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11th conference of the International Sports Engineering Association, ISEA 2016

Maintenance of Artificial Turf – Putting Research into Practice

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Abstract

Artificial turf is successfully utilized around the world for many sports and many levels of performance and competition requirement. Quality assurance systems for elite and community level demand effective maintenance programmes to ensure adequate play performance, with increasing regulation and auditing in the UK. Past research is, however, very limited in this important aspect of artificial turf science. Practical experience is relied upon to plan for and deliver a range of maintenance techniques to sweep, clean, decompact, replace and repair artificial turf carpets and infills. Validation of these techniques has yet to be comprehensively undertaken and reported. The authors have collaborated with an industry maintenance provider over a 4 year period focussed on measuring the effectiveness of common maintenance practice. This paper aims to present an overview of the data and outcomes of detailed studies into power-sweeping, decompaction, and decontamination, in light of temporal pitch monitoring of changes in play performance. The field data provide a unique insight into the short-term and long-term benefits of these intervention processes. The data permit quantitative analysis of key issues such as: the build-up of contamination that clogs infill and can lead to surface flooding; compaction of infill under player loading and how this affects the system hardness; and how loss of fibre resilience influences ball roll behaviour. The results demonstrate that, for example, the monthly power-brushing of a surface may effectively reduce the rate of build-up of contamination by more than 1% per year. This alone can potentially add several years' playing life to a sand-filled pitch before costly deep cleaning or removal of the contaminated infill is required.

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1. Introduction and background

Artificial Grass Pitches (AGPs) are increasingly being selected over natural grass due to increased play capacity and revenue opportunities, and as a community amenity for high intensity multi-use. It is estimated that there are over 2500 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, 3, 4, 5] do not state how long a pitch should be expected to remain playable, an important aspect considering the high capital cost of facilities. It is now generally accepted by the industry and AGP owners that regular maintenance is needed to maximize the lifespan of a playing surface, better regulate performance and for the surface to remain safe for users. It is also an increasing requirement to carry out field compliance testing at intervals of 1-4 years to certify performance, adding to the demand for ongoing pitch care that is effective.

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 (or brushing) processes are concerned with regulating the infill depths across the surface and lifting the fibres so that they do not suffer permanent flattening. The various cleaning processes aim to remove the accumulated detritus within the system caused by surrounding vegetation, soil and airborne

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particles. The final set of processes aims to mitigate the consolidation of the infill material, which leads to an increase in surface hardness, 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. This paper aims to present some key findings from a recent four year primarily field based research project carried out in collaboration with a leading UK industry sports pitch maintenance company. The paper initially considers previous research related to maintaining AGPs and then documents some key areas of investigation and findings from the research project.

1.1. Previous Research

The study by McLeod comprised an extensive investigation into the effectiveness of maintenance on sand filled (2G) pitches [6]. McLeod recorded the level of contamination of the surface before and after specific processes, such as power brushing, deep 'clean' and infill replacement. He also produced a useful simple and relatively quick test for estimating the contamination concentration of a small sample of infill removed from the pitch surface. McLeod also investigated the effects of maintenance on performance of sand filled surfaces by relating infill quantity and contamination concentration to pitch performance test results [7]. From controlled laboratory testing he found that infill quantity significantly affected (hockey) ball rebound, ball roll distance and rotational resistance (grip). He concluded that regular drag brushing and top-up of infill levels was a key requirement. Furthermore, build up of fine contaminants significantly reduced the water infiltration rate, and also reduced ball roll distance.

A long-term monitoring study [8] from 2001 to 2007 in Holland conducted play performance tests on 50 long pile rubber crumb pitches (termed '3G') annually as well as auditing for usage and maintenance applied. This study demonstrated clearly that as 3G pitches aged, play performance deteriorated. In general surfaces become harder (less shock absorbency, reduction by 10%, and vertical ball rebound increased from 0.82 m to 0.97 m) and faster (ball roll distance increased from 10 m to 13 m), although grip remained similar (rotational traction little change from 45 Nm to 46 Nm). A further trend was identified that the lowest performing fields had generally received the highest usage. The author also attempted to relate these observations to the maintenance regimes followed and found that the pitches with the highest usage and lowest maintenance undertaken failed the highest number of test standards whilst the handful of pitches that regulated moderate usage and carried out maintenance more regularly passed the highest number of standard tests. The study lacked detail of the pitch designs however, and it was noted that the play performance standards (and some carpet technologies) changed during the study period.

