John McKently, LeRoy Harbach, Michael Kuhlmeier, Bios:

John McKently is the School Director for CMC Rescue School, specializing in Rope Rescue, Confined Space Rescue and other unique rescue disciplines. John McKently has been with the Los Angeles County Sheriff's, Montrose Search and Rescue Team since 1974, and has experienced over 2100 callouts during that time. The Team is also a member of the Mountain Rescue Association (MRA). John has taught SAR Management for California Governor's Office of Emergency Services OES since 1988. He served on the Board of Directors of the National Association for Search and Rescue (NASAR) and was the Treasurer of that Association for four years. Active in the development of Search and Rescue standards since its inception in 1989, John is a past Chairman of ASTM Committee F-32 on Search and Rescue. John is also certified instructor for US Mine Safety and Health Administration (MSHA) and California State Fire Training. John is a longtime supporter of ITRS.

LeRoy Harbach

LeRoy is a Sr. Instructor for the CMC Rescue School where he specializes in Rope Rescue and Confined Space Rescue (is this true). He is retired from the fire service where served as Firefighter, Battalion Chief, Training Officer and Member of Special Services Team for the Waukesha City and Caledonia Fire Departments. Leroy is also a member of the United States Air Force Reserve. Leroy has become the recognizable face of CMC and an authoritative voice in rescue training through numerous online product and rescue training videos featured on the CMC website. Leroy's main passions are rescue and his family. He travels throughout the world to provide rescue training to a wide variety of clients.

Michael Kuhlmeier

Michael is a Mechanical Engineer at CMC Rescue. He graduated from Washington State University with a degree in Bioengineering. During college he worked both as a Ski Patroller at Silver Mt. and as an outdoor guide. He enjoys getting outdoors, especially to ski, and designing random electro-mechanical devices.

Abstract:

The use of edge protection is a best practice for any rescue scenario where rope transitions over an edge. However, experience in both training and operations tell us that the rescue lines can be damaged despite the use of edge protection. One method of damage occurs though repeated loading and unloading of the line, such as when used as an anchor in a change of direction (COD) or when an individual is ascending a rope. As demonstrated in last year's presentation "Edge Testing of Various Surfaces in the Vertical Plane" this cyclic loading over edges can cause up to a 68% reduction in the breaking strength of the system.

Background:

The use of edge protection is a best practice for any rescue scenario where rope transitions over an edge. However, experience in both training and operations tell us that the rescue lines can be damaged despite the use of edge protection. One method of damage occurs though repeated loading and unloading of the line, such as when used as an anchor in a change of direction (COD) or when an individual is ascending a rope. As demonstrated in our ITRS 2015 presentation “Edge Testing of Various Surfaces in the Vertical Plane” this cyclic loading over edges can cause up to a 68% reduction in the breaking strength of the system.

In a continuation of this experiment, we will explore the impact of a smaller technical use 11mm (7/16”) rope and an associated reduction in load from 280 kg (600 lbs.) to 200 kg (440 lbs.) The results of this testing will allow for correlation to last year’s results and provide insight to the impact of rope diameter and load on the wear characteristics, and final breaking strength of rescue lines.

Purpose:

Our testing was focused on applying force to a small rope section vertically (as opposed to sliding it horizontally) to determine if it would damage or otherwise affect the strength of the sample. It was not our intention to test various types of edge protection or rope designs, although that is partially what happened.

Our test edges consisted of 90 degree corners of concrete pavers and the outside of steel angle iron. We chose those because they could be easily duplicated by others, were commonly found in urban, industrial and fire training locations and simulate the worst case situation for loaded rope over an edge.

For our edge protection we selected: commercially available canvas (24 oz.) edge pads, 2 layers of Cordura (to simulate using a rope bag), a commercial edge guard, and old (lined) fire hose. While several other options were available, we felt these samples would represent the most commonly used pieces of edge protection. To make the test equitable to testing conducted the previous year we went with an ASTM Type IV test mass of 200 kg (440 lbs.) as compared to the ASTM Type V/NFPA “G” General rated two person load of 280 kg (600 lbs.) that we used for the testing in 2015.

