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Surfaces of the tennis courts

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Dimensions

The flat surfaces where the tennis is played are rectangular with specific measures and are determined and regulated by the International Tennis Federation (ITF) in the annual document "Rules of Tennis".

Figure 1
Regulatory measures to the tennis courts as ITF

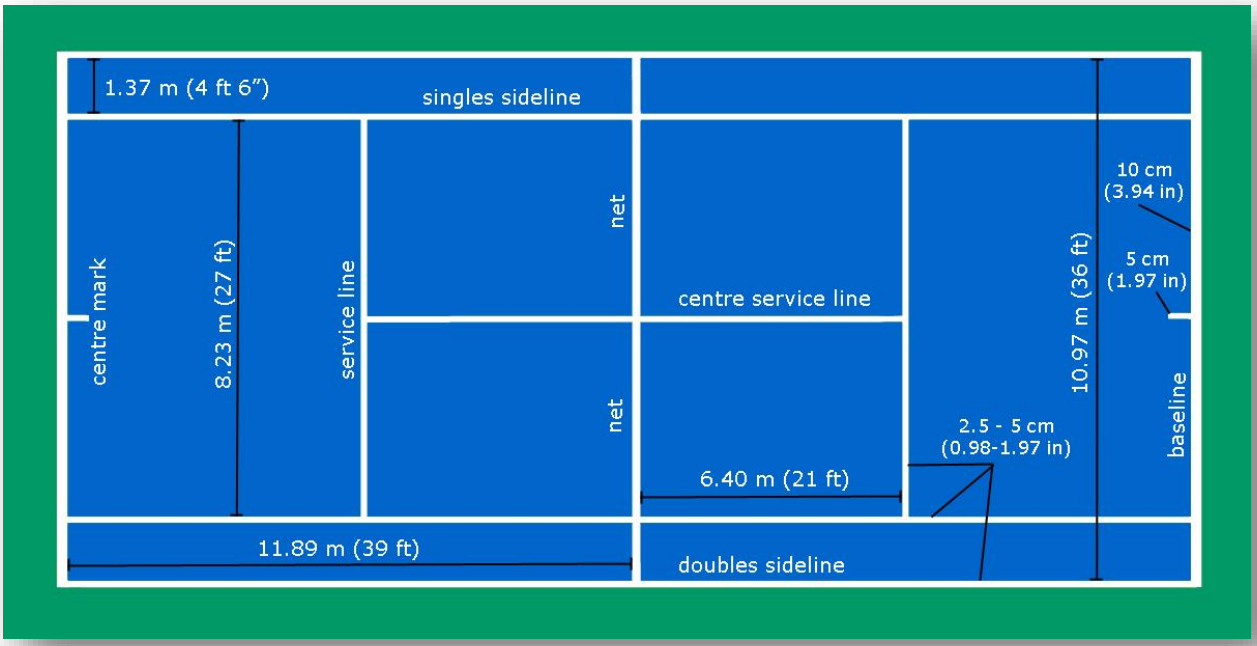
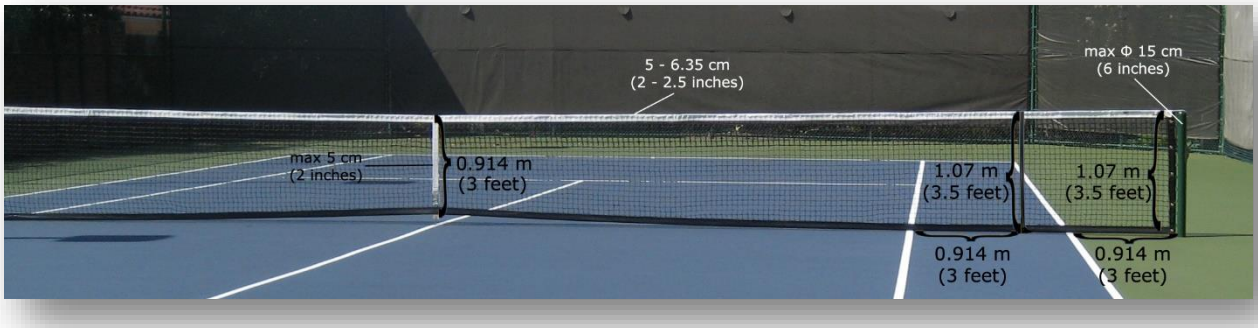


Figure 2
Measures of the net for singles and doubles



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Types of surfaces

Red Clay

The clay courts are made of crushed white limestone, stone or brick. These clay courts make slow the ball bounce, but produce a high bounce when compared to grass and hard courts (asphalt, carpet). For this reason, the clay courts takes away the advantage to the great servers who base their game in their service doing difficult for them play in this kind of surface. The clay courts are cheaper to construct than other types of tennis courts, but have a more costly maintenance. The clay courts must be rolled to preserve flatness. The water content in the clay should be balanced. Furthermore, this type of courts require a slope for water runoff.

