FIFA

FIFA NATURAL TURF GUIDELINES

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INTRODUCTION

I.

The aim of this guide is to provide the reader with background information about natural turf football pitches to assist decision-making and ensure that such pitches are constructed and maintained to a standard that optimises player performance. This guide is designed primarily, but not exclusively, for managers and administrators, to make them aware of the main stages in the development of football pitches and the maintenance resources required to sustain a good-quality playing surface within their climate zone.

USING THIS GUIDE

II.

The methods used within pitch construction, grass selection and pitch management are heavily influenced by the required pitch quality, the budget and other resources available, and the climate of the area in question. As a result, this guide features two standards of pitch provision and information on the cool- and warm-season grasses that affect pitch development according to the climate zone. It is important that all of the relevant stakeholders have a clear idea of the type of facility that is being developed and the main climate constraints in the area.

2.1 Standard of facility

The quality of a pitch depends on the resources available for both its construction and its maintenance. Two standards of playing surface are featured in this guide:

- Basic pitches: these are intermediate-quality pitches that are used primarily to host the activities of club teams, recreational play and training sessions. These pitches are often constructed using the existing soil on the site. The main priorities typically involve upgrading the drainage system, improving surface levels and resources in terms of equipment, fertiliser and plant protection products, etc. and ensuring that there is a sufficient number of ground staff with the appropriate training and turf management skills.
- High-quality pitches: such pitches are appropriate when a top-class playing surface is required, which is mainly the case in professional and international-level sport. In this context, it is important to remove the risks associated with poor playing conditions or fixture postponements/abandonments, particularly due to poor weather conditions, e.g. heavy rainfall, ice and snow. These pitches usually have a full construction profile with a sand-dominated root zone and may include features such as turf reinforcement, growth lights and a vacuum/air ventilation system, especially in difficult growing environments within stadiums.

2.2 Cool- and warm-season grasses

The grasses chosen for a natural turf surface must be suited to the region in which the pitch is located, so as to ensure a hard-wearing surface that is capable of delivering the required playing performance characteristics whilst meeting the desired aesthetic standards. The climate within a region is a dynamic mix of environmental factors that influence the growth and development of turf grasses. Temperature extremes and rainfall patterns have the biggest influence on the adaptation of turf-grass species in a particular location. There are two main groups of grasses, which vary considerably in their biology and climate adaptation.

As their name suggests, cool-season grasses are adapted to cooler climate regions and grow best at soil temperatures of between 16 and 24°C (60-75°F). Root and shoot growth is severely restricted at soil temperatures above 27°C (80°F). Examples of cool-season grasses that are regularly used on football pitches include perennial ryegrass (*Lolium perenne*), smooth-stalked meadow grass/Kentucky bluegrass (*Poa pratensis*) and tall fescue (*Festuca arundinacea*).

Warm-season grasses are adapted to tropical and Mediterranean areas and optimal growth occurs at temperatures of between 27 and 35°C (80-90°F). Examples of warm-season grasses used for football pitches include Bermuda grass (*Cynodon dactylon*), zoysia (mainly *Zoysia japonica* and *Zoysia matrella*) and seashore paspalum (*Paspalum vaginatum*).

Each grass species has unique characteristics that make it better suited to certain climatic conditions, such as tolerance to heat or cold, or drought and disease resistance. Extensive grass-breeding work has been carried out to improve species and it is important that the cultivars of each species be selected on the basis of their resilience to the local climate or with a view to improving wear tolerance and disease resistance.

There are significant problems in relation to grass selection in parts of the world with wide-ranging temperatures. Cool-season grasses are poorly adapted to summer conditions in such climate zones, when high temperatures, water availability and salt accumulation may be significant issues. In contrast, warm-season grasses are intolerant of colder winter conditions and tend to go brown and dormant. Under such circumstances, it is often essential to oversow the main warm-season grass with a cool-season species before the onset of winter and to remove the cool-season grass once the temperatures rise. The main areas requiring this dual-sowing approach are continental (transition) climates and some Mediterranean and dry-summer subtropical climates.

2.3 Specialist advice

This guide explores the most important issues to consider when developing and maintaining pitch facilities. However, advice from a reputable sports turf consultant or specialist is often essential, particularly to determine construction requirements, ensure that construction work is carried out to an appropriate standard and with suitable materials, and provide a good-quality pitch maintenance programme.

2.4 Relevant publications

The following publications offer further information regarding natural football turf:

- FIFA Stadium Guidelines (2022)
- FIFA Test Manual for Natural Playing Surfaces (October 2021)
- FIFA Natural-Pitch Rating System: Natural Playing Surfaces Quality Programme (May 2022)

The documents listed above primarily relate to the construction, management and testing of facilities of the highest standard.

PITCH DESIGN AND CONSTRUCTION

III.

The range of pitch construction options has increased in recent years as pitch and root-zone reinforcement systems have been developed to meet the challenges within amateur and professional football. Pitch construction projects should involve a considered and planned approach so as to ensure that an optimum long-term result is achieved in all instances.

Installing an unsuitable pitch type for the scenario in which it is to be used and maintained will result in future challenges. A poorly constructed pitch reduces the number of games that can potentially be played, is expensive to maintain and impacts on the performance standards that can be achieved, whilst also increasing the risk of match postponements/abandonments due to adverse weather conditions. It is important that the pitch be constructed to an appropriate standard and the pitch type be aligned with the intended use.

3.1 Construction planning and considerations

Pitch construction projects can be broadly divided into two main types:

1. Amateur football and training ground pitch constructions
2. Stadium and professional pitch constructions

This section provides the reader with a list of technical factors to consider when making decisions regarding pitch selection and design in both of the aforementioned contexts.

- The proposed or existing pitch location should be assessed to determine whether it is located on or within landfill, flood zones and/or groundwater protection zones. If the pitch is situated in such areas, specific restrictions, risks or requirements could apply. Likewise, if the pitch is located within an urban environment, this could result in working restrictions that impact on the schedule and costs.
- An assessment should be carried out in relation to a suitable outfall for drainage water. A ditch or stream, or access to the public drainage system, is required. Many pitch drainage systems now require drainage discharge consent, with some sites subject to low flow discharge rates, thus increasing the need for on-site attenuation to cater for peak rainfall events. The need for on-site attenuation of varying degrees is increasing in many regions of the world.
- Existing and desired pitch gradient falls should be assessed and determined, with this information providing the basis to model the extent earthworks/levelling system. This assessment is to be performed using topographical surveys and earthworks modelling software.
- Any existing on-site services must be identified. This includes electricity and gas, as well as water supply for irrigation purposes, and involves determining the location of any existing pipework that needs to be avoided and/or relocated during any construction or drainage work.
- Sourcing a suitable water supply is critical in the majority of instances. Water can be sourced from accessible boreholes, streams, rivers or public water supplies. Where the location is suitable and good planning is in place, it may be possible to collect and recycle drainage water. Assessing whether the water supply is capable of guaranteeing the required quantity and quality of water at a sufficient rate is essential to the immediate and long-term pitch quality standards. Identifying end-user groups and their requirements will also determine whether irrigation is required and, if so, which type of irrigation system is the most suitable.

- Consideration should be given to pitch layout in regard to surrounding features and ensuring correct pitch alignment to reduce issues relating to low sun angles, which can be particularly problematic in the evening. Pitch sizes, run-offs and surrounding infrastructure, such as fencing and ball-stop netting, can be assessed by drawing up a layout plan to scale.
- An understanding of the expected level of pitch use, i.e. the hours of use for matches and training sessions and the required standard of the facility in relation to the teams using the pitch, is needed to determine the most appropriate pitch construction and system.
- Both existing and future plans in relation to pitch use must be considered. Some member associations and leagues may require certain pitch sizes, types and surrounding set-ups, which, if not identified prior to the start of construction work, may limit the future use of the pitch.
- The local climate (including notably the rainfall levels) will have a significant impact on the nature of the pitch installed and the materials used. Rainfall should be assessed by evaluating annual rainfall and peak rainfall events.
- An evaluation of soil characteristics, relating to both the topsoil and the underlying subsoil layers, is required for the design of effective drainage systems. The subsoil and subgrade evaluation should include consideration of the inherent stability and risk of settlement over time.
- The general geology and composition of underlying material should be assessed to determine the scope to build a soakaway and the possibility of hitting rock during the construction work.
- Consideration should also be given to the available budget.
- A timeline should be established for the construction or drainage work, including the length of the grass establishment period and when the facility is likely to be available for use.
- Thought must also be given to the resources available to maintain the facility in terms of staff and equipment.

For professional football pitch constructions, particularly stadiums, the following additional factors apply:

- In the case of existing stadiums, detailed consideration should be given to the attributes of the stadium in question, the pitch surrounds and the sight lines. Modifying the topographical levels of the pitch may impact on stadium seating sight lines or obstruct camera sight lines towards advertising boards, which may result in commercial penalties or reduce advertising revenue.
- Consideration of the pitch construction at an early stage of the stadium design process offers architects a unique opportunity to engage with suitably qualified and experienced pitch experts to optimise the pitch provision in terms of construction, ongoing maintenance and flexibility.
- When it comes to new stadiums, decisions regarding the final pitch location, finish levels and surround arrangements should be made in close conjunction with stadium architects and stadium operators. It is imperative that the pitch size, gradient and run-off arrangements be considered for both existing and future stadiums to ensure compliance with competition requirements.

- FIFA and other football governing bodies, as well as all major competition organisers, issue pitch requirements for their tournaments, as well as instructions on exemption processes to follow. These should be carefully assessed in line with the future plans for the stadium.
- Many modern stadiums host both sporting and commercial events. Establishing a commercial plan for the stadium that features the type, number and schedule of events will significantly enhance the stakeholders' ability to choose the best long-term pitch construction and system.
- The geographic location and climate will have a significant impact in determining the most suitable type of pitch construction and system. For example, the shading offered by stands can be particularly damaging to warm-season grasses. Modern stadium designs tend to hinder the ability to grow and maintain healthy turf cover as they limit air movement and the entry of natural light. Given the widespread use of growing aids, such as lighting rigs and pitch fans, in the modern game, it is important to ensure that an adequate power supply is available. A stadium climate analysis should be conducted and a lighting model (to include fixture modelling) should be established to ensure the selection of a suitable pitch type and power provision with a view to future-proofing the stadium.
- Careful consideration should also be given to the in-stadium temperature projections for the year. This will enable the requirements in terms of undersoil heating and incoming and outgoing power supply to be established. The implementation of zonal heating should be considered in certain situations.
- Pitch surrounds are increasingly becoming the only available areas in which to position matchday services. New and old stadiums now require several conduits and draw pits of specific sizes to comply with current media requirements. Identifying the potential media and technology requirements will help to future-proof the pitch and its surrounds.
- The pitch surrounds at stadiums to be used in FIFA competitions should meet the performance criteria established under the FIFA Quality Programme for Natural Playing Surfaces. In terms of future stadium use, consideration should also be given to whether stadiums need to meet the requirements issued by World Rugby.
- In the case of major stadiums that are designed to host international fixtures, consideration should be given to the possible need to install a vacuum/ventilation system. This technology allows subsurface air and water movement to be fully controlled and enables heat transfer or cooling from underlying layers to the surface. This may be mandatory for some tournaments.
- Most stadium events are held at fixed times so as to accommodate both spectators and television coverage, and consideration must be given to the risk of postponements/abandonments as a result of adverse weather conditions. Such risks must be taken into account when allocating the budget for pitch construction and subsequent maintenance.
- Important secondary factors include ensuring sufficient space for pitch infrastructure, such as an undersoil heating plant, a vacuum and ventilation plant, and irrigation pump rooms and tanks. The identification and provision of suitable spaces for pipeline routing and incoming supplies are often an afterthought. Pitch surrounds may also need to cater for ball-stop netting sockets, goal storage sockets and underground chambers.

3.2 Typical pitch profiles

Once the site-specific factors and appropriate infrastructure for the pitch construction have been fully considered, the next step involves installing a pitch construction profile, which will consist of a combination of the following elements:

- The subsoil and/or base layer on which the pitch is laid
- A primary trench drainage system
- A gravel and/or egg-crate drainage layer
- A secondary slit drainage system
- A lower and/or upper root-zone layer

The following sections provide the reader with a broad introduction to the basic types of pitch profile and information on the environments in which they are typically installed. It is recommended that a detailed assessment and consultation process involving suitably qualified and experienced personnel be undertaken prior to committing to a particular pitch system.

Within each pitch system, site-specific adjustments will be required in terms of material depths, specifications and spacings so as to cater for all of the aforementioned factors relating to pitch design.

3.2.1 Basic pipe drainage

Trenches are typically excavated to a depth of around 600mm, but this may vary according to the circumstances at each individual site. A pipe is placed in the trench base and the trench is backfilled with gravel or other suitable aggregate before being capped off with sand and an appropriate root-zone mix. This system is normally used in low-budget, amateur football pitch scenarios to offer an initial pitch infrastructure to which additional features and improvements may be added in the future.

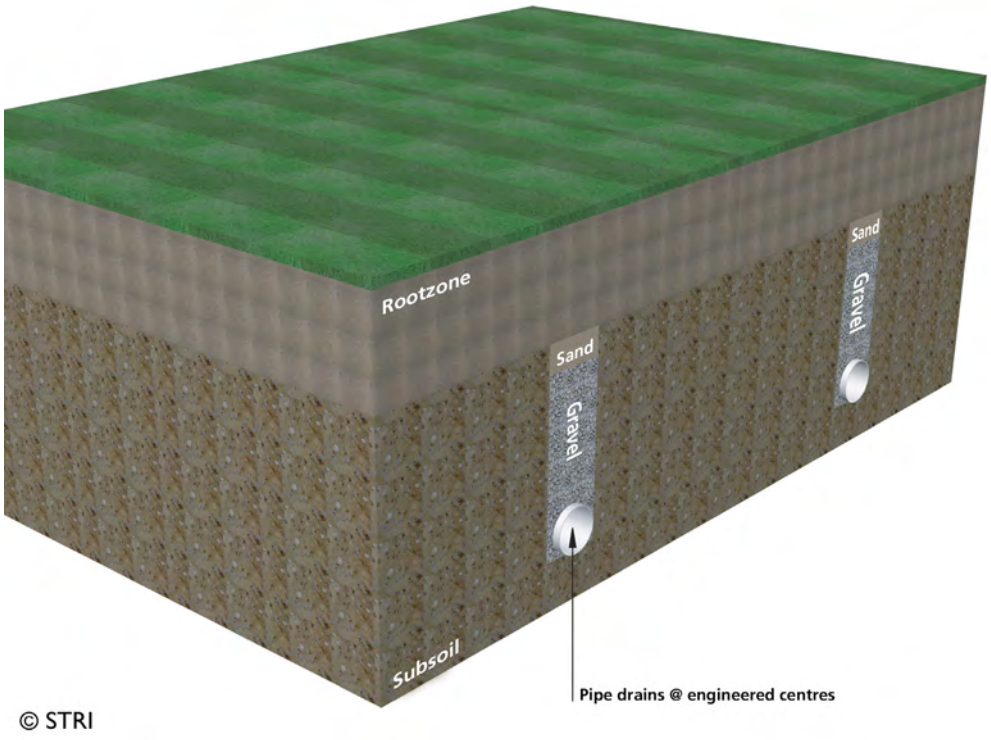


Figure 1: Profile of a pipe-drained pitch

3.2.2 Pipe and slit drainage

Supplementary slit drainage can considerably improve the performance of a pipe-drained system. The slit spacing can vary, but may be as close as 60 to 100cm. The slits serve to intercept surface water and carry it down to the porous backfill of the drain trenches, bypassing the soil root zone, which may be low in permeability. Slits are typically installed in conjunction with a heavy sand dressing to prevent them from being capped by soil. A number of types and forms of slit drainage and a range of backfill materials are currently available on the market. Slit drainage should not be confused with “sand-banding”, which involves cutting narrow sand bands (of 20-25mm) to a maximum depth of 100-120mm. Slit drainage is traditionally used to build amateur football or low-level professional football pitches in low-risk use scenarios such as community pitches and training grounds for low-level football.

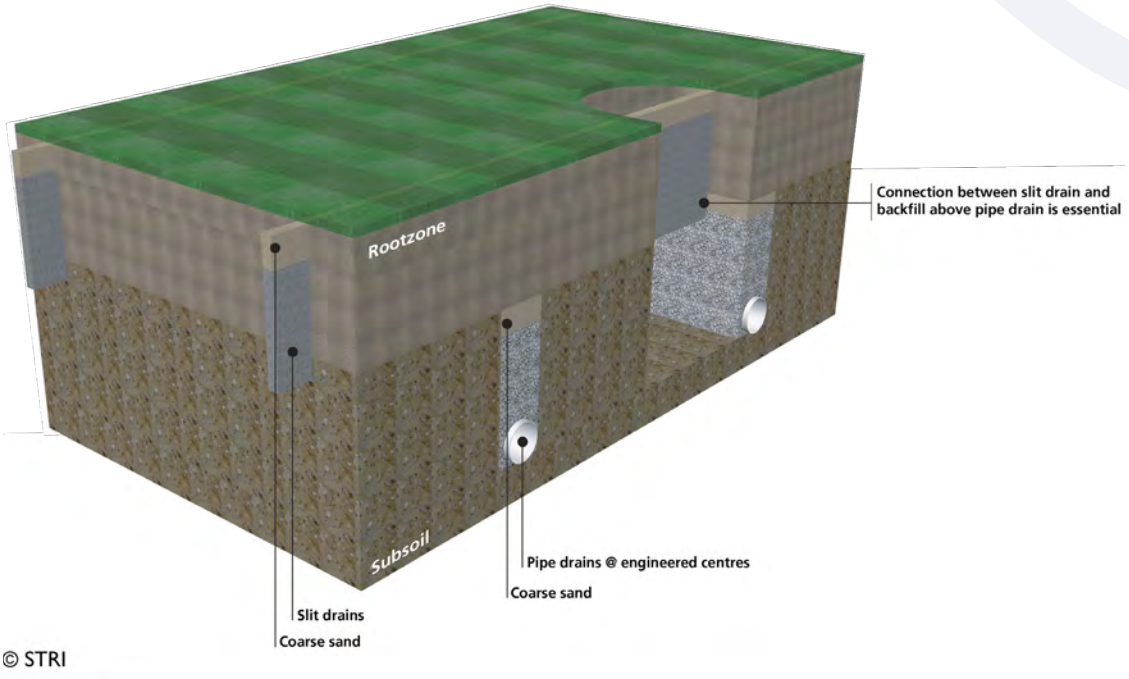


Figure 2: Profile of a pitch with pipe and slit drains

3.2.3 Sand carpet construction

This type of pitch retains the native soil, but the drainage and physical properties of the surface layer are improved by installing a capping of carefully selected sand or a sand-dominated root zone. Careful depth control of such sand layers may be required in order to effectively balance drainage performance and surface stability. This system is traditionally used for amateur football or low-level professional football pitches in low-risk scenarios such as community pitches and training grounds. However, it may be used at a more professional level and at small, low-capacity stadiums in some unique climates.

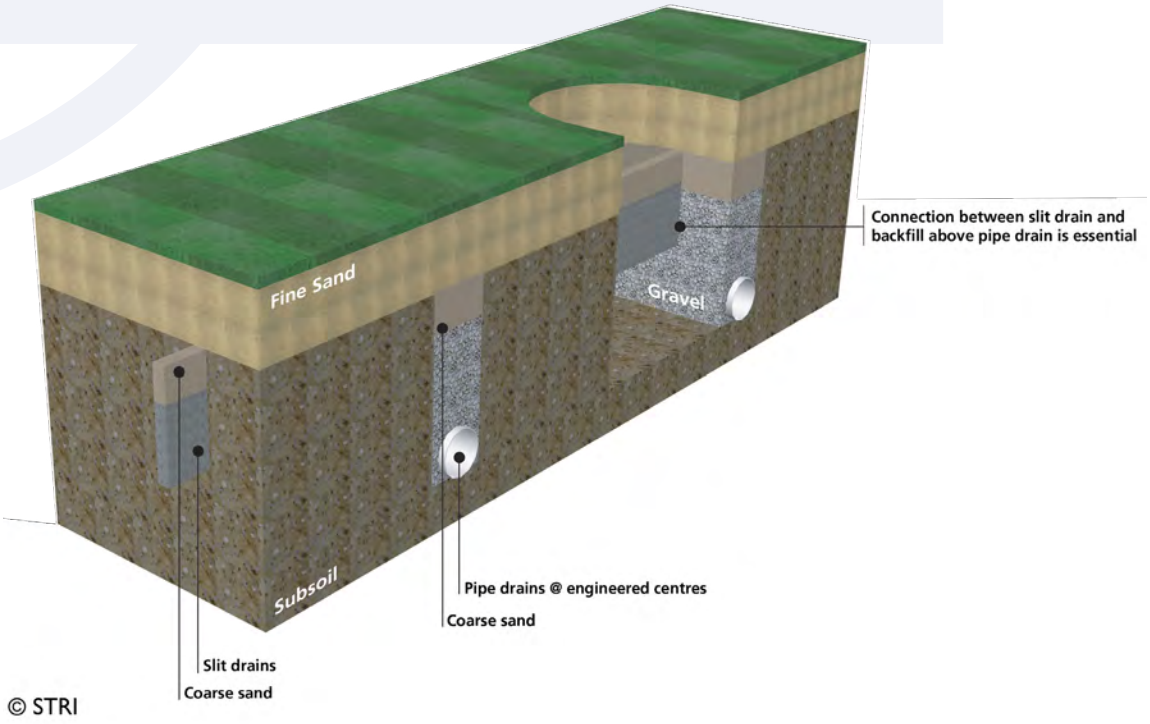


Figure 3: Profile of a sand carpet pitch

3.2.4 Soil over a drainage layer

This method features a base layer formed of gravel or another suitable drainage aggregate and uses soil as the main growing medium. However, it is often necessary to improve the characteristics of the soil layer through slit drainage or sand amelioration.

