Protecting Children from Surface Impact Injuries

What does Critical Height mean?

Is Specified Height (ASTM F3351) the answer?

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This document is intended to provide playground owners and designers with a thinking and risk assessment process in their interaction with surfacing and equipment suppliers and assessment management.

Abstract - Determination of "Specified/Drop" Height

Play is the self-directed activity of the participant presented with a graduated challenge of their own choosing. This is not restricted to the formalized play structure that is found in parks and school yards, however that setting will be the central point of this paper. The key focus will be on the considerations of from what height does the player need protection starting with the installation of an impact attenuating surface and throughout its functional life.

The risk (likelihood of an injury severity and the opportunity to avoid it) of a fall is integral part of the playground. Human beings are hardwired to climb and that exposes the climber to a fall. Prevention of an injury will be based on the user (their skill, ability to avoid a fall, and their capacity to understand the likelihood and consequence) and the physical site (height of the fall, preventative structures, and impact attenuation properties of the surface). The hazard is the impact with the surface, while the hazardous situation is the exposure to the fall. The hazardous event occurs when the person impacts the surface resulting in an injury or harm. The severity of the injury sustained will have a lot to do with the forces exerted onto the body. This is not unlike an automobile accident and that is why automotive data is used to better understand the mechanism of injuries. Like in an automobile the speed of the moving body falling in the playground from high structures is critical to the severity.

Playgrounds are known as "attractive nuisances" in that they attract children who often have a mind of their own and are learning the limits of the bodies rather than acting upon a vast encyclopedia of knowledge and experience that is available to the adult. The CPSC Handbook on Public Playground Safety has consistently stated "all playgrounds present some challenge and because children can be expected to use equipment in unintended and unanticipated ways, adult supervision is highly recommended." Children are building a volume of knowledge with life skill experiences and a significant part of learning comes with failure and by successfully overcoming the challenge and moving to the next one.

Public access play equipment presents physical, mental, and social challenges to the child and their peers, being life skill building. Many of those challenges involve climbing as high as possible. You cannot slide down if you do not first go up. When you swing, the gaining of elevation increases the experience. A balance beam is only interesting if you have the perceived challenge of a fall or you might as well walk a line painted on the floor. Overhead events are only interesting if you are elevated to test your upper body strength. And then we have climbing for the sake of climbing. For each type of play there is the opportunity to FALL.

The Designer/Owner/Operator (D/O/O) will have to understand the frequency of falls that could occur through exposure to the challenge. The D/O/O will also have to understand the severity of injury that is likely and what severity of injury they are prepared to tolerate for their play environment. This will be unique to each playground owner based on their tolerance of risk of harm and potential liability. Falls will occur as a normal result of play on the playground with frequency of injury being the measure of how often the fall results in a medically treated injury. Severity is how badly hurt the child is and what is the extent of the medical intervention. Falling is a benefit of play for all young children. Nobody ever learned to walk without falling several times.

Strangely, the fall is a learning experience, with the child understanding that they need to improve either their skill or modify their approach to the challenge or the taking of risks. How often they fall is up to their ability to overcome the challenge, the European Playground Standard (En1176) introduction states that the

occasional bumps and bruises have the benefit of being great motivators. Society and the D/O/O will decide as to what injury severity they are willing to accept based on local cultural norms. That could be a bump or bruise but is more likely a minor concussion or fracture provided there is no need for surgery or hospitalization, which increases the severity. A consequence that is life-changing, catastrophic, or even results in a fatality are generally unacceptable to everyone.

With this in mind, the following pages will describe how the many existing playground surfacing standards relate to one another and the potential for injury reduction. At the end of the discussion we will present the benefits to the D/O/O in adopting the new ASTM F3351 standard commonly referred to as the "specified height test" to provide better surfacing performance information that could result in everyone providing more impact attenuating protection for falling children resulting from risky more challenging play while better meeting their needs for risky more challenging play and still address the owner's desire for injury reduction without eliminating the more challenging play opportunities. If manufactures and designers of play equipment are ultimately held to the regulatory requirement to prevent serious injuries they might well recommend surfacing with a "specified height" well in excess of the minimum playground equipment fall height or the critical height of the surfacing systems under consideration for purchase to shift some if not all the burden of injury prevention from the owner to the surfacing supplier. This might likely call into question if the piece of playground equipment presents a higher level of challenge thereby increasing the probability for a higher risk of falling and where the "specified height" strategy would beneficial.

The current simplistic approach to playground design is to adopt a specification that requires compliance with ASTM F1292 which establishes the minimum impact attenuation requirements for playground surfacing and the maximum fall height at which the surface would not likely result in a life-threatening head injury. This is more appropriately known as the "Critical Height" of the surface when tested in the laboratory to ASTM F1292_after the surface samples have been conditioned at 3 temperatures. The ASTM F1487 standard which deals with performance standards for public playground equipment requires, and the *U.S. CPSC Handbook on Public Playground Safety* recommends, the critical height rating of the surfacing within the equipment use zones meet or exceed the fall height of the playground equipment. The reality is the injury thresholds in these standards were established in the 1970's and adopted by playground safety standards writing organizations as early as 1981 to 1993. Based on today's preponderance of litigation these standards do not reflect the views of society today. D/O/Os will have to develop a more comprehensive knowledge of the relationship of the falling child to the surfacing impact attenuation performance to truly understand the mechanism of injury probability and severity. Only then will the D/O/Os be prepared to discuss the developmental benefits the play environment they expose the children of their community to and potentially defend their position to a parent, caregiver, superior, or in a court of law.

The following chapters will discuss and examine.

- The content of various standards and regulations in playgrounds, particularly the severity of injuries with "critical height"
- Understanding injury thresholds and establishing impact attenuation surfacing performance
- What effect does fall distance and velocity have upon impact in relation to severity of injury

- The complexity of how various surfacing materials perform for injury prevention over their functional life

At the conclusion of this paper we will make some suggestions to the reader however they must understand the goal of this exercise is to help them develop a decision-making risk/benefit assessment process that provides transparency and documentation that will likely be required after some unfortunate accident occurs. This will require a team that brings various experiences and knowledge necessary to create a quality play environment. This would include.

- those looking to prevent injuries
- those who see a benefit in certain injuries during childhood
- those seeing a benefit in the value of play justifying the risk
- those looking at the big picture of injuries as rate per capita in society
- those concerned for the individual sustaining an injury
- and those concerned with the monetary, social, and reputational loss resulting from an injury.

All these perspectives will work together, or against one another, as they begin to develop the play environment plan to be installed in a community. That is why there are so many styles and types of play experiences found in the many different playground types usually defined by location, specific function, and the intended user group.

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It would be appropriate to stop for a moment and provide some definitions and references necessary for the reader to understand some of the technical concepts and acronyms that will be used throughout this paper. You may need to reference these as you read through this series of chapters. Terminology within the playground safety industry has become very important as we look towards understanding the subject matter from an international perspective where we are all speaking the same technical language of play and playground safety standards.

ASTM - The American Society for Testing and Materials with the ASTM preceding the letter and number of the relevant standard. More recently known as ASTM International, it was founded in 1898 and manages 12,000 plus Global Standards, 30,000 plus volunteers, in 140 plus participating countries. ASTM does not provide certification or conformity assessment. Users of the standards published by ASTM will need to contact an external certification body for that.

ISO – International Standards Organization, founded in 1947 and operating in 164 countries. ISO does not provide certification or conformity assessment. Users of the standards published by ISO will need to contact an external certification body for that.

Standards – Specifications, Practices, Test Methods, Guides, Classifications and Terminology. These are built upon consensus, reviewed, and revised on a regular basis. The implementation of these standards is *voluntary*, but the reader must know that these standards are often quoted as a minimum standard of care and when these are codified as in the ADA, which includes compliance with ASTM F1292 and F1487, they become law. Readers must understand that the consensus process tends to drive the performance that is minimally accepted and not the ideal.

***U.S. Department of Justice 2010 Standard for Accessible Design*, September 15, 2010** – 1990 Americans with Disabilities Act became law but there were only recommendations for what might be considered accessible barrier free playgrounds **–** The *2010 Standard* are the rules for compliance in the built environment and provides performance requirements for ground level accessible routes in playgrounds, including compliance with ASTM F1292-99 or ASTM F1292-04 and ASTM F1951 within the accessible route of the accessible play equipment use zones. It also requires compliance with certain measurements for openings, changes in vertical height, slope, and carpet pile height. Many use the *ASTM F1292-19 Standard Specification for Impact Attenuation of Surfacing Materials within the Use Zone of Playground Equipment* that provides only impact attenuating surface performance laboratory critical height test results, while the *ASTM F3313-19 Standard Test Method for Determining Impact Attenuation of Playground Surfaces Within the Use Zone of Playground Equipment as Tested in the Field* when evaluating compliance with the accessibility requirements of the ADA in the field*.*
ASTM F1292-18 – *Standard Specification for Impact Attenuation of Surfacing Materials within the Use Zone of Playground Equipment* – This is a 3-temperature test that determines the critical height of a surface system in a laboratory (g ≤200 and/or HIC ≤1000). Critical height is measured in full feet at the last drop height resulting in an impact not exceeding 200g or 1000 HIC. Field testing requirements have moved to ASTM F3313.

ASTM F355-16e1 *Standard Test Method for Impact Attenuation of Playing Surface Systems,* (playground IAS Surfaces being one example) *Other Protective Sport Systems, and Materials Used for Athletics, Recreation and Play* is found in the ASTM F1292, F3313 and F3351 to address the ability of using the same testing equipment and test protocol for many different sports and recreation activities.

ASTM F2075-15 – *Standard Specification for Engineered Wood Fiber for Use as a Playground Safety Surface Under and Around Playground Equipment* – The standard outlines a specific wood system that can be certified by IPEMA

ASTM F2479-17 – *Standard Guide for the Specification, Purchase, Installation and Maintenance of Poured-In-Place Playground Surfacing* – This highlights the problems and considerations related to this type of surfacing. This standard was the first to introduce “functional longevity” and warranty requirements for playground surfacing.

ASTM F3313-19 – *Standard Test Method for Determining Impact Attenuation or Playground Surfaces within the Use Zone of Playground Equipment as Tested in the Field* – This is the field test for testing playground surfaces that was formerly the field test in ASTM F1292-17a and previous.

