Boutique Bowlines

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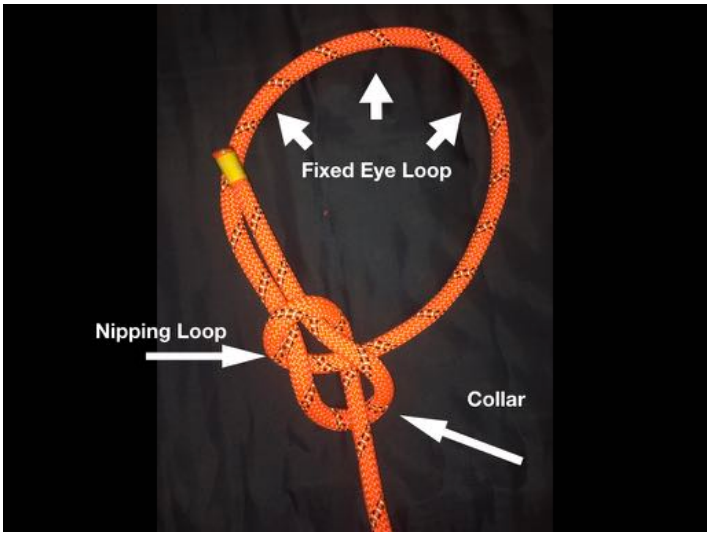
The purpose of this paper is to document the research conducted in looking at various bowlines and their breaking strengths, as well as their susceptibility to cycling loading This was done in order to have a reference as to whether a bowline is suitable for an end line rescue knot as well as an anchor.

Having initially learned the bowline as a great knot as a Cub Scout, told of the tremendous dangers of using it in any rope carried by the fire department, and finally heard it praises sung as I got further into rope rescue; I was understandably confused as to what the correct answer was. This was especially true when it comes to bowlines that weren't your straight ahead "rabbit comes out of the hole" bowline. Boutique Bowlines, if you will. There was no data that I was able to find to suggest that these Boutique Bowlines were suitable for rescue work. Just a collection of anecdotal evidence.

Defining a Bowline

According to some members of the International Guild of Knot Tyers there are over 120 (!!) different names for bowline knots currently known; with at least 55 distinct variations of the bowline knot as well as several bowline based bends. Most of us are probably familiar with the "standard bowline", what Ashley's Book of Knots, where each knot is assigned its own unique number, has listed as #1010. While it is indeed ***a*** bowline, it is not ***the*** bowline.

So just what is it that defines what makes a bowline a bowline? Mark Gommers, of the Professional Associaton of Climbing Instructors and author off the paper "An Analysis of the Structure of Bowlines", suggests that a bowline can be defined by 3 unique elements. His paper, An Analysis of the Structure of "Bowlines" has a much more in depth definition and description of all of these parts. The three unique elements are:



1. A **Nipping Loop** which is loaded on *both ends* of the loop

2. A **Collar** where two parallel legs form a 180 degree bend. Both legs must be fully encircled and clamped by the Nipping Loop.

3. **Fixed Eye Loop** that does not slip or cinch under load.

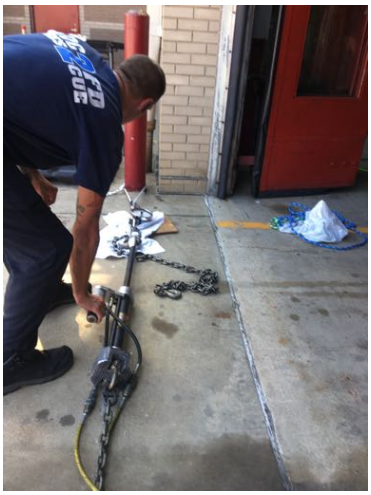
All of the bowlines looked at for this paper do meet the three items that define a bowline. Where they might differ from standard definition is that some of them were pulled from their fixed loop against their forward facing bight rather than on their standing end.

Test Procedure

The majority of the knots were tested using brand new, unused Sterling 11mm High Tenacity Polyester rope with an average breaking strength of 7568 lbs (33.7 kN) per the manufacturer. We did not conduct tests to determine this ourselves, but instead relied on the manufacturers stated numbers. Why? Because I'm lazy. There. I said it.

Testing was also conducted by Mike Forbes of Ropecraft on smaller cordage. Those tests were conducted with Sterling 8mm AZTEK cord as well as 5.5mm Powercord.

