The Viability of Multi-point Rescue Anchors Employing Removable Artificial Protection

Presented to:

The 2009 International Technical Rescue Symposium, Pueblo, Colorado

by **Philip Spinelli and David Pylman, Joshua Tree Search & Rescue**

OBJECTIVE

Our objective was to test multipoint rescue anchors built with removable protection devices (“pro”) for their ability to withstand a dynamic force as great as might be generated by a relative worst case event during a technical rescue.

NEED AND BACKGROUND

Artificial pro anchors have been employed by many rescue teams for decades. A common team protocol is to assign a maximum strength of 5 to 7 kN to each piece of pro in a multi-point anchor, regardless of the manufacturer’s rated strength. This conservative approach is taken because it is impossible to completely assess the quality of the rock in which the pro is placed. The rock is likely the weak point in the system.

Recent studies[1] testing load sharing and load distributing multi-point anchors have indicated that an individual leg of such an anchor would likely receive a force greater than 7kN when the anchor was subjected to a total force of 20kN, such as would theoretically occur from a catastrophic event during a rescue. Given the common safety rating of pro at under 7kN, and the potential for a force on an individual piece of over 7kN, one could form the opinion that artificial protection devices should not be employed for rescue anchors because one leg, and subsequently the anchor, may fail.

We attempted to discover any differences between previous testing in a controlled setting with our dynamic testing in the field.

TEST SETUP

Anchors were built in natural rock cracks at the top of cliffs in locations similar to those we encounter on a rescue in our area. The tests were conducted on cliffs in Joshua Tree National Park. Each anchor was constructed with four pieces of pro, connected with cordage or webbing. The cordage was then brought to a focal point and tied to create pre-equalization with a figure eight, Frost, or overhand knot.

During an adrenaline-fed rescue, perfect anchors will not be achieved. While all the anchors met our minimum criteria, minor flaws were intentionally incorporated to reflect shortcomings that might normally occur. Examples of included imperfections are: placing all four pieces in the same crack, using a piece that was too small in relation to the large grain/crystals of the rock, inability to fully safety-check one piece due to its location, incorrect camming device for the size of the crack, one carabiner levered over a rock edge, one leg of the anchor noticeably out of equalization with the others, or multiple pieces levering a free-standing boulder.

[1] Beverly, Attaway, Miller, et al. Multi-Point Pre-Equalized Anchors Systems. ITRS 2005 and McKently, Parker and Smith. A Look at Load-Distributing and Load-Sharing Anchor Systems. ITRS 2007.

The anchors employed an arbitrary mix of protection types, including SLCDs (spring loaded camming devices, or “cams”) from Black Diamond, Linc-Cams (multi-range extending SLCDs) from Omega Pacific, Tri-cams from CAMP, and Offset Nuts (aka: chocks, tapers, stoppers etc.) from Hugh Banner. The breaking strengths of the pieces ranged from 17kN to 3kN. Appendix “A” provides a chart of the pro and cordage used and the manufacturers rated breaking strength for each.

The pro was connected to the cord or webbing with oval non-locking carabiners from CMC rated at 21kN on the major axis. The focal points of the anchors were connected using a single CMC locking offset “D” carabiner rated at 30kN. Incidental rigging employed CMC locking “D” carabiners rated at 27kN.

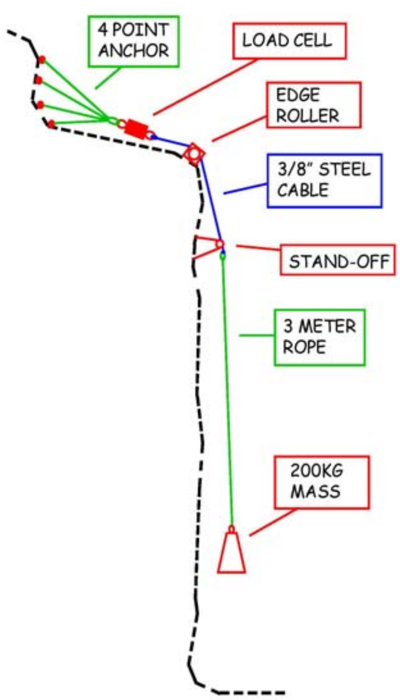

Figure 1: Test Setup Diagram

Pre-equalization, or load sharing, was accomplished with either 10 meter lengths of 8mm nylon accessory cord from Sterling, 10 meter lengths of 25mm nylon tubular webbing from PMI or 16 meter lengths of 11mm nylon or nylon/polyester ‘static’ rope. See Addendum ‘A’ for models and technical data.