The clay courts are more common in Europe (Figure 3) and Latin America than in North America and tend to heavily promote the background game.

In general, the composition of this type of courts contains several layers: Once the field is leveled:

a) Layer with large stones 15-25 cm,
b) Stones 5-10 cm,
c) Composed of crushed gravel with sand stones 1-5 cm,
d) The "crushed white limestone" composed of various types of land between 5-15 cm,
e) Red brick dust from 0.50 to 1 cm

The "crushed white limestone" is that makes faster or slower the court, depending on its thickness. The main disadvantage that presents this type of courts is the costly maintenance in terms of the amount of water required, the amount of clay or dust brick and especially the labor required. On the other hand, the advantage is that the articulations of the players suffer less.

Figure 3
Clay court

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Composition of the Roland Garros courts (Figure 4)

1) Red brick dust: 1-2 cm
2) Crushed white limestone: 5-7 cm
3) Clinker (coal residue): 7-8 cm
4) Crushed Gravel: at least 30 cm
5) Drain

Figure 4
Composition of the clay courts of Roland Garrós

Hard Courts.

a) Porous concrete or asphalt conglomerate

This type of courts are usually built due to the low maintenance and long life. These courts have a greater construction cost than the clay courts. These are the most common courts in the United States, Australia and Asia, both indoors and outdoors. The Australian Open uses a hard surface called Plexicushion® and the United States used a product called DecoTurf®.

These courts have the same layers like the tennis clay courts, except that instead of the layers of limestone and red clay is placed a layer of porous concrete between 5-15 centimeters. The conglomerate asphalt courts suppress the porous concrete layer by another of tar between 5-15 centimeters.

These courts have good water absorption and low maintenance labor, however, the hard surfaces affect the articulations of the players which suffer greatly. These courts offer greater consistency to the bounce of the ball than other courts. They are fast surfaces, uniform and more predictable than clay or grass. These courts vary in rebound velocity being faster than clay courts but slower than grass courts.

The amount of sand mixed with paint of the top layer of the surface and the size of its grains will be decisive for the speed of the rebound and the friction of the ball. While more sand is used in the top layer slower will be the court and the larger sand grains will slow down the game speed.

Figure 5
Tennis court built with DecoTurf®

Composition of the US Open courts (Figure 6)

1) Acrylic US Open blue (textured, pigmented, resin-bound coating)
2) Fine rubber cushion
3) Heavy rubber cushion
4) Acrylic filler course
5) Concrete or asphalt sub-base

Figure 6
Composition of the US Open courts

b) Carpets

These courts have the same basis as concrete or asphalt, but the last layer is composed of a series of resins of different materials and thicknesses. Some of the most used materials for these courts on the professional circuit is the Taraflex® Tennis. This type of courts that have evolved considerably in recent years, have the property of absorbing more the effect of impacts (with regard of the concrete or asphalt courts) that occur between the surface and the articulations, partly due to resins, and also have less maintenance. As a disadvantage, do not absorb water and the last layer is too abrasive, resulting in a permanent material wear (rubber shoes, balls, etc.)

Carpet is a term used in tennis to designate any removable cover. This type of court is widely used in temporary events, indoor and multipurpose stadiums. In these cases, the carpet is usually placed on a wooden or asphalt court. The carpet, generally, is a fast surface (rather than concrete or asphalt) with a low *coefficient of restitution* or rebound (COR).

