ASTM F1163: what is it?

ASTM is an international body of technical experts, manufacturers, and consumers that develop standards for a broad range of industries. The standards are voluntary and consensus-based and may be adopted and/or mandated by other organizations and governing bodies. For example, the United States Equestrian Federation and United States Pony Club require riders to wear a helmet that meets ASTM F1163 and is certified by the Safety Equipment Institute (SEI), a third-party organization that verifies helmets meet the standard. Globally, there are several other standards organizations that have established certification requirements for equestrian helmets. A helmet that is labeled ASTM/SEI has met the requirements of F1163 and has been verified by SEI.

What is/is not tested by ASTM F1163?

ASTM F1163 prescribes how and where equestrian helmets are tested. The standard specifies the type of headform, sensors used for testing, the minimum extent of helmet coverage, the labeling requirements, and the procedures for various tests a helmet must pass to be certified. The integrity of the retention system is tested with a dynamic load applied directly to the chin strap and the helmet's stability is tested by attempting to pull off the helmet from the back. A lateral compression test, recently added to the standard, evaluates the helmet's overall stiffness when compressed on the sides. The test that receives the most attention, however, is the impact attenuation test, which measures the acceleration a headform experiences during a helmeted impact. A headform is a surrogate for a human head that is shaped like and responds similarly to a human head during a helmeted head impact[1]. Headforms provide a repeatable method for measuring head acceleration from sensors inside the headforms during laboratory testing.

The impact attenuation test requires a helmet to be placed on an appropriately sized headform, then released from 2 different heights onto two different anvils or impacting surfaces (Figure 1). The helmet strikes the flat anvil at 6 m/s (13.4 mph), which is equivalent to dropping vertically, unobstructed, from a head height of about 5'10" onto a rigid surface. The helmet strikes the hazard anvil, which looks like an inverted "V" with a 90-degree corner, at 5 m/s (11.2 mph). This anvil challenges the integrity of the shell and is meant to represent a hazard such as a horse's hoof or a head strike against the edge of a jump or fence. A helmet can be struck twice against each anvil with sufficient separation of the impacts such that the previously compressed foam doesn't influence the next impact. This often means that a helmet will be struck against the front, back, and both sides. The helmets must undergo these impacts after being exposed to 4 environments: ambient (63 to 73 degrees F), high temperature (110 to 117 degrees F), low temperature (1 to 9 degrees F), and after being submerging in water (59 to 73 degrees F). The peak linear acceleration from any test cannot exceed 300g.

[1] Bonin, SJ et al (2017) Dynamic response and residual helmet liner crush using cadaver heads and standard headforms. Annals of Biomedical Engineering 45, pp 656-67.