2. Research Findings

This four year collaborative study utilized the same standard test methods as in previous studies, as specified by the international sports governing bodies, such as FIFA (Handbook of Test Methods [3]). In addition, further measurements were taken such as infill depth, masses of materials removed and alternative forms of measuring contamination through sieving. The following sections present outcomes from a number of sub-projects that quantitatively investigated: general long-term degradation behaviour; grooming to remove potential contaminating detritus (power-sweeping); and alleviation of increases in hardness from compaction of infill (decompaction).

2.1. Long-term Monitoring

Carpet wear

A brief summary of the estimated carpet wear rates, data derived from the company's database of site inspection data collected by different operators over several years, is given in Table 1. During site inspections (usually annual) several measurements are made of carpet fibre (pile) length by the operator with a simple ruler and entered into the company database.

Table 1. Summary data from the Company Database of (Annual) Pitch Inspection Data

	Long Pile Rubber Crumb (3G), n=165 pitches		Sand Filled (2G), n = 289 pitches	
	Age (years)	Pile loss (mm/year)	Age (years)	Pile loss (mm/year)
Mean	4.8	0.32	11.5	0.42
Minimum	1	0	1	0
Maximum	15	2.4	25	2

Further analysis of the sand based 2G systems, separating the systems into age groups yields a relatively consistent pile loss/year regardless of age; note approximately 50% of the database pitch population is more than 10 years old. For the 3G systems in general the rate of pile loss/year is observed to accelerate with age. Approximately 60% of the pitch population is 0-5 years old with an estimated average pile loss of 0.2 mm/year. The remaining 40% are over 5 years old and yield a pile loss of approximately 0.5 mm/year. The database does not include any pitch usage information, or other potential influencing factors, and is arguably not necessarily very precise. They do, however, form a useful guide, and with over 450 pitches included perhaps the large range of measurements reflects the large range in artificial turf products marketed and their quality and usage. Fibre wear might be assumed to be largely as a result of mechanical wear. In general, fibres in 2G systems stand up better from deeper infill relative to fiber length (>80%), but have a more abrasive infill relative to 3G. 3G fibres, however, are more slender and longer, and have less infill relative to fibre length (~66%) and tend to fold over and flatten perhaps more than they wear down.

In further related work, the play performance of 11 (3G) pitches was monitored over a 3 year period. In general, the pitch systems comprised long pile carpets of 40 to 65 mm and were 2-3 years old. All pitches were regularly maintained through standard in-house drag brushing and litter collections, power-sweeps done every 2-3 months, and decompaction approximately every 4 months (using metal tines dragged through the surface). The data collected represents a suite of play performance testing from annual visits for 8 of the sites, and more regular quarterly visits for 3 sites. All tests were repeated at 5 or 6 locations across the pitches, dependent on pitch area (6 locations on full size). Pitch usage data were not readily available at all sites but were in the range of 22-55 hrs/week (medium to high usage) for those logged.

The key outcomes showed that, in general, little change in play performance was occurring. The main exception to this was ball roll distance which had increased by up to 3-4 m at several sites (less rolling resistance). For the player interaction tests, rotational traction resistance (studded sole) was observed to have steadily increased at all sites bar one, typically by 4 Nm although at one site an increase of 8 Nm was recorded. Figure 1 demonstrates an important observation that the shock absorbency (also termed force reduction) changed little for pitches built with a shockpad (solid symbols), but noticeably reduced (became harder) for pitches without a shockpad - these rely on the infill for shock absorbency (open symbols). Exclusion of a shockpad saves on capital construction costs however the data suggests that the infill may be compacting more readily, or the system is more sensitive to any losses in infill depth. In contrast, at pitches without a shockpad the changes in vertical ball rebound (VBR) were similar, or only slightly larger, than for pitches with a shockpad. However, the absolute values of VBR for the 'no shockpad' pitches were higher immediately following installation hence will probably fail the upper rebound limit within a shorter period as they slowly get harder.