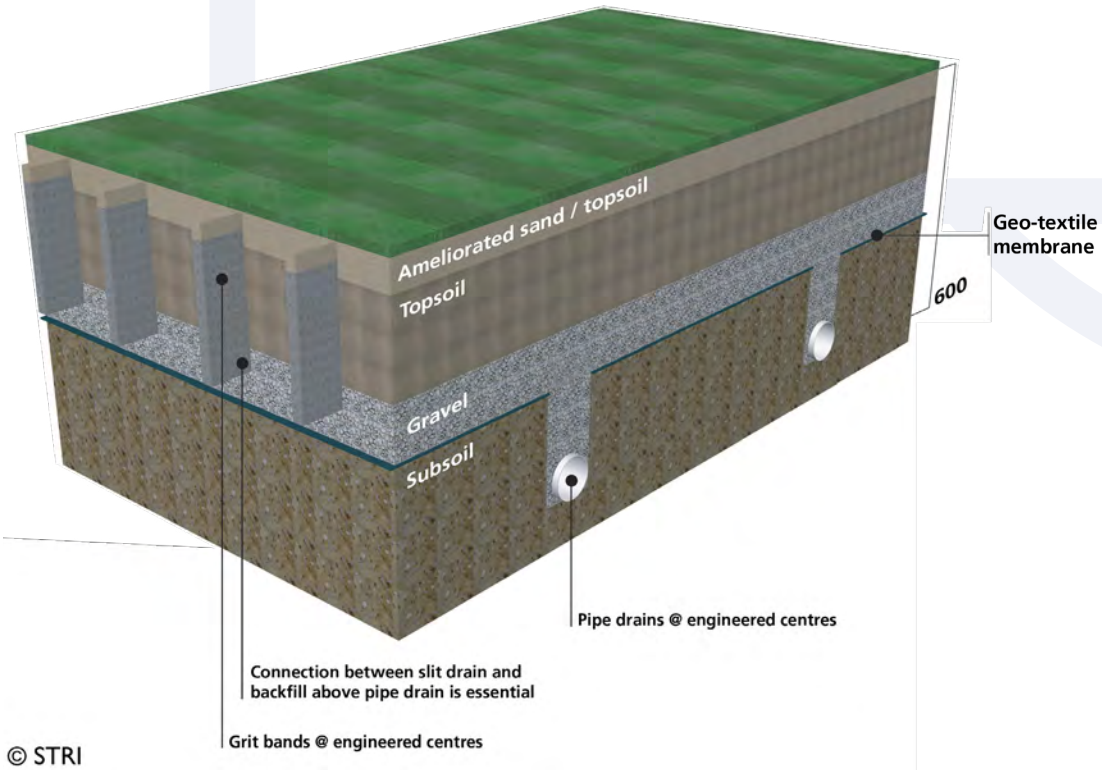


Figure 4: Profile of a pitch with a soil root zone over a gravel drainage layer

3.2.5 Sand-dominated root zone over a gravel drainage layer

This approach is employed when good drainage is essential. The selection of the materials used in the various layers is critical to the success of this type of construction and varies according to the regional climate. Such systems, including variations, are normally used at stadiums and training grounds in the higher ranks of professional football, where effective drainage is essential on account of the climate or event commitments.

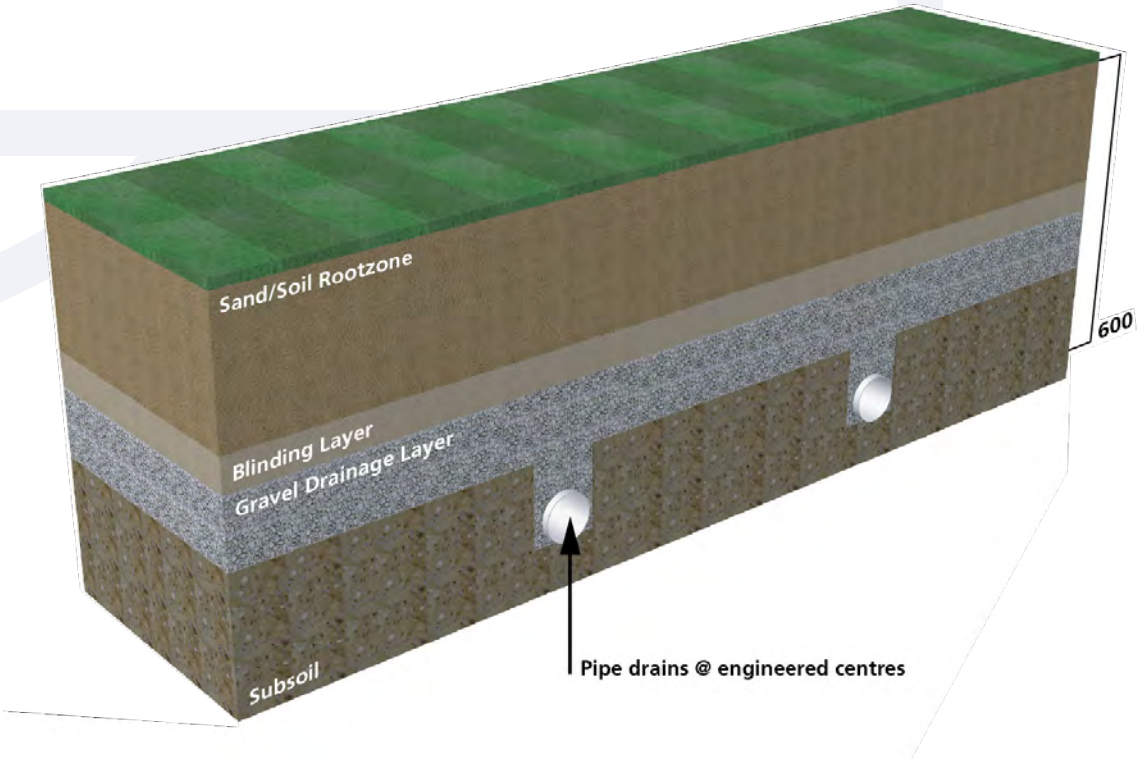


Figure 5: Profile of a pitch with a sand-dominated root zone over a gravel drainage layer

3.2.6 Egg-crate drainage attenuation on a sand-dominated pitch

Plastic-reinforced egg-crate drainage systems are installed in some pitch constructions either in place of or in combination with a gravel carpet. This system can be used either to help pitches cope with limited drainage discharge or to reduce the amount of soil excavated when compared to a gravel carpet. Some proprietary systems also have the capacity to recycle water from the attenuated drainage water below the pitch, where this is deemed to be appropriate. Egg-crate drainage bases can be installed to be permeable or impermeable depending on the requirements. Such systems require higher levels of technical design and installation to ensure that they operate effectively. These systems are traditionally used at elite-level stadiums. The operational performance benefits of such systems are yet to be determined.

Figure 6: Plastic-reinforced egg-crate drainage system

Note

It is recognised that pitch construction requires a significant volume of resources and materials. Ongoing maintenance also requires nutrient inputs, some of which may impact the surrounding environments.

Careful and considerate pitch construction planning that takes all of the factors outlined in these guidelines into account will help to minimise the need for inputs. The consideration of regional climates enables pitch developers to take advantage of any opportunities to reduce specifications or focus resources on key requirements in other areas.

The industry is constantly evolving, with new pitch systems and technology being developed that will serve to reduce the footprint involved in pitch construction.

It is likely that pitch construction and football facilities in many regions of the world will have to adapt to meet the challenge of increasing water control as a part of the global effort to reduce localised flooding, nutrient leaching and water scarcity.

3.3 Root-zone reinforcement options

The standard of pitches throughout the world has increased in recent years. While a number of factors have contributed to this improvement, the development and increased installation of root-zone reinforcement systems have played a significant part.

Three main methods can be deployed to reinforce a pitch root zone, each of which involves an ever-increasing choice of proprietary systems. Careful consideration is required when it comes to selecting the most appropriate system for each environment.

The main categories of root-zone reinforcement systems are as follows:

- Stitched hybrid
- Carpet hybrid
- Fibre-reinforced

Each of these can be subcategorised according to the installation and manufacturing processes or inherent system properties. The following sections offer an overview of these root-zone reinforcement systems.

3.3.1 Stitched hybrid reinforcement systems

These systems consist of elongated polypropylene or polyethylene fibres that are stitched vertically into the pitch root-zone profile at various depths and with varying spacing. The fibres should ideally remain 10-20mm above surface level so as to provide a green appearance to compensate for the absence of natural turf cover. Stitched hybrid fibres, which are designed to be permanent, are traditionally installed to a depth of 180-200mm. Options involving shallower stitching depths are available, but tend to be used for short-term or temporary installations.

Figure 7: Stitcher used to install stitched hybrid reinforcement systems

3.3.2 Carpet hybrid reinforcement systems

Carpet hybrid reinforcement systems consist of an artificial carpet with a permanent or degradable backing to which artificial turf fibres are attached using various methods. The systems can be supplied as turf already grown off-site and simply installed and infilled on-site, or can be laid and established in situ. The systems are infilled using a careful process of controlled depth infilling and brushing.

Figure 8: On-site infill

Some systems feature knitted fibres that enhance the binding strength of the fibre. The carpets are typically installed at depths of between 40 and 60mm. The spacing of artificial turf fibres varies between systems and can be tailored to meet specific requirements.

Figure 9: Carpet-backed system

3.3.3 Fibre-reinforced root zone

A fibre-reinforced root zone involves mixing various synthetic or natural products, which, in their conventional form, are very fine, elongated strands of material. Polypropylene fibres were traditionally used to provide the reinforcement, but other materials are now readily available. Some systems involve amendments that alter the mechanical performance properties of the root zone, including its firmness and energy restitution.

Figure 10: Fibre-reinforced root zone

3.3.4 Considerations when selecting a root-zone reinforcement system

- A competition may stipulate the requirement for a particular type of pitch reinforcement system within its operational guidelines. It is recommended that existing and potential future pitch users be consulted about whether any such requirements are in place.
- The establishment time for the system installation will impact on the viability of a particular system, both at the initial installation stage and in the future.
- Warm-season and continental (transition) climates present unique challenges for reinforced root-zone systems due to their increased organic matter accumulation. It is important to ensure that a system offers the capacity to keep surface organic matter to tolerable levels.
- The presence of existing systems at a stadium or training ground can often mean that uniformity between pitches is a consideration. However, it is important to note that, although a club may use a particular root-zone reinforcement system at its training ground, the same system may not always be viable at the stadium for a number of reasons.
- The presence of growing aids, such as lighting rigs, pitch fans and undersoil heating, impacts on the viability of systems in certain stadium environments.
- Where stakeholders are considering the use of such systems on a longer-term basis, the ability to meet maintenance and renovation requirements is essential. In this regard, consideration should be given to the availability of equipment, materials and expertise.
- When the pitch construction is at a stadium, identifying a clear, long-term business plan will help the relevant stakeholders to select the most suitable root-zone reinforcement system. At stadiums that host events on an ad hoc basis and where pitch use for football purposes is inconsistent, it will generally be challenging to successfully use more permanent reinforcement systems and short-term, temporary options may have to be considered.

PITCH INFRASTRUCTURE

IV.

Plans for suitable pitch infrastructure, including the appropriate technology, are required to ensure effective pitch management and resource utilisation. Technological advances continue to change the way that football pitches are built and maintained.

4.1 Heating systems

Undersoil heating can be used in the case of both natural and artificial pitches. The main functions of such systems are to ensure that the top surface remains frost- and snow-free and raise the ground temperature to a few degrees above freezing to provide players with a safe playing environment.

There are two types of heating system:

Figure 11: Pipe heating system installed in holding racks on the gravel drainage layer to support the pipes prior to root-zone installation

- Pipe system – a water/glycol mixture pumped through the pipes via a direct control system that is linked to temperature sensors located at various soil depths across the pitch, ranging from 30 to 280mm. This allows the system to flag when there is a threat of frost, whilst the water/glycol mixture flows smoothly through the pipes and ensures a rapid rise to operating temperature. The pipes, which total around 30km in length, should be spaced at between 250 and 300mm, at a depth of 300mm.

  The installation of undersoil heating can serve to upgrade existing pitches. This involves drawing the heating pipes through the profile using special tractor-mounted equipment.
- Electric system – this represents another solution for undersoil heating and involves the use of electric wires instead of pipes.

The advantages of an undersoil heating system are:

- protection from frost;
- year-round playability;
- extension of the turf growth and recovery phases;
- reduction in the risk of player injuries; and
- reduction in the risk of matches being postponed/abandoned.

Many domestic leagues across the world stipulate that stadium pitches must have undersoil heating.

Under no circumstances should undersoil heating be used to clear a heavy layer of snow; rather, light equipment should be employed for this purpose. Melted snow results in high volumes of water. If a pitch fails to drain adequately following heavy snowfall, it becomes waterlogged and slippery.

Figure 12: Waterlogged pitch following heavy snowfall

4.2 Pitchside fans

Stadium pitches can be greatly improved through the use of electric fans, which cool the turf canopy and soil temperature and increase root development (Duff and Beard, 1966; Guertal et al., 2005). Fans also help to dry the soil and reduce turf leaf wetness duration, both of which serve to diminish pathogen pressure. Using a fan to dry the pitch also improves the playing surface's wear tolerance. Oppressive heat and humidity make it difficult to grow healthy turf during the summer months in the majority of countries and transition zones if air movement is limited.

It is common for fans to be operated for 24 hours a day during periods of heat and humidity. If fans cannot be used for 24 hours, operating them from the evening to the early morning may offer the greatest benefits when it comes to alleviating heat stress and increasing rooting (Huang et al., 2001).

There are two types of pitchside fan widely available on the market:

Air fans – their performance is measured in cubic metres per hour (CMH or m^3/hour) or cubic feet per minute (CFM or f^3/minute), with these measurements relating to the volume of air supplied in the time in question, which depends on a number of factors: fan engine power, blade pitch and the length and/or shape of the blades. The greater the CMH or CFM, the greater the volume of air moved by the fan. To ensure optimum effectiveness, pitchside fans should record a minimum air flow of 50,000m^3 per hour.

Figure 13: Air fans

Spray cannons – producing and emitting a water vapour, these fans serve to create an evaporating cooling effect at the pitch surface. However, care must be taken with the management of such fans so as to avoid increasing the risk of turf disease. Humidity levels must be monitored to ensure that the fan is operated correctly.

Figure 14: Spray cannons

4.3 Lighting rigs

The amount of natural light (photosynthetically active radiation or PAR) that a turf grass receives throughout the year has a direct impact on its health and resilience. The surfaces produced by turf grasses that receive insufficient PAR for extended periods are rarely of an adequate standard and tend to deteriorate quickly. Natural lighting is usually sacrificed at the expense of the architectural demands of modern stadiums. The main reason for using artificial lighting is to compensate for the deficit of natural light in shaded areas of the pitch.

Stakeholders at venues that are actively considering implementing artificial lighting must also be aware that different types of grasses actively benefit from variable light spectrums and quantities. In addition, the desired final turf quality, along with the pitch use levels, will also impact on the amount of artificial lighting that is required.

In the case of an existing stadium, it is recommended that a year-round lighting model be established or a shade analysis be performed to determine where and when PAR deficits occur across the pitch. This allows the relevant stakeholders to establish the extent to which supplementary lighting is required. A number of artificial lighting providers currently cater for stadiums; indeed, this sector has grown significantly in recent years.

During the stadium design phase, the relevant stakeholders have a unique opportunity to consider PAR deficits during the initial stage of the stadium project. They may actively seek to reduce or minimise the impact of PAR within the stadium or plan to introduce a more efficient artificial lighting infrastructure.

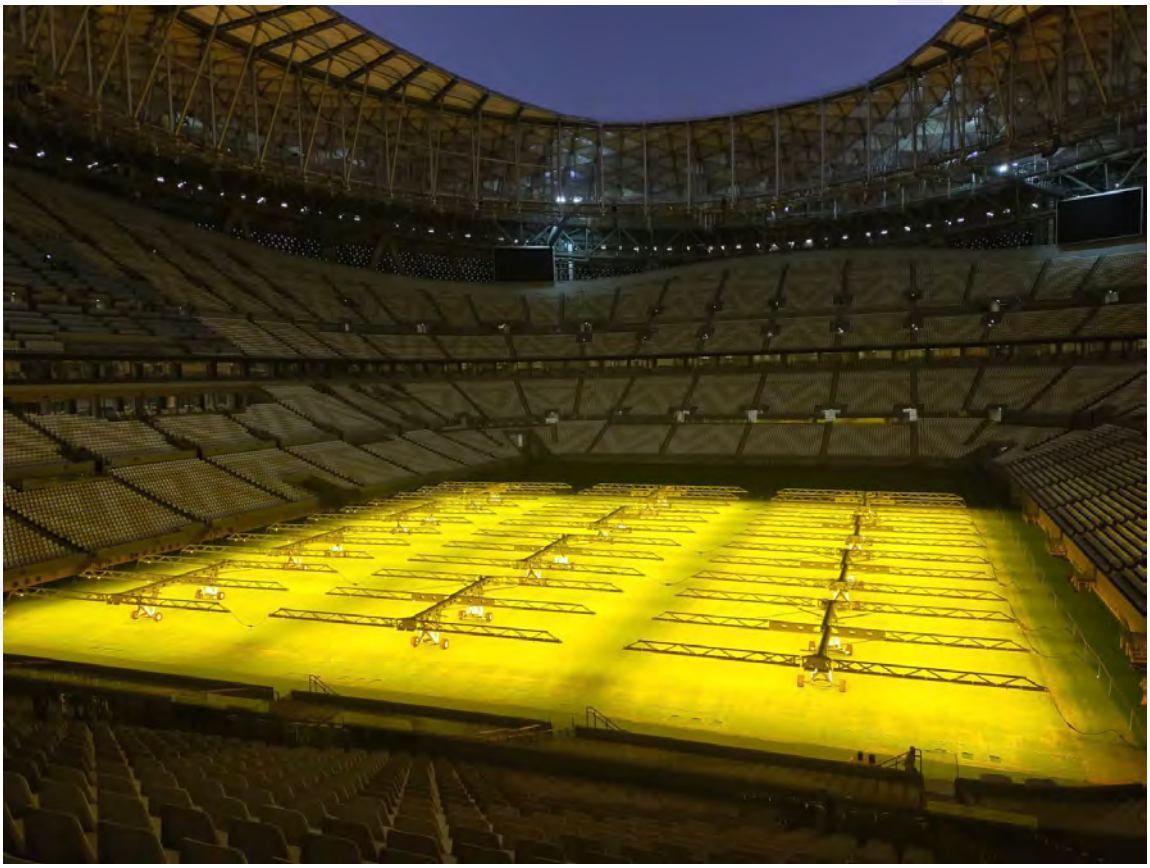


Figure 15: Artificial grow lights with high-pressure sodium bulbs

Shade analysis and lighting metrics

The item of most interest to turf-grass managers is how much PAR strikes a surface throughout the day. This integrates two other metrics – photosynthetic photon flux density (PPFD) and the daily light integral (DLI) – and is much more useful for quantifying the supplementary light for plants. Knowing the DLI requirements for the turf grass, based on the traffic and use, it is possible to calculate how much supplementary lighting must be applied to achieve optimal grass recovery. New technology and sensors make it easier to measure the PAR reaching the turf and the DLI in each location of the pitch by generating an accurate shade analysis of any venue, in order to provide data on supplementary lighting needs.

