Report of some work on the impact of shock loading of some safety line set ups

Introduction

A question was raised about the extent to which the pulley and toothed ascender and the STOP set ups for progress capture or life lining could withstand shock loading. The question lead to a proposal to undertake some preliminary work on the two set ups and a day was spent doing some simple drop testing using the Bradford Pothole Club's instrumented drop test rig. This report describes the set ups, the work done and results, some consideration of the information supplied by manufacturers and of tests set out in various European standards together with some discussion and recommendations.

Set ups

The pulley and toothed ascender set up comes in two variants, see Diagrams 1 and 2, the key difference being which side of the pulley the toothed ascender is located with respect to the live rope, that is to the load which is attached to the rope on the left hand side. The purpose of the set-up is to provide a system where the life line remains securely captured.

The toothed ascender after pulley (Diagram 1) means that the load in arresting the falling test mass is passed around the pulley and then onto the toothed ascender. Whereas in the toothed ascender and pulley set up (Diagram 2), the load is solely taken by the toothed ascender with the pulley being a simple guide to ease the passage of the rope during taking in. A key feature of the toothed ascender after the pulley set up is the need to ensure the toothed ascender is held in a manner such that the toothed ascender does not hit the pulley when under load.

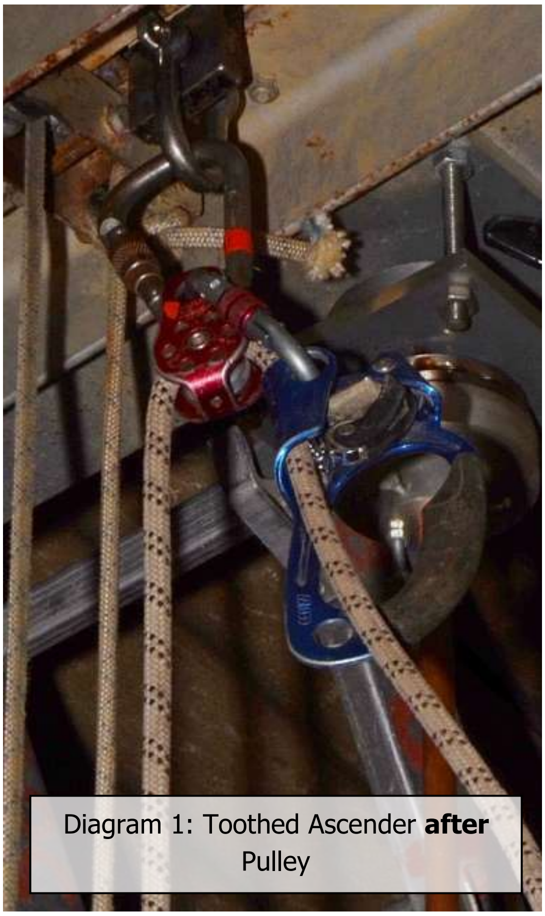

Diagram 1: Toothed Ascender **after** Pulley

Diagram 2: Toothed Ascender **before** Pulley

Report of some work on the impact of shock loading of some safety line set ups

Diagram 3: Assisted handline

A variant in rigging the life line is known as the Assisted Handline, see Diagram 3, was also tested. By securing one end of the life line rope to the head of the pitch (or test rig during our tests), securing the load to the rope through a pulley and back to the pitch head where the rope is secured through the pulley and toothed ascender a nominal 2 to 1 mechanical advantage on the load is achieved.

The STOP can also be set up in two variants, either fully rigged as in Diagram 4 or part rigged as in Diagram 5.

The purpose of the set-up is to also provide a system where the life line remains securely captured. The two variations were investigated as it was unclear as to the significance of having the rope carry on round the second, lower cam.

