# SCIENCE OF SYNTHETIC TURF SURFACES:
# A COMPARISON OF TRACTION TEST METHODS

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# SCIENCE OF SYNTHETIC TURF SURFACES: PRESENTATION OVERVIEW

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INTRODUCTION

MATERIALS

METHODS

- FIFA Rotational Traction Test
- Instrumented Test Device 1
- Instrumented Test Device 2

RESULTS

- Rotational Traction
- Translational Traction
- Stud Penetration
- Vertical Load

SUMMARY

ACKNOWLEDGEMENTS

## TRACTION

Many sports utilise cleats or studs. During sports movements these cleats or studs penetrate and interlock with the playing surface generating traction forces.

Dependent on:

- The sports specific movement
- Sports specific footwear
- The playing surface
- The environment

Since the introduction of synthetic turf surfaces, many have speculated that these surfaces have increased the rate of injury in players due to high levels of traction.

Limited number of studies that have attempted to quantify specific injuries directly related to traction behaviour of synthetic turf surfaces

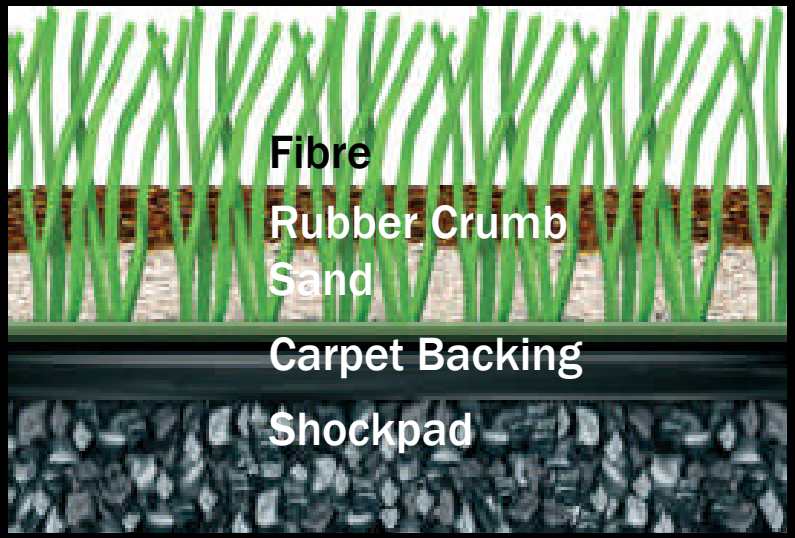
- Large and complex number of variables involved
- Resources required for comprehensive testing and injury surveillance study

## THE PLAYING SURFACE

Synthetic turf surfaces have seen many developments and improvements in quality since their introduction into the market.

### 3rd GENERATION/3G SYNTHETIC TURF SURFACES

- Long pile carpet, with less densely packed fibres, 35 mm - 65 mm in length
- Inclusion of an elastomeric (rubber crumb in most cases) infill material
- Large variety of surface compositions exist




Recognised by both the international governing bodies of football and rugby, Fédération Internationale de Football Association (FIFA) and the International Rugby Board (IRB), for which these surfaces were predominantly design for.

## TESTING

Many sports governing bodies have developed test procedures and performance requirements to that a surface must achieve before that sport can be played on the surface to:

- maximise performance
- minimise risk of injury
- Reduce differences between pitch systems

Traction is no exception:

- For example FIFA state that rotational traction must fall between 25 – 50 Nm for a 1 Star pitch.

Test procedures have been designed to be:

- Portable for field testing
- Simple to use
- Highly repeatable

This does however, lead to questions over their biomechanical representation and sensitivity, including the current standard traction (FIFA, 2009) test used to measure rotational traction.

## TESTING

Many research institutes and sports footwear companies have developed their own bespoke versions of mechanical tests to measure either rotational or translational traction or in some cases both in order to better replicate player movements:

- Sports specific footwear
- Varying the vertical (static) load
- Hydraulically driven apparatus
- Imitations of the lowers limbs

Such variations in the methodologies used have made it difficult to compare historical data.

This presentation reports on a data set comparing traction behaviour of carpet and rubber infill systems using three different test procedures.