ASTM F3351-19 – *Standard Test Method for Playground surface impact testing in a laboratory at a specified test height – This is the primary subject of these chapters.*

CSA Z614- 20 – *Children’s Playground equipment and Surfacing* – The standard for playground structures, layout, impact attenuating surfacing and accessibility

ISO TR20183 – *Sports and other recreational facilities and equipment – Injury and safety definitions and thresholds – Guidelines for their inclusion in standards*. – The document provides many definitions used in the risk assessment and more importantly discusses injury thresholds as provided in the Abbreviated Injury Score (AIS)

Functional longevity – the characteristic of a playground surface to continue to perform as intended and continue to meet all requirements of the relevant ASTM Standards, the ADA and any other requirements the Designer/Owner/Operator (D/O/O) would have placed into the specifications, contract and warranty documents. There are instances, particularly with unitary synthetic surfaces, when the surface visually remains in place, but has become a hazard by having an impact attenuating value greater than 200 g or HIC greater than 1000 when tested in the field. There are also instances when loose fill surfacing displaces and therefore may fail impact test requirements because of loss of appropriate depth, and/or the ability to comply with accessibility requirements for firmness, stability and slope. All these properties are essential to the protection of children.

ISO TR20183 provides the following definitions.

Serious injury – acute physical injury requiring medical or surgical treatment or under the supervision of a qualified doctor or nurse provided in a hospital or clinic and includes injuries such as burns, fractures, lacerations, internal injury, injury to organ, concussion, internal bleeding, etc.

Debilitating injury – injury that diminishes or weakens the human body and has a legacy of greater than one month and that could be categorized as AIS>3 (serious, but not life-threatening)

Life-threatening injury – injury to any part of the human body which is severe or resulting in permanent impairment that would be categorized as AIS>4 (severe with survival probable) or greater.

ISO TR20183 provides the following table for Abbreviated Injury Scale.

ISO/TR 20183:2015(E)

2.37.1
abbreviated injury scale
AIS
numerical rating for quantifying the severity of injury to a human based on body region, anatomic structure, level of injury, and injury severity that must be used in the scope of standards intended for *safety* (2.2) or injury prevention

Note 1 to entry: The range of severity is from 1-9.

Table 1 — Abbreviated injury scale (AIS)

Injury severity	Abbreviated injury score
Minor injury	1
Moderate injury	2
Serious, but not life-threatening	3
Severe, potentially life-threatening, but survival likely	4
Critical with uncertain survival	5
Unsurvivable injury (maximum possible)	6
Severity unknown	9

Note 2 to entry: The AIS system also considers the following:

— different parts of the body: 1 head, 2 face, 3 neck, 4 thorax, 5 abdomen, 6 spine, 7 upper extremities, 8 lower extremity, and 9 unspecified;

— the type of anatomic structure: 1 whole area, 2 vessels, 3 nerves, 4 organs (including muscles and ligaments), 5 skeletal (including joints), and 6 loss of consciousness;

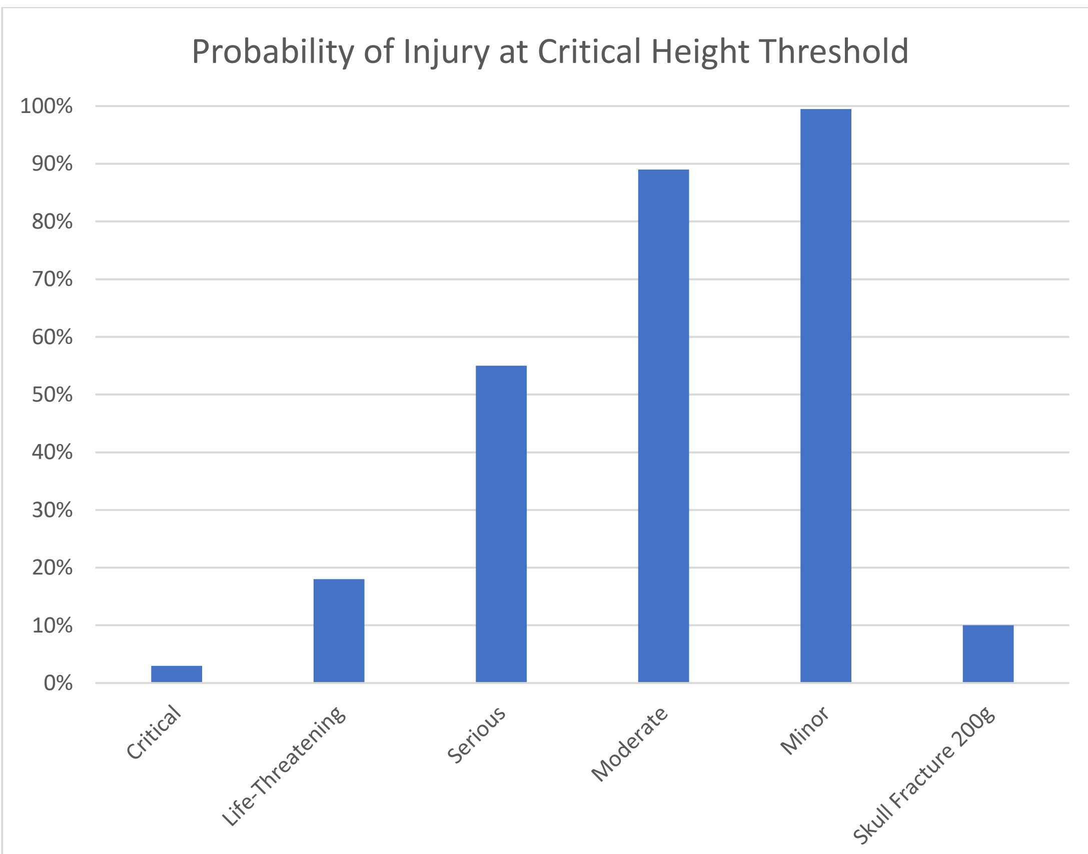
— head only or the entire body.

Chapter One: What is Critical Height?

Critical Height is the maximum vertical fall height below which a life-threatening head injury would not be expected to occur from a fall on the surfacing system beneath it. The critical height is the impact limit for a playground surface established as less than or equal to 200g and/or 1000 HIC. This benchmark is basically the same in the EN, Australian and the ASTM standards with some slightly different drop test and reporting requirements. The ASTM F1292 laboratory test records the critical height in full feet measurement and the EN 1177 defines it as the height at which a specific surface system fails when the drop test impact recorded crosses the values of 200g or 1000 HIC. The results of the test translate to a head injury severity probability of;

- 3% critical (possibly fatal)
- 18% severe (life-threatening)
- 55% serious
- 89% moderate
- 10% risk of skull fracture.

This is likely not an injury threshold that any D/O/O, caregiver, or user would want anyone to be exposed to.



The following are the injury severity curves for head injury based on linear acceleration and duration reported as Head Injury Criteria (HIC). HIC is the measure of impact severity that combines both time and energy at impact, focusing on the most severe portion of the impact. If the peak deceleration of the head during impact related to the duration of deceleration does not exceed 1000 HIC, the 1981 advice of the CPSC is that a life-threatening head injury is not likely to occur, while automotive data indicate this not to be true. These AIS charts have been published by the US National Highway Transportation Safety Administration (NHTSA) and are based on significant research by the automotive industry. These show the risk of various severities of head injury as outlined above and ranging from moderate to death. They show risk of injury severity, on the left, as compared to HIC value, across the bottom. Starting at the lower left axis, (0,0), and increasing risk upwards, while moving to the right, leading to higher values of HIC would indicate the worse outcome for a head injury. Note that at zero HIC the injury risk is zero, while fatality is all but certain to occur at 3000 HIC.

Proposed Amendment To Fmvss No 213 Frontal Test Procedure

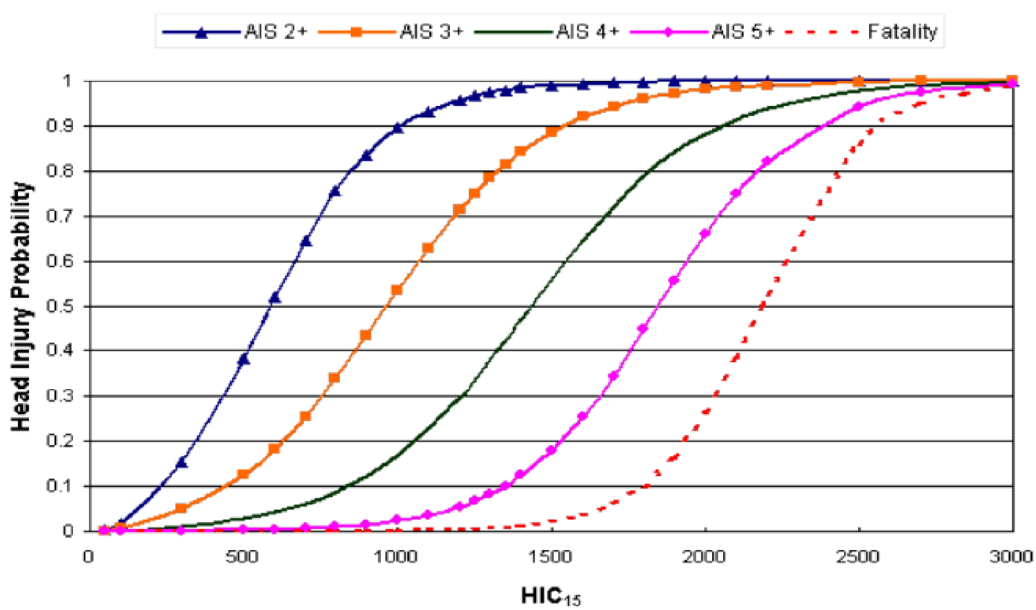


Figure III-1
Head Injury Probability vs HIC_5 for 6-Year-Old Dummy
(Derived From Prasad/Mertz Curves)

Until 2019, international standards for playgrounds and impact attenuating surfacing systems have focused on the determination of Critical Height, causing most playground owners by default being at a higher level of risk of severe injury. As a result, most suppliers and D/O/O install to the limit of the standard without an understanding that the surface is likely to perform even worse over time, increasing the injury severity and frequency. This becomes an economic and public health issue as a result of the cost to society for immediate health care and potential lifelong rehabilitation and care for the injured user. Additionally, there would be economic liability related issues for the D/O/O as the injury severity is likely not acceptable to society or the injured party. Most consumer laws and directives (i.e. The United States Consumer Products Safety Improvement Act (CPSIA) and European Rapid Alert for Unsafe Consumer

Products (Rapex) require the prevention of serious injury as described in the Abbreviated Injury Score (AIS) system known as AIS>3 (serious injury). More precise definitions of these AIS scores can be found above.