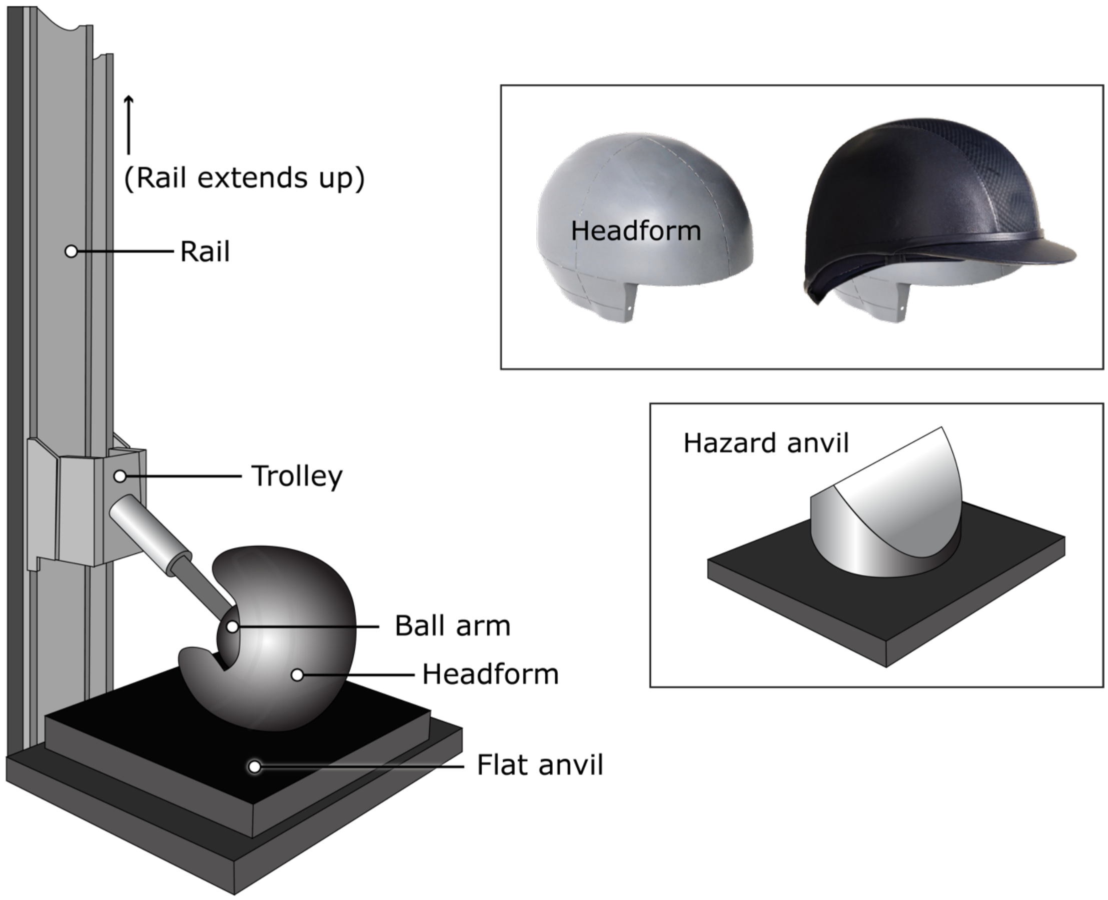

Figure 1: Impact attenuation testing equipment: Left: The headform is attached to an instrumented ball arm, which is attached to a rail to constrain motion in the vertical direction. A helmet is placed on the headform, released from the prescribed height, then strikes the anvil while the acceleration is recorded. Other test set-ups may use a vertical twin-wire system to guide the headform. Upper inset: Metallic headform (left) and headform with helmet (right). Lower inset: hazard anvil.

<u>Linear versus rotational head impact? What's the difference?</u>

In general, the head experiences both linear and rotational (sometimes called angular) acceleration during an impact. In simple terms, linear acceleration is a measure of how quickly the head is stopped by the impact, whereas rotational acceleration is a measure of how quickly the head is rotated by the impact. The linear and rotational motions (kinematics) are measured by sensors inside the headform and while both can be measured during any type of impact, some impacts generate more rotation than others.

The head experiences mostly linear acceleration when the head strikes the ground vertically, like during a simple fall while stopped. The head experiences both of linear and rotation acceleration when it strikes the ground at an angle, like when falling from a moving horse where the head approaches the ground with some horizontal speed. This type of impact is referred to as oblique. In general, linear acceleration causes focal injuries like contusions and skull fractures, whereas rotational acceleration causes diffuse injuries such as concussions.

The foam liner in most single-impact helmets, including equestrian helmets, reduces the linear acceleration the head experiences by crushing and cracking during an impact, which helps spread the impact force out over a larger area and prolongs the impact duration (Figure 2). A foam liner can also reduce rotational acceleration in some circumstances; however, some helmets have technology that is specifically designed to further reduce the rotational acceleration during a head impact.

