

The sloping of drainage pipes is the mechanism that ensures that the water moves through them. As mentioned, sports field drainage sometimes involves long runs that can produce relatively deep excavations at the lower ends, as well as creating problems maintaining these levels above lower lying inverts.

Just as drainage design involves pipe sizing, the sloping of the pipes is also a design parameter. The greater the slope, the faster the water travels. However, if there is not enough slope, sediment or debris in the pipes can result in clogging of the system over time.

Engineers utilize hydraulic flow equations in the sizing and the sloping of a drainage pipe system. Increasing pipe diameter or reducing spacing between pipes can help offset sloping constraints, the only limiting factor being the minimal slope

4.5.6. Open-minded design approach.

Base and drainage design must be tailored to local site conditions and material availability. The abovementioned design parameters are but a few that may be encountered and considered. No specific approach can be applied to all situations. This means that individual projects warrant a personalized design process that takes into consideration all aspects of the overall process.

In some cases, the designer will be required to apply a totally novel approach due to unusual or unfavorable local conditions, material availability or regulatory constraints. This is why it is important to approach this with a clear set of objectives and that the resultant design be specifically tailored to each individual project's specific constraints.

5. CONSTRUCTION AND INSTALLATION

5.1. EARTHWORK aka EXCAVATION AND GRADING

Earthwork is specified in the construction plans, and addresses excavation, cut and fill, and rough grading of the site, the critically important first step in the synthetic turf sports field construction process. The quality of this work will determine the long-term stability of the sports surface. Any shifting of this foundation will affect not only the planarity of the playing surface but, in some cases, the performance of important system components such as drainage.

5.1.1 Sub-Grade Preparation

Proper preparation of the sub-grade, or sub-base, requires:

* A soil report and physical soil examination by a qualified soils technician
* Removal of all topsoil, organic matter, minerals such as mica, stumps and roots, large stones, foreign matter, and soil that does not meet compaction standards or is "plastic". This material must either be trucked from the site, or stored and used in subsequent grassing and planting work;
* Repair of surface cavities using suitable fill either excavated from the site, or brought to the site at additional cost. Fill must be compacted in 6" lifts as the fill moves upward. The compaction should be checked by a qualified soils technician;
* Proof rolling of the sub-grade, which should be verified by the soils engineer prior to starting the next phase of construction.

5.1.1.1. Leveling benchmark

A single benchmark must be established prior to any excavation and maintained by a licensed surveyor of record during the entire construction process. The site should then be excavated to a depth per plan design.

5.1.1.2. Organics & other problematic soil conditions

Organic soils are not appropriate for sub-grade preparation. The first operation in the base construction process is to excavate and eliminate the organic soil that covers the work area.

While conducting cut and fill operations, the contractor will sometimes discover problematic soil conditions that the soil samplings missed and aren't anticipated in the design. These unforeseen soil conditions must be reported to the Project Manager and Project Engineer, as they will have to be corrected before construction continues.

5.1.1.3. Cut & fill – Stabilization

Leveling a site inevitably entails some excavation and/or filling operations. On flat sites, this will be held at a minimum, sometimes being limited to the excavation required for the installation of the base and the drainage infrastructure. But on sites where the level needs to be corrected, cut and fill operations can be quite extensive, and will require the services of qualified soils technician to conduct testing to determine if the contractor has achieved the proper soil density. In the event of a field failure in the future, these test results will be important to assess the likely cause of the failure.

5.1.1.3.1. Material procurement

Ideally, most, if not all, cut and fill operations will have been balanced in the design and minimal quantities of material will need to be evacuated from the site or brought in. Evacuating excavated material is straightforward and the only impacts are the costs this entails and the inevitable environmental consequences associated with the operation of machinery and transportation.

Filling a site with imported material is more problematic because of the availability and cost of suitable material. The Contractor must find a large enough source of material that is appropriate for its intended use and that is compatible with the soil in place. The distance this material must be transported will have a direct impact on the costs. The suitability of this material must be validated by the project engineer before it is imported.

