

FIFA®



# FIFA QUALITY PROGRAMME FOR NATURAL PLAYING SURFACES

October 2021 Edition | Version 1.0

# **FIFA QUALITY PROGRAMME FOR NATURAL PLAYING SURFACES**

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Compliance with the requirements detailed in this Test Manual by a User does not of itself confer upon that User immunity from legal obligations.

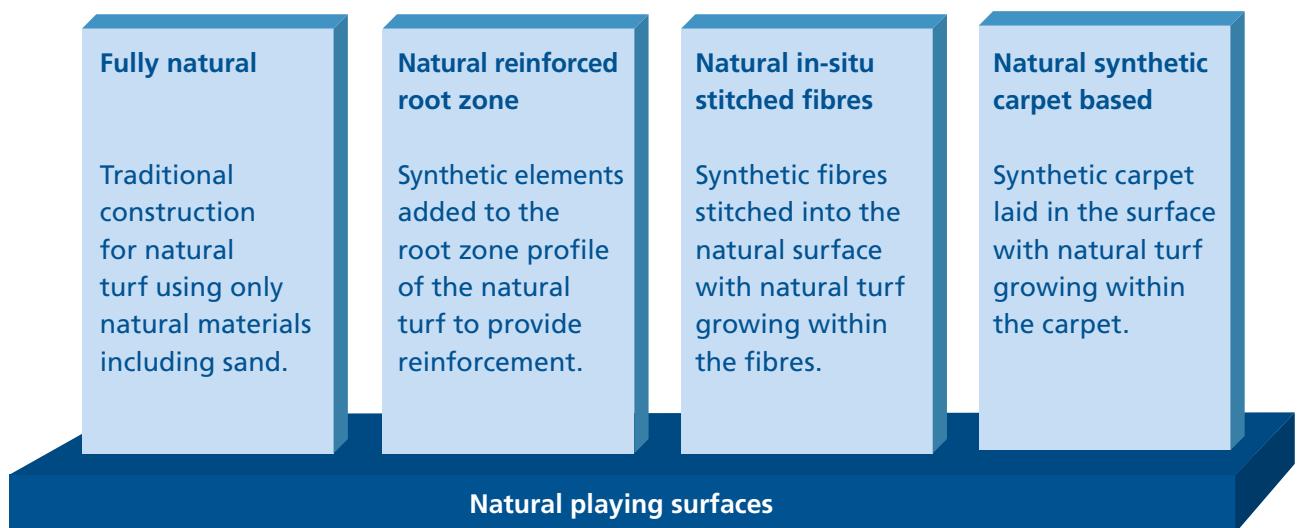
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FIFA reserves the right to amend, update or delete sections of this Test Manual at any time as it may deem necessary.

## 1. INTRODUCTION

This Test Manual describes the procedures for assessing natural turf football pitches under the FIFA Quality Programme.

Natural playing surfaces refer to surfaces that include natural turf in their system. The different systems can be classified as follows:



## 2. NORMATIVE REFERENCES

This Test Manual incorporates, by dated or undated reference, provisions from other publications. For dated references, subsequent amendments to or revisions of any of these publications will

apply to this Test Manual only when incorporated into it by amendment or revision. For undated references, the latest edition of the publication referred to applies.

### 3. FULL AND REDUCED ASSESSMENTS

The FIFA Test Manual for Natural Playing Surfaces has been designed for two types of on-site assessment.

The **full assessment** is designed to be performed by a FIFA Accredited Test Institutes to evaluate

the agronomy performance, player safety and performance (player/surface interaction and ball/surface interaction) of a new installation, an existing installation, or an installation prior to a tournament.

Characteristic	Full assessment Test methods
Test conditions	Ambient temperature
	Ambient humidity
	Wind speed
	Soil temperature
	Vertical ball rebound
Performance	Ball roll
	Shock absorption
	Vertical deformation
	Energy restitution
	Rotational resistance
Agronomy	Evenness
	Surface hardness
	Compaction severity
	Infiltration rate
	Normalised difference vegetation index (NDVI)
	Sward height
	Root depth
	Thatch depth
	Sward colour
	Ground coverage %
	Weed content %
	Insect pests
	Diseases
	Volumetric soil moisture content
	Soil health analysis

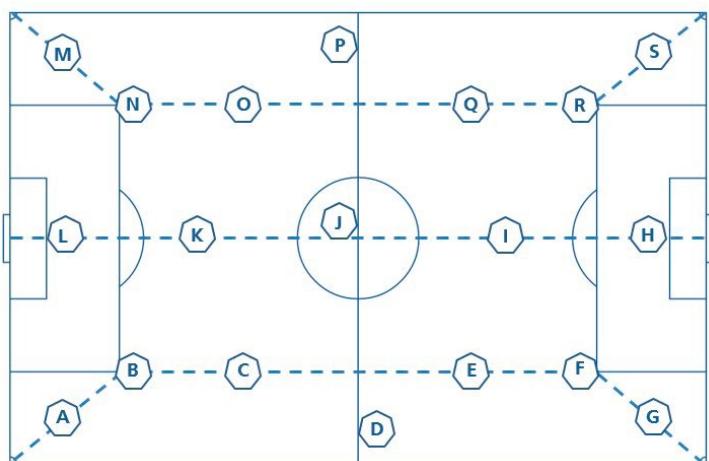
The **reduced assessment** is designed to be regularly performed by the ground staff in charge of the installation to monitor the preparation of

an installation for a tournament or to be part of a regular control process.

Characteristic	Reduced assessment Test Method
<b>Performance</b>	Evenness
	Surface hardness
	Sward height
	Root depth
	Thatch depth
<b>Agronomy</b>	Sward colour
	Ground coverage %
	Weed content %
	Insect pests
	Diseases
	Volumetric soil moisture content

## 4. FIELD TEST POSITIONS

Tests on site shall be conducted in the positions shown below in *Figure 1: Field test positions*.



*Figure 1: Field test positions.*

Characteristic	Test method	Full assessment test positions	Reduced assessment test positions
Test conditions	Ambient temperature	A, L, K, J, Q, H	
	Ambient humidity	A, L, K, J, Q, H	
	Wind speed	A, L, K, J, Q, H	
	Soil temperature	A, L, K, J, Q, H	
	Grass height	A, L, K, J, Q, H	A, L, K, J, Q, H
Performance	Vertical ball rebound	A, L, K, J, Q, H	
	Ball roll	A, L, K, J, Q, H	
	Shock absorption	All test locations (A to S)	
	Vertical deformation	All test locations (A to S)	
	Energy restitution	All test locations (A to S)	
Agronomy	Rotational resistance	All test locations (A to S)	
	Evenness	All playing surface	All playing surface
	Surface hardness	All test locations (A to S)	A, L, K, J, Q, H
	Compaction severity – 100mm	A, L, K, J, Q, H	
	Infiltration rate	A, L, K, J, Q, H	
Agronomy	Normalised difference vegetation index (NDVI)	All test locations (A to S)	
	Sward height	A, L, K, J, Q, H	A, L, K, J, Q, H
	Root depth	A, L, K, J, Q, H	A, L, K, J, Q, H
	Thatch depth	A, L, K, J, Q, H	A, L, K, J, Q, H
	Sward colour	A, L, K, J, Q, H	A, L, K, J, Q, H
	Ground coverage %	A, L, K, J, Q, H	A, L, K, J, Q, H
	Weed content %	A, L, K, J, Q, H	A, L, K, J, Q, H
	Insect pests	A, L, K, J, Q, H	A, L, K, J, Q, H
	Diseases	A, L, K, J, Q, H	A, L, K, J, Q, H
	Volumetric soil moisture content	A, L, K, J, Q, H	A, L, K, J, Q, H
	Soil health analysis	Sampling for laboratory test	

## 5. TEST CONDITIONS – FIELD (SITE) TESTS

Tests on site shall be made under the prevailing meteorological conditions, with the only exception being if the surface is frozen.

