Evaluation of Synthetic Ropes for Log Load Securement

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Rob Jokai, Principal Technologist, Transport and Energy

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ABSTRACT

This study tested ultra-high molecular weight polyethylene (UHMWPE) ropes for log load securement. Destructive testing of used samples showed that their strength decreases with use. This is a significant finding that synthetic rope users should be aware of and account for in their operating practices. Should users continue to use these ropes, following manufacturers' inspection guidelines is recommended, but this alone will not ensure that the ropes have adequate strength to contain a log load. Users should consider using a rope with a greater diameter than specified by the manufacturer.

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REVIEWERS

James Sinnett, Associate Research Leader, Transport and Energy

Jan Michaelsen, Research Leader, Transport and Energy

Doug Bennett, Research Manager, Transportation and Infrastructure

Ray Froneberger, Customer Service Representative, Cortland Company

CONTACT

Rob Jokai
Principal Technologist
Transport and Energy
(604) 222-5694
rob.jokai@fpinnovations.ca

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BACKGROUND

Steel cables with sections of chain on each end are commonly used as wrappers or tie-downs (the term wrappers is used throughout this report and refers to both types of applications) to secure log loads, as outlined in *National Safety Code Standard 10 – Cargo Securement* (Canadian Council of Motor Transport Administrators, 2013). These wrappers are heavy, so it can be difficult for some drivers to throw them over a log load. Some senior drivers develop shoulder injuries that result from throwing wrappers, which may make them unable to continue working in the profession. For others, the inability to throw a load wrapper over a load may act as a barrier to entering this line of work.

There are a few options that eliminate the need for the driver to throw load wrappers, such as using the loader to drape wrappers over the load. Another option that makes it easier to throw wrappers and does not require the loader is to use lightweight wrappers, such as those made from ultra-high molecular weight polyethylene (UHMWPE) fibre. For an equivalent strength rating, these ropes are between 1/6 and 1/8 the weight of steel cables. Synthetic ropes are gaining popularity for use as wrappers in many parts of the country.

FPInnovations (previously the Forest Engineering Research Institute of Canada, or FERIC) had conducted a study on synthetic ropes (Michaelsen, Careau 2006) and found that, after six months or less of use, the breaking strength of synthetic rope dropped to only 50% of the manufacturers' specifications. From the observations made during this study, the causes for this degradation appeared to be from abrasion—both external (from the logs) and internal (from dirt intrusion among the fibres). To meet safety standards, the report also suggested that large-diameter synthetic ropes must be used; i.e., synthetic rope diameters must be larger than the comparable steel cables normally used for this application. The design factor, i.e., the ratio of breaking strength to working load limit (WLL), is generally 3:1 for steel wrapper assemblies, and this was the design factor also used for the UHMWPE wrappers in the FERIC study. Today, most manufacturers of UHMWPE wrappers use a 5:1 design factor.

The concerns raised from this earlier research have prevented FPInnovations from recommending the use of synthetic ropes to its members. However, the increased focus on driver safety and retention, coupled with the increased use of synthetic ropes in some areas, led FPInnovations to revisit this topic. The focus of the new project was to evaluate the synthetic rope technology that is currently available, and to determine if past issues with decreased strength with usage have been resolved. If the findings indicate that this issue no longer exists, then the use of synthetic rope may lead to better driver safety.

OBJECTIVE

The objective of this project is to determine the suitability of using UHMWPE synthetic ropes for securing log loads, with a focus on determining how synthetic rope strength changes with use over time.

METHODOLOGY

To collect more strength data on UHMWPE wrappers, FPInnovations visited Weyerhaeuser's operations in Grande Prairie, Alberta, during 2015 and 2016. Weyerhaeuser requires that all their Alberta operations use synthetic lightweight load wrappers. This requirement was put in place to reduce the frequency of shoulder injuries among their drivers. During this trip, FPInnovations met with the woodlands operations personnel as well as local suppliers of UHMWPE load wrappers. The objective of the trip was to collect operational data on the use of these wrappers. In addition, both new and used rope samples were collected for destructive testing.

The rope samples were assessed for overall condition and any samples that failed a visual inspection were noted. Failure criteria included knots, cut strands, and excessive internal or external abrasion. These samples were then taken to Cortland Company, a synthetic rope manufacturer and supplier in Anacortes, Washington, for destructive testing.