5.1.1.3.2. Proof rolling supervision

The Project Engineer should supervise the proof rolling of the sub-grade. If problems are detected, he will be the one who will specify the proper method that should be used to correct them.

5.1.2. Sub-base grade tolerance

The grade of the sub-base governs the flow of water from the field and stone layers into the lateral drains. If the sub-base is not graded properly, then water will accumulate in depressions between the sub-grade and the stone above. These will cause soft spots, and, in cold climates, will freeze and swell. Therefore, before any further work is done, the sub-base surface should be checked to assure there are no tire tracks or dirt ridges on the surface. The grade must be perfect and drain freely to the ditches that remove the water.

5.2. DRAINAGE SYSTEM

All drains – lateral, collector, or discharge – must be graded to the specified bottom slope. The deviation should be +/- ½” when measured from the plane of the bottom of the ditch. This maximum deviation ensures that there will be no obstructions to the desired flow of water.

5.2.1. Drainage trench excavation

Although the drainage trenches are sometimes filled with clean stone that allows water movement towards the system outlets, any low or high spots will disrupt the water flow in the pipes if they are laid directly at the bottom of the trench, or cause water settling below the drainage system resulting in sub-grade instability or frost heaving in colder climates.

Trench width must be wide enough to allow infill material to fill free space around the pipe and to accommodate the available compaction equipment. Excavation of trenches must be carefully executed to ensure uniform pitch, compaction and care must be extended to the soil adjacent to the trenches to avoid the creation of ridges that could interfere with water movement.

5.2.1.1. Bottom finish

The trench bottom must be smooth and graded to exacting standards. The finish of the bottom of the drain ditch should be firm and be set to the specified slope and grade deviation. This may be achieved with proper operation of a backhoe or excavator (particularly if laser equipped) and finished with a hand shovel. The purpose of the clean ditch bottom is to allow the pipe to be installed on a uniform pitch.

The rate at which this material can be supplied is also an issue. If it is from a big excavation job, the rate at which the material is supplied can be consistent and sufficient to keep up with the sports field's project's earthwork. But, if the Contractor must get his fill from different smaller job sites, the logistics can slow down the process and affect the project's rate of production. This can also affect the consistency of the fill material properties, which will require more supervision on the part of the Project Management team.

5.2.1.1.1. Earthwork supervision

It is important that there is adequate supervision of this stage of the work. Critical is the monitoring of the type and suitability of the fill material that is delivered. Upon arrival on site, the fill material must be sorted and inappropriate materials must be rejected.

5.2.1.2. Proof rolling of sub-grade

Proof rolling is the ultimate step in the preparation of the sub-grade. Once earthwork operations are concluded, a loaded vehicle circulates over the surface. Soft spots can be quite deep, and only proof rolling will allow them to be detected and be corrected before the stone has been spread. This ultimately provides a balanced support structure for the sports field's stone base and other components.

There are different ways of proof rolling a base. Many administrations have standards that are usually set by transport authorities. The same standards that are applied to roadwork should be considered on a sports field's sub base.

Usually, proof rolling is done using a fully loaded single or dual axle dump truck, or a rubber tired roller. The load weight and tire pressure are determined by the soil type. It should be left up to the Project Engineer to determine the proper proof-rolling procedure, as well as the loads to be applied and tire pressures.

HELPFUL TIP:
If, during the proof rolling, the soil rolls in front of the wheel, then the soil is likely to be plastic; if it pumps water, then there is water under the surface; if it sparkles, then there is mica in the soil; and if the wheel track is ¼" deep or less, then the soil is sufficiently compacted.

It is important to avoid flat or low spots. These will collect water, which can soften the surrounding soil, affecting its stability and load bearing capacity. This can also affect the stone base if the drainage pipe is laid in or directly below it. In cold climates, it is important to totally evacuate drainage water before it freezes. Low spots will trap this water and may cause frost heaving. Low spots will be filled in with appropriate clean fill material that is then compacted to conform to the adjoining soil's density.

5.2.1.3. Trench width and depth related to pipe sizing

Using the appropriate tools, the Contractor must properly profile the drainage trenches so that the sidewalls are sloped and stabilized to remain intact throughout the construction process and beyond.