The surface and ambient temperatures and the ambient relative humidity at the time of the test shall be reported.

## 6. BALLS USED FOR TEST

Tests shall be conducted with a FIFA QUALITY PRO football. Immediately prior to any test, the pressure of the ball shall be adjusted so that the ball gives a rebound on concrete to the underside of the ball, at the prevailing ambient temperature, of  $1.35 \pm 0.03$ m, from a drop height of  $2.0 \pm 0.01$ m. If the pressure adjustment is excessive and exceeds the ball pressure of its manufacturer's recommended range, the ball should be rejected.

To prevent damage to the skin of the ball, the ball used to measure ball roll shall not be used for any other tests.

**Note:** to minimise the effect on results due to the inherent variations found in footballs, FIFA Accredited Test Institutes are supplied with specially selected test balls.

## 7. FOOTBALL STUDS USED FOR TEST

The studs used for the Determination of Rotational Resistance (FIFA NPS Test Method 06) shall be in accordance with *Figure 2: Profile of football stud (new)*. They shall be manufactured from plastic and have a Shore A hardness of  $96 \pm 2$ .

### 7.1. Stud replacement – rotational resistance

After a maximum of 50 tests, the length of the studs shall be determined. If any stud is found to be less than 11.0mm, all studs shall be replaced.

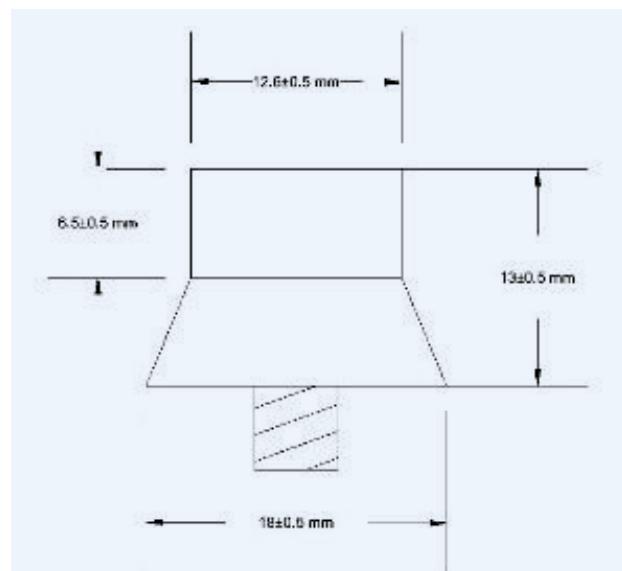


Figure 2: Profile of football stud (new)

## 8. DETERMINATION OF BALL REBOUND (FIFA NPS TEST METHOD 01)

### 8.1. Principle

A ball is released from 2.00m and the height to which it rebounds from the surface is calculated.

### 8.2. Test apparatus

#### 8.2.1. Measuring device

The test apparatus comprises the following:

- a. An electromagnetic or vacuum release mechanism that allows the ball to fall vertically from  $2.00 \pm 0.01\text{m}$  (measured from the underside of the ball) without imparting any impulse or spin.
- b. Vertical scale or laser distance-measuring devices to allow the drop height of the ball to be established.
- c. Timing device, activated acoustically, capable of measuring to an accuracy of 1ms.
- d. Football as specified in Section 5. Balls used for test
- e. Means of measuring wind speed to an accuracy of 0.1 m/s.
- f. A thermometer capable of recording from a minimum range of  $-10^\circ\text{C}$  to  $+60^\circ\text{C}$ , accurate to  $\pm 0.5^\circ\text{C}$ , to record the surface temperature.

### 8.3. Test procedure

Validate the vertical rebound of the ball on concrete immediately before testing and adjust accordingly until it meets the specified value on concrete.

Ball rebound tests (unless the test area is screened from the wind) shall be conducted when the maximum prevailing wind speed is less than 2m/s. The wind speed at the time of the test shall be reported.

Release the ball from  $2.00 \pm 0.01\text{m}$ , underside of the ball to the top of the surface, and record the time between the first and second impact in seconds.

**Note:** to limit the influence of the valve, it should preferably be positioned at the top of the ball when the ball is attached to the apparatus.

### 8.4. Calculation and expression of results

For each test, calculate the rebound height using the formula:

$$H = 1.23 \times (T - \Delta t)^2 \times 100$$

Where:

$H$  = rebound height in cm

$T$  = the time between the first impact and second impact in seconds

$\Delta t = 0.025\text{s}$

Report the value of the ball rebound to the nearest 0.01m as an absolute value in metres, e.g. 0.80m.

The uncertainty of measurement is  $\pm 0.03\text{m}$ .

### 8.5. Field tests

#### 8.5.1. Test conditions

Tests shall be conducted under the meteorological conditions found at the time of the test, subject to the limits of Section 5. Test conditions – field (site) tests. The conditions shall be reported.

#### 8.5.2. Procedure

Record the maximum wind speed during the test.

Tests on site shall be conducted in the positions A, L, K, J, Q, H as shown in *Figure 1: Field test positions*.

At each test location, make five individual measurements, each at least 300mm apart.

### 8.6. Calculation and expression of results

For each test position, calculate the mean value of the vertical ball rebound from the five tests in each test position.

Report the value of the ball rebound for each test position to the nearest 0.01m as an absolute value in metres, e.g. 0.80m.

## 9. DETERMINATION OF BALL ROLL (FIFA NPS TEST METHOD 02)

### 9.1. Principle

A ball rolls down a ramp and traverses the surface until it comes to rest. The distance the ball has travelled across the surface is recorded.

### 9.2. Test apparatus

The test apparatus comprises the following:

- A ball roll ramp as shown in *Figure 3*: Ball roll ramp, consisting of two smooth parallel rounded bars with a maximum diameter of the contact area with the ball of 40mm, whose inside edges are  $100 \pm 10$ mm apart. The ball shall transfer from the ramp to the surface without jumping or bouncing.
- Method of measuring the distance that the ball rolls to an accuracy of  $\pm 0.01$ m (e.g. steel tape, laser).
- Football as specified in Section 6. Balls used for test.
- Means of measuring wind speed to an accuracy of 0.1m/s.
- Ball roll tests (unless the test area is screened from the wind) shall be conducted when the maximum prevailing wind speed is less than 2m/s. The wind speed at the time of test shall be reported.
- A thermometer capable of recording from a minimum range of  $-10^{\circ}\text{C}$  to  $+60^{\circ}\text{C}$ , accurate to  $\pm 0.5^{\circ}\text{C}$ , to record the surface temperature.

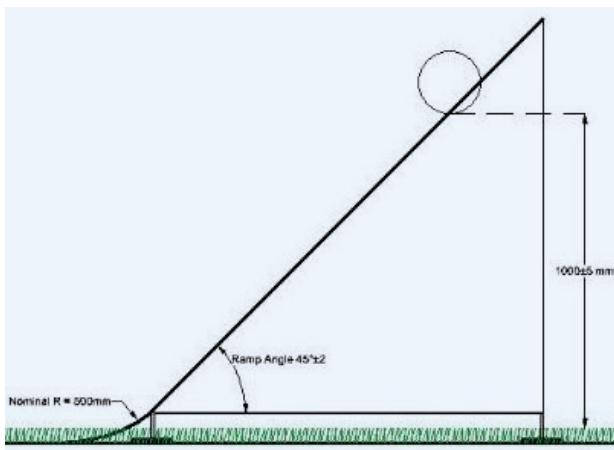


Figure 3: Ball roll ramp

### 9.3. Test procedure

Validate the vertical rebound of the test ball on concrete immediately before the testing and adjust accordingly until it meets the specified value on concrete.

