IBV

REPORT

10 MARCH 2003

ANALYSIS OF ARTIFICIAL TURF STANDARDS

CONTENTS:

1 INTRODUCTION

The aim of this document is to contribute to the future discussion about the improvement of artificial turf standards. This document does not pretend to be a scientific paper. For this reason references to existing literature, mathematical explanations or detailed tests descriptions are avoided. The aim of this document is to contribute to the future discussion about the improvement of artificial turf standards.

Any test method included in the standards must have the following attributes:

1. Must be appropriate and cost-effective.
2. Must be reliable and repeatable. The reliability and repeatability must be known and fixed according to the cost and property that we want to measure.
3. The results have to been related with the properties that we want to measure.

Sometimes the lack of knowledge, the cost-effectiveness or the reliability necessities reduce the relation between the test result and the property that we want to know. One example could be the present European standard for playground surfaces (EN1177). The EN1177 uses the Head Injury Criterion – HIC (test result) for measuring the protection that the surface offers when a children falls (property). A lot of scientific work has probed that HIC has defects, but experts and industry agree that is necessary to have a test method because the other option is to have nothing, and to permit to install very unsafe surfaces. HIC is related with safety and that it is the best test considering the other attributes: cost-effect, reliability and repeatability. Although it is necessary to follow with research in order to improve the test.

The ideas and conclusions written in this document are based on the present biomechanical knowledge, existing studies about sport surfaces for football (including the report written by XLTurf "A biomechanical evaluation of XL Turf systems" in collaboration with the Université du Québec à Montréal, and the preliminary results of the SOCRATRUF project.

SOCRATURF is the acronym of the project "New artificial turf fields with maximal safety, functional, comfort and ecological performance for soccer applications." This project is funded by the European Community under the 'Competitive and Sustainable Growth' Programme (1998-2002), CONTRACT N°: G1ST-CT-2001-50141.

The goal of the Socraturf project is to develop new artificial field concepts, which are pleasant for players to play football on, which lead to optimum performance and which are safe for the users. Several companies and research institutions are working together in the project.

Companies:

Ten Cate Thiolon B.V. (co-ordinator) - Netherlands.

Edel Grass BV - Netherlands

Poligrass Iberica SA – Spain.

Saltex Oy – Finland.

Research institutions:

Institute of Biomechanics of Valencia (IBV) – Spain.

TNO. - Netherlands.

In the following the properties and some of different test methods that appear in the UEFA and FIFA manual are revised according to the attributes described above.

2 SHOCK ABSORPTION AND DEFORMATION

Perhaps one of the most controversial discussions is about safety versus performance: more performance means less safety. This concept is wrong. And it is erroneous to separate the two aspects in different parameters, for example relating more shock absorption with more safety, but with less energy restitution and less performance. People adapt their movements to the surface mechanical properties, for example changing knee flexion or stride length. And this adaptation could produce loss of performance and reduce safety at the same time. The question is to find the optimum properties that maximize safety and performance at the same time.

Shock absorption and deformation is strongly related. For this reason is important to study the two parameters together.

The shock absorption property will be related with the capacity of the sport surface of reducing impact forces with high frequency content that appears when the player runs or jumps. The impact energy must be absorbed and dissipated by the sport surface. Trained athletes are able to reduce impacts themselves adapting their movements, but fatigue will reduce the adaptation capacity and increase the risk of injuries. At the same time the sport surface must not reduce the propulsion forces with low frequency content. The propulsion forces are smooth and this energy is used by the player. Then the ideal surface could be described as low pass filter that eliminates fast forces (high frequency) and maintain low forces (low frequency).

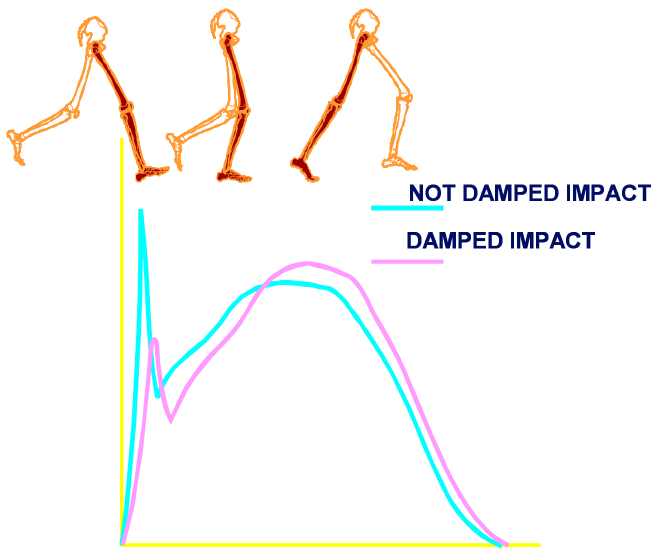

Figure 1 : Vertical force and effect of the ideal surface.