In those cases where the drainage pipe is laid below the sub base, the trenches should be at least as deep as the pipe diameter in order to prevent displacement or crushing by vehicle and machinery traffic during subsequent construction operations.

The width of the drain ditch must be sufficient to allow backfill material to easily flow around the sides of the pipe and under it. Trench width must be wide enough to allow infill material to fill free space around the pipe and to accommodate the available compaction equipment. If a cavity is left under the drain pipe during backfilling, then backfill material may settle into it after installation, creating a depression on the field surface.

5.2.2. Drain system

Drainage pipes have many functions. A perforated pipe will collect water from the medium in which it is laid. It will provide free passage for the water movement down a given slope. It will also create free space for water storage. When it is full, laid below the ambient water level, it no longer carries the water but only provides storage space.

Non-perforated pipe will move water from one point to another at a rate and velocity determined by the pipe diameter and the slope at which it is set. The slope is determined by the trench bottom, its orientation and elevation angle.

5.2.2.1. Pipe grading and laying

Drainage pipes must be laid with a continuous slope, in a true line and slope. Dips and bumps along its path will affect the rate of water flow, which will disrupt the drainage system's performance.

5.2.2.1.1. Drain protection

Many designs place flat drains directly over the sub-base. The Contractor must make sure when applying the base stone that no stones migrate under the flat drain, which will impede water movement.

The flat drains should be tested to assure that they will be able to withstand the weight of the equipment that is used to apply the stone base. To avoid the circulation of equipment directly over the drainage pipes, the equipment should "push" the base stone over the sub-base and underlying drainage system so that the equipment is moving over the stone and not the pipe. Care must still be taken not to displace the drains when covering them with the stone

5.2.2.1.2. Laterals / In-field base drainage pipe network

In situations where the perforated drainage pipe is laid in the sub-grade, below a clean stone layer, there is no need to use fabric-wrapped drain pipes. The pipes are laid in a geotextile lined trench which can be filled with the same clean stone as the base. Usually, the pipe openings will be smaller than the stone, so there is no need to use fabric to keep the stone particles from settling into the pipe.

Often, The drainage design calls for the drain pipes to be laid with very little slope, which causes the water flow to be very slow. This is especially true when the pipes and drainage trenches are laid in the sub-base in a herringbone pattern in order to use the existing slope to guide the trenching equipment. A thin layer of clean stone can be spread at the bottom of the trench before laying the pipe. This ensures that any particles that migrate into the pipe during or after construction will not settle and collect at the bottom of the pipe, possibly restricting the water flow over time.

In this case, the particles pass through the pipe's bottom openings and into the underlying clean stone, ensuring clear passage for the water in the pipe over the lifespan of the system.

In cases where the drain pipe is laid over the sub-grade directly in the finer base material, the pipes will necessarily need to be wrapped in fabric, or some kind of separation layer will need to be provided to keep the fine particles from migrating into the pipe.

5.2.2.1.3. Collectors Drains

Laterals tie into the system's collector drains. The collectors can be either perforated or non-perforated. The non-perforated collectors are usually set at the lower extremity of the drainage system and essentially serve to connect it to the municipal rain evacuation system or other water evacuation infrastructure the system flows into.

Unless the system is planned this way, the non-perforated pipe should be sized in such a way that it allows the free flow of the collected water, without restriction due to pipe diameter or slope. Any restriction of the flow at this end will result in a generalized reduction of the overall system's performance. Increasing the slope or the pipe diameter can help attain free water flow. Using pipe with a smooth interior also allows an increase in flow efficiency.

Collector drains are most often set in trenches that collect water from the laterals, but also from the stone base itself through which water flows over the main slope. In instances of a high intensity rain event, the laterals may not be able to intercept the whole of the drainage water and it can flow over or through the stone mass down towards its lower end. The collector will then be set to collect all this water and help channel it towards the system outlet. This type of collector is necessarily perforated and must be set on a downward slope.