Adjust the ramp so that it is perpendicular to the surface and so that the ends of the guide rails are resting on the top of the surface.

Place the ball on the ball roll ramp so that the point approximately below the centre of the ball sitting on the ramp is  $1000 \pm 5$ mm above the surface.

Check that the wind speed is in accordance with Section 4 Test conditions – field (site) tests.

Release the ball and allow it to roll down the ramp and across the surface until it comes to rest.

Measure the distance from the point that the ball first comes into contact with the surface to the point below the centre of the ball resting on the surface at the position the ball came to rest.

### 9.4. Calculation and expression of results

Report the ball roll value to the nearest 0.1m, e.g. 6.9m.

The uncertainty of measurement is  $\pm 0.05$ m.

### 9.5. Field tests

#### 9.5.1. Test conditions

Tests shall be made under the meteorological conditions found at the time of the test, subject to the limits of Section 5. Test conditions – field (site) tests. The conditions shall be reported.

### 9.5.2. Procedure

Record the wind speed during the test.

Tests on site shall be conducted in the positions A, L, K, J, Q, H shown in *Figure 1: Field test positions*.

At each test location, make three individual measurements, each at least 100mm apart.

Undertake the tests in at least four directions ( $0^\circ$ ,  $90^\circ$ ,  $180^\circ$  and  $270^\circ$ ), with three individual measurements in each direction to determine if the result is influenced by factors such as slope or mowing direction.

If there is a slope, ensure that the ball roll is carried out up and down the slope, and if there is a crown(s) do not perform the test in a location resulting in the ball rolling over the crown in any direction.

If weather conditions make it impossible to undertake ball roll tests within the specified wind speed range, and as a consequence the ball roll is found to exceed the relevant requirement, a reduced test programme may be carried out where screening (e.g. by means of a plastic tunnel) is used to reduce the maximum wind speed to less than 2m/s. In the reduced test programme, ball roll shall be measured in four directions ( $0^\circ$ ,  $90^\circ$ ,  $180^\circ$  and  $270^\circ$ ) on at least one area of the pitch, three ball rolls in each direction.

### 9.5.3. Calculation and expression of results

For each test position/direction, calculate the mean value of ball roll from the three tests in each direction.

Calculate the mean value of ball roll from all four directions at each test position.



## 10. DETERMINATION OF SHOCK ABSORPTION (FIFA NPS TEST METHOD 03)

### 10.1. Principle

A mass with a spring attached to it is allowed to fall onto the surface.

The acceleration of the mass is recorded, from the moment of its release until after its impact on the surface. The shock absorption is calculated by comparing the maximum force on the test specimen with the reference force of impact on concrete. The shock absorption is calculated as a reduction of the impact force on the sample compared to a reference force. Reference force ( $F_{ref}$ ) is fixed to 6760N (theoretical value calculated for a concrete floor).

### 10.2. Test apparatus

The apparatus used to measure shock absorption is called the Advanced Artificial Athlete ("AAA"). The schematic design of the AAA apparatus is depicted in *Figure 5*: Example of curve representing falling mass acceleration versus time below, together with a list of its main components. These essential components are then further specified below.

#### 10.2.1. Electromagnet (2)

The electromagnet holds the mass (3) at the specified height, which can be set to an accuracy of  $\pm 0.25\text{mm}$ .

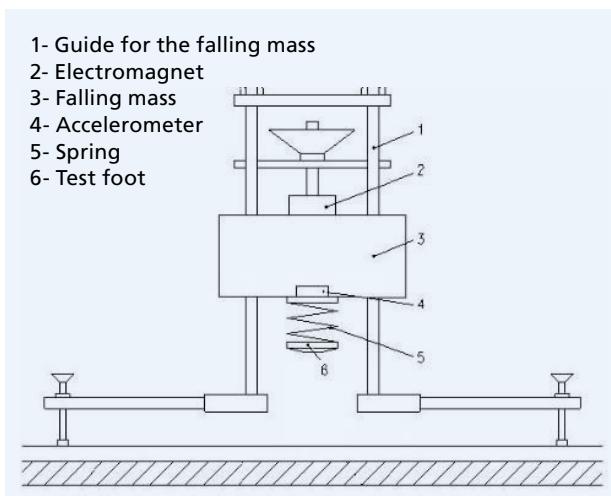


Figure 4: AAA test apparatus

#### 10.2.2. Falling mass (3)

The falling mass incorporates an accelerometer, a spiral metal spring (5) and a steel test foot (6).

The total mass of (3) + (4) + (5) + (6) shall be  $20,000\text{g} \pm 100\text{g}$ .

#### 10.2.3. Piezo-resistive accelerometer (4)

The accelerometer has a 50g full-scale capacity ( $= 50 \times 9.80665\text{m.s}^{-2}$ ), with the following characteristics:

Minimum cut-off frequency of 1000Hz (attenuation of -3db).

Linearity: 2% over the operating range.

The g-sensor should be positioned on the vertical line of gravity of the falling mass over the spiral steel spring. The g-sensor should be firmly attached to the mass to avoid natural filtering or extraneous vibrations of the accelerometer.

#### 10.2.4. Spiral steel spring (5),

The spring rate is  $2000 \pm 100\text{N/mm}$  and is linear over the range 0.1 to 7.5kN.

The linear characteristic of the spring is controlled with maximum increment of 1000N.

The spring shall be positioned centrally below the point of gravity of the falling mass.

The spring shall have three coaxial coils rigidly fixed together at their ends.

The mass of the spring shall be  $800\text{g} \pm 50\text{g}$ .

#### 10.2.5. Test foot (6)

The test foot has a diameter  $70 \pm 1\text{mm}$  and a minimum thickness of 10mm.

The lower side part of the test foot is rounded with a radius of 500 mm  $\pm$ 50mm and has an edge radius of 1mm.

The mass of the test foot shall be 400g  $\pm$ 50g.

#### 10.2.6. Test apparatus frame

The frame consists of three adjustable supporting feet.

- The feet are at a distance of not less than 250mm from the point of impact of the falling mass on the test specimen.
- The frame is designed to ensure that the mass of the apparatus is equally distributed on its three feet.
- For the apparatus with the mass, the pressure resulting on each foot must be less than 0.020N/mm<sup>2</sup>. For the apparatus without the mass, the pressure resulting on each foot must be more than 0.003N/mm<sup>2</sup>.

#### 10.2.7. Signal recording

A means of filtering and recording the signal from the accelerometer and a means of displaying the recorded signal (see Figure 6).

Sampling rate: minimum 9600Hz

Electronic A/D converter with a minimum resolution of 16 bits

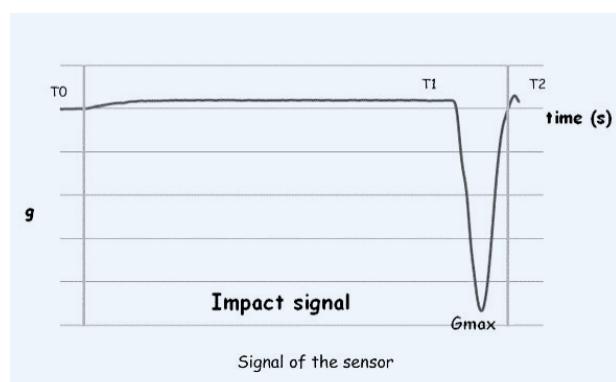


Figure 5: Example of curve representing falling mass acceleration versus time

Signal filtration with a 2<sup>nd</sup> order low-pass, Butterworth filter with a cut-off frequency of 600Hz.