Diagram 4: Stop fully rigged

Diagram 5: Stop part rigged

Work done

The Drop Test Rig set up is described at http://www.roperesearch.co.uk/ . The test mass was adjusted to have a nominal mass of 80kg. Subsequent weighing found it to be 85kg. The speed at which the test mass fell was found to be around 10% slow compared with that required by European Standards. The combined effect of these two factors is to slightly reduce the energy available to extend the rope, thus slightly reducing the recorded forces. The load cell was checked against another more recently calibrated load cell and was found to be within 1%. The results are tabulated in Table 1 at the end of the report. All work was conducted with EN 1891:1998 low stretch used 10mm ropes. One end of the rope was secured to either the test mass or an anchor using a figure of eight knot.

Single Ascender

Two drop tests were conducted with a used Croll ascender, see diagram 6 for set up. The first Drop (labelled 10 BPC 40) used a 0.44m length of rope between the Croll and the test mass. Together with the crabs at the top, the overall drop was 0.54m with a Fall Factor (FF) of 1.2. The peak force measured was 6.6kN and caused the rope to be crushed to an oval shape approximately 9mm by 11mm, no cuts were observed. The second drop (11 BPC 40) consisted of extending the rope used to 0.81m which gave a FF 1.1. The peak force increased to 7.0kN (mostly likely due to the knot having been tightened by the prior drop). The Croll completely cut the sheath and 3 cords were observed to have broken.

Diagram 6: Croll

Pulley and Ascender

Three drop tests were conducted with the toothed ascender after pulley set up using a Petzl Ascender and a Petzl Fixe pulley. The first test (12 BPC 40) used a rope length of 0.45m with a FF 1.4, gave a peak force of 5.4kN and resulted in a badly damaged pulley, see Diagram 7. The second test (13 BPC 40) with a new pulley using a rope length of 0.22m with a FF 1.7 gave a peak force of 4.8kN and visibly pushed the side plates of the pulley apart by a few millimetres. A repeat (the third) test (14 BPC 40) on the same pulley using a rope length of 0.44m with a FF 1.4 gave a peak force of 6.7kN and badly damaged the pulley, similar to the first test, Diagram 7. There was no visible damage to the rope in these three tests.

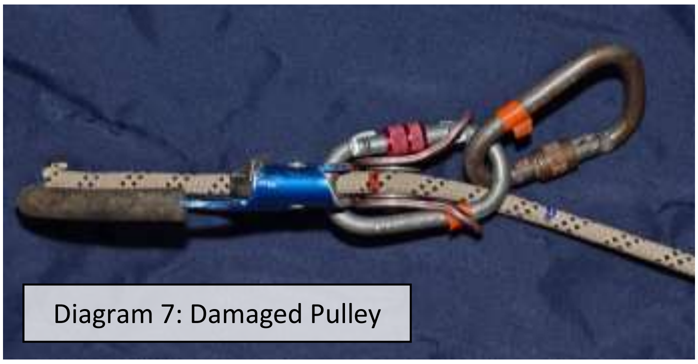

Diagram 7: Damaged Pulley

A simple theoretical analysis indicates that the pulley sees near double the force that is recorded on the load cell due to the mechanical advantage created by this particular set up, see Annex 1.

Report of some work on the impact of shock loading of some safety line set ups

Ascender and Pulley

One drop test (20 BPC 40) was conducted with the toothed ascender before pulley set up using a Basic ascender and a Petzl Fixe pulley. The test used a rope length of 0.50m with a FF 1.3 gave a peak force of 6.7kN and resulted in a jammed cam within the Croll. The cam was released using a hammer and it was noted that approximately half of the sheath of the rope had been cut.

Assisted Handline

Two drop tests were conducted with the assisted handline set up using a Petzl Fixe pulley and a Basic ascender. The first test (25 BPC 40) used a rope length of 1.0m split evenly either side of the bottom pulley (and load). One end of the rope was secured to the toothed ascender and load cell with the other end secured to the head of the drop test rig. An approximate FF 1.2 generated a peak force of 5.2kN. A simple theoretical analysis indicates that the peak force would be the same on both the toothed ascender (as recorded) and the knot securing the other end of the rope to the head of the drop test rig, see Annex 1. So the force on the pulley would be near double that seen by the load cell.

There was no visible damage to the pulley attached to the load. The rope slipped some 2cm before being arrested. There was no apparent damage to the rope though the rope was crushed to an oval shape approx. 9mm by 10mm.