# SCIENCE OF SYNTHETIC TURF SURFACES: MATERIALS

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| Surface | A | B | C | D |
|---|---|---|---|---|
| | | | | |
| **Fibre Material** | Polypropylene | Polyethylene | Polyethylene | Polyethylene |
| **Fibre Type** | Monofilament | Monotape | Monofilament | 2 types of fibrillated fibre, one curly (to help hold infill) |
| **Pile Height (mm)** | 35 | 40 | 50 | 65 (Main fibrillated fibre) |
| **No. of Tufts per sqm** | 10600 | 25200 | 33600 | 33600 |
| **No. of Fibres per Tuft** | 12 | 18 | 8 | 2 for each fibre (which then fibrillate) |
| **Fibre Width (mm)** | 1.5 | 1.5 | 1.3 | 1 – 3 |
| **Fibre Thickness (mm)** | 0.025 | 0.025 | 0.026 | 0.026 |
| **Total Number of Fibres per sqm** | 127200 | 453600 | 268800 | 67200 |
| **Silica Sand 0.2 – 0.7 mm** | 10 kg/m$^2$ | 10 kg/m$^2$ | 10 kg/m$^2$ | 10 kg/m$^2$ |
| **SBR Rubber Crumb 0.5 – 1.5 mm** | 4 kg/m$^2$ | 7 kg/m$^2$ | 12 kg/m$^2$ | 20 kg/m$^2$ |

# SCIENCE OF SYNTHETIC TURF SURFACES: METHODOLOGY

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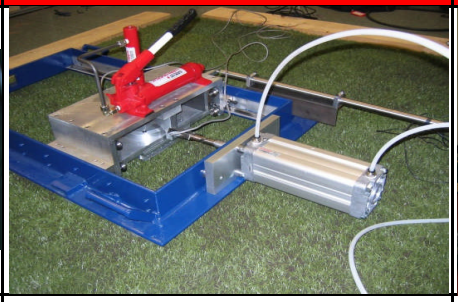
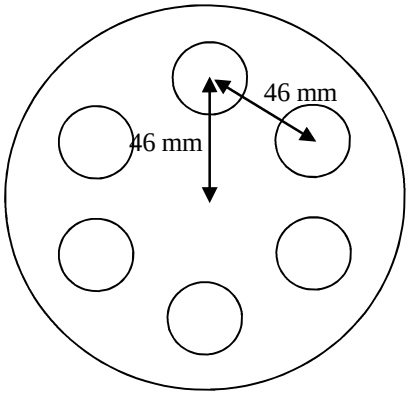
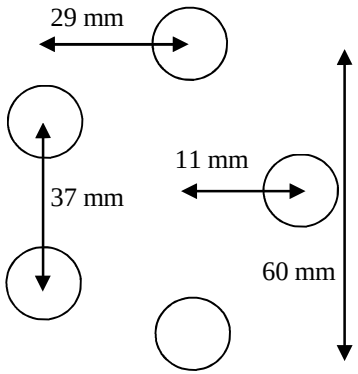
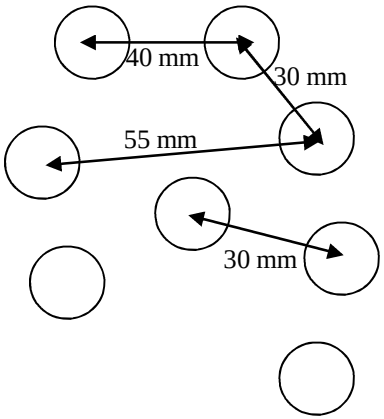
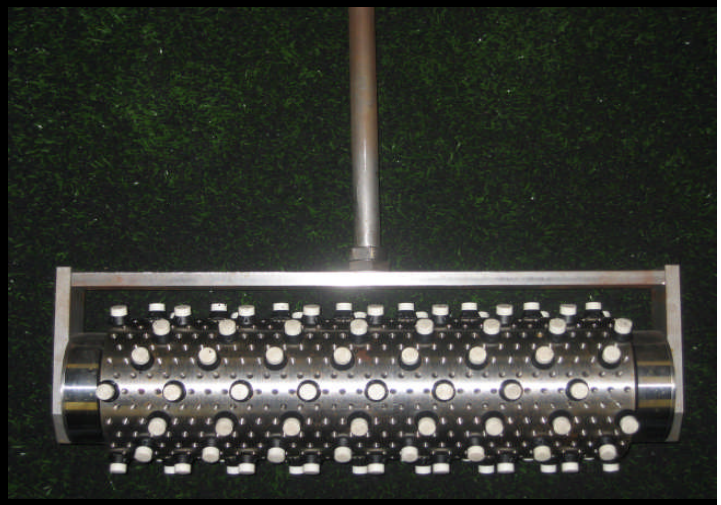
| | FIFA Standard Test | Instrumented Test Device 1 | Instrumented Test Device 2 |
|---|---|---|---|
| **Test Apparatus** | |  | |
| **Traction Measurement** | Rotational | Translational | Both |
| **Operator** | Manual | Automated | Automated |
| **Displacement** | Minimum of 90 degrees of rotation | 200 mm | 60 degrees of rotation<br>50 mm |
| **Speed** | 12 revolutions per minute | N/A | 12 degrees per second<br>10 mm per second |
| **Vertical load** | Free weights | Hydraulic ram | Free weights |
| **Footwear/Base** | Round metal disc with standard FIFA studs attached | Plastic sole shaped disc with standard FIFA studs attached | Actual football boot with studs similar in dimension to FIFA standard |
| **Stud Configuration** |   |   |   |

## TEST PROGRAMME

- Four surface systems, with a 30 mm shockpad
- Four surface conditions were created for each surface system using a standard 30 kg studded roller to change the state of the rubber infill layer; raked (i.e. loose), 50 rolls, 100 rolls and 200 rolls.



