

7th Asia-Pacific Congress on Sports Technology, APCST 2015

Investigating Shear Stability of Rugby Union Natural Turf Pitches

F.D. Anderson^{a,*}, P. Fleming^a, P. Sherratt^a, K. Severn^b,^a*Sports Technology Institute, Loughborough University, Loughborough, LE11 3QF United Kingdom*^b*Labosport UK Ltd. Unit 3, Ariel Way, Nottingham NG15 6DW United Kingdom*

Abstract

The stability of natural Rugby Union pitches continues to be a recurring problem at all levels of the game. The effects of poor turf stability are seen when the pitch surface shears under player loading, creating divots and an uneven surface. However, perhaps surprisingly, there is no objective quantitative mechanical test method for assessing the stability of the natural turf, with regard to shear resistance. This paper details initial work undertaken to assess the effectiveness of current shear testing apparatus in predicting stability for Rugby Union. It has been suggested there are two failure areas in pitch constructions: One on the surface and one deeper in the soil. The results show variability in natural turf constructions, and that current shear test methods are less effective in sandy soils. Penetration readings were relatable to hardness, however shear stability testing requires development

© 2015 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Peer-review under responsibility of the the School of Aerospace, Mechanical and Manufacturing Engineering, RMIT University

Keywords: Rugby Union; Natural Sports Pitches; Hybrid Sports Pitches; Shear Stability; Scrummaging;

1. Introduction

Instability of natural grass turf pitches has been a problem in sports such as rugby union for some time. In rugby football, high horizontal forces generated during play can damage the turf grass and also cause shearing of the supporting soil and roots. This damage causes loss of grass cover, and undulations in the pitch surface, and potentially loss of revenue for the pitch operator. It is usually exacerbated by poor weather conditions such as heavy rain, or post freeze thaw. Recent studies on professional rugby union packs suggest peak horizontal forces of up to

* Corresponding author. Tel.: +44(0)7731390852.

E-mail address: F.Anderson@lboro.ac.uk

13 kN can be generated in the scrum [1]. Currently the average professional player weighs as much as 110 Kg, higher than for previous generations of the game, and improved physical conditioning contributes to a need for greater resistance to damage for the turf grasses. To improve turf durability a number of modern 'hybrid' pitches have been developed which include some form of soil reinforcement, or a combination of natural and artificial turf. Also increasingly sand-based subsoils are used to enhance drainage and reduce moisture susceptibility of clay based systems, but at the cost of increased nutrients needed to feed the plant growth [2].

However, there have been very few investigations into measuring the turf-soil stability. Current understanding suggests that maintaining the correct soil moisture content, drainage (infiltration) capacity and grass coverage are key factors for playability and durability [2,3]. In addition to the intrinsic strength of the soil-water mixture it has been suggested that the grass root and leaf system can increase the 'stability' of the upper soil by 300% [4]. It is well known that the balance of sand clay and silt in the topsoil and sub-sol affects the moisture sensitivity of the soil strength [5], as clay rich soils are more likely to hold water and as they get wetter deform more easily and plastically under load [6]. Best practice requires constant visual inspection, taking small cores and expert advice to maintain good turf pitch health. However it is uncommon for routine mechanical test measurements to be taken regarding play performance or stability, unlike in artificial pitch assessments. From observation of video footage and anecdotal opinion from groundsmen, instability of the turf seems to occur by two mechanisms under the player loading. It appears that if the boot force is high enough and the upper turf weak enough then shear failure can occur between the boot studs and the turf sward (grass body, upper root in the topsoil). A second mechanism is postulated whereby the failure zone within the turf system is deeper, below the topsoil, at a weak horizon such as between specific soil layers. To date these mechanisms have not been investigated.

This paper presents part of a study investigating the engineering behaviour of natural turf, with a focus on stability. The wider study is linked to evaluation of match and training venues for the 2015 world rugby cup (RWC). The data presented explains aspects of the pitch constructions and their behaviour under different stability related test methods. The objectives included; evaluation of a variety of mechanical test methods for evaluating stability related properties of natural turf, investigation of pitch construction types, and the link between the pitch physical properties and potential for instability under load.