Since the in-service life for the used rope samples was unknown, FPInnovations purchased several new wrappers to ensure that the in-service period for these ropes was known. The evaluations took place at the operations of Inwood Trucking, a contractor with West Fraser's Quesnel Division; Isley Contracting, a contractor with Weyerhaeuser's Grande Prairie Division; and two contractors with Weyerhaeuser's Princeton Division. The focus of these evaluations was to determine the suitability of using these ropes to secure log loads and to determine if rope strength changes with use and time.

DESTRUCTIVE TESTING PROCEDURE

Each sample was inspected visually according to Cortland's *Sling Inspection Guidelines* (Cortland Company, Inc., 2011) to determine its condition and whether it was still considered suitable for service. Criteria for deeming a sample no longer suitable for service included severe abrasion, both internal and external; severed strands; hydrocarbon contamination; and the presence of knots. As well, National Safety Code Standard 10 requires that all load wrappers have a tag stating the WLL of the securing device, and the absence of such tags indicates that they are no longer suitable for service (Canadian Council of Motor Transport Administrators, 2013).

The tests were conducted in accordance with the procedures established by the Cordage Institute (2015). Each sample was pre-tensioned to 50% of its breaking strength to set the rope, and this was repeated ten times. They were then removed from the test machine to let any heat that was generated by the load cycling dissipate. The samples were then placed back in the test machine and slowly tensioned until they broke.

RESULTS

Used and new ropes

The first series of tests determined the strength of seven ropes that were randomly given to FPInnovations.

The reason for these tests was to get an idea of the condition and residual strength of synthetic wrappers that were currently being used, and to determine how their residual strength compared to the original rating. Many of the used rope samples did not have tags on them that identified the supplier, the manufacturer, or the WLL limit. Therefore, manufacturers are not shown, but all the ropes tested were UHMWPE and the published strength ratings based on rope diameter were used. With the used ropes, the age of the samples or how long they have been in service is unknown. The only age indicator was the condition of the rope when it was tested, which ranged from near new to those that were no longer suitable for use based on a visual inspection. New rope samples were tested as well and the results from the break tests are shown in Table 1. Note that the rope diameters are noted in millimetres (mm). The metric equivalent for a 3/8 in. diameter rope is 9.5 mm, and for 7/16 in. it is 11.1 mm. Rated strength is noted in kilograms (kg). The metric equivalent for a 21 000 lb. break strength is 9 500 kg and for 18 000 lb. it is 8 200 kg.

Table 1. Break test results for new and used ropes

Sample ID	Condition	Diameter (mm)	Rated strength (kg)	WLL[a] (kg)	Test strength (kg)	Residual strength (%)	Residual load factor[b]
A	New	9.5	8 200	1 600	7 045	86	4.4
B	Lightly used	9.5	8 200	1 600	8 500	104	5.3
C	Lightly used	11.1	9 500	2 100	9 000	95	4.3
D	Well used	9.5	8 200	1 600	5 818	71	3.6
E	End of service life	9.5	8 200	1 600	2 045	25	1.3
F	Lightly used	11.1	9 500	2 000	7 818	82	3.9
G	New	9.5	8 200	2 300	8 091	99	3.5

[a] Since the WLL tags were missing on some of the samples, FPInnovations calculated the WLL by using a design factor of 5:1.
[b] Ratio of used breaking strength to WLL.

As shown in Table 1, the lowest break point was 2 045 kg for a rope with a WWL limit of 1 600 kg. The rope was well used and had a knot in it, which was where it failed. The presence of the knot significantly reduced the residual strength of the rope, and if the rope had been tested without the knot, it is expected that the breaking strength would have been higher. The other samples were still considered suitable for service.

Incorrect splicing

Sample A was a new, unused rope that failed at 7 045 kg. Sample B appeared to be the same type of rope except that it was lightly used, and it failed at 8 500 kg. This difference can be explained by the splices used to attach the pear-shaped ring onto Sample A. The manufacturers of these ropes have detailed procedures for making splices which include tapering the buried end of the rope by removing strands to make it a more gradual transition. The buried end of Sample A was not tapered and that is where the failure occurred, as shown in Figure 1.

Figure 1. Sample A before (left) and after (right) break test.

If the splice had been done in accordance with the manufacturers' recommended procedures, it is expected that the break strength would be comparable to that of sample B. Both of these samples had a WLL of 1 636 kg.

