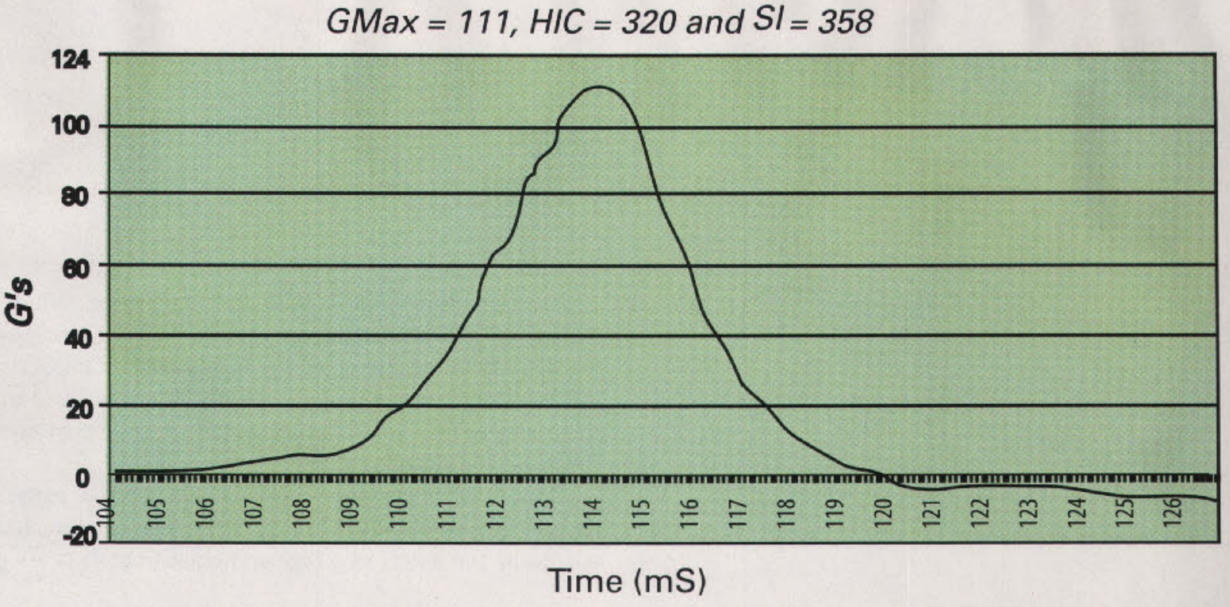


Figure 2. Gmax, Head Injury Criteria and Severity Index values for a 100% crumb rubber infill synthetic football field with no shock pad below the carpet. Time is in milliseconds.

However, softer is only good to a certain extent. Too soft a surface slows play and causes muscle fatigue. If the playing surface is very compressible then the player may actually strike the base (crushed stone, asphalt or concrete) during the impact.

The hardness of natural turf playing systems is also dependent on many things that most turf managers are familiar with. Turf variables include the age and type of turf, turf density, amount of groundcover, the mowing height and the presence of some thatch. Soil factors include texture, moisture content, degree of compaction and whether or not the soil is frozen. Synthetic turf manufacturers, based on marketing literature, want their fields to play like a pristine natural turf playing surface.

Assessing hardness: Gmax, HIC and SI

Impact severity has been studied for many years by automotive and consumer product safety researchers. Of most concern is the possibility of a life threatening head and neck injury. These injuries have been related to how quickly a human head decelerates during an impact and the duration of that deceleration. Deceleration characteristics of an impact tell us a lot about the hardness of the playing surface. A harder surface results in an impact that has a very short but very fast deceleration.

Deceleration (ft./sec./sec.) is the rate at which velocity (ft./sec.) decreases. It is the opposite of acceleration (the rate at which velocity is increasing). Deceleration can also be expressed as the ratio of deceleration to acceleration due to gravity, g. This ratio is called G. At some point over the course of an impact there is a maximum rate of deceleration. This translates into a maximum ratio of deceleration to acceleration, Gmax. Gmax is also called peak deceleration and is the value we are most interested in when assessing the hardness of a playing field.