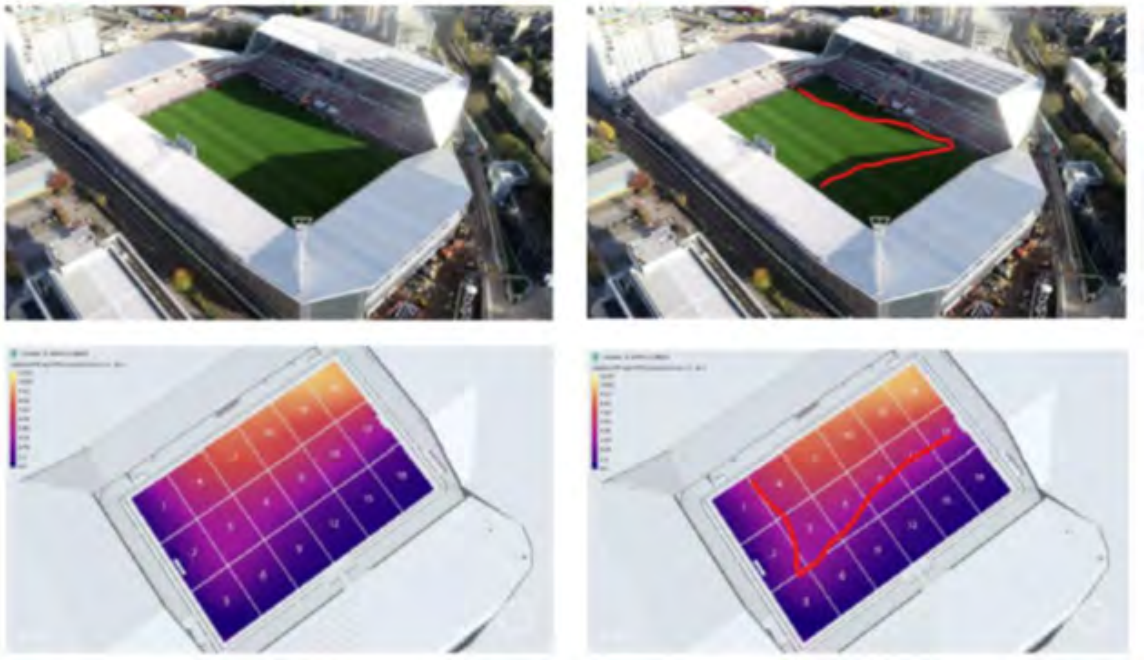


Figure 16: Accurate shade analysis can recognise the shape of the infrastructure causing the shading

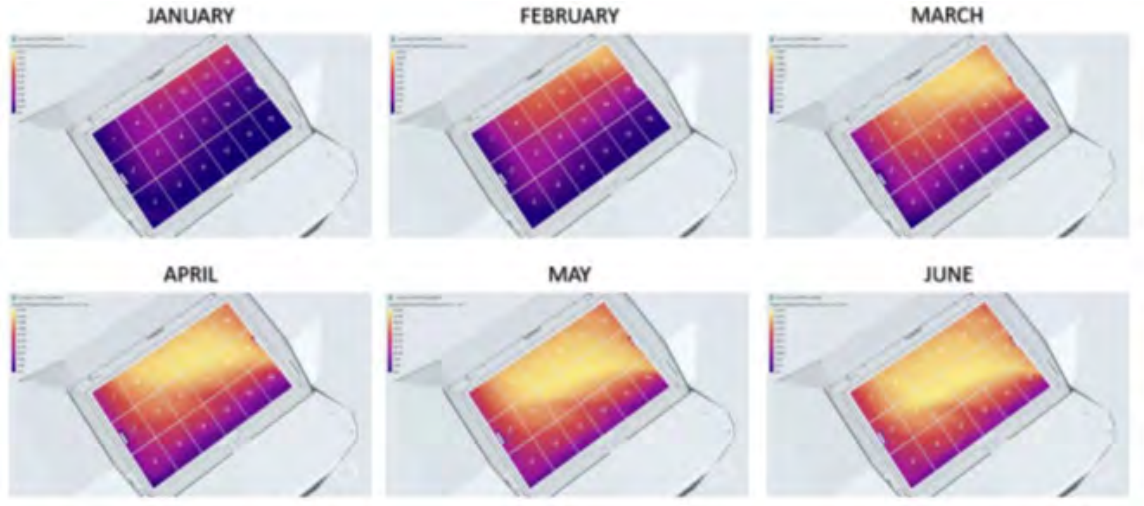
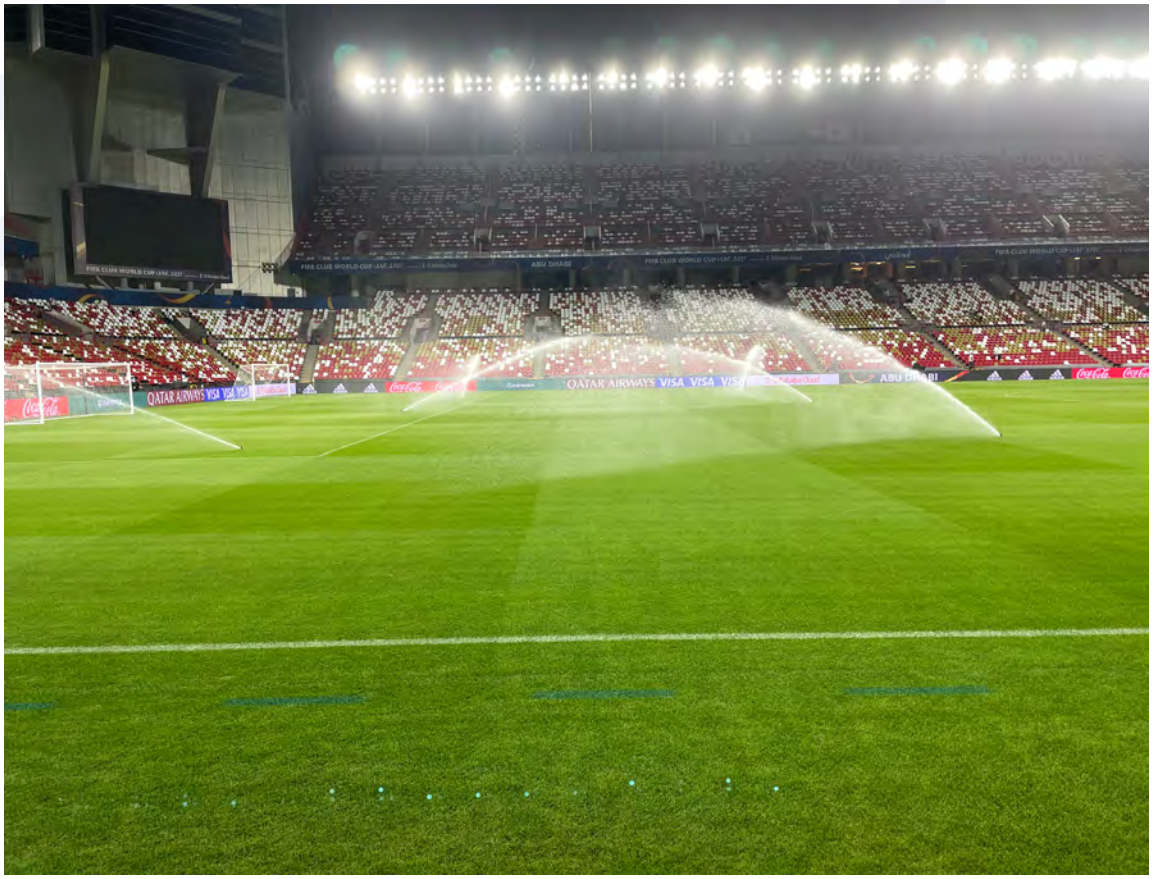


Figure 17: Shade will vary depending on the time of the year and the height of the sun at the specific location

Use of DLI data along with shade analysis can assist the ground manager in making data-driven decisions about the deployment of lighting rigs, making the use of the rigs more efficient and cost-effective.

4.4 Irrigation systems

The irrigation requirements of a football pitch are dictated by both the climate and the level of football played on the surface. In all circumstances, an irrigation system affords ground staff greater control over turf-grass establishment and maintenance. In many regions of the world, the successful establishment and maintenance of a pitch are simply not feasible without a correctly designed and installed irrigation system. The irrigation systems in place at most professional-standard facilities are also used to manipulate surface ball speed through a practice known as ”syringing”.



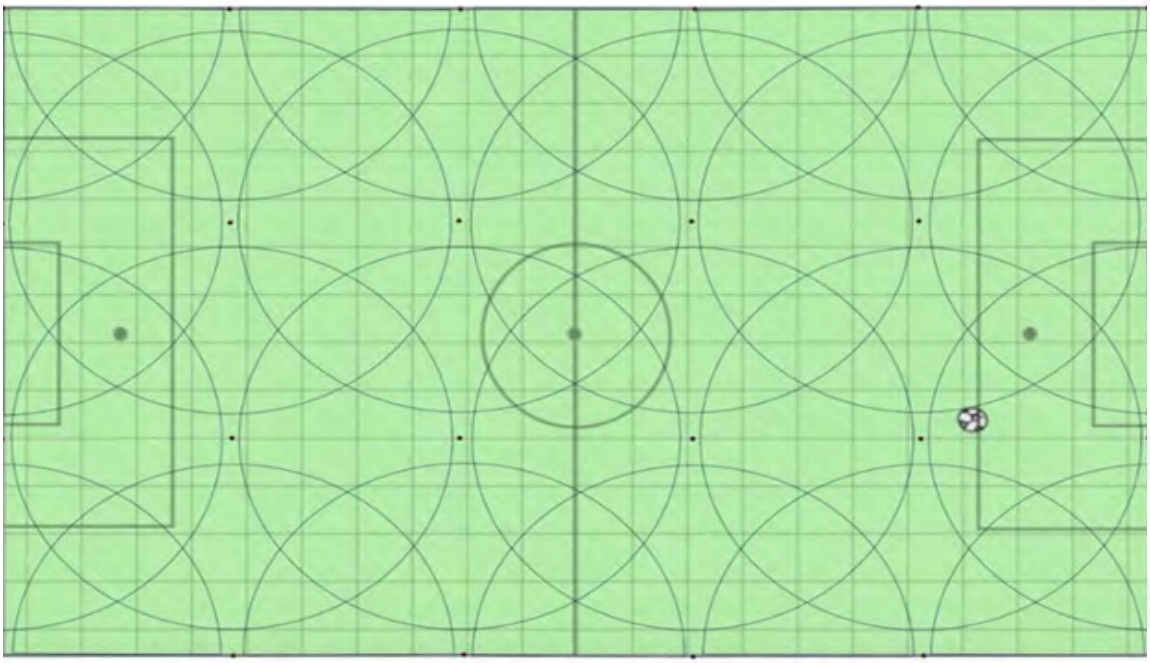


Figure 18: Irrigation system overlaps

Systems must be designed with sections catering for spray angles of 90°, 180° and 360°, with sprinklers able to be run separately and with individual timing to allow even water coverage. A common mistake in irrigation design all over the world involves sprinklers being set in lines whereby 180° sprinklers are run at the same time as 360° sprinklers, resulting in the overlapping areas being double-watered.

In all cases, it is strongly recommended that an experienced and reputable professional be involved in the design of the irrigation system. Consideration should be given to the following:

- The water source and rate of supply
- Determining adequate plant and storage tank locations, along with storage volumes
- Establishing peak irrigation application rates
- Establishing any existing and future competition requirements for infrastructure and techniques to optimise the performance of the irrigation system, such as syringing and in-pitch irrigation head types

Figure 19: Pump room

Figure 20: Storage tank

Although there are other watering methods, in nearly all cases, an automatic pop-up irrigation system is required or is of great benefit to the quality of the pitch in the long term.

Figure 21: Example of poor irrigation coverage

Alternative irrigation systems are sometimes used in amateur football within cool-season climates. Travelling irrigation is the most common alternative to pop-up irrigation systems. While notably slower and less accurate in their application, travelling irrigators do provide a means to apply water reasonably uniformly across a pitch at a reduced cost compared to pop-up irrigation systems. Travelling irrigation systems are rarely, if ever, suitable in climates with high irrigation demands or for pitches that host professional/high-level football.

Figure 22: Travelling irrigator

4.5 Vacuum and ventilation systems

In view of the commercial commitments that professional football competitions have to meet in the modern day, some stadium occupants/owners now choose or are required to install vacuum and ventilation systems. When correctly installed, such systems have the ability to improve the moisture control in the root-zone profile, speed up root-zone heating by forcing hot air upwards and boost surface water infiltration rates. These systems also serve to increase the aeration in the root zone, which improves root development and promotes healthier soil environments.

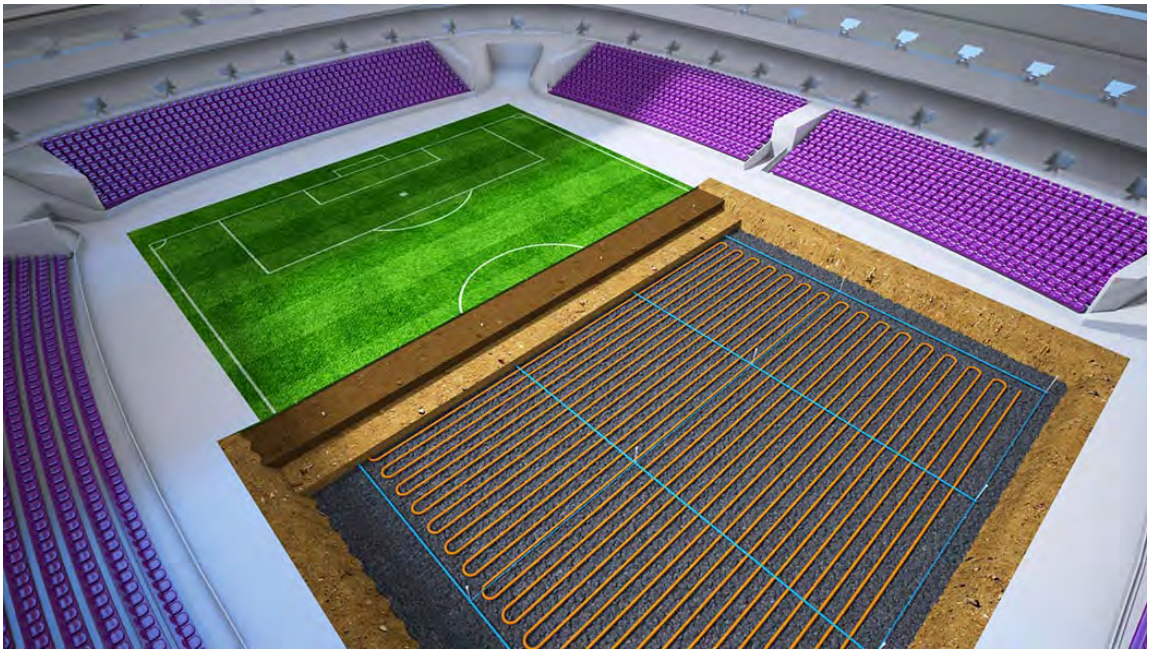


Figure 23: Conventional pipe vacuum and ventilation system

Figure 24: Vacuum and ventilation system with an egg-crate drainage base

Figure 25: SubAir plant room installed within a stadium to operate the vacuum and ventilation system

Several proprietary vacuum and ventilation systems have been developed over the past decade. When the installation of such systems is being considered, it is important to ensure that they are suitably engineered for the installation context. Factors such as the root zone's type and depth, the gravel and sub-base type and the capacity to house the plant should all be considered prior to installation.

4.6 Pitch covers

The climate, the standard of football and other financial and practical considerations dictate the use and necessity of pitch covers. While pitch construction and infrastructure innovations have reduced the need for pitch covers, such infrastructure is not always affordable and cannot be fitted retrospectively at many venues. Under such circumstances, pitch covers can represent a useful alternative.

Various types of pitch covers exist and are commonly used for different purposes:

Frost covers

In regions with severe weather conditions, games can end up being postponed/abandoned as a result of frozen pitches. The use of frost covers allows matches to go ahead and reduces the risk of costly postponements/abandonments. Frost covers can also represent a useful resource at a training ground, where they can be deployed to allow players to continue to train during periods of frosty weather. Frost covers also help to retain heat when used in conjunction with a heating system.

Frost covers can be produced as a single skin, double skin or triple skin, depending on the level of protection and insulation required. They are manufactured from a 130 or 190g/m^2 geotextile material and come complete with reinforced hems and eyelets to peg the cover down.

Frost covers are generally available as flat sheets or on an inflatable roller system. The latter involves less labour and enables the covers to be deployed quickly and easily.

Figure 26: Pitch frost cover

When using frost covers in conjunction with heating systems, care must be taken to avoid overheating the turf-grass canopy under the covers.

Growth blankets

Cover systems can be used to raise the soil temperature by a few degrees, which promotes turf growth and recovery in late autumn and again in early spring.

Rain covers

As is the case with frost covers, a waterproof membrane provides a protective layer, which in this instance serves to prevent excessive rainfall from landing on the playing surface. Rain covers are particularly useful in scenarios where the drainage system is limited.

Figure 27: Pitch rain cover

When considering the installation of a rain cover, pitch gradient falls must be taken into account. Furthermore, establishing suitable surface water outlet/discharge points around the pitch is pivotal to the success of such covers.

Inflatable covers

Pitch covers can be used in conjunction with inflatable tubes that allow the covers to be raised above the turf. These are typically combined with heated blowers that increase the temperature inside the “dome”. Such systems do allow for some maintenance to be carried out under the covers, but this is significantly limited; as a result, this set-up is usually employed for specific, one-off events, such as televised fixtures at low-level football venues during high-rainfall or cold periods of the year.

Figure 28: Inflatable pitch cover

GRASS SELECTION

V.

The durability of a natural turf football playing surface is, in part, determined by the grass species chosen for the pitch. The world's climate can be divided into a range of zones. The climate can vary considerably across continents and within countries. The most influential factor in the success of a playing surface is the turf-grass species, which must be suited to grow and thrive in the climate zone and the specific environmental and climatic conditions at the site in question. It should be noted that temperature extremes and rainfall patterns are the most significant variables affecting the adaptation of turf-grass species. Choosing the most appropriate species is paramount as it has implications for the management of a particular species or playing surface and the associated costs.

As stated above, cool-season turf grasses, which are adapted to cooler regions of the world, generally grow best at soil temperatures of between 16 and 24°C (60-75°F), with limited root and shoot growth above 27°C (80°F). In contrast, warm-season grasses, which are adapted to tropical regions, grow best at temperatures between 27 and 35°C (80-95°F), with the turf going dormant when the soil temperature falls below 10-13°C (50-55°F).

Turf-grass selection should ideally be based on the ability of the species to grow and survive as a perennial, i.e. grow all year round. Cool-season turf grasses generally have poor heat tolerance, but good cold tolerance. They may endure several days of high temperatures, but are likely to be weakened or killed by three or four weeks of prolonged hot weather, especially if humidity is also high. In contrast, warm-season grasses are less tolerant of cold conditions and grow best at high light intensities. The majority of warm-season turf grasses are able to tolerate mildly cold weather for a few weeks, but a single night of extreme cold can cause severe damage.

In climate zones where winter and summer temperatures fluctuate significantly between the optimum for both cool- and warm-season grasses, both types of grass may be used, in a strategy commonly referred to as transitional turf management. Transitioning should ideally only be considered if the growing season is long enough to support the species from turf establishment through to maturity.

The decision to use either cool- or warm-season turf grasses can broadly be based on the ability of cool-season turf grasses to tolerate high temperatures and of warm-season grasses to tolerate cold temperatures.

Days with maximum air temperature >30°C		
<90/year	**90-120/year**	**>120/year**
Most cool-season grasses may be grown, e.g. perennial ryegrass, Kentucky bluegrass	**Some cool-season grasses may be grown, e.g. tall fescue, Kentucky bluegrass**	Unsuitable for cool-season grasses

Table 1: Cool-season grasses – heat tolerance guide

Whether using cool- or warm-season turf grasses, cultivars should be selected on the basis of their suitability for the local climate and resilience to football use. Individual cultivars will have different performance traits relating to their growth characteristics (e.g. leaf width, shoot density, leaf colour or resilience to heat, cold or drought), whilst within the decision-making process, it is also worth considering the available budget and the management resources required to maintain these cultivars in good condition.

Warm-season surfaces are normally established as monocultures of a single species and cultivar. In contrast, cool-season surfaces may be established either as a monoculture of the same species/cultivar or as a mixture of two or three different

species and/or cultivars. Specialist agronomic advice should be sought to ascertain the most cost-effective grass species and blend for a particular site according to the local climatic and environmental conditions and proposed use.

	Warm-season grass species			
Attribute	Bermuda grass (*Cynodon dactylon*)	Seashore paspalum (*Paspalum vaginatum*)	Zoysia grass (*Zoysia matrella* and *Zoysia japonica*)	Kikuyu grass (*Cenchrus clandestinus*)
Growth habit	Stolons and rhizomes	Stolons and rhizomes	Stolons and rhizomes	Stolons and rhizomes
Wear tolerance	High	High	Moderate*	Moderate
Shade tolerance	Low	Moderate	Moderate	Low
Cold tolerance	Low	Low	Moderate	Low
Heat tolerance	High	High	High	High
Drought tolerance	High	High	Moderate	Moderate
Salt tolerance	Moderate	High	Moderate	Moderate/ low
Nitrogen requirements	High	High	Moderate/high	High
Water requirements	Low/moderate	Low/moderate	Low/moderate	Low
Establishment	Sprigs (hybrid varieties), seed/turf	Seed (some cultivars), sprigs/turf	Seed (some cultivars), sprigs/turf	Seed, sprigs/turf

* Poor recovery after wearing.

Table 2: Comparison of the traits of the most common warm-season turf grasses used in natural football turf

	Cool-season grass species		
Attribute	Perennial ryegrass (*Lolium perenne*)	Smooth-stalked meadow grass (*Poa pratensis*)	Tall fescue (*Festuca arundinacea*)
Growth habit	Bunch	Bunch/rhizomes	Bunch/short rhizomes
Wear tolerance	Moderate/high	Moderate/high	Moderate
Shade tolerance	Moderate/low	Low	Moderate
Cold tolerance	Moderate/high	High	Moderate
Heat tolerance	Moderate/low	Moderate/high	High
Drought tolerance	Low	Low/moderate	Moderate
Salt tolerance	Low	Moderate/low	Moderate/high
Nitrogen requirement	Moderate/high	Moderate/high	Moderate/high
Water requirements	High	Moderate/high	Low/moderate
Establishment	Seed/turf	Seed/turf	Seed/turf

Table 3: Comparison of the traits of the most common cool-season turf grasses used in natural football turf

Optimum				**Very undesirable**

Table 4: Colour key for tables 2 and 3

SWARD ESTABLISHMENT

VI.