The UEFA and FIFA manual use artificial athlete and the Force Reduction parameter for measuring the shock absorption property. The spring that is used by the artificial athlete (2000KN/m) and the falling weight applies a high and fast vertical force (Fv) with high frequency content. The spring also permits to test over very rigid surfaces, as concrete, which can be used like reference material. In this manner is easy to test if the device has any defect: excess of friction in the guides, spring or malfunction of sensors.

It is true that horizontal forces (Fh) appear when the player is running. But these forces are minimized because the foot does a rolling movement. For example the rate Fv/Fh when the maximum vertical force appears is 11 or more, that means 85º or more degrees. For this reason the necessity of testing angular impacts is not justified.

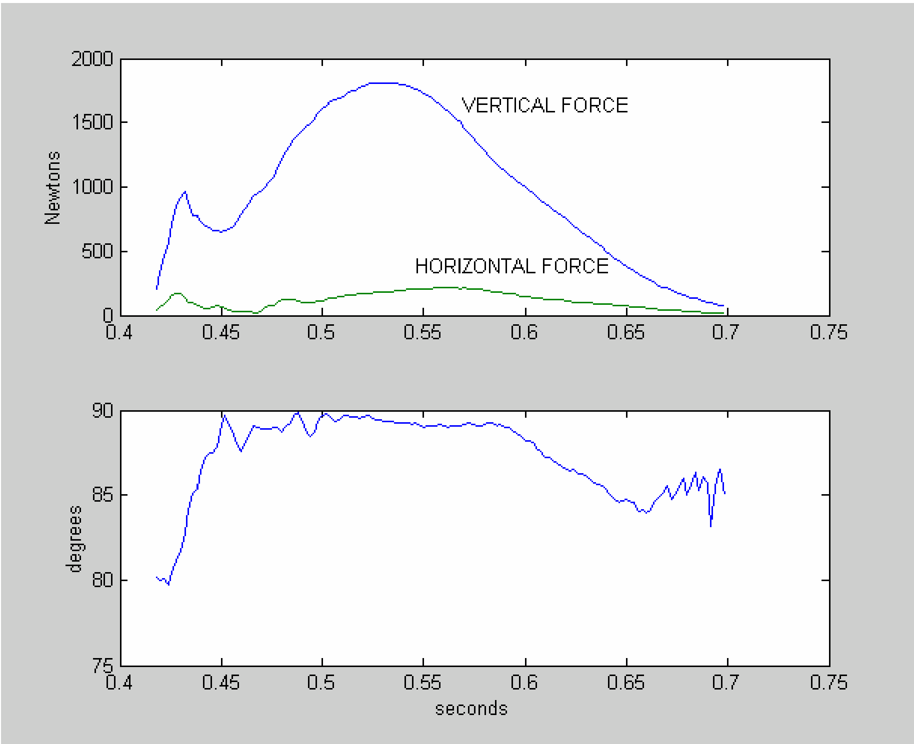

Figure 2: Forces and action angle during a typical heel-toe running

A different problem is the movements that player does for changing direction or turning. The problems that appear with these types of movements are more related with the friction.

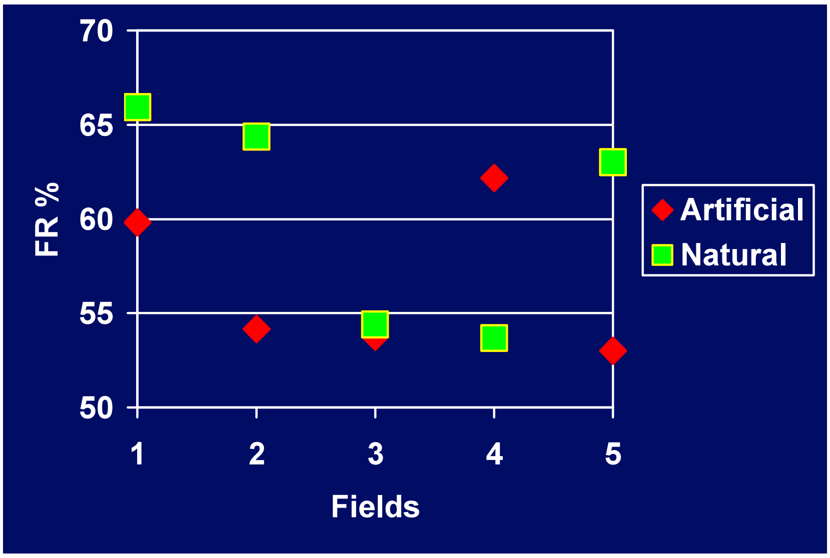

Figure 3: Results in the SOCRATURF project

During the SOCRATURF project 5 third generation artificial turf fields were tested and 5 natural fields (3 Finland, 2 Spain) with players and testing machines. In order to compare the artificial and natural turf each couple of natural-artificial field were testes the same day.

The results (Figure 3) have show that in all cases players consider natural turf more shock absorbent, except for the fields' number 4. Then Force Reduction is related with the shock absorption perceived by the football players.

Is it possible to improve the test in order to increase the relation with the shock absorption property? The answer is yes. The sport surfaces have viscoelastic behaviour. This means that the relation between force and deformation is not linear and will depend of how fast the force is applied. With the same maximum force we can obtain different deformations (

Figure 4).

