Measurement of Sports Surface Resilience

John Dunlop
Acousto-Scan Pty Ltd
http://www.acoustoscan.com.au/

Preamble

The springiness of a sports surface affects to some degree the performance of a player or athlete. The softer the track, the more is the deformation in the surface produced by the athlete's foot and hence loss of energy due to visco-elastic effects so there would seem to be an advantage in running on hard surfaces.. Hard tracks, however, particularly non-resilient surfaces such as concrete, will lead to foot and leg injury after prolonged exposure.
With this in mind various sporting bodies eg IAAF and FIH have laid down specifications for the resilience of playing surfaces.

There are several methods by which the resilience of surfaces can be measured, and the purpose of this note is to compare their usefulness. The principal methods in use are the Berlin Athlete, the Stuttgart Athlete and falling mass methods. These latter are widely used to determine safety standards for playground surfaces and floors, and in this study the use of a 5 kg mass (as used in current ISO Standards) is considered in two situations – determining Critical Fall Heights for 200 G maximum deceleration, and determining maximum decelerations from a 500 mm drop.

A comparison of the effectiveness of these four methods in measuring surface resilience would be helpful in future development of surface measurement and specification.

Surface properties

The Berlin Athlete has been used for some time in the characterisation of sports surfaces, and the criteria set, greater than 35 % Force Reduction (FR) for IAAF, and 40 to 65 % for FIH, have been accepted by the end users, so they might be accepted *ad hoc* standards. However, there does not seem to be much bio-mechanical evidence to support these criteria.

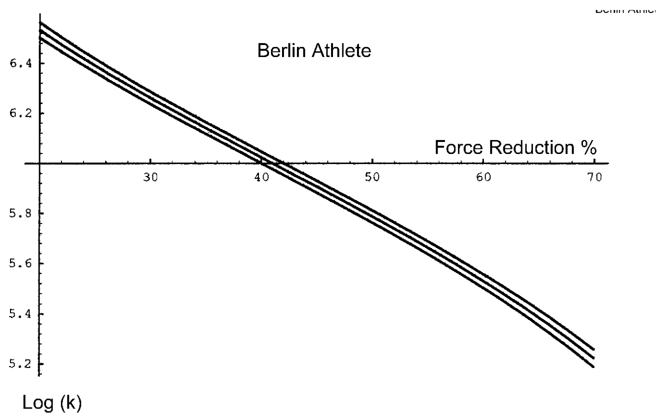
These FR values indicate that athletes are running on tracks with effective spring constants (under a 70 mm diameter foot) of less than 1.3 MN/m, and hockey players on surfaces in the range 0.25 to 1.0 MN/m.

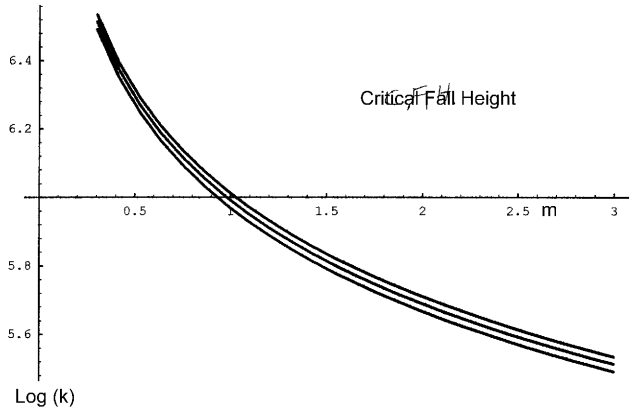
Calculations

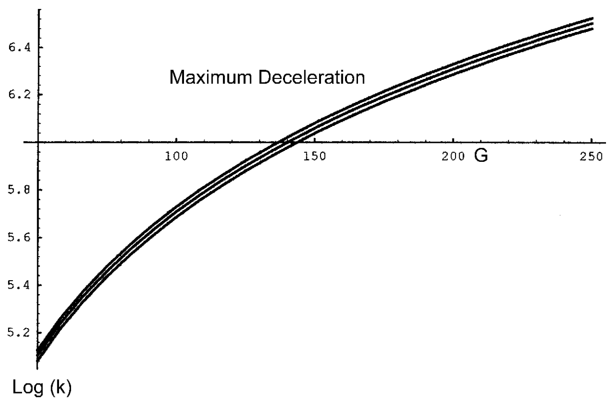
The responses of the four methods to various surface stiffness have been calculated and are shown in the four figures for a continuous range of surface stiffness with spring constants from 0.15 to 3.2 MN/m (plotted as base 10 logs).

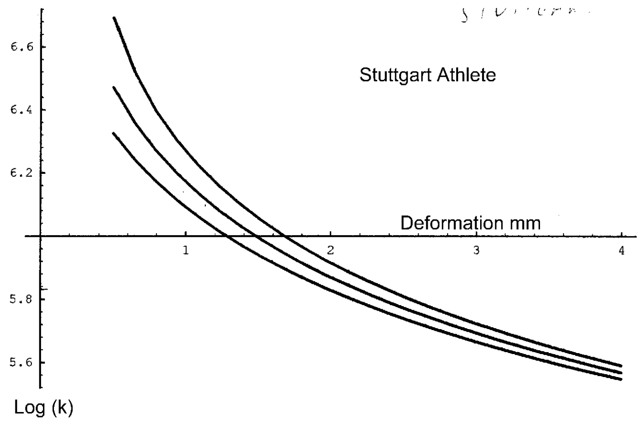
Also shown are the error limits for each method which have been ascertained as follows:

Berlin Athlete – precision of 1 %
Drop mass – Critical Fall Height precision of 5 %
Drop mass – G-max precision of 5 %
Stuttgart Athlete – precision of 0.2 mm









Discussion

From the figures it can be seen that each method will determine the effective spring constant with about the same precision, with the exception of the Stuttgart Athlete, where the 0.2 mm uncertainty in deformation leads to an uncertainty in determined modulus approximately double that of the other methods.

This analysis was made using the model of a linear elastic spring to represent the sports surface. However, the real surface is neither linear nor elastic in its general properties. For example, the surface is likely to increase in stiffness with deformation leading to greater forces being generated than for a linear elastic material. The effects of visco-elasticity will also lead to greater forces being produced, especially with measurement techniques that generate short time actions.

If useful measurements are to be made to determine an athlete's interaction with a surface and compensation cannot be made for this non-linearity and visco-elasticity, then

- the measurement forces should be similar to those produced by an athlete, and
- the force dynamics (times) should be similar.

In Table 1 are shown the different peak forces and times for the measurement methods analysed and for an athlete in interaction with a surface. The McMahon-Green model has been used to represent the athlete.

Table 1: Machine characteristics on measuring a surface of FR = 40 %

Method	Berlin Athlete	Critical Fall Height	Max G from 500 mm	Stuttgart Athlete	McMahon -Green athlete
Peak Force kN	4.2	10.0	7.0	1.5	2.5
Rise time of force - ms	8.0	3.5	3.5	38	49

From Table 1 it can be seen that the two drop methods differ markedly in their characteristics from those of the athlete – the peak forces are much higher and the interaction times are much shorter. (These peak forces could be lowered by using smaller drop heights, but then the precision of the method would deteriorate and the rise time would not be changed.)

The Berlin Athlete is only slightly better than the drop methods - its peak forces and times being similarly different from those of the athlete.

Only the Stuttgart Athlete approaches the athlete in its mechanical characteristics. This therefore should be the choice of methods for measuring sports surface characteristics, provided its precision and accuracy can be made satisfactory.

JID
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