An Initial ITF Study on Performance Standards for Tennis Court Surfaces

Stuart Miller & Jamie Capel-Davies
Background

Wimbledon Men's Singles

% of Tie-Break Sets

Source: ITF I.T. Dept.
Background

Wimbledon Men's Singles

% of Tie-Break Sets

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SportSurf 2006
Background

- Concerns regarding speed of the game – rallies becoming shorter
- Racket/ball research programme, but little surface-specific
- Nothing in Rules of Tennis regarding surface
- Performance standards should be sport-led – rejected by CEN
October 1995

• ITF *Performance standards for tennis surfaces* working group
  • ITF, LTA, FFT, DTB, USTA, KNLTB

• Terms of reference
  • To agree an international system of classification and terminology for tennis courts
  • To agree key performance criteria and a common system of test methods
  • “Impossible to have an international standard to cover all countries and climates”
October 1995

- Restrict to sports performance...
  1. Vertical ball bounce
  2. Angled ball behaviour
  3. Shock absorption
  4. Friction
  5. Spin
  6. Slope/evenness
  7. Reflectance
  8. Permeability
  9. Colour

- Follow-up questionnaire to NAs
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Tested devices</th>
<th>Adopted device(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical ball bounce</td>
<td>Video (UK), acoustic (Ger), photo-cell (Fra)</td>
<td></td>
</tr>
<tr>
<td>Angled ball bounce</td>
<td>Sestée (UK / Fra)</td>
<td></td>
</tr>
<tr>
<td>Dynamic friction</td>
<td>TRRL (UK) / Leroux (Fra) / ‘falling mass’ (Ger) pendulums</td>
<td></td>
</tr>
<tr>
<td>Static friction</td>
<td>Traction tester (UK)</td>
<td></td>
</tr>
<tr>
<td>Shock absorption</td>
<td>Berlin (Ger) / ‘Papendal’ (Hol) / ‘Le Mans’ (Fra) Artificial Athletes</td>
<td></td>
</tr>
<tr>
<td>Spin</td>
<td>No device (but TA...)</td>
<td></td>
</tr>
<tr>
<td>Parameter</td>
<td>Tested devices</td>
<td>Adopted device(s)</td>
</tr>
<tr>
<td>---------------------------</td>
<td>--------------------------------------------------------------------------------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td>Vertical ball bounce</td>
<td>Video (UK), acoustic (Ger), photo-cell (Fra)</td>
<td>All</td>
</tr>
<tr>
<td>Angled ball bounce</td>
<td>Sestée (UK / Fra)</td>
<td>Sestée</td>
</tr>
<tr>
<td>Dynamic friction</td>
<td>TRRL (UK) / Leroux (Fra) / ‘falling mass’ (Ger) pendulums</td>
<td>TRRL pendulum (adapted)</td>
</tr>
<tr>
<td>Static friction</td>
<td>Traction tester (UK)</td>
<td>Further consideration necessary</td>
</tr>
<tr>
<td>Shock absorption</td>
<td>Berlin (Ger) / ‘Papendal’ (Hol) / ‘Le Mans’ (Fra) Artificial Athletes</td>
<td>Papendal Athlete</td>
</tr>
<tr>
<td>Spin</td>
<td>No device (but TA...)</td>
<td>None</td>
</tr>
<tr>
<td>Parameter</td>
<td>Tested devices</td>
<td>Adopted device(s)</td>
</tr>
<tr>
<td>--------------------</td>
<td>-------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>Slope / evenness</td>
<td>Straight edge</td>
<td></td>
</tr>
<tr>
<td>Reflectance</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Permeability</td>
<td>Concentric rings (UK)</td>
<td></td>
</tr>
<tr>
<td>Colour</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Parameter</td>
<td>Tested devices</td>
<td>Adopted device(s)</td>
</tr>
<tr>
<td>----------------------</td>
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<td>------------------------</td>
</tr>
<tr>
<td>Slope / evenness</td>
<td>Straight edge</td>
<td>Straight edge</td>
</tr>
<tr>
<td>Reflectance</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Permeability</td>
<td>Concentric rings (UK)</td>
<td>Concentric rings</td>
</tr>
<tr>
<td>Colour</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>
July 1996