Meaning of Height in Relationship to Playground Surfacing

The word "Height" has a definite meaning to each person effected by a fall from some elevation. The meaning depends on the overall outcome or resulting impact the "height" has on the falling body based on the velocity at initial impact but more on that later. Adding the adjectives such as critical, fall, specified, or drop in front of the word "height" can significantly change or redefine the meaning. Playground structure standards (ASTM F1487) provide descriptions of play structures and state the "**fall height**" for specific playground equipment types. This may or may not reflect the point from which a child would fall from while exercising reasonably foreseeable use. The impact attenuating surfacing standards (ASTM F1292) perform testing at three temperatures and provide a "**critical height**" or the height at which a surface would fail the test parameters and likely result in the risk of injury as stated and illustrated earlier in Figure III-1. "**Specified height**", the newest term and definition is the primary subject of this paper. The Specified Height is the vertical drop height distance selected by the Manufacturer/Supplier (M/S) or the D/O/O as the height selected for impact testing to provide values for g and HIC that are less than the maximum impact threshold established in ASTM F1292 to determine the critical height of a surface. Lastly, we have "**drop height**", which quite simply is the distance from the underside of the test missile defined in ASTM F355-16 to the ground. The D/O/O determines this height prior to purchase for performance testing to ASTM F3313 as installed. The "**drop height"** would likely be the same as the "**specified height"** or **"fall height"** when the installed surface is tested for compliance with the purchasing and installation specifications and warranty documents. We have dedicated an entire chapter to considerations in determining specified height for those wanting greater detail and information to help the reader make the best-informed decision related to long term performance and functional longevity.

The **"specified height"** for the laboratory testing and the **"drop height"** for the field testing are likely to be the same and are established by the D/O/O of the playground prior to purchase and included in contract documents as required in ASTM F1292-17a and F3313. The D/O/O know the **"fall height"** of each structure or component they are purchasing. This is the minimum height for each piece of type of play component per the specification ASTM F1487. The D/O/O can assess the likelihood of climbing the equipment above the minimum stated fall height to assess from what height a child-at-risk might reasonably fall. The **"specified height"** can never be less than the **"fall height"** as described in the relevant standard. Considering many children can climb over a 38 inch (965mm) barrier or that there are features that a child looking for additional challenge would climb to and possibly fall from that height, which is greater than the minimum "**fall height**" for a platform could be specified by the D/O/O. The D/O/O should consider determining a specified **drop height** for testing of the installed surface system using established hazard and risk assessment methodologies. In some cases, they may be better served to work with a consultant or team of consultants depending on the complexity of the playground being designed or simply require a higher specified height than the minimum fall height of the equipment in question as well as a lower impact value for G-max and HIC.

Every play structure is subject to children climbing to unintended new places. The following photographs illustrate what children can do when left to their own talents and skills. The D/O/O should also consider a child's ability to get an adult to help them overcome access barriers and other obstacles intentionally designed to limit access to unintended users by accessing components with dimensions that naturally impede entrance to equipment with developmental requirements beyond the age of the intended user group. While these design and performance requirements can be very effective to specific user groups, they are not perfect or impenetrable. With this in mind, what options does the D/O/O have to address falls from a height that may at best be within the impact thresholds of 200g and 1000 HIC?

The child has used the climber on the right to access the red horizontal bar and then to the roof without a clear path off the roof increasing the potential for a fall from the roof

The younger child has convinced the adult to lift them where they clearly do have an ability to reach with their own skill. capability or upper body strength. A distraction of the adult could cause the child to lose contact with the apparatus and fall.

This chid makes the obvious choice with a climbing component on a composite structure and climbs to the top without any hand supports at a point of transition that might result in an increased potential for a fall height not necesaarily intended by the designer.

The children use an unintended slide surface to climb and thereby exposing the user to higher fall than intended by the designer

Specified Height Test

A **"specified height"** test standard was approved at the November 2019 ASTM Houston meeting. This standard is a variation of the ASTM F1292 3-temperature critical height test. This new standard provides important information to the D/O/O who is looking for a better performing surface over a longer period. This information will also provide insight into purchasing decisions as related to functional life of the surface systems and performance benefits to those wanting to reduce injury frequency and severity. This Standard still must be performed at 3 temperatures in ASTM F1292. What the new Standard does is, it allows the M/S to report the test performance of their surfacing system and certify those results at less than the critical height. Understanding the relationship between the lower impact values at a specified height and how much the impact results are below the 200g and 1000 HIC threshold provide the D/O/O with more relevant data to assist in selection of the most appropriate surfacing system based on the playground project objectives in relationship to the owner's tolerance for risk, the age appropriateness of the equipment as determined by the designer or manufacturer, proposed life cycle of the playground equipment and surfacing system, and the owners tolerance for risk. An example would be that a D/O/O would like to reduce the probability and severity of an injury. First, they must consider the height they anticipate children will fall from during reasonably foreseeable use. Then they must consider what injury severity they find tolerable. The next and final step is to consider what kinds of mitigating factors could be applied to help meet everyone's expectations for a tolerable level of residual risk resulting in acceptable levels of injury frequency and severity.

Assuming the D/O/O wishes to reduce both the frequency and severity of all injuries and knowing that falls are the number one cause of all serious playground injuries (AIS > 3) the D/O/O would need to consider what level of impact attenuation would be required to begin to see a reduction in the most common types of serious playground injuries, fractures. Fractures, simple to compound, are complex injuries that begin to occur at or below 100g. (At the end of this paper, some practical ways of understanding linear acceleration and speed of loading related to fractures are explored.) Therefore the D/O/O would benefit from knowing how each surface type being considered for purchase performs in relation to g at a height directly related to the fall height of the equipment and the desired level of impact performance that would likely have a positive effect at the reduction of the frequency of fracture injuries. The D/O/O has only two options. Either reduce how high a child might be able to fall from or determine what impact value limit might result in an injury severity below the limits that would result in the undesirable outcome. Alternatively, the D/O/O can require the design and performance requirements of the surfacing system to a Gmax <100 and HIC <700 for the height from which the child will likely fall. This **Specified Height** laboratory test report information would help the D/O/O make more informed decisions early in the playground project planning process. Additional consideration for selecting **"drop height"** and the **"tolerable risk of injury"** as well as actual **drop data curves** will be discussed in later chapters.

The **"Specified Height Test"** will also benefit the surface system manufacturer/supplier (M/S). The M/S can submit surface samples to a laboratory for testing at 3 temperatures at a specific height. The test will be performed at the height or a series of heights specified by the M/S and the laboratory will report the results for the performance at all three temperatures. If the M/S has done their homework during research and development the values for both g and HIC will need to be below the D/O/O specified values. This helps to assure the D/O/O that the prequalified M/S can meet their project performance requirements through laboratory test reports and should therefore provide the same results in the field after installation according to the M/S detailed installation instructions.

We have just moved from the initial investigative and specification requirements of your project to the "trust but verify" or final phase of your playground project. Once the surface is installed the D/O/O can select and rely on ASTM F3313, ASTM F1292-99, 04 *(ADA and Canada)* or EN1177 to test the installed surface at the specified drop height based on the owner's purchasing documents and contracts prior to installation. This is to confirm that from the D/O/O specified height the installed surface provides lower values for g and HIC than required by current safety standards or the owner's purchasing documents if more restrictive than the minimum acceptable surface impact thresholds of <200g and 1000 HIC. This field testing should be performed after initial installation and prior to final payment and then again prior to warranty expiration. It is also best practice to repeat field testing compliance over the life of the playground since the standards requires the owner take the playground out of surface until the surfacing can be brought back into compliance should it fail the 200g or HIC 1000 limit. ASTM F1487, Section 13, requires the owner inspect and maintain the surface in compliance with the impact attenuation requirements of F1292. While the owner's original contract specifications provided for the impact attenuation performance at the time of installation, these documents must also include the warranty terms that suit the needs of the D/O/O. The warranty must state the number of years for the warranty and the performance for the surface stating drop height and maximum allowable g and HIC. This recommendation can be found in the ASTM standard guide for poured in place unitary surfacing (ASTM F2479, section 14). Once again, the field testing of the surface as is spelled out in ASTM F3313 will be necessary to complete the "trust but verify" cycle.

Major Factors Influencing Public Playground Purchasing Decisions

The playground impact attenuating surface system marketplace has been expanding as fast, if not faster, than the manufacturers of public playground equipment. Historically, playground equipment manufacturers and playground protective surfacing suppliers have worked almost entirely independent of one another leaving the decision for whether to buy and install some form of impact attenuating surfacing up to the owner. The revised *Consumer Products Safety Commission's Handbook for Public Playground Safety* in 1991, the 1993 ASTM F1487 Standard, and the 1990 ADA changed that kind of thinking. Some decisions and recommendations for better surfacing performance has been supressed by the higher cost of the surfacing associated with better performance. Some of this thinking has been debunked by some surfacing system manufacturers over time but it seems purchasing decisions are still made largely based on cost. Slowly and rather quietly over the past 10 to 20 years the playground equipment manufacturers have begun to strategically buy their way into the playground surfacing market and are now in a position to offer the owner a turnkey playground, complete with equipment, surfacing and all the typical site amenities. This is a rather obvious business decision since there is only so much money set aside for every public playground project. Because the safety of the playground user is on the minds of all owners and because there is only so much money in the playground budget, the need for quality compliant impact attenuating surfacing systems has quickly become a major cost consideration of the total playground project budget that some manufacturers did not want to lose out on. The debate between those who advocate for more play value and riskier play experiences versus those who argue on the side of better impact attenuating surfacing performance has been a factor that can hamper any recommendations by a playground equipment sales representative whose number one priority is to sell playground equipment and whose surface necessary to meet the standards requirements for impact attenuation complies with and not necessarily exceeds the minimum requirement. This does not serve the D/O/O well.

The other main factor playground equipment manufacturers, playground designers and owners have had to come to terms with is the overall impact of the 1990 *Americans with Disabilities Act* and the DOJ *2010 ADA Standards for Accessible Design.* Since the early 1990s public safety and accessibility have been the major selling points for all new public playground equipment and especially for some impact attenuating surface systems. Many opine this change resulted in a lack of play value and loss of risky play for the addition of equal access for people with disabilities. The reality has been positive in enhancing and combining challenging play with accessibility, but many surfacing systems suppliers have been less than forthcoming in their ability to educate the owners on cost of, or their responsibility to, inspect and maintain the surface in compliance with the *2010 Standard.* Some claim they can provide access without maintenance. Nothing is maintenance free. Some surface systems have limited impact attenuation thereby sacrificing injury prevention in favour of the ability of a user to traverse across a surface resulting in more rigid but stable and potentially non-compliant surfaces. The injury prevention requirement is complicated with the accessibility requirement that the installed surface must meet ASTM F1292-04.

