Sensitivity and Relevance of Current Test Methods

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Sport Surfaces Research Group
(Thanks to Kathryn Severn and Dr Colin Young)
Talk Outline

Brief Introduction - Why Test?

Measuring Performance and Safety
Tests methods and some data

Summary of Findings and Research Needs?

- provoke some thought/discussion!
Introduction – Why Test?

1. Users – Safety, comfort, skill level… IGB guidance, biomechanical validity, injury studies
2. Construction Quality Assurance: product compliance, build quality, client confidence…
3. Monitoring and Evaluation… Initial Conditions, long-term behaviour, maintenance effects, (simple tests?)
4. Research (& development)... In-house for product development, develop understanding and ‘science’ that can be applied
Testing – Some Issues

Currently the IGB ‘performance’ guidance used to provide some assurance for the ‘user’, and for CQA, Monitoring (some) and R&D to varying levels.

This is appropriate to a degree, but does raise the question of the relevance of the tests and their sensitivity to the important parameters that are being measured…

Important question – what do the (current) tests measure?
User Requirements - Optimise Performance and Safety

REF!!
Measuring Performance and Safety

USER aspects:

- Player movements (starting/stopping, running, turning, jumping, landing etc.)
- Player individuality, mass, training & conditioning, motor skills (fatigue), specific footwear.

Forces, velocity, acceleration, direction, area and rates of loading.. complex
Measuring Performance and Safety

Surface interaction aspects:
- Hardness, compliance, energy absorption/return
- Friction/traction – linear/rotational
- Materials – stiffness, friction/strength, compressibility, visco-elasticity/non-linearity, fibre/fill interaction, composite layer interaction effects
Measuring Performance and Safety

Test equipment aspects:

- Reliability of the measurement (Repeatability, reproducibility)
- Precision/Accuracy
- Validity – both precise and accurate
Measuring Performance and Safety

Indirect measurements are currently used……

- Validity, accurate relative to the ‘real situation’?
- Sensitivity, precise to a level that is ‘significant’ to the user?
- Player perception vs Data? Useful for ‘ranking’ pitches and their relative performance
- Player safety – hard to quantify ‘risk’ of actual harm, overuse or acute injuries, limits based on experience rather than mechanisms…
Measuring Performance and Safety

- Some observations on Performance/Safety, two key areas

- ‘Impact’ and ‘Friction/Traction’
Factors Affecting Impact Testing

Factors include:
- Test force magnitude and duration (rate)
- Surface contact area
- Plane/Studded footwear - some effect
- Viscous and non-linear strain response of the materials (Carpet, fill, shockpad)
- Composite - layer interactions (zone?)
Simplified Heel-Toe Running - GRF

IMPACT

Time (ms)

Force (N)
Berlin Athlete – Impact Test

**Constant Energy Test**
Drop height: 55cm
Drop weight: 20 kg
Test Foot: 70mm diameter

Typical Contact Pressures:
Concrete: 1700 kPa (6.5kN)
Acrylic: 1600 kPa
Synthetic Turf: 500-1000 kPa (2-4kN)
Load pulse: ~30 milliseconds
<table>
<thead>
<tr>
<th>Testing</th>
<th>Traction (Nm)</th>
<th>Berlin (FRF %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FA FIFA</td>
<td>30-50 Nm</td>
<td>≥ 55 % (studded foot)</td>
</tr>
<tr>
<td></td>
<td>1 star: 25-50 Nm</td>
<td>1 star: 55 – 70 %</td>
</tr>
<tr>
<td></td>
<td>2 star: 30 – 45 Nm</td>
<td>2 star: 60 – 70 %</td>
</tr>
<tr>
<td>IRB</td>
<td>30 – 50 Nm</td>
<td>60 – 75 %</td>
</tr>
<tr>
<td>FIH</td>
<td>None</td>
<td>40-65%</td>
</tr>
</tbody>
</table>
Generic Surface Types

Unfilled (Water Based)

Filled - Sand filled (dressed)

- Rubber (sand mix)

Industry developing ‘low’ friction unfilled surfaces….