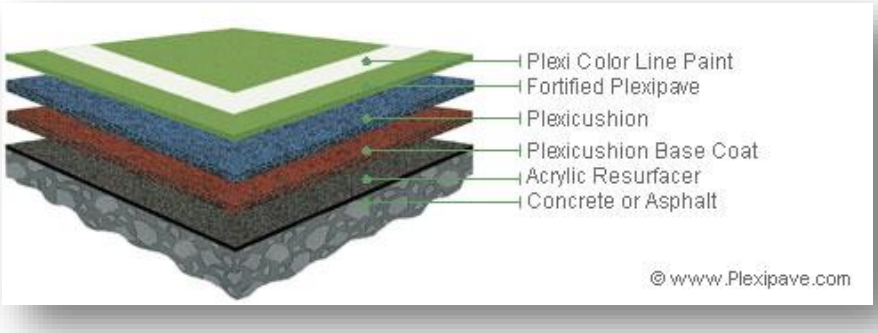
Figure 7
Tennis court built with Plexicushion®

Composition of Australia Open courts (Figures 7, 8)

1) Australian Open blue (textured, pigmented, resin-bound coating)
2) Plexicushion®
3) Plexicushion® base coat
4) Acrylic filler course
5) Concrete or asphalt sub-base

Figure 8
Composition of the Australian Open courts

Figure 9. Layers of Plexicushion® carpet



Natural grass

The grass courts are those with the fastest surface (AstroTurf[1] surfaces are faster still, but are used only for personal courts). They consist of grown grass planted in a compacted soil, we must also consider other aspects such as rebounding the ball depend largely on how healthy is the grass, the elapsed time from the last cut, and wear of it because of use in recent games.

The points are played, usually, very fast, the bounces are low and contribute that the rallies have shorter duration. In this kind of courts the service has greater significance than other surfaces. The grass courts tend to favor serve and volley players. The surface is less firm and more slippery than hard courts, causing more slip and a less bounce of the ball, hence the players must go to get the ball quickly. The players whose game is characterized as serve and volley take advantage of this type of surface to serve (usually serving with "slice" for its greater effectiveness on grass) and then running to the net to volley the return of serve, leaving to his opponent little time due to low and fast bounce of the ball. Frequently, the players, in this surface, execute flatter shots to increase the speed and power of the ball and taking time from the opponent in the execution of his/her punches.

In 2001, Wimbledon organizers changed the 100% of the perennial rye grass, also switched to a harder and more compact soil to cause a higher bounce of the ball and a slower game. As a result, serving and volleying has become rare at Wimbledon and background players (baseliners) dominant as Rafael Nadal, Venus Williams and Serena Williams have been able to win many titles.

The grass courts were once the more common surfaces of tennis courts, but nowadays are rare due to their high maintenance costs, as they must be watered and mowed frequently, besides take longer to dry after rain than hard courts. The grass surface, however, is the most compatible with the human body due to their natural softness.

[1] Astro Turf is a brand of artificial grass. The main reason for incorporating Astro Turf on the court was to avoid the cost of placing natural grass, especially indoor courts.

Composition of the Wimbledon courts

1) Grass
2) Rootzone (23% clay content): 25 cm
3) Blinding layer: 5 cm
4) Stone: 15 cm
5) Drain

Figure 10
Composition of the Wimbledon courts

Figure 11
Court No. 11 in Wimbledon[2]

Artificial grass

Such courts are built on a surface of porous concrete or asphalt conglomerate.

Artificial grass decreases the adverse effects of rain, ice and humidity, which appear on most surfaces. This type of synthetic grass absorbs rainwater and humidity that seeps through the porous pavement, leaving the pitch in perfect condition. The cost/benefit ratio is low so provides optimum return on initial investment. The maintenance is low.

Trend toward the slow play

In the early '90s, tennis fans began to criticize the fast game that only benefited the most boring players to watch. The fast surfaces did not allow long points. Usually the game was based on a powerful serve, followed by a run toward the net, game mode known as *serve and volley.*

[2] Wimbledon (24.06.2010). Court 11, where was played the longest tennis match of all time between John Isner (USA) and Nicolas Mahut (FRA) where the American edged the Frenchman in second round by 6-4, 3-6, 6(7)-7, 7-6(3), 70-68 in 11 hours and 5 minutes.

In Grand Slams, in the last decade, the ITF has been becoming slower surfaces. For example, in Wimbledon have changed the composition of the grass, the Australia Open changed to a slower synthetic and the US Open has added more sand to the top layer of the courts in an effort to make them slower.

Small courts – Play + Stay

The ITF campaign Play and Stay aims to increase tennis participation worldwide, by improving the way children are introduced to the game. The campaign promotes that is played on smaller courts and slower balls of red, orange and green with less compression than usual. This gives children more time and more control to execute the service, to the rally and score from the first lesson in courts that are sized to fit their physical. The ITF has ordered that the official competition for children under 10 years old should be playing in the called Orange courts of 18 meters long for 6 to 8.23 meters wide. Competition for children under 8 years old is played in Red courts that are between 11 and 13 meters long and 4.30 to 6 meters wide. The net has 0.8 meters high at the center.