2. Methodology

The wider study is investigating 53 natural turf and hybrid pitches in England and Wales to both select appropriate venues for matches and practice for the 2015 RWC and to provide feedback and guidance regarding pitch quality. These indicators of quality do not currently include measures directly relating to stability. The sub-study presented here included aspects of the traditional agronomic data collection regarding pitch health and physical samples and also mechanical test methods to evaluate the behaviour of the turf under load. Turf stability and design requirements for a new test method. The agronomic data was collected by intrusive coring. The cylindrical 40 mm diameter corer was driven to a depth of 220 mm. The sample was then used to determine the grass root zone, soil textures and layers, and a probe inserted to measure moisture content (% by volume) of the layers. Grass coverage was assessed using a visual scale at each test location as a score out of 100%, and grass height measured. The equipment used in the wider study were selected to quantify aspects of the turf behaviour under load including hardness, stiffness, resistance to penetration, resistance to shear, and play performance regarding ball interaction. However, for this paper the focus is on hardness, penetration and resistance to shear by a variety of methods. These mechanical test methods were selected from the wider sport surface industry. The test methods presented here include the Clegg impact hammer (CIH) (2.25 kg) for surface hardness, the rotational traction device (RTD) for boot-surface stability, and the Going Stick (GS) which measures both penetration resistance and resistance to shear at a depth up to 100 mm. Of these the RTD is the only common test in turf assessment for sports such as rugby and football. The 2.25 kg CIH appears in some standards to assess when a surface is too hard and unsafe [7].

The CIH measures the deceleration on impact, of the 2.25 kg mass from a drop height of 0.45 m, in units of gravities (g). The RTD measures the resistance to rotation of a 110 mm diameter test disk with six 13 mm long studs equally spaced on its base. The apparatus total mass is 46 kg, it is lifted and dropped from 60 mm to ensure good stud penetration prior to rotation. The operator then rotates the apparatus with a torque wrench to determine the peak

torque. The GS was developed for the assessment of horse racing track ‘going’. Used by racetracks to inform maintenance and horse trainers and pundits as to the surface state. It is a simple to use portable tool, and resembles a garden spade handle with a single metal probe (100 mm long by 21 mm wide) at the base. For a standard ‘going’ test the probe is pushed into the ground to 100 mm and then pulled back by the operator to approximately 45° to derive the going number, a combination of the penetration and shear resistances. Previous work [8] showed some promise for the GS in monitoring turf strength of (clay based) football natural turf pitch over two seasons, and suggested correlation with the CIH and RTD. The test sites were selected to represent different pitch categories (based on soil or system proprietary type) from the pool of the wider study assessing 53 pitches (Table 1). The categories comprise: Clay Based/Native Pitch (variations of this type are very common at lower levels of competition); Sand Dressed; Sand Based; Fibresand (FS)/Fibrelastic (FE); Desso Grassmaster (DG); Mottz System. All are common systems in use, the native and sand-dressed are the most common, apart from the Mottz which is gaining in popularity.