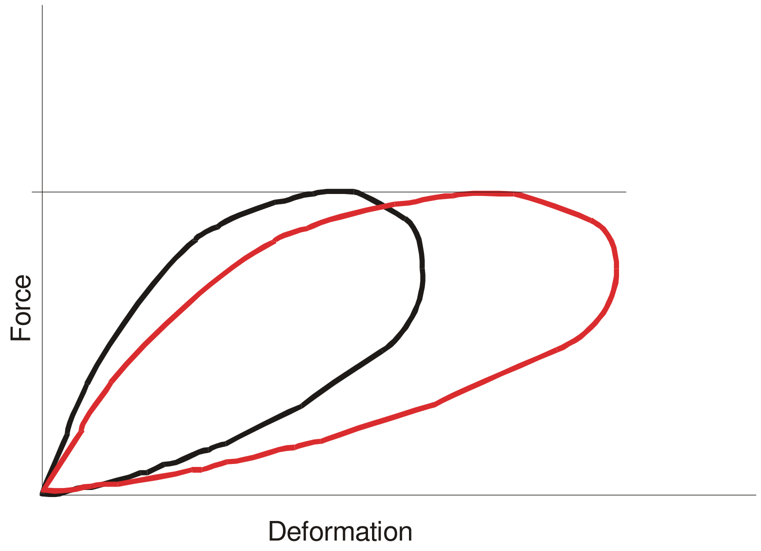

Figure 4

And even different energy dissipation with the same maximum force and the same maximum deformation. The dissipated energy is the area inside the curves (Figure 5).

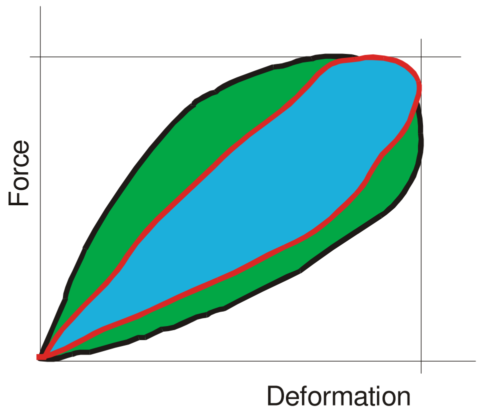

Figure 5: Different dissipated energy with the same maximum force and deformation.

This explains why athletes find differences over surfaces that give equal or similar Force Reduction results. What happens is that Force Reduction is not enough to represent all properties of the viscoelastic materials. The mathematical model of linear viscoelastic materials is represented by two parameters: dynamic rigidity and loss tangent (the loss tangent is the rate between dissipated energy and returned energy). And rigidity and loss tangent depend on the frequency, or what is the same, depend on how fast the force is applied. In a practical this represents that we need to measure the relation between force and deformation (rigidity) and energy restitution with fast and smooth impacts in order to have a complete knowledge of the sport surface behaviour. Besides maximum deformation must be considered as a constraint that limits how much "soft" the surface could be, because high deformation could produce lack of equilibrium when running or jumping.

Using the actual artificial athlete one surface would be better if the rigidity and energy restitution are low with the fast and high impact (using the 2000KN/m spring), and the rigidity and energy restitution are high with the smooth impact (using the 40KN/m spring). The artificial athlete could be useful for testing these variables because the force and deformation are recorded, but research and some redesign is necessary to improve the deformation measurement and repeatability.

Another item that should be considered is the calculation procedure: the mean of the several impacts over the same point, but without the first impact. The reason is repeatability and other surfaces do not change their properties along the impacts, but it is clear that natural turf and third generation artificial turf change. And players feel the first impact.

Assuming that the aim is to simulate natural turf also is necessary to consider that football player wears studded shoes. UEFA has introduced a test with studs. The IBV experience is that results changes slightly with regards to the flat foot because the stud penetrates easily in natural turf and 3rd generation, but this changes probes the necessity of using studs in order to prevent from products with different properties.

XLTurf express in his report some concern about the preload, and suggest increasing preload. That is not correct. Preload is a necessity in testing machines in order to improve control and reproducibility, but the preload does not exist when the player's foot impacts on the surface. The IBV opinion is to reduce preload as much as possible.

Artificial athlete is useful for testing shock absorption and deformation, but is necessary to introduce changes in order to:

- **Testing energy and rigidity dynamic behaviour.**
- **To know how properties changes with each impact.**
- **To use studded foot.**

3 TRACTION

The use of friction concepts is not very appropriate assuming that natural turf is simulated and that players have to be able of wearing the same kind of shoe with studs. Then it is more appropriate traction. The player needs a minimum of traction to avoid falls, but the maximum has to be limited in order to reduce injuries.