A Gmax ratio >200 is the threshold value that the American Society of Testing and Materials (ASTM) has adopted. Surfaces causing this rate of deceleration or above during an impact may cause a life threatening head and neck injury. Bear in mind that in reality there may or may not be an injury, or that an impact on a softer surface could cause one.

Another criterion that is sometimes used in assessing impact severity is the Head Injury Criteria, HIC. This criterion is used a lot in assessing the safety of playground equipment. It takes into account

GMAX CAN BE REDUCED THROUGH THE GROOMING OF SYNTHETIC FIELDS, REPLACING INFILL MATERIALS IN DIVOTS AND, FOR NATURAL TURF, RESEEDING, AERIFICATION AND IRRIGATION.

the duration of the severest portion of the impact, as well as the Gmax. The HIC was developed from the Gadd Severity Index (SI) which analyzes the G data over the entire duration of the impact.

Taking into account impact duration is important for head and neck injuries. Two locations may have the same Gmax, but the field having a shorter impact duration is harder, i.e., the impact energy is returned to the head and neck more quickly. This results in a higher HIC and SI value. However, ASTM has adopted the Gmax value in determining the hardness of a playing field and not HIC and SI because the latter two pertain specifically to head injury and give no indication of how other body parts may be injured.

Peak deceleration, Gmax, is affected by surface hardness. A harder surface causes a greater rate of deceleration. For example, if a player struck a concrete surface they could decelerate (or reach zero velocity) almost instantaneously. Compared to how fast they had been accelerating, Gmax would easily exceed 200. If the player struck a softer surface they would decelerate more slowly because the surface would be compressing below them. However, the surface doesn't compress indefinitely. It becomes stiffer as it is compressed. As a result, the player begins to decelerate more rapidly until they finally stop moving in the downward direction. This is the point of Gmax. Table 1 shows some examples of Gmax for different surfaces.

Gmax will usually increase with high use, compaction, infill segregation, loss of thatch and groundcover, and soil dryness. Gmax can be reduced through the grooming of synthetic fields, replacing infill materials in divots and, for natural turf, reseeding, aerification and irrigation.

