Final Report
Worksite Redesign Program
Oregon Occupational Safety and Health Administration

Using Synthetic Rope to Reduce Workloads in Logging

Submitted by

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Executive Summary

The report describes research supported by Oregon Occupational Safety and Health Administration grants to redesign work sites using ergonomic improvements. The use of ultra high density molecular polyethylene (UHMWPE) fiber rope as a replacement for steel wire rope in logging applications has the potential to reduce workloads and improve effectiveness.

The synthetic rope characteristics compared to steel wire rope are favorable in that it maintains equivalent breaking strengths at the same diameter while weighing about one-tenth that of the wire rope. Stretch (elongation under load) characteristics of the synthetic rope is somewhat greater than steel but suitable for logging applications.

We tested the rope characteristics in laboratory trials for ultimate breaking strengths, typical rigging configurations, broken (cut) strands, use of knots and end connectors, and a sample of rope after three years use as a guyline. Results indicate that the synthetic rope has considerable application to replace wire rope in many logging applications. Future research is now underway to develop end connectors and associated rigging that would expand the use of synthetic rope in logging. Our results indicate synthetic rope should be field tested by selected operators to determine operational opportunities and problems (now underway).

We looked at ergonomic issues during the use of the synthetic and steel ropes by the OSU Research Forest Logging Crew in typical tasks of pulling, carrying and climbing to rig trees. Potential ergonomic gains are shown as heart rate reductions, improved recovery after exertion, reductions in task times and subjective measures of reduced workload. 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. Reducing fatigue with synthetic rope offers potentials for reduced accidents. Common injuries due to “jaggers” (punctures from broken wires of steel rope) are eliminated with synthetic rope.

We assessed the potential economic benefits of using synthetic rope and how to incorporate synthetic rope in logging planning. Some early gains in effectiveness for use during tractor logging show the increased cost of the synthetic rope can be quickly recovered—within weeks. Potentials for cable logging show possible increases in payloads of 10-67% depending on terrain which translates into large economic gains. Other potential improvements identified with rigging gains need to be documented by more operational trials (now underway).

Early results indicated so much potential from synthetic rope applications that additional research was funded by Oregon OSHA to conduct field trials using synthetic rope by additional logging contractors. Log truckers were also added to the research to find ways to reduce injuries from throwing wrappers to secure log loads. Future research is funded to look at needed end connectors for synthetic rope and use of synthetic rope as an operating (moving) line in logging.

The final report consists of this document, a video of the synthetic rope project, and a photo gallery folder on a CD ROM about the research project. Copies may be available from the Oregon Occupational Safety and Health Administration or the authors.

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Figures and Tables

Introduction and Justification

Steel 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 (Astrand and Rodahl, 1986). 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.

Our project began from a trial by a logging contractor, Anderson Resources, of Washington reporting on the use of synthetic rope used for static guylines (Anderson and Temen, 1999). Japanese researchers have also reported on synthetic ropes used 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).

Many logging injuries are associated with slips and falls and fatigue is often mentioned in serious disabling injuries and fatalities. Synthetic rope may provide the needed marginal benefit for logging crews at the critical times when tired workers are trying to rig the tail tree to keep logging, carrying guylines and rigging to the back of the unit, or climbing the intermediate support. Heavy wire rope rigging may be one reason why operators fail to use guylines when needed.

According to recent Workers Compensation Claims reports, the information below is relevant Disability Claims in Oregon:

- 27 percent are chokersetters, rigging slingers, and hooktenders
- 37-50 percent of claims related to overexertion and falls within this group
- 90 claims, $1.6 million
- Jaggers produce punctures from wire rope!
- Sustained exertion / musculoskeletal stress results in various worker claims over time.

