Synthetic Rope Used in Logging: Some Potentials

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(Mention of trade names does not constitute an endorsement)

ABSTRACT - Provides information on the use of synthetic rope in logging applications to reduce workloads and increase efficiency. Field studies were conducted with synthetic rope in cable rigging applications and winch-lining using a skidder. Laboratory tests provided information on the engineering properties of synthetic rope that reaches the strength of wire rope at the same nominal diameter while weighing one-tenth of the weight of wire rope. Ergonomic improvements are described as well as operating efficiencies from selected applications. Further potentials of synthetic rope are outlined and future research is described.

INTRODUCTION

Wire rope is currently used in many logging applications. It has contributed to the advancement of cable logging and is used around the world in quantities of thousands of miles annually. Wire rope is also heavy per unit of length and helps make logging one of the most difficult jobs known. Cable logging in steep terrain is near the top of the most difficult jobs in terms of energy demands. Consequently, fatigue is often present when serious accidents occur. When opportunities arise to replace wire rope in some logging applications, substantial ergonomic and efficiency improvements are possible. New synthetic fibers spun into ropes offer promise in various logging applications. The current OSU research project described is funded by the Worksite Redesign Grant Program of the Oregon Occupational Safety and Health Administration (OR-OSHA, 2000).

Our project began from a trial by a logging contractor, Anderson Resources, of Washington (Anderson and Temen, 1999) reporting on the use of synthetic rope used for static guylines. Japanese researchers have also reported on their use of synthetic ropes for guylines on towers (Takumi, 1998). Earlier Forest Engineering Research Institute of Canada (FERIC) researchers used synthetic ropes in ground-based logging in Eastern Canada (Golsse, 1996). One OSU project is nearing completion and two more are scheduled to start soon to further address important developments with synthetic rope in logging.

SYNTHETIC ROPE

A number of synthetic ropes have been introduced into industrial use including ropes constructed from plastic fibers including nylon, polyester, polyethylene, and polypropylene. AMSTEEL and AMSTEEL-BLUE, products of the American Group of Ferndale, Washington (www.theamericangroup.com) , are two members of a
family of synthetic ropes constructed of polyethylene (lightweight thermoplastic) fibers. The polyethylene fibers are combined into yarns and the yarns are combined into strands that are put into various rope constructions including twisted, plaited, and braided. AMSTEEL and AMSTEEL-BLUE are high (HMWPE) or ultra high (UHMWPE) molecular weight polyethylene 12-strand braided ropes. The rope properties include a higher breaking strength to weight ratio than steel, high flexibility, low stretch (other than the eye splice), a specific gravity less than one (floats), and can be easily spliced. Coatings can be applied to increase resistance to abrasion, prevent contamination, and increase ease of splicing used ropes.

The material is generally the same material commonly used for fuel containers in logging. For a given diameter, it weighs less than a tenth of the weight of comparable lengths of wire rope. The synthetic rope is also flexible and does not produce “jaggers” (sharp broken wire strands) as handling hazards common to wire rope. The cost is approximately four times wire rope in the specially-produced quantities now available. The off-shore drilling (anchoring) and towing industries use similar synthetic ropes in parallel applications.

Table 1 shows comparisons between some common wire rope published breaking strengths and those published for AMSTEEL-BLUE. Rope elongation is also shown for AMSTEEL-BLUE under loads in Table 2.

CURRENT PROJECT

The current project began in summer 1999 with field tests followed by laboratory testing. The OSU Student Logging crew used the synthetic rope and wire rope in tasks common to the work they do in cable logging and skidder logging using a winch line. The limited sample of workers was composed of generally fit young adults ranging in age from 19 to 44 years. Both males and female workers are included in the sample. The sample included two summers of work and the size of the sample ranges from 6 to 13 subjects performing the standardized tasks. Such tasks included: pulling and carrying steel and synthetic ropes on roads and slopes, climbing and rigging intermediate support trees, and pulling winchline to logs for skidder logging.

Time-per-task was measured along with a heart rate profile during the tasks for each subject. Laboratory tests of rope breaking strengths were conducted in the Knudson Wood Engineering Laboratory of Richardson Hall on the OSU campus. The small number of subject workers and limited breaking tests make the research a pilot study rather than a large-scale replicated research effort. Details of the testing apparatus and study procedures are available from the authors and are not outlined here to save space.

Table 1. Ultimate breaking strengths of common diameter ropes used in logging applications: comparison of steel wire rope with AMSTEEL-BLUE UHMWPE synthetic rope.