Where:

- $T_0$ : time when the mass starts to fall
- $T_1$ : time when the test foot makes the initial contact with the surface (it corresponds to the maximum velocity of the falling mass  $V_{\max}$ , see Figure 6: Example of curve representing velocity of the falling mass versus time)
- $T_2$ : time at the maximum velocity of the mass after it rebounds from the impact on the test specimen (determined by  $V_{\min}$ , see Figure 6: Example of curve representing velocity of the falling mass versus time)

\*  $V_{\max}$  and  $V_{\min}$  could be positive or negative values, depending on the accelerometer set-up.

A means of calculating the velocity and the displacement of the falling mass during its travel by integration and double integration of the accelerometer signal (see Figure 6: Example of curve representing velocity of the falling mass versus time).

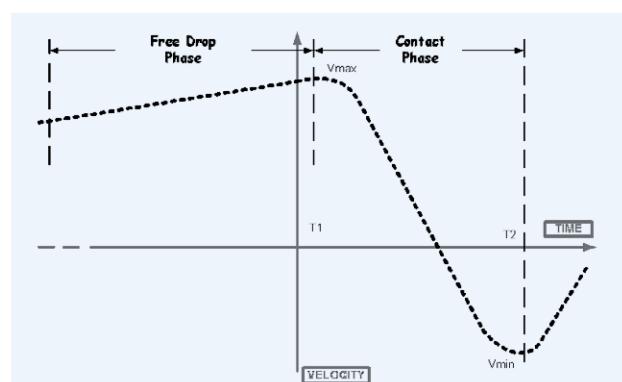


Figure 6: Example of curve representing velocity of the falling mass versus time

### 10.3. Verification of the apparatus: falling mass impact velocity and lift height

This verification is essential to ensure the correct functioning of the apparatus and is compulsory.

For field tests: before any on-site field testing.

The verification procedure consists of four steps and must be carried out on a stable and rigid floor (this is defined as a floor with no significant deflection under a pressure of 5kg/cm<sup>2</sup>).

#### Step 1

Set up the apparatus for a vertical free drop. Verticality tolerance: maximum 1°.

Set the height of the lower face of the test foot at 55.00 ± 025mm above the rigid floor.

Drop the mass on the concrete floor and record the acceleration of the falling mass.

#### Step 2

Repeat step 1 two more times, creating a total of three impacts.

#### Step 3

For each impact, integrate the acceleration signal from T<sub>0</sub> to T<sub>1</sub> and calculate the initial impact velocity. Calculate the mean impact velocity of the three impacts.

The mean impact velocity shall be in the range of 1.02m/s to 1.04m/s.

#### Step 4

After verification of the impact velocity, place the falling mass on the rigid floor.

Measure the height between a static reference point on the apparatus (for example, the underside of the magnet) and the top of the falling mass.

This height will be a reference and shall be used for all subsequent measurements; it is designated as the “**lift height**”.

### 10.4. Test procedure

Set up the apparatus vertically (90° ±1°) on the surface.

Lower the test foot smoothly onto the surface of the surface.

Within ten seconds, set the reference “lift height” described in step 4 of the verification of the apparatus above and attach the falling mass to the electromagnet.

#### First impact:

After 30 (±5) seconds (to allow the test specimen to relax after removal of the test mass), release the mass and record the acceleration signal.

Within ten seconds of the impact, check the lift height and re-attach the mass to the electromagnet.

#### Second impact:

After 30 (±5) seconds, release the mass and record the acceleration signal.

Within ten seconds of the impact, check the lift height and re-attach the mass to the electromagnet.

#### Third impact:

After 30 (±5) seconds, drop the mass and record the acceleration signal.

Do not brush or adjust the surface in any way between impacts.

#### 10.4.1. Shock absorption calculation

Calculate the peak force ( $F_{\max}$ ) at the impact with the following formula

$$F_{\max} = m \times g \times G_{\max} + m \times g$$

Where

- $F_{\max}$  is the peak force, expressed in Newton (N).
- $G_{\max}$  is the peak acceleration during the impact, expressed in multiples of  $g$  ( $1g = 9.81m/s^2$ ).
- $m$  is the falling mass including spring, test foot and accelerometer, expressed in kg.
- $g$  is the acceleration by gravity ( $9.81m/s^2$ ).

Calculate the shock absorption ("SA") by using the following formula:

$$SA = \left[ 1 - \frac{F_{\max}}{F_{\text{ref}}} \right] \times 100$$

Where:

- SA is the shock absorption in %.
- $F_{\max}$  is the peak force measured on the sport surface, in N.
- $F_{\text{ref}}$  is the reference force fixed to 6760 N (theoretical value calculated for a concrete floor).

#### 10.5. Calculation and expression of test results

Report the shock absorption value to the nearest 0.1%, e.g. 56.9%.

The uncertainty of measurement is  $\pm 1.8\%$  absolute.

#### 10.6. Field tests

##### 10.6.1. Test conditions

Tests shall be conducted under the meteorological conditions found at the time of the test, subject to the limits of Section 5. Test conditions – field (site) tests. The conditions shall be reported.

#### 10.6.2. Procedure

Tests on site shall be conducted in all the positions (A to S) shown in *Figure 1: Field test positions*.

#### 10.6.3. Calculation and expression of results

Report the three individual drops of shock absorption values.

Calculate the mean values (second and third impacts) of shock absorption (force reduction) for each test location.



## 11. DETERMINATION OF VERTICAL DEFORMATION (FIFA NPS TEST METHOD 04)

### 11.1. Principle

A mass with a spring attached to it is allowed to fall onto the test surface. The acceleration of the mass is recorded, from the moment of its release until after its impact on the surface. The vertical deformation of the test specimen is calculated by the displacement of the falling mass onto the surface after its impact on it.

### 11.2. Test apparatus

See description in 9.2

### 11.3. Verification of the apparatus

See description in 9.3

### 11.4. Test procedure

See description in 9.4

### 11.5. Calculation and expression of Vertical Deformation

The displacement of the falling mass  $D_{\text{mass}}(t)$  is calculated by integration of  $V_{(t)}$  on the interval  $[T_1, T_2]$ . Integration starts at  $(T_1)$ , the moment when the mass has reached its highest velocity.

On the time interval  $[T_1 - T_2]$ , the vertical deformation (VD) of the test specimen is defined as:

$$VD = D_{\text{mass}} - D_{\text{spring}}$$

Where:

- $D_{\text{mass}} = \int \int_{T_1}^{T_2} g G dt$ , with  $D_{\text{mass}} = 0\text{mm}$  at  $T_1$
- $D_{\text{spring}} = \frac{m \times g \times G_{\text{max}}}{C_{\text{spring}}}$
- $F_{\text{max}}$  is the peak force, expressed in Newton, N
- $G_{\text{max}}$  is the peak acceleration during the impact, expressed in g ( $1g = 9.81\text{m/s}^2$ )
- $m$  is the falling mass, including spring, base plate and accelerometer expressed in kg
- $g$  is the acceleration by gravity ( $9.81\text{m/s}^2$ )
- $C_{\text{spring}}$  is the spring constant (given by the certificate of calibration)

### 11.6. Calculation and expression of test results

Vertical deformation is reported to the nearest 0.1mm.

The uncertainty of measurement is  $\pm 0.1\text{mm}$ .

### 11.7. Field tests

#### 11.7.1. Test conditions

Tests shall be conducted under the meteorological conditions found at the time of the test, subject to the limits of Section 5. Test conditions – field (site) tests. The conditions shall be reported.

#### 11.7.2. Procedure

The vertical deformation is calculated for the position tested for the shock absorption (see 9.6.2).

#### 11.7.3. Calculation and expression of results

Report the three individual drops of vertical deformation values.

Calculate the mean values (second and third impacts) of vertical deformation for each test location.

## 12. DETERMINATION OF ENERGY RESTITUTION (FIFA NPS TEST METHOD 05)

### 12.1. Principle

A mass with a spring attached to it is allowed to fall onto the surface. The acceleration of the mass is recorded, from the moment of its release until after its impact on the surface.