Infill height was measured using a standard penetration gauge, and infill density was calculated for each condition.

Rotational and/or translational traction was measured for each surface system with the different devices at a vertical load of 450 N (or a close as possible).

Effect of varying the vertical load:

- FIFA (160 N, 260 N, 360 N and 460 N)
- Test Device 1 (250 N, 350 N and 450 N)
- Test Device 2 (450 N, 550 N and 650 N)

The values chosen were dependent on the mechanics and capabilities of the devices.

## RUBBER INFILL DENSITY

- Four surface conditions were created using a weighted studded roller to compact the infill material.

- The level of compaction and resulting bulk den
dependent to an extent on the quantity of infill u
surface system.

| Number of Fibres per sqm | | | |
|---|---|---|---|
| Carpet A | Carpet B | Carpet C | Carpet D |
| 127200 | 453600 | 268800 | 67200 |

| | Rubber Crumb Infill Height (mm) | | | | Net Bulk Density of Rubber Crumb (g/cm³) | | | |
|---|---|---|---|---|---|---|---|---|
| Surface Condition | Carpet A | Carpet B | Carpet C | Carpet D | Carpet A | Carpet B | Carpet C | Carpet D |
| Raked | 10 | 20 | 28 | 37 | 0.40 | 0.37 | 0.43 | 0.54 |
| 50 Rolls | 8.5 | 16.5 | 24 | 34 | 0.47 | 0.43 | 0.50 | 0.59 |
| 100 Rolls | 8 | 15 | 22 | 31 | 0.50 | 0.47 | 0.55 | 0.65 |
| 200 Rolls | 7 | 13 | 20 | 30 | 0.57 | 0.54 | 0.60 | 0.67 |

Infill height and bulk density of the rubber crumb from compaction with a studded roller

