

9<sup>th</sup> Conference of the International Sports Engineering Association (ISEA)

## Artificial grass: A conceptual model for degradation in performance

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Accepted 02 March 2012

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### Abstract

Artificial grass pitches (AGPs), with long fibres and sand and rubber infill, have seen growth within many sports at both professional and community levels. Academic research has tended to focus on athleticism, injuries and the development of equipment and test standards, while research and development for the turf, infill and shockpad layers has generally been undertaken by the manufacturers. This has led to an under researching and / or reporting of the factors influencing AGP degradation and the subsequent effects on pitch performance. Long term testing has shown that as rubber filled AGPs age their performance worsens; they generally become harder and play faster with ball roll often reported as one of the first standards to be affected. This paper presents a hypothesised model to describe the numerous factors causing degradation and their effects on performance. It is designed as a useful tool for research aimed at assessing and improving current maintenance operations which will ultimately lead to increasing the useful life of AGPs.

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*Keywords:* Artificial grass; play performance; degradation; maintenance; durability

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### 1. Introduction

Artificial Grass Pitches (AGPs) are increasingly being selected over natural grass due to higher play capacity and revenue opportunities. This has led them to become a popular choice for community use, however AGPs are now also accepted at the professional level of the game within association, American and Australian football, rugby, baseball, hockey and Gaelic sports. It is estimated that there are over 1700 full-sized AGPs in England [1] with many more reduced sized pitches facilitating small sided games. AGPs are designed to meet specific criteria to ensure that they mimic the play performance of good quality natural turf, are safe and durable. However the standards [2] do not state how long a pitch should remain playable, which is an important aspect considering the high capital cost of the facility. An AGPs

life is dependent upon the amount of use, system design, installation quality, geographic location and the maintenance regime. The amount of use a facility receives will directly affect the useful life. Use should be calculated by factoring the number of players operating over the playing area for a period of time. For example, one ninety minute association football match consisting of 22 players will impact less wear on the surface than three small sided games across the surface with 6 players per team for the same period of time. AGP systems can be artificially worn in laboratory conditions, and separately the components can be assessed against the effects of weathering. However there is not currently a test method available which can wear and weather an AGP system and assess the change in performance. This leads to manufacturers having to predict the durability of the products prior to marketing the system as they would have to wait too long to assess the actual durability of the products from being installed outdoors.

Initially AGPs were thought to be virtually maintenance free, however it is now generally accepted by the industry and AGP owners that regular maintenance needs to be undertaken to regulate performance and retain a safe playing surface. The current maintenance techniques can be grouped into three separate categories (grooming, cleaning and decompaction) which have been developed by experience in response to observations. Grooming processes are concerned with regulating the infill depths across the surface and lifting the fibres so that they do not suffer permanent deformation. The various cleaning processes aim to remove the accumulation of detritus within the system from surrounding vegetation, soil and airborne particles. The final set of processes aims to mitigate the consolidation of the infill material which forms a harder surface, by decompacting the infill layer. However the effects of maintenance, and hence the optimal maintenance regime for a given AGP, have been under researched and are therefore still not fully understood.

A long term monitoring study has shown that as rubber-filled AGPs age play performance deteriorates (table 1). It was found that on average surfaces become harder and faster [3] with a trend showing that the lowest performing fields received higher usage. A shorter term study found that on average the ball roll distance had increased by 3.9m and the force reduction decreased by 4.9% during the first playing season of six AGPs [4]. This demonstrates that the performance begins to deteriorate relatively quickly. Joosten's [4] study also included player perception which found that 47% of participants rated the surface as too hard and 77% felt the ball roll was too quick. A recommendation from the study was therefore to amend the force reduction and ball roll standards. These studies do not include detailed information about the pitch construction or the maintenance and testing regimes. Despite these unknowns, it demonstrates the trend for the performance of rubber-filled AGPs to deteriorate with time.

