Gmax Vs. HIC and Other Common Misconceptions in Synthetic Turf Field Testing

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What is H.I.C.?

A specific integral of accelerated-time history of impact, used to determine risk of head injury.
What is H.I.C.?

<table>
<thead>
<tr>
<th>HIC Value</th>
<th>Minor Head Injury</th>
<th>Moderate Head Injury</th>
<th>Critical Head Injury</th>
<th>Fatal Head Injury</th>
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<td>2750</td>
<td>100%</td>
<td>100%</td>
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<td>100%</td>
</tr>
</tbody>
</table>

**Minor Head Injury:** A skull trauma without loss of consciousness; fracture of nose or teeth; superficial face injuries.

**Moderate Head Injury:** A skull trauma with or without dislocated skull fracture and brief loss of consciousness. Fracture of facial bones, without dislocation; deep wound(s).

**Critical Injury:** A skull trauma with loss of consciousness for 12 hrs and having permanent brain damage.
What is Gmax?
The maximum acceleration of an object during an impact, expressed in “g” units.
DIFFERENT TYPES OF IMPACT FORMS

**Advanced Artificial Athlete**
55mm Drop Height

**F355E Missile**
Variable Drop Height

**F355A Missile**
24” Drop Height

44 lbs

spring

2.75” dia Face

10 lbs

6.3” dia Hemi Face

20 lbs

5” dia Face
IMPACT ATTENUATING LAYERS

Ball

Underfoot

Head

Body
What correlation can be made between the missiles?
No correlation should be made between the missiles described.

Some of the differences include:
- Missile Weight
- Surface Contact Area
- Penetration into the playing surface
- Drop Height
Different Missiles, Different Fall Heights Means Different Results.

EACH FALL HEIGHT/SURFACE AREA REPRESENTS A DIFFERENT IMPACT PRESSURE
“Gmax testing” ASTM F1936-19 Impact Attenuation of Turf Playing Systems as Measured in the Field
Testing Summary for F1936-19

A theoretical drop height of 24 in. (61 cm), as measured from the bottom of the missile face to the top of the turf playing system, shall be used.
Testing Summary for F1936-19

A theoretical drop height of 24 in. (61 cm), as measured from the bottom of the missile face to the top of the turf playing system, shall be used. At each test point, the impact **missile is dropped onto the turf playing system three times, with an interval of 60 +/-30 seconds** between successive drops.
A theoretical drop height of 24 in. (61 cm), as measured from the bottom of the missile face to the top of the turf playing system, shall be used. At each test point, the impact missile is dropped onto the turf playing system three times, with an interval of 60 +/- 30 seconds between successive drops. Following the third drop, the average g-max value for the second and third drop are averaged together.
Primary sport shall be determined by lines on the field. Where there are multiple sports lined, the primary sport is determined by looking at what line is dominant in a line intersection.
“Gmax” Performance Requirements

When tested in accordance with this specification, the average g-max at each test point shall be less than 200 g’s. Often there is an additional number specified by the designer that is often tied to the warranty of the field.
The purpose of “gmax” testing is to measure the absorption capabilities of the surface by mimicking a head to ground impact. This testing is not intended to replicate a players performance interaction with the surface. A low gmax value does not necessarily mean that there is a lack of stability in the surface.
ASTM F355E: HEMISPHERICAL DROP FORM “HIC” Methods

- ASTM F1292-18
- ASTM F3146-18
- EN 1177:2018
ASTM F1292-18 Standard Specification for Impact Attenuation of Surfacing Materials Within the Use Zone of Playground Equipment

Critical Fall Height Procedure—The critical fall height of the surface shall be determined as the maximum theoretical drop height at which impact test results meet the performance criterion and shall be rounded to the nearest whole foot equal to or below the actual value.
How is Critical Fall Height determined according to ASTM F1292?

The series of reference drop heights shall consist of an increasing sequence at intervals of 1 ft increments until the impact test results do not meet the performance criterion of 1000 HIC or 200 g’s. As a minimum, impact tests must be performed at theoretical drop heights of 1 ft above and 1 ft below the theoretical drop height at which the impact test results approximates the limiting performance criterion. Results from the second and third of three consecutive drops are averaged to give average scores.
EN 1177:2018 Impact attenuating playground surfacing — Methods of test for determination of impact attenuation

To determine the Critical Fall Height (CFH), Drop the headform 1 time from at least 4 increasing drop heights, at a previously untested position without compaction, ensuring that the material is present at the same layer depth at each test position, and report the results. Interpolate the curves to obtain the drop height equivalent to a HIC of 1000 and the drop height equivalent to a gmax of 200g, using impact measurements with at least two values giving HIC and gmax values below and at least two giving HIC and gmax values above these target values.
How is Critical Fall Height determined according to EN 1177:2018?