The second test (26 BPC 40) used the same rope but extended in length to 2.0m split evenly either side of the pulley. An approximate FF 1.1 gave a peak force of 6.1kN on the toothed ascender which was secured to the load cell. The rope slipped some 3cm before being arrested. The rope was crushed to an oval shape approx. 8mm by 12mm and showed some indentations replicating the teeth of the ascender.

Two Toothed Ascenders

One drop test (27 BPC 40) was conducted with a Croll ascender at one end of the rope and a Basic ascender at the other end. Thus there was no knot present. The set up used a 1.0m length of rope with a FF 1.1 and gave a peak force of 6.6kN. The Basic ascender allowed the rope to slip some 3cm but the Croll completely cut the sheath and 3 cords of the core.

STOP

Two drop tests were conducted with a fully rigged STOP. The first drop (30 BPC 40) used a rope length of 1.0m with a FF 1.2 and gave a peak force of 7.7kN. Although the STOP allowed some 3cm of rope to slip through before arresting the rope, no visible damage was observed to the rope. In addition, the STOP's lever moved freely after the test whilst still under load and allowed the test mass to descend. The second drop (31 BPC 40) using the same STOP used a rope length of 0.5m with a FF 1.4 and gave a peak force of 6.2kN. The STOP allowed some 4cm of slippage on this occasion, there was no damage to the rope and the STOP functioned as post the first drop.

The next two drop tests were conducted with a part rigged STOP. The third drop (32 BPC 40) used a rope length of 0.5m with a FF 1.4 and gave a peak force of 6.1kN. A similar result to the fully rigged STOP occurred, the slippage being around 3cm. The forth drop (33

BPC 40) used a rope length of 1.0m with a FF 1.2 and gave a peak force of 7.3kN. A similar result to the fully rigged STOP occurred, the slippage being around 3cm.

Diagram 8: Stop and Cow's Tail

A fifth drop test (34 BPC 40) was set up to reflect a situation where the STOP was indirectly anchored via a length of rope as would be common practice when rigging a pitch head, see Diagram 8.

To emphasise the bottom rope has a figure of eight knot at each end of the additional short section of rope plus another mid-way between them making three knots plus the main rope's knot available to absorb some of the energy from the fall. The overall drop height was set to be 1.0m with a FF 1.0 and gave rise to a peak force of 5.0kN. It is considered that the reduction in peak force is due to the presence of the additional knots and rope. The STOP performed post drop as before.

Dig. 9: worn Stop cam

A sixth drop (35 BPC 40) was conducted with a similar set up but using a different, more worn STOP, see Diagram 9 which shows substantial wear of the top cam or sheave. Whilst the overall drop height was set at 1.0m with fresh rope and knot, because of the reuse of the additional rope and tightening of the knots within that rope, the peak force observed rose to 6.2kN. The drop did result in some slippage compared to the few centimetres observed with the much less used STOP.

Edelrid Eddy Semi-Automatic Belay Device

Diagram 10: Eddy

A drop test (40 BPC 40) was conducted using an Edelrid Eddy semi-automatic belay device, see Diagram 10. The overall drop height was set to be 1.0m with a FF 1.1 and gave rise to a peak force of 7.4kN. It is noted that the manufacturer's instructions state that an Eddy should only be used with EN 1891 low stretch rope if either belaying one person in a top rope set up or if lowering one person, in addition the manufacture highlights slack rope "build up" should be avoided. The rope slipped some 5cm before being arrested.

Discussion

It is notable that in only four of the 16 drop tests conducted were the peak force recorded less than 6kN. Annex 2 presents a review of European Standards and other work which highlights the fact that 6kN is considered to be the safe limit of shock loading to a human body.

Annex 3 presents some information that indicates that the peak force in a rope induced by arresting the fall of a human body is around 80% of that induced by a rigid steel mass. Thus our use of an 80kg rigid steel mass directly simulates a human body of 100kg. (It should be noted that whilst the 100kg value is based on the 95% percentile of the weight profile of the UK adult population, see http://www.hse.gov.uk/research/rrpdf/rr342.pdf.) Hence the majority of drops resulted in peak forces likely to cause an injury to a person.

