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Turf Standards for Head Injury

Close is for Horseshoes and Hand Grenades, not Athletic Field Standards

The issue of prevention of injury, primarily head injuries, has been a concern of manufacturers, designers, owners and users of synthetic turf fields. For more than 45 years impact attenuation has been measured through the use of ASTM F355, Procedure A. Although there had been some connection to the early automotive injury prevention data and the recommendation of the CPSC in the 1981 Handbook for Public Playground Safety that “a surface should not impart a peak acceleration in excess of 200 g’s to an instrumented ANSI headform, dropped on a surface from the maximum estimated fall height”, it has been determined that this needed revisiting given current information related to head injury studies in field sports. The key to this investigation is accuracy. It must also generate a standard that allows for anyone to perform the testing following the requirements of the standard.

For many years there was concern that the impact attenuation pass/fail of 200g in the ASTM F1936, Standard Specification for Impact Attenuation of Turf Playing Systems as Measured in the Field, utilizing the ASTM F355 A missile was not providing the protection particularly for head injuries. This was brought to a head with a ballot in the ASTM F08.65 sub-committee on Artificial Turf Surfaces and Systems to lower the maximum g from 200 to 160. The Synthetic Turf Council (STC) and NFL have set their threshold to 165g. Some of the concern was that a 200 g value with the 20lb A missile could not be equated to the same energy as the 11lb ANSI C missile of the original CPSC recommendation and because anything measured with the A missile does not represent a bare head impact. Additionally work in the mid-1990s in the ASTM F08.63 sub-committee on Playground Sur-

To page 2

Thanks Paul Hogan

Triax History and ASTM F1292 were Parallel paths not identical

Impact attenuation for playground surfacing in North America gets its start through the work of the US CPSC and the first publishing of the Handbook on Public Playground Safety in 1981 with, “most injuries associated with playground equipment involve falls, which would not be addressed by equipment specification alone”. The work on impact attenuation leading up to the recommendations in the Handbook come from the automotive industry, the Franklin Institute and National Bureau of Standards. The recommendation of the CPSC was that the Gmax shall not exceed 200 when an instrumented ANSI headform is dropped onto a surface from the maximum estimated fall height. Although the ANSI headform was not defined in the Handbook, the testing in reference 32 of the Handbook utilized the ANSI C headform. This headform was formally adopted into ASTM F355 as procedure C and ASTM F1292 in 1991. In Canada, there was a recommendation in the CSA Z614 M90 that synthetic surfacing suppliers should be able to provide testing data to ASTM F355. That is where some of the problems begin as ASTM F355 is the description of the headform and some of the procedures use, but not the determination of Critical Height.

The CSA committee can’t take all of the blame for the wrong reference as they published the Z614 in 1990 and ASTM did not publish the first F1292 until 1991. There was an anticipation of the ability to test surfacing and therefore the reference to F355 and not F1292. By the time CSA published its 1991 revision, ASTM had caught up, but the reference was not changed until the 1998 revision to the CSA Z614. So the focus for surface testing during the 1990s is on the work at ASTM as the CSA committee was not in a position of developing their own performance test and skills were predominantly in the US and Europe through CEN. There was also considerable cross-

To page 3

face Systems determined through round robins and scientific analysis that the 10.1lb ASTM F355 E missile provided identical, repeatable and reproducible results for all surfacing systems, loose fill and synthetic, used in playgrounds as with the ANSI C. The ANSI C and F355 E were allowed interchangeably in the ASTM F1292-99 and the ANSI C was dropped in the 2004 revision.

Another driving force to change the manner of measuring impact attenuation was that World Rugby established a turf performance requirement for impact attenuation was based on dropping an E missile to determine a critical height greater than 1.3 meters (51.2"). Currently this uses the test method in EN1177, Impact attenuating playground surfacing – Determination of critical fall height, which has used the ASTM F355 E missile since the 1990s. At this time there is a standard for impact attenuation for Rugby fields working its way through the ASTM process to mirror the EN1177 standard for use in the USA by the NCAA and others playing rugby.

As it turns out the determination of impact attenuation for all athletic fields, crossed paths with the work in rugby. Although there have been many people involved in the work, a certain degree of the credit must be given to FieldTurf for bringing in Biokinetics and Associates Ltd. of Ottawa, Canada to the investigate the issue. Biokinetics brought excellent credentials in impact attenuation in a large variety of fields, and particularly, Chris Withnall, Senior Engineer - Sport Biomechanics, and being a major contributor to the NFL concussion study. Biokinetics performed experiments and provided updates to F08.65 on their progress over a 2 year period bringing the group to the point where in May of 2017 testing with the F355 E missile will be performed on a variety of sport surface systems. This should lead to the writing of a new standard for the testing of Turf Systems in the Field using the F355 E.

