HEADS UP

Part 2 of the Helmet test report

Following the publication of the helmet test results in Summit 19 several climbers have asked the question – "which is the best helmet?" And in response we have been generally annoying people by saying "it depends" and "any helmet is better than none". The bottom line is that it's all about making an informed choice. To help out in this issue Mark Taylor takes a closer look at the helmets tested during the programme - which one will work best for you?. Also included is a reminder of the test results - remember lower is better.

As part 1 showed different helmets have a great variation in their strengths and weaknesses and so what's good on big alpine routes may not be ideal for Stanage and vice versa. What also came to light was the weakness of the standard test in terms of giving a true reflection of how a helmet might perform in practise. In addition the testing programme has shown up worrying inconsistances between test houses, both in results achieved and methods used. A UIAA working group and other interested parties are now attempting to address this.

Here we will look in detail at the technical attributes of the helmets tested and the way in which different material react to impacts. All this adds up to you knowing a lot more about your next helmet than the fact that it passes the CEN standard, but it's still going to be up to you to make the choice.

Shell/Cradle style

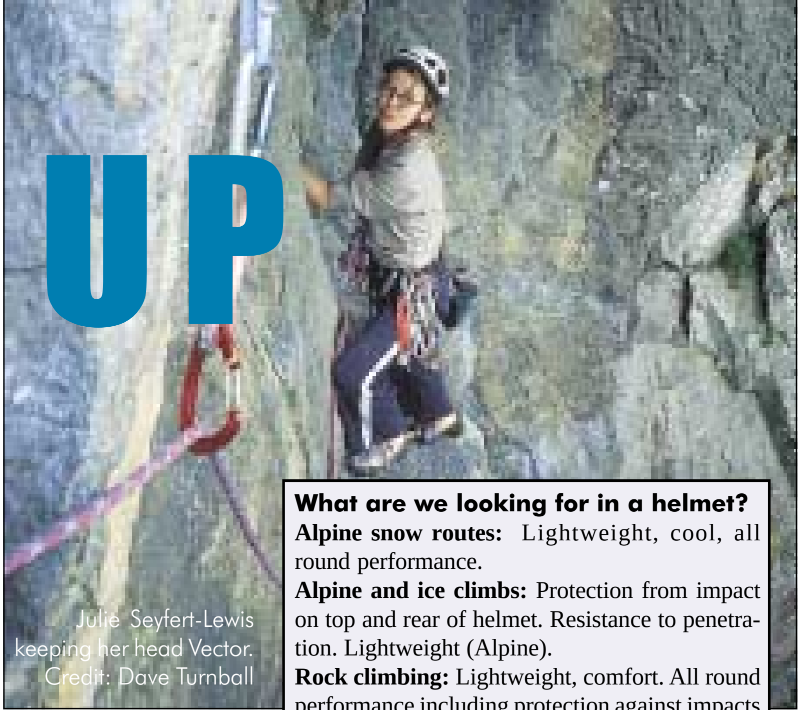
In crown impact situations traditional style helmets, which feature a shell and a cradle, offer the best performance. During the impact several energy-absorbing mechanisms come into play. Any slack is taken up in the cradle, and then the shell deforms whist the cradle stretches. Some shell materials deform more than others and so designers have to allow different amounts of shell cradle clearance for different helmets. In an off centre impact the cradle may offer less protection and the deforming shell may touch the head, this is very dependant upon the design of the shell and helmet. This is a field we are planning to investigate.

HB Astral (Blue Water in the USA)

A traditional style helmet with a 2.2±0.1mm thick vacuum formed ABS (Acrylonitrile Butadiene Styrene) shell, a three strap polyester webbing cradle and an adjustable padded headband, where adjustment is via a webbing which slides through a locking buckle. The chinstrap is easy to adjust and features a quick release buckle, which is curved for comfort. The shell features a raised crown profile for improved impact performance. This helmet has a shell/ cradle clearance of approximately 30mm. There are elasticated bands at the front and rear to hold a head torch.

Pros & Cons: The thick polymer shell is very impact resistant. The performance of ABS polymers can be seriously compromised if they are allowed to come into contact with the wrong solvents, so paint and stickers should never be used without first seeking the manufacturer's approval. After an impact the shell returns to its original shape,

The HB Astral after a test impact: Note the striations



Julie Seyfert-Lewis keeping her head Vector. Credit: Dave Turnball

What are we looking for in a helmet?

Alpine snow routes: Lightweight, cool, all round performance.