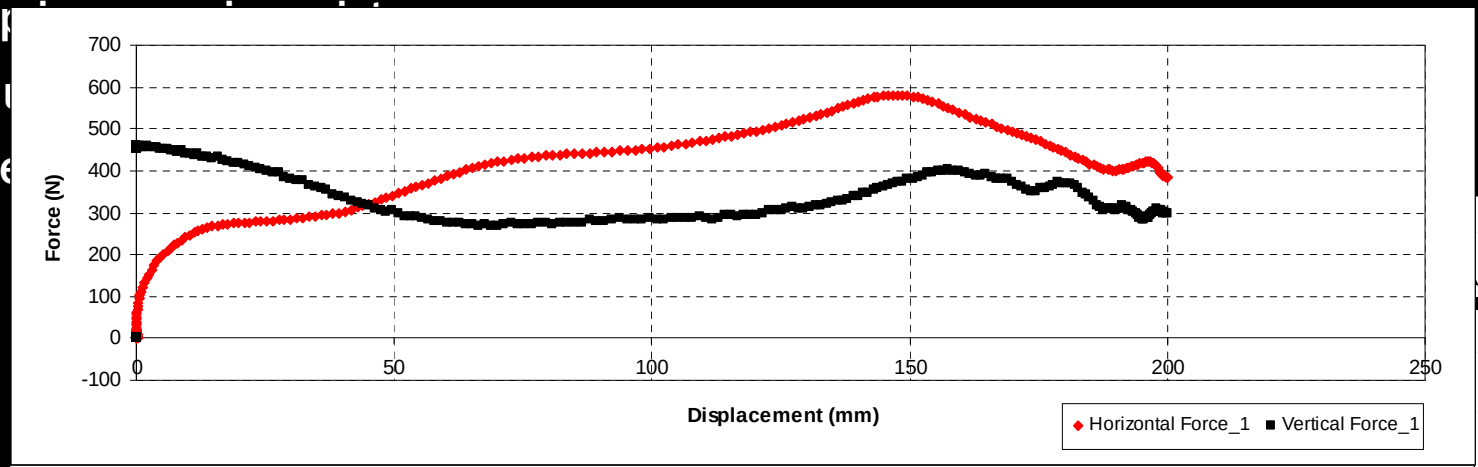
## FORCE/DISPLACEMENT HISTORY

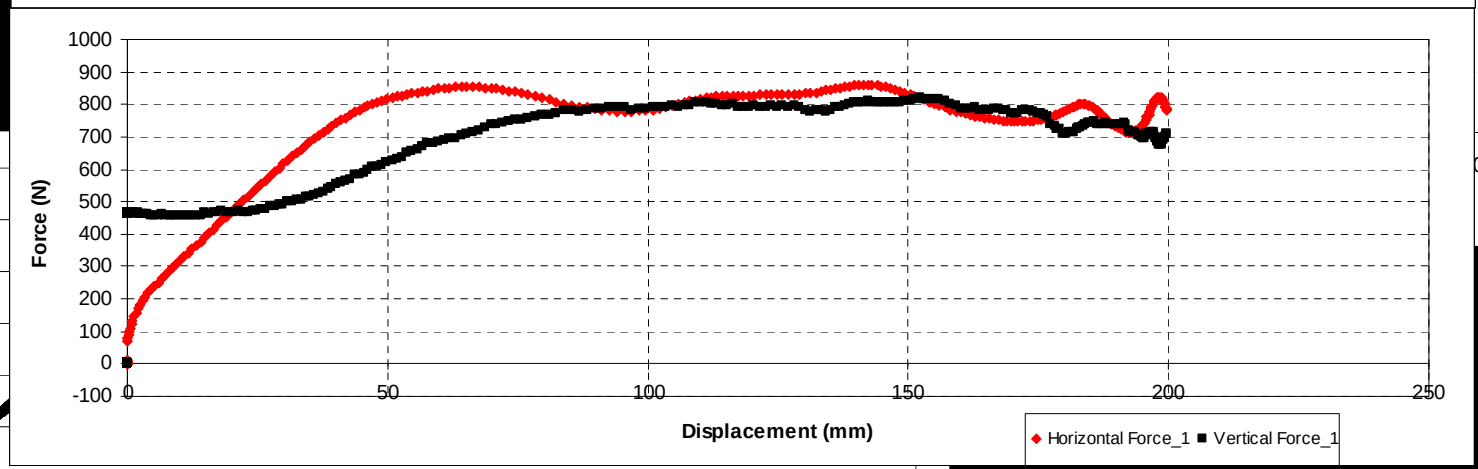
Test Device 2: Both constraints and effect of vertical load on peak traces showed three key regions.

