INFORMAL SYSTEMS TESTING
Belay & Brake Device Loading Evaluation

by Pete Vickers

Technical Rescue magazine has always been an advocate of real-world testing rather than purely 'laboratory' testing. This is because we work in the real world in far from ideal conditions and if there's a way for something to go wrong it eventually will. Informal testing may not be the most scientific but it can highlight a possible problem with equipment when used in a certain way or in combination with other equipment. This is the first in a series of INFORMAL TEST articles submitted by various rescue teams and agencies in which we hope to prove or disprove current convention. Remember that the results shown in this series will be specific to the test conditions, state of equipment, combination of the specific brands of rope and hardware, nature of the load applied, accuracy of the measuring equipment or individual's interpretation of results. These tests will not necessarily be repeatable but could highlight a problem with a system similar to yours that might warrant some further testing of your own.

Abstract
A variety of rope brakes/belay devices were attached to a line, and loaded until failure occurred. The failure methods and loads were then compared and contrasted.


System overview. Note intermediate 'change of direction' pulley to minimise hazard potential under system failure.

Introduction
Many different opinions exist, and indeed figures are often quoted regarding both absolute and relative failure loads of the various types of rope friction (brake, belay, etc) devices. This paper compares some of the more popular (river) rescue devices by both quantitively and qualitively evaluating their performance under loading.
The investigation was conducted at Riksanlegget, Sjoa, NORWAY. On 27th August 2006, by Pete Vickers (Sjoa Adventure AS – http://www.sjoaadventure.com) and Jan Gjeterud (Rescue 3 Norway- http://www.rescue3norge.no/).

System Description
An anchor (tree) was used to tether a load cell, via a triple loop of 25mm webbing. Various friction devices were then fixed to the load cell, and then connected to themain line, this in-turn was connected to a load. A truck with a heavy-duty engine and automatic transmission was used to progressively load the system. Since nearly all of the devices failed while the operator was still slowly & gradually releasing the vehicle brake, there was little or no shock loading on the systems.
The main line used was a 10.4mm diameter semi-static rescue line from Beal. (See Appendix 3 for more details). After each test run, the anchor was relocated along the rope, so that subsequent tests were performed on


Close-up of measuring rig attachment. Note backup loop to 'catch' the failed system.

a fresh section of rope.
The load cell used was a TEO 2000-SK 10. (See Appendix 2 for more info). All loads are quoted in daN, where 1daN = 10N (~=1 kg weight in the vertical plane). Prussik loops were constructed from individual 6mm diameter static cord, and closed with a double-fisherman's knot.

CASE 1: 2-WRAP PRUSSIK

DEVICE TYPE	FAILURE LOAD	FAILURE MODE	MECHANISM
Normal prussik with 2 wraps	180 kg	Initially gradual & controlled, then catastrophic.	Prussik slipped along rope, until burned through


Above Left: 2-wrap prussik, prior to loading
Above Right: 2-wrap prussik, after slippage occurred. Note blackened trail on the main line (to left), and bunching of the sheath (to right). Additionally, prussik loop is melted.

CASE 2: 3-WRAP PRUSSIK

DEVICE TYPE	FAILURE LOAD	FAILURE MODE	MECHANISM
Normal prussik with 3 wraps	550 kg	Initially gradual & controlled, then catastrophic.	Prussik slipped 15cm leaving a black trail along rope, until prussik burned through

CASE 3: 4-WRAP PRUSSIK

DEVICE TYPE	FAILURE LOAD	FAILURE MODE	MECHANISM
Normal prussik with 4 wraps	800 kg	Initially gradual & controlled, then catastrophic.	Prussik slipped 10cm leaving a black trail along rope, until prussik burned through

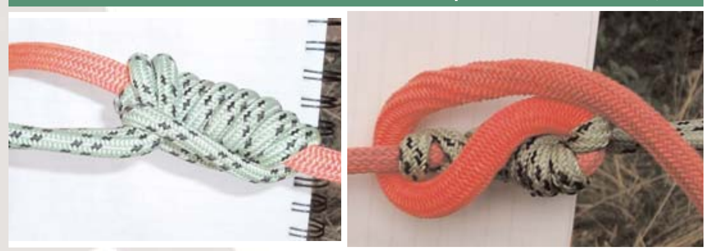
CASE 4: Twin 3-WRAP PRUSSIKS

DEVICE TYPE	FAILURE LOAD	FAILURE MODE	MECHANISM
2 normal prussiks with 3 wraps	700 kg	Initially gradual & controlled, then catastrophic.	One prussik slipped leaving blackened main line, until it met the other prussik, and in doing so induced slide in second prussik. Load sharing was thus poor.