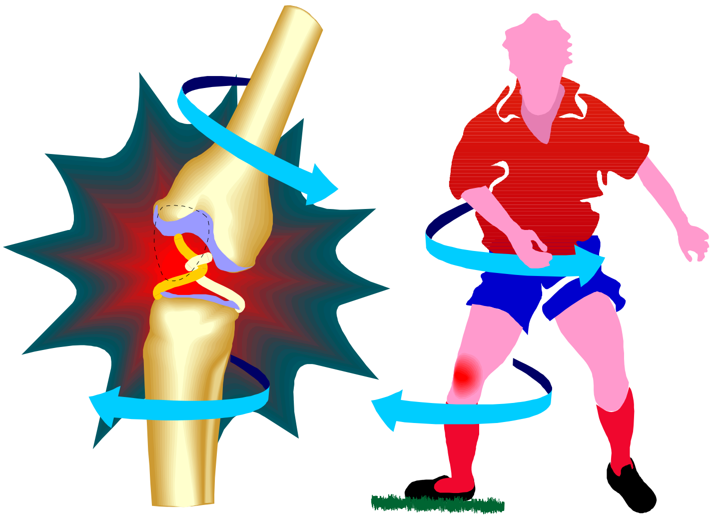

Figure 6: Injury due the foot fixation.

The different pendulum methods used in other areas has been strongly criticised in the biomechanics and ergonomics literature. It is clear that pendulums are not appropriated because the vertical force applied and the movement is not related with the sports necessities. The use of pendulums could be justified in case of absence of other methods more appropriated. The pendulum detects big problems only, but it is not useful to find the optimum solution.

The rotational resistance device (46Kg) with studs has repeatability problems because is hand controlled and the technician could influence in the results. The results during the SOCRATURF project have not shown correlation with players' opinion. Even natural fields with 60-70 Nm were well considered by players (Figure 7).

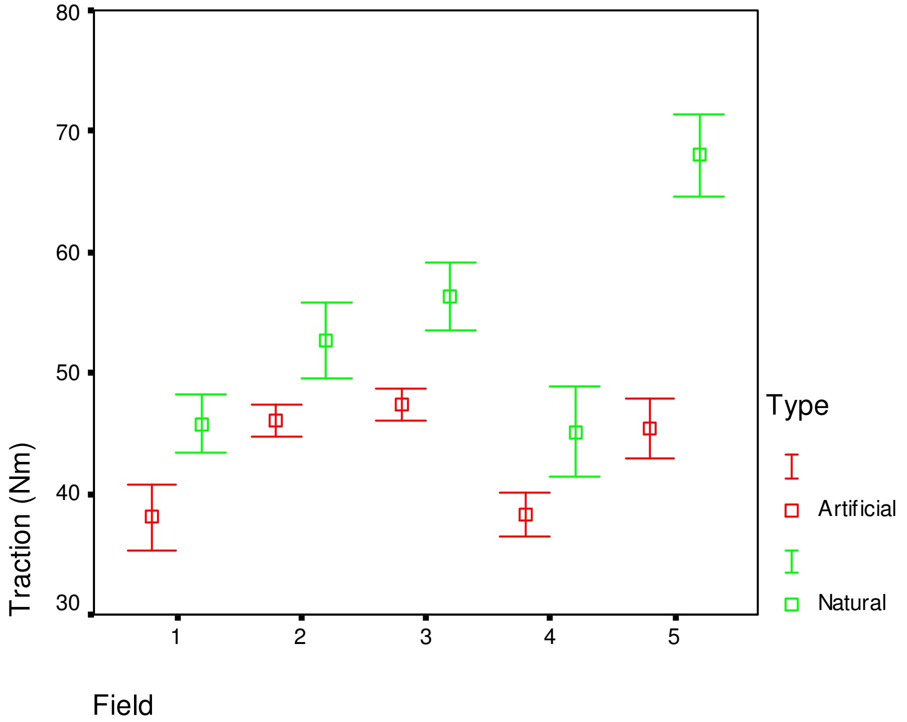

Figure 7: Results of standard traction test.

In the SOCRATURF project other devices developed by TEN CATE THIOLON have been used. One linear friction device (Figure 8)and one rotational device (Figure 9) similar to the Security Test developed by LABOSPORT.

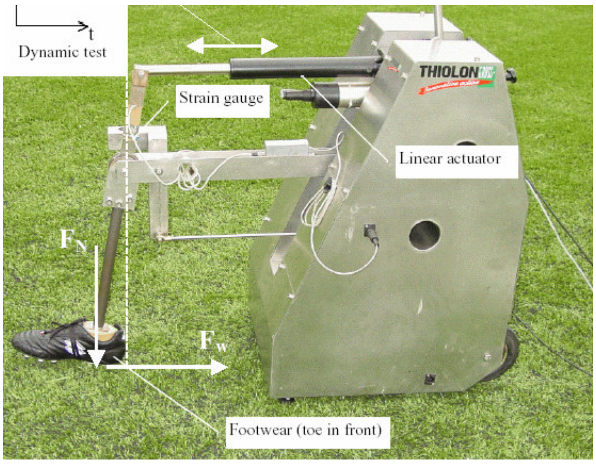

Figure 8: Linear friction device

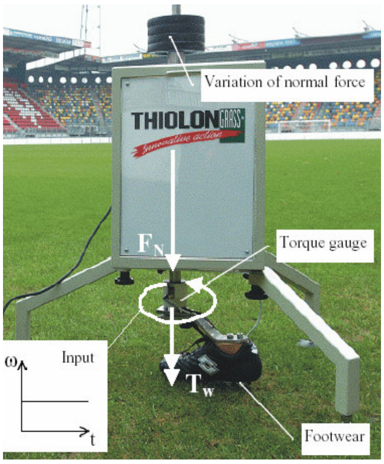

Figure 9: Rotational device

These devices are better controlled and more repetitive. But, the relation with player's movement is not probed. The results of the SOCRATURF project show some correlation between the rotational device and players' opinion. But this correlation depends on the shoe.