Synthetic Rope Characteristics

A number of synthetic ropes have been introduced into industrial use including ropes constructed from plastic fibers of nylon, polyester, polyethylene, and polypropylene. AMSTEEL BLUE, a product of Samson Rope Technologies (formerly, The American Group) of Ferndale, Washington (www.samsonrope.com), is a member of a family of synthetic ropes constructed of high molecular density polyethylene (lightweight thermoplastic) fibers. The polyethylene fibers are combined to yarns and the yarns are combined into strands that are formed into various rope constructions including twisted, plaited, and braided. AMSTEEL-BLUE is an ultra high molecular weight polyethylene (UHMWPE) 12-strand braided rope. This synthetic rope has a comparable breaking strength to steel and higher breaking strength to weight ratio than steel, by a factor of 9 to 10 (Figures 1&2 below). Other favorable characteristics include 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.

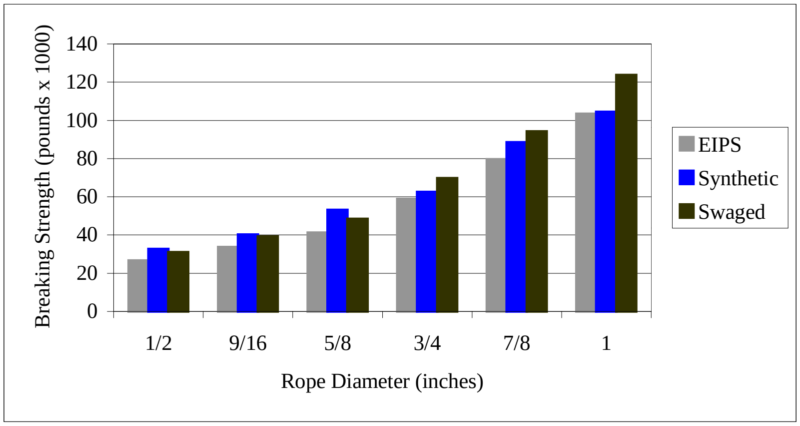

Figure 1. Breaking strengths of steel versus synthetic ropes

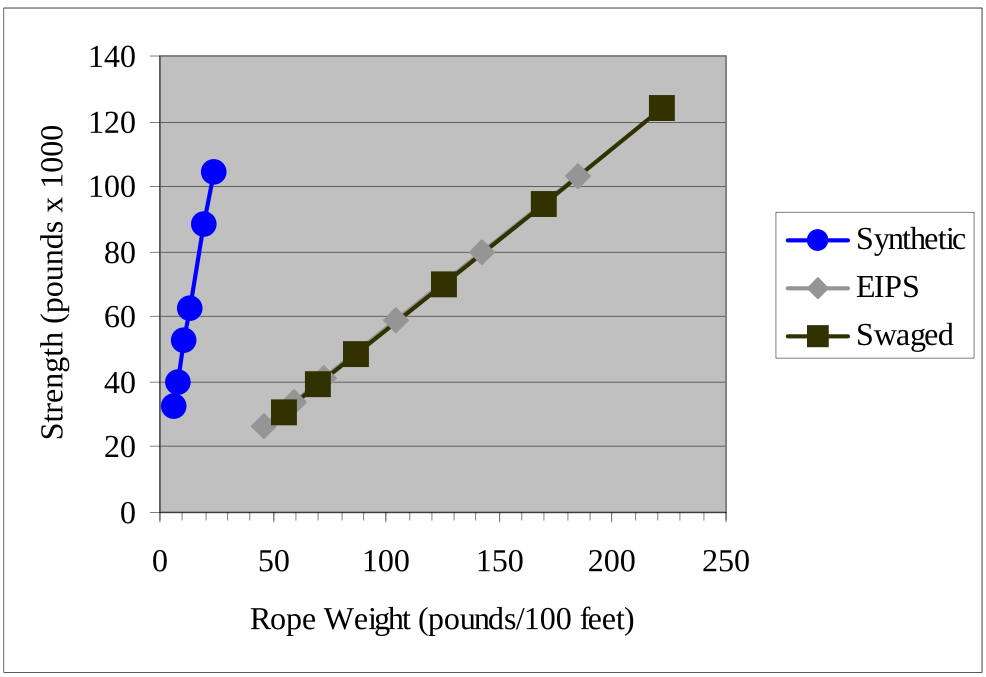

Figure 2. Strength to weight ratios of synthetic rope compared to steel wire rope.

