Comparisons of Motorcycle Helmet Standards
Snell M2005, M2010/M2015, DOT and ECE 22-05
Edward B. Becker, September 29, 2015

The following compares four standards: Snell M2005, Snell M2015/M2010, DOT, and ECE 22-05. M2005 and the current DOT Standard (Federal Motor Vehicle Safety Standard 218) apply largely to motorcycle helmets intended for the US and Canada. ECE 22-05 applies to helmets for sale in Europe. M2015 is essentially the same as the previous Snell M2010. It is the current Snell motorcycle helmet standard and is intended to apply to helmets in every part of the world.

DOT and ECE 22-05 are mandatory; motorcycle helmets distributed for sale in particular geographical regions are obliged to meet them. Snell standards are voluntary but Snell certified helmets distributed in particular geographical regions must also meet applicable mandatory standards. Snell certification is intended to identify a subset of those helmets available to motorcyclists which provide superior protective capabilities beyond those mandated by government. Snell standards call for helmets to be tested at higher levels of impact severity than either DOT or ECE 22-05. However, M2005 is incompatible with ECE 22-05 for helmets intended for smaller head sizes. Medium, Small and Extra Small size helmets which meet Snell M2005 requirements for superior protective performance are still almost certain to be rejected for ECE 22-05. M2010 and M2015 correct this and are compatible with both DOT and ECE 22-05 while, at the same time, demonstrating more impact energy management than either of them.

The first table deals with impact testing. All four standards call for the helmet to be placed on an appropriately sized metal head form and dropped at specified impact velocities onto a shaped impact surface. Instrumentation measures the shock accelerations seen at the head form center of gravity and these accelerations are compared to one or more criteria to determine whether the helmet performed acceptably.

The test head forms are a critical element. Differences in the mass of the head forms and ancillary equipment account for the incompatibility between M2005 and ECE 22-05. M2005 used the mass specification set forth in ISO DIS 6220-1982 and in BSI 6658-1985 which effectively called out a head form mass of 5.0 kg regardless of head form circumference. M2010 and M2015 shift to the mass specification called out in ECE 22-05 which sets head form mass according to the cube of the head form circumference. This shift is the basis for almost every other difference between M2005 and the two subsequent Snell motorcycle helmet standards.

The device type is also important. Snell and DOT both call for guided fall devices. Guided fall allows for precise positioning of the head form center of gravity relative to the impact surface. This positioning improves repeatability and also reduces the impact energy and impact response that may be lost to head form rotation. The twin wire guidance system may have an additional advantage in that the head form and guidance hardware combine to shift the total c.g. directly over the center of the impact and also to increase the mass moment of inertia of the falling mass. These reasonably will further reduce rotation in response to impact assuring a maximum of helmet damage and linear shock transfer during the impact event.

The impact regimen is described in terms of impact velocities. Previously, Snell had described impact in terms of the kinetic energy of the falling head form and guidance assembly just prior to impact. This was useful when the mass of the drop assemblies did not vary with head form circumference. However, the energy formulation is much more cumbersome when the masses vary so M2010 and M2015 describe impact severity in terms of impact velocity. The nominal impact velocities for M2005 work out to 7.75 m/s for the first of two impacts and, for the flat and hemispherical anvils, a second impact of 6.63 m/s. M2010 and M2015 retain 7.75 m/s for the first impact but the second impact velocity depends on the test head form. The greater mass of the larger head forms implies much higher levels of stress to helmets tested at comparable impact velocities. For this reason, it is possible to build more impact velocity management into smaller helmets than into larger ones, particularly for impacts with the load concentrating hemispherical anvil. For the smaller A, C and E head forms, the M2010 and M2015 second impact velocity is appreciably higher than in M2005 and, for the J head form, this second velocity is still slightly higher. But the second impact velocity is much lower than in M2005 for the M and O head forms. In fact, though, the M2010 and M2015 total impact energies for the M and O head forms are the about same as in M2005. The substantial increases in head form mass account for the differences in the second velocities. However, the mass reductions for the smaller head forms imply significantly lower total impact energy requirements for smaller helmet sizes in spite of the increased second impact velocity.