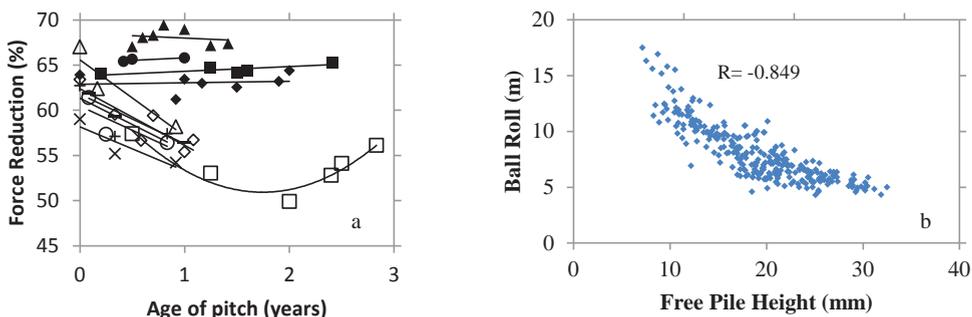


Fig. 1. (a) Changes in force reduction of 11 (3G) pitches over 3 years; (b) Relationship between ball roll distance and free pile height for 15 (3G) pitches.

Fibre Resilience and effect on Ball Roll

A further sub-project, on 3G pitches, illustrated the relationship between the ball roll distance (BR) and the height of carpet fibre standing above the level of the rubber infill, termed the 'Free Pile Height' (FPH). Ball roll distance is often the first criterion to result in a 'fail' from performance standards testing. A very strong relationship between FPH and BR was established for a new indoor pitch [9], gradually expanded to a larger dataset of 15 pitches (Figure 1b). The findings reinforce the need to keep fibres as upright as possible through regular grooming, i.e. power-sweeping, and also maintain the correct infill levels to provide the correct FPH. FPH measurement requires a simple low cost prism mirror gauge and camera, and is less affected by environmental conditions, such as wind on outdoor facilities, than the ball roll which uses a large ramp apparatus.

2.2. Degradation 'Model'

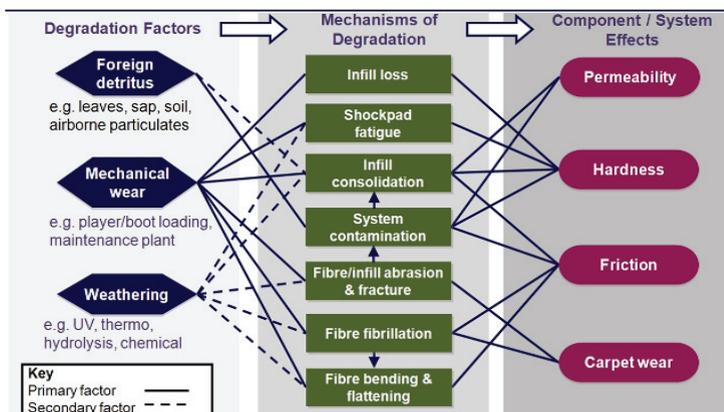


Fig. 2. Conceptual model of degradation [10].

The project team set about constructing a conceptual model of pitch degradation to aid discussion and debate around the long-term changes that may be expected (shown in Figure 2) and to aid focus for the sub-projects of the research.

A fuller explanation can be found in [10], and the model is considered useful to identify the aims of the maintenance processes, to alleviate and reduce both the factors and mechanisms of degradation. For example the important role of regular grooming and sweeping to remove the buildup of detritus, lift carpet fibres and redistribute infill. Whilst these degradation processes can be slowed, inevitably over time the carpet will wear and will need replacement.

2.3. Contamination of Pitches

Contamination is important to the play performance and specifically the drainage capacity (rain water infiltration rate) of the pitch. Previous work by McLeod on 2G systems [6, 7] appears to be the only work to document both the levels of contamination found and the short-term benefits of routine brushing and cleaning maintenance processes. In addition, McLeod usefully developed a relatively simple methodology to remove a sample of infill from the carpet insitu, and then test the concentration level, expressed as the % volume of detritus per unit volume of the whole sample of infill and detritus. In brief, the work observed that the level of concentration of contamination (CoC) for 12 sand filled (2G) pitches in the age range of 1-14 years (mean 8 yrs) was 5-9% (typical total infill depth around 20 mm). McLeod also noted from careful efforts to remove the infill in two layers that in many cases the upper infill layer had up to twice the CoC of the lower layer. These pitches were in general maintained to a reasonable standard with regular cleaning and brushing. McLeod measured the effects of power-sweeping and suggested levels of CoC at two sites reduced by 0.4-0.9% (from 5-6%) post treatment. He noted that the depth of brushing was approximately 2-3 mm. CoC measurements for a deeper clean (7-8 mm brushing depth) gave changes in CoC of 1.5-1.7% for the two sites. These measurements were made with his settling tube technique [7] and expressed as CoC for the whole depth of sample removed, despite the processes having restricted depth of influence. Furthermore, from a controlled laboratory study utilising a synthetic 'sandy loam' contaminant McLeod showed that a CoC level of greater than 10% became 'critical' to the performance of the carpet/infill system above which play performance was reduced, and surface water drainage capability was drastically reduced to below acceptable standards (for hockey) [6].