There is a new conversation emerging related to injury frequency and severity based on the realization of the inseparable relationship between public playground equipment and the surfacing around the equipment where children are likely to fall. This is a rather complicated discussion related to the cause and effect of the playground injuries. The concern is two-fold when it comes to injury prevention. Does the mechanism of injury become more obvious the more challenging the equipment becomes or is it the surfacing that the falling child impacts? This raises the question as to the responsibility of the overall designer, possibly Landscape Architect, of the playground area and the play equipment designer in relationship to specifying the surface the falling child will land upon to only meet the minimum~~s~~ requirements of the F1292. They know the risk is likely higher that children will fall more frequently from more challenging play equipment and the probable risk of harm associated with the known values for impact attenuation will be their responsibility. Each Playground equipment designers should understand the reasonably foreseeable use of their design thereby placing them in the same or worse liability position as the owner that has relied on their expertise.

Every Surface Specification should include a Specified Height and Field Testing

To take advantage of this new standard the D/O/O will have to establish a specification that ensures compliance. The following is a sample specification.

1.0 The M/S shall provide a laboratory certificate that at (X) height, the g is less than (G) and the HIC is less than (H) at all 3 temperatures of the test.

- X is the height from which children are anticipated to fall from the structures under reasonably foreseeable use. This cannot be less than the fall height for the structures as per ASTM F1487.
- G is the value for g that is determined as the threshold for the specified height test (ASTM F3351).
- H is the value for HIC that is determined as the threshold for the specified height test (ASTM F3351).

1.1 The surface once installed will be tested in the field using one of the procedures in (ASTM F3313, ASTM F1292-99,04 or EN1177) from (X) height, as specified at the time of purchase, and the result for g must be below (G) and the value for HIC shall be less than (H).

- Select which of the three field tests is relevant to your jurisdiction
- The values for X, G and H will be set in Section 1.0.

1.2 At any time during the warranty period, when the installed surface is tested using one of the procedures in (ASTM F1292-99, 04, ASTM F3313 or EN1177), from (X) height, the g shall not exceed (G1) and the HIC shall not exceed (H1) unless performance is stated in the warranty requirements in the purchasing documents.

- Select which of the three field tests is relevant to your jurisdiction.
- X is the specified height as in Section 1.0 & 1.1.
- G1 is a value determined by the D/O/O and could be the same as G in Section 1.0 & 1.1 or an increased value for g, allowing and increase over time, but can never exceed 200g
- H1 is a value determined by the D/O/O and could be the same as HIC in Section 1.0 & 1.1 or an increased value for HIC, allowing for an increase over time, but can never exceed 1000

The reader must note that a failure to the specified height test in the field means that if the surface system is just installed or still within the warranty period, the D/O/O is entitled to remedial action. If the warranty has expired the surface must meet the minimum requirements of ASTM F1292. That requires the surface impact attenuation for the equipment **"fall height**" as stated in ASTM F1487 will not have an impact value for g greater than 200 and the HIC value greater than 1000. This would mean a failure of ASTM F1292, ASTM F1487, the CPSC Handbook and the 2010 ADA Standards and would require the owner remove the play equipment from use until the surface could be brought into compliance.

Injury Severity Tolerance

The D/O/O will need to understand injury severity to understand their tolerance for injury. The introduction of the EN1176:2008 states, "The aim of this standard is first and foremost to prevent accidents with disabling or fatal consequences" and ASTM F1487's scope states "its purpose is to reduce life-threatening and debilitating injuries". Effectively this would include anything except killing or maiming a child. It is not likely that most D/O/O or caregivers would accept this as their accepted level of injury severity. D/O/O will need to consider injury severity in a practical sense from the more minor bumps and bruises through simple fractures and minor concussions to life-altering injuries.

The next chapter outlines the history and methods of using the Abbreviated Injury Scale (AIS) curve graphs to consider the severity and likelihood of a head injury occurring. Suffice it to say these probability of injury severity curve graphs can be used in conjunction with the **"Specified Height Test**" results from a M/S to determine what performance outcome based on drop height the D/O/O wishes to specify for the surface that is to be installed. This information provides the D/O/O with all the information they need to determine what impact attenuation requirements for (g and HIC) is reasonable from a fall height in order to reduce the likelihood of serious injuries beyond the scope of the respective national or international standards or health directives.

Follow-up Testing of Installed Surfacing

Testing of surfacing systems became a reality in 1991 with the release of the laboratory critical height, three temperature specification with ASTM F1292-91. This standard quickly evolved to include a field test in 1999. Twenty years later the cost is going down and availability of drop testing in the field after installation and throughout the life of the playground continues to grow as more testing equipment is available throughout the world. Costs related to mobilization costs just to get to the test site is substantially reduced. As the availability of impact attenuating testing equipment continues to grow and costs for unitary surface systems increases it becomes more likely the owner will require post installation testing to protect their investment. The cost of ownership of a test device is now within the ability of most playground D/O/O to perform their own testing. Based on one public playground owner's current contractual costs for conducting field testing on 20% of their playgrounds a year, it was determined that the cost of ownership of a drop test device can easily be amortized when placed it into the hands of a trained CPSI.

With the decreasing cost and availability of field testing, regardless of the playground location, the D/O/O will be placed in a difficult, if not indefensible position, for not knowing the current performance of their playground surfacing is still in compliance with the current standard.

There are other factors to consider when determining the frequency of follow-up field testing. Previous testing performance and impact values will determine if the testing is to consist of a single drop or full three drops at three locations per piece of playground equipment as required by the more vigorous test requirements of the ASTM F3313 field test report. The options for testing in the field and the many different surfacing types will be an even later chapter.

Chapter Two

Understanding Injury Thresholds

With any sport or recreation activity there is always the likelihood of an injury. The severity of the injury and the acceptability of that injury will have a bearing upon whether steps should be taken to remove or mitigate a hazard to some acceptable level. Acceptable levels of injury severity are based on personal assessment guided by personal experience. Today, within, society it is often necessary to codify injury thresholds to allow others to identify, specify, think, and speak in the same terms. Both the Abbreviated Injury Scale (AIS), with 6 thresholds, and the Health Canada Risk Characterization Methodology, with 5 thresholds, provide a series of injury levels that are generally understood throughout the medical profession. The AIS was first developed in 1973 by the Association for the Advancement of Automotive Medicine (AAAM)[i] as an anatomically, consensus based, global severity scoring system that classifies an individual injury by body region and can therefore be used by trained persons to determine the severity of an injury. This scale, in relation to injury severity, has been adopted into the ISO TR20183 as pointed out in the previous chapter.

The AIS scale provides for Minor (1), Moderate (2), Serious (3), Severe, Life-Threatening with survival probable (4). Critical (5) and Fatality (6) for severity. Many of these severities are defined in ISO TR20183. Some of these and the AIS scale can be found in the annex of this section.

For head injuries specifically, the automotive industry for decades has been measuring impact to sub-human primates, cadavers, and test dummies; recording and plotting the injury severity to the AIS. There are two charts with results measured in g, or with inclusion of duration, HIC value. The g and duration can be measured using an instrumented headform. In the playground and sports setting the ASTM F355 E missile provides equivalent results to the automotive Hybrid III headform at g values below 140g and slightly more conservative up to 200g. This allows for the comparison of playground data with the potential for injury determined from the AIS curves. The AIS curves developed for HIC and g are presented below. These can be used in the selection of impact attenuating materials. An exercise for the selection of AIS injury curve, risk of injury, and the associated HIC; is presented below.

The AIS curves, when first viewed, can be confusing to those not familiar with levels of injury severity from a simple fracture to compound fracture requiring reduction or a mild concussion to one where the person is unconscious for an extended period of time or requires surgery to reduce swelling pressure on the brain can have a severity assigned and plotted. Each curve covers only a single severity as it is associated with risk of that severity against the magnitude of the impact values measured in either g or HIC across a range within each level of AIS curve. It becomes evident that these curves overlap, and no single impact value is specifically associated with an injury severity. This is where the appetite for risk of a type of injury and the associated risk of higher severity becomes important.

Looking at the AIS curves for HIC, a reader will find the value for 1000 across the bottom. Drawing a line vertically, it will go through all the severities associated with all six AIS levels of severity at specific points described and illustrated in the first chapter.

Annex 1: AIS Curves for HIC and g for Head Injury

The following are the AIS risk of injury curves from the sources shown related to head injury for values of HIC and g. They are purposely provided in a larger scale to allow the user to print them and with a pencil and ruler draw lines from the "risk value" to the selected "injury severity" as described by the AIS level and then drawing a vertical line down to the appropriate HIC or g. These values can be inserted for g and HIC in the "specified height test", which will be explained in the following pages.