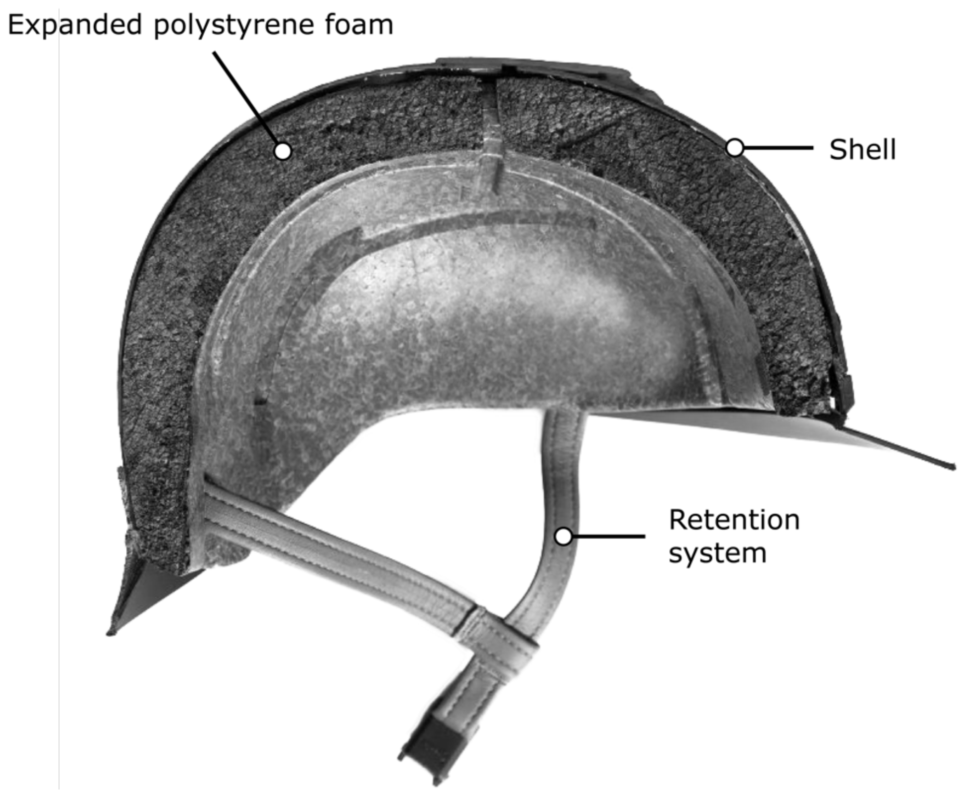

Figure 2: Helmet cross-section revealing an expanded polystyrene (EPS) foam layer, hard outer shell, and a retention system. A low-density comfort liner (not shown) is attached to the inside of the EPS liner and rests against the rider's head.

<u>How do you perform oblique impacts in the laboratory?</u>

An oblique test can be performed by launching the helmeted headform at the ground at an angle, by dropping it vertically onto a moving surface, or by dropping it onto an angled anvil (Figure 3). The latter approach is easier to control and repeat in a laboratory environment. After the helmeted headform strikes the angled anvil, it can freely rotate while the instrumented headform records its kinematics.