The energy of restitution is given by the comparison of energy of the falling mass before and after impact on the surface.

### 12.2. Test apparatus

See description in 9.2

### 12.3. Verification of the apparatus

See description in 9.3

### 12.4. Test procedure

See description 9.4

### 12.5. Calculation and expression of test results

Calculate the energy restitution (ER) (%) defined by the formula:

$$ER(\%) = \frac{E_2}{E_1} \times 100$$

Where:

- $E_1$  is the energy before impact.  $E_1 = 0.5 \times mV_{\max}^2$
- $E_2$  is the energy after impact.  $E_2 = 0.5 \times mV_{\min}^2$
- $V_{\max}$  is the velocity before impact at  $T_1$  (see figure 7) in m/s
- $V_{\min}$  is the velocity after impact at  $T_2$  (see figure 7) in m/s
- $m$  is the falling mass, including spring, base plate and accelerometer, expressed in kg

### 12.6. Field tests

#### 12.6.1. Test conditions

Tests shall be conducted under the meteorological conditions found at the time of the test, subject to the limits of Section 5. Test conditions – field (site) tests. The conditions shall be reported.

#### 12.6.2. Procedure

The energy restitution is calculated for the position tested for the shock absorption (see 9.6.2).

#### 12.6.3. Calculation and expression of results

Report the three individual drops of energy restitution values.

Calculate the mean values (second and third impacts) of energy restitution for each test position.

The uncertainty of measurement is  $\pm 0.7\%$  absolute.

## 13. DETERMINATION OF ROTATIONAL RESISTANCE (FIFA NPS TEST METHOD 06)

### 13.1. Principle

The rotational resistance of a surface is defined as the measured torque required to rotate a loaded foot placed flat upon a test surface with an axis of rotation central to the test foot and perpendicular to the surface.

### 13.2. Test apparatus

A schematic presenting the mechanical configuration of the apparatus is provided in *Figure 7: Lightweight rotational resistance apparatus*. It comprises the following components:

- A circular test foot of diameter  $150 \pm 2\text{mm}$  with six football studs (as described in Section 7. Football studs used for test) equally spaced on the underside of the test foot on a pitch radius of  $46 \pm 1\text{mm}$  from the centre of the disc.
- A shaft is rigidly attached to the test foot and supported by a minimum of two low-

friction bushings or bearings positioned at least 200mm from one another. The shaft-foot assembly must freely rotate around the vertical (z) axis only. When in operation, the shaft-foot assembly slides linearly in the vertical axis, facilitating compression of the internal spring.

- The body of the device is rigidly attached to a baseplate upon which the operator stands or kneels. A minimum of six football studs (as described in Section 7. Football studs used for test) are arranged on the underside of the baseplate to minimise any counter-rotation during operation.
- A digital torque meter, of minimum range 5-60Nm and resolution of at least 0.1Nm, is mounted on the top of the shaft-foot assembly. During operation, torque shall be applied using a single-handled torque bar of length  $500 \pm 10\text{mm}$ .

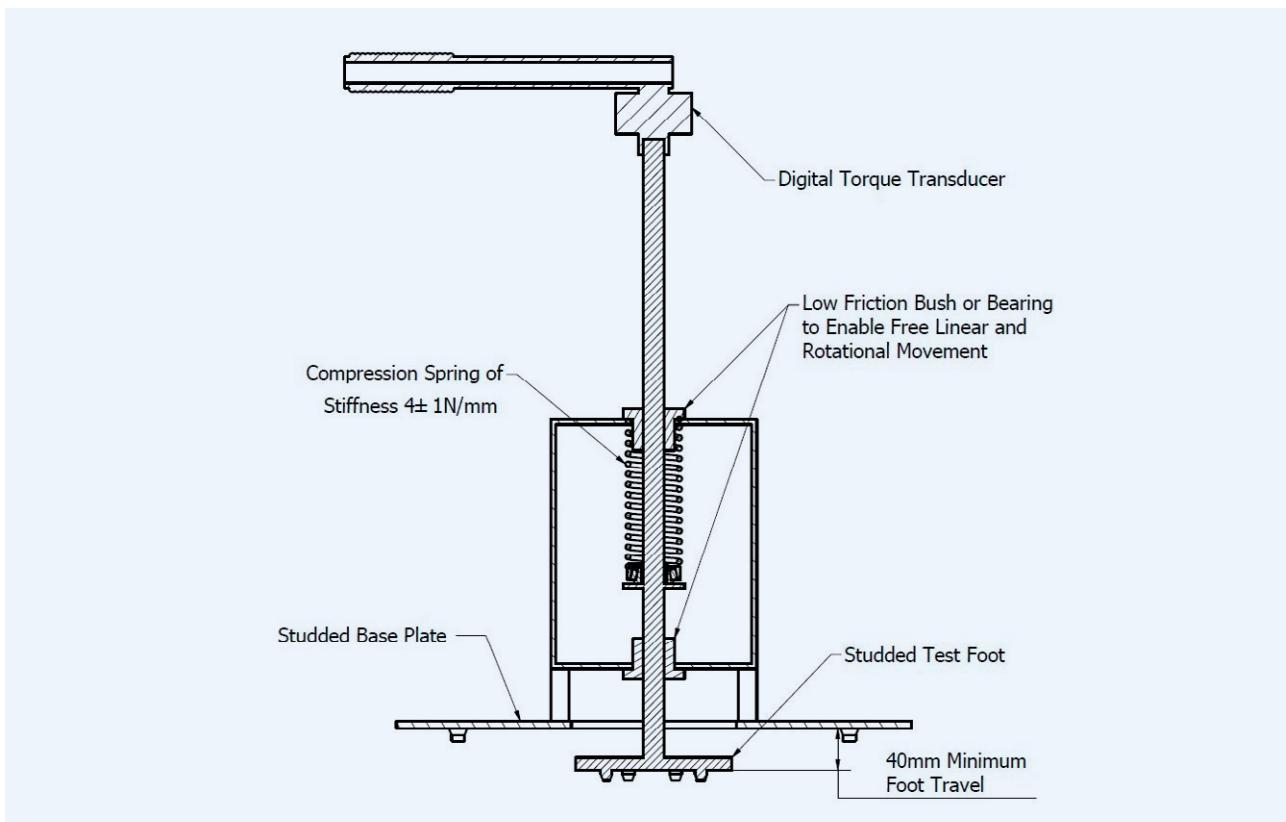


Figure 7: Lightweight rotational resistance apparatus

- The device houses a spring of stiffness  $4 \pm 1\text{N/mm}$ . The spring stiffness must remain within this tolerance over a compressed distance of at least 50mm following any pre-compression or 150mm when no pre-compression is used.

The device applies a force of  $450\text{N} \pm 20\text{N}$  through the test foot onto the surface when compressed by the operator standing mounting the baseplate. The spring shall compress by a minimum of 40mm when the device is mounted, at which point the underside of the test foot shall align horizontally with the underside of the baseplate.

The applied force must include the force generated by the compression spring in addition to any downward force resulting from the mass of the shaft-foot assembly and any rigidly affixed components thereof.

When standing on the baseplate, the technician must take extra care to ensure that the underside of the studded disk is parallel to the underside of the baseplate and no counter-rotation of the baseplate occurs whilst applying torque to the shaft-foot assembly.

Thought must be afforded to the equipment design to reduce to a minimum any source of rotational friction not resulting from the interaction between the test foot and surface, including but not limited to the shaft support mechanism, spring support mechanism and any other mating surface that may affect the peak torque value measured.

### 13.3. Test procedure

Before conducting each test, ensure that the disc and studs are cleared of any detritus.