Alpine and ice climbs: Protection from impact on top and rear of helmet. Resistance to penetration. Lightweight (Alpine).

Rock climbing: Lightweight, comfort. All round performance including protection against impacts at the rear and sides.

but white striations on the surface of the helmet show it has been damaged (unfortunately these are not obvious in helmets with a white shell).

In test-transmitted forces: Top impact 5.5kN, Front 0.7kN, Side 0.8kN, Rear 2.7kN.

HB Olympus

The Olympus is very similar in construction to the Astral, with a 2.0±0.2mm thick vacuum formed ABS shell and the same cradle, headband and chinstrap as the Astral. The shell has several raised features to improve performance. The shell/cradle clearance is approximately 40mm. There are elasticated bands at the front and rear to hold a head torch.

Pros & Cons – See HB Astral.

In test-transmitted forces: Top impact 6.3kN, Front 1.8kN, Side 2.2kN, Rear 5.7kN.

HB El Cap; El Cap Kevlar/Carbon

The shell of the El Cap is manufactured from 2.0±0.5mm thick glass fibre reinforced polymer (GRP), whilst that of the Kevlar/Carbon version is the same thickness, but some of the glass fibre layers have been replaced with Kevlar and Carbon fibre woven cloth. The cradle, headband and chinstrap are the same as that on the HB Astral helmet. These helmets have a shell/cradle clearance of approximately 30mm. There are elasticated bands at the front and rear to hold a head torch.

Pros & Cons: These composite shells are very penetration resistant, the Kevlar/Carbon version offering slightly more resistance than the GRP version. During an impact, the shell dissipates energy by breaking; the mechanical bonds between the resin and the Glass/Kevlar/Carbon fibres are broken, resulting in very obvious shell damage.

In test-transmitted forces: Top impact 5.4kN, Front 2.9kN, Side 3.5kN, Rear 2.0kN.

HB Joe Brown Lightweight

Other than its distinctive shape, this helmet is of the same construction as the El Cap, except the shell/cradle distance is increased to approximately 40mm. There are elasticated bands at the front and rear to hold a head torch.

Pros & Cons: The increased cradle clearance allows a design which results in a lower transmitted force. See El Cap.

In test-transmitted forces: Top impact 4.2kN, Front 2.9kN, Side 2.5kN, Rear 3.1kN.

JB Lightweight after impact - note the obvious damage indicative of fibre glass helmets.

HB Carbon/Dyneema

This new shell material is constructed from resin bonded woven Carbon/Dyneema matting, this is 2±0.2mm thick. The cradle, headband and chinstrap are the same as that used in all the other HB helmets. The shell/cradle clearance is approximately 40mm. There are elasticated bands at the front and rear to hold a head torch.

Pros & Cons: The new shell material produces a helmet with the best crown impact performance with almost the lightest weight. In penetration tests this helmet has shown that it can resist repeated impacts on the same location. The shape of the helmet has resulted in a higher front impact result than might have been expected, although few impacts occur here it does show that even with the most modern materials designers have to make best use of them. After an impact there are obvious circular striations visible through the resin, but the resin doesn't usually delaminate.

In test-transmitted forces: Top impact 4.2kN, Front 7.4kN, Side 2.5kN, Rear 4.8kN.

Petzl Ecrin Roc

The Ecrin Roc features a 2.2±0.2mm thick injection moulded polycarbonate shell that is supported by a two-strap cradle. The shell has some 3.7±0.2mm deep reinforcing buttresses on the inside of the crown. There is a fully adjustable foam padded headband, and the helmet is supplied with a thicker foam replacement for those with a smaller head. The chinstrap has an adjustable neck strap that helps maintain the helmet in the correct position on the head. The shell/ cradle clearance is approximately 38mm. The shell features four clips to facilitate the fitting of a head torch.

Pros & Cons: The buttresses on the inside of the shell do a very good job of improving the helmets performance, similar shells without them have, in the past, struggled to meet the required standards. The outer shell is very impact resistant when undamaged, but polycarbonate can be very weak if it is already damaged. It is also prone to the effects of solvents so no paint or stickers other than those supplied by the manufacturer should be used. The shell shows no signs of damage after an impact, but the cradle is stretched making further use of the helmet unadvisable.

In test-transmitted forces: Top impact 4.4kN, Front 7.1kN, Side 2.7kN, Rear 1.4kN.