Original objectives
- To agree an international system of classification and terminology for tennis courts
- To agree key performance criteria and a common system of test methods

New objectives
- Guidance to NFs for development of new or refurbished courts
- Guidance to manufacturers and suppliers for product development
- Describe minimum requirements for ITF events
Vertical ball bounce

Criteria for Vertical Ball Rebound (ITF CS05/01)

Figure 11: Classification of Vertical Ball Rebound
Surface Pace

Criteria for Surface Pace (ITF CS 01/01)

Figure 2: ITF Surface Pace Rating

<table>
<thead>
<tr>
<th>Rating</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>VERY SLOW</td>
</tr>
<tr>
<td>15-30</td>
<td>SLOW</td>
</tr>
<tr>
<td>30-40</td>
<td>MEDIUM</td>
</tr>
<tr>
<td>40-45</td>
<td>MEDIUM FAST</td>
</tr>
<tr>
<td>45-55</td>
<td>FAST</td>
</tr>
<tr>
<td>55+</td>
<td>VERY FAST</td>
</tr>
</tbody>
</table>

Figure 3: Illustration of Apparatus of Test Method for ITF Surface Pace Rating (ITF CS 01/01)

- Photo cell screen 1 to measure ball velocity and angle before impact
- Photo cell screen 2 to measure ball velocity and angle after impact
- Ball Projection cannon
- Air Compressor
- Test Surface
Dynamic Friction

Criteria for Slip Resistance ITF CS 02/01

Figure 5: Preferred Range for non-sliding Tennis Surfaces

The maximum variation in value due to any directional pattern, (eg: in textile surfaces) should preferably be less than 10%.
Static Friction

Criteria for Traction (ITF CS 03/01)

Figure 7: Preferred Range for Traction Measurements on Tennis Court Surfaces
Shock Absorption

Criteria for Shock Absorption (ITF CS 04/01)
Figure 9: Initial Criteria for Shock Absorption of tennis court surfaces.
Permeability

Criteria for Permeability (ITF CS 06/01)

Figure 15: Classification of Water Infiltration Rate

Figure 16: Illustration of Permeability Apparatus
Evenness
Issues

- Introduction without sufficient industry consultation

- Perceived as a definitive document by many users

- USTC&TBA comments complimentary and covered in amendments

- “Test methods...are likely to be amended and improved”
Initial Study review
Aims

Define and quantify key properties that affect play, such that:

• A minimum level of quality can be established, and high-quality workmanship is encouraged
• Standards can be improved, based on what is achievable by experienced contractors using quality materials and conventional methods at reasonable cost
• Courts can be compared, giving constructors and end-users a common language
• Contractors are protected against unreasonable demands by customers
Introduction

- Stage 1 – theoretical review: what is important?
- Stage 2 – review existing properties and tests: what should we keep?
- Stage 3 – research new tests where appropriate: what should we add?
- Stage 4 – produce revised document
Test selection

1. Identify variables: Relevant? Measurable?


3. Specify achievable criteria inc. tolerance. Surface-specific?
Identifying variables

Performance variables

- Topspin
- Slice
- Pace
- Colour
- Visual*
- Reflectance
- Size*
- Maintenance
- Durability*
- Climate
- Use
- Bounce
- Consistency
- Footing
- Spin*
- Vertical ball rebound
- Consistency
- Maintenance
- * = new variable
## Existing tests

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Existing Test</th>
<th>Change Test?</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical ball rebound</td>
<td>Vertical ball rebound (CS05/01)</td>
<td>Yes (Sestée).</td>
<td>Accurate and realistic</td>
<td>Expensive</td>
</tr>
<tr>
<td>Pace</td>
<td>Surface pace (CS01/01)</td>
<td>No. Develop (conversions for) low-cost devices (Tortus, Haines Pendulum, Crab)</td>
<td>Accurate and realistic</td>
<td>Expensive</td>
</tr>
<tr>
<td>Consistency</td>
<td>Evenness (CS08/01)</td>
<td>No. Review criteria</td>
<td>Simple, cheap, accessible</td>
<td></td>
</tr>
</tbody>
</table>
New tests