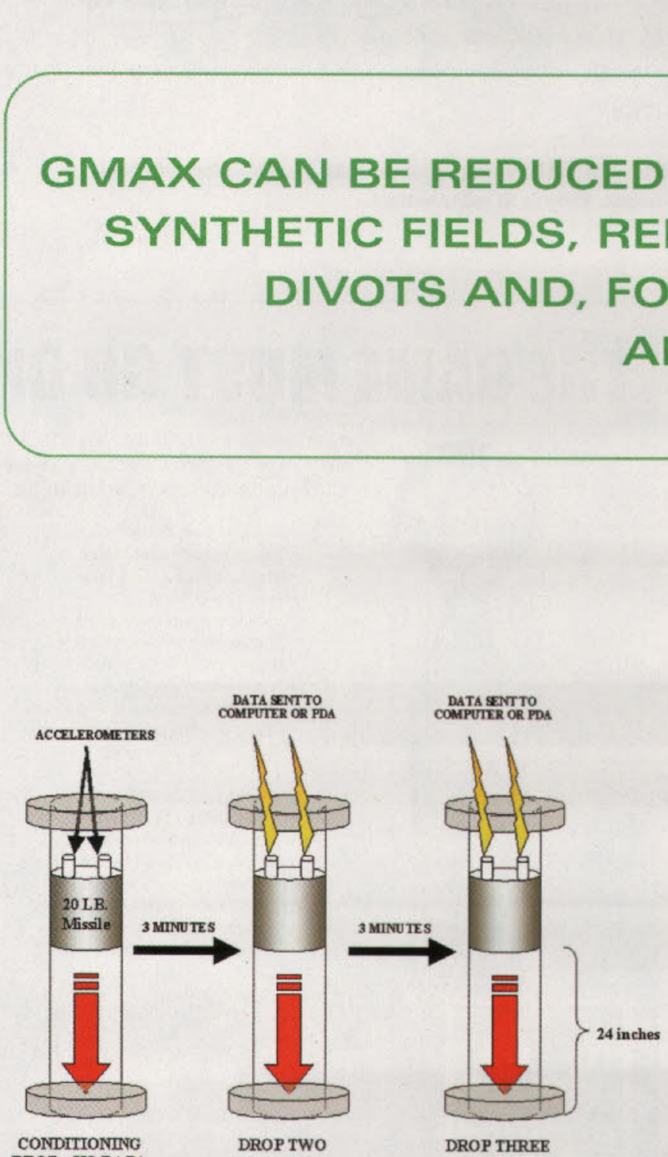
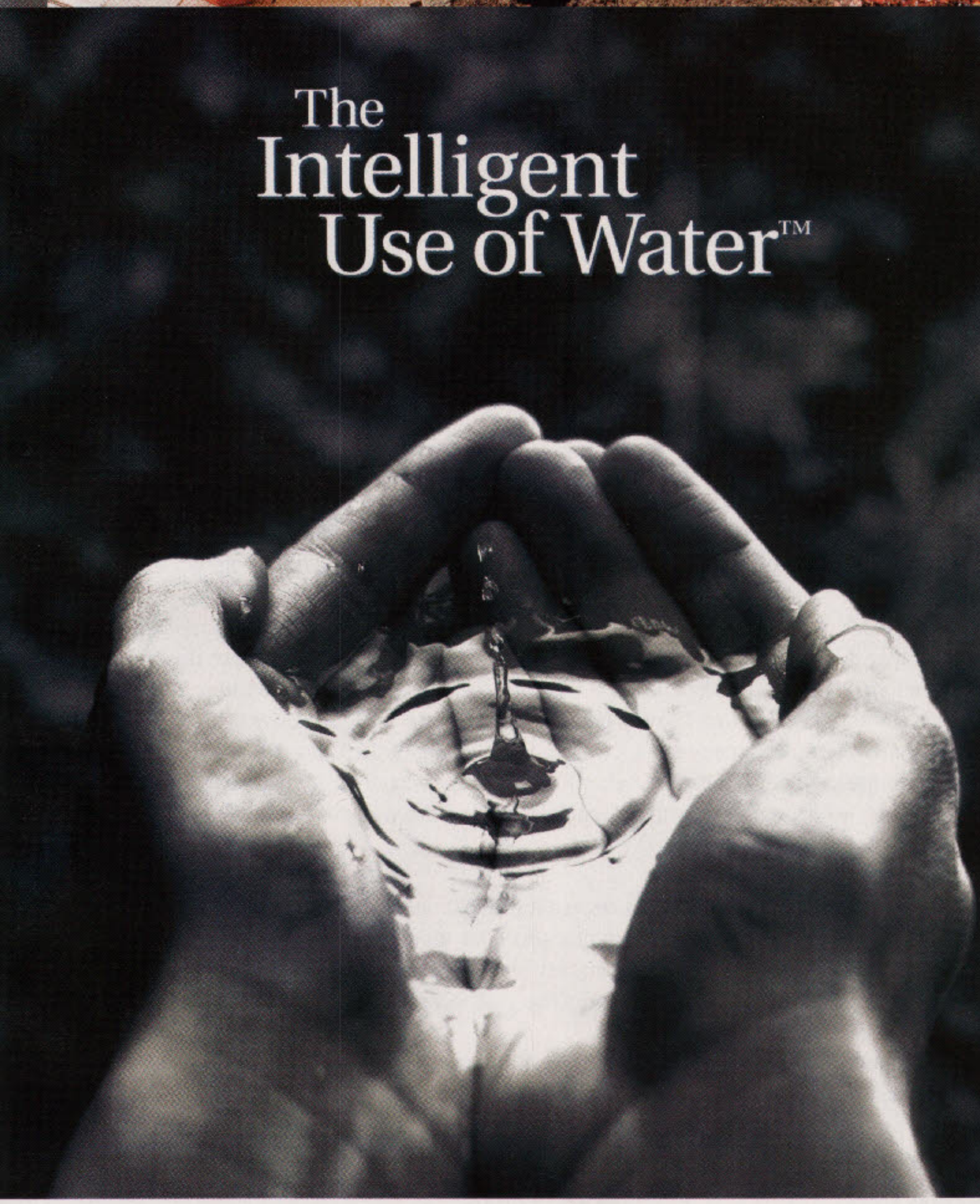