Camp High Star/ Rock Star

These two helmets are essentially the same, with the more expensive High Star having greater comfort levels. They have an injection moulded high-density polyethylene (HDPE) shell of thickness 3.6±0.5mm. Unlike the other helmets with cradles, these have an injection moulded polymeric cradle featuring three straps and a reinforced crown at the junction. The headband adjusts similar to a tie-wrap, and so is easy to make smaller but can be difficult to enlarge. There is an adjustable chinstrap, with a curved buckle. In the crown of the helmet is an energy-absorbing piece of expanded polystyrene foam, with a thickness of approximately 21mm at its thickest point.

The Rock Star has a 6.0±0.1mm thick piece of soft foam between the cradle and the wearer's head, a thinner foam is also used to pad the headband. There is also a small piece of 5±0.1mm thick closed cell foam covering a rivet at the rear of the shell. The **High Star** features the same foam comfort pads as the Rock Star, but they have a different face textile and the whole cradle assembly is covered. The closed cell foam on the inside shell covers almost the whole rim of the helmet to a depth of 40mm. This covers all the cradle and chinstrap mounting points. This helmet also features an elasticated head torch holder at the front and a strap/press-stud cable retainer at the rear. There is no clearance between the cradle and the foam insert.

Neil Morris on his new route "The Laughing Russian" at Rhoscolyn, at a recent BMC youth meet. Credit: John Arran

Pros & Cons: Previous research in the field of Industrial helmets has shown that shell/cradle helmets can receive a boost in their performance by the inclusion of foam inserts which is the case with these helmets. The inclusion of the press-stud at the rear of the High Star helmet probably explains why its rear impact result is higher than the Rock Star. After an impact the shell returns to its original shape, but in coloured shells there are obvious strain marks in the colouring, unfortunately these are hard to see on white-shelled helmets. The foam insert will however be seriously compromised and the helmet should be discarded.

In test-transmitted forces (Rock Star): Top impact 7.2kN, Front 2.7kN, Side 2.8kN, Rear 2.9kN.

In test-transmitted forces (High Star): Top impact 7.1kN, Front 2.4kN, Side 3.2kN, Rear 5.6kN.

Edelrid Ultralight

The construction of this is similar to the Camp Rock Star. The shell is made from 2.7±0.2mm thick injection moulded polyolefin (this is probably polypropylene but could be polyethylene we were unable to determine exactly which). There is an expanded polystyrene energy absorbing crown insert of approximately 18mm thickness. The cradle has three straps and the plastic, adjustable, headband has a synthetic fabric comfort lining. The adjustable chinstrap has a flat buckle. On the inside of the shell, at the front there is a 40mm square piece of hard, closed cell foam, which is 11.0±0.1mm thick. The helmet features four small metal hooks to help mount a head torch. The shell/cradle clearance is approximately 26mm to the foam insert.

Pros & Cons: For general points see the Camp Rock/High Star. This helmet offers more protection than those, but is also reliant on the foam insert The helmet can withstand several impacts, but this is true but only if the foam insert remains in place. It would seem that the function of the foam pad at the front of the shell is to reduce the force of the front impact. The shell does show striations after impact, even though it returns to its original form.

In test-transmitted forces: Top impact 5.5kN, Front 3.1kN, Side 2.4kN, Rear 3.5kN.

Hard shell, foam style

An impact resistant outer shell contains a foam liner for shock absorption, without the foam liner these helmets would be useless. In most cases the liner only offers protection from impacts on the crown. During an impact the outer shell deforms and the foam liner is pushed into contact with the head, the foam is thus crushed from both sides. If the liner is deformed too much then the impact force will be passed directly to the skull.

Camp StarTech (post May 2000)

A 2.0±0.2mm thick vacuum formed polycarbonate shell which prevents penetration and protects a 24±2mm thick expanded polystyrene foam energy absorbing liner which covers the inside crown of the helmet shell. There is an 8.5±0.1mm very soft foam comfort panel that is purely for the wearer's comfort and contributes very little to the helmets performance. There is an adjustable, padded headband, where the adjustment is via a very convenient twisting adjuster allowing quick changes of the helmet. The chinstrap also features an easy to adjust buckle with a quick release button. The shell features four clips to facilitate the fitting of a head torch.

Pros & Cons: The outer shell is very impact resistant when undamaged, but polycarbonate can be very weak if it is already damaged. It is also prone to the effects of solvents so no paint or stickers other than those supplied by the manufacturer should be used. The foam liner is good at absorbing impacts, and without it the helmet would be useless. This liner only offers protection from impacts on the crown and the only protection from off-centre impacts comes from 0.7±0.1mm thick soft foam panels around the rim of the helmet. After an impact the shell returns to its original shape and shows no obvious signs of damage. The foam liner may show some cracking, but not in all cases, it will however be seriously compromised and must not continue to be used.