Table 1 presents the pitch types investigated in this paper. Pitches 1 (P1) and 2 (P2) are well maintained university pitches used for first-team rugby union and association football respectively. P1 is a native clay systems with sand dressing. P2 is a 2-year-old FS system. FS is a sand-based system with on average 0.3% by mass of small synthetic fibres that provide local reinforcement. Pitch 4 (P4) is a well maintained and heavily used elite rugby union training pitch, a FS system, and was reportedly due to be de-compacted. Pitches 3(P3), 5(P5) and 6(P6) are also training pitches, not so heavily used relative to the other pitches, reportedly. P3 is a well maintained 2-year-old FS system. P5 is a well maintained 6-month-old DG system. The DG system comprises of 200mm long synthetic fibres inserted into the existing turf to reinforce it, leaving approximately 20 mm above ground level. P6 has a 6-month-old Mottz system, reportedly poorly maintained. The Mottz system comprises a bio-degradable synthetic mesh with 50 mm long synthetic fibres. Within this artificial carpet 50 mm of topsoil is added and seeded to grow natural turf. At each venue the corer was used near the center of the pitch to extract a sample. The moisture probe was inserted into the core at intervals of 0, 25, 50, 75, 100, 150 and 200 mm. The GS, CIH and RTD were used in six positions across the pitch with three replicates at each position. In addition, the GS was used to take measurements at depths 25, 50, 75 and 100 mm. Grass length and coverage was also assessed at the same six positions. Coverage was rated as good (90-100%) medium (80-89%) or poor (<80%). Weather conditions were generally dry in the period of days prior to the data collection, except at P1, P2 where some rainfall occurred the night before testing.

3. Results

Table 1 presents the soil descriptions derived from the agronomy standard method (BS 3882:2007), the effective root depth (depth of the major system) and maximum root length were both derived visually from the cores. Fig.1 shows visually the soil profile with moisture contents added for comparison. The results show a large variation in water content and in general the clay soils are wetter than the sandy soils, as might be expected. P1 has a uniform clay soil texture below the top 15 mm, and a relatively high water content. P1 grass coverage was ‘good’, grass length was high (rugby specific) with large grass root length. P2, P3 and P4 are interesting to contrast as they are all FS systems but to slightly different depths. They all gave similar effective root zone depths, and P2 recorded the maximum root length. The FS P2-4 showed large variation in water content, P2 generally the largest (possibly due to the recent rain in the upper layer), P3 with a silty clay subsoil had lower content than P2 but a higher content than P4 comprised of more sand. P4 also had exhibited less grass coverage. P5, with the artificial fibres to depth exhibited the lowest moisture contents in general. P6, the Mottz artificial carpet based system, caused issues such that extracting a full core was not possible. There did appear to be moisture trapped at the base of this system. The grass coverage was poor, and root depth poor, though this field was reportedly poorly maintained.

The GS results for shear and penetration resistance are shown as boxplots in Fig 2. The box plots show the full range of values measured across the 6 locations as the whiskers, the median as a solid bar, and 25% quartiles in the size of box. P4 FS system gave the highest penetration resistance at 100 mm (108 N), of any one position. A trend of increasing average resistance with depth was observed for all pitches in general.

When considering averages P4 and P6 gave consistently high values. However the Mottz system has a reinforcing layer at the carpet base at 50 mm depth. P3-6 showed a large range of values across the field. The lowest penetration resistance at P1 (individual and median values) is perhaps attributed to the high water contents in the clay rich soil. The CIH results for hardness (Fig.3a) in general support pitch ranking shows higher peak deceleration (i.e. hardness) at P4, P5 and P6 and lowest results at P1.

Table 1. Pitch construction details and grass turf measurements.

Test Pitch	Pitch Construction Type	Soil Texture to 200 mm	Grass Coverage/ height / effective Root / maximum Root Length
Pitch 1	Sand Dressed	<5 mm Sandy Silt Loam 5 mm -15 mm Clay Loam, 15mm - 200 mm Compacted Clay	Good/ 60 mm /80 mm / 115 mm
Pitch 2	Fibresand	Sandy Clay Loam with fibres 10 mm, Sandy Silt Loam with fibres 100 mm Silty Clay 200 mm	Good / 20 mm / 90mm / 220 mm
Pitch 3	Fibresand	<5 mm Fibresand, Sandy Clay 5-70 mm Loam Fibresand, 70mm-200 mm silty clay	Good / 20 mm / 90 mm / 120 mm
Pitch 4	Fibresand	<150 mm Sandy Clay Loam fibresand, 150-200 mm loamy Sand	Poor / 20 mm / 90 mm / 120 mm
Pitch 5	Desso Grasmaster	<100 mm Sandy Clay, Loamy Sand 100- 200 mm synthetic fibres throughout to 240 mm	Good /20 mm / 80 mm / 90 mm
Pitch 6	Mottz System	<10 mm Loamy Sand, Sandy Clay Loam and synthetic fibres10- 50 mm, Synthetic carpet 50 mm Silty Clay 50-200 mm	Poor / 20 mm / 50 mm / 55 mm