On most of the tested fields, players said that they felt more fixation on the artificial field in comparison with the natural turf. However the standard test result is the contrary.

The real problem is that we are using test devices without knowing how the player's movement is. What are the forces? What are the velocities? Do we want to simulate all the movement or one critical instant only? The present tests break the surfaces and do troughs. But, does player break the surface?

All this questions have to be answered in order to improve or redesign tests.

The present standard tests have poor correlation with players' opinion or necessities. Work is necessary on order to:

- **Define player's movement parameters.**
- **Design a test device according to the player's movement parameters.**

4 BALL VERTICAL BOUNCE

During the SOCRATURF project five test locations in Finland and Spain were tested. The players' opinion where compared in both the artificial and the natural turf field. On three of these fife fields most players said that ball bounce is higher on the artificial turf than on the natural turf field. The mechanical test results confirm this, but the differences between the natural and artificial turf are relatively small, especially regarding standard deviations of the results.

Then, it is possible to conclude that the ball vertical test measures the correct variable in the correct way.

Other problem to discuss could be the limits in the standards. Because if the ball bounce is higher than 50% (>1m) the players do not complain.

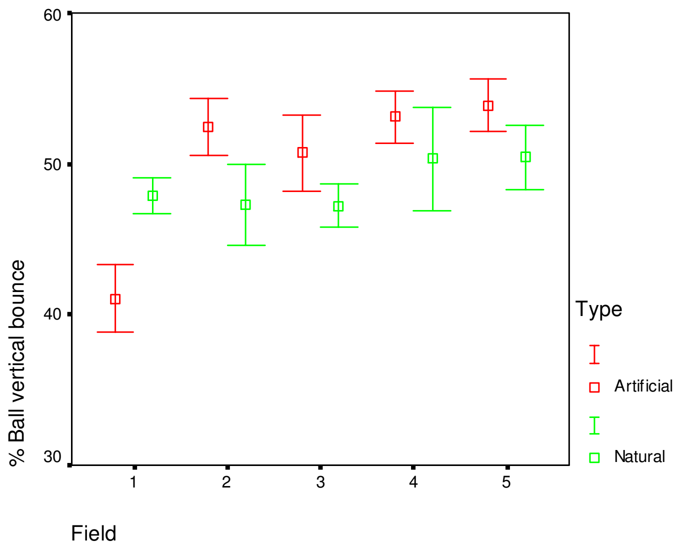

Figure 10: Ball vertical bounce results

The present standard is adequate, but limits in the standards could be reconsidered.

5 BALL ROLL

The results of the five sites tested show that there is no clear relationship between the ball rolling distance and the absolute opinion of the players, although there is an indication that lower distances are preferred within the measured range of 6 to 15 m. This means no correlation can be found between the mechanical test and the user test for ball rolling in the comparison of natural and artificial turf.

It seems that players the players judge the ball rolling on the combination of how the ball rolls and how long/far it rolls. Players complain when the ball rolling behaviour is not homogeneous: the ball bounces, the ball does not go straight, etc.

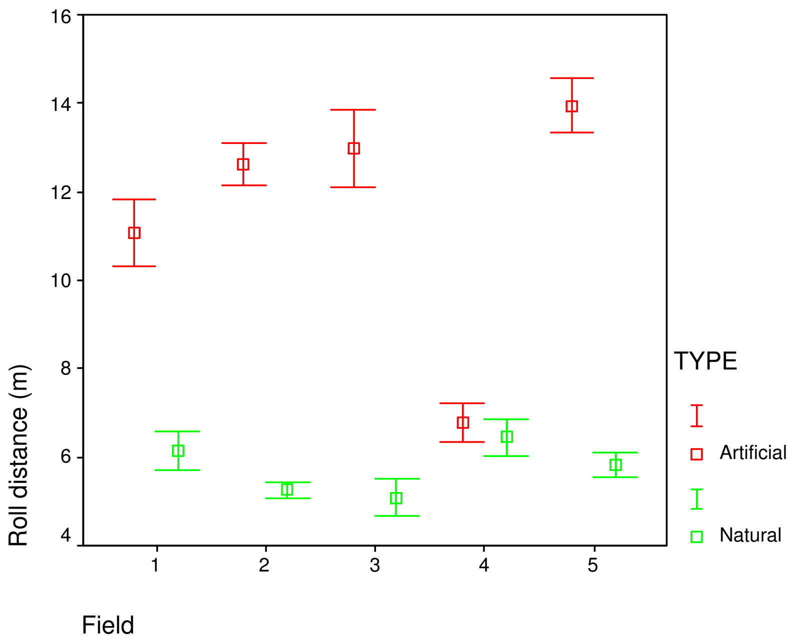

Figure 11: Ball roll results

The present standard test measures a variable (roll distance) that is only one of the parameters related with the ball rolling behaviour. Other variables (homogenous rolling and predictability) are necessary.