To gain broad acceptance of the new standard, it is important to provide an understanding of the scientific process that has unfolded. The highlights are;

g values between 150 and 200 are severe, but not life-threatening and include severe, but reversible fracture and concussion damage

g values over 200 are potentially life-threatening with survival unlikely

NFL Study – specifically for this data set, the 50% risk of concussion is 80g, 5500rad/s^2, HIC 235, SI 290 and concussions occurred at 98g ±28g

Rowson and Duma (2011) using the HITS instrumented football helmets found concussions at 105g ±27g. This technology has never been correlated to the hybrid 3 headform as required for inclusion in the standard; however it does help bring head injury concerns to light. Thid does point out that standards cannot be based on ad hoc, non-complaint devices or technologies.

Rotational kinematics dominate concussion risk; however linear forces always produce rotation head kinematics

Dropping a Hybrid 3 dummy from the same height a 45° angle or vertically indicates the vertical is the more severe and therefore the more desirable test. It was initially considered the that rotational kinematics would be greater on an angle as a result of an interaction with the turf, but the data shows the rotation kinematics were higher with the vertical drop.

Tests comparing the Hybrid 3 dummy and the F355 A missile concludes that the F355 A does not simulate the actual outcome to the human head, therefore a new missile must be found

F355 E missile testing on a variety of turf systems and compared with the Hybrid 3 using regression analysis results a relationship of 0.9828. Therefore the E missile becomes the appropriate test device with a best fit, particularly for values under 140g

Introduction of injury functions utilizing automotive studies provides

HIC of 1000 is a 16% risk of severe head injury, life-threatening with survival probable (AIS>4)

HIC of 700 is a 5% risk of AIS>4, 55% risk of AIS>3, serious injury

180g is a 5% risk of skull fracture

200g is a 10% risk of skull fracture

Conclusion is that for testing surfaces in the field for head injury prevention the most appropriate device is the ASTM F355 E missile, with a threshold of not to exceed 180g and HIC value not to exceed 700 with the focus being on the bare head.

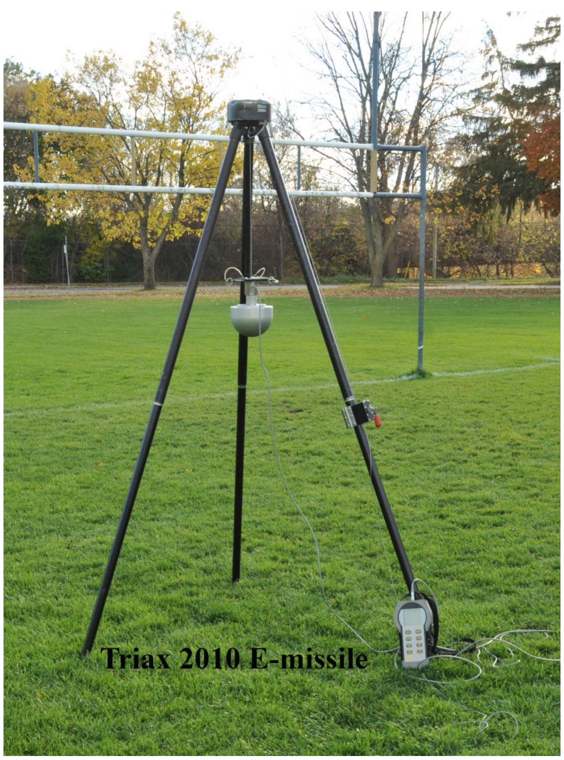
The two remaining elements to the completion of a standard are the drop height for the F355 E missile and the number of drops to the turf surface system. Currently World Rugby requires a critical height, where HIC is not

 To page 3, C1

greater than 1000 at 1.3 meters (51.2") with 12 drops to four points on the turf, consisting of 3 drops to each test point. This is a very severe test, particularly where infill is the main impact attenuator and is not applied to natural turf systems. It has been suggested and data will be generated to evaluate the dropping of the E missile from the same height to three points close to each other. The dropping to 3 separate points would also not be biased against natural turf. It is anticipated that this testing will result in a determination of drop height, 24", 39.4", 51.2" (610mm, 1000mm, 1300mm) and whether the three drops will be from the same height to the same point on the surface or three drops from the same height not less than 6" (152mm) and not greater than 12" (305mm) apart.