Breaking Strength (pounds)			
Nominal Diameter (inches)	Extra Improved Plow Steel	Swaged Steel	AMSTEEL BLUE Synthetic
1/2	26600	31000	32600
9/16	33600	39200	40100
5/8	41200	48400	53100
3/4	58800	69800	62600
7/8	79600	94800	88400
1	103400	124000	104400

Table 2. Elongation as a function of loading for AMSTEEL-BLUE UHMWPE synthetic rope.

LOAD (Percent of breaking strength)	ELASTIC ELONGATION (percent)	Tensioned Length of a 100-foot section (feet)
10	0.44	100.44
20	0.62	100.62
30	0.79	100.79

SOME INITIAL FINDINGS

Our research and analysis are continuing but we can offer some insights on synthetic rope used in logging from three perspectives: laboratory tests, ergonomic implications, and economic potentials. Much more testing is planned and more refined analysis will help our understanding as the current project concludes and other projects are initiated.

LABORATORY TESTS

Splicing of AMSTEEL BLUE involves a buried eye splice similar to the concept of the common children's finger puzzle where the harder the pull, the tighter the device grips the fingers. The rope is tapered and inserted into the middle of the twelve-strand rope with a "fid" to form an eye. The fid is an aluminum tapered needle-like rod with a hollow end to hold the rope and a pointed end to ease passage down the center of the strands. The American Cordage Institute (1997) prescribes testing procedures to follow for standardize testing. We conducted a variety of tests to gain experience with the synthetic rope. Here are some general findings that confirm existing experience with this rope. Figure 1 shows a sample test for a rope segment involving cycled test procedures for a long-splice.

- ♦ Most synthetic ropes we tested break at the end of the inserted section of the eye-splice in the rope, making the breaking strength actually a measure of a splice. Wire rope breakage is given from the actual rope strength and reductions are made for the end connectors.
- ♦ Compression fittings common to wire rope are not possible with synthetic rope.
- ♦ Knots of various types are used in some applications but AMSTEEL BLUE did not hold knots or they broke at relatively low breaking strengths. Spliced or other end connectors are recommended.
- ♦ Elongation of the rope samples on initial loading is high, due to effect of the eye-splices and the rope itself. Testing procedures call for cycling the rope ten times to 20 percent of its nominal breaking strength to remove elongation before final loading to failure.
- ♦ The permanent extension due to rope construction deformation, rope compaction and yarn deformation was on the order described in product literature. Ropes may need cycling and partial loading before their length may be predicted for specific uses, e.g. guylines.
- ♦ Our cycled (per Cordage Institute test protocols) and uncycled tests produced similar breaking strengths.
- ♦ A rope section soaked in water overnight confirmed that AMSTEEL BLUE does not take up water and breaking strengths were not reduced.
- ♦ Rope failures, while violent and sudden, seem to fail in-line with the rope tension without wide swings due to stretch. See Figure 2 for testing apparatus.

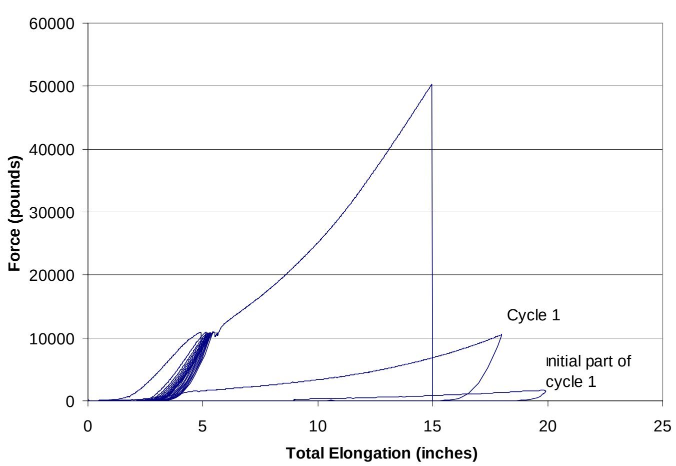

Figure 1. Ultimate load test for 5/8-inch diameter AMSTEEL-BLUE UHMWPE synthetic rope section containing a long splice.

Figure 2. Failed test section showing break at the end of splice.

ERGONOMIC IMPLICATIONS

The benefits from reduced weight for lines can be measured in part by the reduction in heart rates or by a reduction in time to recover after the task completion. An additional measure is the reduced time per task for heavy task work. Results of heart rate profiles are still being analyzed; however, some observations are pertinent. The study confirmed the high demand on workers as shown by the level of heart rates in the subjects. Pulling, carrying, climbing and using wire rope produces energy demands and subsequent heart rates to fuel the muscles with oxygenated blood. When heart rate levels and/or time to recover is reduced when using synthetic rope, overall fatigue may be lessened.