A load cell was attached to the master point of the anchor to record the total force received by the anchor. An 11mm or 7/16” static rope, three meters in length, was connected to the load. Because of the short ropes used, it was necessary to extend the focal point to the test rope by means of a 3/8” steel cable. Due to resource considerations in Joshua Tree National Park, where the testing took place, it was also necessary to protect the vertical face of the cliff from any impact by the test load during or after the drop. For this, a two-foot steel structure was placed horizontally against the vertical face, with a pulley at the end through which the cable was run.

TEST PROCEDURE

For six days during September and October 2009, we performed a series of tests, dropping a 200kg iron mass on fourteen anchors.

The initial drop on each anchor had a fall distance of one meter on three meters of rope, conforming to the British Columbia Council of Technical Rescue (BCCTR) Belay Competence Drop Test Method, for a fall-factor of 1/3. Each anchor then received a second drop of 2 meters to create a fall-factor of 2/3. The time interval between the first and second drop varied from about five to fifteen minutes, during which the load was reset and the data downloaded. The final anchor received a drop of 3 meters with a fall-factor of 1. A fall-factor of 1/3 is often described as the ‘relative worst case event’ that could occur, for example, when a belay system catches after a mainline failure. Equivalent longer falls would be a drop of five meters on fifteen meters of rope, or a drop of 10 meters on 30 meters of rope.

The drops of 2 meters on 3 meters of rope equate to a drop of 12 meters on 18 meters of rope (about a 39 foot fall on 59 feet of rope). We chose to perform these extreme, high-force drops because we feel this is well beyond any potential occurrence during a rescue performed by a trained team.

In an attempt to find a failure force for this type of anchor system, our final drops were of 3 meters on 3 meters of rope to achieve a fall-factor of 1.

VARIABLES AND COMPROMISES

Many variables are inherent in a test incorporating natural elements such as cracks in rock. The strength of pro placements, length of cordage to each anchor leg, environmental conditions, the coefficient of friction of the rock, and many other factors make duplication of this study not viable.

Due to time limitations, location, Park regulations and safety, it was necessary to make several adaptations to our setup. All had some effect on the final forces registered from the drops.

The following are the major adjustments, and their probable affect on peak forces.

1) A 3/8” steel cable was inserted between the load cell and the 3 meter rope. The length varied between two meters and ten meters. The minor elongation in this cable would have reduced the forces on the anchor, while the extra slack introduced by the kinks and bends in the unloaded cable increased the drop distance by as much as 0.3 meters. The overall effect, on average would likely have been neutral.
2) A large, high efficiency edge roller held the cable over the rock, before and at the edge. While this also added some friction, a rope running over the edge might have added more. Effect: probably neutral. Compared to a belay system where minimal or no edge protection is used, the effect of our setup would likely be an increase in recorded forces.
3) The three meter ropes were connected directly to the load. In a real situation, there would be many force-absorbing connections in between, such as litter rigging and attendant rigging. The attendant and subject’s bodies would also have absorbed significant force away from the anchor. The effect of our compromise: a likely increase in recorded forces.
4) Time and logistics forced us to make the second drop on each anchor with the same 3 meter rope. The knots in the rope for the second drop (2 meters, or fall-factor 2/3) were therefore pre-tightened, and the rope somewhat elongated. This would of course increase the forces seen by the anchor compared to those generated with an unused rope.

While it is impossible to calculate all the forces acting on our system, we believe the combination of compromises in our setup resulted in recorded forces somewhat higher than those seen by a similar anchor on an actual rescue.