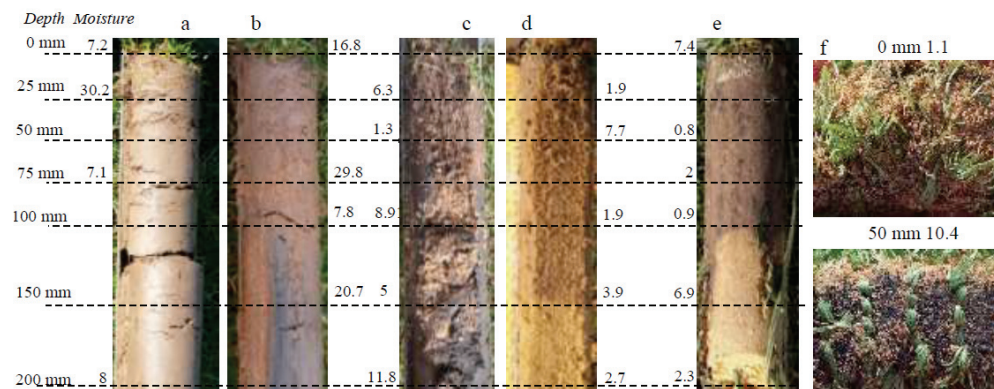


Fig. 1. Pitch sections from the extracted core samples showing soil layers visually and with moisture content (by volume) added for comparison, for pitches 1-6 (a –e) respectively. The Mottz system shown in (f) could not be cored, the diagrams show the top and base of a small sample of the carpet only.

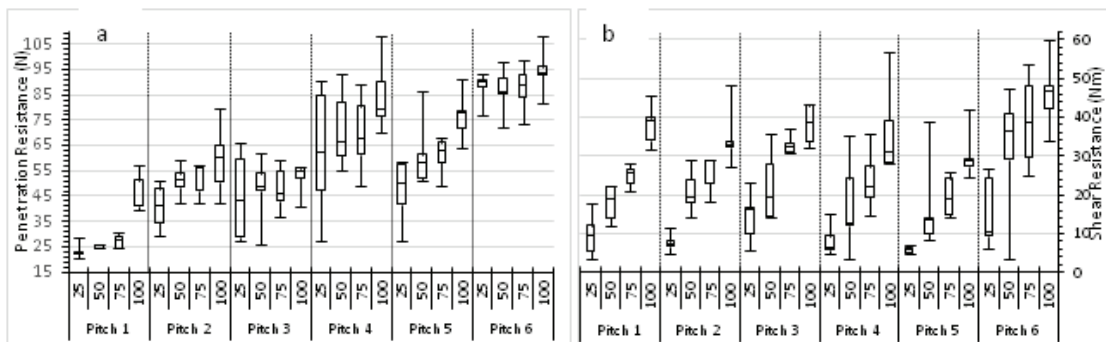


Fig. 2 (a) Going Stick Penetration Results (b) Going Stick Shear Results

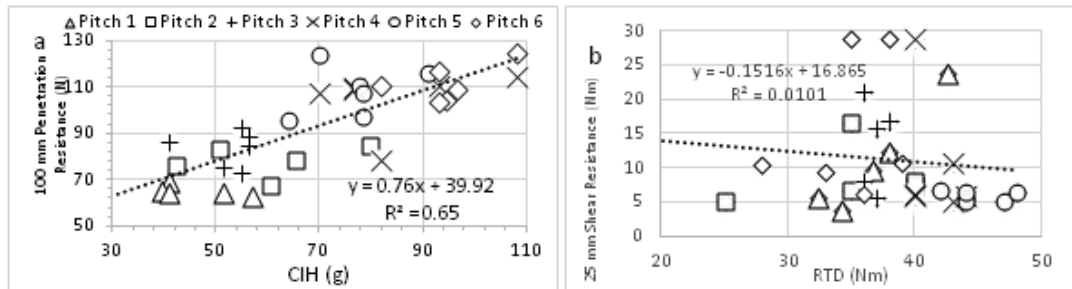


Fig. 3. (a) Average Clegg Impact Hammer vs 100 mm Penetration Resistance (b) Average Rotational Traction vs 25 mm Shear resistance