Figure 3. Illustration of drop sequence used during an F 1936-98 test sequence.



IT HAS BEEN SUGGESTED THAT A GMAX OF 150 TO 175 MAY BE MORE APPROPRIATE FOR F 1936-98 IF THE PLAYERS ARE HELMETLESS.

ASTM standard tests

ASTM has two standard test methods for measuring the shock-absorbing ability of playing surfaces. The first is the primary method used on synthetic surfaces. This procedure is ASTM F 1936-98 "Standard Specification for Shock-Absorbing Properties of North American Football Field Playing Systems as Measured in the Field." The second method is for use on natural turf and soil playing surfaces. It is ASTM F 1702-96, "Standard Test Method for Measuring Shock-Attenuation Characteristics of Natural Playing Surface Systems Using a Lightweight Portable Apparatus." The two methods have many similarities, but the differences are important enough so that the numerical results cannot be compared, or at least not at this time.

Both F 1936-98 and F 1702-96 use instruments called impact testers. These testers indirectly measure the hardness of the playing surface by dropping a cylindrical weight, called a missile, down a guide tube onto the surface. Peak deceleration of the missile as it strikes the surface is measured. Figure 1 shows a typical impact tester used in each procedure.

The impact tester used for synthetic turf has a 20-pound missile equipped with accelerometers. A computer captures the acceleration-deceleration data for the entire impact. The 24-inch drop height came from the automotive industry and the missile weight came from a Northwestern University study of helmeted middle linebackers during actual play. With modification this test method can be used on wrestling mats, playgrounds, body padding, trampoline frame padding, goalposts, shoulder pads and gymnasium walls. Figure 2 shows an impact curve for a 100% crumb rubber infill synthetic football field with no shock pad.

The Clegg Impact Tester is an impact tester equipped with a missile of approximately 5 pounds and a bottom face of approximately 3 square inches. This missile is dropped from 18 inches. The Clegg Impact Tester results in lower Gmax values than the F 355 tester and the numerical data obtained by each tester cannot be compared. The F 355 missile is said to simulate a head striking the playing surface while the D 5874-02 missile has been described as an elbow striking the surface. Researchers at Penn State are trying to correlate the two methods to one another.

A very important difference between these two methods is that ASTM uses the Gmax threshold of 200 for F 1936-98, but does not have a threshold for F 1702-96. It has been suggested that a Gmax of 150 to 175 may be more appropriate for F 1936-98 if the players are helmetless. A Clegg reading of about 125 may be a reasonable upper limit for natural turf fields according to some university researchers and values from 60 to 95 are regarded as acceptable.

In the field

ASTM 1936-98 covers testing for Gmax on synthetic North American football fields. In this procedure six test locations are tested for hardness with the F 355 impact tester. These test locations are based on known field wear points. The test locations are:

Point 1 - Goal Line, End A, Center Field,

Point 2 - 10 Yard Line, End A, 1/4 the distance measured from sideline C to center field,

Point 3 - 25 Yard Line, End A, 1/2 the distance measured from sideline C to center field,

Point 4 - 50 Yard Line, Center Field,

Point 5 - 25 Yard Line, End B, 1/4 the distance measured from sideline D to center field,

Point 6 - 12 Yard Line, End B, Center Field.