A cool-season grass sward can be established by seeding or turfing, also known as sodding, whilst a warm-season sward can be established by seeding, sprigging or turfing. The decision to seed/sprig or turf is largely dictated by the following factors:

- Budget – seeding or sprigging is generally cheaper than turfing.
- Seed availability – some varieties of warm-season grasses fail to produce viable seed and can only be established by sprigging or turfing.
- Establishment time – turfing can generally provide a playing surface in a shorter time period.
- Availability of suitable turf – the quality of available turf can vary substantially and should be considered within the decision-making process.
- The availability of specialist skills, resources and knowledge should be considered, in particular when installing turf.

Seeding/sprigging avoids potential compatibility problems between the soil and root zone of an imported turf and the pitch soil and root zone. Compatibility issues can be overcome to some extent through turf washing, a specialist process in which the turf-growing medium is removed following harvest and prior to installation. This technique, however, raises the cost of pitch resurfacing.

Establishment times to achieve a durable surface for regular play are longer with seeding compared to turfing. Establishment times for turfing operations depend on the climate and local growing conditions at the time of installation, the density and maturity of the supplied turf, the thickness of the turf rolls and the quality of the laying process. Where a short return-to-play period is required, it may be necessary to use “instant-play” turf, which is generally thick-cut sod that includes a stabiliser or hybrid turf product.

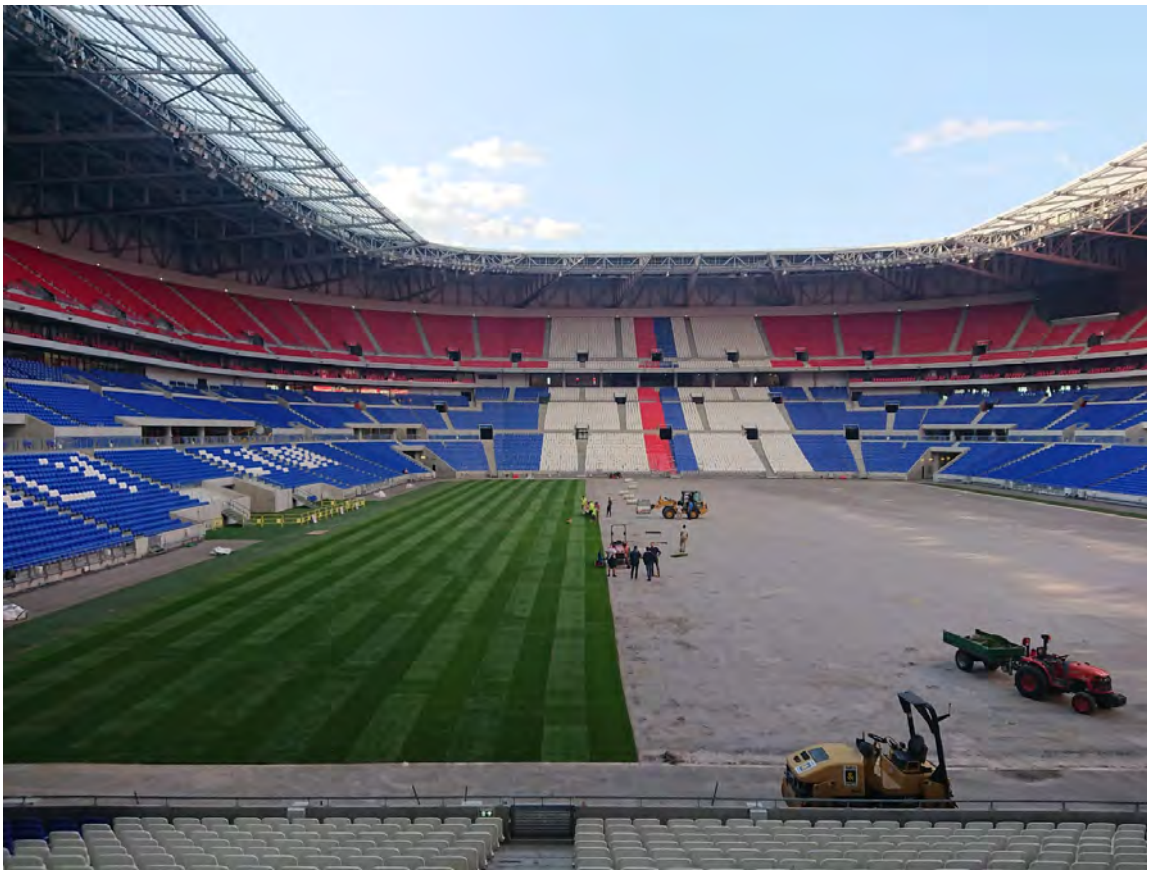


Figure 29: Pitch returfing in progress at the Parc OL, Lyon, France

Mature, thick-cut turf (typically 35-40mm in width) can be used to turf to a high standard on a localised basis to repair damage. In some instances, whole pitches can be laid and be ready for play within a matter of days when the operation involves experienced installers who use modern, specialist laying equipment.

Figure 30: Push machine for turf lining

Ground preparation for seeding, sprigging or turfing

A well-prepared seed or turf bed is important for successful sward establishment. The following general ground preparation principles should be applied:

- Conduct a soil/root-zone test of a representative root-zone sample at a recognised soil-testing laboratory to determine the nutritional status of the growing medium.
- Ensure that the soil test results are obtained sufficiently in advance of the planned installation to allow the necessary adjustments to be made at the point of construction.
- When the final pitch contours are set, where required, apply the recommended levels of lime, sulphur, macronutrients and micronutrients and introduce them into the upper 100-150mm of the root zone. In some instances, the necessary amendments will be mixed into the chosen root zone off-site at a dedicated mixing plant prior to placement.
- Trim and level the surface to design grades, but avoid excessive consolidation of the growing medium, which could hinder establishment and root development. The finished surface should be uniformly smooth and meet the tolerances as specified in the design parameters.

- Apply a pre-plant granular fertiliser in accordance with the recommendations issued by the soil laboratory, taking into account the type of root zone and the climatic conditions in the region.

Seeding

Seeding represents the most favourable method for sward establishment in the case of a cool-season turf type. A seeded pitch:

- is generally held to be superior to a turfed pitch, both from an agronomic perspective and in terms of playing quality;
- results in a more homogeneous profile, which usually offers better infiltration performance and root growth than a turfed pitch;
- is significantly cheaper than a turfed pitch;
- avoids compatibility problems between the turf-growing medium and the underlying root-zone material;
- minimises the risk of importing weeds, pests and pathogens that may be present within the turf and/or soil layer; and
- avoids the importation of a thatch layer that will inevitably be present in the imported turf.

Seed should always be sourced from a recognised, specialised sports turf distributor or directly from the plant breeder to ensure that the appropriate product is obtained. When delivered, seed bags should be appropriately labelled and certified to guarantee cultivar selection, purity and viability.

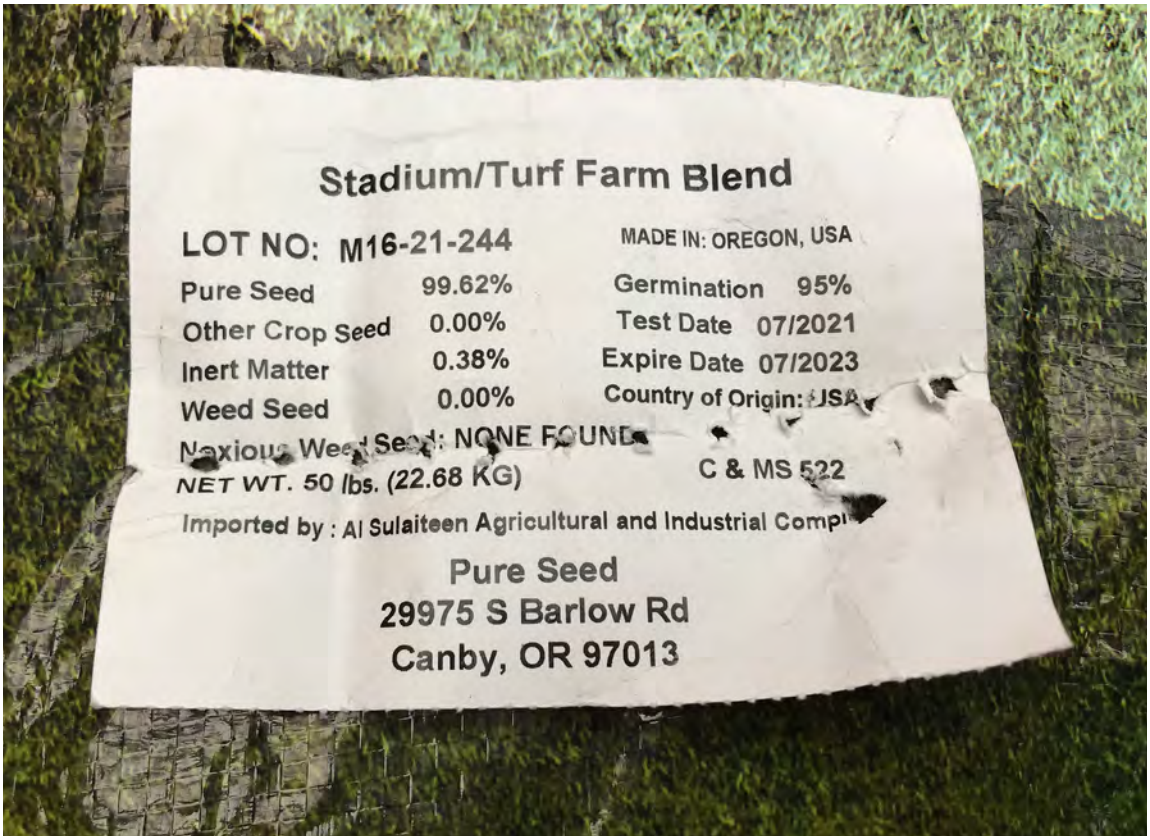


Figure 31: Seed bag label

Where a carpet-backed hybrid reinforcement is in place, it is vitally important for the preparation to be carried out in a manner that ensures that the artificial fibres remain at the surface and upright. The carpet manufacturer/installer should provide guidance regarding the length of fibre that should be left exposed following installation. Once the carpet is laid, fibres should be brushed until fully upright, whilst sand should be applied in several dressings and brushed into the pile after each dressing using a tractor-mounted static or rotating brush.

Seed should be sown into the prepared surface to an appropriate depth to ensure adequate seed and soil contact. The most widely used seeding machines are disc (or slot) seeders and dimple seeders. These machines open the surface to ensure that the seed is planted to the required depth. A cultipacker dimple seeder is usually preferred when seeding into a prepared seedbed as it ensures uniform seed distribution, seed placement at the correct depth and firming of the soil around the seed.

Figure 32: Tractor-mounted dimple overseeder

Figure 33: Pedestrian dimple overseeder

If hybrid reinforcement (stitched or carpet-backed) is present at the surface, it is important to note that a dimple seeder must be used. The artificial fibres at the surface inhibit the ability of a disc seeder to penetrate the surface, making it unable to sow the seed uniformly to the required depth.

Sowing should always involve the use of seeding machines. Seed should not ordinarily be broadcast on the surface, as this fails to ensure appropriate seed and soil contact. Furthermore, seed that is left sitting on the surface is prone to loss through bird grazing and wind displacement, and water uptake is inadequate, which affects germination and the uniformity of establishment.

When seeding with a species mixture, the following points should be considered:

- The germination time required for each species

  For example, under ideal temperature and moisture conditions, perennial ryegrass (*Lolium perenne*) will typically germinate in five to seven days, whilst smooth-stalked meadow grass (*Poa pratensis)* will require 14-21 days to achieve germination. In some circumstances, these species might be sown separately rather than as a blend, with the introduction of the quicker-germinating ryegrass delayed.

- The desired composition ratio of the sward species

As species of grass seed vary in size and weight, it is important that the seeding ratio be calculated on the basis of the number of seed, rather than by weight. Warm-season grasses are usually grown as monocultures, whereas cool-season grasses can be sown as either monocultures or mixtures. Achieving the correct seeding rate is more critical for bunch-type cool-season grasses as they do not have the ability to spread vegetatively once established.

Turf-grass species	Approximate number of seeds (per g)	Typical seeding rates (g/m^2) as monocultures
Perennial ryegrass (*Lolium perenne*)	500	35-45
Smooth-stalked meadow grass (*Poa pratensis*)	4,800	5-7
Tall fescue (*Festuca arundinacea*)	500	35-45
Bermuda grass (*Cynodon dactylon*), hulled	3,970	5-7
Zoysia grass (*Zoysia* spp.)	3,040	10-15

Table 5: Seed number per gramme and typical seeding rates of the most common cool- and warm-season species

6.2 Sprigging

Sprigging refers to the vegetative establishment of grasses and is most typically used for those that fail to produce viable seed, such as hybrid Bermuda grass. A sprig is a vegetative stem (rhizome or stolon) that has multiple nodes that initiate growth when properly planted. Sprigs are obtained with a sprig harvester or by using a vertical cutter that is operated across a donor site (nursery) consisting of a weed-free, uniformly mature turf-grass stand. Sprigs typically measure in the region of 75-125mm in length, and feature at least two (and usually three or more) nodes. Harvesting and planting operations should be coordinated so as to prevent the sprigs from being exposed to excessive heat or suffering from desiccation prior to covering.

Sprigging is generally performed in the spring/early summer, when soil temperatures reach a minimum of 18°C (65°F). Late sprigging can increase the risk of poor establishment or even winterkill, particularly if there is insufficient time for the sprigs to establish and develop good root systems prior to winter dormancy.

Sprigs should ideally be planted within 24 hours of harvest. Commercially supplied sprigs should preferably be harvested and delivered on the same day. If planting is delayed, sprigs should be stored away from direct sunlight and kept cool (efforts should be made to avoid them becoming overheated).

Sprigs can be planted in rows or furrows using a sprigging machine or broadcast uniformly over a prepared surface. Row planting typically sees the sprigs placed at least 50mm apart in furrows that are 25-50mm deep. The planting rate is increased by reducing the spacing between sprigs and/or the distance between furrows.

Where specialist sprigging machinery is unavailable or difficult to use, broadcast

sprigging may represent the preferred planting method. Broadcast sprigging involves scattering the vegetative plant parts uniformly over the prepared root zone/soil and rolling/cutting into the surface to a depth of 25-50mm or lightly top-dressing with 3-6mm of matching root-zone soil. Good contact between the sprig and root zone is essential to protect against desiccation and promote rapid growth and establishment.

A suggested sprigging rate is 200-250 sprigs per m^2, which approximately equates to a 1:6 harvested-to-sprigged ratio. Lower sprigging rates may cost less, but a longer period is required to achieve full pitch coverage. In contrast, extremely high sprigging rates may result in weaker plants in the first season of establishment.

Some considerations immediately prior to seeding/sprigging

The establishment time is determined by:

- how favourable soil temperatures and moisture conditions are for the desired species;
- the anticipated degree of weed competition;
- the anticipated incidence of disease, insects, etc.; and
- the germination/establishment requirements of the specific turf-grass species.

Cool-season grasses are best established in late spring or late summer, whilst early-summer plantings are preferred for warm-season grasses.

Alongside soil temperatures, soil moisture is the other critical factor that influences seed germination.

Good moisture in the upper 60mm of the soil profile should be maintained throughout the period between sowing and germination. Regular irrigation cycles may be required throughout the day to ensure that the surface does not dry out.

Irrigation distribution through the irrigation system should be uniform and checked prior to seeding. Wind can affect water distribution, and irrigation cycles may need to be supplemented with localised hand-watering. Water pressure around the irrigation heads can result in localised “washouts” and seed displacement, which may require targeted repair work.

Seed and sprig aftercare

Early aftercare maintenance, particularly irrigation, nutrition and mowing, is important for successful establishment.

Irrigation

During the first three to four weeks following installation, the surface must not be allowed to dry. Depending on local climatic conditions, irrigation may be required several times a day for the first seven to ten days after planting to prevent desiccation. Sprigs may remain brown for one to two weeks before “greening up”. As the roots develop and visible signs of growth become evident, the watering frequency should be reduced to allow some drying, which promotes strong root development.

The following factors are important considerations when irrigating:

- Wind and weather conditions – evapotranspiration rates are higher on hot, sunny and/or windy days, and newly seeded/sprigged areas may require more water.
- Water distribution – as mentioned above, irrigation distribution through the irrigation system should be uniform and checked prior to seeding. Wind can affect water distribution, and irrigation cycles may need to be supplemented with localised hand-watering. Excess water volume can disperse seed or sprigs, particularly during the early stages of establishment and in areas adjacent to irrigation heads.

Nutrition

Due to the diversity of climatic influences, soils and root zones, there is no one-size-fits-all fertiliser programme. However, the following principles should be observed:

- A starter fertiliser should normally be applied when seeding or sprigging, and subsequent applications should be made with the relevant frequency and intensity to promote steady growth.
- Younger grasses generally have a higher demand for nutrients than mature swards and nutrient requirements vary between grass species.
- During the establishment phase, normal practice involves the use of a balanced fertiliser that contains adequate amounts of nitrogen, phosphorus and potassium. Supplementary micronutrients might also be required during establishment and this is to be determined through a soil laboratory analysis. The precise requirements and quantities, based on the soil analysis, should be determined in consultation with a local agronomist who is familiar with the grow-in requirements of the proposed surface and grass species.
- Nitrogen-use efficiency can be improved through the use of slow-release nitrogen sources, which are particularly important to reduce the potential for leaching on sand-based root zones.

Nutrient	Benefit	Deficiency: shoot symptoms	Additional considerations
Nitrogen	Encourages rapid shoot growth and overcomes losses due to leaching	• Initial stunting of shoot growth, older leaves turn pale green/yellow, decreased tillering • Yellowing (chlorosis) then develops across entire leaf blade	• Excessive application of water-soluble products often leads to leaching on sandy soils • Nitrogen deficiency is most likely to occur on young swards, particularly when growing on coarse-textured, sandy soils featuring intense irrigation or high rainfall
Phosphorus	Promotes root development and maturation during establishment	• Leaves initially turn dark green, plants tend to be spindly, with reduced shoot growth • Leaf blades turn dull blue/green with purplish colouration along leaf margins	• Phosphorus is relatively immobile and not readily leached • Sandy soils tend to have lower phosphorus concentrations • Once established, phosphorus applications should be made based on a soil/root-zone analysis
Potassium	Boosts wear tolerance and hardiness to heat, cold and drought	• Leaves become soft and drooping, excessive tillering • Interveinal yellowing in older leaves • Leaf margins become scorched, leaf tips roll back	• Deficiencies occur under high rainfall or where leaching occurs, on sandy soils or following high levels of nitrogen application

Table 6: Breakdown of the importance of the three main nutrients contained in fertilisers following sprigging

Mowing

The setting of the mowing height for the initial cut is determined by the surface evenness and the standard of play that the pitch is to cater for. In addition, the surface should be firm and dry before mowing so as to avoid rutting and scalping. A light roller may be required prior to the first cut to level out the surface.

Efforts should be made to avoid mowing too low on the initial cuts. For example, if the desired final cutting height is 20-25mm, mowing should ideally commence when the grass sward is approximately 30-35mm long, with the aim of removing no more than a third of the leaf blade in one go. Surface levels can be perfected with top dressing as the cutting height is gradually reduced to the desired final height.

It is important that adequate resources be made available to sustain a regular mowing programme, as this will help to encourage lateral growth and the development of turf density, durability and strength.

6.3 Turfing

Turfing or sodding is the practice of installing pre-grown rolls or slabs of turf grass (turf or sod) onto a prepared root zone to create a playing surface. Some of the advantages and constraints associated with turfing are highlighted in Table 7 and are compared against seeding/sprigging as a method of establishment. Turfing is often preferred where seeding/sprigging to establish a playing surface is not viable or a quick turnaround time (before reuse) is required.

	Seeding/sprigging	Turfing/sodding
Cost	The cheapest and most cost-effective method of establishment.	The turf procurement and installation process is more expensive than with seeding/sprigging. The greatest proportion of the cost is often attributed to the harvest, delivery and installation of the turf.
Cultivar selection	Generally, a greater choice of cultivars is available for selection and use. Grass cultivars should be selected based on their performance characteristics in a particular climate.	Will be determined by the turf producer unless the turf is custom-grown.
Growing media	Seeds/sprigs can be sown directly into the prepared root zone with no layering problems.	The soil/root zone on which the turf is grown (which is often silt or clay) together with the imported surface may be incompatible with the pitch profile and could restrict drainage and/or rooting and require additional maintenance. The nursery growing medium can be washed from the turf prior to installation but this will add to the cost and increase the establishment time. The risks of incompatible turf may be reduced by growing bespoke turf on a specified growing medium.
Time to produce a playing surface	A longer period is needed to establish a durable playing surface.	The interval between installation and play can be shortened considerably.
Surface levels	Seed or sprigs can be sown directly into a well-prepared surface.	Immediate surface levels will be determined by the uniformity and quality of the harvested turf and the techniques employed at the time of installation. Top dressing is generally needed following turf installation.
Root development	When managed in accordance with best practice, seed/sprigs will root seamlessly into the profile, and deeper and denser root systems will generally develop than with imported turf.	On occasion, root development can be impeded where different materials are used.