The GS shear resistance data shows a trend of increasing resistance with depth of penetration of the blade. The shear resistance at any depth is probably a function of the size of failure wedge of soil occurring along the full length of the penetrating blade. Large ranges of values are evident at each of the pitches, and in general the average values are similar between pitches for 100 mm penetration with values around 30-40 Nm. P6 is ranked the highest, probably due to the carpet base at 50 mm. The shear resistance data provide little evidence of a weak zone at any depth, and do not seem affected by the soil type, or water content. The 25 mm depth data aim to represent the upper sward, and might be expected to show a relationship to the RTD data (Fig.3b). The RTD average data show similarity across all systems at around 35 Nm except for P5 whereby 45 Nm was measured. The RTD is, however, known to have poor reproducibility, influenced by the operator [9].

To investigate potential correlations Fig.3(a) also presents the results from the average third drop of the CIH versus the GS maximum penetration resistance for 100 mm depth. The CIH has an impact diameter of 50 mm and elastic theory suggest a zone of stressing of around 100 mm. The figure shows a correlation, albeit with large scatter ($R^2 = 0.65$). Fig 3(b) presents the RTD peak traction versus the GS shear resistance from a depth of 25 mm (representing the upper sward). The data points presented are the average of the three repeat tests at the six positions across all the pitches. There appears little correlation and very large scatter ($R^2 = 0.01$) in both data sets. This is in contrast to Caple [8] with a more positive relation between the GS and RTD. However, in his work the sports fields were predominantly clay based, in contrast to this data set which is from largely sand based and hybrid systems. It is also interesting to note however that the RTD data fall within published guidelines for rugby and football of between 25 and 50 Nm. On this basis the sward might be expected to remain stable during play. In Australia guidelines suggest 2.25 kg CIH readings should typically fall between 50-120 g, and above 120 g above 120 g being unacceptably hard [7].

4. Discussion

The data gathered in this initial study has highlighted the variable range of constructions utilized in natural turf (and hybrid) systems, and a large range of water contents in the upper and lower soil layers. The pitches evaluated are at the elite level of use for matches or training. It is clear that many systems utilize sand dressing, high sand content and a bespoke FS mix – to reduce the moisture susceptibility aspects of clay rich soils and their propensity for plastic deformation and lower strength at high water contents. However, further detailed analysis of the particle size distributions is necessary to refine the soil descriptions (poor drainage characteristics outside the scope of this study). The CIH and RTD data can be combined to suggest the pitches evaluated were within the acceptable range of hardness and traction respectively. The GS was intended to evaluate if it is usefulness as a rapid pitch assessment tool, and specifically in relation to measuring resistance to shear at depth to determine if a weak layer may exist leading to a potential deeper failure under player loading. After review of the literature for soil shear related tests no other routine test was found that had this potential, notwithstanding the small hand vane and hand penetrometers used in geotechnical investigations. Although the data in this study was not included the portable hand vane was evaluated and found to provide no consistency in its measurements and was discarded – it is not recommended in sandy soils. The GS proved to be a quick and easy to use tool. However, from the data presented it is hard to conclude at this stage as to its effectiveness for evaluating general pitch stability. The penetration resistance showed

some positive relation to the CIH, and a form of penetrometer may be useful in identifying layers and relative strength – albeit under vertical loading. The primary issue for rugby however is to ensure the turf and sub-soil has sufficient stability in regard horizontal shear forces.