All tests on 11mm were done using the Chant Engineering slow pull test machine at BA Products with a maximum capacity of 150k lbs and a pull rate of approximately 1 foot per minute.The tests on the smaller cordage were were performed on a Ropecraft Tensile Tester V1. The knots in the 11mm rope were all tied by the same person to eliminate as much variability as possible. Due to the geographic difference smaller cordage knots were all tied by Mike of Ropecraft.



Because several of the knots were knowingly tied in an “incorrect” manner to establish how much this mattered, all knots tested were initially pulled to 2000 lbs with a Griphoist prior to full scale testing to see if the knots immediately capsized or if they held. Passing that test, they were then subjected to full scale testing to failure.

Lastly, given the popular lore of bowlines failure due to cyclic loading, several of the bowlines were subjected to cyclic loading to determine if there was any creep anywhere in the knot. This was a little less scientific and was done utilizing an Amkus hydraulic ram usually used for vehicle rescue. An analog 4000 lb Dillon dynamometer and a calibrated eyeball was used to measure the forces applied. This method was used because it sped up the process quite a bit versus the slow pull tester.

Knots Tested

The following knots were pulled to determine their breaking strengths:

Bowline with a correct Yosemite finish.

Bowline with an incorrect Yosemite finish, where the tail goes over the fixed eye loop rather than under.

Bowline w/ a bight and Yosemite finish, puller from fixed loop to standing end

Bowline w/ a bight and incorrect Yosemite finish pulled fixed loop to standing end

Bowline w/ a bight and Yosemite finish pulled fixed loop to forward facing bight

Bowline w/ a bight and incorrect Yosemite finish pulled fixed loop to forward facing bight

Triple Bowline w/ bight and Yosemite pulled fixed loop to standing end

Triple Bowline w/ bight and Yosemite pulled from fixed loop to forward facing bight

Table 1

	Failure (rupture) in lbs	Notes	
Bowline w/ Yosemite Finish		All samples pulled from fixed loop to tensionless hitch	**All tests conducted with Sterling Rope 11mm High Tenacity Polyester (HTP) with an MBS of 30.5 kN (6856 lbs) and an average breaking strength of 33.7 kN (7568 lbs) on the BA Products Chant brand 150,000 lb slow pull test machine.**
	4520		
	4368		
	4325		
	4561		
	4295		
	4413.8	Average Breaking Strength	
Bowline w/ Improper Yosemite Finish		All samples pulled from fixed loop to tensionless hitch	
	4557	Video	
	3923		
	4076		
	4775		
	3712		
	4208.6	Average Breaking Strength	

	Failure (rupture) in lbs	Notes	
Bowline w/Bight and Yosemite Finish		All samples pulled from fixed loop to forward facing bight	
	7801	Video	
	7910		
	8104	Video	
	6873		
	8215		
	7958	Cycled to 1000 lbs 5 times and then pulled to failure	
	7810.16666666667	Average Breaking Strength	
Bowline w/Bight and Improper Yosemite Finish		All samples pulled from fixed loop to forward facing bight	
	7865	Video	
	7402		
	8259		
	7319		
	6407		
	7983		
	7266		
	8001		
	7762		
	7584.88888888889	Average Breaking Strength	
Bowline w/ Outside Bight and Yosemite Finish		All samples pulled from fixed loop to forward facing bight	Looks correct until it loads, then one of the top stands rotates. Does not appear to affect strength or stability.

	Failure (rupture) in lbs	Notes	
	7973		
	8463		
	8126		
	7792		
	8088.5	Average Breaking Strength	
Triple Bowline w/ Bight and Yosemite Finish		All samples pulled from fixed loop to forward facing bight	
	8412	Video	
	9113		
	9532		
	9889		
	10750		
	10433		
	9688.16666666667	Average Breaking Strength	
Triple Bowline w/ Bight and Yosemite Finish		All samples pulled from fixed loop to tensionless hitch	
	0	Maillon on tensionless hitch broke at ≈4000	
	5007		
	5025		
Portuguese Bowline w/bight and Yosemite Finish		Pulled from anchors to forward facing bight.	
	8307		
	8700		

	Failure (rupture) in lbs	Notes	

The tests below were provided by Mike Forbes of Ropecraft on **8mm Sterling AZTEK** cord and **Sterling 5.9mm PowerCord.**