Above Left: 2 'manual load sharing' normal prussiks with 3 wraps, prior to loading.
Above Right: 2 'manual load sharing' normal prussiks with 3 wraps, after failure.

CASE 5: KLEIMHEIST PRUSSIK

DEVICE TYPE	FAILURE LOAD	FAILURE MODE	MECHANISM
Kleimheist Prussik	250/>900 kg	Initially gradual slip, further loading gave later sudden failure.	Prussik inverted at 250kg, and then lodged against corrugated sheath, which held until > 900kg (where main line failed- see appendix 1 for details)


Above Left: Kleimheist prussik, prior to loading. Above Right: Kleimheist prussik, after loading. Note both blackened slide trail and sheathbunching on main line.

CASE 6: BULLDOG PRUSSIK

DEVICE TYPE	FAILURE LOAD	FAILURE MODE	MECHANISM
Bulldog Prussik	350 kg	Gradual Slipping	Gradual controlled slippage, with minimal damage to either rope or prussik.


Above: Bulldog prussik, prior to loading.

CASE 7: TAPE PRUSSIK

DEVICE TYPE	FAILURE LOAD	FAILURE MODE	MECHANISM
1" Flate Tape webbing Prussik	800 kg	Gradual slipping.	Prussik slips 3cm on rope, leaving pink dis-colouring from prussik rope.


Above Left: Tape prussik prior to loading.
Above Right: Tape prussik after loading. Note 'inversion' of tape loop which 'locks up' the system

CASE 8: PETZL TIBLOC

DEVICE TYPE	FAILURE LOAD	FAILURE MODE	MECHANISM
toothed ligh-weight rope grab	450/650 kg	Initial re-seating, then later catastrophic rope destruction.	Initial 'teeth' bite and slight travel at 450kg, then catastrophic separation of sheath from core at 650kg


Above Left: Petzl Tibloc prior to loading.
Above Right:: Petzl Tibloc at onset of failure at 450.
Note frays on upper side of main line & sheath bunching
Below: Petzl Tibloc after loading. Full separation of main line sheath from core, and sheath bunching on slack side.

CASE 9: PETZL RESCUECENDER

DEVICE TYPE	FAILURE LOAD	FAILURE MODE	MECHANISM
profiled cam rope grab	320/350 kg	Slight 'hop' at 320, then gradual slippage from 350	Compression of main line leads to slippage, and very squeezed (dam-aged) line.


Above Left: Petzl Rescuecender, prior to loading.
Above Right:: Petzl Rescuecender during slippage. Note flattened rope, and slack end sheath bunching.

CASE 10: CLOG ASCENDER

DEVICE TYPE	FAILURE LOAD	FAILURE MODE	MECHANISM
toothed cam rope grab	500 kg	Sudden device damage and release.	Sudden failure occurred when the alloy housing flared open enough for the pivot to over-cam, and the rope jump out.

Clog Ascender, prior to loading. Note that rope was realigned after photo, before loading

Rope damage, after failure of Clog Ascender.

Clog Ascender, after fail-ure. Note over-cam of pivot, and cracked body.

CASE 11: PETZL SHUNT on SINGLE ROPE

DEVICE TYPE	FAILURE LOAD	FAILURE MODE	MECHANISM
smooth profile cam rope grab	230 kg	Gradual slippage	Gradual controlled slippage with minimal damage to either rope or device.

Petzl Shunt on single rope, prior to loading.

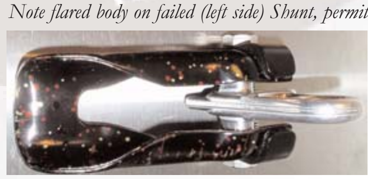
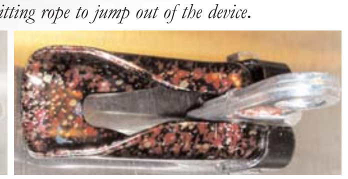
CASE 12 PETZL SHUNT on DOUBLE ROPE

DEVICE TYPE	FAILURE LOAD	FAILURE MODE	MECHANISM
profiled cam rope grab	400/650 kg	Gradual slip-page, then sud-den device fail-ure & full release.	Initial slippage at 400. Then increased loading forces device body to flare allowing rope to jump out, at 650kg. Both rope and device perma-nently damaged.