Both male and female workers expressed subjective preferences for using synthetic ropes during the trials. More specifically, an example chart of a 25 year-old, male subject, weighing 200 pounds, can help illustrate differences between carrying steel wire rope and synthetic rope for 150 feet. The task was conducted on a 25% slope with a 150- foot rope, 5/8 inch in diameter. Weight of the steel was 111 pounds while the comparable length of synthetic rope with steel thimbles included was 18 pounds.

Figure 3 below shows the difference in heart rate for the task and a difference in time for the task itself. Also shown is the longer recovery time needed for the more demanding task involving steel wire rope. Depending on task frequency, it is not hard to see where workload reductions using synthetic ropes are possible. We found similar profiles for male and female subjects in pulling ropes on roadways and slopes, carrying synthetic and steel ropes, and climbing and rigging trees as intermediate support trees or tail trees.

The study also included trials using steel and synthetic rope as a winch line on a John Deere 540 skidder. Turns of logs were winched both uphill and downhill with steel and synthetic ropes by the Student Logging Crew. Measures of time per task and heart rates were taken. Reductions in workload were noted and the time to pull the line to the logs was reduced. However, downhill line pulling with steel wire rope tends to push workers perhaps “aiding” their speed. More specific assessments of ergonomic benefits are planned as the current project concludes.

ECONOMIC POTENTIALS

Everyone who handles the synthetic rope is curious to know how much it costs. Compared to steel wire rope of the same breaking strength or diameter, AMSTEEL-BLUE costs from four to six times the cost of steel. Current markets for synthetic ropes are for specialty applications and in produce-to-order quantities. It is unclear what price structure will evolve if substantial quantities of synthetic ropes are used in the logging and forestry sector.

However, it is clear that gains in effectiveness can offset the costs of synthetic rope at current prices. For example, if the gain to pulling winch line for single machine operators setting their own chokers might be about 25%, then a 10% increase in productivity on a daily basis might be possible. For a skidding operation where the machine cost is $65/hour, the operator is paid $17/hour, profit and risk is 10%, and daily production is 10,000 board feet, the return to the operator would be $72.16/thousand board feet. If the synthetic rope allowed 11,000 board feet per day production without changing operation rates during a comparable 110 day logging season, the cost savings would be $7,938. That is enough to buy 7 winch lines of synthetic material.

If synthetic rope could increase payloads for cable systems or allow access to difficult terrain, substantial benefits might be attributed to the synthetic rope. Gains might also come during cable equipment set-up, faster manual work, use in helicopter logging, balloon logging and many applications not yet considered.

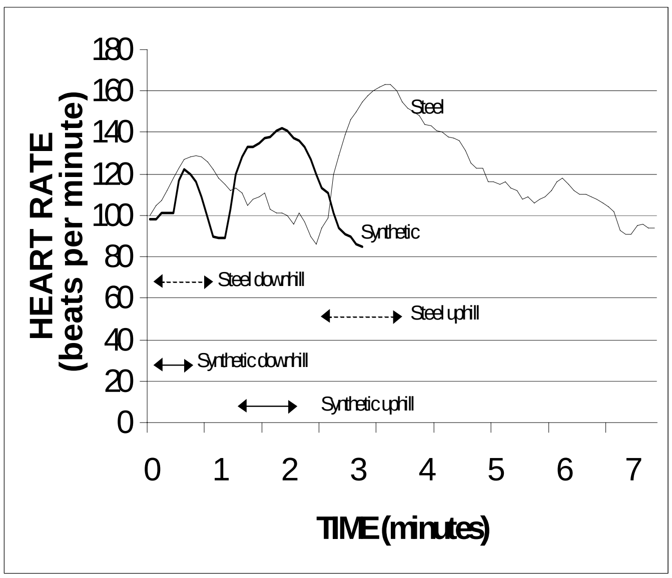

Figure 3. Heart rate and task duration to carry a 150-foot coil of rope 150 feet on a 25 percent slope. Rope diameter 5/8-inch, steel wire or AMSTEEL-BLUE synthetic construction.

FUNDED FUTURE RESEARCH

Based on promising results to date, OR-OSHA has funded two additional research projects on using synthetic rope in logging at about the same level each as the current project. The projects will run for two years commencing in July, 2001.