Table 7: Key differences between turfing and seeding/sprigging

Provided that there is adequate time for grow-in and before reuse, seeding or sprigging is largely the preferred method for establishing a new natural turf playing surface. However, when it is not possible to grow in a surface from seed/sprigs quickly enough, turfing may be the only option. Moreover, turfing or turf plugging is the only viable method when localised repairs are required, and when the surface needs to be made playable within a very short space of time.

Once the decision to turf has been made, the following should be taken into account, among other key factors:

- The ideal time to install turf will depend upon the type of turf grass used, the local climate and the weather conditions likely to be experienced during and immediately after turfing. In general, it is best to carry out turfing during periods of optimum growth to enable the quickest possible rooting and anchorage of the turf.
- The project time frame and budget will play a key role in the selection and sourcing of suitable turf.
- It is important to inspect the nursery turf to ascertain its suitability; it should be ensured that the turf meets the required performance criteria in regard to sward species, blend/cultivar requirements, and turf uniformity, density and strength.
- The compatibility of the soil type used at the nursery and the pitch root zone/soil should also be checked.
- The cost of delivery and installation of the turf should be borne in mind. Consideration should also be given to the possibility of independently monitoring the harvesting/turfing works.
- If the turf is being sourced from abroad, there may be import regulations or protocols that will have to be met during the importation process. These can affect the project in several ways, such as by resulting in additional paperwork, increased costs and potential delivery delays .
- The interval between installation and play should be considered to allow for the development of a playing surface that meets the standard of play that the pitch is intended to cater for.
- Any constraints at the turf farm that might restrict the ability to harvest the selected turf should be identified. Where practical, an alternative source of material should be sought so that a backup is available if required.
- It should be ensured that the turf producer has the capacity to supply enough of the required turf, allowing for wastage and contingencies.
- Consideration should be given to the weather conditions at the proposed time of installation, since they could affect turf quality at the turf farm or hinder the harvest, delivery and installation process.
- It should be ensured that there is a competent contractor/installer available, with experience in laying turf, preferably on football pitches.
- It is imperative for the installer to have thought through the practicalities of the installation process, particularly if there are restrictions, such as space constraints, at the site.
- All installations should take account of any local environmental or legislative constraints.

- A logistics plan should be developed that is aligned with the turf harvest, delivery and installation schedule, to minimise the time between harvesting and laying.
- It is essential for adequate resources and equipment to be available for maintenance during installation and aftercare during the turf establishment phase.

Turf format

Turf comes in a variety of formats for installation. The decision on which format is employed will generally be made according to the planned use of the pitch, time constraints, budget and availability. Formats include the following:

1. Standard turf – turf established at a turf farm and grown on the local soil type. This is often the cheapest type of turf and is commonly used for landscaping or community pitches. It is not generally recommended for use at stadiums or for high-quality pitches.
2. Specialised turf – a type of turf grass that is specifically geared towards sports pitches and is established on an imported proprietary sand-based root-zone material. The seed or sprigs from which the turf has been established are certified and an analysis of the root-zone material is performed before installation. This information can then be used to examine the suitability of the turf for the playing surface on which it is to be installed.
3. Custom-produced turf – this turf follows the same production principles detailed above for specialised turf. However, the type of turf grass and the root-zone material are specified prior to establishment in order to ensure that they are the same as (or as close as possible to) the ones at the venue at which the turf is to be installed.
4. Reinforced turf – specialised or custom-produced turf prepared using a proprietary sand-based root-zone material typically reinforced with fibres or mesh elements, or grown within a carpet of artificial fibres, and combined with a proprietary backing material. Such turf is often "instant-play".
5. Washed turf – harvested turf is washed to remove the soil material in which the turf has been grown.

Turf thickness and roll (or slab) size

Most commercially available turf is harvested with a thickness of between 15 and 40mm, although some producers supply turf tiles (slabs) that are up to 90mm thick. Thicker-cut turf is required if the surface is expected to be playable quickly, since the turf "slab" affords the surface a degree of stability in the absence of rooting.

Turf rolls can vary in width and length, with the width determined by the harvesting machinery used at the turf farm. The most commonly available types of turf can be divided into the following two categories:

1. Standard rolls – these are more commonly used in the landscaping industry. Because they are thin (15-25mm), narrow (30-50cm) and short (up to 3m), they are labour-intensive to lay, leave more joints and are not stable for play immediately after laying. This ultimately means that almost as much time is needed to establish the surface as with seeding.
2. Big rolls – these are generally the preferred format for turfing stadium pitches when there is a limited amount of time between installation and play, as they provide a more immediately stable surface and their installation is more efficient.

Such rolls are usually cut 30-50mm thick, with a width of between 0.6 and 2.4m and a length of 5-15m. Due to the weight of the biggest rolls, purpose-built machinery must be used to lay the turf. If the rolls are too long and/or heavy, they can be easily damaged during the harvesting, transportation or installation process. It is worth noting that some turf suppliers (and harvesters) prefer to produce turf in tiles or slabs.

The main challenges associated with the supply of big-roll turf include transportation, particularly of cool-season grasses, and the risk of overheating and the turf being damaged. There are several factors that affect the risk of damage, including the ambient ground and weather conditions at harvest, the length of the roll and the interval between harvesting and installation. In certain circumstances, there may be a requirement to transport the harvested turf in refrigerated trucks to reduce the potential for damage. Of the cool-season grasses most commonly used in natural football turf, perennial ryegrass (*Lolium perenne*) is the most susceptible to such damage. Damage is normally visible in the first 12-24 hours after laying, in the form of a blackening of the turf that commences in the centre of the roll. The turf may recover in certain circumstances, but turf decline and death will occur in severe cases.

Figure 34: Turf roll

Turf installation

Given modern harvesting and installation equipment, a specialist turf producer and well-resourced installer can often lay a hectare of turf in 24 to 48 hours. However, a full-size football pitch is more typically turfed in four to five days.

Turf installation should be completed to the highest possible standard and it is recommended that the installation be monitored closely, since correction is more difficult once the turf has been installed. The main quality requirements are listed below:

- Turf should be laid on a well-prepared, firm, smooth and rut-free surface that is reflective of the desired finished playing surface.
- Turf rolls should be butted tightly together, with no gaps at the ends or edges of individual rolls.
- Turf should be laid in a staggered, brick-like pattern.
- Turf should be of a uniform thickness and match the turf identified at the producer's farm.
- Turf-grass plants should not be inverted or trapped between joints.
- Turf-grass rolls should be of uniform vigour, density and colour, with minimal variation in these characteristics across the pitch.
- Small pieces of turf should not be used to repair damaged turf or fill gaps, as these can dry out rapidly. If the pitch is to be brought into play quickly, such patches may not provide sufficient surface stability for immediate use.
- The edges of successive rolls should be flush to ensure that the surface is safe for players and minimise the need for a heavy top dressing.
- Care must be taken to ensure that any turf installed around pitch infrastructure, e.g. irrigation heads, is even. Changes in levels can adversely affect the safety of the surface for players.
- It is extremely rare for an entire turfed pitch to be perfect upon completion. The surface should be carefully checked so that appropriate rectification works can be implemented before the installer leaves the site.

Early aftercare

A specific aftercare programme should be developed for the pitch on the basis of the turf species, format, climate, day-to-day weather conditions and use requirements. If there is any concern regarding the maintenance programme, it is best to employ a professional to review the proposed programme or develop a programme tailored to your requirements. It is also common practice to engage the installer for a period of maintenance to ensure that the surface is correctly managed.

It should be appreciated that turf begins to decline almost as soon as it is harvested and that this is influenced by the harvesting, transport and installation processes. This decline might also continue if the conditions in the receiving environment are poorer than at the turf farm. Subsequent maintenance is therefore important in the recovery of the turf from the stresses associated with harvesting, the completion of the installation and everything in between.

Details of the initial maintenance to be implemented in the first seven to ten days following installation are provided below, although it is worth noting that not all of the operations will necessarily be required:

- Hand-watering (in addition to overall irrigation), as turf is vulnerable to drying without a well-developed root system
- Rolling with a suitable flat roller to improve evenness and help bind the turf joints*
- Brushing to remove soil or plant debris and lift the flattened turf grasses
- Mowing to trim the surface and remove any straggly growth**
- Liquid fertiliser application for rapid plant uptake to aid growth/recovery in the absence of a well-developed root system
- Fungicide application, where the environmental conditions are conducive to disease development
- Granular fertiliser application to aid growth and turf establishment

* The width and weight of the roller should be carefully considered in conjunction with the moisture content of the turf to avoid excessive consolidation or damaging the turf.

** The cutting height will be determined by surface levels, the height at which the sward was maintained at the farm and how much growth has occurred since the last cut.

ROUTINE MAINTENANCE OPERATIONS

VII.

7.1 Planning

There are several essential operations that need to be carried out on a pitch to maintain the quality of the grass and ensure that the underlying soil or root-zone material will support good root development and provide a well-drained and stable playing surface.

The maintenance requirements are site-specific and will be determined by a combination of factors, including the following:

- The local climate and prevailing weather conditions
- The species of turf grass
- The pitch construction, drainage and irrigation
- The expected level and frequency of use (i.e. the maximum usage capacity)
- The machinery and human resources available for pitch maintenance
- The budget

7.2 Mowing

Purpose

For healthy grass growth and an attractive playing surface, all pitches require regular and frequent mowing. Mowing serves to:

1. ensure the grass is at a suitable height for play;
2. promote density and vigour to create a thick and compact sward;
3. create mowing lines (bays), which are important for the aesthetic appearance, especially at elite professional level; and
4. lift surface debris after use, as a “clean-up” exercise.

Equipment

There are two main forms of mowing equipment used.

- Cylinder/reel mowing involves a sharpened, spinning reel on a fixed axle, which creates a shearing action against a fixed bottom blade and provides a high-quality finish.
- In rotary mowing, a rotating, sharpened horizontal blade is used to cut against the grass with a scything action when undertaking a clean-up operation or to achieve a reduced-quality finish.

Another method is flail mowing, which features angled blades that rotate vertically. However, it is more commonly used for rough cutting and would not be appropriate for a match finish.

Mowers should be regarded as precision tools, which need to be kept clean and sharp to cut grass well. Cylinder mowers should be checked for the quality and height of cut with every use, to make sure that they leave a good-quality finish. A badly set mower will not only provide an inferior playing surface, but the ragged edge left on the grass leaf will be more susceptible to disease. Both cylinder and rotary mowers are available as pedestrian-operated units, self-propelled units or tractor-mounted units.

The larger self-propelled and tractor-mounted units have multiple cutting cylinders to cover an extensive area, and are more suited to major sports facilities with multiple pitches. The quality of cut is invariably sacrificed in exchange for the ability to mow larger areas with fewer personnel.

Pedestrian cylinder mowers

Figure 35: Pedestrian cylinder mower

Pedestrian cylinder mowers provide the best-quality cut and match finish for elite professional football. They create an attractive appearance, including a uniform height of cut. The machines should be fitted with six or eight bladed cylinders and have traditionally featured petrol engines, although battery-powered units have recently entered the market.

Pedestrian rotary mowers

Generally fitted with a rear roller, pedestrian rotary mowers are excellent machines for post-match clean-up. They act like a mini-vacuum cleaner, quickly and efficiently picking up debris from the surface. The rear roller helps to maintain a high-quality aesthetic appearance at elite level. Wheeled rotary mowers (equipped with wheels at each corner) are not as effective in leaving an attractive surface after mowing.

Figure 36: Pedestrian rotary mowers

String lines

Figure 37: Examples of string lines in use and final product (a pitch with an attractive pattern)

A high-quality aesthetic appearance is achieved when strict mowing protocols are adopted to ensure the mowers pass along the same line in the same direction with every cut. String lines are used to determine the position and width of each mowing band across the length and width of the pitch. Every time the pitch is cut, the string lines should be put down to ensure that the pattern is retained. The depth of colour in the pattern intensifies with each cut.

Figure 38: Ride-on cylinder mowers

Recommendations

At elite professional level, it is highly recommended that pitches be maintained with complementary pedestrian cylinder mowers for matchday preparations, and that pedestrian rotary mowers with rear rollers be available for post-match tidying up.

Self-propelled units are useful where a good-quality cut is still required and there are limited human resources, although daily mowing with pedestrian machines is still not practical. Pre-start checks are recommended to make sure that the machine is cutting well and the best-quality finish can be achieved on the day.

For some local authorities, tractor-mounted, trailed gang units are still used to cut grass. These are not designed to create a well-manicured playing surface, but they do keep the grass under control. Such solutions are not recommended for professional sport, or where league football is played.

For professional football, all grass clippings should be removed during every mowing operation to leave a clean surface and reduce the potential for organic matter build-up at the turf base, which would be detrimental to the quality of the playing surface.

- The cutting frequency is determined by the rate of growth. As a rule of thumb, no more than a third of the leaf of the grass plant should be removed with any single cut. The height of cut can range between 20 and 30mm, depending on turf condition, the time of year and the tournament/league requirements/preferences.
- The grass length will be dictated by the standard of play, the time of year and the expectations of the manager/coach, as well as the type of turf used (warm- or cool-season grass species, as elaborated on below). Moreover, hybrid turf should not be compromised by mowing too short.
- The height of cut on the mower is set “on the bench” using a setting bar. The height is measured between the front and back rollers of the machine using a straight edge and the gap to the top of the bottom blade. The “actual height of cut” is measured using a prism gauge (see picture), which can be slightly different to the bench setting and will be governed by the softness of the playing surface/ weight of the mower. The actual height of cut should always be the reference point.

Figure 39: Prism gauge

Specific guidance on warm-season grasses

Warm-season grasses have a different growth habit and vigour compared to cool-season species. As a rule, warm-season grasses, with their stolons and rhizomes, require more frequent cutting at a lower height to maintain similar playing qualities to those of cool-season turf. The height of cut can range between 15 and 25mm, and will be determined by the pitch condition, the mowing equipment available and the demands of the tournament/league.

7.3 Scarification, verticutting and brushing

Scarification and verticutting treatments are designed to promote upright growth of the grass plant and remove/control organic matter that would otherwise become deposited as thatch (dead and decaying vegetative material). Thatch creates a soft and spongy surface that is not ideal for the grass plant or for play.

These mechanical raking treatments are also applied to control turf density, which is particularly important with a dense sward, since player and ball movement could be compromised by an overly thick grass cover.

Scarification

While all three operations can be seen as a mechanical raking of the surface, scarification is the general term given to the deepest and most aggressive form of raking, where the blades are often set to cut into the surface of the turf. This operation is essential to remove accumulated organic matter at the turf base. Scarification should only be carried out when the grass is actively growing, to allow for rapid recovery.

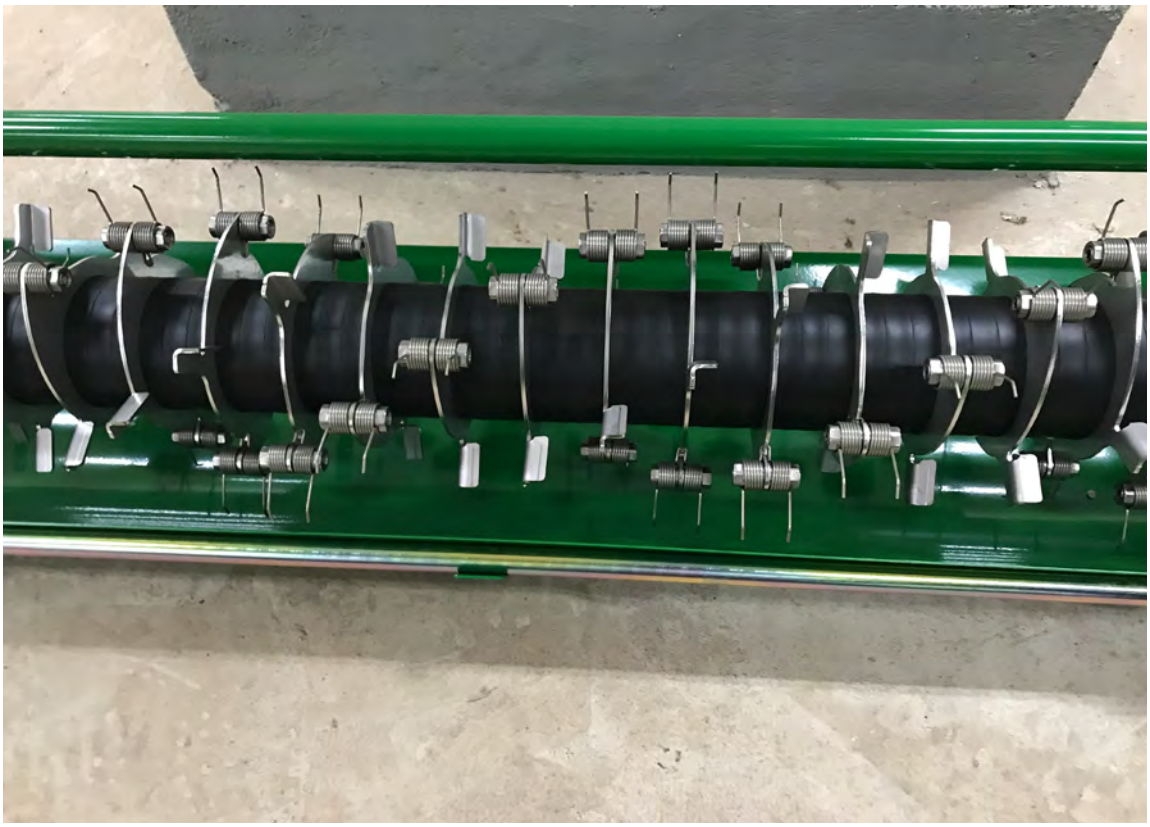


Figure 40: Rake

Verticutting

Verticutting is generally confined to the surface vegetation and entails cutting through flat or procumbent growth to encourage upright growth and prevent organic matter/ thatch build-up. The blades are usually closer-spaced, but not set as deep as the scarifier.

Both verticutters and scarifiers have contra-rotating blades for effective organic matter removal, throwing the debris forward to be collected in a grass box or later hoovered from the surface.

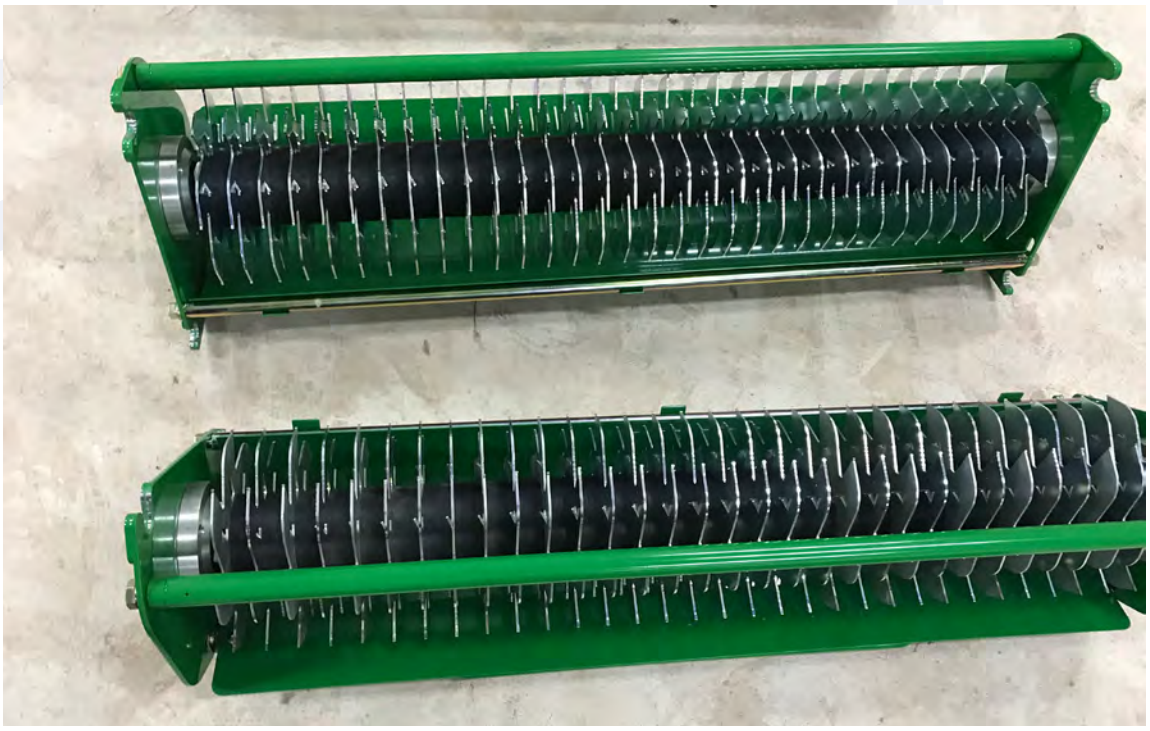


Figure 41: Verticutter

Brushing

Brushing can be regarded as the lightest form of mechanical surface raking and is generally used as a means of removing surface debris. Brushing is also useful for removing surface dew before mowing and encouraging the grass to stand up in order to achieve a clean cut. Brushes can also serve as an implement to work in top dressing and thus avoid smothering the turf.