Petzl Shunt with double line, slipping under load.

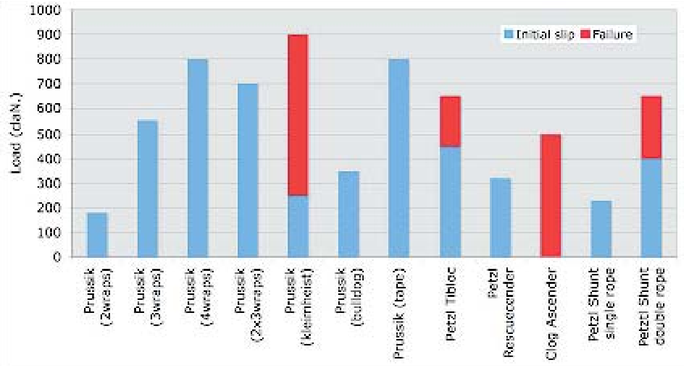
Rope damage, from failure of Petzl Shunt.

Below: Comparison of failed Shunt (left), with original article (right).
Note flared body on failed (left side) Shunt, permitting rope to jump out of the device.

Analysis of results

For comparison, the results of the individual tests can be best summarised graphically:



Graph 1. Comparison of brake/belay device failure loads.

Whilst some of the devices tested are definitely not intended for such use, they are all of a type that are frequently found in rescue senarios, and thus it is of value to know if they are suitable for inclusion in such rope systems. Where manufacture's information was available for a device, we endeavoured to ensure that the rope was within the specificed usage range.

It can be seen from the above results that if time and skill are available to properly set a prussik on a system then for a single static loading they perform as well as, if not better than mechanical devices.

This statement obviously has a number of qualifiers:

• Most mechanical devices are designed to be quick and easy to use, with minimal training, whereas setting a good prussik requires significantly more pratice.

• The test considered a single instance of a gradually increasing load, which may or may not be the case in a given rescue senario. This would be the case with haul systems utilising a cam or prusik as the load hauling device. More dynamic or 'snatch' loads can often be present in backup systems or as loads transfer during movements. Prussiks *may* fair significanly worse in relation to mechanical devices under such circumstances.

• The test considered a single use, whereas most equipment is not 'disposable', and multiple uses are expected. During the test most prussiks were destroyed, as indeed were several of the mechanical devices. A number of mechanical devices (e.g. the Petzl tibloc) appear to be unaffected, and suitable for re-use, whereas only the bulldog prussik (with it's low slip load) could be considered for re-use after slippage.

• The test was conducted using a single type of rope, with properties specific to that particular rope. Any given belay/brake device may perform differently on an alternative rope type, or indeed under a different environment such as a wet or iced line.

• It can be seen from the included images that mechanical devices are fairly 'cruel' on the rope, and distort at least the sheath considerably. Prussiks however appeared to distribute the loading across a large area of the rope surface, and thus were correspondingly 'kinder' to rope, although there was some transfer of burned prussik material into the sheath of the main line under slippage. Prussiks are thus obviously of limited use where the belay must travel whilst under load.

Note that since only a single test was done with each device, these results are obviously not 'statistically significant'. That is to say that in order to get a more informed comparison the tests should be repeated a suitable number of times, thus permitting calculation of an average value for each device. This is a somewhat arduous and expensive task for a single organisation, but reasonably trivial when spread across a large number of agencies. Furthermore a wide range of testing stations would also produce results across a correspondingly large spectrum of available devices and ropes.

Conclusions

The tests indicate that given suitable conditions and correct usage, the humble prussik can have an important role to play in rescue rope systems along side more sophisticated mechanical devices. Pressed plate mechanical devices like the Clog ascender are obviously significantly weaker than the extruded body devices like the Rescuecender and can result in catastrophic failure when used as part of a haul system subjected to high loads. The fact that toothed cam devices are more aggresive would seem to be a moot point if the cam enclosure is going to fail!

It should also be noted that prussik loops can be purchased with appropriate CE/EN marking, potentially permitting their use where such equipment standards are mandatory.