It is important to understand that the ASTM process is open, subject to anti-trust requirements and generally driven by industry. It is highly unlikely for a group, "old boys club", and single block or individual to write or maintain a standard in a consensus process that does not have broad support. This is particularly the case in the F08.65 as there are diverse interests at work that have demonstrated more of an ability to delay than advance a single objective.

The conclusion of this work should result in better protection of players on turf playing systems and provide consistent measurements that give users confidence in the use of the field they are playing on.



Triax 2010 E-missile

From page 1 History

membership between the CSA and ASTM playground structure and surfacing committees and it was believed that duplication of effort would not be beneficial.

ASTM F355 procedure C consists of aluminium headform that was used to duplicate the injury prevention data in the US automotive industry for head first head injury. Much of the underlying research came from the National Highway Transportation Safety Administration (NHTSA). The ANSI C shape of the headform was more like a human and the technology utilized a uniaxial accelerometer. This technology did not lend itself to free-fall testing, but was found to be more reliable when guided on a rail or wire and to ensure capturing all of the impact data this later incorporated a triaxial accelerometer. The ASTM F1292 provided for a laboratory test as well as the option of testing in the field. Due to the shape of the ANSI C it was always mostly used as a guided device indoors. The initial free-fall field testing was with an unguided ANSI C, but this presented issues of safety of the test operator as the head bounced in every direction on landing. There were also accuracy issues where the values. Although repeatable and reproducible, values would be higher than what the result should have been were a problem of failing surfaces that should not have failed. This was an economic burden on surfacing suppliers. These were later addressed in the F1292 revision in 1999 through a change in the shape of the missile to hemispherical and the requirement of a triaxial accelerometer. But we are getting ahead of ourselves.

In the late 1980s Paul J. Hogan petitioned the CDC for the development of a field test device for the measurement of impact attenuation of surfacing in playgrounds to compliment the guidance of the CPSC in their Handbook and confirm the ability of the surface to meet these requirements. The CDC granted Mr. Hogan and Playground Clearing House approximately $50,000 to develop a device. This led to a patented device for impact testing that also allowed the data to be transmitted by wire or wirelessly. As it turned out the development of what has become known as precursor to the Triax impact attenuation systems took significantly more money, time and technological changes. First it was found that the shape of the headform did not lend itself to a free fall test and soon there was a change from the ANSI C to the 4.6kg (10lb) hemispherical headform that was being used successfully in Europe, first in the BSI and later CEN Standards. The second major change was from a uniaxial to a triaxial accelerometer to capture all of the impact data. Many of the technical requirements for the free-fall test method were developed during this period. It is important to understand that "free-fall" still requires the device to be supported to ensure specific and measurable drop height and the headform landing in a specific location. It does mean that once it is released the headform falls freely from the support to the ground a minimum of 3 times.

One might think that just coming to the ASTM F08.63 sub-committee on playground surfacing with a "better mousetrap" would lead to the quick adoption of the 4.6kg hemispherical headform with a triaxial accelerometer even with the success in Europe. Not likely, there was the very serious issue that standards reflect accuracy in measurement to contend with. First there was the change in shape and secondly the change in mass.

There was legitimate concern that the new headform would not reflect the data collected with the tried and true guided ANSI C headform and the traceability back to the original automotive data. There was also the concern that there were many different surfacing materials in the field that have significantly different materials properties. Some of these were fine and course sand, fine and course gravel, woodchips and engineered wood fibre (EWF), rubber mats and poured rubber surfacing, which all absorb energy differently. Having erroneously high drop test results struck fear in the hearts of the surfacing suppliers concerned with false negatives and costly removable and replacement of their surfacing material. One might think this would not be a problem as the risk of false negatives would push suppliers to provide surfacing with better impact attenuating properties. Not true as some suppliers at the time, as is true today, did not possess the technical ability to perform better. Additionally in a competitive world where the bidding process pushes everyone to the lowest quality that "meets spec" having the lowest price to still win the bid is problematic. False failures could also cost suppliers significantly reducing profits and potentially putting them out of business.

The opposite side of the same coin is the false positive where a surface could be found to pass with a non-standard device when it actually places a child at even greater risk of injury than the 10% risk of skull fracture or 16% risk of a life threatening head injury that the F1292 allows. This obviously is contrary to the public health initiative of the CPSC Handbook and more importantly could result in extraordinary costs to an owner in litigation when the surface is tested with the device and to the procedure specific to the relevant standard.