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Proposed Test</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spin</td>
<td>None (surface pace adequate)</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Visual</td>
<td>None (no agreed method of measurement)</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Durability</td>
<td>Surface pace, slip resistance, vertical ball rebound, shock absorption, evenness</td>
<td>Consistency in recommendations for resurfacing</td>
<td>See relevant tests</td>
</tr>
</tbody>
</table>
Identifying variables

- Water retention
- Permeability
  - Slope
  - Slip resistance
  - Turning
  - Slipping*
- Shock/energy absorption
- Safety variables
  - Stiffness*
  - Area elasticity
  - Point elasticity

* = new variable
# Existing tests

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Existing Test</th>
<th>Change Test?</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shock absorption</td>
<td>Berlin Athlete (CS04/01)</td>
<td>Possibly (LWD, AAA)</td>
<td>All surfaces, mobile, realistic</td>
<td>Cost, somewhat bulky</td>
</tr>
<tr>
<td>Slope</td>
<td>CS07/01</td>
<td>Currently refers to CivEng procedures?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slip resistance (coefficient of dynamic friction)</td>
<td>TRRL pendulum (CS02/01)</td>
<td>No</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## New tests

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Proposed Test</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stiffness (deflection)</td>
<td>LWD or AAA?</td>
<td>Can be used on all surfaces, quick</td>
<td>Cost; somewhat bulky</td>
</tr>
<tr>
<td>Slipping (coefficient of static friction)</td>
<td>None identified (XL inadequate)</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Consistency (size)</td>
<td>Dimensions</td>
<td>Simple, cheap, accessible</td>
<td>Time consuming</td>
</tr>
</tbody>
</table>
## Deleted tests

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Existing Test</th>
<th>Reason for deletion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water infiltration</td>
<td>Permeability (CS06/01)</td>
<td>Destructive; not appropriate to all surfaces; not a factor determining safety or performance</td>
</tr>
<tr>
<td>Turning</td>
<td>Traction (CS03/01)</td>
<td>Delete</td>
</tr>
</tbody>
</table>
Summary

Original *Initial Study*
- Surface pace (retain unchanged)
- Slip resistance (retain unchanged)
- Traction (delete)
- Shock/energy absorption (expand with new devices)
- Vertical ball rebound (change device)
- Permeability (delete)
- Slope/evenness (retain; new specifications)

Revised *Initial Study*
- Surface pace (retain unchanged)
- Slip resistance (retain unchanged)
- Shock/energy absorption (BAA, LWD and/or AAA)
- Vertical ball rebound (Sestée)
- Slope/evenness (new specifications)

Review
- Durability (retest onsite tests; tbc)
- Spin (no)
- Slipping (to be determined)
- Visual (no)
- Stiffness (to be determined)
- Dimensions
- Dimensions

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Key characteristics

• *Surface pace*: The ‘speed’ of the court; the change in speed and angle of a ball following impact with the surface.

• *Friction*: The resistance to movement of the player on the court surface:
  - Force at the beginning of movement, which prevents slipping, and/or
  - Force that acts during movement, which opposes sliding (slip resistance)
Key characteristics

- **Shock/energy absorption (elasticity):** The surface’s ability to absorb/return energy
- **Topology and dimensions:**
  - Geometrical regularity (evenness)
  - Gradient (slope) and planarity
  - Location of court markings (lines)
- **Consistency:** Uniformity of properties over the playing area and their stability with time, use and maintenance
Surface pace

- Existing test, existing apparatus

- Tolerance: +/- 5 SPR
Surface pace - simulation

- Sestée simulates a 120 mph flat serve
- What about other shots?