In the authors' more recent study, the contamination data make an interesting addition and complement McLeod's work. Five 2G pitches (20 mm infill depth) age range 8-10 years old were evaluated for CoC levels using the settling tube method, and gave an average CoC of 12%, range 8-14%. Careful extraction of the upper and lower portions of infill yielded much greater CoC in the upper 10 mm, in many cases between 1-3 times that of the lower 10mm.

To evaluate the level of contamination *extracted* during power-sweeping (as opposed to CoC within the infill before and after treatment) an alternative method to the settling tube was trialled. The amount of material removed by the machine and collected in the hopper was measured (by mass) from three repeat monthly visits at three 2G pitches (infill depth 15-18 mm), all aged 8-9 years and all regularly maintained. The material removed in the brushing hopper contained some infill (sand) and detritus material (typically fibre fragments, dust, organics, leaves etc.). The recovered material was sieved to determine the particle size ranges. The specification for the infill sand (Garside 2EW) size range was 0.15-1.18 mm, and material outside of this range was deemed a 'contaminant'. In addition, a loss on ignition test (LOI) assessed the combustible organic content. For the 2G sites the sieving results suggested detritus of between 25-38 kg per year (of which approximately half, 13-21 kg, was organic) was removed by the power-sweeping. The estimated CoC % can be expressed as the mass removed as a proportion of the total mass of infill in the pitch, or as a proportion of the infill volume actually *agitated* by the brushing. The brush depth was set at 2-3 mm (McLeod confirmed this as the approximated depth). Assuming a 3 mm depth gave a contaminant concentration (by mass) range of 0.06-0.2% removed by (dry) mass per year. However, it is useful to consider the volume this contamination may occupy, and from laboratory appraisal using the settling tube this suggested a scaling factor and from this a volumetric CoC of between 0.4 to 1.3%. This level of removal of contamination by simple frequent power-sweeping is considered a significant proportion of what may build up on the pitch surface and may be expected to find its way into the deeper infill with time.

Three 3G pitches were also studied, 4-6 years old and 35-40 mm pile length. The total mass of contaminant removed per year, based on sieving and the mass of material outside the infill specification size range of 0.6-3.2 mm, was in the range of 20-28 kg. These masses were similar but a little lower than the 2G pitch data, and suggest CoC removed in the range of up to 1% (by volume). These values are possibly conservative as it was observed that some carpet fibre fragments were retained on the same sieve sizes as clean infill. Furthermore, the study took place February to April and more contamination is expected in the autumn.

2.4. Decompaction of 3G Pitches

A process of decompacting the rubber crumb infill is common practice within the industry, primarily implemented from observations of pitches becoming harder with use. A common system is to drag a large width metal tined rake through the infill, set to a depth of approximately 15 mm, and is commonly carried out monthly in conjunction with a power-sweep. The tines agitate the infill to loosen it and reduce the density, hence the term 'decompaction'. The machinery may perform multiple passes and operators are required to use their experience to determine the appropriate depth and number of passes. In principle if the infill is looser the increased void space will improve drainage infiltration rate, soften the pitch and increase the shock absorbency and reduce the ball bounce. A series of laboratory trials were carried out to estimate the potential infill density increase that might occur through repeated mechanical compaction [11]. The infill bulk density of the crumb rubber infill (dry) was estimated from the mass/unit area applied and the depth of infill. The volume of fibres within the infill layer was then estimated and subtracted to estimate the *net infill bulk density* (NIBD). It was assumed the lower sand infill layer remained at the same volume.