The need to ensure the accuracy of the testing to the accepted ASTM F1292 was essential and, although financially painful, Mr. Hogan submitted the hemispherical device with the triaxial accelerometer to the ASTM process for formal round robin testing. This consisted of travelling to more than 6 testing laboratories around the United States and Canada with 6 different materials representing the surfacing materials available for playground use at the time. All of this test data was provided to ASTM for the rigorous analysis of the round robin process. It was found that the data, although not "mathematically equal" represented the same data collected with the ANSI C headform with the same results. This was presented in a paper prepared by Dr. Martyn Shorten of Biomechanica. It was also found that the synthetic surfaces, which are more linear and travel well between laboratories were more consistent between and across laboratories and devices. Loose fill materials tended to have a higher degree of variability as a result of sample preparation during the round robin testing and this was reflected in the precision and bias statement for the Standard in 1999. This was corrected for the test device in the revision of the precision and bias statement in 2004. The precision and bias statement is important as it states the anticipated variation in results, for any given person using a device that meets the requirements of the standard and following the procedure of the standard could get. This is not a tolerance nor does it open a door for any imagined devices that are non-compliant to F1292.

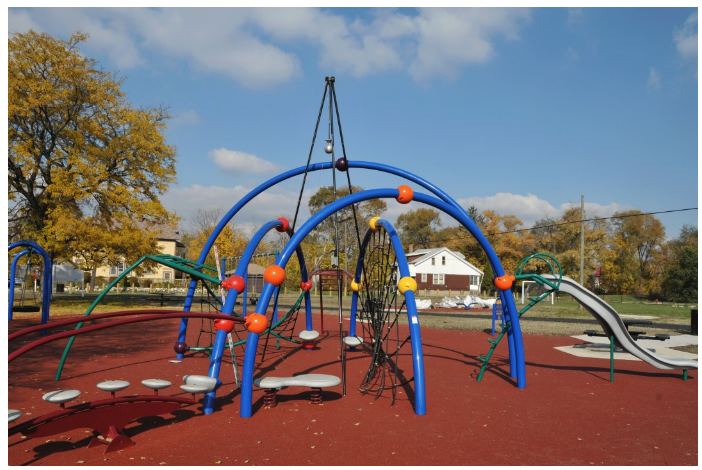
One would think that this would be the end and people would be out in the field holding a 4.6kg hemispherical device in the air and dropping it from a supporting device three times from approximately the same height to approximately the same point, but not so fast. Standards are not approximate, they are about measuring accurately. It was noted that in the round robin testing the free-fall test device was actually suspended to ensure the dropping from the exact same height to the exact same position and this provided accurate data. A logical extension of this thinking was that if the use zone of most play equipment is a minimum of 1800mm or 6', the use zone is further out than the arm length of the person performing the test and using a step ladder on soft surfacing does not offer a stable platform for the accurate support and the dropping of a test device. As a result, the ASTM F08.63 sub-committee required that the device include a stable mechanism to suspend the headform and ensure it was being dropped from the same height to the same location 3 times. This precludes the option to perform "hand drops" and still be compliant to the standard.

A further concern of the sub-committee was that this is a sophisticated electronic device measuring impact in an outdoor setting and likely subject to damage or environmental influences. As a result, there was the need for bi-annual calibration as is required by almost all scientific testing devices. Additionally, there is the performance of a pretest on a known material or MEP pad to ensure the device was traceable back to the calibration of the accelerometer.

Additionally the members of the committee we used to working with professionals, trained and working in laboratories and ASTM was about to unleash technicians on the playground world without the benefit of training or understanding the data they were collecting or further verifying it's validity. This included the review at the time of testing of the drop graph to ensure that the curve was continuous and did not include spikes indicating a failure of the filtering requirements. And lastly that since the people performing the testing in the field would not likely be trained in laboratory techniques, standards and report writing that they would be required to be trained. To satisfy this, Alpha-Automation Inc. and Canadian Playground Advisory Inc. have been providing training to more than 1,500 people around the world since 1999.

With all of this in place, the ASTM F1292-99 was published and the free-fall test method became the subject of an ASTM standard. It turned out that although the device that Mr. Hogan had developed was the model for the free-fall method, it did not initially meet the new Standard and technical changes were made and the Triax2000 was the first free-fall test device that was fully compliant with ASTM F1292-99. As it turned out the test device was also compliant with the technical requirements of the CEN EN1177 Standard for measuring the impact attenuating properties of playground surfacing. These two standards became recognized as the only surface performance measure standards in the world and interestingly CSA allows for either test to be used in to determine compliance. The reason there are no other choices goes back to the word "may" and the inclusion of the option of either F1292 or EN1177 as the stated options.