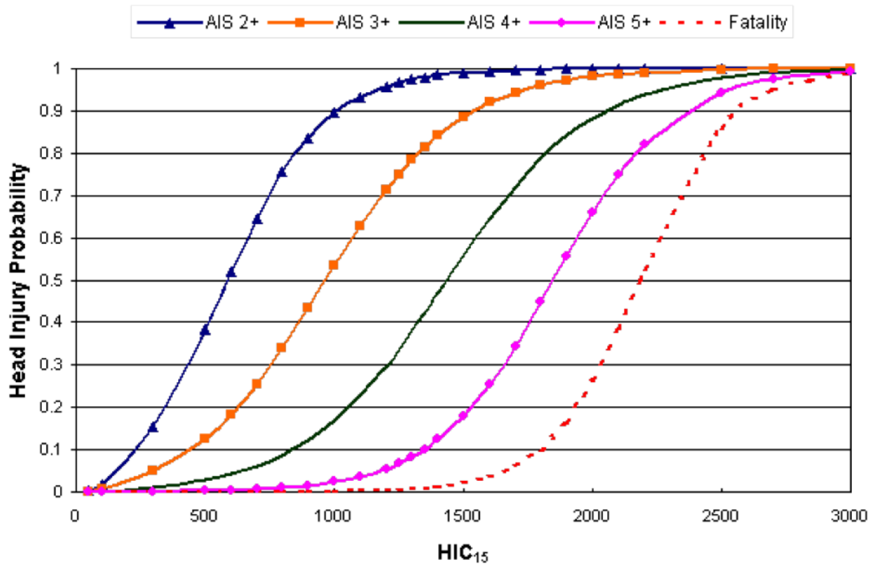
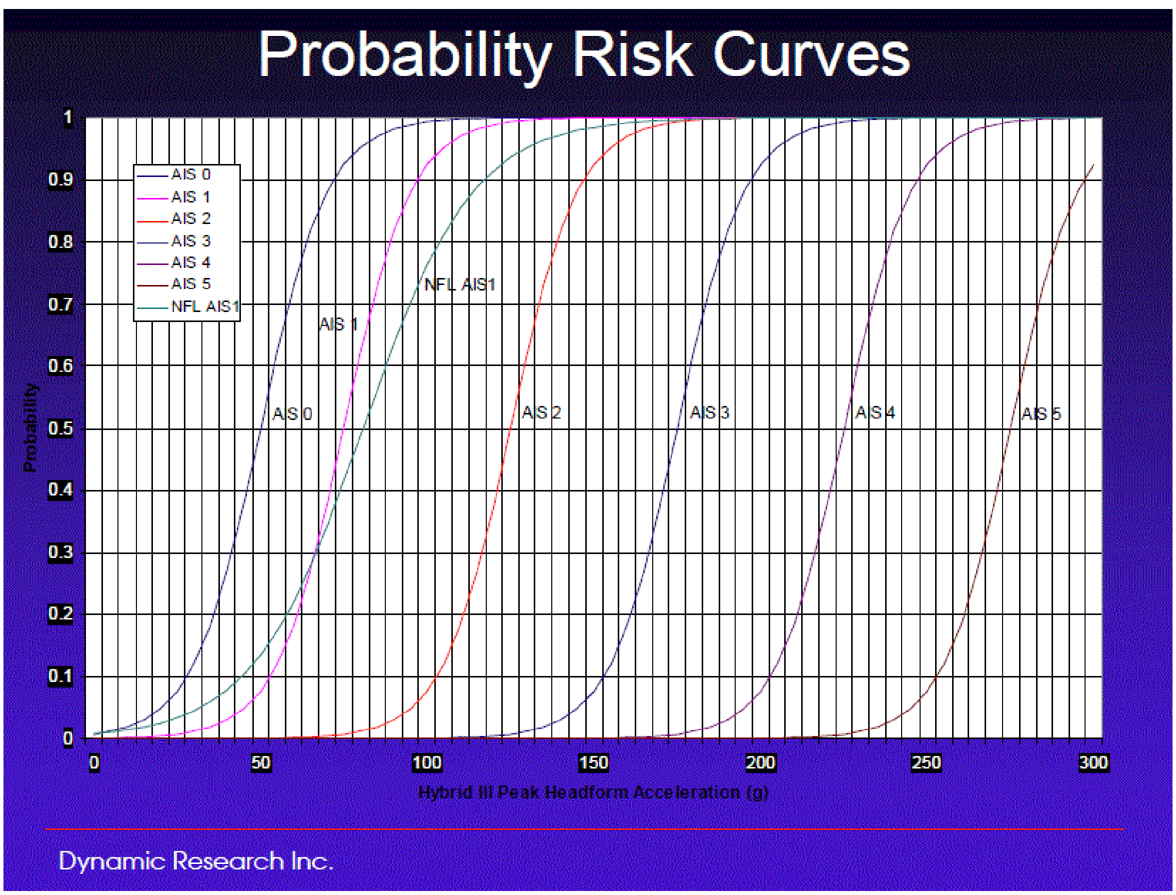


Figure III-1
Head Injury Probability vs HIC_5 for 6-Year-Old Dummy
(Derived From Prasad/Mertz Curves)



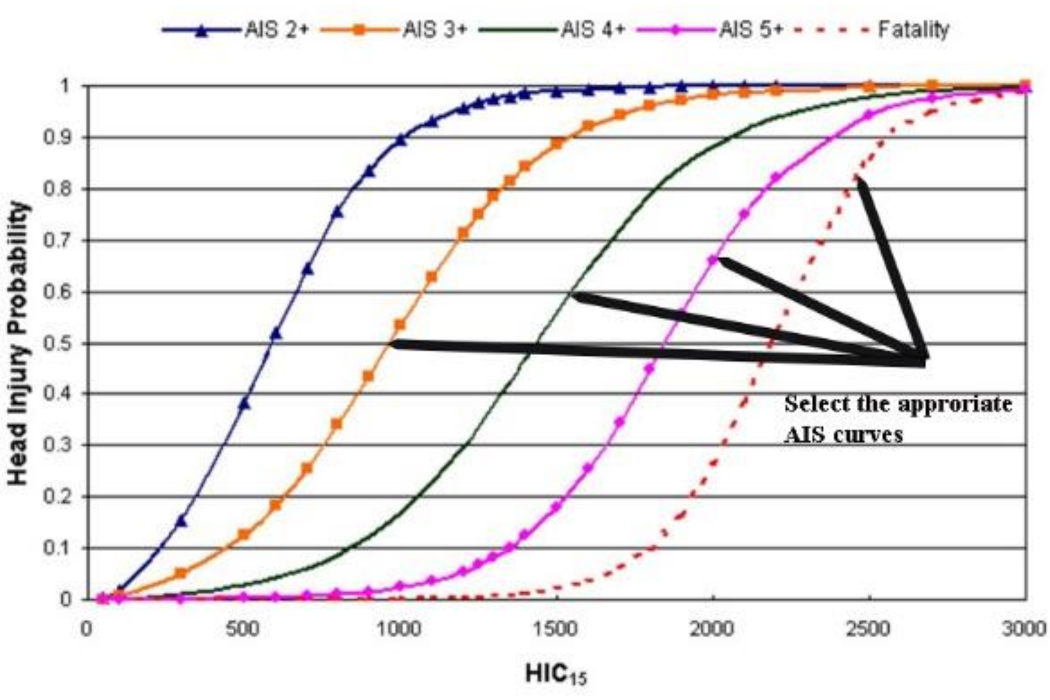
The primary concerns for injury prevention in sport and play have been the AIS>3, serious and AIS>4 severe (life-threatening with survival probable). This is because the prevention of serious injury is the requirement of most regulations (US Consumer Product Safety Improvement Act (CPSIA) and EU (Rapex) while prevention of life-threatening and debilitating injuries is in the scope of most playground and sport surfacing standards.

This should provide the person assigned to determine the acceptable level of risk, i.e. risk assessor enough information to determine the injury threshold that is acceptable or tolerable to their organization and select the appropriate AIS curve from the charts above.

Determination of Impact Attenuation value based on AIS curves for HIC (exercise)

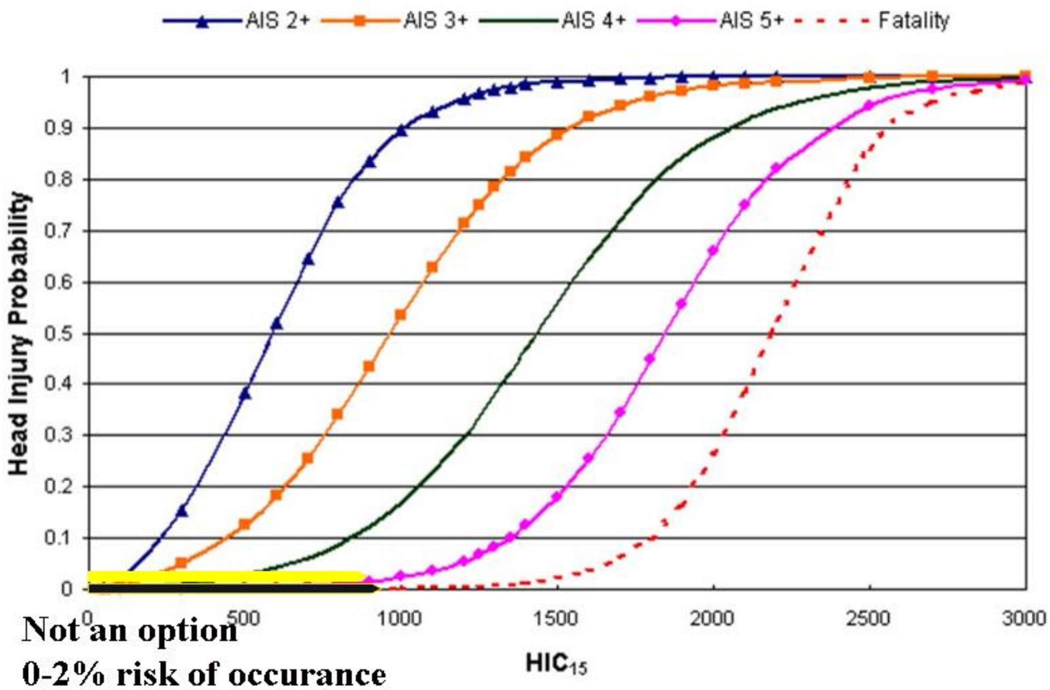
Step 1 – The assessor and their team must examine in real terms the types and/or severity of injuries that are not acceptable. Working backwards, knowing what you do not want helps in understanding what types of injury are acceptable or tolerable, remembering these are on an individual level and not as an incidence per (X) exposures or (X) of a population and therefore acceptable to a community.

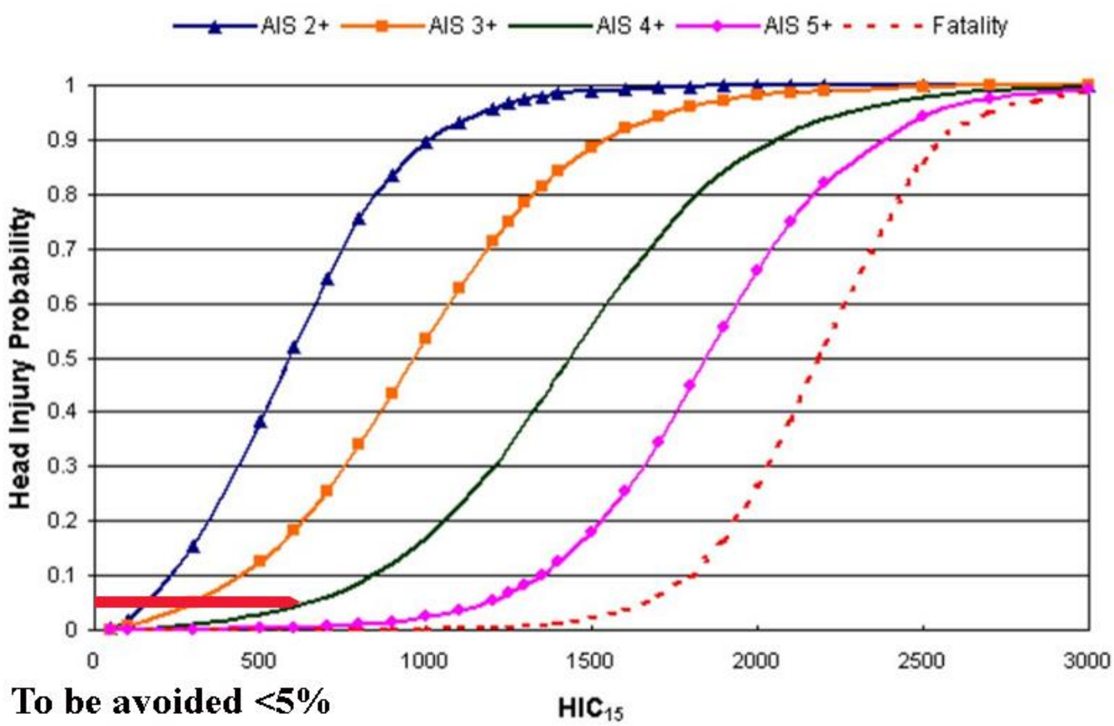
> In this exercise, risk of fatality and critical injury are not options, severe (life-threatening is to be avoided and serious injuries are to be reduced. All the frequency words (not an option, avoided and reduced) are qualitative and will later be given quantitative values. These will still be somewhat subjective to the assessor or the team.