6 ANNEX: OVERVIEW OF THE TESTS DONE IN THE SOCRATURF PROJECT

All the tests were done in each site the same day. That means that players' test and tests with machines (standard and TEN CATE THIOLON) were done in one day in one artificial field and in one natural turf field. In this manner the field conditions are the same and it is possible to compare the results of the players' test and the results of the machines.

Figure 12:Jumping over hurdles

6.1 PLAYERS' TEST

The players' test is based on evaluating all user relevant characteristics of a pitch. These characteristics are divided in 5 main aspects:

- Shock absorption.
- Stability.
- Sliding properties.
- Grip/traction:
  - Translational friction/fixation.
  - Rotational friction/fixation (pivoting)
- In relation to ball behaviour and handling:
  - Ball bounce.
  - Ball roll.
  - Ball handling:
    - Shooting. (passing, chipping the ball)
    - Receiving the ball and dribbling with the ball. (ball control)

Figure 13: Romberg test

The user test consists of a combination of interviews and an exercise circuit. Before performing the test, the players receive information about the goal and content of the test. There are interviews before, during and after the exercise circuit:

- Damping / shock absorption:
  - Jumping over 5 hurdles.
  - Balance/stability: Romberg balance test.
- Friction - Skin-field interaction: Make 3 slidings.

- Ball behaviour:
    - Dribble with the ball around a marker and back
    - Play the ball to each other over the ground without receiving the ball. (one touch: 10 m.)
    - Chip the ball to each other (high through the air: 10m.
    - Drop the ball and volley the ball after the bounce to the other player. (20 m)
    - Passing through the air with one bounce. (20 m)
    - Pass with outside foot (effect ball) over de ground. (20 m)

Figure 14: Passing the ball

- Grip:
    - Turning with the ball of the foot on the field.
    - Slalom around 6 markers, as fast as possible. (replace the markers on natural turf if necessary)

The number of players tested in each site (artificial and natural) is:

Figure 15: Sliding

Site	Players tested
1	8
2	9
3	8
4	8
5	7

6.2 STANDARD TESTS

Different standard tests were carried in three areas of the field (Figure 16):

- Ball vertical bounce.
- Ball roll.
- Artificial athlete:
  - Force reduction (spring 2000KNw/m) and Standard Deformation (spring 40KN/w/m) according to the FIFA and UEFA standard with two foots. The flat foot used in the FIFA and UEFA standard. The studded foot that appears in the UEFA standard only for information.
  - The maximum force, the maximum deformation and the energy restitution.

Ball pace (angled ball behaviour) was not included due the short time available for testing and moving machines from one field to other.

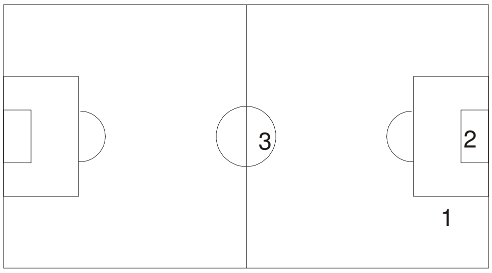

Figure 16: Tested points

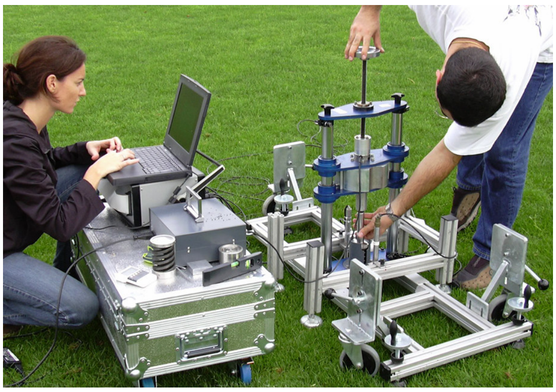

Figure 17: Test with the artificial athlete.

6.3 TEN CATE THIOLON DEVICES

The TEN CATE THIOLON test devices have been used in one area of the field.

6.3.1 Linear friction

Figure 18 schematically shows the principle of operation of the linear friction meter.