The relationship between peak force, rope length and drop length / Fall Factor is complex. Unpublished work indicates that even short lengths of rope (a few tens of centimetres) can give rise to falls resulting in peak forces greater than 6kN in situations such as those which arise at the pitch head during getting on or off the rope, or anchor failure. Even higher peak forces are also encountered where some of the connections between person and anchor are metal in place of rope.

In those drops where the toothed ascender directly saw the forces in the rope, a range of rope damage was observed. This is in line with observations reported on the internet, such as can be seen at https://www.youtube.com/watch?v=4P5DX2mgPoM&feature=youtu.be .

The question which initiated the work used the two phrases "progress capture" and "life lining". The term belaying is also used to cover similar activities. No authoritative definition of these terms has yet been found. However, it is considered that progress capture does involve the use of mechanical equipment to securely hold the rope without the need for human intervention unlike life lining or belaying. What appears clear from the preliminary work undertaken is that toothed ascenders can obtain a secure hold of the rope so quickly as to create consequences of potentially injurious peak forces as well as damage to the rope.

Given the damage to ropes observed, and peak forces recorded, the question has to be asked should toothed ascenders be used in a system where a dynamic load is foreseeable?

What was surprising was the degree of damage impacted on the pulley in the pulley and toothed ascender set up. The spreading of the pulley cheeks is only made possible by the fact of the pulley being on the CONVEX side of the crab. A simple theoretical analysis indicates that this is the set up places a force on the pulley near double that seen in the rope and the load cell, see Annex 1. Thus the peak force seen by the pulley were around or above 10kN. Petzl note that the safe working load on their Fixe pulley is 2.5kN on the rope or 5kN across the pulley. Studies on rope access workers personal protection equipment (PPE) undertaken for the Health and Safety Executive, see http://www.hse.gov.uk/research/crr_pdf/2001/crr01364.pdf have indicated that "It is possible to increase peak forces to 200% of the gross weight of the operative by moving abruptly or braking"; 200% of gross weight being equivalent to 2kN (2 times 100kg). So the safe working load can be approached by abrupt movement.

It is therefore considered that the technique is not acceptable and should no longer be used.

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The work on assisted handlines brought out the fact that if the person being assisted falls, then the peak force felt by them is double that felt by the life liner, see Annex 1. A key feature of an assisted handline is that the person is not being suspended; they are perforce in contact with the climb. Thus the potential for high peak forces is much reduced. Hence the risk of an injurious fall or damaging the rock are considered to be acceptable. Even so it emphasises the need for keeping a very tight rope when using the assisted handline technique.

The STOP work indicates that with a suitable energy absorbing connector, the STOP may be suitable for use in progress capture. Discussions with representatives of Petzl have clarified that the manufacturer does not consider the Petzl STOP to be a belay device of any form. Furthermore, Petzl have never advocated the use of the STOP part threaded. So use of the STOP in this manner would be out with manufacturer's guidance. It is an open question as to whether insurers would condone such usage as a planned activity, as opposed to an improvised technique brought into use to extricate a person.

One feature of the STOP is that there is no need to obtain slack in the rope to release it. However, studies on rope access workers PPE mentioned above, found in dynamic testing that the rope could become jammed between the cam of the STOP and the side plate, causing significant damage to the rope and jamming the devise.

A review of the appropriate standards for descenders, rope adjustment devices and braking devices is presented in Annex 4, together with the associated dynamic test requirements. Of these only EN 12841: 2006 relates to work positioning devices and applies to devices for use on low stretch EN 1981 rope. EN 15151-1:2012 applies to braking devices using EN 892 dynamic ropes in any mode. It also applies to braking devices used for lowering or abseiling using EN 1981 low stretch ropes, that is not to an ascending mode.