Three missile drops are performed at each test location with each drop being three minutes apart. Gmax data from the first drop, the "conditioning drop", is disregarded but Gmax data from the second

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Fill in **116** on reader service form or **visit http://oners.hotims.com/9133-116** and third drops are used to calculate an average Gmax for that test location. This procedure is repeated for the other five test locations. Figure 3 illustrates the procedure. If for some reason there is a need for an additional drop at any test location then the test instrument should be moved to a new spot within 36 inches of the required test location. One additional test location is permitted on each field if an area is found to differ from the overall general condition of the field. Any location with an average Gmax >200 must be repaired or replaced.

"Hot spots" on the field can be identified and corrected. For the field owner, routine hardness testing can insure that the field is performing up to the manufacturer's claims. (The manufacturer's warranty for Gmax may be considerably lower than 200). For the manufacturer, testing can insure that the owner is maintaining the field in an appropriate and responsible manner.

Finally, while hardness-testing does not address all the safety concerns of an athletic field, nor guarantee that an injury won't occur, it is a very practical way to assess the impact injury risk of the field. Hardness testing will provide you with very important information about your investment. Written documentation concerning your fields' hardness and your monitoring program could be very valuable in the event of injury-related litigation. No documentation could place you in a "No-Win" situation.

Table 2. Required Information in ASTM F 1936-98 and F 1702-96 Reports.

F 1936-98	F 1702-96
Issue Date of Report.	Assumed to be reported.[1]
Name of lab, company or individual issuing report.	Assumed to be reported.[1]
Name and location of test site.	Name and Location of test site.[1]
Date(s) of site test.	Date(s) of site test.
Range of surface and air temperatures during test.	Environmental conditions at the time of test including temperatures and humidity.
General weather conditions and overall weather influenced field conditions.	
Full and complete description of the surface system including all layers, date of installation, and person providing this information.	Type and density of vegetation, and depth of thatch if present. Soil texture and moisture should be given.
Name and method of test version and procedure.	Type and model of instrumentation.
Drop height and velocity.	Total missile mass.
Location of each test point.	Location and type of surface (turf or soil).
List of the average Gmax by test point and location.	Average *Gmax* at each test location and average *Gmax* values for similar surface characteristics (optional).
List surface temperature, % turf cover, and soil moisture at each test location.	Note on report: "Numerical data with this test method will not be comparable to data obtained using a different missile mass or geometry, a different drop height, or using a different method, for example, Test Method F 355."
Description of any site abnormalities that lead to an imprecise test point location or deviation from location.	
Conclusion: All test points met the requirement of <200 average Gmax or all test points met this requirement except for the test points listed.	
Note on report: "Test results reported herein reflect the conditions of the tested field at the time testing and at the temperature(s) reported."	

[1]Not specifically stated in procedure.

Reporting results

Table 2 shows the required field and environment information for ASTM F 1936-98 and F 1702-96 reports. Optional information may include HIC, SI, rebound velocity, time to Gmax, as well as other impact characteristics.

The measurement of the shock absorbing properties of an athletic field should be an integral part of any maintenance program, regardless of whether or not the field is synthetic or natural. Procedures have now been developed that simplify the procedure by standardizing how the testing is to be performed. Routine testing can help the field manager track changes in hardness and modify their maintenance plan accordingly.

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Photo credit: University of Idaho

Managing **Kentucky blue** against **summer stress**

By Dr. Bingru Huang

Kentucky bluegrass is a widely used cool-season grass on sports fields in the north central and northeastern regions, although it is found throughout the United States. This species grows most actively at temperatures between 65 and 75°F and require as much as 2-3 inches of water per week during summer months.

Kentucky bluegrass forms attractive turf when supplied with adequate water and when temperature is cool in spring and fall. However, turf performance of Kentucky bluegrass often declines during summer when temperature exceeds 75°F and/or under drought stress conditions. Kentucky bluegrass generally undergoes dormancy during severe summer stress that increases the chance of turf survival, but substantially lowers turf quality. The lack of heat tolerance restricts its use in cool climatic regions.