The reason for the energy disparity is this: the change in head form masses also affects the shock acceleration levels measured in impact testing. The same helmet tested with a lighter head form will obtain higher G levels. The helmet itself will transmit the same shock forces to the head form but the lower head form mass means these comparable shock forces will produce higher levels of shock acceleration. The design of smaller sized helmets must change in order to keep peak G's within accepted limits. The smaller sized M2010 and M2015 certified helmets will differ from comparable M2005 certified helmets. However, the largest sizes of M2010 and M2015 helmets are expected to remain quite similar to their M2005 counterparts. Helmets tested on heavier head forms, as these larger helmets will be, will obtain lower G levels. In particular, M2005 helmets tested on the heavier M and O head forms will obtain appreciably lower G levels than those permitted in DOT and ECE 22-05. Rather than allow the larger sized M2010 and M2015 helmets to transmit higher levels of shock force than permitted in M2005, the Foundation has instead lowered the G criteria for helmets tested on the M and O head forms.

The effect of all of this is that M2010 and M2015 are a conservative accommodation of M2005 to ECE 22-05. For the smaller sizes, M2010 and M2015 effectively demand softer, more yielding helmets which will reduce the shock forces transmitted to the head form, and to a wearer's head, in impact. For the larger sizes, M2010 and M2015 continue M2005's demands for softer, more yielding helmets than allowed by either DOT or ECE 22-05.

Of course, there is still the issue of impact energy management. The smaller M2010 and M2015 helmets must necessarily manage less impact energy than their M2005 counterparts. Since recent studies suggest that smaller sized heads weigh less, these M2010 and M2015 helmets will still provide more impact velocity management to their wearers than M2010 and M2015 helmets intended for larger sizes. However, a reasonable person might conclude that a smaller sized M2005 helmet would provide even greater levels of impact velocity management. Of course, the smaller M2005 helmet would also transmit higher levels shock force and shock acceleration but these would still be within tolerable limits. Riders have been wearing Snell certified motorcycle helmets for many years and there has not yet been any suggestion that smaller sized Snell helmets are any less effective at preventing serious head injury than larger sizes.

The impact surfaces are also an important issue. Although most helmeted impacts are against flat surfaces, riders also strike their heads against convex, load concentrating surfaces which pose different problems for the helmet. The flat surface impacts load a relatively broad area of the helmet wall while the load concentrating surfaces work a much more limited area. For this reason, flat surface impacts generally produce higher shock acceleration but lower levels of helmet wall compression than comparable impacts against load concentrating surfaces. However, since load concentrating impacts lead to more helmet compression, an inadequate helmet may not allow all the wall compression necessary to manage an impact. Generally, if a helmet wall is not soft enough to attenuate impact, the first indication will be test failures in flat impact. If the helmet wall is too thin to manage impacts of the required severity, the first indication will be test failures against the load concentrating surface. Flat surface impacts test for softness and load concentrating surfaces test for wall thickness. A helmet might pass one or the other and still be inadequate. A good helmet meeting requirements on both types of impact surface will be good for almost any intermediate surface as well.

Snell and DOT both impact against a flat surface and a hemisphere with a four centimeter radius. ECE 22-05 also impacts against a flat surface but, instead of a hemisphere, its load concentrating surface resembles a section of curb. This “kerbstone” is composed of two planes oriented at 135 degrees to each other with a 15 mm radius at the corner where the planes meet. It is not as severe a load concentrating surface as the hemisphere; the shock accelerations in comparable impacts are greater, though not so great as for flat impact and the helmet wall compressions are smaller though not as small as for flat impact. If Snell or DOT were to drop the hemispherical impact surface from their tests in favor of the kerbstone, it seems likely that manufacturers could meet the requirements with thinner walled helmets or helmets with weaker external shells. However, if ECE 22-05 were to drop the kerbstone for the hemisphere, many helmets which currently qualify would begin to fail. Of course, the test technicians might also encounter difficulties with test repeatability. Obtaining consistent results with a free drop system against the kerbstone is difficult; doing so against the hemisphere may be unworkable.