The dynamic test requirement in EN 12841:2006 uses criteria that the device shall have a maximum braking force of 6kN and an arrest distance of no more than 2m in a designated test set up using a 100kg rigid steel mass. However, although the device is for use with EN1891 low stretch ropes, it does specify linkage to a seat harness. The test set ups also refers to using the manufacturer's specified connector. One manufacturer provides an energy absorbing connector of 0.25m length which together with the extra connector means an overall length of approximately 0.35m. (That is based on their already being one connector in use to connect the device to the anchor.) However, such energy absorbing connectors are not reusable after taking a fall. The standard offers an alternative being a 1m long 11mm EN 892 (dynamic) rope with knotted loops at each end.

Tests incorporating a length of EN 1891 low stretch rope to reflect how a pitch head would be rigged illustrated a noticeable reduction in impact force. It is noted that the impact is reduced as knots tighten, however repeated drops significantly reduce the ability for a knot to absorb the impact of a fall. Further work using EN 892 dynamic rope could provide evidence for much lower peak forces.

It is noted that as part of the research to produce this paper, changes in manufacturers' advice was identified which was previously unknown to a range of persons. It raises the question as to whether BCA should provide a service to monitor a range of devices produced by various manufacturers and alert BCA members when such changes occur.

Recommendations

1. The Equipment & Techniques, Qualifications Management and Training committees should consider whether toothed ascenders are no longer used as "progress capture" devices for life lining/belaying.

2. BCA should recommend that the pulley and toothed ascender set up outlined in Diagram 1 should no longer be used.

3. QMC should discourage the use of the STOP for planned belaying activities.

4. QMC should consider further testing with the STOP descender using a dynamic rope connection system to understand its limitations for use as an improvised belay device in an emergency/unplanned activity.

5. QMC should highlight to instructors the impacts observed when using low stretch EN 1891:1998 rope to belay; highlighting the need to maintain a tight rope at all times if using EN1891 low stretch rope, or consider the use of dynamic rope within the system.

6. BCA should consider setting up a service of monitoring new and changes on manufactures' devices so as to provide alerts to BCA members of significant changes

Acknowledgements

Thanks goes to the Bradford Pothole Club for the use of their rope test rig and to R Rodgers for helpful advice and assistance.

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26 March 2019

Drop	Device	Location	Other End	Rope	Rope length	Extra Drop	OL	FF	Peak Force	Max Rope Length	Peak Energy	G prime	Rope Slip	Damage
				# 1	m #2	m #3	m #4	#5	kN	m #6	J	m/s^2 #7	m #8	
10 BPC 40	Croll	Top	knot	fresh	0.44	0.10	0.54	1.2	6.6	0.77	600	8.47	0.02	rope crushed to oval 11 by 9mm
11 BPC 40	Croll	Top	knot	part reused from 10	0.81	0.10	0.91	1.1	7	1.06	945	8.46	N/E	rope sheath cut & 3 cords broken
12 BPC 40	P&A #9	Top	knot	fresh	0.45	0.16	0.61	1.4	5.4	0.84	647	8.42	0.02	rope none visible, pulley badly damaged
13 BPC 40	P&A #9	Top	knot	fresh	0.22	0.16	0.38	1.7	4.8	0.50	383	8.48	N/E	rope none visible, pulley plates spread by few mm
14 BPC 40	P&A #9	Top	knot	part reused from 13	0.44	0.16	0.60	1.4	6.7	0.78	625	8.55	N/E	rope none visible, pulley badly damaged
20 BPC 40	A&P #10	Top	knot	fresh	0.50	0.16	0.66	1.3	6.7	0.95	776	8.54	0.04	rope sheath part cut, ascender cam firmly wedged
25 BPC 40	Assisted handline	Ascender	knot		2 * 0.5	0.08			5.2 #11	1.00	414	8.56	0.02	rope crushed to oval 9 by 10mm
26 BPC 40	Assisted handline	Ascender	knot	part reused from 25	2 * 1.0	0.08			6.1 #11	1.51	566	8.56	0.03	teeth crushed to oval 8 by 12mm
27 BPC 40	Ascender s	Basic	Croll	fresh	1.00	0.10	1.10	1.1	6.6	1.61	1408	8.47	0.03 at top	rope at bottom sheath cut & 3 cords broken