Table 1 — HIC values

<table>
<thead>
<tr>
<th>Impact number</th>
<th>Targeted HIC value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact 1 → m₁</td>
<td>700 to 800</td>
</tr>
<tr>
<td>Impact 2 → m₂</td>
<td>850 to 950</td>
</tr>
<tr>
<td>Impact 3 → m₃</td>
<td>1050 to 1150</td>
</tr>
<tr>
<td>Impact 4 → m₄</td>
<td>1200 to 1300</td>
</tr>
</tbody>
</table>
How to Plot Critical Fall Height according to EN 1177:2018

Key
1. impact measurements $m_1$ to $m_4$ in HIC at drop heights $H_1$ to $H_4$
2. critical fall height at HIC = 1 000
3. critical fall height at $\eta_{\text{max}}$ = 200
$m_1$ HIC = 700 to 800
$m_2$ HIC = 850 to 950
$m_3$ HIC = 1050 to 1150
$m_4$ HIC = 1200 to 1300
$m'_1, m'_2, m'_3, m'_4$ impact measurements $m'_1$ in $\eta_{\text{max}}$ at drop heights $H'_i$
$H_1, H_2, H_3, H_4$ drop heights $H_1$ to $H_4$ (m)
EN1177:2018 Performance Requirements

The specification does not provide a performance requirement. Critical fall height can be determined by project specification, owner, or manufacturer. The Synthetic Turf Council’s “One turf Concept” recommends a minimum fall height of 1.3 meters.
Impact attenuation is calculated by dropping an impactor of known mass and dimensions onto the surface from four different drop heights and the HIC value for each drop height calculated. Linear regression analysis is used to define the relationship between measured drop heights and corresponding HIC values. The linear regression equation is used to estimate the drop height that corresponds to a representative HIC value equal to an established criterion. This value is the Critical Fall Height (CFH). CFH values are compared to an established criterion to determine if a field’s performance is acceptable.
How is Critical Fall Height determined according to ASTM F3146?

**Performance requirements:** When all four characteristic HIC values for known drop heights have been calculated, the values are plotted as drop height versus representative HIC. The drop height at which the HIC value is equal to the impact attenuation performance criterion value must be estimated using a linear regression model of the points charted with the intercept calculated normally. This is determined to be the CFH calculated for that test point.
Procedure A must be used for laboratory testing. For field testing, Procedure A can be used in all scenarios. Procedure B is only acceptable for use for field testing and only where minimum performance requirement is provided.

If this minimum performance requirement is not provided then Procedure B must not be used and only Procedure A must be used. It is not permitted to alternate between Procedures for drop height tests on an individual location.

Procedure B is not intended to provide equivalent results with Procedure A, it is to be used as a separate test and must have a separate minimum requirement level associated with it.

This level should be chosen so that passing when tested to Procedure B is unlikely to result in the surface failing if tested to Procedure A. If there is any doubt regarding the performance of the surface then Procedure A shall provide the defining result.
ASTM F3146 Procedure A and B - What are the differences?

1. Procedure A—Perform three drops of the missile from the same height onto the same test point on the surface so that the impact centres for the three drops are as close as possible to each other.

2. Procedure B—Perform one drop of the head form from the drop height onto a point on the surface.
What are the basic differences between the “HIC” methods described in the field?
Minimum number of drops per fall height and how they are recorded

- F1292-18
  - 3 drops, average of drop 2 and 3

- EN1177:2018
  - 1 drop

- F3146-18
  - Procedure A - 3 drops, highest value of the drops
  - Procedure B - 1 drop
Calculation of Critical Fall Height

➔ F1292-18
  ◆ Round down to the nearest whole foot

➔ EN1177:2018
  ◆ Regression model
  ◆ Round down to the nearest 0.01 m

➔ F3146-18
  ◆ Linear regression model
  ◆ Round down to the nearest 0.01 m
What is the limiting criteria used to determine Critical Fall Height?