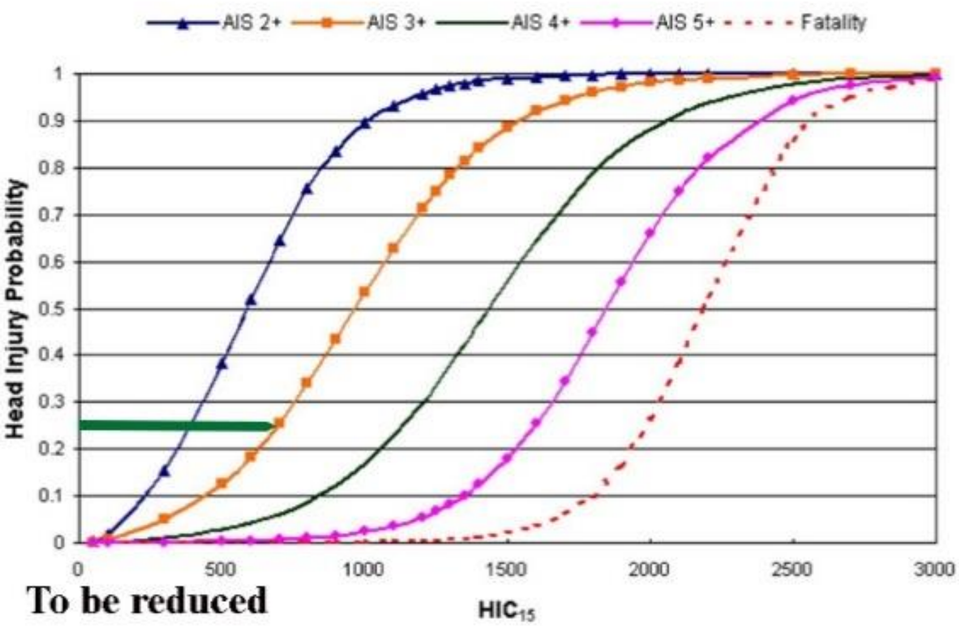


Step 2 – having found the AIS 3, 4, 5 and fatality curves on the chart above, the assessor and their team are able to convert their qualitative words from **Step 1** to quantitative words by giving values to **"not an option"** as 0-1% risk of occurrence, **"avoid"** as <5% risk of occurrence and **"reduced"** as <25%.

Taking the AIS curves draw a line from the left to the right. For fatality select the 0 risk on the left and go to the right until the **"fatality"** curve is touched. The same process applies for the AIS 5, AIS 4 and AIS 3, as indicated below.

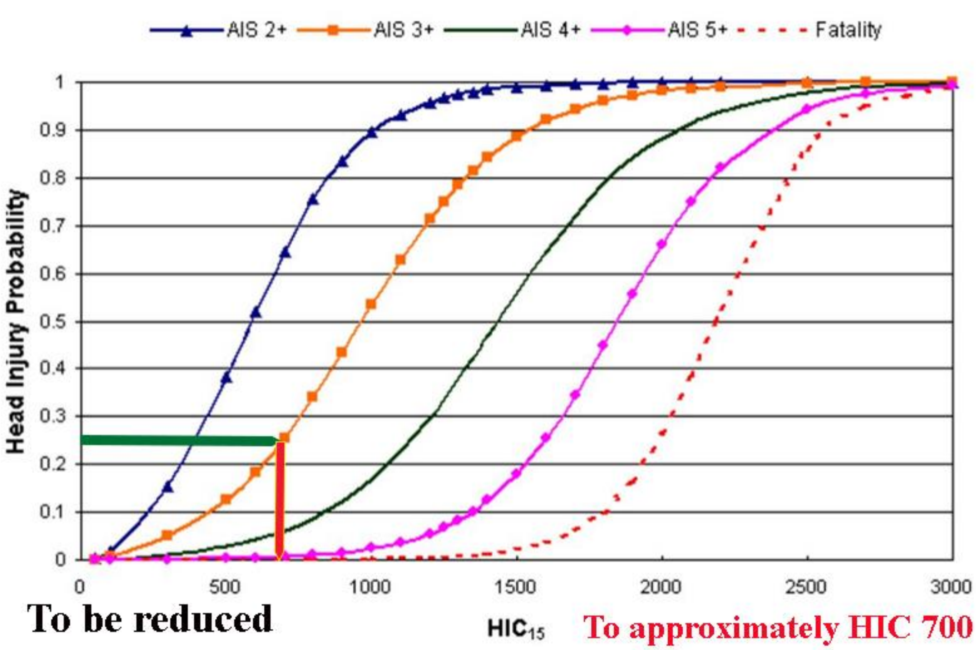






Step 3 – Considering the point at which the risk of occurrence touches the selected AIS curve, the assessor and their team are beginning to understand their tolerable risk of injury. At the same time there is acceptance of certain injury outcomes with a subjective degree of acceptability.

The last step for determination of impact attenuation properties that a surface should provide in the case of a fall can be established by taking the **"to be reduced"** graph and determine the HIC value by drawing a vertical line down to the HIC value on the lower line.



These values for HIC can change should the assessor and their team select different values for risk or injury threshold for their activity or facility.

Step 4 – The assessor and their team or the owner/operator of the facility (playground, sport surface, swing seat, padding, etc.) must consider the height from which a user would have a freefall or propelled fall to the surface, and this becomes the **"specified"** or **"drop height"**. They now take that drop height and incorporate that into the specification for the impact attenuating surface and insert the determined HIC.

Step 5 – Once the impact attenuating surface has been installed, the surface shall be tested in the field from the drop height using, as appropriate, ASTM F3313-19, ASTM F1292-99 or 04 with the same device as described in ASTM F355-16, Procedure E to determine whether the surface meets the specification.

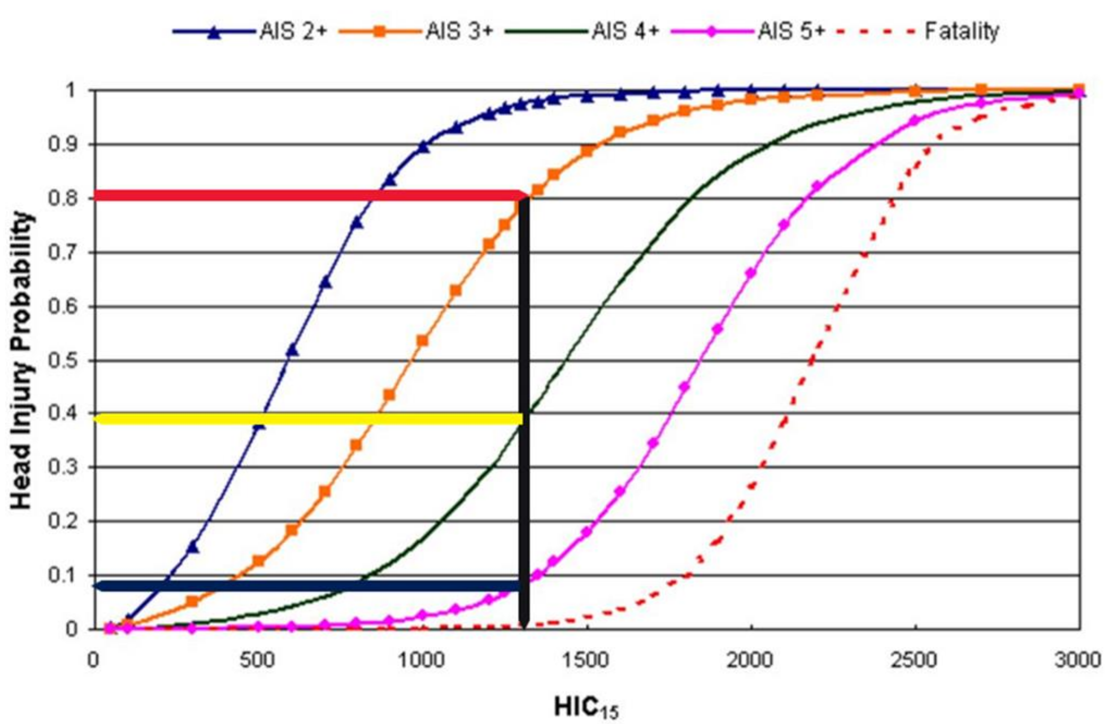
Step 6 – The installation shall be the monitored and tested using the procedure in **Step 5** to ensure that that risk of injury remains tolerable over the functional life of the facility.

What happens if you start with risk of specific severity or reverse the operation?

We have considered starting with fatality and moving backwards and it is time to consider how one would look at determining the acceptability of a specific severity of injury and how that affects other severities.

Step 1 – The owner or designer decides that they are willing to accept a **"serious"** or **AIS>3** as acceptable

Step 2 – The level of risk of **"serious"** they accept is **80% AIS>3**



Step 3 – Draw a line from 0.8 to the right to intersect with the AIS>3 curve.

Step 4 – Draw a line down from the intersection with AIS>3 to determine an HIC value, in this case approximately 1300

Step 5 – Consider that the vertical line's intersection with other AIS curves and notice that it passes through the severe (AIS>4), critical (AIS>5) and fatality (AIS>6)

Step 6 – Determine and document whether this combined risk is acceptable to the organization

Chapter Three: Thoughts on the Determination of Drop Height

Determination of Drop Height and Specified Height

If there are no falls, there is no need for surfacing, but falls are a reality of playground injuries. Falls are the number one cause of all serious injuries on playgrounds comprising 72-78%. Impact attenuating surfacing is all about reducing injuries from falls. These injuries obviously occur when a child falls from somewhere. The vertical distance between the surface where the fall begins to the surface on which the falling body lands will be the "free height of fall" or the "drop height" for testing. There are two issues with establishing fall height. First there is the association of higher capital cost for better performing surfacing and secondly, there is the greater frequency and severity of injury as fall height increases.