[ASTM F2266-03 (2015) *Standard Specification for Masses Used in Testing Rescue Systems and Components*]

The tests were conducted in the lab at CMC Rescue in Goleta, CA on three different brands of rope using the test methodology described below.

Materials and Methods:

Each sample was a new piece of 11 mm (7/16”) kernmantle rescue rope 20 ft. long. One end was attached to an anchor and routed over the test rig and attached to a 200 kg (440 lb.) mass simulating a two person “mountain rescue” load. The test rig consists of a shelf, approximately 12” square, upon which the artificial edge material is installed. It rests on the top handrail and is secured using two pairs of arms that extend down to the mid rail for support and stability. (Figure 1) The edge material cantilevers over one edge of the shelf so the rope makes a 90 turn from horizontal to vertical where it is attached to the mass. At the other end of the shelf is a 3" diameter roller that provided a low friction surface for the rope to roll over as the ram was extended and retracted. The roller also insures that the rope travels over the edge material at the same angle throughout the test cycle. The sample ropes were secured to the anchor and mass using a bowline.

Figure 1: Edge test rig

The rope samples moved over the edge 2in. during each test cycle. This was controlled via limit switches at either end of the ram's stroke. A vector pull consisting of two pulleys and a 30 in. length of Static Pro attached to a hydraulic ram was used to produce this movement as displayed in Figure 2 on the next page.

This is a relatively time consuming process. Five samples of each rope type were tested over each edge type using each type of protection-150 test samples total.

Figure 2: The test set up utilizing a vector pull to produce travel in the sample

When setting up each test sample the hydraulic ram was extended fully, this was so that upon retraction any creep or elongation of the rope was taken up. This prevented the wear point from shifting over the course of the initial cycles. If that had happened the values would be different across rope types thus biasing the results. The vector raising system consisted of a 3-3/4" pulley on the sample rope that was then attached to a 30 in. length of Static Pro running through a second 3-3/4" pulley and then attached to a horizontal hydraulic ram. A chain hoist was used to lift the mass and hold it in position while the sample was attached at which point it was lowered so that the sample took up the weight.

After securing the sample rope the ram was retracted, and then the cycle protocol engaged. The ram was controlled electronically via a programmable logic controller (PLC). The programmed cycle consisted of an initial extension lasting approx. 18 sec, until it hit the limit switch, which caused the sample rope to travel 2 inches over the edge. After extending, the ram paused for 5 seconds, and then retracted where it paused for 5 seconds before commencing another cycle. The pauses at either end of the stroke were included to prevent any heat build-up, thus eliminating another potential variable that could affect results. The rope was cycled 30 times before stopping (A cycle constituting a full extension and retraction of the ram).

After 30 cycles the sample was removed and attached to a vertical test machine and secured around 4" bollards. The sample was installed in such a way that the wear point was in the center between the two anchor points. It was the pulled to failure per the CI 1801 standard.
The results were divided into populations divided by rope type, edge type, and protection type. The average and standard deviation were calculated for each population. Then a two-tailed t-test was conducted on each test population against each rope's baseline population with an alpha value .05.

Results:

Average breaking strength and standard deviation for each sample population

Rope	Edge/Protection	Average (lbf)	Standard Deviation
Type A Control: 8082	Angle/None	0	Failed prior to 30 cycles
	Angle/Cordura	3248	1137
	Angle/Edge Pad	7403	1188
	Angle/Edge Guard	4536	1389
	Angle/Firehose	7582	562
	Concrete/None	2156	465
	Concrete/Cordura	2737	1312
	Concrete/Edge Pad	7623	1183
	Concrete/Edge Guard	4610	565
	Concrete/Firehose	8105	187
Type B Control: 8122	Angle/None	0	Failed prior to 30 cycles
	Angle/Cordura	3725	937
	Angle/Edge Pad	7909	245
	Angle/Edge Guard	5440	424
	Angle/Firehose	8028	123
	Concrete/None	2666	854
	Concrete/Cordura	4359	1203
	Concrete/Edge Pad	7897	207
	Concrete/Edge Guard	4637	442
	Concrete/Firehose	7865	282
Type C Control: 8144	Angle/None	1441	879
	Angle/Cordura	5020	897
	Angle/Edge Pad	7642	363
	Angle/Edge Guard	5751	1034
	Angle/Firehose	7915	104
	Concrete/None	2817	653
	Concrete/Cordura	4659	873
	Concrete/Edge Pad	7468	275
	Concrete/Edge Guard	4831	554
	Concrete/Firehose	7724	331

