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## Additional Comments on the Artificial Athlete Stuttgart

In recent negotiations among synthetic turf experts, the following issue was raised:

Should **Standard Deformation** (StD) be determined by using the regular formula specified in the CEN prEN standard or should it be calculated without reference to the 1500N figure for standard impact force.

The latter proposal is preferred by some experts.

$$\text{StD} = 1500 * \frac{\text{DEF}_{\max}}{\text{F}_{\max}} \quad \text{or} \quad \text{VD} = \text{DEF}_{\max}$$

where

$\text{DEF}_{\max}$	is	maximum deformation during the first impact in [mm]
$\text{F}_{\max}$	is	peak force during first impact in [N]
VD	is	<b>Vertical Deformation</b> in [mm]

The reason that the reference to the standard peak force was introduced is that in practical tests it is difficult to adjust the drop height so that the peak force is exactly 1500N. By using the reference peak force, the results of Standard Deformation tests are easily comparable.

The argument against use of the peak force reference is based on reported user impressions that certain products show Standard-Deformation readings above the limits set in Turf Manuals but are never-the-less physically/personally felt suitable by the players when running on such surfaces. This is seen as an unfair disadvantage to those products.

The effect of eliminating the reference to 1500N is a reduction of the StD to a point where the problem seems to have disappeared (i.e.  $\text{VD} < \text{StD}$ ). Thus far, the reasoning presented for this proposed change is that synthetic turf has a non-linear and highly viscous stress-strain behavior.

The IST has considered the question and undertaken some research into this. The result is that the above arguments were found to be non-persuasive and any change of the evaluation formula not justified. Furthermore there is nearly 40 years of use of the Artificial Athlete as specified in the CEN standard prEN 14808. If subjective contradictions between the StD measurements and the feelings of the players seem to exist it is due to the requirement set for StD in the Turf Manuals (CEN, UEFA, FIFA) since it is compliance or non-compliance to these requirements which cause products to appear non-suitable or less suitable to the public. If there is such incompatibility, the requirements have to be adjusted, not the test procedure.



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The IST has developed a program to control not only the force versus time and deformation versus time traces but also to display the relationship of force and deformation during an impact for each individual drop/impact. A typical record of such a drop is shown on attachment 1. From the force-deformation diagram it can be seen that the trace with increasing stress/load is, in principle, rather straight. However, it begins with a slight delay and goes above the straight line in the range of 0.6 to 1.0 kN. From then on, the trace follows the straight line with only small oscillations. After reaching the peak force, the deformation gently starts to recover and a major part is still there when the drop weight has already left the spring. It takes a few seconds to reduce this deformation to a remaining amount of 1-3mm.

The deviation of the trace at the beginning of the impact and after 0.4 kN is due to a resonance effect occurring within the spring of the Artificial Athlete (the AA is a two-mass swinging system). After this one initial swing the force-deformation trace follows rather perfectly a straight line. Thus for example, if the test was performed so that the peak force is 1450N instead 1500N, it is very easy to extrapolate the reading to the standard peak force of 1500N. There is no systematical error or principle mistake in it.

The suggestion that the viscous character of the synthetic turf could be the rational to oppose the 'tried and true' formula for StD lacks adequate substance. The IST would put it this way: the fact that the increasing and the decreasing branches of the trace are different is the effect of the viscous nature of the surfacing. According to physics the area formed by the two arms of the trace is a measure of the **Energy Loss**. Thus, it could be the solution for the question of how to determine the **Energy Restitution** as requested in the prEN standards. This does not need any additional testing - it is just an additional parameter from the same record.

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