Table 1 Data from Drop Tests

Drop	Device	Location	Other End	Rope	Rope length	Extra Drop	OL	FF	Peak Force	Max Rope Length	Peak Energy	G prime	Rope Slip	Damage
				# 1	m #2	m #3	m #4	#5	kN	m #6	J	m/s^2 #7	m #8	
30 BPC 40	Stop fully rigged	Top	knot	fresh	1.00	0.20	1.20	1.2	7.7	1.50	1132	8.47	0.03	No visible rope damage and more rope was able to freely slide post drop
31 BPC 40	Stop fully rigged	Top	knot	fresh	0.50	0.20	0.70	1.4	6.2	0.89	659	8.49	0.04	
32 BPC 40	Stop part rigged	Top	knot	fresh	0.50	0.20	0.70	1.4	6.1	0.88	651	8.56	0.03	
33 BPC 40	Stop part rigged	Top	knot	fresh	1.00	0.20	1.20	1.2	7.3	1.42	1076	8.46	0.03	No visible rope damage and more rope was able to freely slide post drop
34 BPC 40	Stop part rigged with rope belay	Midway	knot	fresh	1.00	0.00	1.00	1.0	5	1.23	983	8.59	N/E	
35 BPC 40	Different Stop part rigged with rope belay	Midway	knot	fresh	1.00	0.00	1.00	1.0	6.2	1.16	1107	8.63	N/E	
40 BPC 40	Edelrid Eddy	Top	knot	fresh	1.00	0.08	1.08	1.1	7.4	1.46	1113	8.51	0.05	
Notes														
#1 Toothed Ascender work used a 10mm used rope. Fresh means not previously tested.														
#2 length was from point of exit from device to metal belay of test mass so included knot.														
#3 The Extra Drop was due to the crabs and devices taking up height and estimated.														
#4 OL = Overall length of drop being sum of rope length and extra drop.														
#5 FF = Fall Factor.														

Table 1 Data from Drop Tests

#6 max Rope Length is the maximum length the rope extended to whilst arresting the test mass.
#7 Gprime is the value of the acceleration of the test mass during its free fall period.
#7 cont. Note it is some 13% lower than the acceleration due to gravity and 11% below that required by the standards.
#8 estimated by eye, N/E not estimated
#9 P&A Ascender after Pulley see Dia 1
#10 A&P Ascender before Pulley see Dia 2
#11 The pulley saw double this load, see Annex 1

Table 1 Data from Drop Tests

Annex 1 – Forces on the Pulley

A1.1 It is obvious that in a static situation, suspending two equally sized masses connected by a rope though a pulley will result in the pulley seeing the weight of both masses. Also, that part of the rope on one side of the pulley will be parallel to the rope part on the other side of the pulley. But if the rope parts are not parallel, then the force on the pulley sheave bearing will also depend upon the angle between the two ropes and as a consequence be somewhat less. If the angle between the two rope parts is 60 degrees, then the force reduces by approximately a factor of 0.9. Hence the use of the phrase "nearly double" in the report.

A1.2 It is noted that in the dynamic situation of arresting a falling mass, the bearing is likely to not be freely running with the high forces generated so it is feasible that the angle between the rope parts could be even more distorted. Assuming a freely running bearing and given the rope is not turning the pulley sheave, then the forces in the part of the rope on one side of the pulley must equal the force in the part of the rope on the other side of the pulley.

A1.3 In the pulley and ascender set up, the rope parts on either side of the pulley are clearly not parallel due to the location of the ascender. The ascender transfers the force from the rope back into the crab, thus offsetting the nearly double force seen by the pulley back to the force caused by arresting the fall of the test mass.

A1.4 In the assisted hand line set up, the force measurement was made on one rope part. By the above argument, the force on the other rope part is nearly the same. So the force on the pulley sheave bearing is nearly double that recorded. Hence in use, a person falling on an assisted hand line would experience nearly twice the force experienced by the life liner.