Brushes can be tractor-mounted or pulled by hand.

Figure 42: Brushes

Specific guidance on cool-season grasses

During the playing season, the more aggressive scarification and verticutting treatments should only be carried out when productive growth is occurring, to enable the surface to make a full recovery within a few days. If the lines are still visible after one week, this may signal that the operation was a little too severe for the conditions; if the lines disappear on the same day, the treatment may not have been vigorous enough to achieve the best effect.

Figure 43: Koro Field Topmaker in action

End-of-season renovation will call for the removal of subsurface organic matter through heavy scarification, fraise mowing or the complete replacement of the surface using a specific machine such as the Koro Field Topmaker, which will strip off at least the upper 20mm, with the debris being carried on a conveyor belt to a waiting trailer for removal from the pitch.

Specific guidance on warm-season grasses

Warm-season grasses generally have a creeping growth habit, which, if not controlled, will result in a soft, puffy surface, which is not suited to football. Regular, light and frequent verticutting can help control this lateral growth and encourage a more upright growth habit. Good growth is required to facilitate rapid surface recovery, but the speed of recovery can also be species-dependent, with Bermuda grass (*Cynodon dactylon*) recovering much more quickly than zoysia.

Scarification is an essential operation during the transition phase between warm- and cool-season grasses, removing dead and decaying organic matter from the turf base and creating a seedbed to enable the ryegrass to make contact with the root zone. This will ensure rapid germination and establishment.

7.4 Aeration

Even a single aeration operation can provide multiple benefits. The primary function of aeration is to alleviate compaction in the root zone, fostering gaseous exchange and allowing water to penetrate the profile. Gaseous exchange not only assists root development, but will enhance beneficial microbial activity in the root zone, which can encourage thatch degradation. Aeration can also be used to integrate materials into the root zone and, through hollow tining, remove unwanted material and replace the cores with improved root zone or sand. Similarly, aeration can serve to reduce surface firmness, especially leading up to a match or tournament, when intensive mechanical operations may have hardened the pitch.

A Clegg Impact Soil Tester should ideally be used in conjunction with a moisture meter to gauge the soil conditions and surface hardness.

In its simplest form, aeration is the creation of holes within the root zone. Aeration devices can promote some additional root-zone movement, but without disrupting the surface.

There are several types of soil aeration equipment available to turf managers. These include the following:

- Punch-action aerators, usually with solid or hollow tines, which insert the tines vertically with minimum disruption. Punch-action machines can be adjusted to create closely or wide-spaced aeration patterns of variable depth (ranging from as shallow as 50mm to a maximum of 250mm with larger machines). Some aerators can also “heave“ the soil to varying degrees, which can be advantageous.
- Solid and hollow tine spikes, which come in a variety of diameters and lengths, depending on the intended outcome. Large hollow tines are effective in removing soil and thatch as part of a soil exchange programme. Smaller solid tines may be used for compaction relief and lowering compaction while maintaining a playing surface during a tournament.
- Bladed devices, which cause a degree of shattering within the root zone. These include a range of commercial machines, some with oscillating blades and others with fixed blades.

- Specialised compressed-air machines, which can achieve more deep-seated compaction relief, though it is necessary to be mindful of undersoil heating pipes and irrigation prior to undertaking any deep aeration.

Figure 44: Tractor-mounted aerator

Figure 45: Pedestrian aerator

Figure 46: Air injection aerator

Figure 47: Hollow tining

Figure 48: Tractor-mounted solid-tine aerator

With any soil conditioning, the ground should be soft enough to allow the tines entry (before aeration), but dry enough to achieve fissuring of the soil profile.

Specific guidance on aeration of hybrid turf

Care must be taken to avoid excessive surface disruption when aerating a hybrid pitch. Hybrid systems include both carpet-type products and stitched hybrids. The manufacturer's recommendations, which may be available as a guide, should always be taken into account. With stitched hybrid systems, it is important to avoid unnecessary heave with the machinery, which can disrupt the fibres and potentially compromise the system.

7.5 Plant protection – weed, pest and disease control

Weeds, diseases and pests impact on football surfaces in two ways. Firstly, they can affect turf quality and, in turn, pitch playing performance. Pests and diseases can damage or destroy the turf cover, while weeds can cause a bumpy surface. Secondly, they can be detrimental to the aesthetic appearance of the turf. Aesthetics is a critical part of the modern game, especially with televised events.

With any weed, pest or disease, the first step is to make a positive identification of the problem. Without a positive identification, an effective treatment programme cannot be formulated. Poor turf health could be the result of numerous things apart from pest or disease outbreak, such as a nutritional disorder, soil water repellence or wear from players and machinery. A professional diagnosis should, however, be able to pinpoint the cause(s) of the problem.

Integrated pest management (IPM) is an approach that should always be implemented when tackling a turf weed, pest or disease problem. Good cultural management practices to favour the grass species involved are an ideal starting point in order to provide a healthy grass plant with good density and vigour and give the turf a competitive edge.

IPM initially focuses on the non-use of chemicals to deal with problematic weeds, pests or diseases and, more importantly, creating a growing environment to favour the turf before potential problems arise. Overall, an IPM approach includes the following aspects:

- The use of appropriate grass types for the local conditions. There are cultivars that can now be selected for specific disease and pest tolerance, should a particular location require a specific trait.
- Optimum nutrition to maintain a balance between growth and the playing demands. Sufficient fertiliser should be applied to offset the wear and tear of play. Soil analysis will be required to check the soil nutrient status.
- Good mowing practices to promote density and vigour. A clean cut will reduce the surface area of the cut leaf that is exposed to fungal invasion.
- Avoidance of over- or underwatering. Leaf wetness can promote disease, so the timing of watering is important.
- Pitchside fans can help dry the surface of the turf to reduce disease activity in a stadium environment.
- Hand-weeding should not be discounted and can be an effective way of removing broadleaved weeds from the turf.

There will be situations where IPM dictates that a weed, pest or disease is either too aggressive or will not respond to cultural practices alone, in which case chemical intervention is required. Any pesticide used on turf must be approved for this purpose by government legislation. All pesticides **must be applied strictly in accordance with the manufacturer's recommendations (including the stipulated application rates), taking all necessary safety precautions.**

The application rate is extremely important for the efficacy of the product and must be adhered to. Adding more chemical to the tank mix will not improve the effectiveness – indeed, it is likely to be counterproductive and could even result in turf damage.

The sprayer used to apply the treatment must be clean to avoid any residual product being inadvertently applied to the turf. Contamination happens often, but is easily avoided with good practice. The machine must be calibrated to apply the chemical according to the manufacturer's recommendations (including the stipulated application rate), and the operator must take all necessary safety precautions.

Where chemicals are used regularly, it is advisable to alternate between active ingredients to reduce the potential for resistance build-up. Resistance build-up is normally identified on the product label, and products may have a limit of two or three applications per year per site to avoid resistance.

Figure 49: Hand-weeding

Figure 50: Pedestrian sprayers

Figure 51: Mounted sprayers

Irrigation

Irrigation of the grass is essential for both agronomic and playability reasons. Water is vital for plant growth and the uptake of nutrients. It also provides some internal support for the grass plant; the plant is turgid when full of water, but will show signs of wilting when water is limited. Watering also boosts the stability of sand root zones and enables chemicals and fertiliser to be safely applied without the risk of leaf burn. Water is also applied to the surface prior to play to speed up the movement of the ball across the surface. In this situation, leaf wetness is the key, rather than the whole profile needing to be wet.

It is good policy to test the quality of the water being applied in order to establish whether a build-up of salts is likely to be an issue and check that the pH is favourable for turf. It should not be assumed that all water is good water – even drinking water (which is chemically treated) can sometimes create turf-related issues.

To ensure that the correct amount of water is applied to the pitch, it is useful to have a moisture meter available to test the root zone's moisture content. It is good practice to water on demand rather than by the calendar, as ground and weather conditions will determine soil moisture and plant needs. Both over- and underwatering should be avoided to prevent agronomic and playability issues, such as weeds or an overly soft and slippery surface.

As a rule of thumb, irrigation applied in the morning will penetrate the soil profile, allowing the leaf to dry off quickly and reducing the risk of disease. Deep watering cycles, which promote deep rooting, are encouraged. There may be occasions during the heat of the day when a "syringe cycle" is required to cool the surface but avoid excessive leaf wetness. The water applied will evaporate quickly, thereby cooling the turf.

Equipment

A wide range of equipment is available for the application of water, with the main priorities being the uniformity and speed of application. The following are the most common types of irrigation systems available, from least to most effective:

- Handheld hose pipes – these are useful for small areas of the pitch that require specific attention.
- Portable rotary and oscillating sprinklers – these must be moved manually on a regular basis to water the whole pitch. A full day is often required to water a pitch effectively.
- Travelling sprinklers – these progressively move across the surface by themselves, applying water as they go.
- Water cannons on the edges of the pitch – these can apply a lot of water in a short amount of time, but can also be badly affected by wind.
- Fully automatic/semi-automatic pop-up irrigation – this is the ultimate water delivery system, offering the greatest control, flexibility and uniformity of water application.

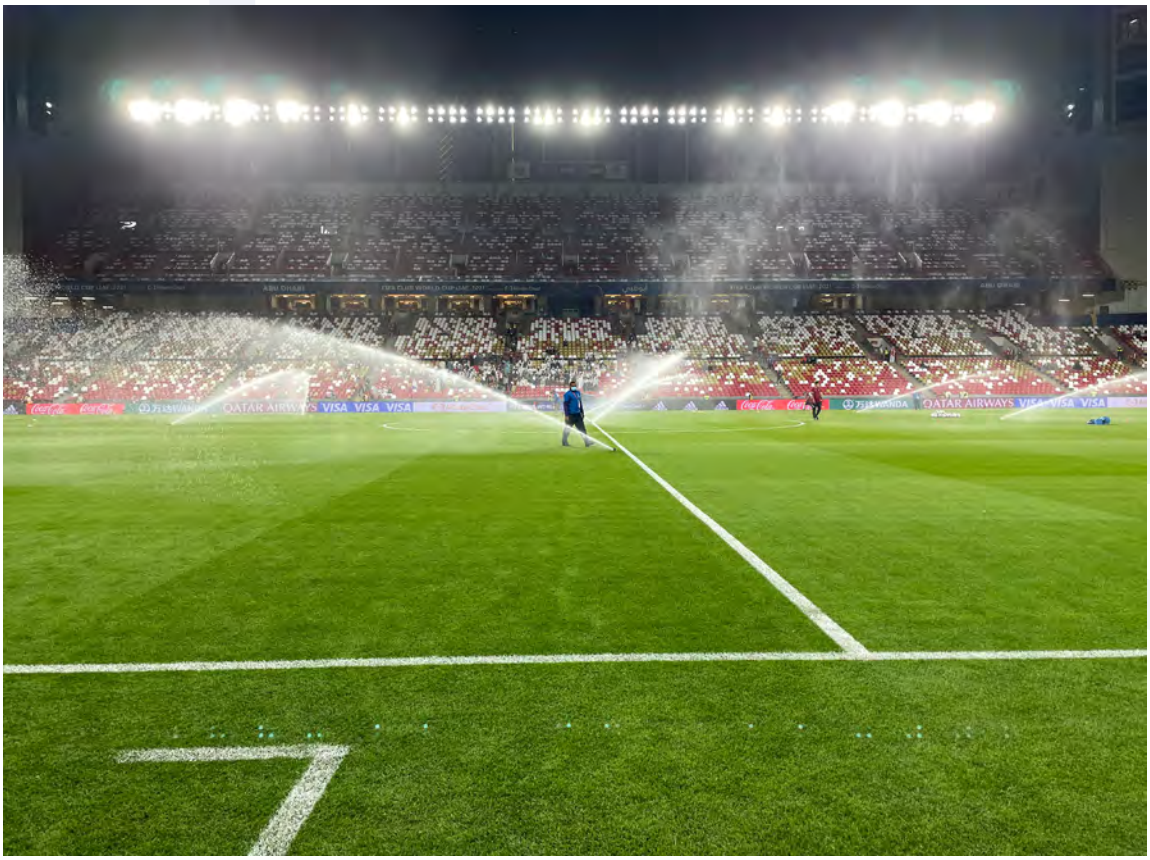


Figure 52: Hosepipe, portable sprinklers and fully automatic irrigation system

7.6 Preparing the pitch and equipment for play

7.6.1 Line marking

Football pitches must always be marked in accordance with the Laws of the Game. All lines must be of the same width, which must be the same as the width of the goalposts and the crossbar (minimum of 100mm and maximum of 120mm per the FIFA Quality Programme for Football Goals). It is not permissible to mark the field of play with broken lines or furrows. Only lines indicated in Law 1 of the Laws of the Game are to be marked on the field of play. **No additional markings may be made for other sports** (such as American football, rugby, hockey, etc.). The following measurements from the Laws of the Game must be adhered to:

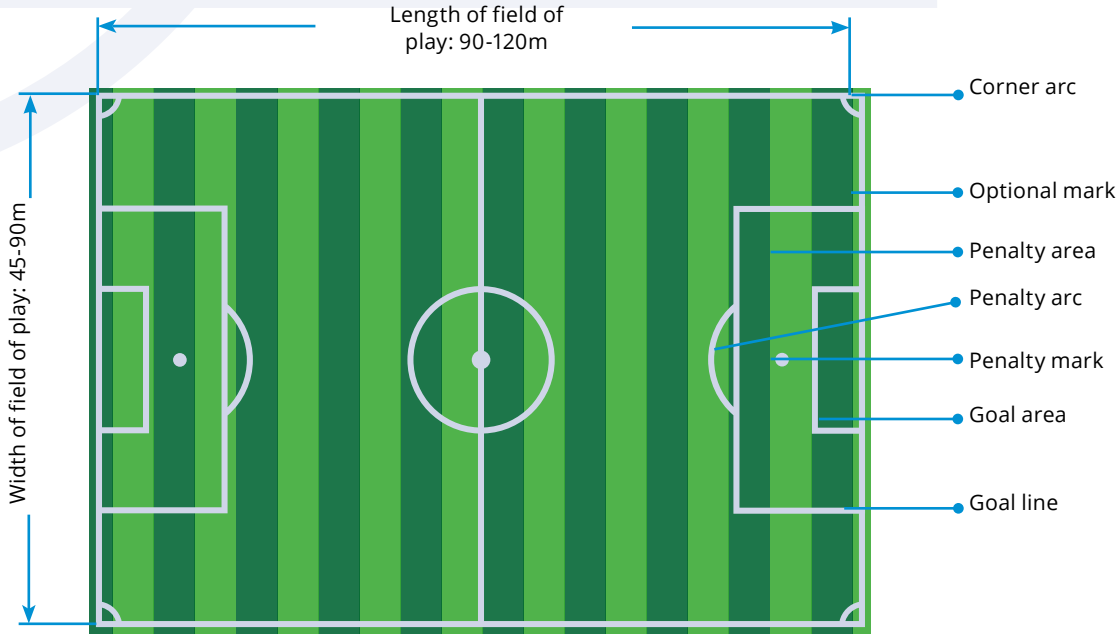


Figure 53: Laws of the Game pitch markings

The marking of lines, which are normally white, should always be the final operation during surface preparations, to avoid the transfer of paint across the surface, which is known as ghosting. A string line will help to guide the marking process, which will normally be carried out using either a transfer wheel marker or a spray jet marker. It is even possible to use a paint roller to mark the lines. Although this is very time-consuming, it can produce excellent lines where a specialist machine is not available.

Figure 54: Transfer wheel markers

All paints used must be turf-specific (and thus non-toxic to the grass) and quick-drying. White emulsion paint should not be used.

A 3, 4, 5 triangle (based on Pythagoras' theorem) should be employed to ensure that the corners are square.

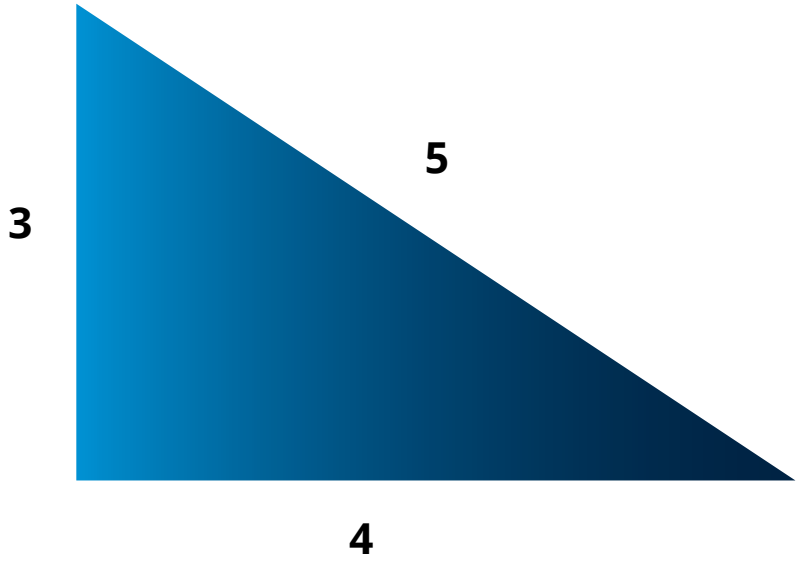
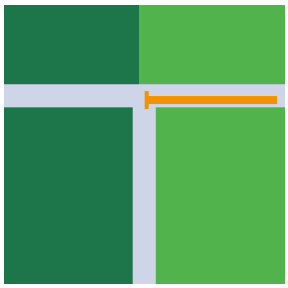


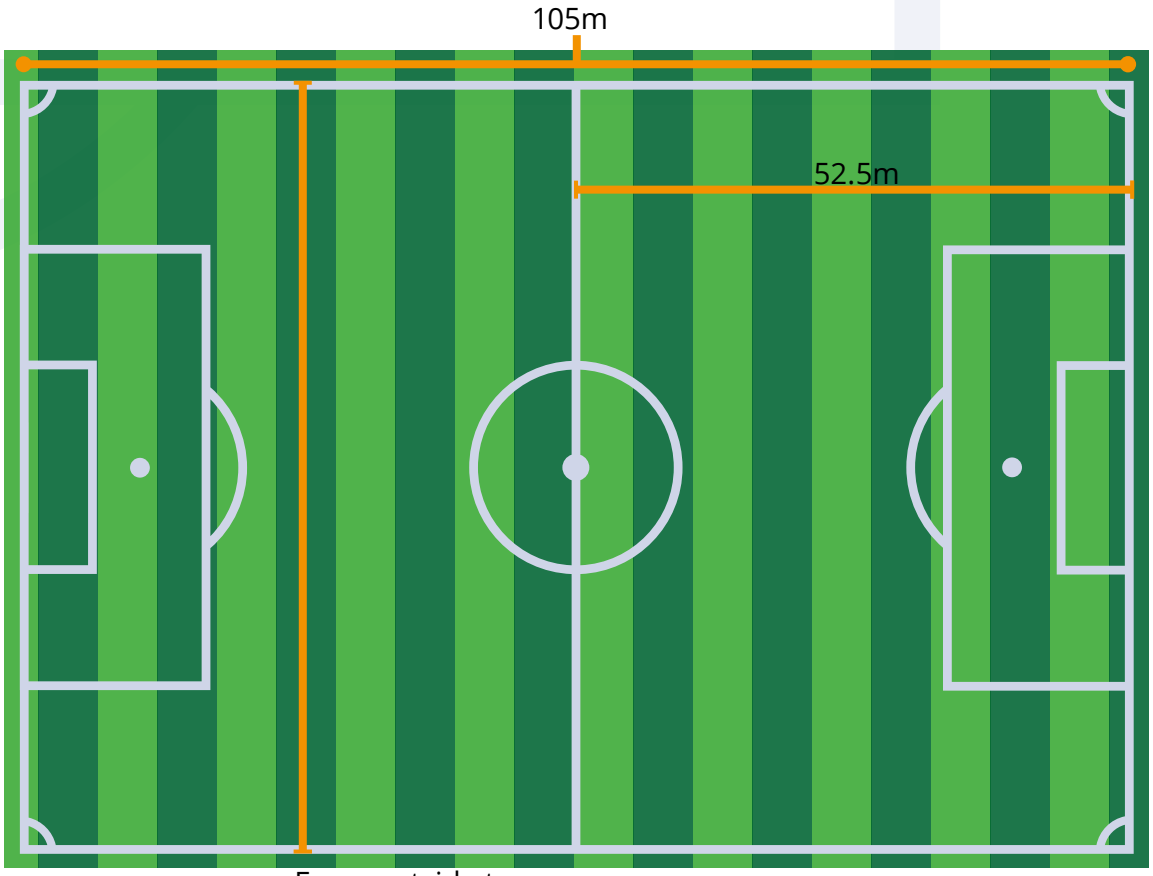
Figure 55: Triangle used to ensure corners are square