<table>
<thead>
<tr>
<th>Serve</th>
<th>Fast</th>
<th>Medium</th>
<th>Slow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Velocity (m/s)</td>
<td>51</td>
<td>48</td>
<td>45</td>
</tr>
<tr>
<td>Direction of Motion</td>
<td>-6.0</td>
<td>-4.0</td>
<td>-1.7</td>
</tr>
<tr>
<td>Initial Spin (rad/s)</td>
<td>0</td>
<td>150</td>
<td>300</td>
</tr>
<tr>
<td>Initial Height (m)</td>
<td>2.74</td>
<td>2.74</td>
<td>2.74</td>
</tr>
<tr>
<td>Impact speed (m/s)</td>
<td>35.5</td>
<td>33.1</td>
<td>30.7</td>
</tr>
<tr>
<td>Flight time (s)</td>
<td>0.43</td>
<td>0.46</td>
<td>0.49</td>
</tr>
<tr>
<td>Impact distance (ft)</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>impact angle (rad)</td>
<td>-0.204</td>
<td>-0.242</td>
<td>-0.285</td>
</tr>
<tr>
<td>impact angle (°)</td>
<td>-11.7</td>
<td>-13.8</td>
<td>-16.4</td>
</tr>
</tbody>
</table>
Surface pace - serve

- Players with fast serves should perceive pace just like SPR test
- Players using topspin or slice may disagree on slow and medium courts
Surface pace - simulation

Perceived pace

- Fast, no spin
- Medium, low spin
- Slow, high spin

Actual pace

Forehand

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Surface pace - forehand

- Players with fast (flat) forehands should perceive pace just like SPR test
- Players always using topspin or slice may perceive all courts to be the same
Surface pace - perception

Perceived pace vs. Actual SPR for grass surface.
Surface pace - definition

- Players do not always play shots as in SPR test
- ‘Fast’ players should perceive SPR as expected
- ‘Spin’ players could perceive SPR ‘wrongly’
- Grass can be different to other surfaces
- Player perception correlates with SPR...
- ...with the possible exception of grass
Surface pace - definition

![Graph showing the relationship between surface pace and CoR for different surfaces: Mean Clay, Mean Acrylic, Mean Artificial Grass, Mean Artificial Clay, Mean Carpet, Mean Other, and Averages. The graph is color-coded to distinguish between different surface types.](image-url)
Surface pace – definition

- Tennis GUT uses a damping/ramping model (of a non-rigid surface) to include VCOR.
- Can a revised definition of surface pace do the same?

![Diagram with equations and angles]
Surface pace - prediction

- Crab Mark II
Surface pace - prediction

**Comparison of two different operators of the Mark II on a variety of surfaces**

1. **SPR v RCH Mark II deflection on a variety of surfaces**
   - Equation: \( y = -0.5524x + 82.522 \)
   - \( R^2 = 0.8263 \)

    ![Graph of SPR v RCH Mark II deflection](image1)

2. **JD Mark II deflection**
   - Equation: \( y = 0.9279x + 4.1151 \)
   - \( R^2 = 0.867 \)

    ![Graph of JD Mark II deflection](image2)
Limits of agreement (95% confidence) client predicted SPR between 1.5 lower and 1.1 higher than the ITF.

Paper: SPR between 61.2 and 60.7
P1200: SPR between 39.3 and 39.9
P180: SPR between 17.7 and 17.0

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Surface pace – durability

Change in SPR with time on four acrylic courts (from new)

Mean SPR

Court 1

Court 2

Court 3

Court 4

Mean

Jul-04 Sep-04 Nov-04 Jan-05 Mar-05 May-05 Jul-05 Sep-05 Nov-05
Friction (slip resistance)

- Existing test, existing apparatus
- Acceptable range: 60-110 (dry and wet)
- Tolerance: N/A
Vertical ball rebound

- Revised test, using Sestée
- Tolerance: TBA
Vertical ball rebound - angle

- Clay
- Asphalt
- Grass
- Acrylic (outdoor)
- Carpet
- Acrylic (indoor)
Shock/energy absorption

