Provision of Turf Surfaces for Major Football Stadiums in Europe: Environmental Issues and Design Criteria

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Provision of turf surfaces for major football stadiums in Europe : environmental issues and design criteria

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Key points : Major football stadiums present a significant challenge for the growth of healthy turf because of soil compaction and wear resulting from play , in an environment with significant levels of shade and restricted air movement . Turf drainage and growth can be improved by the use of carefully selected sand-dominated rootzones . The stability of the turf , which may decrease if grass cover is lost , can be improved by reinforcement of the grass layer by various types of plastic fibre . Quantification of potential light levels and airflow during the design stage is important to maximise the amount of light and air movement for the pitch in relation to the constraints of other architectural design criteria . A number of potential methods of improving the growing environment within stadiums is discussed , of which transparent roof tiles and artificial lighting systems in particular are being increasingly used .

Key words : football pitch , rootzone , reinforcement , shade , photosynthetically active radiation

Introduction

Football (soccer) is the most popular spectator sport in Europe and in most countries large stadiums are needed to accommodate supporters . Some of the largest stadiums in Europe include Wembley in England (capacity=90 ,000) , the Millennium Stadium in Wales (capacity=74 ,500) , the San Siro Stadium in Italy (capacity=85 ,000) , the Nou Camp Stadium in Barcelona , Spain (capacity=98 ,000) and the Stade de France , Paris (capacity=80 ,000) . Particularly in northern Europe , where protection from rain is important , many of these large stadia have extensive roof structures that create significant problems with shade and air movement (Baker 1995a , b) .

Pitch provision in stadiums of this size provide some unique challenges with respect to ensuring healthy grass growth and a high quality playing surface . Problems are often made more acute by multiple use of the stadiums for events as diverse as pop concerts , motorcycle racing , boxing and evangelical meetings . The main design requirements for the pitch include :
i) adequate drainage rates to avoid the risk of surface water which could result in games being cancelled or abandoned ,
ii) a suitable growing medium that allows a reasonable balance between air-filled and capillary pore space to support healthy grass growth ,
iii) adequate light to support the most appropriate grass species for the area concerned ,
iv) adequate air movement to help dry the surface and reduce the risk of problems with surface algae and disease ,
v) heating systems or pitch covering in colder climates to prevent problems with snow and frost .

The objective of this paper is to review the technology used to support high-quality playing surfaces and to provide the best possible growing conditions for turf in areas with potentially high levels of wear and environmental stress .

Construction profiles and rootzone selection

Europe has a wide range of climatic conditions and this can influence both the construction methods that are used and grass selection . Examples of average temperatures and rainfall totals are given in Table 1 . Excess rainfall over evaporation rates for much of the playing season means that good drainage is essential in most of northern Europe but , even in drier areas in southern Europe , allowance must be made for high intensity rainfall events , which could disrupt play . In most of Europe , the main playing season is from August , through the winter months into May , but in Scandinavia the harsher winter means that play is mainly from spring through the summer into the autumn , and elsewhere in parts of northern Europe (eg . Germany) there is a short winter break .

Most major grounds in Europe are constructed with a rootzone layer over a gravel drainage layer , eg . Figure 1a (Adams , 1986 , DIN 1981 , Baker 1988) . However , for smaller stadiums or in drier parts of Europe , the rootzone may be placed over the natural soil with varying intensities of under-drainage being added , dependent on soil type and design rainfall rates (Figure 1b) (Adams 1981 ; Baker 1982 ; Baker 1988) . The composition of the rootzone layer is usually dominated by sand-size particles but there can be some variation depending on climate factors and , to a lesser extent , availability of suitable materials .

Table 1 *Climate data relevant to pitch design for selected capital cities in Europe .*

	Latitude	Annual rainfall (mm)	Highest monthly average temperature(℃)	Lowest monthly average temperature(℃)
Oslo	60 .2N	863	16	-7
Berlin	52 .5N	581	18	-1
London	51 .5N	611	17	4
Paris	49 .0N	612	19	3
Madrid	40 .5N	429	24	5

The grading of the sand used and , in addition , the uniformity of particles and particle shape will have a major influence on drainage performance , air-filled pore space , water retention and stability (Baker 1983 ; Zhang & Baker 1999) . In the United Kingdom , examples of typical rootzones for professional football grounds are given by Baker (2006) and usually contain only 4-8% silt and clay with the sand fraction dominated by material in the range 0 .125-0 .5 mm diameter (Figure 2) . In Central Europe , published standards for rootzones in Germany , for example , (DIN 18 035 Part 4 1991) allow 5-18% silt and clay and potentially coarser sand materials . In hotter and drier parts of Europe , such as Italy , Cereti *et al* . (2004) indicate that 20% of pitches used at professional and semi-professional level had all sand profiles while most of the remaining pitches had a sand-soil mix as the rootzone layer .