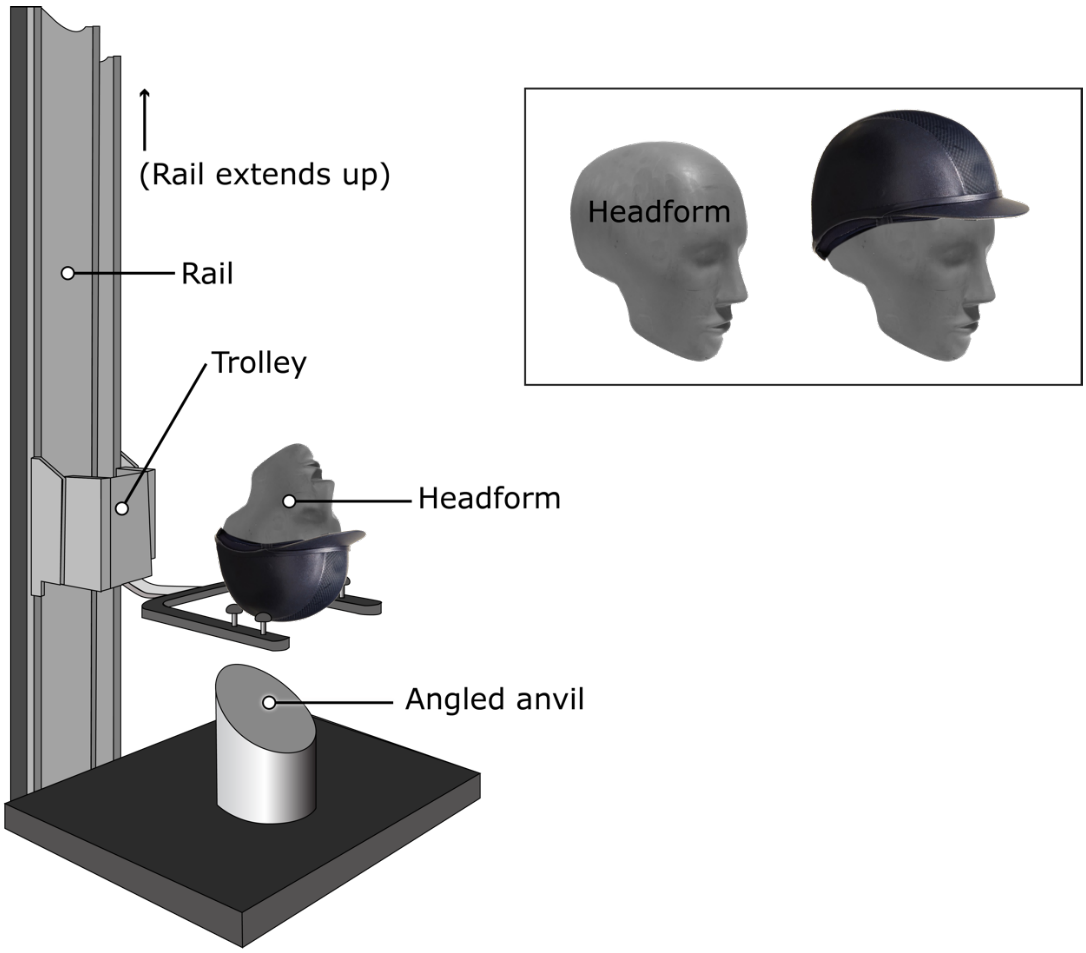

Figure 3: Example test set up for oblique helmet testing. The instrumented helmeted headform strikes the oblique anvil and is free to rotate at impact while recording kinematics.
Inset: Example headform (Hybrid III) used to in rotational testing. The Hybrid III is often covered with a shear-layer to change the friction between the headform's "skin" and the helmet[2].

What's next for ASTM F1163?

ASTM F1163 does not currently require an oblique impact test, in part because oblique testing methods are relatively new and in part because there is currently no consensus on an acceptable rotational threshold within the biomechanics community. The advances in sensors that measure the rotational acceleration experienced by human heads have improved greatly over the past 5-10 years. Today, athletes wear mouthguards embedded with sensors that can measure their head kinematics during a head impact and the data can then be correlated to a

[2] Bonin, SJ et al (2022) The effect of MIPS, headform condition, and impact orientation on headform kinematics across a range of impact speeds during oblique bicycle helmet impacts. Annals of Biomedical Engineering 50, pp 860-870.

concussion diagnosis. With enough high-quality head impact data and accurate concussion diagnoses from a diverse population, the risk of concussion can be estimated from the measured head kinematics. Such a database can help define an acceptable rotational threshold for an oblique impact test.

As more reliable kinematic and concussion data become available to establish a meaningful acceptance criterion, a rotational test will likely be added to F1163. The process for changing an ASTM standard requires committee consensus. Changes are proposed when compelling data become available to motivate the change, and these changes are then voted on before being implemented.

In addition to a rotational test, the ASTM F1163 committee has been considering lowering the allowable peak acceleration for the current impact attenuation test and/or including a lower speed impact attenuation test to evaluate helmet effectiveness in a range where many head impacts occur. Improvements to the standard are routinely reviewed as more and better data become available.

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Stephanie Bonin is a biomechanical engineer at MEA Forensic in Laguna Hills, CA where she analyzes injuries in involving cycling, pedestrian, equestrian, and workplace accidents, automobile collisions, and helmet effectiveness. She conducts research on helmets, is the chair of the ASTM F1163 Equestrian Helmet Committee, and is an avid equestrian.