Table 1

Graphical representation of the average of each sample population

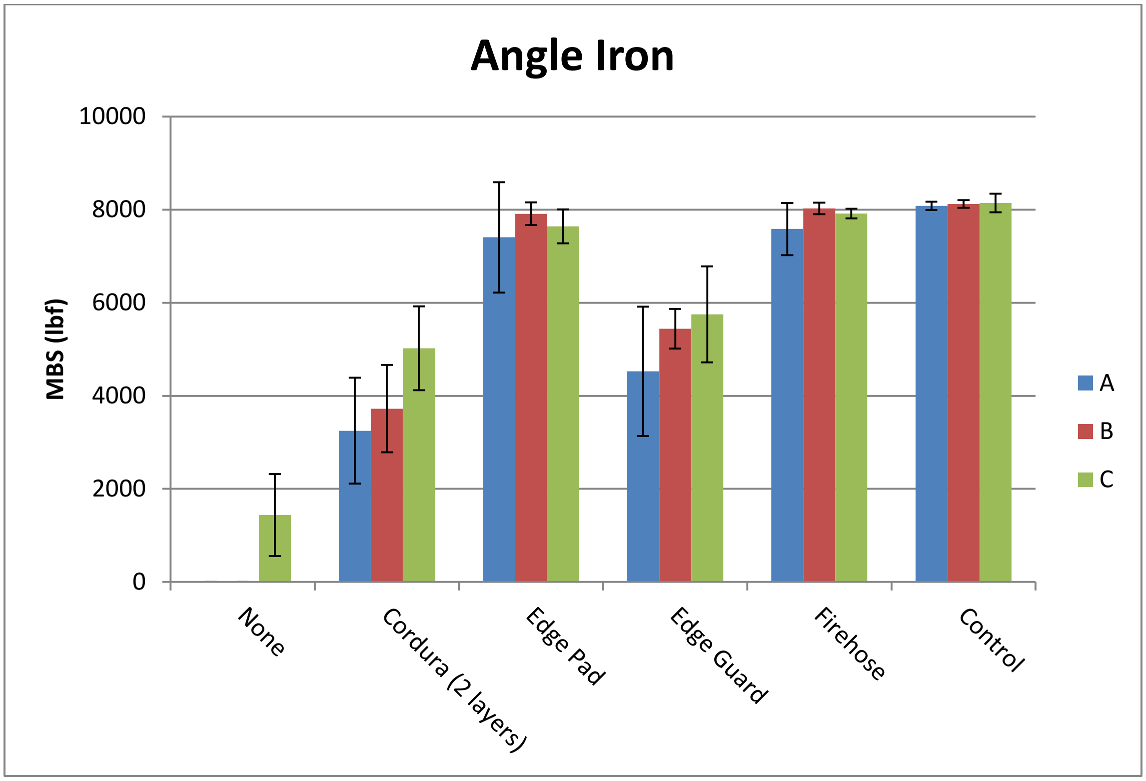

Figure 3

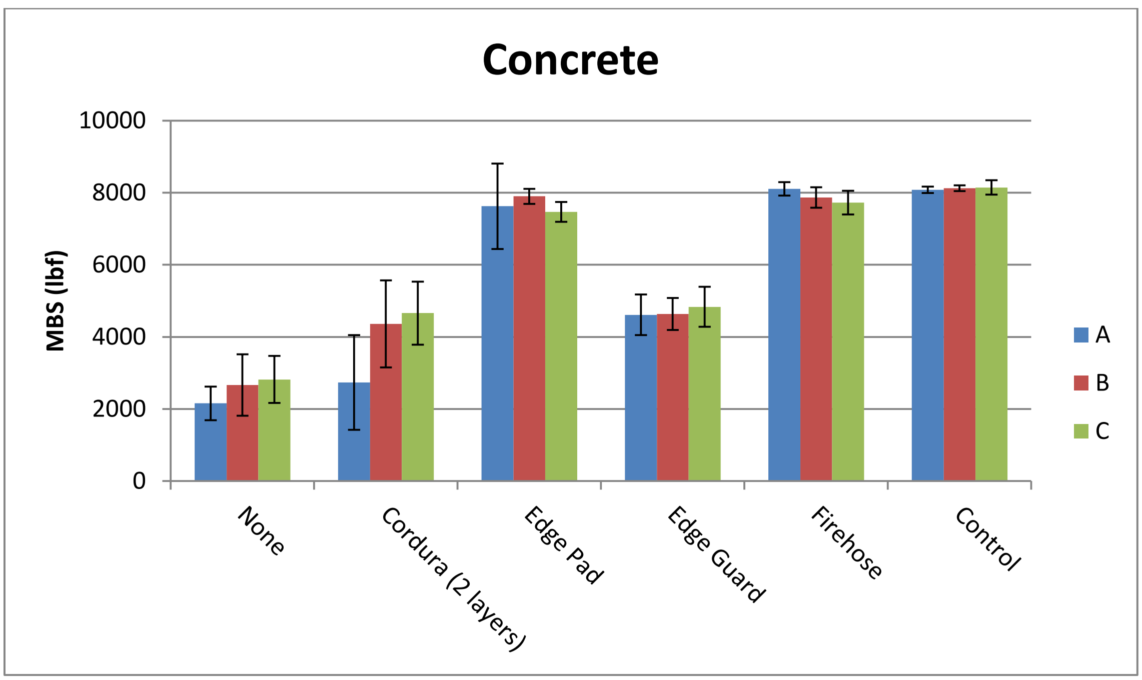

Figure 4

Conclusion:

Before stating the obvious-edge protection is a good thing, the type and amount of protection were influencing factors on how well the rope maintained its strength and survived the testing cycles. Canvas edge pads and cotton jacketed/rubber lined fire hose remained the best overall with minimal effect on the strength of the rope.

While not surprising, the test results are congruent with those of last year's testing on 12.5 mm (½") kernmantle with a 280 kg (600 lb.) load. One of the primary differences being, during angle/none testing rope samples would fail completely. A similarity shared with prior testing is the groove the rope samples wore into the concrete block without causing damage to the edge protection. We realize that the concrete paving block is not as hard as some rocks that might be encountered in a wilderness rescue scenario. To repeat, it was selected because it is commonly used in construction, it was suitable for multiple tests because the test rope could easily be repositioned to a new place for each test and it is commonly available for others to perform similar tests.

All of the rope samples were new and "T" rated with a minimum manufacturer stated MBS of at least 28.5 kN (6407 lbf). Control testing showed much higher baseline MBS values for all three samples of near 36 kN (8082, 8122 & 8144 lbf MBS). After the edge cycling process, all showed a significant decrease in strength except when the edge pad and firehouse were used as edge protection.

Needless to say edge protection is an absolute necessity in rescue operations, particularly in an industrial setting where the interface between rope and hard square edges are a common occurrence. The type and amount are up to the response personnel on scene, but more is generally better – especially at the edge or on a change of direction, and it appears that type may matter as well. It wouldn't be an ITRS paper without the standard "more testing is required" disclaimer… DO try this at home.