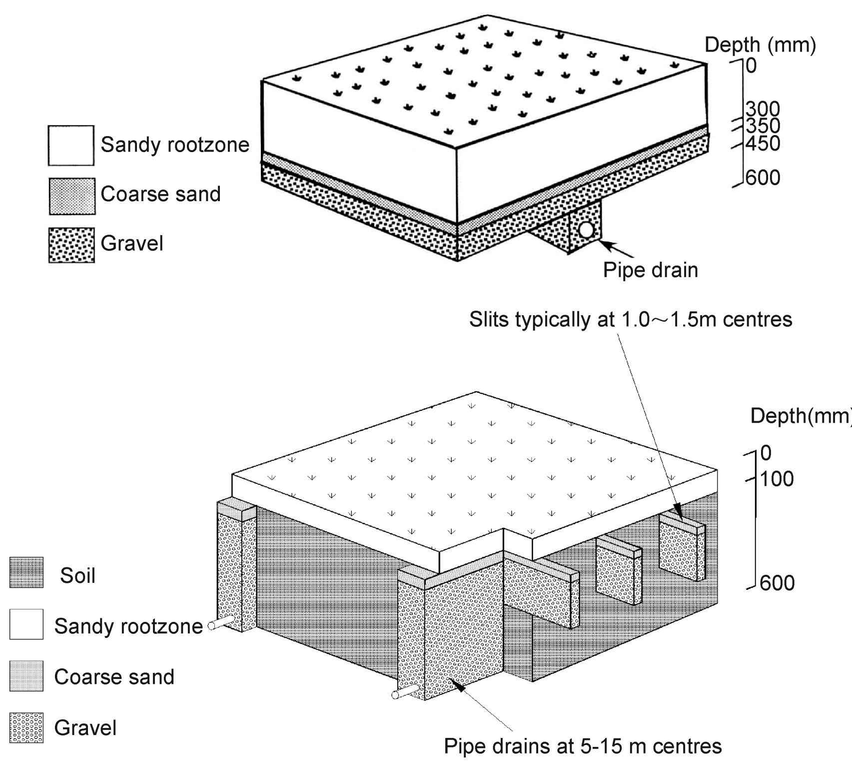

Figure 1 *Typical construction profiles of suspended water table construction with rootzone overlying a gravel drainage layer (1a top) and the rootzone layer placed on top of the existing soil with varying levels of under-drainage (1b , bottom) (from Baker 2006) .*

Surface stability can be an issue on sand-dominated surfaces when play takes place outside the main period of grass growth , and grass cover and root density are lost through wear (Van Wijk & Beuving 1978 ; Adams *et al* . 1985) . Under these circumstances , a variety of artificial reinforcement materials are frequently used to retain surface stability and improve playing quality (Baker *et al* . 1988 ; Baker 1997a ; Adams 1997 ; Gibbs 2002 ; Spring & Baker 2006) . Examples currently in use at professional football clubs in England include Fibresand , consisting of polypropylene/polyurethane fibres of around 0 .1 mm diameter and 35 mm length blended with the rootzone mix at a rate of 0 .25-0 .35% by weight ; GrassMaster consisting of fibres punched into the rootzone to a depth of 200 mm and 20 mm spacing , and XtraGrass , a system whereby natural turf grows through a woven synthetic fabric .

Although the selection and appropriate management of the rootzone should provide adequate drainage, a number of major stadiums in Europe also incorporate a suction system linked to the pitch drainage in case of exceptionally high intensity rainfall either just before or during matches.

Undersoil heating and pitch covering systems

Undersoil heating systems have been available since the 1950s (Escritt 1954) and by the 1980s were commonly used at major stadiums with, for example, 32% of top division clubs in England and 27% of top division clubs in Scotland using some form of undersoil heating (Murphy & Baker 1988). Today virtually all clubs in the upper divisions of football in England have undersoil heating and this would also be the case in larger stadiums in much of northern Europe. By far the most widely used systems are heated water pipes typically at 250 mm depth and 250 mm centres (Boocock 1994, Baker 1997b). Pitch covering systems are also used to retain heat (Boocock 1994).