The resistance to shearing from the tests evaluated in general showed similar average readings across all of the pitch types, with some scatter in the individual locations. It is interesting to postulate the possible reasons and mechanisms during the testing. In clayey soils (>15%) when the pores are saturated with water they behave in a specific way under load - termed undrained if loading is not very slow. The shear strength then remains constant independent of load magnitude. Strength is affected by changes in water content however. Clays also hold water with atomic electrical forces such that it is hard to squeeze water out once held within the small pore spaces. Whilst the grass root enhances the strength in principle the strength will remain stable if the water regime remains stable, hence the need for good drainage on clay based pitches. In contrast a sand rich soil (with low clay content) behaves differently and obeys classic friction laws whereby the normal force and friction coefficient control the resistance to shearing along a defined plane. Depending on the sand particle size, shape, and packing, the friction coefficient (termed angle) remains relatively constant, and is not affected by water content unless the water is confined. As a consequence, the shear strength of a sandy soil is primarily controlled by the initial state and additional load. The RTD applies a normal compressive static force of approximately 450N during rotation. An average mass rugby player could apply a static compressive force of up to 550 N (through each foot). The GS applies no such compressive force during shearing, and as such is measuring a form of unconfined strength. The GS may show relative differences in the shear resistance of turf samples but cannot replicate the static compressive loading. In a clay rich soil however, the GS may prove to be a useful indicator (from frequent monitoring) of the effects of changes in water content by assessing changes in shear resistance as has been demonstrated [8]. It seems appropriate that a shear stability test for turf may need to apply appropriate compressive loading during shear. Whether the RTD device applies an appropriate static load and whether the large strains it applies before reaching a maximum are applicable to the behaviour of the turf under a rugby player loading is more debatable [9].

5. Conclusions

The study investigated the shear stability of natural pitch constructions using a number of methods from agronomy, performance testing and trialing reliable equipment. The core results suggest that the elite level pitches are varied in their construction and hybrid systems are prevalent to improved durability. In general mechanical testing suggested the sandier soils gave higher hardness. GS shear resistance showed no differences between the soil types, however results suggested correlation between the CIH and GS.

Acknowledgements

The authors kindly acknowledge Turftrax Ltd. for the loan of the Going Stick

References

- [1] Saletti D, Chicoulaa G, Raszdowsky M, Dreville X, Piscione J, Retière D, et al. Kinematic and dynamic responses of the scrum. *Comput Methods Biomech Biomed Engin.* (October 2013):204–5.
- [2] James IT. *Natural Turf Sports Systems*. Routledge Handbook of Sports Technology and Engineering. New York: Taylor & Francis; 2014.
- [3] Tengbeh GT. The effect of grass roots on shear strength variations with moisture content. *Soil Technol.* 1993;6:287–95.
- [4] Serensits TJ, McNitt a. S, Petrunak DM. Improving surface stability on natural turfgrass athletic fields. *Proc Inst Mech Eng Part P J Sport Eng Technol* 2011 Jun 2;225(2):85–92.
- [5] Caple MCJ. Mechanical behaviour of natural turf sports surfaces [Internet]. 2011.
- [6] Guisasaola I, James I, Llewellyn C, Stiles V, Dixon S. Quasi-static mechanical behaviour of soils used for natural turf sports surfaces and stud force prediction. *Sport Eng.* 2010 Feb 4 12(2):99–109.
- [7] Twomey DM, Finch CF, Lloyd DG, Elliott BC, Doyle TL a. Ground hardness and injury in community level Australian football. *J Sci Med Sport. Sports Medicine Australia*; 2012 Jul;15(4):305–10.
- [8] Caple MC, James IT, Bartlett MD. Using the GoingStick to assess pitch quality. *Proc Inst Mech Eng Part P J Sport Eng Technol*
- [9] Twomey DM, Otago L, Ullah S, Finch CF. Reliability of equipment for measuring the ground hardness and traction. *Proc Inst Mech Eng Part P J Sport Eng Technol.* 2011;225(3):131–7.