Table 1. Average results from performance testing of 50 AGPs built in 2001/02 and retested in 2007 [3] with current FQC requirements [2]

Standard	2001 result	2007 result	Change	FIFA 2*	FIFA 1*
Force reduction	53%	43%	-10%	60-70%	55-70%
Vertical deformation	11mm	6mm	-5mm	4-8mm	4-9mm
Ball Roll	9.9m	13.4m	+3.5m	4-10m	4-12m
Ball rebound	0.82m	0.97m	+0.15m	0.6-0.85m	0.6-1.0m
Traction	45Nm	46Nm	+1Nm	30-45Nm	30-50Nm

The most common surfaces used today for soccer are referred to as rubber-filled or 'third generation' artificial surfaces. The carpets used within the majority of rubber-filled systems today range from 35-65mm where the carpet fibres are typically derived from polypropylene or polyethylene. The behaviour of the polymer is controlled through the use of stabilisers and fillers as well as the processing conditions [5], where further properties can be controlled by the density, cross-sectional shape, thickness and width of the fibre. The carpet layer is typically filled with a base layer of sand for stability and a top layer of rubber granules for controlling player and ball surface interactions. Depending on the design requirements

of the AGP, a shockpad of rubber or closed/open cell foam may be incorporated to control player and ball surface interactions, however some systems rely on the increased volume of rubber infill offered in the longer piled carpets. The carpet and shockpad layers are installed upon solid baseworks which will incorporate a system for removing excess water from the playing area.

The aim of this study was to bring together research investigating the factors which cause the performance of rubber filled AGPs to decline over time to form a model for pitch aging processes. Other than pitch usage in the Jan-Kieft study [3], reasons for the observed decline in performance is under researched and /or reported. The model has potential to be a useful tool for research aimed at improving current maintenance operations.

## 2. Model development

The requirement for a model was initially conceived to explain the observed decline in performance of AGPs over time [3, 4]. This led to the model being developed from the available research, material science and industry experience. The model comprises three elements; the degradation factors, mechanisms and effects (fig.1). During the literature review the main factor highlighted to cause AGPs performance to decline were from the mechanical interactions of players which is exacerbated by one or more weathering processes. The introduction of foreign detritus into the AGP system, e.g. vegetation, will also cause certain performance properties to decline. The second part highlights the mechanisms of degradation which describe what happens to the AGP components as they are used. The final part of the model features the system and component effects. Once one or more of the system effects deteriorates to a certain point, as determined by the testing standards / facility owner, the AGP will reach the end of its useful life, when it can be disposed, re-used or recycled and replaced with a new system.

### 2.1. Degradation factors and mechanisms

Mechanical wear from player loading is the primary factor identified causing AGP systems to degrade in particular the interaction between the boots and the system components. Players will deform the surface with a variety of forces, including shearing, torsion, compression and tension. AGPs will also be subject to wear from maintenance equipment and external events that may be held on the surface, e.g. music events. The mechanical wearing results in fibres splitting, fibrillating and flattening across the infill layer. The infill material may fracture under repeated impacts reducing the particle size distribution (PSD) of the system. The fibres and infill are further affected by abrasion caused by player movement, agitating the surface [6]. As the void space is reduced under the repeated loading from players the infill layer will consolidate which is further affected by a reduction in the PSD. Some infill material and to a lesser extent whole fibres, are removed through interaction with players and maintenance machines. Cyclic loading from repeated impacts of players and maintenance machinery may cause the shockpad layer to suffer some permanent fatigue deformation.

AGPs are mainly installed outdoors where many forms of weathering will affect the materials which can often work in tandem exacerbating the effects. The degradative factors include thermo-oxidation, photo-oxidation, hydrolysis and degradation from contact with chemicals. The strength of these degradative factors is dependent upon geographic location as the amount of UV radiation, temperature and rainfall varies. As polymers degrade their material properties can change e.g. increase in brittleness, loss of flexibility, loss of colour, and changes in viscosity. The system elements become more susceptible to damage from mechanical wear and are therefore referred to as secondary factors within the model. The shockpads are subjected to weathering from water causing an increase in brittleness but also fracturing from repeated freeze/thaw cycles during cold weather.