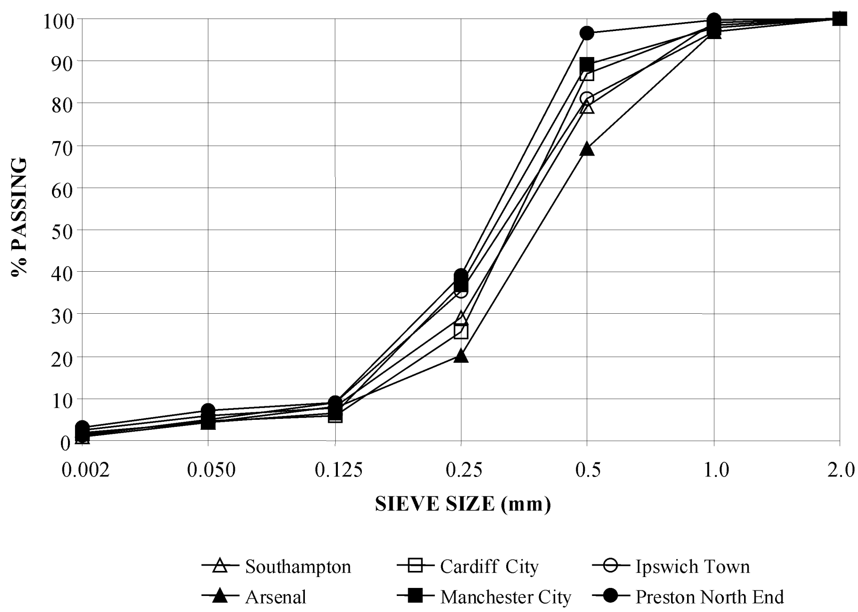

Figure 2 *Particle size distribution of rootzone used at professional soccer grounds in England.*

Grass selection

The main grass species used for football pitches in north-west Europe are *Lolium perenne* and *Poa pratensis* (Canaway 1983, Newell 1994) but *Poa annua* is particularly invasive, resulting in need for appropriate control strategies (Baker *et al*. 2005). In northern and central Europe, the use of *P. pratensis* is usually increased (eg. Skirde 1989; DIN 18 035 Part 4 1991). In their survey of Italian pitches, Cereti *et al*. (2004a) report *L. perenne* and *P. pratensis* to be the dominant sown species with *P. annua* the main weed grass in winter and *Cynodon dactylon* the main weed species in summer. They also found some use of *Festuca arundinacea*. There is increasing interest in the use of warm season grasses (eg. *C. dactylon* and *Paspalum vaginatum*) in the south of Spain and Italy (Croce *et al*. 2001; Volterrani *et al*. 2001), although the use in heavily shaded stadiums may lead to problems of growth and winter dormancy.

Environmental conditions within stadiums

Improvements in construction methods, turf reinforcement and the widespread use of undersoil heating or pitch covers in colder climates have helped address issues that 20-30 years ago were likely to have a significant impact on the quality of pitches. The greatest problem in more recent years has been the effects of stadium design on environmental conditions within stadiums, particularly in terms of shade and air movement. Shade problems have increased significantly because of increased use of all-seater stadia responding to the demands of safety legislation, spectator comfort and a greater range of facilities within stadia, such as executive boxes and dining areas. This has meant that that size of building structures surrounding the pitch have increased (Baker 1995a, b, Newell 1997). For example, Baker (1995a) found that the amount of shade on pitches of English Premier League clubs at midday in December/early January averaged 63% and, for Scottish Premier Division clubs, the average figure was 71%, because of the higher latitude. This problem has undoubtedly worsened and several stadiums have no direct sunlight on any part of the pitch during the winter months. Total radiation is substantially reduced by heavy shade and for example Newell (1997) indicates that light energy in the middle of the day in autumn and spring can be reduced from about 220 W m^{-2} to 40 W m^{-2} where there are very large solid structures surrounding the pitch. The main problems associated with heavy shading and reduced air movement include poor growth, loss of grass cover, leaf characteristic modification, reduced surface stability , more divoting , shallow rooting , increased weed grasses (eg . *P . annua*) , surface algae and slow clearance of frost (Baker 1995a , b ; Cereti *et al* . 2004b) .

Technological advances to improve growing conditions A number of responses to poor light and limited air circulation have been used at different grounds and these include transparent or moveable roof sections , regular re-turfing , artificial lighting systems and moveable pitches .

i) Transparent roof panels and moveable roof sections Stadium design can have a major impact on the amount of light reaching the playing surface . This issue often appeared to be ignored in the design of large stadiums until the mid 1990s but technology is now available to calculate potential light levels in new stadiums and modify the architectural design to maximise the amount of light reaching the pitch , within the constraints of the required stadium capacity . For example , Newell (2000) used a grid of hemispherical images (upwards looking , 180o views) to predict the movement of the sun at the appropriate latitude in relation to fixed structures surrounding a given position . The amount of light reaching different parts of the pitch can then be calculated and in the example given a new stand development would have reduced light levels in the south-west corner of the ground by about 70% .

Transparent roof panels are widely used at larger stadiums and Table 2 shows the proportion of the roof area with light panels at the five largest Premier League stadiums in England , based on analysis of overhead photographs . The figures presented include the struts and support structures for the panels and these will inevitably cause some reduction in the amount of light reaching the pitch . The key issues are to ensure maximum transmission rates of photosynthetically available radiation and that performance does not change with time , either because of deterioration in the transmission properties of the panels or because of a build-up of dirt , moss and algae . In the latter case , regular cleaning is necessary .