Appendix 1 – ***Main rope failure example.***

During the testing of case 5 the main line rope failed at ~900 within the double bowline knot which was attaching the load.

Above Left: Failed main line within double bowline knot.

Above Right: Replacement, improvised 'no knot' on load.

Appendix 2 – ***Load Cell Specification***

load cell used = 2000-SK 10

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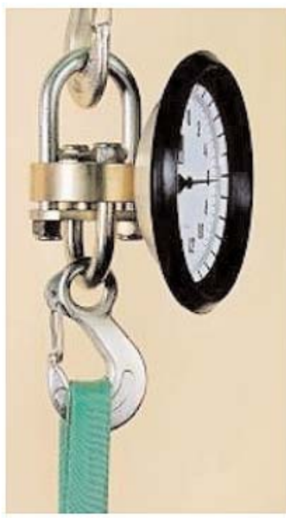
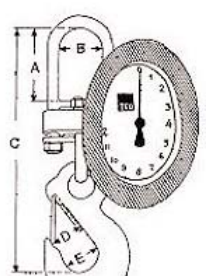
Appendix 3 - ***Main line (Rope) Specification***





load cell used = 2000-SK 10

Type	Veil. pris	Mål mm (se figurer over) A	B	C	D	E	SW/WLL	Kapasistet	Skala-innd.	Vekt
200-SK 1	4.710	60	53	230	27	35	5:1	0-200 KG	1 KG	5 KG
320-SK 2	4.890	60	53	230	27	35	5:1	0-320 KG	2 KG	5 KG
500-SK 2	4.890	60	53	230	27	35	5:1	0-500 KG	2 KG	5 KG
750-SK 5	4.980	60	53	230	27	35	5:1	0-750 KG	5 KG	5 KG
1250-SK 5	4.980	60	53	230	27	35	5:1	0-1250 KG	5 KG	5 KG
2000-SK 10	5.120	60	53	230	27	35	5:1	0-2000 KG	10 KG	5 KG
3200-SK 20	6.230	75	53	280	34	46	5:1	0-3200 KG	20 KG	5,5 KG
5000-SK 20	6.960	75	53	300	42	56	4:1	0-5000 KG	20 KG	6,5 KG
7 500-SK 50	9.500	40	41	213			4:1	0-7500 KG	50 KG	8,1 KG
12 500-SK 50	9.500	40	41	213			4:1	0-12500 KG	50 KG	8,1 KG
25 000-SK 100	13.500	55	42	287			4:1	0-25000 KG	100 KG	12,9 KG
32 000-SK 200	16.000	75	58	329			4:1	0-32000 KG	200 KG	25 KG
50 000-SK 200	19.000	75	58	329			4:1	0-50000 KG	200 KG	25 KG
85 000-SK 500	50.000	85	60	390			4:1	0-85000 KG	500 KG	60 KG

The main line used for all test was a Beal 'Rescue 10.4mm' semi-static polyamide rope, conforming to EN 1891. The rope was new in 2004 (batch V173), and has subsequently been used intensively for training purposes. For more information see Beal's website:

http://www.bealplanet.com/notices//index.php?id=33&lang=us

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	Performances Performance	UIAA Norm Euro Norm
• TYPE	B	
• DIAMETER	10,4	
• STATIC STRENGTH	2100 daN (kg)	
• STRENGTH WITH FIGURE 8 KNOT	1500 daN (kg)	
• NUMBER OF FACTOR 1 FALLS	10 (80 kg)	≥ 5
• IMPACT FORCE FACTOR 0.3	4.70 kN	≤ 6 kN
• ELONGATION 50/150KG	4,8 %	≤ 5 %
• SHEATH SLIPPAGE	0 %	
• WEIGHT PER METER	68 g	
• SHEATH PERCENTAGE	43 %	≤ Smin = (4D-4)/D²
• WEIGHT OF THE CORE	57 %	≥ Cmin = (40/D²)x100
• SHRINKAGE IN WATER	2,5 %	
• MATERIAL		

Technical Rescue *magazine* welcomes submission of your informal testing for publication. The results should be accompanied by clear photographic detail of the tests and test method and precise description of the type and condition of ropes and tested devices. We also need to know how any numerical data was collected (eg. load cell). Contact us at info@trescue.com

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