Assemble the apparatus and ensure the free movement of the shaft and test foot. Place

the test foot onto a representative area of the surface and avoid any large particles that may be present that could affect the stability of the baseplate or the values recorded by the test foot. The technician stands or kneels on the baseplate, forcing the baseplate studs into the surface and ensuring that it is both flat and stable upon the surface.

Without placing any vertical pressure on the torque wrench and applying minimum rotational torque to the torque wrench, turn the wrench and test foot smoothly, without jerking, a minimum of 120 degrees over a duration of approximately four seconds.

Record the maximum value displayed on the torque meter to the nearest 0.1Nm.

## 13.4. Field tests

### 13.4.1. Test conditions

Tests shall be conducted under the meteorological conditions found at the time of the test, subject to the limits of Section 5. Test conditions – field (site) tests. The conditions shall be reported.

### 13.4.2. Procedure

Tests on site shall be conducted in the positions A, L, K, J, Q, H shown in *Figure 1: Field test positions*.

At each test location, make one individual measurement.

## 13.5. Calculation and expression of results

Report the result of rotational resistance for each test position to the nearest 0.1Nm, e.g. 40.3Nm.

Report the mean result to the nearest 0.1Nm, e.g. 40.3Nm.

The uncertainty of measurement is  $\pm 1.6\text{Nm}$ .

## 14. PROCEDURE FOR THE ASSESSMENT OF SURFACE PLANARITY (FIFA NPS TEST METHOD 07)

### 14.1. Principle

The evenness of the playing surface is measured with the aid of a straightedge pulled over the surface longitudinally and transversally between the lines of play. Deviations beneath the straightedge are measured using a calibrated graduated wedge known as a "slip gauge".

### 14.2. Apparatus

#### 14.2.1. Straightedge design:

- a. Length  $3000 \pm 10\text{mm}$ , Width  $75\text{mm} \pm 5\text{mm}$ , Height  $40\text{mm} \pm 5\text{mm}$
- b. Minimum weight  $6.6\text{kg}$
- c. Linearity of the straightedge:  $\pm 2\text{mm}$
- d. Rigidity of the straightedge:  $2\text{mm}$  minimum
- e. Sliding side on the surface:  $75\text{mm} \times 3000\text{mm}$
- f. A means to pull the straightedge along, typically a rope. This can be attached to the straightedge directly or passed through a hollow core in the straightedge. The length of the rope should be sufficient so as to allow the technician to pull the straightedge in a straight line and observe the potential deviations under it. The technician shall be at a distance of a minimum of  $3.0\text{m}$  and a maximum of  $5.0\text{m}$  from the straightedge when pulling it.

#### 14.2.2. Wedge (slip gauge):

- g. Length  $250 \pm 5\text{mm}$
- h. Width  $15 \pm 2\text{mm}$
- i. Height ranges from  $2$  to  $18\text{mm}$
- j. Angle of the wedge:  $5 \pm 1^\circ$

The slip gauge should be graduated on its upper surface at intervals corresponding to a  $1.0\text{mm}$  increase in height.

Where the  $250\text{mm}$  wedge is too big, a small wedge or small ruler may be used to assess the deviation.

### 14.3. Procedure

- Starting from one of the corners with the centre of the straightedge on the centre of the touchline, the straightedge should be dragged across the playing surface parallel to the longitudinal lines.
- The straightedge should be pulled along the surface at such a speed and without sudden movements to ensure that it remains in contact with the surface and does not bounce off the surface.
- To ensure that the playing surface is completely checked, a minimum overlap of  $0.5\text{m}$  between each successive pass is recommended.
- All deviations  $\geq 10\text{mm}$  should be recorded on a site plan. It should be made clear whether the deviation is a high or low spot.
- Upon completion of the surface check parallel to the longitudinal lines, the procedure should be repeated perpendicularly to the longitudinal lines.

### 14.4. Additional remarks

Other defects may present themselves during the inspection. All such defects should also be recorded on the site plan.

## 15. PROCEDURE FOR THE ASSESSMENT OF SURFACE PLANARITY (REDUCED PROTOCOL) (FIFA NPS TEST METHOD 07R)

### 15.1. Principle

The surface regularity (evenness) of the playing field is assessed.

### 15.2. Test apparatus

The straightedge and wedge as described in FIFA NPS Test Method 07.

### 15.3. Test procedure

The procedure is described in FIFA NPS Test Method 07. The nature of some natural turf pitches creates more surface regularity variations

than would be common on approved football turf fields. Therefore, to reduce the time that would be consumed in undertaking a full test as described in FIFA NPS Test Method 07 a reduced programme is recommended that only requires the operative to assess the field in one direction (length of the pitch).

### 15.4. Calculation and expression of results

Note on a plan of the field any undulations as defined in FIFA Test Method 12 that are greater than 10.0mm.

## 16. PROCEDURE FOR MEASURING SWARD HEIGHT OF NATURAL TURF (FIFA NPS TEST METHOD 08)

### 16.1. Principle

This is a procedure for measuring the sward height of natural turf. Care should be taken to ensure that the measurements are made on upright grass tufts and not on flattened areas due to, for example, newly mowed grass.

### 16.2. Apparatus

- A steel and glass prism frame of a minimum 150  $\pm$ 5mm length; a minimum 125  $\pm$ 5mm width; and a minimum height of 70  $\pm$ 5mm.
- The frame should contain a transparent prism with a mirrored bottom surface of reflective material which should be angled at 45  $\pm$ 0.2 degrees.
- A scale in mm to a height of 40  $\pm$ 1mm with a measuring resolution of 1mm.

### 16.3. Procedure

Place the prism gauge/steel reflector on the natural turf surface on top of the substrate

supporting the grass. Do not force the prism/steel reflector into the substrate, but place it onto the substrate without exerting additional pressure. Ensure that the prism gauge/steel reflector is flat on the surface by means of a bubble/spirit level. Record the length of the ten representative lengths of sward (ignore outliers); repeat this procedure at 90° to the first test. Alternate between longitudinal and cross-pitch directions for each test position.

Tests on site shall be conducted in the positions A, L, K, J, Q, H shown in *Figure 1: Field test positions* and at three locations at least 100mm apart from each other.

### 16.4. Calculation and expression of results

Calculate the median of the highest sward lengths in mm from the 20 representative grass tufts and report the value to the nearest mm.

## 17. DETERMINATION OF AMBIENT TEMPERATURE (FIFA NPS TEST METHOD 09)

### 17.1. Principle

This test method describes the procedure for measuring the air temperature.

Hold the thermometer  $1.5 \pm 0.1\text{m}$  above the surface and record the maximum temperature.

### 17.2. Test apparatus

Handheld digital thermometer accurate to  $\pm 0.1^\circ\text{C}$ , with a minimum operating temperature range that covers  $-10^\circ\text{C}$  to  $+60^\circ\text{C}$ .

The thermometer should not be held in direct sunlight.

### 17.3. Test procedure

Validate the handheld digital thermometer utilising the appropriate section of ITS-90.

The thermometer should not be used during precipitation.

The thermometer should be held in such a position so as to allow for natural air flow.

### 17.4. Calculation and expression of results

Report the measurements to the nearest  $0.1^\circ\text{C}$ .

## 18. DETERMINATION OF AMBIENT HUMIDITY (FIFA NPS TEST METHOD 10)

### 18.1. Principle

This test method describes the procedure for measuring the humidity in the air (relative humidity).

Hold the hygrometer  $1.5 \pm 0.1\text{m}$  above the surface and record the maximum % relative humidity.

### 18.2. Test apparatus

Handheld digital hygrometer, accurate to  $\pm 1\%\text{RH}$ .

The hygrometer should not be held in direct sunlight.

### 18.3. Test procedure

Validate the handheld digital hygrometer in accordance with NIST regulations.

The hygrometer should not be used during precipitation.

Tests on site shall be conducted in the positions A, L, K, J, Q, H shown in *Figure 1: Field test positions*.