The criteria for M2010 and M2015 impact testing is based on the peak value of acceleration measured at the head form center of gravity. For head forms A through J, this peak must not exceed 275 G which is the same level set in ECE 22-05. For the M and O head forms, M2010 and M2015 set lower levels corresponding to the shock level demands for set these head forms in M2005. DOT limits peak acceleration to 400 G but also sets limits on the total duration the acceleration response may exceed 200 G and also 150 G. ECE 22-05 limits peak acceleration to 275 G for all head forms but also limits the Head Injury Criterion (HIC) to 2400.

The Foundation has not adopted the duration criteria or the HIC for use in Snell standards. The time durations were originally developed for an impact test method which has since become obsolete. This method, called swing-away, called for the helmeted head form to be mounted on an armature held out horizontally under a falling impactor. When the impactor struck the helmet, the arm was allowed to "swing away" under the force of the blow. An accelerometer at the center of the head form measured the shock transmitted through the helmet much as today's systems do and peak G restrictions were applied to the measurements as well as time duration criteria. In fact though, the mechanics of the interaction are not quite the same. The impact velocities must be substantially higher for swing-away testing in order to assure comparable exercise of the helmet's impact management. If the velocities are correct, the same G criteria may apply but shock transfer will be accomplished much more quickly. That is, the acceleration pulse measured at the center of the head form will be similar for both guided fall and swing away testing with comparable amplitudes but the swing away results will be time compressed. The time durations for a swing away test will be shorter than for a comparable guided fall test.

The 1968 American Standards Institute allowed both guided fall testing or swing-away testing and made suitable adjustments to impact velocity for the two systems but no allowance was made for time duration differences. Since most of the testing done at that time employed swing away devices, few people suspected that there might be a problem but later, in 1971, when the renamed American National Standards Institute published the ANSI Z90.1 motorcycle helmet standard, all testing was to be done on guided fall devices. At that point, the time duration criteria began to fail helmets that, till then had performed very well. ANSI corrected the problem with an addendum to the Z90.1 standard published in 1973 but by then, the US Federal Government had already adopted the requirements of the 1971 ANSI document for the DOT standard. The government did not incorporate the 1973 addendum into the DOT standard, perhaps because they expected to write a HIC requirement into the standard within a few years of putting DOT into effect. HIC was already a part of Federal requirements for occupant protection in automobiles. It seemed a reasonable basis for head protection for motorcyclists as well except that much of the data on which it was based applied to bare headed impact. The HIC limits set for vehicle occupant protection are far too restrictive for crash helmets. The criteria that had been adopted temporarily for DOT at the outset have been left in place ever since. Instead, HIC was written into ECE 22-05 but, rather than accept HIC 1000 which had been deemed a reasonable upper limit when the criterion was created, the drafters of ECE 22-05 went with HIC 2400. To the best of my knowledge, there is no biomechanical basis for this value.

Researchers have questioned the value of time duration criteria and HIC in helmet evaluation. Apologists point out that the additional criteria for DOT and ECE 22-05 may act to restrict peak G acceleration for flat surface impacts to levels below 400 G and 275 G respectively. However, this could be accomplished more directly by resetting the peak G criteria directly.

The rest of the tables compare other aspects of helmet performance. The European standard pursues a number of items not addressed by either Snell or DOT. This is not necessarily a shortcoming in Snell standards. The Foundation evaluates those aspects of helmets that:

1. Have a demonstrable bearing on protective performance.
2. Can be tested reliably.
3. Are invisible, that is: cannot be easily evaluated at purchase time by the riders themselves.

If the wearer can make the determination for himself, he is likely neither to need or want the Foundation's advice. Unless it's important, hard to measure and we know it for a fact, we won't waste anyone's time.

The projections and surface frictions tests required in ECE 22-05, for example, have not been taken up by Snell largely because there is no body of evidence demonstrating that such testing is useful. Pertinent crash studies indicate that helmets are neck injury neutral. Furthermore, the tests themselves are difficult, if not impossible, to reproduce so that the procedures are, at best, a research tool and have no place in the administration of a standards enforcement program. In another regard, conspicuity is a well regarded safety feature but do riders really need help identifying conspicuous helmets?