System Components? Many available – 100s of bespoke designs…
Unfilled
Impact Data

- Use of Impact Devices for Monitoring and Evaluation (Berlin and Clegg)
- Use of Impact Devices for Research and Development (sports hall floors)
Data - IMPACT
Unfilled Hockey Pitches
Data – SPATIAL changes
Unfilled Hockey Pitch

Force Reduction (AAB) %

Frequency

2004

2006

Loughborough University

SPORTSURF
Clegg Hammer – Impact Test

Drop height: 45cm
Drop weight: 2.5 kg (0.5kg)
Test Foot: 50mm diameter

Typical Contact Pressures:
Synthetic Turf: 1000-2000 KPa
Load pulse: ~5-10 millisecs

Useful, simple, sensitive?
Berlin & 2.5kg Clegg Correlation
6 Water Based Pitches

\[ R^2 = 0.97 \]

Hard

Soft
Force Plate Data – Berlin and Clegg
Unfilled Carpets and shockpad combinations

![Graph showing force plate data for Berlin and Clegg systems with different combinations of unfilled carpets and shockpads.](image-url)
Long-Pile – rubber filled

3rd generation long pile turf for soccer

- long multiple flat yarn piles
- siliceous sand infill
- shock pad – rubber or bitumen underlay
- rubber granulate infill
- backing cloth
- sub base - gravel
Data
Filled Football Pitches

2004 Impact Data
(FR range 44-64)

2006 Impact Data
March (v cold) FR Range 37 - 48
July (hot) FR Range 48-53

FRF Berlin

Clegg 2.25 (CIV)
### Data-Case Study 2

**Filled Football Pitches**

“Synthetic Surface Heat Studies”, C. Frank Williams and Gilbert E. Pulley, Brigham Young University

<table>
<thead>
<tr>
<th>Surface</th>
<th>Ave Surface Temp between 7AM &amp; 7PM</th>
<th>high 157° F (69 °C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Art’ Soccer</td>
<td>117.38° F (47 °C)</td>
<td></td>
</tr>
<tr>
<td>Art’ Football</td>
<td>117.04° F</td>
<td>156° F</td>
</tr>
<tr>
<td>Natural Turf</td>
<td>78.19° F (26 °C)</td>
<td>88.5° F</td>
</tr>
<tr>
<td>Asphalt</td>
<td>109.62° F</td>
<td></td>
</tr>
<tr>
<td>Bare Soil</td>
<td>98.23° F</td>
<td></td>
</tr>
</tbody>
</table>

Safety Officer set 120° F (49 °C) as the maximum temperature that the surface could reach before cooling was required.
Data
Filled Football Pitches-Base Effect?

2006 College Pitch
Unbound Base

2006 LU Pitch
Asphalt Base

Clegg 2.25 (CIV)
Filled Football Pitch
3 Impacts – Berlin Athlete
Rubber Fill – Compression Behaviour

Force-Deflection Behaviour

Force [N] vs. Deflection [m]
‘R&D’ Testing

Peak ‘G’ impact reaction & Berlin ‘Force Reduction’
Floor – Pad & Board Effects

41 cm

41 cm
Test Equipment: Prima Plate Test

Controlled Force
Drop height: up to 85 cm
Drop weight: 10 - 20 Kg
Pulse Time: 15 – 30 ms
Plate Size: 100, 200 or 300 mm
Load Range: 0 – 15 kN
Deflection Sensor: 0 - 2200μm
Sample Frequency: 4000 Hz
Floor – Bending Behaviour

Deflection Row - Prima

Distance from Load Centre (cm)

Deflection (um)

- ▲ Between Pads - Flt 4, 5 Rows Pads
- ○ On Pad - Flt 14, 5 Rows Pads
- □ Between Pads - Flt 17, 4 Rows Pads
- ● On Pad - Flt 17, 4 Rows Pads

Sportsurf

Loughborough University
Berlin vs. Prima

R² = 0.7111

Prima D1 (um)

Berlin FRF %

R² = 0.7111
Factors Affecting Friction/Traction

- Not Coulomb friction
- Relative velocity
- Normal force (and shear?) – significant effect..?
- Surface contact area
- Footwear – stud penetration, configuration, length, number etc.
- Material response (carpet, fill etc..) – interface(s) friction, fill shear strength, compression (dilation), fibre reinforcement/entanglement…
Linear Friction/Traction
Rotational Traction
Rotational Traction
Traction Measurement

- Unfilled systems – Monitoring & Evaluation
- Filled Systems – Monitoring & Evaluation
Rotational Traction at Pitch F (Row E)
Rotational Traction at Pitch F
(Row E - Algae)
Data - Rotational Traction
Unfilled Hockey Pitches

![Graph showing rotational traction in Nm for different pitches (BOW, BV, CAN, HF, Lboro, OL) for 2004 and 2006.]
Data - Rotational Traction
Unfilled Hockey Pitches
Construction/Design Effects
Rotational Traction vs Shockpad thickness