The hygrometer should be held in such a position so as to allow for natural air flow.

### 18.4. Calculation and expression of results

Report the measurements to the nearest  $1\%\text{RH}$ .

## 19. DETERMINATION OF WIND SPEED (FIFA NPS TEST METHOD 11)

### 19.1. Principle

This test method describes the procedure for measuring the wind speed.

### 19.2. Test apparatus

Handheld digital anemometer accurate to 0.1m.s-1 and compliant with ISO 17713-1:2007.

### 19.3. Test procedure

Tests on site shall be conducted in the positions A, L, K, J, Q, H shown in *Figure 1*: Field test positions.

Hold the anemometer at the test location and at one metre approximately ( $\pm 0.1\text{m}$ ). Continue to record the wind speed during the time of each individual test. Reject any values if the wind speed exceeds 2.0ms-1.

### 19.3.1. Calculation and expression of results

Report the measurements to the nearest 0.1m.s-1.

## 20. DETERMINATION OF SOIL TEMPERATURE (FIFA NPS TEST METHOD 12)

### 20.1. Principle

This test method describes the procedure for measuring the temperature of the upper layers of the soil.

At each location using the probe, penetrate the soil at an angle of approximately 20° to the horizontal of the surface for a minimum of 30 seconds. Remove the probe and repeat the insertion of the probe within 5cm of the original. Allow the temperature to stabilise and record the value.

### 20.2. Test apparatus

A calibrated handheld digital thermometer accurate to  $\pm 0.1^\circ\text{C}$  with a minimum operating temperature range that covers  $-10^\circ\text{C}$  to  $+60^\circ\text{C}$ . The digital thermometer must have a probe attachment that can be used to penetrate the soil structure to a minimum depth of 11cm.

Repeat the procedure at each location.

### 20.3. Test procedure

Tests on site shall be conducted in the positions A, L, K, J, Q, H shown in *Figure 1*: Field test positions.

If the surface is partially shaded, it will potentially have a significant effect on the soil temperature values measured. If, during the measurements, part of the surface is shaded and part is in sunlight, note whether the area is shaded or in sunlight.

Recognise if the area is shaded and indicate the north.

### 20.4. Calculation and expression of results

Report the average value to the nearest  $^\circ\text{C}$  for each of the positions.

## 21. DETERMINATION OF SURFACE HARDNESS (FIFA NPS TEST METHOD 13)

### 21.1. Principle

This test method describes the procedure for measuring the hardness of natural turf using an impact tester.

### 21.2. Test apparatus

A 2.25kg compaction hammer as described in ASTM F1702. A mechanical holding and releasing is recommended to ensure the exact drop height.

### 21.3. Test procedure

Place the guide tube on the playing surface and maintain it in a vertical position during the drop.

Lift the missile to obtain a drop height of 457mm  $\pm 3\text{mm}$ .

Release the missile and record the g max value.

Tests on site shall be conducted in all of the positions (A to S) shown in *Figure 1: Field test positions*.

### 21.4. Calculation and expression of results

The values are reported to the nearest multiple of g.



## 22. DETERMINATION OF COMPACTION SEVERITY (FIFA NPS TEST METHOD 14)

### 22.1. Principle

This test method describes the procedure for measuring the compaction of the soil using a penetrometer.

### 22.2. Test apparatus

#### 22.2.1. Penetrometer

An analog or digital handheld penetrometer

Tips of 12.7mm (0.5 inches).

### 22.3. Test procedure

Select and attach the tip appropriate to the soil to be tested.

Place the tip on the surface and vertically apply even pressure to the handles located on either side of the central dial. At a slow even pace, penetrate the soil.

As the device penetrates the soil, note the depth with the maximum reading (maximum compaction) up to 152mm (6 inches).

**Note:** the presence of stone will have a detrimental effect on the penetration and any results that occur due to this should be discarded.

Tests on site shall be conducted in the positions A, L, K, J, Q, H shown in *Figure 1: Field test positions*.

### 22.4. Calculation and expression of results

Report the depth of the maximum compaction in metres with to decimal places (0.01m)

Report the compaction values in MPa rounded to five decimal places.

## 23. DETERMINATION OF WATER INFILTRATION RATE (FIFA NPS TEST METHOD 15)

### 23.1. Principle

Two concentric cylinders are sealed into the tested surface. Water is poured into the cylinders. The exterior cylinder function is to prevent lateral infiltration from the inner cylinder. The water penetration speed into the tested surface is measured.

### 23.2. Apparatus

Two concentric cylinders as per EN 12616 Method B.

Inner cylinder diameter ( $300 \pm 5\text{mm}$ )

Outer cylinder diameter ( $500 \pm 25\text{mm}$ )

**Note:** The use of smaller cylinders ( $150 \pm 5\text{mm}$  and  $300 \pm 25\text{mm}$ ) is permitted.

### 23.3. Test procedure

Follow the test procedure described in EN 12616 Method B.

Tests on site shall be conducted in the positions A, L, K, J, Q, H shown in *Figure 1*: Field test positions.

### 23.4. Calculation and expression of results

The values are reported to the nearest mm/h unit.



## 24. DETERMINATION OF NORMALISED DIFFERENCE VEGETATION INDEX (NDVI) (FIFA NPS TEST METHOD 16)

### 24.1. Principle

The Normalised Difference Vegetation Index (NDVI) is a dimensionless index that describes the difference between visible and near-infrared reflectance of vegetation cover and can be used to measure the density of green on an area of land (Weier and Herring 2000). The NDVI can help to detect stress on a natural grass surface earlier than visual monitoring.

NDVI is used to estimate a number of properties, including Leaf Area Index, Fractional Vegetation Cover, etc. Issues arise from many sources, namely moisture content in soil, which creates variations as does cloud cover, shading, etc. Special care should be taken when measuring NDVI on poor ground coverage surfaces, high weed content surfaces or in the presence of surface algae.

### 24.2. Apparatus

A NDVI device with an internal light source to negate the effect of sunny versus cloudy conditions and capable of measuring the reflectance at the specific wavelengths corresponding to the red spectrum 660nm to near infrared 840nm or 850nm.

### 24.3. Test procedure

Hold the device at approximately 1m from the surface. A digital reading of the surface is generated and is either stored within the software of the device or should be manually recorded.

Point the device to the surface and walk for a distance of approximately 4m (four steps), recording in the meantime the NDVI value and then reporting the average NDVI of the surface tested.

Care should be taken to not point the device to the feet of the technician.

Tests on site shall be conducted in all positions (A to S) shown in *Figure 1: Field test positions*.

### 24.4. Calculation and expression of results

NDVI is calculated from the formula:

$$\text{NDVI} = \frac{(\text{NIR}-\text{Red})}{(\text{NIR}+\text{Red})}$$

**NIR:** Near Infrared

The values are reported to the nearest NDVI unit.

## 25. DETERMINATION OF EFFECTIVE ROOT DEPTH (FIFA NPS TEST METHOD 17)

### 25.1. Principle

This test method describes the procedure for measuring the root penetration into the soil.

### 25.2. Test apparatus

The test apparatus comprises the following:

- a. A corer (auger) of a minimum diameter of  $25 \pm 5\text{mm}$  and a maximum diameter of  $50 \pm 5\text{mm}$  and a maximum length of  $300 \pm 5\text{mm}$ .
- b. A mallet
- c. A calibrated 300mm steel ruler capable of measuring to 1mm

### 25.3. Test procedure

Tests on site shall be conducted in the positions A, L, K, J, Q, H shown in *Figure 1: Field test positions*.

At each location, drive the corer vertically progressively into the turf surface. Withdraw the corer and the sample of soil and root attached. Measure the length of the roots that have developed with the steel ruler. The length should be recorded to the nearest whole mm. Ensure that the appropriate value obtained corresponds to a specific area on the field.