In test-transmitted forces: Top impact 9.3kN, Front 3.1kN, Side 4.0kN, Rear 2.2kN.

Black Diamond Half Dome

The shell is 3±0.3mm thick injection moulded ABS; the liner thickness varies from approximately 20mm at the crown to 8mm at the front and 10mm at the rear. There is a two-strap cradle with a shell / cradle clearance of 7mm. The padded headband is adjusted via a leather strap with Velcro. There are four clips on the helmet to take the straps of a head torch.

The Black Diamond Half Dome. Note how no sign of damage is visible

Pros & Cons: The tests results from Leeds show a relatively high level of transmitted force in the top impact test. Because the initial certification tests at notified body CRITT show a very low level of transmitted force this helmet has been subjected to additional examination. A further test at Leeds using the same method and batch as the original test has confirmed the 12.7kN result. As stated in part 1 the original tests were conducted to give a comparison between helmets and did not intend to test exactly against the standard. Because of the variance of Leeds and CRITT results further tests have also been carried out to ascertain whether the helmet meets the standard. At the time of writing tests at Leeds have shown that depending on the exact method used and the batch tested it is possible to get results down to 9.3kN and possibly below, although most are still above 10kN. Because of the variation in test method and batch characteristics already noted this does not tell us whether the helmet passes the standard, but it does suggest that the helmet is on the threshold. The manufacturer is of course concerned by these results and by the time you read this, representatives of the manufacturer, the BMC, Leeds and CRITT will have met to examine the test results and re-test the helmet under the original certification conditions. This should finally resolve the issue. The manufacturer is committed to providing a helmet that meets the standard and will take whatever steps necessary to ensure this. The result of these test will be posted on the BMC website.

As far as the basic design is concerned - the helmet is designed to give a low, comfortable fit and in this respect it succeeds well, although some find the chinstrap uncomfortable. The ABS shell may be prone to degradation by chemical attack due to solvents and so stickers / paint should not be applied unless supplied by the manufacturer.

In test-transmitted forces: Top impact 12.7kN, Front 5.3kN, Side 3.3kN, Rear 4.9kN.

Thick foam style

The foam shell deforms under impact, the amount of deformation depends on the size and shape of the impacting mass. It seems as though the more the mass penetrates the shell, the better the energy absorption (this means that for a given weight the thinner the impacting mass the better the energy absorption), but at present the limits of this are not known. We do know that a pointed mass impacting the shell penetrates nearly all the way through, and if the headform used in testing was soft then this type of shell may actually fail the penetration test.

Petzl Meteor

This helmet features an expanded polystyrene foam shell which at the rim varies in thickness from 21±1mm to 27±1mm, this increases to 33mm at the crown. A 0.8±0.1mm thick polycarbonate shell protects this foam. There are three 38±2mm diameter, 4.1±0.2mm thick soft foam comfort panels, which serve little purpose during an impact. Adjustment is via three screw-in soft foam columns of 40.5±0.1mm diameter and 14.0±0.2mm long, which compress very quickly under impact and serve little purpose in an impact. They do, however, when used correctly, allow good ventilation of the top of the head. There is no headband. The chinstrap is easy to adjust and quick release.

A cut away of the Petzel Meteor following a penetration test.

Pros & Cons: The lightest helmet on test. The polycarbonate outer layer is very thin and is only present for cosmetic reasons, it is so thin that it offers virtually no resistance to penetration. After an impact the foam is permanently deformed, and the helmet should be discarded as soon as possible.

In test-transmitted forces: Top impact 9.2kN, Front 4.7kN, Side 4.7kN, Rear 3.7kN.

Grivel The Cap

Another expanded polystyrene foam shell, this time varying in thickness from 20 to 31±1mm, protected by a 0.8±0.1mm thick polycarbonate shell. At the crown of the helmet there are three parallel ventilation slots, which are covered by a 3mm thick rigid plastic panel. This panel is 148mm long and 64mm wide at its widest point. On the versions tested the headband and chinstrap were identical to those on the Camp StarTech, but this year's have a different chinstrap buckle to prevent accidental opening whilst looking over ones shoulder.