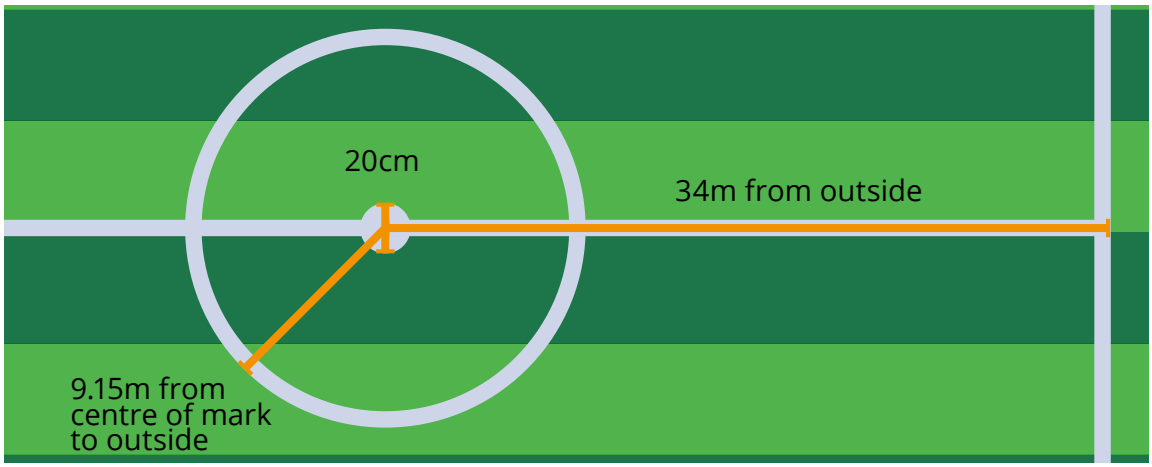
From outside to outside

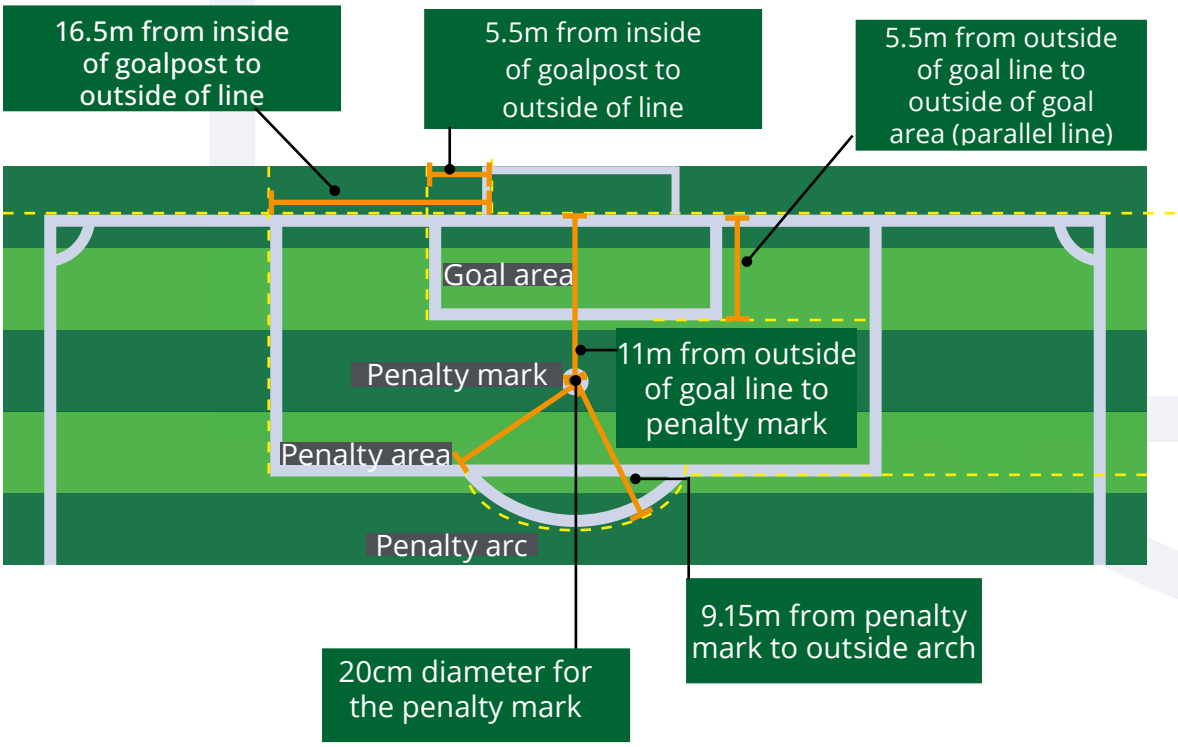
From centre to outside

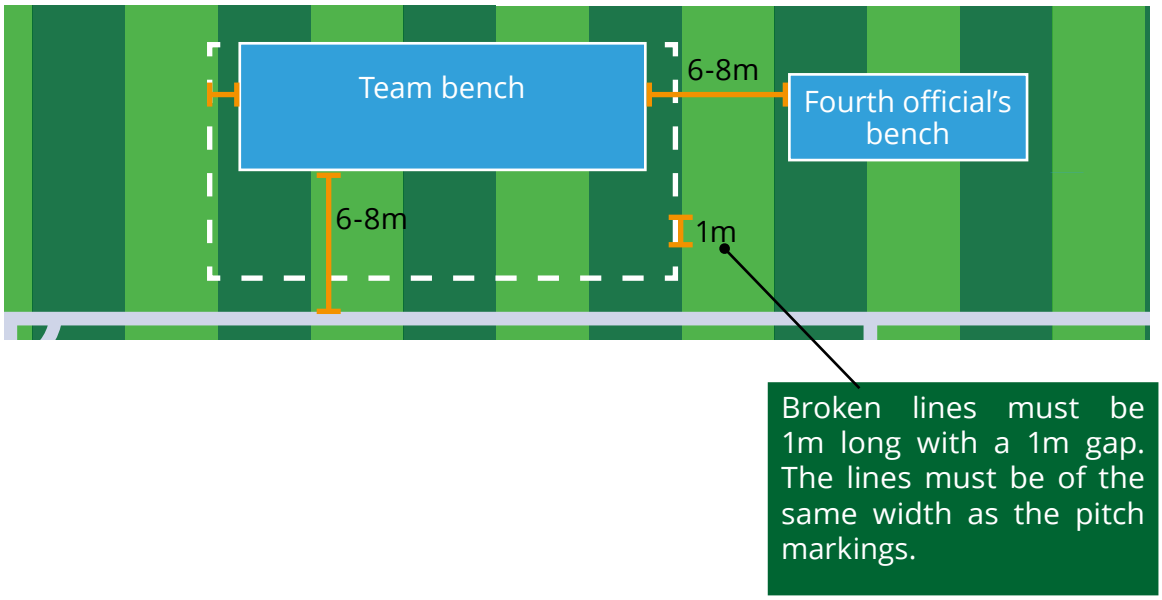


From outside

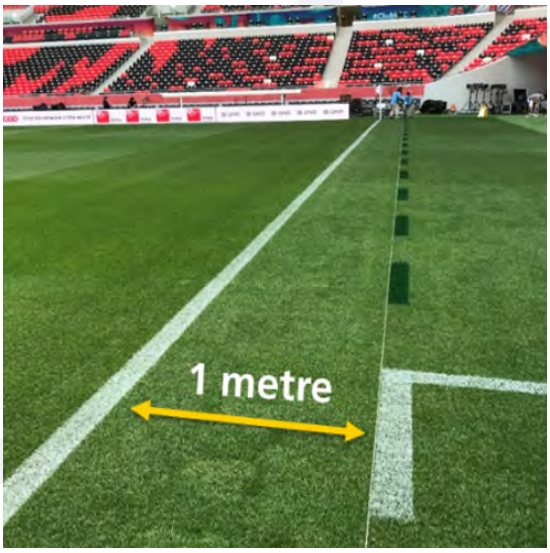





16.5m from inside of goalpost to outside of line
5.5m from inside of goalpost to outside of line
5.5m from outside of goal line to outside of goal area (parallel line)
Goal area
11m from outside of goal line to penalty mark
Penalty mark
Penalty area
Penalty arc
9.15m from penalty mark to outside arch
20cm diameter for the penalty mark


Team bench
6-8m
Fourth official's bench
6-8m
1m
Broken lines must be 1m long with a 1m gap. The lines must be of the same width as the pitch markings.


1 metre
1 metre
1 metre


1 metre


FIFA
CLUB WORLD CUP
QATAR 2020
PRESENTED BY
Alibaba Cloud
#ClubWC
30 cm
1 metre

Figure 56: Line-marking measurements and guidance (based on a 68x105m pitch)

7.6.2 Setting up corner flags, optional halfway flagposts and goals

A flagpost, at least 1.5m high, with a non-pointed top and a flag must be placed at each corner. Flagposts may be placed at each end of the halfway line, at least 1m outside the touchline.

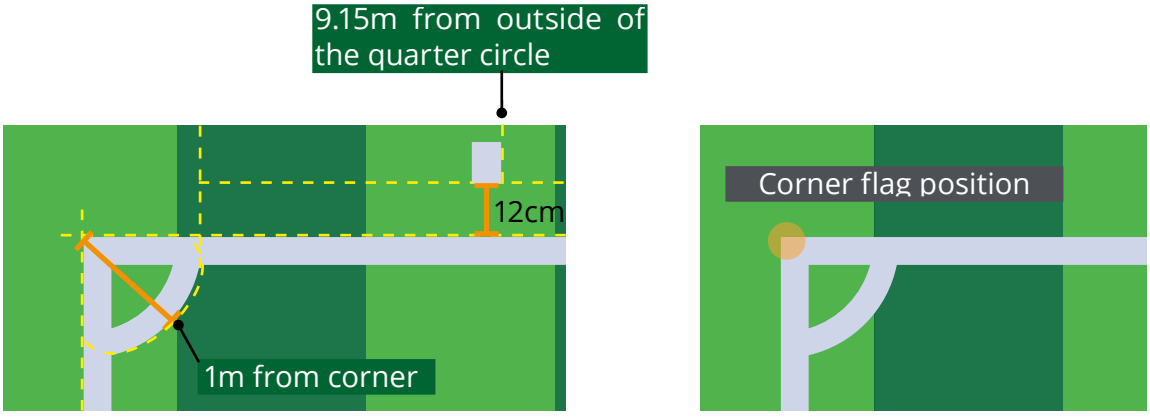


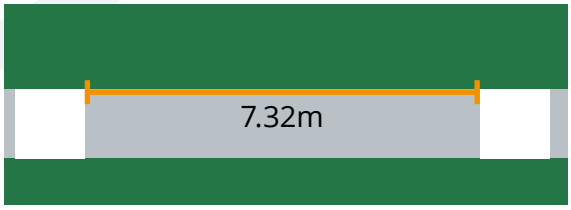
Figure 57: Measurements/positioning for corner arc and area, optional mark denoting minimum distance of defending players at corner kicks, and corner flag

A goal must be placed on the centre of each goal line. A goal consists of two vertical posts equidistant from the corner flagposts and joined at the top by a horizontal crossbar. The goalposts and crossbar must be made of approved material and must not be dangerous. The goalposts and crossbar of both goals must be the same shape, which must be square, rectangular, round, elliptical or a hybrid of these options. The distance between the inside of the posts is 7.32m and the distance from the lower edge of the crossbar to the ground is 2.44m. The position of the goalposts in relation to the goal line must be in accordance with Figure 59. The goalposts and the crossbar must be white and have the same width and depth, which must not exceed 120mm (the minimum is 100mm per the FIFA Quality Programme for Football Goals).

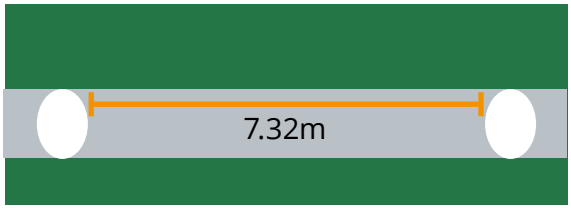
Safety

Goals (including portable goals) must be firmly secured to the ground.

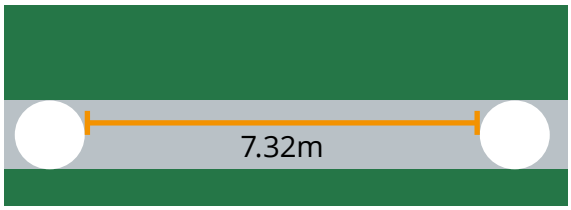
Square goalposts (view from above)



Elliptical goalposts (view from above)



Round goalposts (view from above)



Rectangular goalposts (view from above)

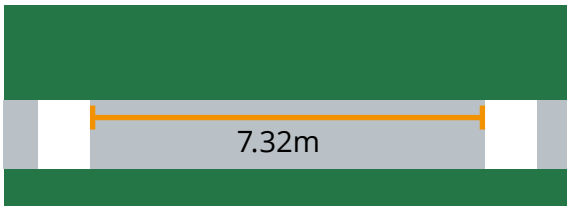


Figure 58: Guidance on goalpost placement

More details and specifications regarding football goals themselves can be found in the FIFA Test Manual for Football Goals.

RESOURCE PLANNING AND PROCUREMENT

VIII.

It is important to plan the resources needed for a pitch. This includes both the machinery and the staff required to maintain and operate the pitch. Certain brands are recommended based on their performance in quality tests, although the choice of equipment may ultimately depend on the standard of the facility, as well as cost and availability.

8.1 Machinery

Equipment can be purchased outright by a venue, leased or contracted in.

Item/activity	Description	Quantity	High-quality standard	Basic standard
Mower	3-unit ride-on cylinder mower with groomers *8-blade units with collection baskets* *Height of cut: 10-25mm* *Width of cut: 216mm*	1	✓	✓
	Walk-behind cylinder mower *8-blade cylinder unit with 1mm verticutting cassette and 1 multi-brush cassette, sorrel roller cassette, and grooved roller* *Width of cut: at least 34in.*	3	✓	✓
	Walk-behind rotary mower *With wide deck and rear rollers with catchers* *Width of cut: at least 34in.*	3	✓	✓
Top dresser	Utility vehicle-mounted top dresser *With disc spinners, wireless controller and utility vehicle*	1	✓	✓

Sprayer	Utility vehicle-mounted spray unit *With hydraulic boom and electric calibration panel featuring form marker, and GPS technology* *Utility vehicle to be used to operate device with fully enclosed safety cab* *Capacity: 600l*	1	✓	✓
	Pedestrian sprayer *Capacity: 60 to 100l*	1	✓	
	Knapsack sprayer	1	✓	
Fertiliser spreader	Utility vehicle-mounted fertiliser spreader *With hopper cover and calibration container*	1	✓	
	Walk-behind fertiliser spreader	2	✓	✓
Aerator	Pedestrian aerator	1	✓	
	Tractor-mounted stadium aerator	1	✓	✓
Drag mat		1	✓	✓
Utility vehicle	Utility vehicle from commercial range of supplier	1	✓	
	Utility vehicle for sports turf supervisor	1	✓	
Easy-load trailer		2	✓	✓
Sod cutter (18in.)		1	✓	✓
Lawn edger		1	✓	
Line trimmer		1	✓	
Blower	*Non-backpack model*	2	✓	
Turf doctor		2	✓	✓

Hand rake		4	✓	✓
Lawn leveller		4	✓	✓
Leaf rake		4	✓	
Yard brush		4	✓	✓
Pitchfork		8	✓	✓
Hose with nozzle	*Length: 50m*	4	✓	✓
Dew switch	*For removal of dew*	4	✓	
Soil moisture sensor	*With cloud service*	1	✓	
Golf hole cutter		1	✓	
Half-moon cutter		4	✓	✓
Spade		4	✓	✓
Shovel		4	✓	✓
Snow shovel		4	✓	✓
Wheelbarrow		1	✓	✓
Prism height-of-cut gauge	*Unit per FIFA specifications*	1	✓	✓

Line marking	Football pitch line-marking machine (transfer model)	2	✓	✓
	Football pitch line-marking machine (spray model)	1	✓	
	String line	4	✓	✓
	Tape measure *Size: 120m* *Stainless steel*	2	✓	✓
	Pins and marking accessories	1 (set)	✓	✓
	Set of stakes and plastic chain *Length of string: 210*m	1	✓	
	Metric measuring wheel	1	✓	✓
Grinding	Bedknife and reel grinder	1	✓	
Sweeper collector	Tractor-trailed driven sweeper collector	1	✓	
	Tractor-trailed driven debris collector *With all blade and brush options*	1	✓	
	Tractor-mounted verticutter *With 1m³ collection hopper and all range blades*	1	✓	
Rake	Tractor-mounted rake	1	✓	✓
Verticutter	Tractor-mounted verticutter *With 2mm blade*	1	✓	
Top dresser	Tractor-pulled top dresser *With at least 3m³ hopper*	1	✓	
Drag brush	Trailed multifunction brush	1	✓	
Seeder	Tractor-mounted seeder	1	✓	

Roller	Tractor-mounted sorrel roller	1	✓	
	Ride-on roller *At least 1.8m wide*	1	✓	
Tractor and accessories	70HP tractor *With air-conditioned cab and turf tyres*	1	✓	
	50HP tractor *With air-conditioned cab, turf tyres, front bucket and rear counterweight*	1	✓	
	40HP tractor *With air-conditioned cab and turf tyres*	1	✓	✓
	Koro Field Topmaker *Minimum width: 1.5m* *With 3mm and 10mm blades*	1	✓	
	Tractor trailer *With hydraulic dump and turf tyres* *Load capacity: at least 4 tonnes*	2	✓	✓
	Triangle brush *Working width: at least 2m*	1	✓	
	Decompaction Verti®-Groom for artificial turf *Working width: at least 1.5m*	1	✓	
	Utility vehicle-drawn (ground wheel-driven) artificial turf cleaner	1	✓	
	Tractor-mounted rotating brush (synthetic)	1	✓	
	Tractor-mounted aerator *For training sites*	1	✓	✓

Table 8: Machinery and equipment to be provided by the venue authorities and/or contractor

Figure 59: Top dresser

8.2 Personnel

The personnel needed to operate and maintain a stadium or training pitch are detailed below, along with their responsibilities.

Role	Responsibilities	Number of personnel	High-quality standard	Basic standard
Stadium manager	**- Overseeing budget and strategic operations as part of overall stadium team** **- Reporting to senior management and directors**	- 1 leading a team of up to 6 at a stadium - For a training site, there is generally minimum of 2 per pitch	✓	✓
Ground staff/ manager	**- Directly responsible for leading grounds team at stadium or training site (or, in some cases, both)**	Same numbers as above	✓	✓

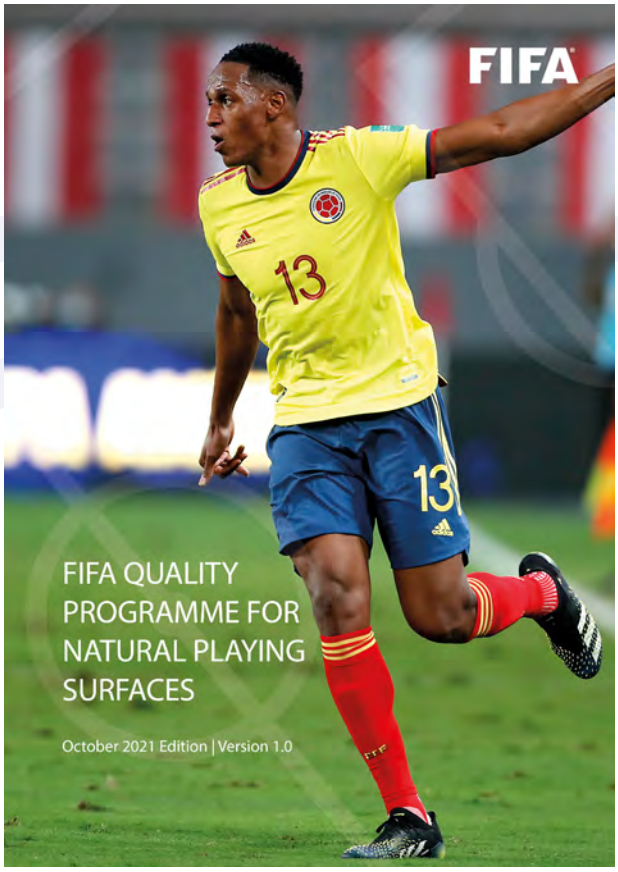
Table 9: Personnel requirements and responsibilities

MONITORING PITCH PERFORMANCE

IX.

9.1 FIFA Quality Programme for Natural Playing Surfaces

In October 2021, FIFA launched the FIFA Quality Programme for Natural Playing Surfaces and published an accompanying test manual. The purpose of the document is to help competition organisers, pitch owners/authorities and ground staff to monitor and optimise their pitches by standardising the assessment process.



The FIFA Test Manual for Natural Playing Surfaces covers two types of on-site assessment: a full assessment and a reduced assessment.

The full assessment is designed to be performed by FIFA-accredited test institutes to evaluate the agronomic performance, as well as the player safety and performance (player-surface interaction and ball-surface interaction), of a new installation, an existing installation or an installation prior to a tournament. The reduced assessment is designed to be performed regularly by the ground staff in charge of the installation, whether to monitor the preparation of an installation for a tournament or as part of a regular quality control process.

The document details standardised test methods and agronomic properties and provides sports performance recommendations. A list of accredited test institutes is also included.

The test manual can be downloaded here

9.2 Testing and pitch rating system

The testing of a natural turf pitch can be divided into three basic categories – climatic testing, sports performance testing and agronomic testing – albeit there is a certain amount of overlap between these categories and some tests fit into more than one of them.

Climatic testing can be undertaken by a range of individuals. Some stadiums incorporate dedicated weather stations that record the climatic conditions continuously.

Sports performance testing focuses on how players and the ball interact with the surface. This area of testing is usually undertaken by specialist test institutes.