RED (Stage 3)
Court 36-42ft (10.97-12.8m) x 14-20ft (4.27-6.1m)
Net Height (at the center): 31.5-33in (0.8-0.838m)

ORANGE (Stage 2)
Court 58-60ft (17.68-18.29m) x 20-27ft (6.1-8.23m)
Net Height (at the center): 31.5-36in (0.8-0.914m)

GREEN (Stage 1)
Full Size Court 23.77 x 8.23m
Standard Net Height (at the center): 36in (0.914m)

Technical aspects of the surfaces

Tennis is played on different surfaces whose properties affect the style and quality of play.

Among these properties we can mention the following:

- *Friction*. It is the relative resistance between a court surface and the tennis ball with that surface. Friction is measured by the "friction coefficient" (COF) which is the ratio of the components of the horizontal and vertical forces between the ball and the surface. While rougher the surface will be greater the friction coefficient (COF), causing a reduction in the horizontal velocity (m/s) so that it will be "slower" in this case, the playing surface.

- *Energy restitution*. It is the energy not absorbed by the surface after ball impact. A decrease in the rebound energy is considered as a reduction in the vertical speed of the ball after impact. The "coefficient of restitution" (COR) is the ratio of the horizontal velocity (m/s) after the bounce and vertical speed (m/s) before ball impact with the surface. A surface with a lower COR is often perceived as a slower surface, because the player has more time to reach the ball.

- *Topography and dimensions*. Refers to the geometric regularity of the surface (uniformity); slope and planarity designed to assist drainage; and the relative locations of court markings (dimensions).

- *Consistency.* This aspect relates to the uniformity of the properties of the surface over the entire playing area, its stability over time, the use and maintenance.

General considerations for the professional tennis circuit

To test the surfaces is advisable to perform the in situ tests, although it is acceptable to analyze samples from surfaces in laboratories. Ideally do both, on-site and labs tests.

For testing on site is required one stabilization period that may vary depending on the type of surface. Thus, for the case of an acrylic surface stabilization period could be a week or several months in the case that the surface is clay or grass.

At the time of the in situ tests should be taken into account aspects such as:

- Maximum and minimum air temperature, surface and balls.
- Maximum and minimum relative humidity.
- Maximum and minimum atmospheric pressure.
- Surface condition. For example, wet, dry, etc.

It is advisable to perform tests on the court when it is as dry as possible, to minimize the environmental conditions as possible.

Once you have done all the surface tests, whether in situ or laboratory, a report is made that must contain:

- Reference of the method and the ITF code[3].
- Detailed description of the composition of the surface and its layers.
- Information on environmental conditions during testing, temperature, humidity, atmospheric pressure, altitude, location.
- The type and brand of ball used in the tests and the country of manufacture.
- All measurements and results, their averages and statistical variations (compared to each category or recommendation).

ITF COURT PACE RATING (CPR)

The Court Pace Rating (CPR) is a coefficient that measures the effect of the interaction of the ball with the surface and is used as a criterion to qualify courts. The concepts implicit in the calculation of CPR are the friction (COF), which is determined by the reduction in the horizontal component velocity after impact of the ball with the surface and restitution (COR) of the vertical component, which determines the time between two successive bounces.

The CPR is derived from a theoretical model of contact ball/surface, assuming that the ball and the surface are rigid during the impact and the ball slides along the contact with the surface. These circumstances make it necessary for such impacts possess negligible spin of the ball with a particular speed and angle.

This whole process is carried out with devices that accurately measure the coefficients of friction, restitution, etc. For example, to measure the spin or rotation speed of the ball a video camera or high speed photographic strobe is used.

Calculation of CPR[4]

A report includes information of the results for each impact. According to the ITF, the variables and formulas for calculation are:

V_{ix} = horizontal inbound velocity (m/s)
V_{iy} = vertical inbound velocity (m/s)
V_{fx} = horizontal outbound velocity (m/s)
V_{fy} = vertical outbound velocity (m/s)
e = coefficient of restitution (COR)
μ = coefficient of friction (COF)
$\mathbb{T}$ = mean ball temperature for test (°C)
c = temperature coefficient (0,003)
e_T = adjusted COR for temperature $\mathbb{T}$
α = pace perception constant (150)
β = mean coefficient of restitution for all surface types (0.81)
CPR = Court Pace Rating

[3] "ITF APPROVED TENNIS BALLS, CLASSIFIED SURFACES & RECOGNISED COURTS 2014 – a guide to products and test methods" (page 39). www.itftennis.com/technical
[4] Ibid. page 38

The formulas for calculating the COR, COF and CPR are,

$$e = \frac{V_{fy}}{V_{iy}} \qquad \mu = \frac{V_{ix} - V_{fx}}{V_{iy}\,(1 + e)} \qquad e_T = e + c(23 - T) \qquad CPR = 100(1 - \mu) + \alpha(\beta - e_T)$$

The test consists of the average of the CPRs of all impacts on the court, not considered the impacts on the lines. The statistical variation is given by the maximum difference from the average of the CPRs for each area of the court, excluding the impacts on lines or other marking.