Helmet selection cannot be a matter of simply looking at certifications. We hope that Snell certification will help narrow the range of choices but riders still have many important decisions to make. Proper fit is essential and reasonable comfort is critical as well. So is the look of the helmet; even the most rational and conservative rider will not wear a helmet he thinks is ugly, at least, not very long. Vision is important as well. Some new riders may notice the edges of the headgear at the limits of their peripheral vision but at speed, a rider's visual field contracts. However, if the face shield distorts or obscures, it's got to be replaced and, maybe, the helmet as well. Hearing is also essential. Although most helmets actually improve hearing at speed over riding bareheaded, prolonged exposure to wind noise may destroy hearing over time. A helmet's effectiveness in reducing wind noise depends on its structure and on the fit quality. Finally, it's not sufficient to make these decisions when the helmet is purchased, these decisions must be reconsidered every time the helmet is worn.

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Standard	**M2005**	**M2010/M2015**	**DOT**	**ECE 22-05**
		Impact Gear		
Circumference	**ISO/EN 960**	**ISO/EN 960**	**DOT**	**ISO/EN 960**
50 -51.9 cm	**5.0 kg (A)**	**3.1 kg (A)**	**3.5 kg (S)**	**3.1 kg (A)**
52 - 53.9 cm		**3.6 kg (C)**		
54 - 56.9 cm	**5.0 kg (E)**	**4.1 kg (E)**	**5.0 kg (M)**	**4.1 kg (E)**
57 - 59.9 cm	**5.0 kg (J)**	**4.7 kg (J)**		**4.7 kg (J)**
60 - 61.9 cm	**5.0 kg (M)**	**5.6 kg (M)**	**6.1 kg (L)**	**5.6 kg (M)**
=>62 cm	**5.0 kg (O)**	**6.1 kg (O)**		**6.1 kg (O)**
Device Type	**Guided Fall Twin Wire**	**Guided Fall Twin Wire**	**Guided Fall Monorail**	**Free Fall**
		Impact Regimen		
Flat Anvil	**Two Drops 1^{st} 7.75 m/s 2^{nd} 6.63 m/s**	**Two Drops 1^{st} 7.75 2^{nd} 7.09 m/s ACE 2^{nd} 6.78 m/s J 2^{nd} 5.73 m/s M 2^{nd} 5.02 m/s O**	**Two Drops 6.0 m/s (both)**	**One Drop 7.5 m/s**
Hemi Anvil			**Two Drops 5.2 m/s (both)**	**-**
Kerbstone Anvil	**-**	**-**	**-**	**One Drop 7.5 m/s**
Edge Anvil	**One Drop 7.75 m/s**	**One Drop 7.75 m/s**	**-**	**-**
HIC	**-**	**-**	**-**	**2400**
Duration	**-**	**-**	**2.0 msec @ 200 4.0 msec @ 150**	
Peak G	**290**	**275 ACEJ 264 M 243 O**	**400**	**275**

	M2005	M2010/M2015	DOT	ECE 22-05
Retention System				
Retention Strength	Dynamic 23 kg static 38kgx12cm shock 30 mm criterion	Dynamic 23 kg static 38kgx12cm shock 30 mm criterion	static 50 lb baseline 290 lb load 1 inch criterion	Dynamic 15 kg static 10kgx75cm shock 35 mm criterion
Roll-off	4kgx60cm shock retention criterion	4kgx60cm shock retention criterion	-	10kgx50cm shock 30° criterion
Strap Micro-slip	-	-	-	yes
Strap Abrasion	-	-	-	yes
Inadvertent release	-	-	-	yes
Release Durability	-	-	-	yes
Removability	yes	yes	-	-
Free End Retention	velcro forbidden	velcro forbidden	-	required for D-rings

	M2005	M2010/M2015	DOT	ECE 22-05
Shell Requirements				
Shell Penetration	**60° cone 3 kg 3 m fall**	**same as M2005**	**same as M2005**	**-**
Shell Rigidity	**-**	**-**	**-**	**loading to 630 n (141 lb) from 30 n (6.74 lb) baseline 40 mm max deflection 15 mm max residual**
nape clearance	**-**	**-**	**-**	**yes**
conspicuity	**-**	**-**	**-**	**yes**
Projections and Surface Frictions	**-**	**-**	**-**	**Method A or Method B**
Visual Field				
lateral	**> 210°**	**> 210°**	**> 210°**	**> 210°**