Annex 2 – Requirements of EN standards on Peak Forces

A2.1 EN 355:2002 on energy absorbers as personal protective equipment against falls from a height, has a requirement for the breaking force of not exceeding 6kN. The test set up requirements refer to EN 364:1993 which uses a 100kg mass in a Fall Factor 2.0 based on a 2m overall length of lanyard.

A2.2 EN 958:2017 on energy absorbing systems for use on via ferratas has a requirement that the maximum impact force shall not exceed 6kN. The test set up requirement is complex but involves using a 120kg test mass.

A2.3 EN 1496:2017 on rescue lifting devices has a requirement that the braking force shall not exceed 6kN. The test set up requirements refer to EN 364:1993 which uses a 100kg mass in a Fall Factor 0.15 based on a 4m overall length of line.

A2.4 Although there are other standards covering items such as descenders, lanyards, full body harnesses, sit harness and rescue harnesses, the requirements relating to dynamic performance are based on simply not breaking or releasing the load.

A2.5 Crawford, see http://www.hse.gov.uk/research/hsl_pdf/2003/hsl03-09.pdf , undertook a major piece of work for the Health and Safety Executive with the objective of seeing *"if it is medically supportable to develop energy absorbing devices with arrest force greater than the present CEN standard 6kN maximum advised for wearers of industrial full body harnesses"*. He concludes that *"the present 6kN limit (EN standards) is a wise choice for body weights in the range 80kg to 100kg"*. Though he does go onto recommend that *"4kN maximum arrest force is more suitable for body weights in the range 50kg to 80kg, and 8kN max would be suitable for body weights in the range 100kg to 140kg"*.

A2.6 Given that EN standards all relate to using rigid steel test masses, a factor needs to be taken into account for the difference in response to such forces by a human body. (Although it is acknowledged that Crawford omits discussion on this specific topic.) This is the subject of Annex 3.

A2.7 In contrast, EN 892:2012 +A1 2016 on dynamic mountaineering ropes has a requirement that the peak force shall not exceed 12kN (for a Fall Factor 1.7 using an 80kg mass) for a single or twin rope. (Half ropes have a lower requirement of 8kN.) Whereas EN 1891:1998 on low stretch kermantle ropes has a requirement that the peak force shall not exceed 6kN (for a Fall Factor 0.3 using an 100kg mass for Type A and 80kg for Type B ropes. The reason for these significantly differing values is not known. It is speculated that they reflect the widely different uses of the two types of rope, viz climbing verses rope access.

Annex 3 – Relationship of peak forces arising from falling steel masses and human bodies

A3.1 The work conducted by us has been based on a nominal 80kg rigid steel mass. It is known that the equivalent peak force experienced by a human body is proportionally less, though there is a lack of evidence to clearly indicate that relationship.

A3.2 In this discussion we will focus on the ratio of the peak force seen by a human compared to that seen by a rigid steel mass and express it as a percentage value. Thus if the ratio is 80% and a rigid steel mass experiences in a fall set up a peak force of say 10kN, then the expected peak force which would be seen by a human body in the same fall set up is 8kN.

A3.3 One of us did hear of anecdotal information which suggested a ratio of 50% but with no literature to back the value.

A3.4 Petzl has reported a range of work, including https://www.petzl.com/GB/en/Sport/Fall-comparison-with-rigid-human-mass?ActivityName=Rock-climbing . Although the text claims the ratio is 70%, the values cited in the figures indicate 50%.

A3.5 Work published on a commercial web site reports RopeLab have found values between 70 and 80%.

A3.6 A paper by Holden, May and Farnham, see http://www.itrsonline.org/PapersFolder/2009/Holden-May-Farnham2009_ITRSPaper.pdf gives a single value of 80%.

A3.7 A comment on a web based forum by an individual who has a good reputation within the climbing world, see https://www.mountainproject.com/edit/forum-message/0?replyToId=114310951&quoteId=114321524 states that an "80kg steel mass represents the effect of a 100kg human body in a harness". That is a value of 80%. This comment also offers an explanation of why one of the criteria within the EN 8921 standard for climbing rope and in EN 1891 for Type B low stretch rope is based on using an 80kg mass.