A visit to the International Playground Equipment Manufacture Association (IPEMA) website will be instructive when you consider how many suppliers have the same types of surface materials with increasing thickness to address the need for a higher critical height or height from which you could fall and still meet or exceed F1292 standard requirements. Put simply, the higher the "fall height", the more material needed and a commensurate increase in cost. Since the "critical height" of the surface system must be greater than the "fall height" of the equipment, whenever the "fall height" increases, the total cost of the playground would logically likely increase. It therefore may be in the best interest of some of the play equipment structure manufacturers to ensure that minimum "fall heights" as stated in ASTM F1487 do not always reflect reasonably foreseeable use or "where children can really climb to". This is especially true for many composite structures consisting of two or more different play components that are assembled to create continuous play opportunities.

There is an obvious disincentive to raise equipment fall heights in playground safety standards. Canada, with the Canadian Standards Association CSA Z614 Standard moved elevated platform fall heights to the tops of barriers and guardrails surrounding platforms in 2007. Therefore, should the playground budget be fixed, the amount of money available for play structures will be reduced. This was seen as only increasing costs for one item in the playground – Impact Attenuating Surfaces. Formerly in the field test in ASTM F1292 and now with F3313, the D/O/O can select a "drop height" greater than the "fall height", or require better surface impact attenuation performance measured in lower g and HIC values prior to purchase this concern or complaint might be even greater. However, the "specified height" standard is not intended to increase cost, but rather make the surfacing an investment and empowers the D/O/O to ask suppliers to prove their capability during the selection process.

We have all heard the term “the bigger they are, the harder they fall”, but the reality is that “the higher you fall from, the harder your landing”. This all has to do with gravity and the acceleration due to gravity. Keeping this simple, let’s look at the definition in ASTM F1292 for “Standard Gravity”.

- the nominal value of the acceleration due to gravity at sea level having an international standard value of exactly 9.80665 m/s^2 (approximately 32.174 ft/s^2)

The important part of the expression is the ($/s^2$), which means that as the distance or time increases, the velocity or speed increases exponentially. This means that given the same surface performance, a higher fall will result in an increase in the g and HIC values and the injury severity will be greater. Let’s just look at this from the point of view of a fall from the platform or the top of the barrier that the child went over. There is a difference in elevation from the platform height and the top of the barrier of a minimum of 38”. There is an increase in velocity of the falling body related to the 38” additional fall height above the platform elevation.

For those who like math, read on, while others can skip to the Usain Bolt analogy. The velocity for any height can be calculated as 8.025 X (√) of the height in (ft.) Therefore, for a 38” (3.17’) barrier the calculation would be.

- the square root of 3.17 (√3.17) = 1.78
- now multiplying 1.78 X 8.025 we get the velocity of 14.28 ft/s
- this value, 14.28 ft/s, converts to 9.7364 mph

Consider that Usain Bolt’s world record 100M average velocity was 23.35mph, while we generally walk at 2.5 to 4 mph or ride a bicycle at 10 to 12 mph as a beginner. More experienced riders reach speeds of 16-19 mph. Now think about hitting a wall at any of these speeds.

When you fall 38” from the top of a barrier you are going almost 10 mph before coming to where the fall height is measured from, the platform. Consequently, for an 8’ platform with an 11’ top of barrier; the falling child is travelling 18.15 mph from the top of the barrier and only 15.43 mph at the platform. This is a fast bicycle ride. The need for impact attenuating protection is significant.

Another consideration in the anatomy of a fall is how long it takes from the time you start to fall, to the time you land, and the energy at impact. For this there is an interesting website focused on rock climbers call the “Splat Calculator” https://www.angio.net/personal/climb/speed comes into play. You can enter the distance you will fall, and your weight, and it will tell you the speed at impact, the time to impact, and the energy at impact. The time is important as many people believe a falling child will prepare to protect themselves during the fall. A 12-year-old boy and girl are approximately 90lbs (41kg). Plugging in 8’ (2.44m) we get the time to impact is 0.71 seconds. Thinking back to your driver education, the fastest braking reaction time is 0.7 seconds, while the average is 2.3 seconds. This means the child, concentrating on their activity, will be on the ground before they fully understand they are falling and should prepare themselves to do something about it.

The following table shows the fall height, kph, mph, time to impact and energy of impact for the 12-year-old child

Height	Kph	Mph	Time to impact in seconds	Energy at impact in joules**
1.5m (5’)	19.6	12.2	0.55	602.70
2.45m (8’)	25.0	15.5	0.71	984.41
3.0m (10’)*	28.0	17.3	0.78	1205.40
3.6m (12’)	30.0	19.0	0.86	1445.48
4.5m (15’)	34.0	21.0	0.96	1808.10
5.5m (18’)	37.3	23.2	1.06	2209.90

* 3m or 10’ is the maximum fall height for play equipment compliant with the European EN1176 irrespective of how high the overall structures are.

** Joules are a measure of energy “equal to the energy transferred to (or work done on) and object when newton acts on that object in the direction of motion”. Up until 2003, the Canadian playground standard required that swing seats impact a child’s head not exceed 50 joules.

All these factors should be considered when evaluating the height from which a child will fall in a play or climbing setting.

Other considerations will be, how challenging is the play component and does this challenge warrant the setting of a higher drop height or a better performing surface from where the child might fall.

Other chapters in this discussion outline considerations for determining the specified height or drop height for a structure and therefore the performance of the impact attenuating surfacing system.

Chapter Four

The Complexity of Impact Attenuating Surfacing – Simplified

Impact attenuating surfacing is a requirement for all playground standards to reduce the frequency and severity of injuries as a result of a fall. Injury severity will be dependent on the height from which the child falls, the speed they are travelling when they land, the impact absorbing characteristics of the surface, body orientation during the fall, body structure (bone density, etc.). That appears to be intuitive and simple, but it gets more complicated when you throw in the multiple standards that define.

- when to use surfacing (ASTM F1487),
- where to use surfacing (ASTM F1487),
- what the fall height of various equipment types are (ASTM F1487),
- how to test the surface material in the laboratory (ASTMF1292, F3351),
- how to test the surface in the field (ASTM F3313),
- what are the absolute performance criteria (ASTM F1292),
- that you can choose lower values for g or HIC (ASTM F3313),
- that you can select a higher drop height higher than the fall height (ASTM F3313),

- that there is a new ASTM standard that allows you to require testing for better impact attenuation performance and higher drop heights (ASTM F3351)
- that the CPSC Handbook has significant recommendations for surfacing performance
- that the DOJ 2010 Standards for Accessible Design has surfacing requirements for the ground level accessible route within the use zones of accessible equipment entrances and exits

Next comes the multitude of surfacing options that are presented to the D/O/O presenting hard choices that have to be balanced based on project objectives and budget as set by the playground owner.

- What is the fall height of the playground equipment being considered?
- What is the critical height rating of the surfacing systems under consideration for purchase?
- What is the life expectancy of the playground equipment and surfacing system?
- What is the owner's acceptable level of risk of injury versus ability to reduce to a desired level the likelihood of injury and severity of injury?
- Ability to meet and maintain the ground level accessible route requirements of the ADA?
- Initial capital cost?
- Ongoing maintenance frequency and cost?
- Aesthetics – colour, texture, and shapes?
- Skill and knowledge required to install and repair – in-house versus contractor?
- Frequency of repair, result of vandalism or wear and tear cost of repairs? Flammability
- What are the Environmental factors? Heat of the surface to bare feet, UV and thermal radiation, moisture and extreme temperature fluctuation?
- Warranty considerations?

These considerations in relation to injury prevention will have a bearing on initial capital expenditures and long-term maintenance cost. Increased focus on injury prevention will require lower values of g or HIC. For all surfacing types the lowering of these values requires that the thickness or depth of surfacing must be increased adding to the capital cost of the playground. For the unitary surfaces (tiles, poured-in-place and synthetic turf) this increase makes an already expensive system more expensive, while loose-fill systems (sand, gravel, wood products, rubber mulch and crumb rubber, etc.) will require frequent maintenance and additional material from time to time to keep the depth as originally intended. Engineered Wood Fiber, compliant with ASTM F2075, when properly installed (*with compaction in at least 2, 8" layers)* can have a lower maintenance requirement. Beyond maintaining the proper depth of surface as the cause for failure of the system there are other causes of failure to provide impact attenuation that result from environmental conditions and/or contamination. These factors must be taken in account as part of the surfacing system selection process and determining the necessary capital budget prior to the final design of the playground that includes a maintenance budget to ensure success and playground safety standards compliance over the expected life of the playground.

Compliance with the requirements for ground level accessible routes can have even greater consequences as a failure can result in an ADA complaint that could cost far more than the initial cost of the playground surfacing. The major consideration will be compliance with ASTM F1292 followed closely by all the mechanical requirements to allow a person with a mobility device to traverse the playground. The obvious choice is the unitary surface, but should this fail to function, the cost of total replacement might cripple an agency's budget and plans and cost the agency in the area of public relations that could have a long term detrimental impact on the reputation of the public agency when a play area has to be taken out of service when the public does not see or understand why the agency's action was required.

There is no perfect surface, even though most suppliers will tell you that they have the ideal solution. The D/O/O must evaluate the options that best meet their needs. The owner must ask many questions. The supplier does not want to tell you anything but good things about their product. If you do not ask the right questions you will not get the information you need to make an informed decision. ASTM has provided some assistance with the provision of standards related to certain surface types. These include.

- ASTM F1951 Standard Specification for Accessibility of Surface Systems Under and Around Playground Equipment
- ASTM F2075 Standard Specification for Engineered Wood Fiber for Use as a Playground Safety Surface Under and Around Playground Equipment
- ASTM F2223 Standard Guide for ASTM Standards on Playground Surfacing
- ASTM F2479 Standard Guide for Specification, Purchase, Installation and Maintenance of Poured-In-Place Playground Surfacing
- ASTM F3012 Standard Specification for Loose-Fill Rubber for Use as a Playground Safety Surface under and around Playground Equipment (currently

These standards, at best, are starting points. The ASTM F2075 standard is a recipe of how to take ordinary woodchips and turn them to a specific product, commonly known as Engineered Wood Fiber or EWF, that is widely used in the United States and Canada. This EWF standard is the base document for the Loose-Fill Rubber standard, but compliance with the ADA and removal all metal and wire from the loose rubber have conveniently been dropped. The ASTM F2479 standard guide for poured-in-place unitary (PIP) surfacing does not provide answers but raises a lot of questions about what can go wrong with PIP depending upon temperature, humidity, chemistry, or layering systems. The one benefit of the PIP Standard Guide is a listing of the measurable requirements for the ADA compliance. Lastly the F2223 Standard Guide outlines all the standards relating to playground surfacing. Noticeably and unfortunately there are no specific standards for sand, gravel, synthetic turf, or tiles. In all, these standards should be helpful as a first step to understanding surfacing systems.