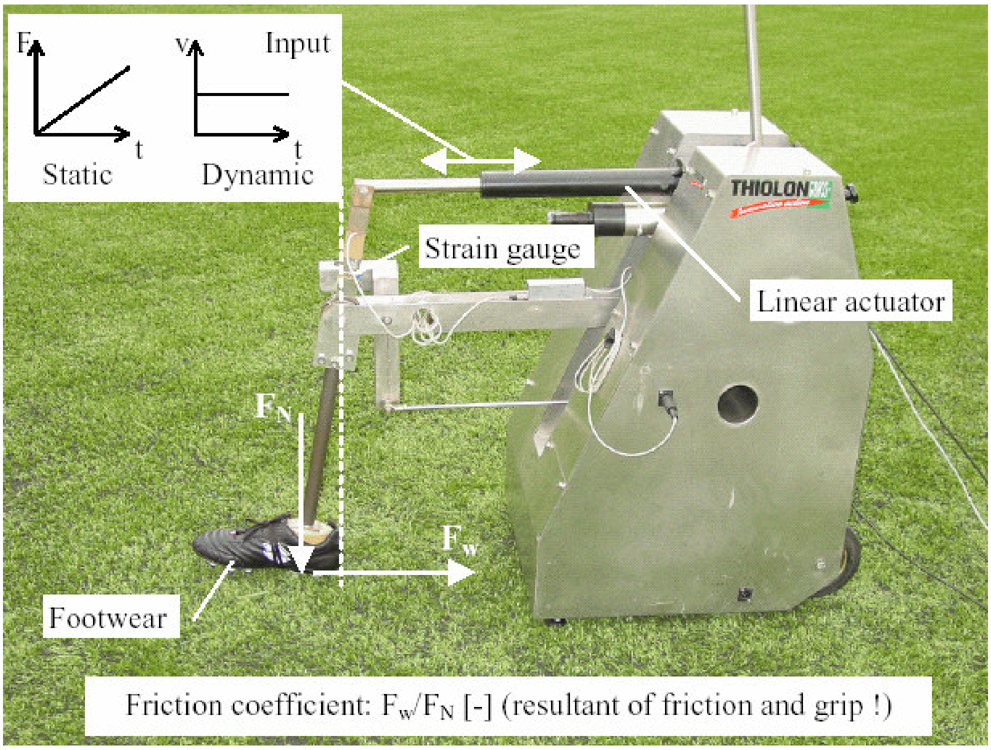

Figure 18: Linear fricton

The tests have been realized by means of the following parameter:

- static test;
- linear force increase: 80 [N/s];
- normal force: 85 [N];
- foot orientation: heel;
- 4 repetitions per field / parameter.

6.3.2 Rotation friction

The Figure 19 schematically shows the principle of operation of the rotation friction meter:

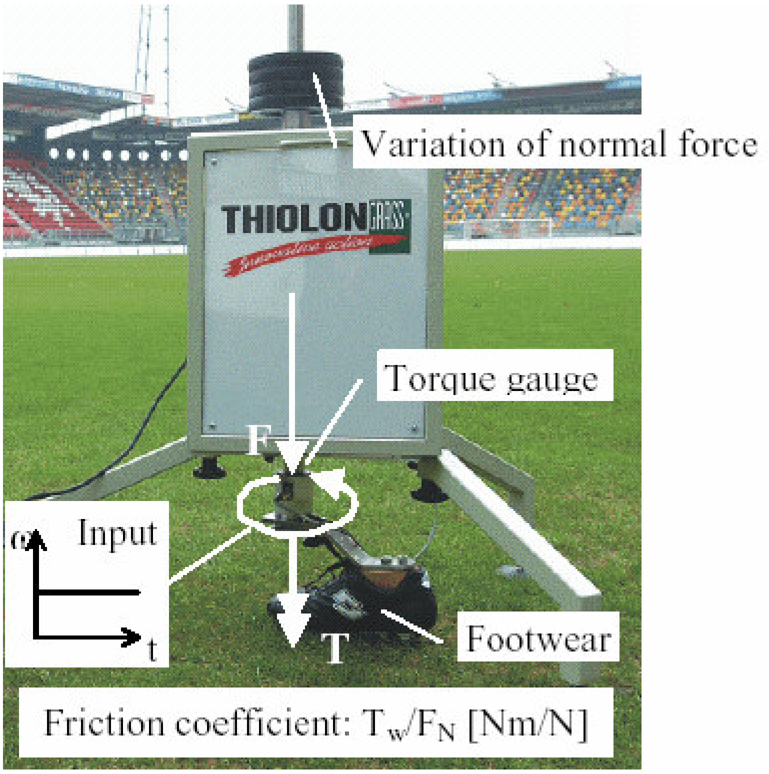

Figure 19: Rotation friction

The tests have been realized by means of the following parameters:

- constant rotation speed: 6 [rpm];
- normal force: 190 [N];
- 4 repetitions per field / parameter (results presented in chapter 4.