WLL

Sample G was another new rope that was comparable to samples A and B, but had a WLL of 2 300 kg. The reason that this particular supplier rates this rope with a significantly higher WLL compared to the other samples is unknown. Because of this higher WLL, break tests showed that it only had a residual load factor of 3.5, less than the residual load factor for samples A and B, which were 4.4 and 5.3, respectively. Had the WLL been set at the same level as samples A and B, the residual load factor would have been equivalent. This illustrates that there is some variability in the way WLLs are determined by different suppliers for similar rope products.

Cortland is both a manufacturer and supplier of rope and it supplied the ropes for samples A and B in this study. These ropes had a manufacturer's design factor of 5:1. The supplier of the other ropes in this test was unknown. In most cases, suppliers buy rope from the rope manufacturers and assemble the wrappers. Since Cortland is the supplier, it applies its own WLL tags.

New in-service ropes

The second set of tests with UHMWPE ropes were with new samples that were put into service, and periodically removed from service for break testing to determine the changes in strength with use. Ropes from three different suppliers were used, and the results of the break tests are shown in Table 2. The break strength shown is from the manufacturers' specifications for that particular rope, and not from break tests conducted by FPInnovations.

Table 2. Break test results for ropes that were used in service.

Sample ID	Service (months)	Diameter (mm)	Rated strength (kg)	WLL (kg)	Test strength (kg)	Test strength (lb)	Residual strength (%)	Residual load factor
17746-1-2	5	11.1	9 500	1 900	2 741	6 031	29	1.4
17746-1-4	5	11.1	9 500	1 900	2 990	6 578	31	1.6
17746-3-1	6	11.1	9 500	1 900	4 759	10 470	50	2.5
17746-3-2	6	11.1	9 500	1 900	4 655	10 240	49	2.4
17746-3-4	2	11.1	9 500	1 900	2 980	6 556	31	1.6
17746-3-6	5	11.1	9 500	1 900	3 998	8 796	42	2.1
17746-4-3	2	11.1	9 500	1 900	5 741	12 630	60	3.0
17746-1-3	6	11.1	9 500	1 900	5 005	11 010	52	2.6
17746-1-1	6	11.1	9 500	1 900	4 636	10 200	49	2.4
17746-1-5	6	11.1	9 500	1 900	4 868	10 710	51	2.6
17746-1-6	6	11.1	9 500	1 900	5 132	11 290	54	2.7
17746-4-2	n/a[a]	11.1	9 500	1 900	5 982	13 160	63	3.1
17746-2-1	5	11.1	9 500	1 900	3 500	7 700	37	1.8
GP001	2	11.1	9 500	1 900	5 768	12 690	60	3.0
GP004	4	11.1	9 500	1 900	4 241	9 331	44	2.2
GP006	2	11.1	9 500	1 900	4 627	10 180	48	2.4
GP005	4	11.1	9 500	1 900	2 724	5 992	29	1.4
11904	1	9.5	8,200	1 640	2 611	5 744	32	1.6
I1	7	9.5	8,200	1 640	2 024	4 453	25	1.2
I2	1	9.5	8,200	1 640	2 806	6 174	34	1.7
I3	7	9.5	8,200	1 640	1 774	3 902	22	1.1
I4	7	9.5	8,200	1 640	1 737	3 821	21	1.1

[a] The in-service duration for this sample was unknown.

Based on a visual inspection, all ropes were still considered suitable for use. However, one set of ropes (samples I1 to I4) was removed from service. When ropes from this co-operator were sent for testing, it was found that the manufacturer had not tapered the buried end of the splice, as was the case with some of the used rope samples in the first series of tests. Not tapering the splice decreased the ropes' strength. The duration of use for these ropes was not long—they were used on a very short haul to transfer wood from a local storage yard to the mill, and were used several times per shift.

The decrease in strength of the ropes, even after as little as one month of use, was apparent during the test and there is little correlation between residual strength and service life. Cortland assigns a design factor of 5:1 for the wrappers that it manufactures, as do many other manufacturers and suppliers. For one sample, after two months of use, the residual load factor decreased to 1.6. In some cases, the break strength was the same as the WLL, which means that those ropes are inadequate for securing loads and must be removed from service.

The WLL ratings for steel cables are one-third of their break strength, i.e., they have a design factor of 3:1. When FERIC tested steel cables, there was no decrease in strength found after six months of use (Michaelsen and Careau, 2006). It is expected that the strength of steel cables would decrease after a certain amount of time, but not at the same rate as UHMWPE ropes. It is unknown at what point the decreased strength makes the UHMWPE ropes unsuitable for use, and this requires further investigation.