Agronomic testing considers the health and quality of the turf and supporting infrastructure, with factors such as feeding, watering and disease control also being assessed. Agronomic evaluations are normally carried out by experienced agronomists, although some techniques are also routinely applied by ground staff.

FIFA Natural-Pitch Rating System

Natural Playing Surfaces Quality Programme

May 2022, version 1.0

A pitch rating system has been developed to allow the quality of natural playing surfaces to be assessed objectively. The system rates a pitch's quality up to a maximum score of 100.

The pitch rating system explanatory document can be downloaded here.

Unacceptable quality	Poor qualty	Satisfactory quality	Good qualty	Excellent qualty

FIFA test reports

FIFA test reports can be provided when the testing complies with the comprehensive quality process developed by FIFA through its Quality Programme for Natural Playing Surfaces. Only testing performed by an accredited test institute is eligible to receive a FIFA test report.

FIFA test reports were developed to allow non-experts to understand the agronomic evaluation of the pitch. The first part of FIFA test reports includes the overall rating of the field, followed by an additional, colour-coded risk assessment report and the overall conclusion from the pitch assessment. All the detailed test results and photographic evidence can be found in the second part of the reports.

9.2.1 Climatic testing

		Tests undertaken by	
Attribute tested	**Equipment used**	**Qualified test institutes**	**Ground staff**
Ambient temperature	Thermometer	✓	✓
Ambient humidity	Hygrometer	✓	✓
Wind speed	Anemometer	✓	✓
Soil temperature	Temperature probe	✓	✓

Table 10: Climatic testing summary

9.2.2 Sports performance testing

		Tests undertaken by	
Attribute tested	**Equipment used**	**Qualified test institutes**	**Ground staff**
Ball rebound	Ball release device	✓	✓
Ball roll	Football and ball-roll ramp	✓	✓
Shock absorption	Advanced Artificial Athlete	✓	
Vertical deformation	Advanced Artificial Athlete	✓	
Rotational resistance	Traction device	✓	
Surface evenness	3m straight edge and slip gauge	✓	✓

Table 11: Sports performance testing summary

Ball rebound is a measure of the response of a football when it rebounds vertically off the surface. Logically, the ball bounces higher off a hard surface and lower off a soft, muddy surface. The density of the turf will also have an influence, with denser turf offering less bounce. Players anticipate that a ball will behave in a controlled manner when rebounding off the pitch. If it behaves "differently", they have to adjust to allow for the different behaviour. This is made more difficult if the pitch is hard and soft in different locations or the grass cover varies significantly.

Ball roll relates to the speed of the surface. A ball that rolls relatively "far" is effectively not encountering as much resistance from the turf, resulting in the ball moving more quickly over the surface. A number of factors can influence this, including the height and density of the cut grass, the type of cultivar used and moisture on the grass.

Shock absorption testing is a mechanical attempt to simulate the impact that a player feels when running on the surface.

Deformation refers to the extent to which the surface is depressed as a player runs on the pitch and their boot makes contact with the ground. A surface that deforms too much will feel unstable to the player, causing them to adjust to compensate for the instability.

Rotational resistance is a measure of the "grip" that a player feels when changing direction as they run across the pitch. Too much grip puts stress on the lower-extremity joints; conversely, if there is too little grip, the player will lose control of their movement and could slide or slip on the surface.

Surface planarity testing assesses the evenness of the pitch. Beyond a minimal amount of surface irregularity, the movement of the ball will be affected in an adverse manner, resulting in it bobbling over the pitch or deviating from its path.

9.2.3 Agronomic testing

		Tests undertaken by	
Attribute tested	**Equipment/method used**	**Qualified test institutes**	**Ground staff**
Surface hardness	Compaction hammer	✓	✓
Compaction severity	Soil penetrometer	✓	
Water infiltration rate	Infiltrometer	✓	
Normalised difference vegetation index (NDVI)	NDVI handheld device	✓	
Mowing height	Ruler	✓	✓
Sward height	Prism	✓	
Effective root depth	Soil corer and ruler	✓	✓
Thatch depth of natural turf	Ruler	✓	✓
Ground cover of natural turf	Grid or net	✓	✓
Weed content (%)	Grid or net	✓	✓
Insect pests	Visual assessment	✓	✓
Diseases	Visual assessment	✓	✓
Volumetric soil moisture content	Volumetric soil moisture probe	✓	✓
Soil pH	pH probe	✓	✓
Soil pH	Chemical analysis in laboratory	✓	
Soil nutrient levels	Chemical analysis in laboratory	✓	

Table 12: Agronomic testing summary

NDVI is a measure of the health of the plant. The NDVI device records the amount of photosynthetic activity at the surface. Higher readings are recorded with healthy, dense turf.

9.3 Typical problems on natural turf football pitches

Poor drainage, leading to loss of grass cover

Poor surface levels, poor drainage and weed invasion

Poor grass establishment

Grass loss through heat stress and disease

Weed invasion, affecting consistency, pitch appearance and playing quality

Weed grasses and broadleaved weed

Irrigation system with poor coverage due to the sprinkler overlap arrangement

Uneven watering, affecting the grass density and playing performance

Uneven fertiliser application, leading to poor appearance and uneven grass growth

Excessive use and poor surface levels in the goalmouth

GLOSSARY

X.

Soil

Term	Description
Clay	Soil particles smaller than 0.002mm in diameter. Clay-rich soils usually have poor drainage characteristics and are water-retentive.
Peat	A material consisting largely of un-decomposed or partially decomposed organic material accumulated under conditions of excessive moisture. Often used to improve water and nutrient retention.
Silt	Intermediate-size fine particles of more than 0.002mm and less than 0.05mm in diameter. Silt-rich soils tend to be water-retentive and have poor drainage characteristics.
Sand	Coarser soil particles (0.05 to 2mm in diameter). Most modern sports pitches are built using sandy materials because of their good drainage and other physical attributes. Sands can vary with respect to properties such as particle size, shape, density and water retention.
Soil	The natural medium for plant growth, consisting of mineral particles mixed with organic matter.

Plant

Term	Description
Annual meadow grass	A cool-season grass species. Traditionally shallow-rooted and not suited to a professional football pitch.
Disease	A pathological condition, usually as a result of environmental factors interfering with the plant's metabolism.
Fertiliser composition	The percentage of nitrogen, phosphorus and potassium and other plant nutrients found in a fertiliser.
Fungicide	A chemical that controls or prevents the growth of a fungus.
Grass	Any of various plants having slender leaves characteristic of the grass family.

Insect	A small arthropod animal of the class *Insecta*, with an adult stage characterised by three pairs of legs, a body segmented into a head, thorax and abdomen, and usually two pairs of wings. Insects include flies, crickets and beetles.
Perennial ryegrass	A cool-season grass species (*Lolium perenne*).
Pest	An insect, grub or other species/soil organism that may cause damage to the grass plant.
Pesticide	Any substance or mixture of substances intended to prevent or control any unwanted species of plants and animals, including any substances intended for use as a plant growth regulator, defoliant or desiccant. Examples include fungicides, herbicides and nematicides.
Roots	The underground portion of a plant, which serves as support, draws minerals and water from the surrounding soil, and sometimes stores food.
Seed	The reproductive structure of a plant, containing an embryo, food supply and protective coat. Seeds are used for the establishment of grass.
Seeding	Adding seeds to the soil to produce new grass.
Smooth-stalked meadow grass	A cool-season grass species (*Poa pratensis*). Also called "Kentucky bluegrass" in some countries.
Sod	Strips of turf grass, usually with adhering soil, used in vegetative planting (also called "turf" in some countries).
Stolon	A vegetative material (a sprig, rhizome, tiller or combination) used to establish turf, usually for warm-season grass species.
Thatch	An organic layer made up of intermingled dead clippings and living shoots that builds up on the surface between the base of plants and the root zone.
Turf	1) The grass-covered surface of the ground growing within the upper soil layer. (2) Strips of turf grass, usually with adhering soil, used in vegetative planting (also called "sod" in some countries).
Weed	Any plant that does not belong in the pitch sward.

Machinery, equipment and operations

Term	Description
Aeration	Any operation carried out to improve turf by physical methods to increase surface drainage, promote air exchange and encourage better root development.
Boom sprayer	A machine with a line of nozzles on extending arms for spreading liquid chemicals onto turf.
Cover	A sheet of material used for protection against extreme weather or to promote growth.
Cutting height or height of cut	The height above ground level at which the grass is cut. The height will be set by moving the front roller up or down against a setting bar.
Cylinder mower	A grass-cutting machine whose cutting blades' rotational action generates a scissor-type cut against the bottom blade.
Grow light	An artificial light used to promote the growth of grass.
Hollow tining	A form of aeration in which a cylindrical tine is used to remove cores from the soil.
Irrigation	The controlled application of water to turf.
Line marker	A machine for marking lines on a pitch.
Mower	A grass-cutting machine.
Mowing	The action of cutting grass.
Rotary mower	A powered mower that cuts turf through the high-speed impact of a set of blades rotating in a horizontal cutting plane.
Scarifier	A machine used to cut through horizontal growth and thatch with a raking or vertical cutting action.
Slit tine	A knife or bladed tine.
Solid tine	A spike or blade used to create holes in the turf surface during aeration work.
SISAir	A subsurface aeration system (not in use at all stadiums).
Spiker	A machine used to create aeration holes in the turf.

Sweeper collector unit	A machine usually equipped with a rotating brush and collector.
Vacuum system	A suction device mainly used to lift grass clippings and other debris from the surface of the pitch.
Verticutting	Use of a machine with vertically rotating blades that slice into the turf to remove thatch or cut stolons.
Verti-Drain®	A machine to break up compaction to a set depth by means of tines/pins. Can be tractor-mounted or pedestrian.

Construction

Term	Description
Brush	A device consisting of bristles held in a suitable frame to sweep the grass.
Drag mat	A flexible steel mat that is pulled along to work in top dressings, particularly on undulating turf surfaces.
Drainage system	A network of drains to remove excess water from a pitch.
Gravel	Rock fragments or small pebbles, typically of a diameter of 2-10mm.
Renovation	The repair of an area of turf by cultivating, relevelling and reseeding, particularly carried out at the end of the playing season.
Root zone	A mix of sand and soil, or sand and organic matter, used as the growing medium for the grass plant.
Slit drainage	A drainage system in which a series of sand- and/or gravel-filled channels link the pitch surface with porous aggregate over pipe drains, allowing excess surface water to bypass the soil.
Stone	Large particles of mineral matter or rock, typically with a diameter of greater than 10mm.

ANNEXE – FURTHER INFORMATION ON MAINTENANCE

Maintenance explained

The maintenance of a sports turf pitch comprises a set of actions to be carried out on the surface in order to preserve it in the best conditions for the sport and minimise the damage after each use, so as to avoid hindering its playability and undermining the sporting spectacle.

The scheduling of operations for the maintenance of the pitch cannot be limited or generalised and must take into account several factors, such as the climate, the type of water used in the irrigation system, the drainage capacity and the intensity of use, which will condition it and require a specific maintenance plan.

Conditioning factors for maintenance

Sunlight – essential for photosynthesis, the process by which plants absorb solar energy and convert it into chemical energy. Shade conditions hamper grass's development and the maintenance should provide for the supply of those substances that the plant cannot synthesise in such an environment, such as carbohydrates, enzymes and amino acids.

Temperature – with a direct influence on practically all factors responsible for the development of plants, such as photosynthesis, respiration, transpiration and absorption of water and nutrients, cellular permeability and enzymatic activity, etc., temperature should be monitored and reflected in the maintenance programme.

Humidity – strongly influenced by architectural factors like the shade conditions mentioned above, this is a constant concern, particularly from mid-spring to mid-autumn, when – combined with high temperatures – the humidity provided by irrigation promotes ideal conditions for the development and proliferation of fungi. To tackle the development of diseases, it is necessary to have a balanced fertilisation programme and use preventive and curative phytosanitary treatments.

pH – for a sand-based pitch, it is advisable that the pH be monitored frequently because these soils are more susceptible to variations in pH. In order to ensure that the development of the grass is not affected, it is important that the pH of the soil be kept within the ideal range (6.5 to 7.0). A high pH promotes the appearance of algae and inhibits the absorption of nutrients.

Irrigation water

Salts – the content of salts in water can promote the emergence of soil salinity problems, with serious consequences for turf development. Excess salts inhibit the absorption of water by the roots, causing water stress in the plant.

Mowing – this is one of the main maintenance operations for a natural grass pitch and has an influence on the sward/density, homogeneity and health of the grass, as well as the aesthetics.

Aspects to be taken into account in mowing operations

Direction – the direction of the mowing should be changed frequently, so that the plant does not become prostrated in one direction, thus avoiding permanent contact of the leaf with the soil. This allows better aeration of the soil surface and sun exposure.

Frequency – the cut should be executed on a regular basis in the growing season, always respecting the "1/3 rule" (no more than a third of the leaf should be cut). However, the cutting frequency will vary depending on the time of year and climatic

conditions.

Height of cut – this is determined by the grass species and cultivars used in the grass seed mix composition and by the time of year. Thus, the average height of cut used will be in the range of 20-24mm in the spring and autumn periods and 24-28mm in the summer and winter. Consideration should also be given to varying the height of cut when there is a break during tournaments, so as to reduce the stress being applied to the plant through mowing operations.

Quality – the type of machinery used has a vital influence on cutting quality. The best quality will be achieved by employing a cylinder-type machine delivering a scissor-type cut to the leaf. This type of cut reduces the stress on the leaf tip, which, in turn, decreases the chance of the plant succumbing to fungal attack. The use of rotary mowers should be limited to surface cleaning; the rotor delivers a tearing-like action to the leaf, increasing plant stress.

Cylinder hygiene and husbandry – the cutting units of the machine(s) being used must be kept sharp to ensure that a clean cut is delivered each time. A badly delivered cut will affect the plant's ability to grow and it takes time for the plant to repair the wound/injury inflicted by the poor delivery. This also paves the way for diseases to afflict the plant, by putting the leaf under increased stress.

Fertilisation

In order to obtain a sports turf with the required quality and appearance, a balanced fertilisation programme must be prepared and executed, always taking into consideration the plant requirements, the soil and climatic conditions, and the intensity and type of use. To do so, it is necessary to consider the following factors:

a) Conditioning factors for fertilisation programmes

- Grass species
- Soil analysis (root-zone type/chemical and nutrient contents)
- Sunlight exposure
- Temperature
- Humidity
- Intensity/type of use
- Irrigation water quality

b) Aspects with a direct impact

The **turf quality** is decisive and is determined by a host of factors, notably the proportion between leaf and root systems, the colour, the formation of thatch, the depth of rooting and the degree of resistance to diseases and pests.

The frequency and intensity of other maintenance operations, such as cutting, watering and phytosanitary treatments, are also influential.

Issues affecting the soil should also not be overlooked; these include contamination (such as through acidification and salinisation), water run-off and leaching in sandy soils, and atmospheric losses through volatilisation and denitrification.

c) Criteria to be taken into account in any fertilisation programme

- Replacement of mineral nutrients extracted by cutting

- Correction of nutritional deficiencies of the root-zone layer
- Compensation of soil nutrient losses
- Stimulation of grass growth and strength to improve tolerance and recovery

d) Nutrients necessary for grass development

Primary macronutrients

Nitrogen – a major food source for the plant

Phosphorus – a genetic material constituent involved in a number of physiological functions and reactions such as energy transformation (through adenosine triphosphate), the transformation of carbohydrates into sugar, rooting, etc.

Potassium – responsible for protein synthesis, cell division and osmotic potential regulation (respiration and transpiration)

These nutrients are generally absorbed by plants in high amounts.

Secondary macronutrients

Calcium – responsible for the formation of young cells and involved in the strengthening of cell walls

Magnesium

Sulphur

Secondary macronutrients are absorbed in lower amounts compared to primary macronutrients.

Micronutrients

Iron

Zinc

Copper

Manganese

Boron

Molybdenum

Micronutrients are essential nutrients for plants but, unlike macronutrients, they are absorbed in small amounts and can be phytotoxic when absorbed in excess.

e) Intervention vis-à-vis adverse grass development conditions

The following are important features for the grass on a natural turf football pitch:

- **Healthy and balanced development**
- **Root development with maximum depth**
- **Good resistance to stress and a good recovery capacity**

There are three essential processes underlying these attributes: photosynthesis, respiration and transpiration, the last of which can sometimes occur at the expense of the first two.

Photosynthesis involves the production of amino acids (organic compounds consisting of an amino group, NH_2, and a carboxylic group, COOH, which can be considered the

"bricks" used in the construction of various proteins, enzymes and chlorophyll).

Amino acids can be synthesised in roots and leaves and then sent to other parts of the plant where they are needed to ensure proper growth and development.

Plants have a constant need for amino acids and can obtain them in several ways.

Normal synthesis comes at the expense of a high amount of energy, and this production may not be enough for the plant in periods of stress.

In stressful situations, enzymes can be used to hydrolyse reserve proteins (structural proteins of the roots), if available. This can be accomplished through foliar or root applications by maintenance professionals.

Therefore, it can be affirmed that plants save energy when treated with amino acids, since they avoid the thousands of chemical reactions necessary to produce these compounds, helping to maintain their reserve of carbohydrates, which are essential to overcome periods of stress and/or diseases and also have a high capacity for protein and chlorophyll production.

A good, balanced and well-executed maintenance programme is the key to success.

Key features of the main climate types

Cool maritime climates

- These are high-latitude areas that have cool summer temperatures, with a short growing season for grass.
- Winter temperatures are affected by close proximity to the sea; there tend to be cold periods but no continuous periods of frost or snow, unlike in more continental areas.
- Rainfall levels are variable. An effective drainage system is essential to remove water due to low evapotranspiration. Undersoil heating, as well as vacuum and ventilation systems, are also considered vital for stadiums.
- Only cool-season grasses are used.

Temperate maritime climates

- Summers are warm to moderately hot and usually offer good levels of rainfall, though good irrigation is essential during periods of dry weather.
- Rainfall is regular during the cold winters, but there are no continuous periods of frost or snow.
- The winter conditions make good drainage essential for good-quality pitches; undersoil heating, plus vacuum and ventilation systems, should also be considered for stadiums.
- Only cool-season grasses are used.

Cool continental climates

- Summers are warm to moderately hot, usually with some rainfall. A good irrigation system is essential for drier periods.
- Winters are cold, with continuous periods of frost and snow.
- Conditions are generally poor in early spring and late autumn – undersoil heating, as well as vacuum and ventilation systems, should be considered for stadiums.
- Only cool-season grasses are used.

Mediterranean and dry-summer subtropical climates

- Summers are hot, usually with little rainfall.
- Winters are relatively mild and tend to offer more regular rainfall.
- Cool-season grasses are mainly used, with warm-season grasses also appropriate in hotter parts of such regions. These are generally oversown with cool-season grasses in the winter.
- Irrigation is essential and the perched-water-table method of construction will help with water management. In dry weather, there may be a requirement for 8mm of water per m^2 ($64m^3$ for an $8,000m^2$ pitch) per day during the establishment phase, and the provision of a storage tank for 24-hour watering is therefore advised.

Continental (transition) climates

- Summers are hot.
- Winters are relatively cold, with a possibility of frost and snow.
- The hot summer temperatures cause significant turf stress for cool-season grasses.
- Warm-season grasses are likely to become dormant in cooler winters.
- Both warm-season and cool-season grasses are used, with cool-season grasses being overseeded into the warm-season grasses before the start of the winter.
- Rainfall can be limited during parts of the year. An effective irrigation system is essential.

Subtropical climates

- Summers are hot.
- Winters are mild or warm, with little or no risk of frost or snow.
- Annual rainfall is often relatively high, but there can be some drier periods. Effective irrigation is essential. In dry weather, there may be a requirement for 8mm of water per m^2 ($64m^3$ for an $8,000m^2$ pitch) per day during the establishment phase, and the provision of a storage tank for 24-hour watering is therefore advised.
- Warm-season grasses are mainly used, but in cooler parts of the region, e.g. at altitude or at stadiums, it may be necessary to overseed with cool-season grasses during the winter.

Tropical climates with high rainfall

- Tropical climates require the use of warm-season grasses.
- Rainfall is regular and often intense and prolonged.
- There may be occasional dry spells despite the high annual rainfall and, given the high temperatures, an effective irrigation system is essential. In dry weather, there may be a requirement for 8mm of water per m^2 (64m^3 for an 8,000m^2 pitch) per day during the establishment phase, and the provision of a storage tank for 24-hour watering is therefore advised.

Tropical climates with seasonal rainfall

- Temperatures are high year-round, meaning that warm-season grasses are required.
- There is significant seasonal variation in rainfall, with high and often intense rainfall during part of the year, but prolonged dry periods at other times.
- Dry periods and high temperatures require an effective irrigation system. There may be a requirement for 8-10mm of water per m^2 (64-80m^3 for an 8,000m^2 pitch) per day during the establishment phase, and the provision of a storage tank for 24-hour watering is therefore advised.

Tropical semi-arid and arid climates

- The hot conditions dictate the use of warm-season grasses.
- The combination of high temperatures and low levels of rainfall make an effective irrigation system a priority. There may be a requirement for 8-10mm of water per m^2 (64-80m^3 for an 8,000m^2 pitch) per day during the establishment phase, and the provision of a storage tank for 24-hour watering is therefore advised.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