Moveable roof panels have been used at a limited number of stadiums . For example , at the Amsterdam Arena in Holland and the Millennium Stadium in Wales , the entire roof can close . At Wembley Stadium in London , a section of the roof moves back at the south end of the ground to improve light levels when the stadium is not in use .

Table 2 *The proportion of the roof space with light transmitting panels at the five largest Premier League Stadiums in England .*

Location	Ground capacity	Area of roof with light panels (%)
Manchester United	76 ,100	41
Arsenal	60 ,432	28
Newcastle United	52 ,327	49
Manchester City	48 ,000	24
Liverpool	46 ,000	17

In other cases , the design of the roof has been modified to allow more light to reach the pitch . For example , at Manchester City and Huddersfield Town , the corners of the stands are lower than the central areas , and at Arsenal the roof is lowest next to the pitch , reversing the conventional slope used at most stadiums . The design at Manchester City also incorporates opening , louvered shutters to allow more light to enter from the sides of the stands and to improve air circulation when the ground is not being used .

ii) Re-turfing One approach to pitch deterioration in poor growing conditions was regular re-turfing . For example , the Amsterdam Arena in Holland was re-turfed on 24 occasions from 1996 to 2001 and , before the use of supplementary lighting , the Millennium Stadium in Wales was re-turfed 2-3 times per year . Selection of appropriate turf is essential as high levels of fine material or organic matter in the turf can reduce water infiltration rates (Canaway 1990) and inappropriate selection of grass type may lead to excessive wear . Typically , 40 mm thick turf is used when the pitch will be used within 2-3 weeks after laying .

iii) Artificial lighting systems Artificial light has been used for football pitches at a limited scale for about 15 years and there are early examples at the Parken Stadium , Denmark (1992-93) , Southampton Football Club , England (1998) and Bristol City , England (2000) . However , the use of artificial lights at major stadiums has become much more widespread in the last five years as the logistics for portable lighting systems have improved . Typical examples include wheeled frames holding 40-60 600W/400V high pressure sodium lamps covering areas of 360-580 m^2 , although smaller units are available for goalmouths and other high wear areas . With current light systems , the lights are typically 2 .0-2 .4 m above the ground to provide clearance for working underneath .

To support photosynthesis of the grass plant , it is important that the light units work within the range of photosynthetically active radiation of 400-700 nm (Fitter & Hay 1987) . Newell (2000) suggests that light levels commonly found in autumn or spring would be the minimum required to produce healthy turf and this would be in the region of 2 .5-3 .0 MJ m^{-2} per day . This would apply particularly to *L. perenne*, *P. pratensis* and *P. annua* swards typical in north-west Europe. A key issue in the effectiveness of pitch lighting systems is a logical deployment plan to ensure that the most shaded areas receive sufficient supplementary light. Modelling of light levels based on HemiView analysis (Newell 2000) can be used to indicate how much supplementary light is required on different parts of the playing surface on a monthly basis. Use of artificial light will have some effects on the pitch maintenance programme, particularly for mowing frequency and the amount of fertiliser applied as the length of the growing season is substantially increased.

iv) Moveable pitches Methods have been developed for moveable pitches whereby the pitch can be moved outside the stadium so that it can receive greater levels of natural light when not in use. Two main approaches have been used. At Arnhem in the Netherlands, the whole pitch moves out of the stadium on a hydraulic system. At the Millennium Stadium in Wales, the pitch was laid with 7,412 moveable pallets, each of 1.2 m by 1.2 m. There are clearly logistical issues in moving such pitches and it is essential that there is sufficient area next to the stadium (which is free from shade) for the pitch to be stored when not in use. With the apparent success of supplementary pitch lighting systems, the need for moveable pitches has reduced, except where the central area of the stadium is used for a wide range of other activities.

v) Air movement As well as improving light levels, a number of methods have been used to improve air movement as poor air circulation tends to cause problems of disease and surface algae because of excess moisture on the grass leaf and soil surface (Baker 1995a, b). Approaches have included wind tunnel tests at the design stage to establish stadium design and orientation to maximise air movement, opening shutters on vertical panels behind the spectators, open grills on gates to tunnels to help natural air flow, and use of fans of about 1.5 m diameter,

Conclusions

Large stadiums are potentially extremely difficult areas for grass growth, with the main problems being soil compaction and concentrated turf wear in areas with restricted light levels and poor drying conditions. Understanding and quantification of these potential problems is essential in the design of stadiums and, with sufficient investment in appropriate technology, the quality of the playing surface can be improved considerably, provided that usage levels of the pitch are realistic in terms of potential wear stress.

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