Compaction of the rubber infill with a (standard) studded roller up to 500 passes produced a NIBD range of 0.45 – 0.73 g/cm³ for the loosest to densest states achievable. This corresponded to changes in Force Reduction of 66% to 50% and in VBR of 0.50 m to 0.95 m. These changes in play performance were deemed large, and as a consequence large changes were expected for the field results from before and after a decompaction process. However, in the field the initial density is not known and as a result the *potential for further changes in density* through agitating the infill is also unknown. Measurements of infill depth before and after did show an increase in depth of typically 1-3 mm indirectly demonstrating a (small) change in density. The research team developed a novel approach in the laboratory whereby repeated impacts of the Artificial Athlete (AAA) test measuring FR showed the potential for further compaction through the changes in FR, and this was correlated to the initial density state. However, in the field the application of repeated impacts with the AAA tended to suggest that the infill was already at the lower end of the NIBD range, and little change was seen in the FR values pre and post decompaction. VBR was identified as more sensitive to the changes in infill state than FR, however, with changes of 0.05 m to 0.18 m observed from decompaction at 5 AGP sites. The comparison between the field sites and the laboratory trials was further complicated by the variations in carpet types, e.g. fibre dimensions and tuft spacing, often the detailed information is lost for older field sites. However in general no sites displayed changes from decompaction of the magnitude expected from the laboratory controlled testing [11].

Since this study was published, the decompaction maintenance process applied has been enhanced by adding more passes of the agitating tines to a greater depth of approximately 15 mm. Trials across 5 sites have compared the old versus new enhanced process, and shown the newer process to effect larger changes in infill depth, VBR and FR. However, again the site measurements demonstrated similar but notably smaller magnitudes of change, caused by reducing the NIBD following the decompaction process, than the extremes obtained in the laboratory. At sites with regular brushing and decompaction it may be that the infill is unlikely to reach the higher end of the density range achieved in the controlled laboratory testing. The research is ongoing in this specific area to further enhance and optimize the decompaction process.

3. Discussion

The data presented above, together with that from the few previous studies that have monitored the long term performance of AGPs [4, 5], demonstrate the inevitable wear and tear and changes in play performance that might be expected during the life of an AGP, 2G or 3G. Carpet fibres wear down, they bend and flatten and may not recover well, infill compacts and can trap finer particles leading to many issues through ‘contamination’ and loss of drainage capability. Manufacturers of artificial turf carpets strive to balance the need for soft fibers for player (skin) interaction with the need for fibers to be resilient and recover after bending, especially for consistent ball roll. Increasing hardness (underfoot comfort) and increase in ball bounce and ball roll are symptomatic of the long-term changes observed. Changes in ‘grip’ are observed to be less of an issue it seems based on mechanical testing data. However, the grip (traction) test is simplistic and players are likely to adapt to the surface changes through changes in footwear or movement. The importance of regular maintenance is evident to maintain levels of performance by: drag brushing for levelling the infill; power sweeping to help keep fibres upright and remove surface detritus; and decompaction to keep the infill loose and reduce hardening effects.

Little quantitative data and evidence existed prior to this long-term (and ongoing) study. However, there exists a real challenge in that the carpet products being installed are changing in design, with new infills and shockpads also being introduced. It is also challenging to consider or evaluate in detail the effect of the AGP’s local environment on the research findings, such as weather e.g. rainfall and UV radiation. The potential impact of chemical degradation is also less clear. The effects of mechanical wear are perhaps easiest to hypothesize.

The contamination data presented from this and McLeod’s study [6] showed that, despite brushing, contamination levels do inevitably increase over time. The detritus materials clog up the infill and reduce infiltration rates, ultimately affecting play performance in general. McLeod suggested a CoC of >10-15% (by volume) as potentially critical, albeit this was from a laboratory study and utilized a sandy loam as ‘simulated’ contamination. In this research real contamination from site was used in the controlled laboratory study. The CoC % site data presented for 2G pitches of 8-9 years old were close to the ‘critical’ limit, despite their ongoing maintenance. This work suggests brushing may remove potentially around 1% contamination per year, and this suggests then that the rate of build-up of contamination is greater than 1% and possibly up around 2% or more. Furthermore, there is some evidence that the contamination is more concentrated in the upper zone of the infill, raising the question as to how best to estimate the ‘CoC’ – presently averaged over the infill total volume. In addition to further work to corroborate these findings, it seems prudent to trial further improvements to the maintenance to extract more of the contaminants through brushing/sweeping. It is also considered important to recognize the role and importance of regular leaf and litter collecting to preempt their possible influence. The data might also suggest that for a poorly maintained field, contamination related problems such as poor drainage could appear in as little as 5 years. It is clearly challenging to take into account all the variables that may influence AGP degradation and contamination, however, and provide accurate estimates of quantities and effects.

Decompaction appears to have some useful effect in ‘loosening’ the infill, increasing the infill depth and in particular reducing the ball bounce. However, there is a requirement for better understanding of how much the infill can compact and cause changes in hardness in practice and then be alleviated. Laboratory investigations suggested larger potential changes in infill density than has been observed indirectly through field monitoring to date.