APPENDIX A

CORDAGE

	Model	Manufacturer	Sheath	Core	Strength	Elongation at 300lbf
11mm	Static Pro	Sterling	Nylon	Nylon	35.7kN	3.0%
7/16"	EZ Bend	PMI	Nylon	Nylon	30kN	1.8%
7/16"	Access Pro	PMI	Polyester	Nylon	27kN	3.0%
7/16"	Tallon	PMI	Nylon	Polyester	27kN	1.1%
8mm	Accessory	Sterling	Nylon	Nylon	16.7kN	
25mm	tubular webbing	PMI	Nylon			

PROTECTION DEVICES

	Manufacturer	Size/Number	Strength	
Offset Nuts	Hugh Banner	7	12kN	
		8-11	13kN	
Linc Cams	Omega Pacific	0.75	10kN	
		1-2	14kN	
Camelots	Black Diamond	0.75 -5	14kN	
			as Cam	as Nut
Tricams	CAMP	0.25	5kN	3kN
		1.5-2	14kN	12kN
		3	17kN	14kN

STATISTICAL ANALYSIS OF ALL DROP TESTS

	Peak Force (N)	
Anchor	1 meter	2 meter
5	8,905	14,154
6	7,375	12,054
7	8,211	13,175
8	8,282	12,534
9	9,385	14,260
10	8,181	12,606
11	9,599	13,388
12	8,549	13,451
13	7,944	12,054
14	7,633	12,543
Ave	**8,431**	**13,022**
Std Dev	**756**	**794**
Samples	**9**	**10**
MIN	**7,375**	**12,054**
MAX	**9,599**	**14,260**
+1 Std Dev	**9,188**	**13,816**
+2 Std Dev	**9,944**	**14,609**
+3 Std Dev	**10,700**	**15,403**
-1 Std Dev	**7,675**	**12,228**
-2 Std Dev	**6,919**	**11,435**
-3 Std Dev	**6,163**	**10,641**

APPENDIX B

Anchor #	Drop #	Meters of Fall	Rope Type/#	Piece #1	Piece #2	Piece #3	Piece #4	Anchor Cord	Peak Force, Kn	Pass or Fail	Notes
5	10	1	11mm Static Pro	#3 Cam	#1 Cam	#4 Cam	#3 Tricam	8mm Cord	NA	NA	Haul connection not removed
	11	1	7/16" EZ Bend	"	"	"	"	"	8.905	P	
	12	2	"	"	"	"	"	"	14.154	P	
6	13	1	11mm Static Pro	#1 Linc Cam	#1.5 Tricam	#.75 Linc Cam	#7 Nut	8mm Cord	7.375	P	
	14	2	"	"	"	"	"	"	12.054	P	
7	15	1	11mm Static Pro	#4 Cam	#3 Cam	#11 Nut	#.25 Tricam	11mm rope	8.211	P	Tricam pulled out
	16	2	"	"	"	"	"	"	13.175	P	Tricam replaced and held
8	17	1	7/16"Access Pro	#1 Linc Cam	#7 Nut	#2 Linc Cam	#1.5 Tricam	25mm Web	8.282	P	
	18	2	"	"	"	"	"	"	12.534	P	Linc Cam pulled out
9	19	1	7/16" Tallon	#5 Cam	#1 Linc Cam	#9 Nut	#.75 Linc Cam	8mm Cord	9.385	P	
	20	2	"	"	"	"	"	"	14.260	P	
10	20	1	11mm Static Pro	#3 Cam	#2 Tricam	#1 Linc Cam	#1.5 Tricam	8mm Cord	8.181	P	Force reading from display
	21	2	"	"	"	"	"	"	12.606	P	
11	22	1	7/16" Tallon	#2 Cam	#1 Linc Cam	#9 Nut	#3 Tricam	25mm Web	9.599	P	
	23	2	"	"	"	"	"	"	13.388	P	
12	24	1	11mm Static Pro	#4 Cam	#4 Cam	#3 Cam	#3 Cam	8mm Cord	8.549	P	
	25	2	"	"	"	"	"	"	13.451	P	
13	26	1	11mm Static Pro	#4 Cam	#3 Cam	#.75 Cam	#2 Tricam	8mm Cord	7.944	P	
	27	2	"	"	"	"	"	"	12.054	P	
14	28	1	11mm Static Pro	#2 Tricam	#4 Cam	#.75 Linc Cam	#9 Nut	8mm Cord	7.633	P	
	29	2	"	"	"	"	"	"	12.543	P	
	30	3	"	"	"	"	"	"	12.500	NA	Load carabiner broke
	31	3	"	"	"	"	"	"	12.050	NA	Cable clamps broke