If the system is designed in such a way that the drainage pipe must evacuate the water without any detention, the slope and the pipe diameter should be designed in such a way that the flow rate is sufficient to keep up with the design storm rainfall intensity.

In cases where the out-flow from the system must be controlled at a certain rate or if detention is provided directly under the sports field within the drainage network itself, the collectors are set in a trench that acts also as a detention structure. Inevitably, in such a situation, the pipes will occasionally find themselves completely immersed under water, in which case the flow towards the outlet will occur both through the pipe and the clean stone mass in which it is encased. In these cases, the system's defining factor is the volume of the trench, because the pipe diameter and slope will have little effect on the system's performance, at least as long as the water level is above the pipe.

As with the laterals, slopes must be continuous and even all through the run. A reduction in the slope will cause water to backup in the drainage network. A sudden increase in the slope will cause the water flow to increase. If the slope returns to its initial level, the water will then slow and, again, a backup can occur. Such situations are more critical at the outlet of the drainage system since it is situated at the lower end where the volumes are greater and the consequences can affect the playing surface itself.

5.2.2.2. Fill settlement

Fill settlement can affect the drainage system if it occurs under the drainage pipes as well as around and above them.

Settlement under the pipe will cause a change in the slope of the pipe, resulting in a disruption in the water flow. This is especially critical in the case of non-perforated collector pipes where the water is constricted in the pipe. Any sudden increase in the volume in the pipe will cause a disruption in the flow. This can be prevented by slightly oversizing the pipe, so that it doesn't work at, or close to, capacity.

Settlement of fill over both lateral and collector trenches is a serious consideration. Collector drains may have larger pipe in them and the trenches may be wider, which increases the possibility of later settlement.

Fill settlement may be mitigated by the use of small diameter stone as backfill around the larger pipe; the smaller stone is much more likely to flow into the shadow (bottom cavity) along and under each side of the pipe. Larger stone will not easily flow into this cavity and will settle into it later, possibly creating a problem on the field surface.

As soon as the backfill stone reaches a level that is several inches over the top of the pipe, then the trench should be thoroughly vibrated with a plate tamper. The vibration aids the small stone to flow into the cavity under the pipe and into cavities that may exist along the sides of the ditch.

As the ditch is backfilled, the backfill stone should be vibrated every 6”-8” lift. This technique should also be used for lateral drains.

The Designer may specify that all drain trenches should be lined with a geotextile of their choice. This allows the pipes to be placed directly against the geotextile, and if the collector drains are also acting as a French drain (by being perforated) around the outside of the field, water may infiltrate the pipe without fear of soil contamination in the pipe.

5.2.2.3. Manufactured connectors

Some designers will allow Contractors to let water flow from the laterals into collector trenches without securing a direct connection between the pipes. The theory behind such an approach is that, if water flows into a trench filled with clean stone, the drainage water will inevitably reach the collector pipe without the need of a secure connection. This is true. But, one must take into account that water flows through and out of a pipe through numerous small openings, which diffuses the flow through a large area. In high intensity rain events, if water is allowed to flow out of a lateral into a stone mass, the flow’s intensity may cause the displacement of the surrounding stone and eventually cause settling of the base.

The use or not of manufactured connectors is ultimately a decision that should be left to the project engineer.

5.3 STONE BASE

5.3.1. Stone handling and placement

The manner and methodology of placing stone is one of the most important elements of building the field base.

5.3.1.1. Stone fragmentation and segregation due to improper handling and placement

The base stone fragments at every stage of the construction process -- when it is loaded in trucks, unloaded on site and as it is spread and compacted; the impacts and friction of stone within the mass cause the stone particles to break down, thus altering the mix’s granular distribution and increasing the proportion of finer particles. This directly affects the base’s drainage properties.
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down, thus altering the mix's granular distribution and increasing the proportion of finer particles. This directly affects the base's drainage properties. Softer stones are more sensitive to this than others. But all types of stone will suffer from this manipulation, although at varying degrees.