In addition, water supply is often inadequate to maintain high quality turf due to lack of rainfall or limited water availability for irrigation in many areas. Maintaining Kentucky bluegrass in situations requiring high quality or playable turf such as sports fields can be challenging in areas with limited rainfall or irrigation during summer months.

Can you identify this sports turf problem?

Problem: Brown Turf
Turfgrass Area: Athletic Field
Location: Southern United States
Grass Variety: Bermudagrass

Answer to John Mascaro's Photo Quiz on Page 31

Answer to John Mascaro's Photo Quiz on Page 31

John Mascaro is President of Turf-Tec International

Management strategies for **KENTUCKY BLUEGRASS**

Sufficient irrigation is an effective means to prevent or alleviate summer decline in turf quality due to drought and heat stress. Several other cultural practices could be utilized to prevent or alleviate summer stress injury in Kentucky bluegrass:

1. Using **stress tolerant cultivars** is the primary means for improving turf performance of Kentucky bluegrass in hot and dry environments.

2. Keeping **mowing heights at highest level** allowed to promote plant tolerance to both drought and heat.

3. Using **growth inhibitors and anti-transpirants** for water conservation and delaying drought stress injury in water-limiting environments. However, anti-transpirants may not be used in the situations with high temperature.

4. Maintaining **adequate fertility could alleviate stress injury**. Proper use of nitrogen may delayed or suppress leaf senescence during extended period of high temperatures. Increasing potassium may enhance plant tolerance to both drought and heat stress.

–Dr. Bingru Huang

Drought and high temperature are two major summer stresses limiting the growth of cool-season turfgrasses during summer months. It is not uncommon that drought and heat stress may occur simultaneously during summer months, which can severely reduce turf quality and field playability.

Drought stress and growth

Leaf wilting or desiccation and reduction in cell enlargement and growth due to water deficit characterize drought injury in turfgrass, although many physiological and morphological changes are induced. Under drought stress, water loss from stomatal pores on leaf surface (transpiration) increases while root growth and water uptake from the soil is limited. Leaf wilting or rolling is a typical symptom of drought stress. Turf experiencing drought stress initially becomes bluish, dull green color and then turns to brown color as chlorophyll content decreases with stress progression.

Kentucky bluegrass is relatively more tolerant to drought stress compared to other cool-season grasses. This species produces rhizomes (underground stems) that give rise to new plantlets. Rhizome formation enables bluegrass to recuperate from injury and fill in thin areas. Kentucky bluegrass may go dormancy resulting in loss turf quality, but can survive several months without significant rainfall or irrigation. Then, after rainfall or significant irrigation the grass will quickly regenerate new shoots and roots and recover.

For perennial turfgrasses, one of the most important drought-tolerant strategies is the ability to survive and recover rapidly from the stress after rainfall or irrigation. Our study found that the recuperative ability of Kentucky bluegrass from drought stress varied with the duration of exposure to drought stress, the duration of rewatering, and growth or physiological parameters. Turf quality could not recover completely (100% of the pre-stress level) after 6 days of rewatering when turf quality declined below 5.0 (quality of 1 = dead turf and 9 = completely turgid and green turf) due to drought stress.

Short-term drought brought reversible effects on Kentucky bluegrass growth, but prolonged soil drying was detrimental to the whole-plant performance for Kentucky bluegrass. How long to let plants go drying before recovery upon irrigation depends on the severity of drought stress. The critical physiological status or injury level may be used to determine when rewatering or irrigation is needed following a period of drought stress. Optimum leaf relative water content (RWC) is about 85 to 95% for most plant species when water uptake by roots equals leaf transpirational water loss; the critical RWC is approximately 50% (varies among species and tissue types), below which tissue physiological injuries and death occurs. Our study found turf quality of Kentucky bluegrass could recover completely following rewatering as long as leaf RWC was maintained at or above 25%.

Kentucky bluegrass has high environmental plasticity. The recuperative response may represent an important adaptive strategy that permits a rapid regrowth following a rainfall event or irrigation. The critical values for physiological parameters could be used as a guideline to