When using UHMWPE ropes, it may be worthwhile to consider upsizing, e.g., replacing a 9.5 mm diameter steel cable with a 11.1 mm diameter UHMWPE rope, but giving it the same 1 600 kg WLL rating as the 9.5 mm diameter rope. New 11.1 mm diameter ropes have a breaking strength of 9 500 kg, and if the strength decreases with use by 50% to 4 750 kg, it would still retain a 2.9 residual load factor. Using an even larger 12.7 mm diameter rope with a breaking strength of 14 100 kg will result in an 8.6:1 design factor when new. If the strength of the rope decreases by 50%, it will still have a residual load factor of 4.3, while still being significantly lighter than steel cable. None of the ropes tested were in service for longer than seven months; therefore, it is difficult to determine longer-term trends from the data collected.

DISCUSSION

Condition of wrappers

During the trip to Grande Prairie, some contractors were using synthetic ropes that were no longer suitable for service. Figure 2 shows one such tie-down that had a knot in it and should have been removed from service.

Figure 2. Tie-down with knot.

Figure 3 shows a rope that has some severed strands and was therefore considered unsuitable for service.

Figure 3. Rope with severed strands that is no longer suitable for service.

Following manufacturers' inspection guidelines for synthetic rope will identify weakened ropes that should be removed from service.

User feedback

The co-operators in both Quesnel and Princeton bundle wrap their log loads and secure them with cinches. With new rope, the strands are tightly set and there is limited stretch in the rope. However, with use, the strands lose their set and the amount the rope will stretch for a given load increases. The drivers found it difficult to tighten the used ropes using cinches due to the increased amount of stretch of the used ropes.

The percentage of elongation for each sample was calculated during the rope pre-load tensioning cycles and during the break tests. The results are shown in Figure 4.

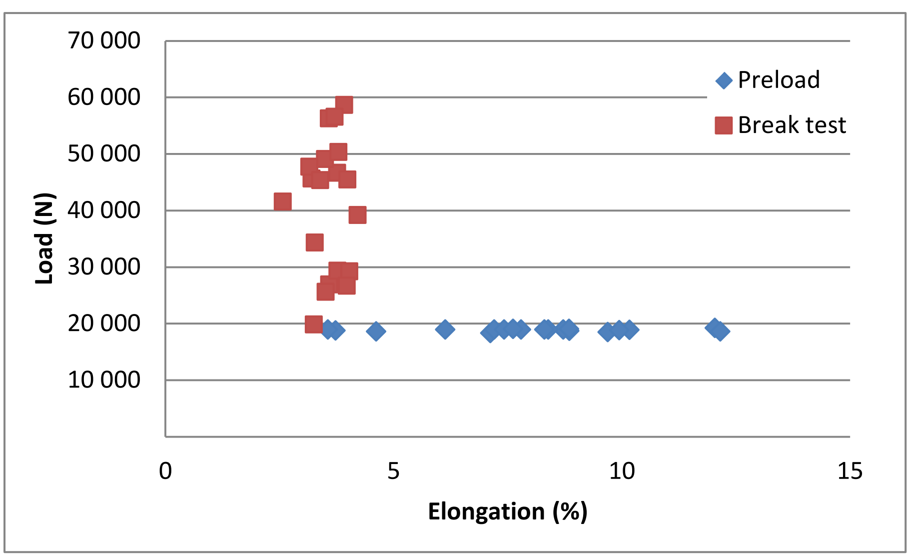

Figure 4. Percentage elongation for pre-load and break tests.

During the pre-load tensioning, a force of about 2 000 kg was applied to the ropes. This resulted in elongation of the ropes by about 4 to 12%. For the break tests, the percentage elongation was fairly consistent at about 4%. This is consistent with the manufacturers' specifications which state that the percentage elongation at break is 4 to 5%. The percentage elongation for used ropes is not provided by the manufacturers.

The amount of stretch for both cycles was compared. On average, the rope stretched 4.9 times more for a given load during the pre-load cycles compared to the break tests. This explains why the co-operators who were using cinches were having a difficult time getting the wrappers tight. The cinch was unable to take up the slack because of the excessive stretch. This is not an issue with winches because they have the ability to take up the excess slack needed to get the ropes to their required tension.