Pros & Cons: As with all thick foam helmets, the polycarbonate layer is just for cosmetic reasons. The rigid plastic panel at the crown has the effect of preventing sharp objects piercing the shell, but only for impacts in the small area it covers. Outside this area sharp objects will pierce the foam just as with any other foam helmet. One undesirable effect of the rigid plastic is that after an impact on the crown, the foam is deformed, but the plastic panel elastically recovers, so the shell reverts to its original shape and the helmet appears undamaged.

In test-transmitted forces: Top impact 9.8kN, Front 1.1kN, Side 5.0kN, Rear 1.4kN.

Cassin Mercury

The final thick foam helmet considered in the current study. The foam varies in thickness from 42±1mm at the front to 18±1mm at the rear. The polycarbonate shell is 0.5±0.1mm thick. There is a headband with an easy to adjust zip style fastener and an adjustable chinstrap, which features removable ear protectors. The inside shell of the helmet is covered with a removable 3mm thick fabric covered foam insert that serves to improve the comfort of the helmet. The helmet design is heavily influenced by cycle helmets as is shown by the large front and rear air vents for forced air circulation.

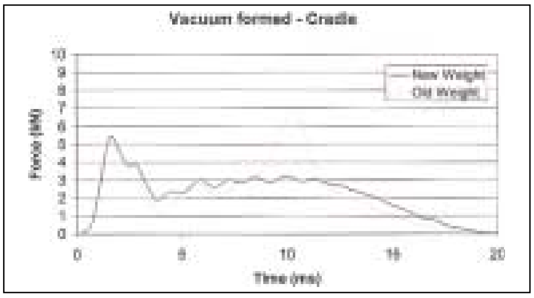
The Cassin Mercury showing obvious post impact damage.

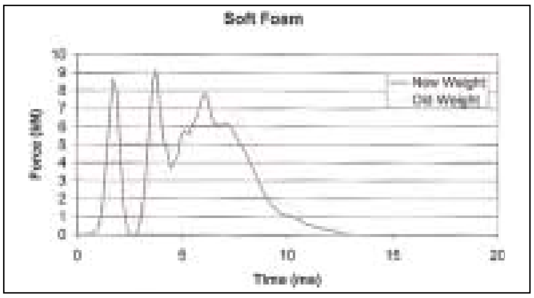
Pros & Cons – see Petzl Meteor.

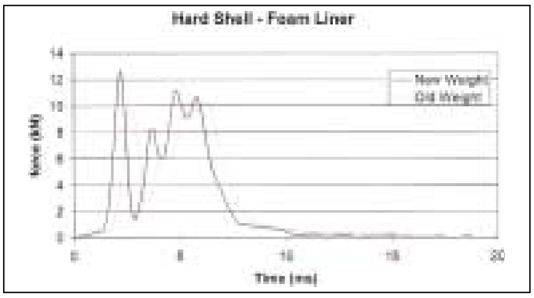
In test-transmitted forces: Top impact 10.4kN, Front 3.9kN, Side 4.8kN, Rear 3.8kN.

The Force/Time curves:

What happens during an impact







Shell/Cradle Helmet

The force time curves for this type of helmet indicate what is happening during an impact. First the cradle settles and the slack is taken out over the skull, resulting in a sudden increase in transmitted force (the initial peak on the chart). The shell then begins to deform and the cradle to stretch, which providing the two do not meet results in a plateau on the force/time curve, which then tails off to zero. If the cradle and shell meet, then a bump will occur on this plateau, the severity of which depends on the duration and intensity of the contact; this is the usual failure mechanism of this style of helmet.

Hard Shell/Foam Lined & Thick Foam Helmets

The force/time curve characteristics of these types of helmet is not yet fully understood, and is the subject of ongoing high speed video and deceleration studies. Careful inspection of the curves for these two types of helmet reveals that they are very similar in shape. They both feature a large peak that occurs immediately upon impact that is followed by a sudden drop off in transmitted force. This is most likely due to something “collapsing” in the helmet, similar to the cradle settling described above. What then follows is the result of the impacting mass penetrating the foam layer (pushing the deforming hard shell into the foam in the case of the hard shell/foam helmets).

The change in drop test weight

The switch from the smaller diameter (90mm) 1996 standard drop test weight (which has been in use since the very first UIAA standard was introduced) to the 2000 (100mm diameter) drop weight had an unexpected result. As can be seen from the generic force/time curves shown, helmets that rely upon foam as the major energy absorbing mechanism transfer more force with the new weight (blue line). We believe this is because the wider weight does not penetrate the foam as far as the old one (dotted red line). For the same reason the wider weight benefits more traditionally styled helmets, as the weight can no longer deform the shell as much and no contact occurs between the cradle and the head.