The combined data and findings reinforce the conceptual degradation model that was proposed early in this research program. The aim is to develop it into a more useful asset management tool for pitch life modelling and plan maintenance interventions, clearly driven by cost also.

A related and important concern often raised by owner/operators of AGPs is that of potentially ‘over-maintaining’ a pitch perhaps leading to accelerated fibre wear and mechanical degradation. This has not been studied in depth, however McLeod [6] concluded from controlled laboratory brushing, simulating a 15 year life with 4-10 power-sweeps per year, that whilst some splitting of fibrillated fibres occurred little damage to the fibres was observed. Similarly, Fleming [12] reported on a fibre brushing damage study across a range of carpets and concluded that a small percentage of fibers (monofilament and fibrillated) were observed to split or break from a very high number of repeat passes of a powered rotating stiff brush.

From the work presented herein, previous studies and current industry guidelines recommendations for maintenance practice can be proposed. A formal and well-structured maintenance plan should be followed *and recorded* for all AGP’s, 2G and 3G. For moderate to normal use an effective generic maintenance suite is suggested as:

- Daily - Safety inspection, check surface and seams for damage/failure, pick litter.
- Weekly – Drag brush to level infill and lift fibres 1 or 2 times, can be done in-house with basic machinery and drag mats or specialist static brushes (e.g. of flexible stiffness). Check and top up infill at high wear areas.
- Monthly - Rotary (power) brush and clean the surface, pick up fibre debris, detritus, agitate infill. For 2G sand filled surfaces relatively shallow depth, 2-3mm (if very wet weather infill clumps and can pick up too much infill). For 3G rubber crumb can adjust to brush a little deeper (less resistance is encountered). Requires specialist equipment. Chemical or vegetation treatment of the surface for any weed, moss or algae growth.
- Yearly - At least 3-4 times per year on 3G, a decompaction to agitate the infill combined with power-sweeping to vacuum off detritus. Check and top up infills. For 2G a deeper power brush (termed ‘revitalisation’) can remove the top 10 mm of sand infill, separate out ‘contamination’ and replace the infill, with specialist equipment. Annually detailed inspection of the site and testing to evaluate carpet wear, infill contamination, key play performance tests (sport dependent but minimum of FR, VBR, infill depth and free pile height/Ball roll). Every 5 years or so, if experiencing poor drainage of a 2G AGP, consider infill removal and replacement (termed ‘rejuvenation’).

Experience has suggested that with more frequent monitoring, visual inspection and direct performance testing, the ground staff or specialist contractor can develop a more fine-tuned maintenance schedule; such as setting brushing depth, frequency of infill top-ups and utilizing the (annual) inspection test data to consider the indicators of contamination building up or hardening through compaction. Whilst sport governing body regulations are tightening, there still exists a very large pool of AGP pitch assets used at community level that receive very basic maintenance and are likely of much poorer quality as a result.

The research team is extending the research work at present to provide further evidence and enhance practice for specific processes, and develop/evaluate new methods of AGP aftercare, e.g. end of life carpet and infill recycling.

4. Conclusions

Very few studies have previously focussed on the long term monitoring of AGPs and the effectiveness of maintenance processes. Very limited quantitative data was available prior to this study. Collectively the findings show the inevitable degradation of the sport surface system, and help identify the benefits of maintenance in slowing this degradation process. Contaminant concentration inevitably increases with the age of the AGP, and reduces the rainfall infiltration rate, and if under-maintained severe accumulation of contamination may occur within a few years after installation. Regular power-sweeping was effective in removing a significant level of this contamination. AGPs will get harder and ball roll become faster, partly due to compaction of the infill and part due to fibers bending and not fully recovering. Brushing aided fiber resilience, and the decompaction process was effective in increasing shock absorbency and ball rebound, and reducing changes in the net rubber infill bulk density. However, the field data changes recorded for decompaction were of a lower magnitude than could be achieved in the laboratory. A field method for estimating infill state (relative density) would be useful in this regard.

The study findings demonstrate the importance of regular and appropriate maintenance of AGPs to enable them to continue to perform well and meet their life expectancy, and a generic maintenance schedule is offered which may be adjusted based on type of the AGP, location, weather conditions, etc. Further evidence needs to be collected to improve current practices for AGP maintenance and develop better methods to measure the effectiveness of maintenance processes.

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