Rotation Traction (Nm)

Dry
Saturated
20 Minutes after Saturation
40 Minutes after Saturation

LUC
BVC
LUC & 6 mm SP
BVC & 6 mm SP
LUC & 9 mm SP
BVC & 9 mm SP
LUC & 11 mm SP
BVC & 11 mm SP
LUC & 12 mm SP
BVC & 12 mm SP
LUC & 20 mm SP
BVC & 20 mm SP
Rotational Traction data
Rubber Filled Football Pitches
# Rotational Traction Data

Filled Football Pitches

## Traction Test Results (Rotational Resistance)

<table>
<thead>
<tr>
<th>LU Pitch 1</th>
<th>2003 – Test house</th>
<th>28 (Range 27 - 29)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2004 – Project</td>
<td>25-28</td>
</tr>
<tr>
<td></td>
<td>2004 – Project</td>
<td>24-32</td>
</tr>
<tr>
<td>College Pitch 2</td>
<td>27-30</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fill density (kg/m³)</th>
<th>Torque Nm</th>
<th>Berlin FRF %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory 10 a</td>
<td>22-24</td>
<td>57</td>
</tr>
<tr>
<td>16 b</td>
<td>24-26</td>
<td>62</td>
</tr>
<tr>
<td>22 c</td>
<td>21-23</td>
<td>68</td>
</tr>
</tbody>
</table>
Rotational Traction Data
Filled Football Pitches

Rotational Resistance (Nm)

Position Reference

1a 3a 5a 2b 3b 4b 1c 3c 5c 2d 3d 4d 1e 3e 5e

Minimum
Maximum

LU Pitch
2004
Other Data – Rotational Traction

- 45-65kg static force increased Torque from 36-49Nm, infilled SBR. (Vachon, 2005)
- IBV (2003) measured 38-47 on Infilled Artificial Turf, 38-68 on Natural turf
- Shorten (2002) – shoe and surface required. Rotational traction should be as low as possible - not linked to athletic manoeuvre
- Strathclyde Research has looked at multivariate approach...
Pitch Tester (The ‘Beast’)

Steve Blackburn, Colin Walker, and Sandy Nicol.

Strathclyde University, 2003-2006
Ground Loadings – a) Player Study, b) c) and d) from Rig

a) Example of player/ground loadings on artificial turf during a 45° cut on 3G turf

b) Combined shear & torque dynamic loading (static 250N vertical load):

- 3G Turf

- Vertical
- Shear
- Torque

S Blackburn/ C Walker/ S Nicol, Strathclyde University.
Some Findings…1 (Traction)

- Rotational Traction Device - not a very sensitive tool?
  Torque expected to vary with thickness of compressible layers and normal force etc....?
- Current Equipment - wrong level of (static) normal force, and load rate....(operator influence)
- Are the torque levels specified correct for Rotational Traction??
  Accuracy and precision look low...
Some Findings…2 (Impact)

- Impact testing – several tools available, selection should be based on purpose (standards, monitoring, research..)
- Good understanding of *material* stiffness, damping and layer interaction effects is required.
- Berlin is a constant energy test, large experience gained hence continuation..?
  Controlled force could be more effectively utilised? Fits biomechanical data better…?
FILL ISSUES

- Fill material type (recycled rubber, EPDM, sand, water, other…)
- Fill source – size ranges, shape, method of production
- Mechanical properties – test methods for particle packing, friction, compressibility/strength? Temperature effects?
- Ease of installation – ‘equilibrium’ state..?
- Long-term behaviour – degradation, fouling, compaction, drainage effect
Fill Mechanics - Shear strength (linear)

Increased peak for higher density/compaction, higher normal force, internal suctions, rate of shear

Shear Stress

Peak Resistance

Residual

Dense Fill
Loose Fill

Strain
3G Maintenance – Effects?

Frosty day – reverse compaction effects?
CARPET ISSUES

- Yarn type
- Yarn properties – strength, stiffness, resilience...
- Yarn source - size ranges, shape, method of production
- Long-term behaviour – degradation through wear, environmental effects
- Mechanical properties – test methods?
- Temperature effects?
- Other – seaming, rucking, colour etc..
General Research Required

- DEVELOP PITCH SCIENCE
  - Classification of surface systems and ‘state’ – way of comparing between data sets
  - Accurate/Sensitive Test Methods (based on player loadings, material behaviour aspects)
  - Thorough investigation of the factors influencing measurement accuracy & sensitivity

MORE HIGH QUALITY PUBLISHED DATA NEEDED !!!