Kelly Bowline Tests				Abbreviations	
				bwb	bowline with bight
				yos	yosemite finish
				tb	triple bowline
				port	portuguese bowline
		Moosl Conv	66.9	f8b	figure 8 on a bight
				Per	8mm Sterling AZTEK cord. (MBS 15.6 kN; 3506 lbs)
				Pc	5.9mm Sterling PowerCord (MBS 19.7 kN; 4429 lbs)

Anchor Side	Moving Side Attachment	Cord	kN	M volts	Notes
bwb w/yos	fwd face loop	per	19.0	1273	
			19.6	1312	
			23.7	1586	
			21.3	1423	
			19.5	1306	
bwb incorrect yos	fwd face loop	per	24.0	1607	
			22.7	1517	
			24.1	1614	
			23.4	1566	
			23.0	1542	
bwb w/yos	fwd face loop	pc	11.0	733	standing slip
			13.8	921	
			12.5	839	fail, no slip

			16.1	1077	slip
			12.4	832	slip
tb w/yos	fwd face loop	pc	26.6	1777	slip, fail in knot then slip
			26.6	1781	no slip
			28.5	1907	
			21.9	1464	
			30.3	2028	
port w/yos on bight	standing part (- 1" bollard	per	11.4	766	slip opposite of y finish
			9.7	652	slip opposite of y finish
			9.6	645	slip opposite of y finish
			9.8	658	slip opposite of y finish
			10.1	674	slip opposite of y finish
port no yos		per	9.1	608	slip right
bwb w/yos	f9	per	14.5	973	f8 fail
bwb w/yos	standing part -	per	15.6	1046	
	standing part - f8b		16.8	1121	
	standing part - f8b		16.2	1083	
	standing part - f8b		15.8	1055	broke at bollard, not knot,
	standing part - f8b		15.7	1052	

Cyclic Loading

After much looking, I was unable to determine a standard test method for cyclic loading of knots. The information ranged from a paper developed by some canyoneering people who decided on 15 cycles as sample all the way down the rabbit hole to the Journal of Arthroscopic and Related Surgery who published tests with 1000 cycles of loading to determine the best knots for Ultra High Molecular Weight Poly Ethylene (UWMWPE) strands used in shoulder surgery. There is definitely room in the rope world for a standard test method for cyclic loading. I just don't know what it is. I decided on a 50 cycles for each knot. I used a ram with a pull rate of approximately 3 seconds per foot. Each knot was tied, dressed, and well set by hand and then sequentially loaded as follows:

250 lbs. x 10 cycles
500 lbs x 10 cycles
1000 lbs x 10 cycles
2000 lbs x 10 cycles

Aside from initial, very minimal settling in of the knot and rope stretch, there was note notable creeping of rope through the knot.

The following knots were tested with Sterling 11mm HTP to note any slippage or creep of the knot during cyclic loading.

1. Bowline w/ Yosemite finish pulled from fixed loop to standing end

2. Bowline w/ Yosemite finish pulled from fixed loop to standing end with Yosemite on bottom of nipping loop

3. Bowline w/ Yosemite finish pulled from fixed loop to Yosemite tail

4. Bowline w/ Bight and Yosemite Finish pulled from fixed loop to standing end

5. Bowline w/ Bight and Yosemite Finish pulled from fixed loop to bight

6. Triple Loop Bowline w/ Bight and Yosemite Finish

Conclusions

The group of bowlines tested appear to be suitable for rescue work in regards to breaking strength as well as cyclic loading. Three broad generalizations that can be made in observing the test data:

1. When loaded from the fixed loop to the standing end of the rope, the bowlines tested showed ≈ 30 - 40% strength reduction; which is in line with available results on bowline tests. Having more strands inside of the nipping loop, such as with the Triple Bowline with a bight, do increase the strength a bit when pulled from fixed loop to standing end.

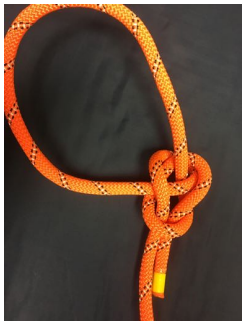
2. When loaded from fixed loop to a forward facing bight from a Yosemite, there is almost always a higher breaking strength than unknotted rope. This makes as the force of the load is more evenly distributed across more strands of rope.

3. Well set bowlines that get loaded, appear to have very minimal slippage.

Bowline (Ashley's Book of Knots #1010)


Bowline with Yosemite Finish


Bowline with Incorrect Yosemite.

Bowline with a Bight and Yosemite


Bowline w/bight and "incorrect" Yosemite.


Triple Bowline w/ Bight and Yosemite