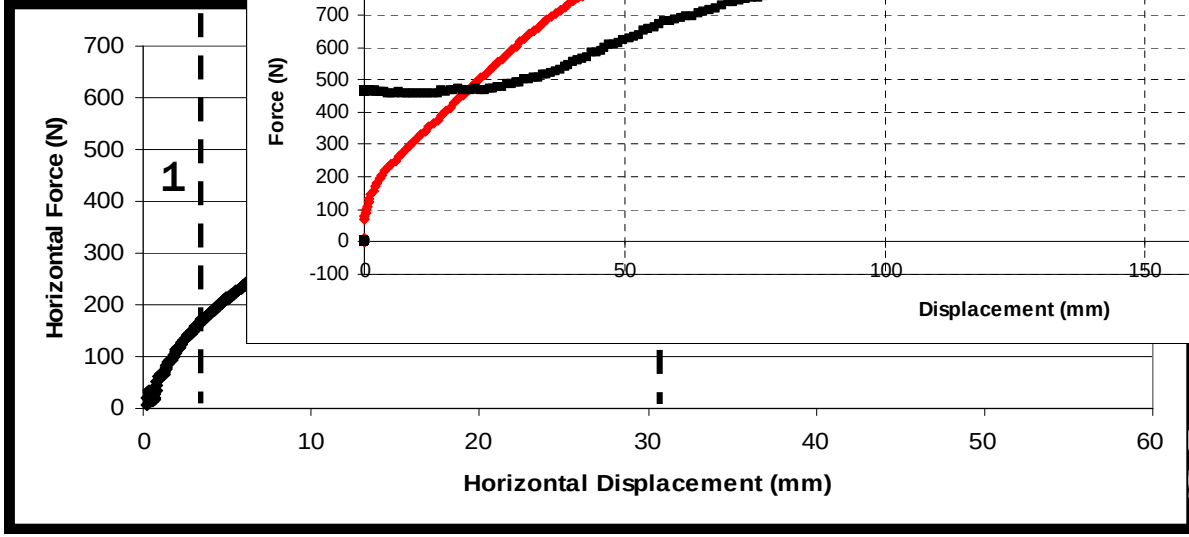
1 – Sharp

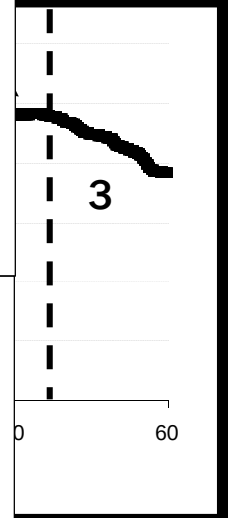
2 – Gradu

3 – Decre



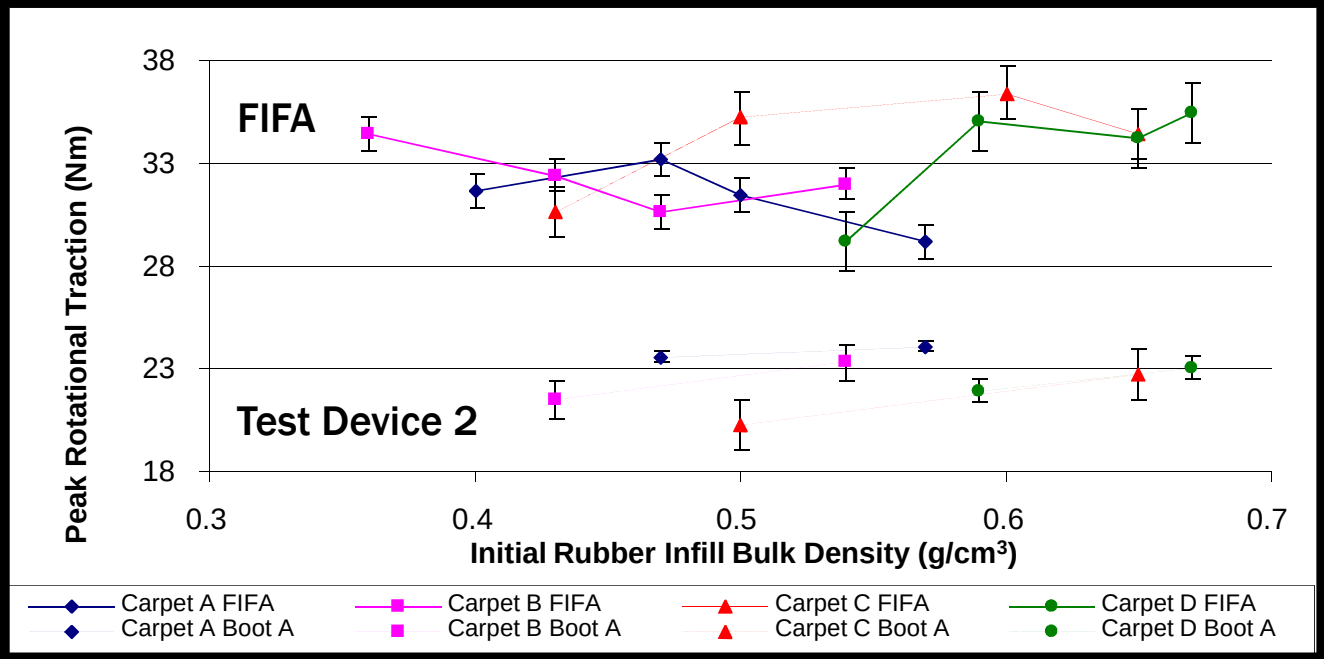



## ROTATIONAL TRACTION

**FIFA:** Good repeatability but no trend with increasing the initial bulk density of the rubber infill layer or carpet systems.

**Device 2:** Increase in rotational traction with initial bulk density of the rubber infill layer.

Large difference in peak rotational traction values between the two devices.



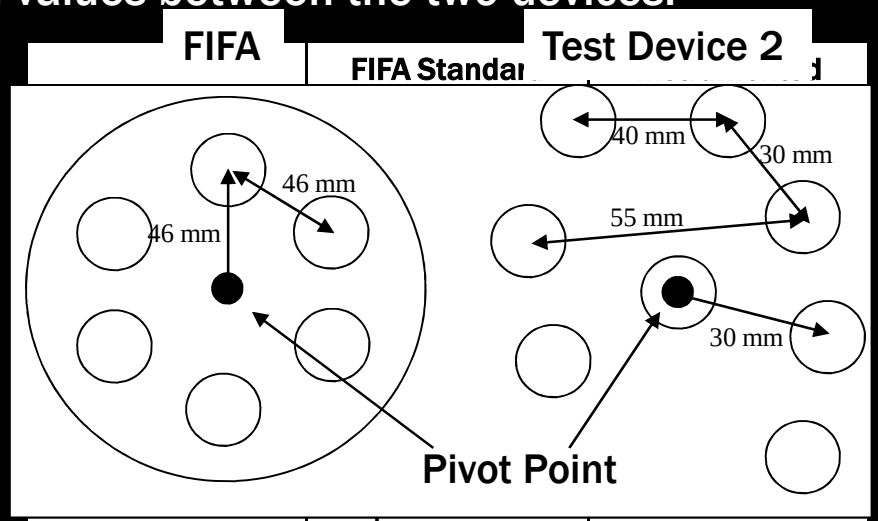
The effect of initial rubber infill bulk density on the peak rotational traction