Other characteristics of synthetic ropes like AMSTEEL-BLUE can be modified by the manufacturer to enhance characteristics suitable for logging applications. For example, the rope construction itself may be changed to enhance strength or flexibility and rope coverings may be added to improve wear characteristics needed for abrasion.   With the basic characteristics of the rope established, enhancements can further tailor the rope to logging applications.

Field Trials

Beginning in July 1999 and carrying through Fall 2000, field trials were conducted with the Oregon State University Koller Logging crew on the McDonald-Dunn Research Forest north of Corvallis, Oregon. Heart rate data and subjective evaluation data were collected to evaluate the physiological and subjective response between using traditional steel wire rope and synthetic 12 strand braided rope in logging related tasks.

The tasks were designed to simulate activities encountered in both ground based skidding and steep slope cable yarding harvest processes including cable layout, rigging activities, and skidder bull line winching. The following activities were performed for heart rate monitoring:

1) Drag Road – Both rope types (5/8-inch steel, 150 foot segment, 111 pounds; 5/8-inch synthetic, 150 foot segment, 18 pounds with steel thimbles) were pulled (extended) 300 feet along a gravel surface road grade of 4 percent, downhill then uphill. Pulling the steel rope was the base task for the dragging and carrying trial comparisons.

2) Drag Ridge - Both ropes were pulled 150 feet along a native surface ridgeline of 25 percent slope, downhill then uphill.

3) Drag Steep - Both ropes were pulled 150 feet along a native surface slope of 45 percent, downhill then uphill.

4) Carry Road - The rope segments were coiled and bailing wired for carrying, repeating the 300 foot traverse along the road grade, down then up.

5) Carry Ridge - The coiled segments were carried on the ridge 150 feet, down then up.

6) Carry Steep - The coiled segments were carried on the slope 150 feet, down then up.

7) Climb - (Base activity for rigging comparison). Workers climbed an 18-inch DBH Douglas-fir tree to a height of 50 feet.

8) Climb and Rig - The worker climbed then rigged the tree as an intermediate support tree with 2 fiber rigging straps, a six-inch steel block, and either a ½-inch steel wire rope or a 5/8-inch synthetic rope guyline at a height of 50 feet.

9) Skidder Bull line - The winch line (“bull” line) on the skidder was either a 9/16-inch swaged IWRC steel wire rope or a ¾-inch 12-strand braided synthetic rope. Each worker pulled the bull line and set a choker for a series of 5 turns. Distances, slope percent, and uphill/downhill were randomly assigned.

There were 13 workers participating over the two year period. The group was comprised of 10 males and 3 females. Ages ranged from 20 to 47 years, averaging 29. All participants self rated their physical fitness as “Good” and free of physical limitations.

Subjective Evaluation

After each trial, the worker completed a subjective evaluation form to rate the effort required for a given task and rope type in comparison to the base task. The forms had a linear scale with midpoint being the “same” effort comparatively. The left endpoint was labeled “Extremely Easy” and the right endpoint labeled “Extremely Difficult”. The linear difference between marks was converted to a percentage value from zero (same) to plus/minus one (difficult/easy).

Field Trial Results

Heart rate results were recorded for individual work elements within the previously mentioned activities. This included downhill traverse, recovery (determined by worker to what they felt was heart rate prior to task initiation), uphill traverse, and uphill recovery for the drag and carry activities. Climb and Rig had a similar set of elements defined.

Figure 3. shows the range and average heart rate values for the Drag Road (base) activity of pulling the rope. This is representative of the other tests with respect to differences associated with rope type and direction of travel. It should be noted a standing, at rest, heart rate of 70 beats per minute (bpm) was assumed for all individuals. Heart rate exertion intensity zones (average person, 20-30 years of age) can be described as follows (Astrand and Rodahl, 1986):

Heart rate (bpm)	Exertion Level (onset of)
< 90	Light Work
91 - 110	Moderate Work
111 - 130	Heavy Work
131 - 150	Very Heavy Work
151 - 170 +	Extremely Heavy Work

The reader should be cautioned to keep these values in mind when reviewing the results. The initially tendency is to think of a 15 bpm difference as small. However, this represents a 20 percent increase over the standing at rest rate. A 15 bpm increase can move an individual from one exertion level to the next.