Chapter Five

Conclusions

The Designers, Owners and Operators (D/O/O) will have to make decisions based on their understanding of the standards that are available to them. The Specified Height Standard is the only playground standard that treats all surfaces systems equally from the standpoint of performance at a specified height. All things considered equal the D/O/O will have the opportunity to compare apples to apples from a performance perspective before selecting a surface system for their project. Next the D/O/O must consider whether they wish to include a built-in margin for error with regards to performance. This might have a positive result on reducing the potential fall related injuries and the severity outcome of those injuries based on the owner's risk management objectives. All involved stakeholders need to discuss and reach consensus on some target level of injury severity they can expect to experience during normal playground usage.

There are many other variables the D/O/O needs to consider before the final surface system selection is made. While initial cost always seems to be driving the owner's purchasing decision, they need to consider long term costs over the expected life of the playground. The surfacing must perform within the impact attenuating performance standard requirements throughout the life expectancy of the entire playground. Has the owner clearly articulated what that life expectancy should be? Has the owner included their life expectancy requirement in the purchasing and construction documents? What is a reasonable length of time to expect from a manufacturer's product warranty? Impact attenuation performance is important, but some systems will continue to perform within the minimum standard requirements yet fail other purchasing performance considerations such as accessibility compliance. What are the installation requirements? Can the owner or general contractor install the surface system and if not, what will all the final installation costs be? What are the costs specific to the site and base preparations required as part of the surface system installation? Not all surface systems require special site preparation and subgrade requirements, but many do and some of these base requirements can be very costly. Does the installation require a drainage component be included and installed as part of the base preparation? All these costs, including any containment border and special drainage requirements also need to be included into your total surface area cost per unit. Once all the installation requirements and associated costs are known the owner must decide whether or not they can install the surfacing system with their own people or will the owner need to hire the general contractor or special subcontractor to install the surface system. This is another obvious additional installation cost to the project budget.

Regardless of the surface system that is installed, each is required to have an inspection, maintenance and repair protocol provided to the owner by the manufacture of any proprietary surface system. The owner needs to implement these procedures over the life of the surface system. For systems requiring physical labour and equipment, the manufacturer/supplier should provide an estimate of number of hours per week or month as well as anticipated top-up or replacement materials. What are these total projected costs likely to accrue over the life of the surface system? Can the owner conduct the inspections, maintenance, and repairs with in-house staff and if so at what cost? This indirectly brings us back to what is a reasonable surface system warranty for both impact performance and functional durability? The marketplace is not where it needs to be with regards to surface system warranties therefore it is up to the owner to set the bar with some realistic and specific expectations for a reasonable functional life.

Having the knowledge and understanding of all the playground impact attenuating surface performance standards puts the D/O/O in charge of the decisions for performance.

- at the time of surface system selection
- before the purchasing specifications are written
- prior to any pre-construction meetings
- prior to project layout
- at initial surface subgrade verification
- during surfacing base preparation and drainage installation

and for sure.

- before any payments are made related to the compliance with all purchasing requirements for the surface system as specified in the final contract documents.

All this is to assure the owner they are getting what they paid for from the time of installation and project acceptance throughout the functional life of the playground surfacing based on consideration for the performance compliance to all the related surfacing standards.

As you can see from this paper, this is not an easy process. Playground impact attenuating surfacing is just one piece of the puzzle. There are a lot of different performance standards and guidelines to consider. There are many competing and conflicting interests involved in the design, purchase, and installation of the playground equipment, the necessary impact attenuating surfacing, and all the other site amenities and hardscape that make up the entire play space. The owner should not automatically turn over their responsibilities to some outside consultant. Even if they hire an outside consultant the owner needs to oversee and take responsibility for the process and understand there is a cause and effect of each decision that will need to be made throughout the process. It starts with initial concept and the design process and runs through final plan approval to the ribbon cutting dedication ceremony, through to its end of useful life and replacement.

The real question is what happens after that ribbon cutting ceremony? Who will be around to help the owner with the inevitable problems that will occur throughout the play area's life expectancy? The owner needs somebody they can trust in charge of their interests whether it be an outside consultant, their qualified sales associate, or an in-house staff person. These persons need to understand the standards they are being held to. The person in charge or making decisions needs to be trained and experienced in all aspects of the developmental benefits of play, understanding child development needs, application of playground equipment and surfacing standards requirements, ability to identify playground hazards, skill to conduct compliance inspections and finally has the ability to inspect or supervise those knowledgeable in playground equipment and surfacing inspection, maintenance and repair. Often this might be a team of experts in specific, but together, all aspects of this process. Someone still must be given the ultimate authority to make decisions. Are you up to the challenge? All things considered, the ASTM F3351 *Standard Test Method for Playground Surface Impact Testing in Laboratory at Specified Test Height* is the best place to start an objective review and selection process for an appropriate impact attenuating surface system that meets the D/O/O's playground project's needs, goals and objectives based on the owner's tolerance for risk of injury and reasonable functional life expectancy.

The D/O/O should consider joining ASTM at www.ASTM.org and the ASTM F08.63 sub-committee to participate in the advancement of these surfacing standards. Canadian Playground Advisory Inc. and the International Playground Safety Institute, LLC stands ready to provide assistance in better understanding the processes of how the risks associated with surfacing are determined as well as the selection of injury threshold or determining fall height/drop height or how to articulate best surfacing performance requirements into purchasing specifications for the surface system.

Chapter Six: Future considerations

Thoughts on understanding Impact curves and fractures

Since the first published safety recommendation in 1981 to the first published ASTM surfacing standard for testing surfacing compliance in 1991 the scope of these standards was to reduce life-threatening head injuries from falls on public playgrounds. While the CPSC Handbook has always had a desire to reduce all serious, injuries not just head injuries, they had always recognized how complicated and improbable it was to eliminate all injuries on playgrounds. There are far too many variables to consider justifying a one size fits all solution.

Today it would be easy to say that the largest expense attributable to injuries that occur annually on our public playgrounds is the total cost of liability claims against the owner, designer, manufacturer, installer, assembler, maintainer, repairer, and inspector of the playground equipment and impact attenuation surfacing in and around the equipment where the users are likely to fall.

Right after the head injury, the next injury of interest is the fracture. There is also a lot of interest in the types of concussion that are frequently discussed when an NFL player spends up to 15 minutes in the “tent”. These injury thresholds will require low g and HIC values as well as long impact durations.

A fracture is a direct reflection and result of the destructive energy generated by the injury event. The fracture morphology reflects,

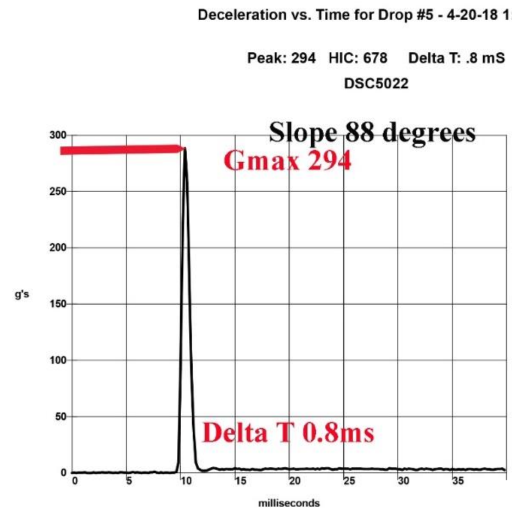
- The forces and resultant stress generated by the specific mechanism
- The ability of the bone (with its surrounding tissue) to resist these forces

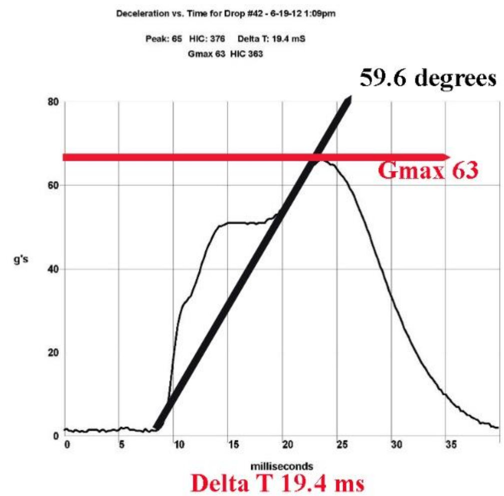
There are three pure forms of fracture.

- Compression – compressive force directed axially through the body or region
- Tension – a force directed axially, but results in a stretching or pulling
- Shear – a force that tends to cause one part of the body to slide in relation to an adjacent part

It is likely that a child falling will experience some combination these mechanisms. Distance of the fall, body orientation, bone density and structure as well as the surrounding tissue and most importantly the ability of the surface to absorb the impact will be factors in the outcome. In any event it is logical that falling with greater force, from a linear acceleration upon impact with the surface will result in a more severe injury. Reducing the load and speed of loading of the forces are likely to contribute a less severe injury.

These are samples of test results on asphalt and a playground surface point out that the data collected during drop testing can be predictive of the outcome of the injury.





	Asphalt surface 15cm (6") drop	Playground 3.65m (12') drop
Linear acceleration	294g	65g
HIC	678	376
Slope of the curve	88º	59.6º
Critical time for HIC	0.8ms	19.4ms
Potential severity	Very severe	No injury to a simple fracture

Very few surfaces are installed to the performance on the right where the peak load and speed with which that load is achieved are both very low. Where a surface performs with this performance can be purchased, the D/O/O must give it consideration.

This simple presentation of the data shows that the impact data generated for surface impact testing can be used to predict long-bone injuries. Although prevention of fractures is a laudable goal, surfaces that currently just meet relevant standard thresholds are not close to this level of injury prevention.

Since certain fractures are an expectation of play, care must be taken how standards writers use in the realm of standards. It certainly opens a discussion for future research and consideration.

The reader is cautioned that before anyone embarks on the inclusion of this topic, considerable research will be required before this is utilized in the field.

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[i] Association for the Advancement of Automotive Medicine, 2015