Frozen ropes

During winter, the trucks often travel to a high elevation to pick up a load, and then return to a lower elevation to deliver the load to the mill. Temperatures can be below freezing at high elevations but can be above freezing in valleys. The ropes absorb water in the warmer air at lower elevations, but then the water may freeze at the higher elevations which results in the ropes becoming stiff and difficult to use. Due to this freezing problem, the co-operators in Princeton have stopped using the ropes and went back to using wrappers made from steel cable. The freezing problem can be resolved if the ropes are stored in the cab when they are not in use. Storing ropes in the cab does require that they are properly secured.

CONCLUSION

Load wrappers made from UHMWPE rope are lighter than conventional wrappers made from steel cable and are easier for the driver to throw over a log load. Break testing performed on the UHMWPE ropes indicate that their strength does decrease with use, sometimes significantly, to the point where they do not retain adequate strength to secure a load. Damage such as abrasion, knots, or broken strands significantly decreases a rope's strength, and indicates that a rope is no longer suitable for use.

RECOMMENDATIONS

This study, as did the earlier FERIC study (Michaelsen and Careau, 2006), showed that the strength of load wrappers made from UHMWPE ropes decreases fairly quickly with use. It is important that the suppliers and users of synthetic-rope wrappers are aware of these findings and that they account for the decrease in strength with continued use. The Cordage Institute's Recommended Safety Practices for Use of Fiber Rope (Cordage Institute, 2015) recommends the selection of a design factor in the general range between 5:1 and 12:1, and that a design factor at the low end of this range should only be selected with expert knowledge of conditions and professional estimation of risk. Note that the 5:1 design factor used by most synthetic wrapper suppliers is at the low end of their recommendations. Furthermore, the Cordage Institute states that consideration should be taken in increasing the design factor given certain conditions.

The following conditions that it mentions are present in the use of synthetic ropes for load securement: problems have previously been observed in similar applications; the rope is tensioned for long periods; and abrasion may occur from exposure to rough surfaces or sharp edges, or due to contamination from dirt and grit.

Users of synthetic-rope wrappers must follow the rope manufacturers' inspection guidelines to ensure that damaged or weakened ropes are removed from service, but this alone will not ensure that the ropes have adequate strength to meet the requirements of the cargo securement standards. To help mitigate the loss in strength, users may consider using a rope diameter size that is larger by one to two sizes than suggested by the manufacturer. However, selection of the appropriate rope diameter for the load retention application requires careful consideration. Further work is required to determine how the strength of larger-diameter ropes used as log wrappers change with use, and to determine if using larger-diameter ropes is a viable option for log load securement.

The manufacturer of the ropes tested in this study also suggested that minimizing dirt and sand contamination will slow the rate at which the ropes lose strength.

The reductions in driver injuries that are caused by throwing heavy load wrappers are too significant to abandon the use of synthetic ropes for load securement. However, given the findings of both this report and the earlier report from FERIC, there is need for further research work to ensure their safe application. It is recommended that FPInnovations pursue its research on synthetic ropes with the following activities: work with the Cordage Institute and synthetic rope manufacturers and suppliers in setting clear recommended design factors for ropes used in log securement; test the recommendation of using larger-diameter rope to offset the loss of break strength with time; and explore practices and methods that can mitigate the loss of strength over time.

REFERENCES

Canadian Council of Motor Transport Administrators. (2013). National safety code for motor carriers: standard 10 – cargo securement (version: June 2013). Retrieved from https://ccmta.ca/images/pdf-documents-english/cargo_securement/NSC_Standard_10-_June_2013.pdf

Cordage Institute. (2015). Guideline CI 1401-15 - Recommended Safety Practices for Use of Fiber Rope (October 2015). Retrieved from http://www.ropecord.com/new/CI1401.pdf

Cortland Company, Inc. (2011). Plasma® 12x12 sling inspection guidelines. Retrieved from http://www.cortlandcompany.com/sites/default/files/downloads/media/manuals-plasma-12x12-sling-inspection-guidelines.pdf

Michaelsen, J., Careau, M. (2006). Evaluation of UHMWPE synthetic cables for securing roundwood on trucks. FERIC, Pointe Claire, Que. Internal Report IR-2006-12-18. 15 pp.

Head Office

Pointe-Claire
570, Saint-Jean Blvd
Pointe-Claire, QC
Canada H9R 3J9
T 514 630-4100

Vancouver
2665 East Mall
Vancouver, BC.
Canada V6T 1Z4
T 604 224-3221

Québec
319, rue Franquet
Québec, QC
Canada G1P 4R4
T 418 659-2647

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