If there is concern that the root structure is developing sporadically, a photograph of the cores should be taken with the ruler placed at the side of the cored sample.

Repeat the procedure at each location.

Avoid sampling very dry areas or those that have been subjected to excessive water. Also avoid any areas that have an atypical soil structure. Take note of the general condition of the turf, paying particular attention to any areas that have been subject to intensive use, stress, shading or any factor that may have influenced the normal growth of the turf.

Special care should be taken of the drain pipes when taking a core sample.

### 25.4. Calculation and expression of results

Maximum root depth: the maximum length of the roots.

Effective root depth: the depth from which roots can easily extract most of the water needed for transpiration. It can be limited by physical (e.g. compaction) or chemical (e.g. pH) properties. It is the section of the roots which is more dense and active.

Report the values to the nearest 5mm.



## 26. DETERMINATION OF THATCH DEPTH OF NATURAL TURF (FIFA NPS TEST METHOD 18)

### 26.1. Principle

This test method describes the procedure for measuring the thatch depth of a natural turf.

### 26.2. Test apparatus

The test apparatus comprises the following:

- d. A corer (auger) of a minimum diameter of  $25\pm 5$  mm and a maximum diameter of  $50\pm 5$  mm and a maximum length of  $300\pm 5$  mm.
- e. A mallet
- f. A calibrated 300mm steel ruler capable of measuring to 1mm

### 26.3. Test procedure

Tests on site shall be conducted in the positions A, L, K, J, Q, H shown in *Figure 1: Field test positions*.

At each location, drive the corer vertically progressively into the turf surface. Withdraw the corer and the sample of soil and root attached. Measure the thatch depth with the steel ruler. The length should be recorded to the nearest whole mm. Ensure the appropriate value obtained corresponds to a specific area on the field.

Repeat the procedure at each location.

Special care should be taken of the drain pipes when taking a core sample.

### 26.4. Calculation and expression of results

Report the values of the thatch depth to the nearest mm for each test location.

## 27. DETERMINATION OF GROUND COVER OF NATURAL TURF (FIFA NPS TEST METHOD 19)

### 27.1. Principle

This test method describes the procedure for measuring the ground coverage of the surface.

### 27.2. Test apparatus

A square frame as described in EN 12231:2003 Method B.

### 27.3. Test procedure

Place the frame on the surface. The frame comprises a number of subdivisions. Count how many subdivisions are occupied by the soil. The number of full divisions can be calculated as the percentage value.

Tests on site shall be conducted in the positions A, L, K, J, Q, H shown in *Figure 1: Field test positions*.

Repeat the procedure 3 times at each location (4 measurements in total).

### 27.4. Calculation and expression of results

Percentage of the ground coverage and soil for each location.

## 28. DETERMINATION OF WEED CONTENT (%) (FIFA NPS TEST METHOD 20)

### 28.1. Principle

This test method describes the procedure for measuring the weed content of the surface.

Tests on site shall be conducted in the positions A, L, K, J, Q, H shown in *Figure 1: Field test positions*.

### 28.2. Test apparatus

A square frame as described in EN 12231:2003 Method B.

Repeat the procedure at each location.

### 28.3. Test procedure

Place the frame on the surface. The frame comprises a number of subdivisions. Count how many subdivisions are occupied by the weed. Repeat the process for all of the weeds present within the frame. The number of full divisions can be calculated as the percentage value.

**28.4. Calculation and expression of results**  
Percentage of the weed content for each location.

## 29. DETERMINATION OF INSECT PESTS (FIFA NPS TEST METHOD 21)

Definition: an insect pest may be regarded as any species of insect that may have a harmful effect on the development of healthy turf.

carefully noting the location on the pitch. Where possible, note the different species present, and if unknown take photographic evidence and check the species later. If the species is not above the surface but is clearly present below the surface, this should also be noted.

### 29.1. Principle

This test method describes the procedure for counting the number of invasive insect pests present in the pitch.

Move the frame to a new area and repeat the procedure.

### 29.2. Test apparatus

The frame as described in EN 12231:2003 Method B section 7.1.

Tests on site shall be conducted in the positions A, L, K, J, Q, H shown in *Figure 1: Field test positions*.

### 29.3. Test procedure

Place the frame on the natural turf surface.

**29.4. Calculation and expression of results**  
Report the total number of individual invasive species per pitch and emphasise where necessary specific areas where there is a higher infestation.

Count the number of invasive insect pests within the frame and note the number present,

## 30. DETERMINATION OF DISEASES (FIFA NPS TEST METHOD 22)

### 30.1. Principle

This test method describes the procedure for assessing the presence of diseases in the natural turf and soil.

### 30.2. Test apparatus

The frame as described in EN 12231:2003 Method B section 7.1.

### 30.3. Test procedure

Tests on site shall be conducted in the positions A, L, K, J, Q, H shown in *Figure 1: Field test positions*.

Place the frame on the natural turf surface.

Count the number of diseased plants within the frame and note the number present, carefully noting the location on the pitch. Where possible, note the different diseases present, and if

unknown take photographic evidence and check the infected plant later. If the infection is not above the surface but is clearly present below the surface, this should also be noted.

Move the frame to a new area and repeat the procedure.

For a standard-sized pitch, undertake 30 separate evaluations in the standard "W" pattern. However, if an area is prone to a particularly high level of infection, further readings in the area(s) may be beneficial in assessing the extent of the problem.

### 30.4. Calculation and expression of results

Report the total number of individual diseased plants per pitch and emphasise, where necessary, specific areas where there is a higher level of infection.

## 31. DETERMINATION OF VOLUMETRIC SOIL MOISTURE CONTENT (FIFA NPS TEST METHOD 23)

### 31.1. Principle

This test method describes the procedure for measuring the moisture content of soil.

### 31.2. Test apparatus

Measurement accuracy:  $\pm 0.01\text{m}^3\cdot\text{m}^{-3}$  (1%)

Full accuracy over: 0 to  $0.5\text{m}^3\cdot\text{m}^{-3}$

Soil moisture measurement range: 0 to  $1.0\text{m}^3\cdot\text{m}^{-3}$

Rods: 50mm to 80mm

### 31.3. Test procedure

Place the probe on the natural turf surface and insert it to its full length. Take four measurements.

Move to a new location and repeat the procedure.

Tests on site shall be conducted in the positions A, L, K, J, Q, H shown in *Figure 1: Field test positions*.

### 31.4. Calculation and expression of results

Report the average and variation for each test location.

## 32. DETERMINATION OF SOIL PH IN LABORATORY (FIFA NPS TEST METHOD 24)

### 32.1. Principle

This test method describes the procedure for measuring the pH of soil in laboratory from samples taken on-site.

### 32.2. Test procedure

The sampling position and sampling depth are at the discretion of the technician and shall be reported.

Samples shall be tested according to ASTM D4972.

### 32.3. Calculation and expression of results

Position and depth of the sampling, method used (A or B) in laboratory, pH level of each sample.

## 33. DETERMINATION OF SOIL NUTRIENT LEVELS IN LABORATORY (FIFA NPS TEST METHOD 25)

### 33.1. Principle

This test method describes the procedures for assessing soil health in laboratory from samples taken on-site.

A basic soil test shall provide information on the levels of the macronutrients phosphorus (P), potassium (K), magnesium (Mg) and calcium (Ca).

### 33.2. Test procedure

Sample extraction procedure: Mehlich 1 (M1) or Mehlich 3 (M3)

A complete soil test shall provide information on the levels of the macronutrients phosphorus (P), potassium (K), magnesium (Mg), calcium (Ca), sulfur (S), and micronutrients iron (Fe), zinc (Zn), copper (Cu), manganese (Mn) and sodium (Na).

### 33.3. Calculation and expression of results

Report the concentrations of the various elements for each individual sample location.