AGPs are affected by the introduction of foreign detritus within the infill layer that can consist of organic matter, soil and airborne pollutants. The system contamination will also include fragments from the infill and fibres as they break down from mechanical wearing. If this contamination is allowed to accumulate it can clog the system, through the reduction in void space within the infill layer [6]. As AGPs are predominantly used outdoors they exhibit good environments for organic matter to proliferate on the surface in the form of moss and algae, if left untreated.

## *2.2. System effects*

The degradative mechanisms will cause the system and component properties to change affecting both the performance and life of the AGP. Changes to the system performance can be measured using the standardised test methods within FQC [2], however they do not explain how the change in performance arises. This section focuses on linking the mechanisms of degradation with their effects on the system and components. For clarity within the model, the effects have been grouped together into permeability, hardness, friction and carpet wear.

## *2.3. Permeability*

The void space within the infill, shockpad and base layers will affect the permeability of an AGP system. The void space of the infill layer will be reduced by the introduction of fine detritus as well as infill consolidation. These mechanisms have the effect of reducing the water infiltration rate through the carpet layer as well as causing the infill layer to retain water for longer [6].

## *2.4. Hardness*

The system hardness will primarily be affected through impacts from players running, jumping and falling onto the surface. As noted previously AGPs will lose a certain amount of infill material over time and it has been demonstrated that as the rubber infill thickness within the carpet layer decreases, the system becomes harder [7]. It is anticipated that when rubber infill material is removed from a system without a shockpad, the increase in hardness will be even greater. A decreasing PSD for the rubber infill layer has been shown to produce a harder surface after artificial wearing from the Lisport device [8] which would suggest that a reduction of the void space in the rubber infill layer produces a harder surface. The hardness properties may be further influenced by rubber embrittlement due to the weathering processes. This embrittlement causes the rubber granules to be less deformable under impacts creating a stiffer layer. As the shockpad ages it may become harder due to embrittlement of water degradation. The shockpad will also suffer from fatigue however the effects are normally only small due to the protection offered from the carpet and infill layers. For this reason they are generally recommended that they will last up to two carpet cycles.

## *2.5. Friction*

The friction effect within the model refers to the interactions of player traction, skin abrasion and ball resistance. Severn [7] noted that an increase in net bulk density of the rubber infill layer causes an increase in the observed traction. The size of the rubber granules and carpet structure have also been shown affect the player-surface interaction [9]. The proliferation of moss and algae on the surface will cause the friction between player and the surface to reduce, producing a slippery surface.

Ball roll distance is thought to be affected by the bending resistance, friction and orientation of the fibres. It has been found that the ball roll distance increases after wearing from the Lisport device where the resistance of the fibres to loading has also been shown to be a factor [5]. Laboratory testing has so far only investigated the effects of heat and time under a static load but it is thought that the damage caused by other weathering processes will further decrease the resistance to bending of the fibres.

### 2.6. Carpet wear

As the AGP ages the fibres will fibrillate, fracture and break due to mechanical wear which is exacerbated by the weathering processes. As the pile height begins to reduce, it will have an adverse effect on performance properties as the amount of infill the system can hold will reduce. There will become a point where the system fails to meet the requirements within FQC [2] or other standards, however community use AGPs will often need to last longer in line with the business plan. Ultimately there will come a point where the pile height of the carpet has reduced such that the system becomes unsafe and the needs to be replaced.