Table 1
Categories of surfaces sorted by CPR

Category	CPR
Category 1: Slow	≤ 29
Category 2: Medium-slow	30 – 34
Category 3: Mediium	35 – 39
Category 4: Medium-fast	40 – 44
Category 5: Fast	≥ 45

As a guide, the accepted tolerance in the value of CPR for an installed court (from experience of contractors using quality materials and conventional methods at a reasonable cost) is ± 5 points from the calculated CPR. This tolerance applies to new courts. The testing variation of the CPR in the on-site, excluding line markings, should not exceed 10 points CPR. The CPR may vary depending on the composition of the materials supporting the playing surface of the court.

The coefficients of friction (COF) and restitution (COR) of a surface are classified as follows:

Table 2
Categories of the coefficients of restitution and friction

Category	COR	COF
High	≥ 0.85	≥ 0.71
Medium	0.79 – 0.84	0.56 – 0.70
Low	≤ 0.78	≤ 0.55

Surfaces with a COR less than 0.70 are not recommended for use of tennis courts. The maximum variation[5] in COR between tests means that, excluding the marks of the lines, must be ≤ 0.05. The maximum variation of COF on-site testing means, excluding line markings, should be ≤ 0.05.

[5] Variation is expressed as the standard error, that is to say, the standard deviation of all tests, divided by the square root of the number of tests.

Official Classification of the surfaces according to the ITF

The descriptions in the table 3 are a reference to classify surfaces by identifying the type of surface associated with each listed product. Description refers only to the construction of the court, and not their characteristics (ROC, COF, CPR).

Table 3
Official Classification of the surfaces

Surface code	Type	Description
A	Acrylic[6]	Textured, pigmented, resin-bound coating.
B	Artificial clay[7]	Synthetic surface with the appearance of clay.
C	Artificial grass[7]	Synthetic surface with the appearance of natural grass.
D	Asphalt[8]	Bitumen-bound aggregate.
E	Carpet	Textile or polymeric material supplied in rolls or sheets of finished product.
F	Clay[9]	Unbound mineral aggregate.
G	Concrete[8]	Cement-bound aggregate.
H	Grass	Natural grass grown from seed.
J	Other	E.g. modular systems (tiles), wood, canvas.

All surfaces may be porous or non-porous, with the exception of "clay" and "grass", which are always porous.
For example, the following products to the surface of the tennis courts have been classified by the ITF and divided into five categories[10]:

Category 1 (slow)
Category 2 (medium-slow)
Category 3 (Medium)
Category 4 (medium-fast)
Category 5 (fast)

[6] Typically represents a layer of a few millimeters of a court.
[7] For "appearance" refers only to the shape of the material of the top surface and no other features (such as color). These surfaces are typically composed of a matrix carpet coated with clay, artificial grass, sand and/or rubber granules.
[8] It is used only when the material itself forms the playing surface. When used as a base for other surfaces (e.g. acrylic), refers only to the playing surface.
[9] This term denotes a type of surface to be constructed from natural materials and includes a fine sandy component as the upper layer of the playing surface. The integrity of the surface will not be dependent on the addition of a membrane or structural layer.
[10] This classification does not in any way imply approval of the ITF, it's just a reference to facilitate the analysis of surfaces.

We see an example for Category 1 only (Slow):

Table 4
CATEGORY 1 (Slow)

Name of Surface product	Surface code
Acryflex T Cushion	A
Advanced Tennis Court-Meiguflex Series	E
Çevika Cushion	A
Classic Clay (sand-dressed)	B
ClayTech® (clay-dressed)	B
Confort Clay (clay-dressed)	B
Conipur Pro Clay	F
Cremonini Red Clay	F
Decoflex D6 System	A
Dreamfield	J
Har-Tru Court	F
Liddell Grass LD TG 19 (sand-filled)	C
…	…