## ROTATIONAL TRACTION

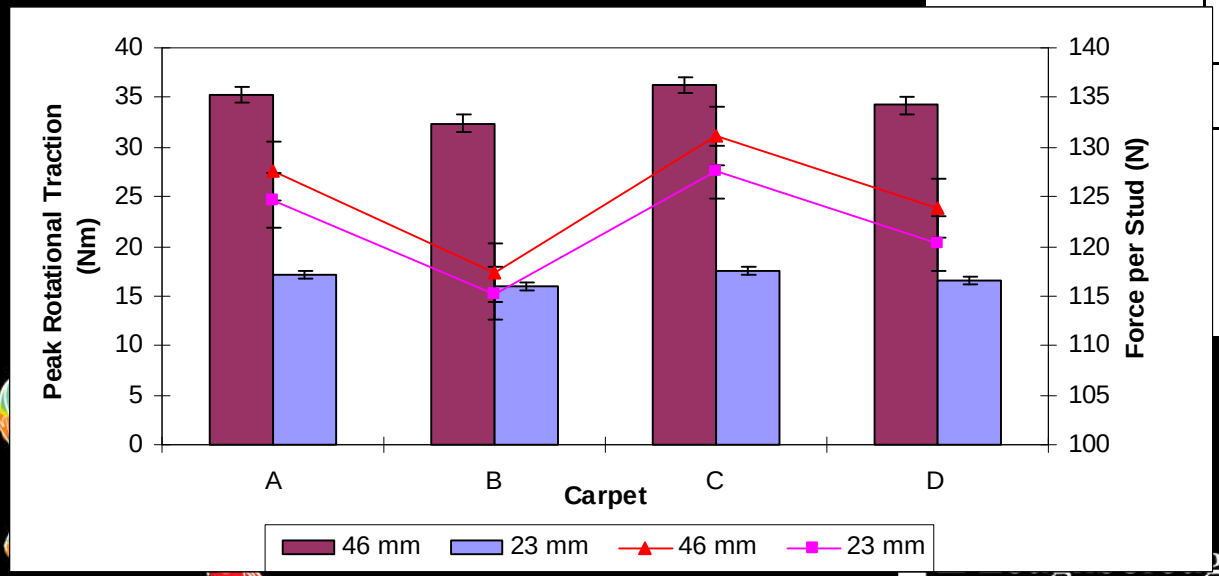
Large difference in peak rotational traction values between the two devices.

Variations between the two devices:

- Number of studs
- Stud spacing
- Outsole material
- Speed and distance of rotation