6.3.3 Shock absorption test

The Figure 20 schematically shows the principle of operation of the shock absorption meter:

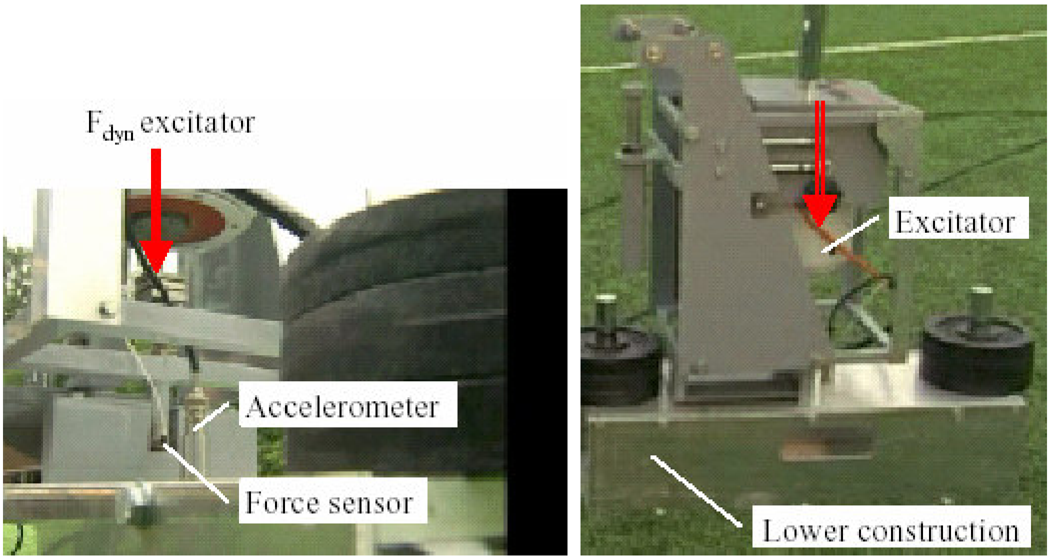

Figure 20: Shock absorption device.

The excitator generates a dynamic force (for the tests discussed in this report a random signal between 10 – 110 Hz) in the (rigid) lower construction. The force sensor is registering this force. The lower construction transfers the force to the underlying (artificial) grass system. The reaction of the grass system to this force is being registered by the accelerometer.

6.4 RESULTS

SHOCK ABSORPTION RESULTS

		Standard test: Force reduction %			
		artificial turf flat shoe	*artificial turf studded shoe*	*Natural turf flat shoe*	*Natural turf studded shoe*
Fields	6 of 9 players: artificial turf is harder	54	52	55	61
	6 of 8 players: artificial turf is harder	54	52	64	66
	7 of 8 players: artificial turf is harder	60	59	62	66
	8 of 8 players: artificial turf is softer	62	63	54	57
	8 of 8 players: artificial turf is harder	53	49	63	65

ROTATIONAL TRACTION RESULTS

		TEN CATE THIOLON device Max. coefficient (Fn=190 N) L=Lotto, A= Adidas		*Standard test*	
		artificial turf	*natural turf*	*artificial turf (Nm)*	*natural turf (Nm)*
Fields	2 of 9 players: more fixation on artificial turf 8 of 9 players: easy to turn on artifcial turf	L: 0.089 ± 0.009 A: 0.074 ± 0.012	L: 0.088 ± 0.004 A: 0.085 ± 0.009	45.8	38.1
	7 of 8 players: more fixation on artificial turf; 0 of 8 players: easy to turn on artificial turf	L: 0.083 ± 0.009 A: 0.083 ± 0.010	L: 0.073 ± 0.002 A: 0.085 ± 0.009	47.4	56.3
	4 of 8 players: more fixation on artificial turf* 6 of 8 players: easy to turn on artificial turf	L: 0.082 ± 0.008 A: 0.073 ± 0.004	L: 0.065 ± 0.012 A: 0.065 ± 0.003	46.1	52.7
	3 of 8 players: more fixation on artificial turf 7 of 8 players: easy to turn on artificial turf	L: 0.083 ± 0.006 A: 0.082 ± 0.003	L: 0.065 ± 0.007 A: 0.077 ± 0.008	45.5	68.1
	6 of 8 players: more fixation on artificial turf; 2 of 8 players: easy to turn on artificial turf	L: 0.097 ± 0.014 A: 0.088 ± 0.002	L: 0.080 ± 0.003 A: 0.088 ± 0.015	37.7	43.5

BALL ROLL RESULTS

		artificial turf (m)	*natural turf (m)*
Fields	4 of 9 players: artificial turf is faster; 2 of 9 players: artificial turf is slower	11.1	6.2
	8 of 8 players: artificial turf is faster	13.0	5.1
	6 of 8 players: artificial turf is faster; 2 of 8 players: artificial turf is the same	12.6	5.3
	8 of 8 players: artificial turf is slower	6.8	6.5
	5 of 7 players: artificial turf is slower; 2 of 7 players: artificial turf is faster	14.0	5.8

BALL BOUNCE RESULTS

		artificial turf %	*natural turf %*
Fields	4 players prefer the artificial turf 5 players prefer the natural turf no consensus about height	41.1	47.9
	2 players prefer the artificial turf 6 players prefer the natural turf all players: higher and faster on the artificial turf	50.7	47.2
	6 players prefer the artificial turf 2 players prefer the natural turf all players: higher on the artificial turf	52.5	47.3
	4 players prefer the artificial turf 2 players prefer the natural turf	53.1	50.3
	all players prefer the natural turf all players higher on the artificial turf	53.9	50.4