A3.8 It would therefore seem that either one uses 80% to prudently predict the impact on a human body from a fall situation which has been measured using a rigid steel mass or one uses an 80kg rigid steel mass to directly simulate a human body of 100kg. (The 100kg value is based on the 95 percentile of the weight profile of the UK adult population, see http://www.hse.gov.uk/research/rrpdf/rr342.pdf though the report notes that the true 95% percentile is likely to be nearer to 118kg.)

Annex 4 – Requirements of EN Standards for descenders, rope adjustment devices and braking devices

A4.1 EN 341:2011 covers descenders and covers four types. The most flexible is Type A which allows the highest rate of descent. There is only one requirement related to a scenario involving shock loading (Clause 4.3) which requires that the device shall not release the test mass and that no part of the device shall show any signs of breaking or tearing. (There is no condition laid down on the state of the line post test.)

A4.2 The test set up is to hang the device from a line 4m below the attachment point and then attach a test mass equal to the maximum rated load of the device. The mass is then raised by 0.6m. The mass is released and an observation is made as to whether the device show any signs of breaking or tearing.

A4.3 EN 12841:2006 covers rope adjustment devices which are designed to "… link a seat harness to a working line … to allow access … to work positions, to give support and protection against falls". They therefore allow movement both up and down a rope. The standard describes three types of rope adjustment devices. The most flexible (Type A) *"accompanies the user during changes of position … and which locks automatically to the safety line under static or dynamic loading"*. The others either manually lock on the rope or provide sufficient friction to *"achieve a controlled downward motion and a stop…"*. The type A device is subject to more stringent testing and has two requirements involving shock loading. The first requirement (Clause 4.2.5) is that the device shall have a maximum braking force of 6kN and an arrest distance of no more than 2m in a designated test set up using a 100kg rigid steel mass. The second requirement (Clause 4.2.6) is that the device shall not release the mass and an arrest distance of maximum 2m in a separate designated test set up using a 100kg rigid steel mass.

A4.4 Both designated test set ups refer to using the manufacturer's specified connector. At least one manufacturer provides an energy absorbing connector of 0.4m length which together with two connectors / crabs means an overall length of approximately 0.6m. The standard offers an alternative being a 1m long 11mm EN 892 (dynamic) rope with knotted loops at each end.

A4.5 The test set up for the first requirement (Clause 5.6.2) is to hang a rope using a figure of 8 knot to the load cell attachment point and fit the device 1m below the attachment point. Then a 100kg mass is attached via the specified connector to the device. After allowing it to hang for 60 seconds from the device, the mass is lifted up twice the height of the connector and at a horizontal distance of 0.25m from the attachment point. Then the mass is released and the peak force recorded together with the distance the device has slipped down the rope.

A4.6 The test set up for the second requirement (Clause 5.6.3) is similar to that for the first requirement except that the mass (and device if need be) is lifted up 2m (rather than just twice the length of the connector). The mass is then released and an observation is made as to whether the device has released the mass together with the distance the device has slipped down the rope.

A4.7 EN 15151-1:2012 covers 8 types of braking devices, the most demanding being Type 8, a device *"for belaying and abseiling with a panic locking element"* but limits devices to only using EN 892:2012 dynamic ropes when used in a dynamic situation. The standard has one requirement related to shock loading, (Clause 5.4) which requires that the falling mass shall not be released, that the average slippage of rope through the device shall not exceed 1500mm and that the test mass can then be lowered.

A4.8 The test set up is to use a length of rope of more than 3.8m length and tie a figure of eight knot in it to attach it to an 80kg test mass. Then pretension 1.2m of the rope by hanging the mass for a period of 60 seconds. Then insert the rope into the device and lift the mass 1m above the point where the rope leaves the device. Straighten the rope to the mass by pulling on the rope on the other side of the device and ensure that the horizontal distance between the centre of gravity of the mass and the axis of the rope hanging down from the device is less than 0.3m. The mass is then released and an observation is made as to whether the device has released the mass together with the distance the device has slipped down the rope.