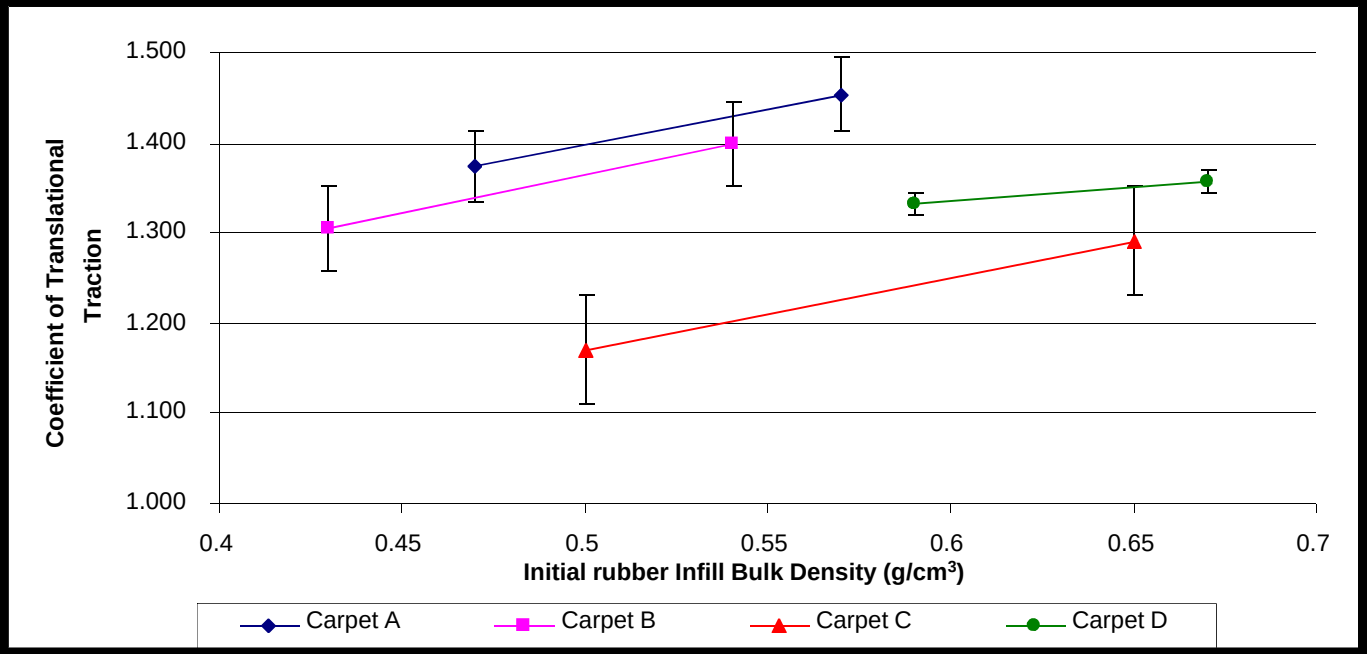

| | |
|---|---|
| | 10 mm per second |
| Free weights | Free weights |
| Round metal disc with standard FIFA studs attached | Actual football boot with studs similar in dimension to FIFA standard |




and 23 mm from the central pivot point.

## TRANSLATIONAL TRACTION

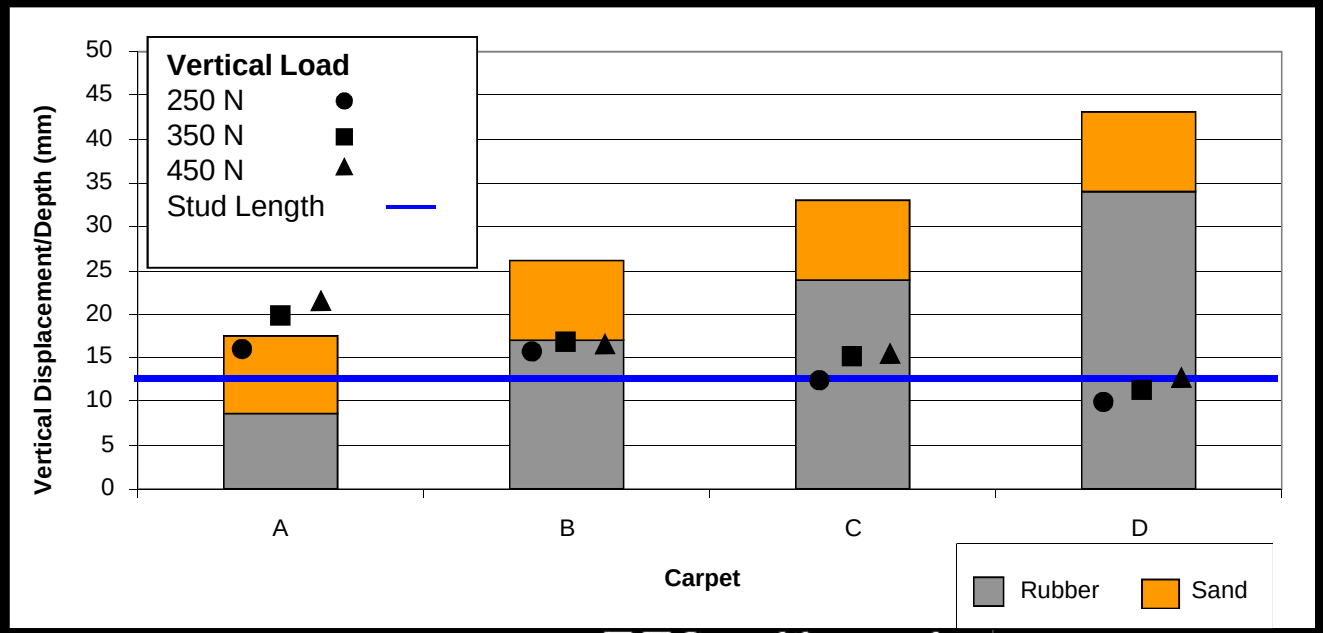
Device 2: Increase in translational traction with an increase in the initial bulk density of the rubber infill layer.




Device 1: Peak translational traction difficult to interpret due to poor repeatability and variations in vertical force. Measurements taken at 10 mm of displacement found to have better repeatability, but no differences were found between surfaces and did not correlate with Test Device 2.