- Revised test (new apparatus)
- Categories: TBA
- Tolerance: TBA
Lightweight deflectometer

- Problems with existing device (BAA)
  - Cumbersome
  - Limited applicability to tennis?
- Project aims with Loughborough
  - Establish relevance and validity of LWD for tennis
  - Establish a test protocol
Lightweight deflectometer

- Range and sensitivity appropriate for tennis (particularly for harder surfaces)
- Good repeatability and reproducibility
- Plate size and drop height can varied to simulate tennis conditions
- Protocol needs finalising (test procedure and calculation of results)
- Need to compare with AAA
Shoe-surface - peak g

- Shoe 1
- Shoe 2

Peak g

- Shoe only
- PU1
- Acrylic
- PU2
- Turf

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Shoe-surface - peak g

- Shoe 1
- Shoe 2

- Shoe only
- PU1 Acrylic
- PU2 Turf
- Shoe only
- PU1 Acrylic
- PU2 Turf
- Turf

Peak g

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Shoe-surface combinations

- Impact absorption
  - Surface influential in reducing impact forces (as measured by BAA)
  - Need to establish effects of shoe-surface combinations
  - Shoes may be more important than surfaces
## Evenness and dimensions

<table>
<thead>
<tr>
<th></th>
<th>Acrylic</th>
<th>Artificial Grass/Clay; Carpet</th>
<th>Asphalt/Concrete</th>
<th>Clay</th>
<th>Grass</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gradient</strong></td>
<td>1:100(^1)</td>
<td>1:120 (max.)</td>
<td>Impervious: 1:100 (max)</td>
<td>1:120 (max)</td>
<td>1:120 (max)</td>
</tr>
<tr>
<td><strong>Evenness(^2)</strong></td>
<td>6 mm (95% of all measurements)(^3)</td>
<td>6 mm</td>
<td>10 mm (single layer), 8 mm (2 or more layers)(^4)</td>
<td>7 mm</td>
<td>6 mm</td>
</tr>
<tr>
<td><strong>Deviations(^3)</strong></td>
<td>5% of measurements(^3)</td>
<td>2 (PPA)/4 (TPA)(^5)</td>
<td>4 (PPA)/8 (TPA)(^6)</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td><strong>Planarity(^5,6,7)</strong></td>
<td>± 10 mm from true ± 25 mm from true</td>
<td>± 10 mm from true ± 25 mm from true</td>
<td>± 10 mm from true ± 25 mm from true</td>
<td>± 10 mm from true ± 25 mm from true</td>
<td>± 10 mm from true ± 25 mm from true</td>
</tr>
<tr>
<td><strong>Dimensions</strong></td>
<td>0.05% (12 mm length, 6 mm width)</td>
<td>0.05% (12 mm length, 6 mm width)(^8)</td>
<td>0.05% (12 mm length, 6 mm width)</td>
<td>0.05% (12 mm length, 6 mm width)</td>
<td>0.05% (12 mm length, 6 mm width)(^8)</td>
</tr>
</tbody>
</table>

**Notes**
- \(^1\) 1:120 where courts are required to drain.
- \(^2\) Measured with a 3 m straight edge.
- \(^3\) In no instance should any imperfection exist that could cause the ball to deviate significantly from its path on a perfectly level surface, or expose a player to a significantly increased risk of injury.
- \(^4\) Specifications are for porous asphalt. For impervious asphalt, see ‘acrylic’.
- \(^5\) This should only be established when there is appropriate equipment available to do so.
- \(^6\) Unless design, specification or construction necessitate otherwise.
- \(^7\) 10 mm specification is for laser-guided paving; 25 mm specification is for hand-laid paving.
- Movement of the grass should be taken into account.
To do

- Receive feedback from industry
- (Re)define surface pace
- Review/develop predictor devices
- Establish test(s) for surface elasticity
- Establish test for static friction
- Recommend limits for durability
- Investigate climate-sensitivity
- Further understanding of perception