## 3. The model

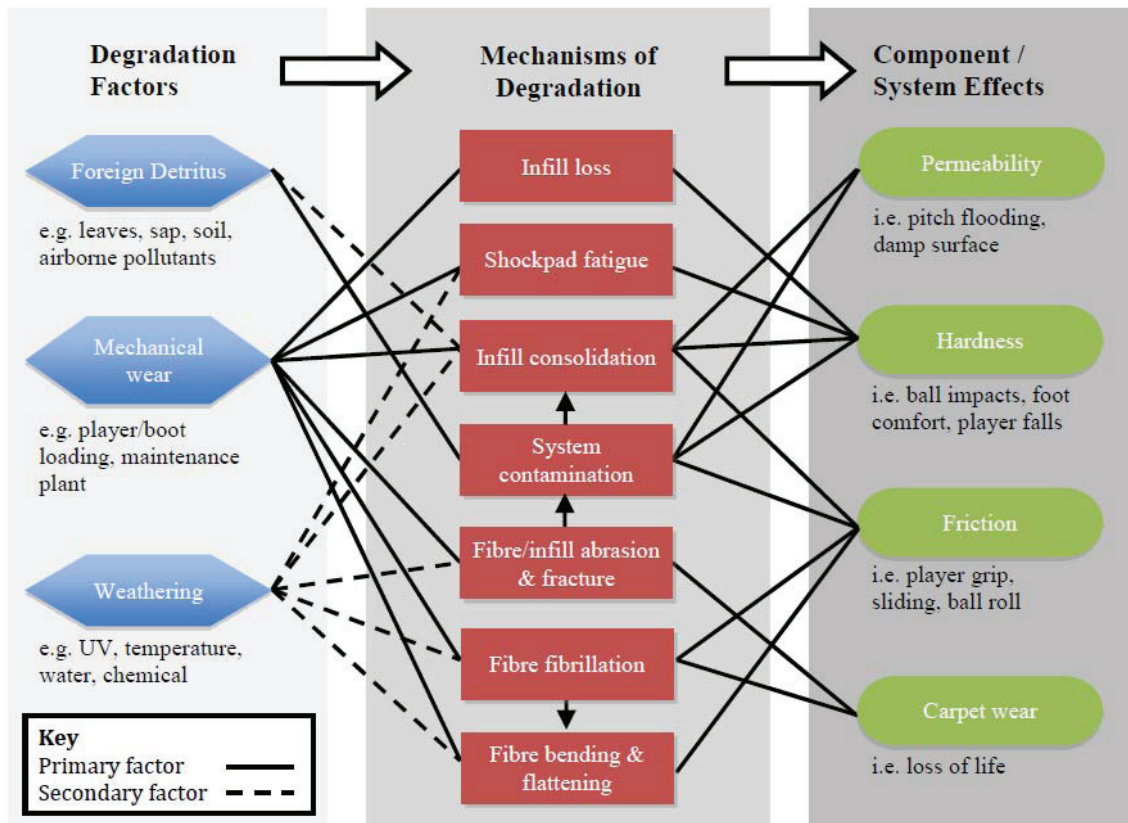


Fig. 1. Model describing the degradative factors and mechanisms which cause the performance of AGPs to decline over time

#### 4. Discussion

AGP performance is determined by a complex set of interactions between the carpet, infill and shockpad components. Hardness and ball roll properties of AGPs have been found to deteriorate with time [3], with the mechanical wearing from player interactions thought to be the primary factor initiating a change. The effect of the mechanical wearing will be exacerbated by weathering and the presence of foreign detritus causing the components to weaken and clogging of the system respectively. A reduction in the void space caused by consolidation and the presence of fine detritus in the infill layer was identified as the main factor causing the permeability of the system to change with time. An increase in the hardness of an AGP with time will be affected by the interaction of the infill changes such as infill removal, a reduction in void space and less deformable rubber infill due to weathering. The frictional properties of an AGP encompass the different elements of player traction as well as horizontal ball interactions. The ball roll will primarily be affected by the fibres resistance to bending. Player traction is affected by changes to the fibres and infill layer as well the abundance of detritus on the surface. Carpet wear is primarily due to mechanical wear fracturing the fibres which is accelerated by the weathering processes to the polymers.

This model is a useful tool for understanding the mechanisms and contributory factors which cause degradation and decline in performance of AGPs. The next stage of the research will be to evaluate the effects of current maintenance processes and their role in alleviating these mechanisms of degradation and the decline in play performance.

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