Since the CSA Z614 was due for publishing in 1998 and the ASTM F1292 did not include the free-fall test method until 1999, the Z614 could only recommend the periodic testing of surfacing in the field in section 10.4.6. Section 10.2 stated that "The test method specified in ASTM Standard F 1292 shall be used to evaluate the shock-absorbing properties of a protective surfacing material." Now the words "shall", "recommended" and the reference to ASTM "F1292" become important. Knowing that the free-fall test was imminent and knowing that the installed surface performance was important, the use of the word "shall" allowed for the testing in the field, only to



the ASTM F1292 Standard. Lastly the use of F1292 without a reference to a revision year allowed the user of the Z614 to perform field testing to the ASTM F1292-99, free fall test method, once it was published.

The Z614 was revised again in 2003 and the requirements for surface testing was modified again in recognition of the changes in standards and testing throughout the world. There also was an interest to go back to the old "Hogan" hand drop testing rejected by the ASTM F08.63 subcommittee. The proponents were looking for a "cheap and easy" solution that even today appears to be the holy grail of surface testing rather than measuring accurately.

The EN1177 Standard for Impact Absorbing Surfacing was published, but poorly understood in its detail. It was presented to the CSA Technical Committee as a potential alternative to ASTM F1292 and was therefore added to the CSA Z614 as an alternate and acceptable test between the two choices. Only on further examination was the detail of the EN1177 requiring a series of 3 drops from a specific height to a specific location, and this was repeated at 4 increasing heights and provided the more complicated procedure leading testing agencies in Canada to revert almost exclusively to the ASTM F1292. Since the CSA Z614 states that either ASTM F1292 or EN1177 "may" be used reverting to the ASTM F1292 is totally appropriate. The problem arises when people do not accept the definition of "may" as a choice between stated options and not like a school child asking "may I" and thinking that anything in their wildest imaginings become acceptable.

Today there is the potential of even more confusion for the playground owner, specifier, surfacing installer or regulator working to ensure compliance to the recommendations of the CPSC, and the requirements of the ADA, ASTM F1487, and CSA Z614. There are a few "magic devices" in the market that for the most part clearly state on their web sites that they do not comply with ASTM F1292, but are "cheap". Someone using any of these devices, particularly in conjunction with any of the above standards is non-compliant and an owner, regulator or inspector is not only placing themselves at risk for liability should an injury occur, or an ADA complaint be filed, but they are placing children at risk.

That is the history and Paul Hogan at 89 years old should be thanked for his vision, investment and perseverance. As a result of his initial efforts, and the demands for measuring accurately from the Surfacing sub-committee at ASTM, children are better off and at lower risk of a life-threatening or critical injury.

As to the future, there is work going on. The F1292 4.6kg hemispherical headform has moved to the headform Standard ASTM F355 as procedure E. It has also been adopted as the test device for wall padding, pole vault and other surface applications and is being considered for replacement of the A missile for testing of sports systems to determine the risk of head injury with an impact on those surfaces. As to ASTM F1292, there is an effort to clearly delineate the laboratory and field tests and there will likely be an ASTM test procedure for measurement of impact attenuation for playground surface systems as measured in the field. It will likely be that the ASTM F1487 sub-committee (F15.29) will set the performance requirements at the time of installation and throughout the life of the playground as they are the connection of the surfacing with the child falling off of their structures.

Stay Tuned

Challenging play and Risk Assessment Questions to Ask

First, what are you prepared to do to a child? This has three parts, What is the maximum injury you are willing to accept as the provider of the playground? What is the maximum injury the parent or caregiver is prepared to accept? What is the maximum injury the user, the child, is prepared to accept, in the short and long-term?

What is the level of Play Value, defined by challenge, both physical and mental, social interaction with peers, and understanding the world around them that you want children to experience?

Now you need to balance the two. Often the failure to achieve a level of challenge will result in a fall (72% of the time). Depending upon the impact attenuation performance of the surface, the outcome can be determined once you know the height that a child will fail from. You can then consider the g and HIC values that result in an injury less than the tolerable injury.

Ultimately, it is not about the level of challenge as that is easy to provide, it is about the prevention of injury associated with the challenge and the ability to prevent that injury. Therefore stretch the challenge to the maximum and install and maintain surfaces that keep you below the tolerable injury threshold.

Remember that long-bone fractures and concussions occur at approximately 100g, while a value of 200g is a 10% risk of skull fracture. On the other hand a HIC value of 1000 is a 10-15% risk of fatality, a 5% risk of critical head injury, an 18% risk of severe head injury and 55% risk of serious head injury.

Recommend that for playgrounds for children 2-5 years the g should not exceed 100 and the HIC should not exceed 570m while playgrounds for 5-12 years the g should not exceed 100 and the HIC should not exceed 700. Test and maintain the surface regularly.