The Contractor has little control of the manipulations the stone has been subjected to before it is delivered on site. All he can control is how he manipulates it. The acknowledged rule of the art is that the stone must be spread in such a way that it is immediately level with the proposed slope. It is important to avoid having to modify the grade once the stone is laid, and even more important, once it has been compacted. Decompacting a stone surface in order to correct an incorrect grade will permanently affect a base's ultimate drainage properties.

Stone separates by size whenever it is handled—the coarser stone moves to the top of the pile and the finer stone moves towards the bottom of the pile. Stone should never be mixed on site to avoid separation; great care must be exercised by the wheel equipment operators at the stone plant to insure a homogeneous mix. This care must also be applied when manipulating the stone on site before, during and after it is spread and compacted so that the stone mix stays as homogenous as possible and that the fines do not migrate down. Graded stone should never be totally dry when it is manipulated and compacted. A certain level of humidity in the stone mass will give it better cohesion, which will help reduce segregation, and attain desired compaction levels more easily. Water also acts as "lubricant" between the particles, reducing friction and fragmentation.

The soil lab that tests the stone and determines its modified Proctor value will recommend the optimal humidity content for specific stone types and grades. It is the Contractor's responsibility to maintain optimal working conditions, including the presence on site of the necessary equipment to maintain the stone base at its optimal humidity level.

HELPFUL TIP:
Bulldozers and other stone spreading equipment should work in a forward-backward manner rather than turning at the end of a run to avoid disturbing the compacted sub-grade and the drains.

5.3.1.2. Compaction and over compaction

It may be difficult to achieve a 95 % Proctor when open graded stone is used as a base. A high Proctor number is usually achieved by using a large vibrating roller on the stone, which crushes the stone in place and firms the stone layer, but also significantly lowers the available pore space and the percolation rate through the stone layer.

It may not be possible to achieve 95% Proctor for base structures that must be both stable and permeable. Consequently, the compaction of the stone base must be carefully conducted, and should be terminated once sufficient stability has been attained.

5.3.2. Grading techniques and equipment

5.3.2.1. Base protection

After the soil base, with drains, is completed and checked for planarity, etc., the stone is applied in prescribed lifts. This process generates many trips from the edge of the field onto the soil sub-grade to deliver stone. This traffic over the sub-grade might cause pumping of the soil base or otherwise compromise the grade and soil integrity. The Project Engineer may specify that the entrance be "planked" or otherwise protected to prevent this.

The machinery traffic can also cause over-compaction of the sub-grade at these routes. The Contractor can avoid this by widening or varying the access and circulation routes.

HELPFUL TIP:
The stone should be dumped onto the soil sub-grade in deep strips that can then be used as circulation routes for the bulldozers and other machinery as they spread the stone. This technique will significantly reduce the pressure on the sub-grade and the underlying drainage pipes.

The same applies to the stone base itself, during stone placement and during subsequent leveling operations. Vehicular traffic can affect compaction, resulting in over-compaction of access points and other more trafficked areas on the base. The Contractor should vary circulation patterns over the base and possibly create temporary circulation routes that will be taken down at the end of the base construction and leveling process. The stone used for the creation of these circulation routes can then be used in other project works.

HELPFUL TIP:
A temporary circulation route can be created by spreading a deep layer of un-compacted base stone on the surface. Vehicular traffic will compact this layer while preventing the deeper base stone from being affected. As base construction work progresses towards the base's main vehicular access point, this "temporary road" is gradually eliminated. This stone should be taken off the base, since its properties will have been affected by all this manipulation.

5.3.2.2. Edge Grading

It is easy to grade and compact the main body of the field; it is much more difficult to insure that a proper grade extends to the concrete curb of the field. The grade and compaction results must not deviate at the curb or in a field corner. To accomplish this requires diligent handwork.

HELPFUL TIP:
A field's grade and compaction should be first checked in the corners and along the edges.

For example, it was common that construction specs require that surfaces attain a grading precision to the order of 1 cm (2/5 inch) under a 3-meter (10 foot) leveling edge. This was pretty much the limit that traditional grading methods could be expected to attain. Today, using modern grading methods, lasers and GPS guided equipment, builders can attain 4 to 6 mm precision (.15 inch) for a stone dust mix grading layer.