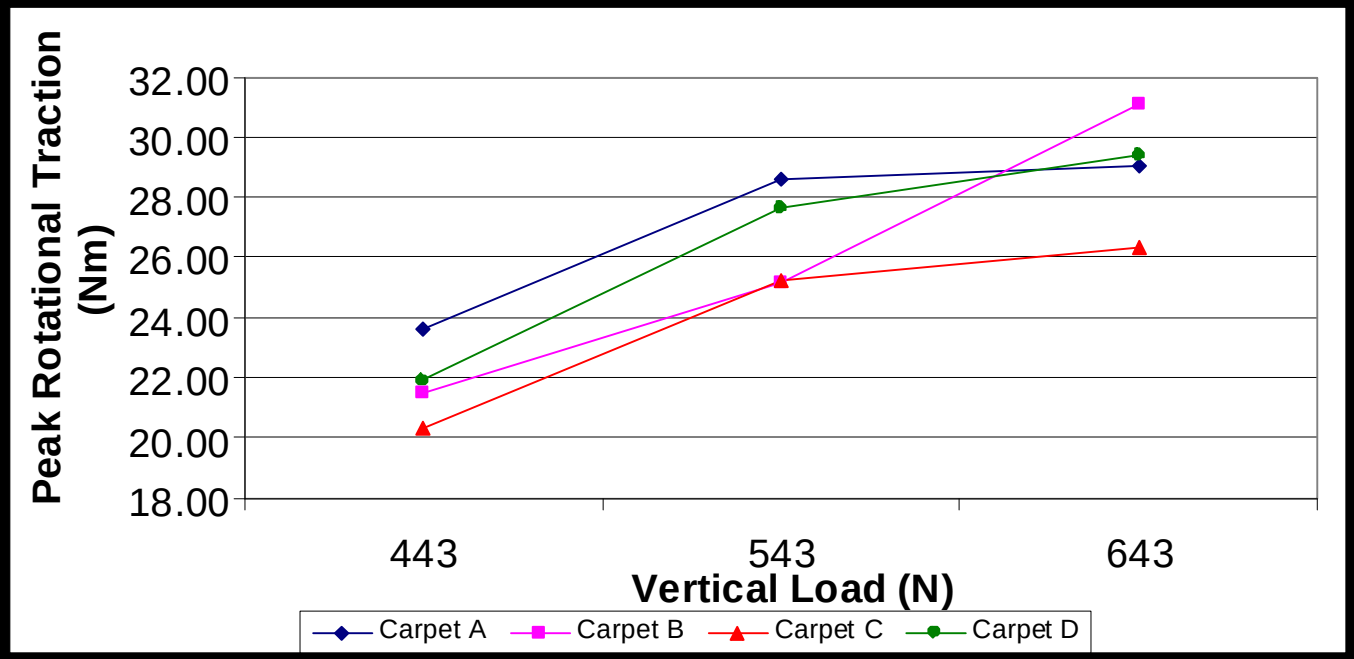
## STUD PENETRATION

- A reduction in stud penetration was found as the thickness (mass) of the rubber infill layer increased.
- Increasing the vertical load of the generally showed an increase in stud penetration.
- Full penetration of a FIFA standard stud (13 mm length) was found with all carpets suggesting compression of the surface layer occurred.
- No pattern was found between stud displacement and initial bulk density of the rubber infill layer.



## VERTICAL LOADING

- An increase in traction was shown with all three test devices with an increase in the vertical load applied to the surface.
- A non-linear relationship was observed as the vertical load increased.




The effect of vertical load on peak rotational traction with Test Device 2.

# SCIENCE OF SYNTHETIC TURF SURFACES: SUMMARY



Rotational and translational traction behaviour of four carpet and rubber infill systems has been measured using three different test devices.

The surface composition and conditioning applied had an effect on the density of the rubber infill.

Peak rotational traction measured with the standard FIFA test showed little difference between the four surface systems or with varying net bulk density of the rubber infill.

Device 2 showed an increase in both rotational and translational traction for an increase in the initial net bulk density of the rubber infill.

Modifying the standard test procedures demonstrated that traction at the shoe-surface interface is greatly influenced by changes in the normal force applied and spacing of studs from the central pivot point for peak rotational traction.

Stud penetration (Device 1) was measured and was found to be influenced by vertical load, though no real conclusions were reached on these effects on the translational traction measured.

These comparisons between test devices and surface systems suggest that more research into traction behaviour of systems is clearly warranted

To better understand traction mechanisms under player loading, traction related research needs to incorporate both more surface materials behaviour and develop test apparatus that control loads and measure penetration/compression.

Test Device Wish List:

- Use of real boot, or a boot shape with the ability to adapt the studs
- Control of vertical loads
- Vary the loading rate
- Measure the stud penetration
- Measure compression of the surface under loading
- Measure the whole force-displacement history
- Portable for field testing
- Programmable with feedback control to permit simulation of different player manoeuvres

This is an ambitious wish list, but coupled with careful sample selection and preparation, is considered essential to better determine the mechanisms of traction at the shoe-surface interface.

ACKNOWLEDGEMENTS

- The Adidas Test Centre in Germany
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For their support for some of the testing work for this study

# Thank You