➔ F1292-18
  ◆ Gmax (200g) or HIC (1000)

➔ EN1177:2018
  ◆ Gmax (200g) or HIC (1000)

➔ ASTM F3146-18
  ◆ HIC (1000)
Will all the Methods Discussed Give You the Same Results?

Comparison of HIC Methods on a Turf System
Will all the Methods Discussed Give You the Same Results?

Comparison of HIC Methods on a Shockpad
Does “gmax” testing or “HIC” testing give you a full evaluation of the field performance and safety characteristics?
All of the methods in discussion are designed to establish a risk of head injury.

There are many other field test methods in use to evaluate the performance of a field.
“HARD / SOFT” UNDERFOOT FORCE REDUCTION

**Too High** - The surface will feel heavy to the players and will sap their energy tiring them out quicker.

**Too Low** - The surface will feel too hard and result in an increased risk of injury to players from compaction of the meniscus in the knee joints and the spinal column.
UNDER FOOT VERTICAL DEFORMATION

**Too High** - The field will deform too much under the player which may result in overstretching of ligaments

**Too Low** - The field does not have enough compressibility and will feel hard to run on resulting in potential joint and muscle soreness
ROTATIONAL RESISTANCE

**Too High** - The natural slippage that is expected is reduced meaning that the likelihood of excessive grip between the cleat and the surface increases the risk of potential joint injuries, especially ankle and knee.

**Too Low** - The players are more likely to slip and have less confidence in their foot holding; it makes change of direction much more difficult and slippage can result in over extension injuries.
HORIZONTAL BALL ROLL

While Ball Roll is a specific playability requirement for soccer and field hockey, the use of Ball Roll as a tool to identify the condition and orientation of the fibers is recognised by all sports. It is included here as a maintenance indication tool and also an on-field guide to the potential for friction burns and abrasion to occur. A high Ball Roll indicates that the fibers may be lying flat and that this risk is increased.
VERTICAL BALL REBOUND

Too High - The surface will make the ball bounce an unusually high amount.

Too Low - The ball will bounce less than is expected resulting in a deadening of the ball.
SURFACE REGULARITY

A surface that is beyond tolerance for planarity can affect the aesthetics of a field as well as play a role as a tripping hazard. Out of tolerance planarity will also have an affect on the trajectory of a surface ball roll.
INFILTRATION METHODS

- BS EN 12616:2013 Surfaces for sports areas. Determination of water infiltration rate
- ASTM D3385 Standard Test Method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometer
This is the most common infiltration method that we perform. It is specific to the unique characteristics of sports fields. Results can be comparable to most dual ring infiltrometer methods.

- Measures the speed of water moving through the surface
- Not intended to measure field capacity
- Can use common civil methods to calculate minimal needs for water infiltration
ASTM D3385 Standard Test Method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometer

- Very common to see this method in project specifications. Not specific to sports fields, but an acceptable method.
- Measures the speed of water through the surface
- Not intended to measure field capacity
- Can use common civil methods to calculate minimal needs for water infiltration.

- Can be performed with commonly found materials to self assess infiltration on a sports field.
- Results should not be compared to commonly used dual ring infiltrometer methods. Results can be ½-¼ of what you may find in a typical dual ring method.
- Because of the lack of head pressure within the method this test is the preferred method of assessing a possible hydrophobic infill scenario.
What Infiltration Method should be used When?

- It is most common to use a dual ring infiltrometer method as this is standard in many areas of civil construction.
- Base construction/performance layers typically use a dual ring method as most project designers are familiar with the results and how they relate.
- Where there is concern of a hydrophobic infill the F2898 removes the head pressure in the test. It can isolate a situation where water can infiltrate, but leaves a thin layer of water on the surface.
  - In sports fields more than other surfaces this layer of water may present a drainage problem. The surface does drain in general, but leaves a small amount of water on the surface where there is a lack of head pressure to assist in moving the water through the system.
Questions?

Referenced Documents:
ASTM F1292-18
ASTM F3146-18
ASTM F2898-18
EN 1177:2018
EN 1177:2008
BS EN 12616:2013
ASTM F2898-11
ASTM F355-16E1
ASTM F3189-17
ASTM D3385-18
Synthetic Turf Council “One Turf Concept”

*Video portrayal of testing is for demonstration purposes only and does not accurately depict time in between drops and typical testing locations.