5.3.2.3 Grading methodology

Today, surface grading can attain extreme precision levels, using laser, GPS and other measurement and equipment control systems. But, before the advent of these cutting edge techniques, there were manual techniques that provided totally acceptable results.

Traditionally, grades were attained using stakes and string. Although this technique may seem a little antiquated, it was and is still useful in situations where the newer electronic techniques are not available. Wooden stakes are set in the stone base in a grid pattern and the desired grade level is inscribed on each to guide the grading equipment operator to grade the sub-base as well as lay the drainage and base stone in even lifts. Once the stone is leveled between the stakes, string is stretched between the stakes to spot low or high spots. These are then marked on the surface to be corrected. Once this is done, the stakes are removed and the rest of the surface is leveled out.

The advent of electronics in the grading process has allowed grading standards to be significantly increased, to a point where traditional methods are no longer appropriate. Laser levels have greatly simplified the grading process and made it possible to attain high levels of precision that aren't possible with stakes and string. GPS guidance systems directly control the leveling equipment, adjusting the edge level and slope according to the position of the machinery on the surface. Near perfect grading is attainable.

5.3.3. Grade tolerances and verification

The grade tolerances should be checked over the whole surface, and especially in the corners of the field, next to the curbs, and along the sides of the curbs around the field. These areas are most prone to bad grading.

After checking these areas, the remainder of the field should be checked.

FIFA prescribes a maximum grade tolerance of 0.4 inch (1 cm) under a 10 foot (3,0 m) straight edge, which is easily attainable. Grade tolerances of +/- 1/4" to

1/8" when measured over the plane of the field can be achieved with modern grading equipment and techniques.

5.3.4. Stone base testing

Before turf installation is to start, the base should be tested for planarity, stability and drainage. Maintaining these properties at their optimal levels should guide the Contractor throughout the construction process. Thorough testing must be conducted so that any needed corrective measures can be instituted before turf installation. Once the turf is laid down, there is little that can be done to correct base defects.

5.3.5. Stone base sign-off

Once the stone base is graded and thoroughly checked, it is ready for the synthetic turf installation.

Before this starts, the synthetic turf installer should be asked to check and approve the planarity of the base, as well as permeability. He should have access to base design specifications and details as well as records of the compliance of installed materials with the design specifications.

Disclaimer

The *STC Guidelines for Synthetic Turf Base Systems* are voluntary. This document does not, in any way, imply, suggest or guarantee that a warranty, environmental, or performance issue could not arise if the system, product or component meets the suggested guidelines; nor does it imply or suggest that if any of the guidelines are not met that the product will fail to perform. These guidelines are not standards and are not to be used as the basis for warranty or other claims.

About the Synthetic Turf Council

The Synthetic Turf Council (STC) is the world's largest organization representing the synthetic turf industry, representing over 200 companies with operations in 9 countries. Founded in 2003, the STC assists buyers and end users with the selection, use and maintenance of synthetic turf systems in sports field, golf, municipal parks, airports, landscape and residential applications. It is a resource for current, credible, and independent research on the safety and environmental impact of synthetic turf, as well as technical guidance on the selection, installation, maintenance, and environmentally responsible disposal of synthetic turf. Membership includes builders, landscape architects, testing labs, maintenance providers, manufacturers, suppliers, installation contractors, infill material suppliers and other specialty service companies. For more information, visit www.syntheticturfcouncil.org.

Synthetic Turf Council (STC) Guidelines

Considerations When Buying Synthetic Grass for Landscape Use

Guidelines for Crumb Rubber Infill Used in Synthetic Turf Fields

Guidelines for Maintenance of Infilled Synthetic Turf Sports Fields

Guidelines for Minimizing the Risk of Heat Related Illness

Guidelines for Synthetic Turf Base Systems

Guidelines for Synthetic Turf Performance

Removal, Recovery, Reuse & Recycling of Synthetic Turf and Its System Components

Suggested Environmental Guidelines for Infill

Suggested Guidelines for the Essential Elements of Synthetic Turf Systems

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