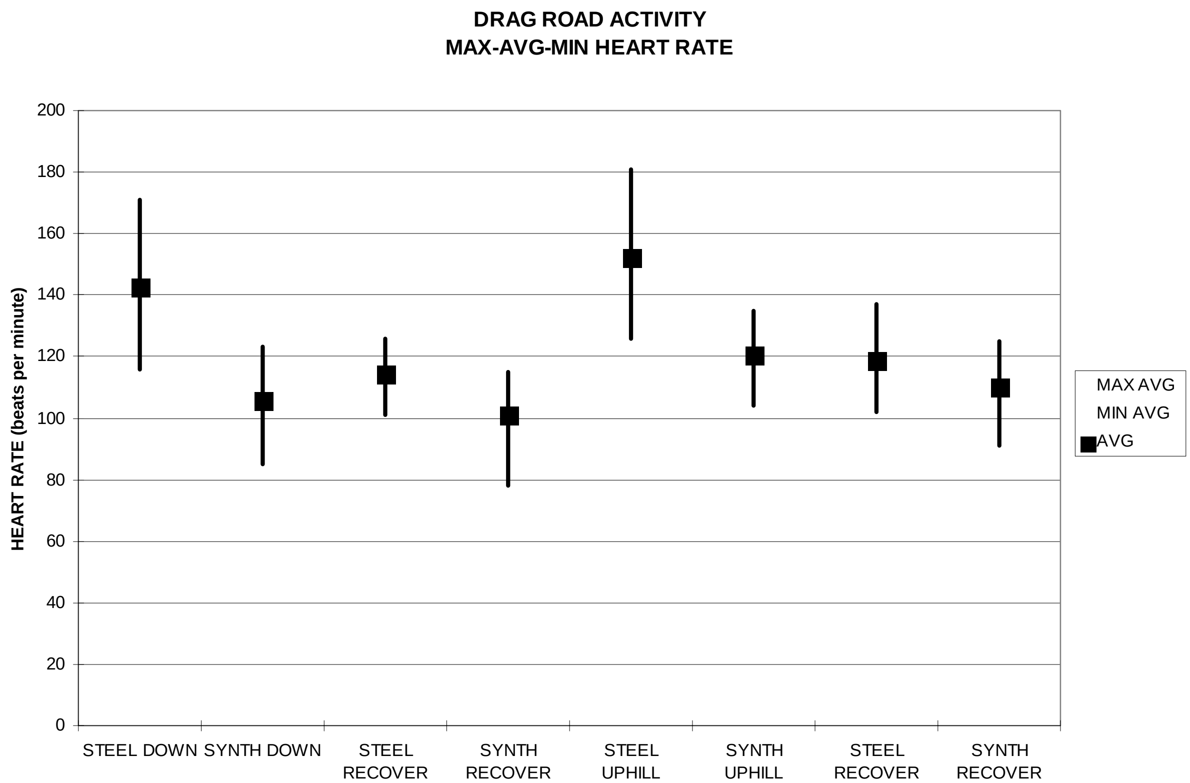

Figure 3. Average and range of heart rates for Drag Road activity.

The differences between heart rates for the Drag Road activity were statistically different for going down the road, with an average increase of 37 bpm with the steel wire rope, even though the task times were not statistically different. Again, think of this as a 50 percent heart rate increase required with the steel. Not surprisingly, task time and heart rates were different statistically, by rope type, going up the road.

For the Drag Ridge activity, task time was about a minute going downhill with either rope (Figure 4). Note the increase in task time from 1 minute (synthetic) to 4 minutes (steel) to travel 150 feet. Even though the downhill times are similar, heart rates were significantly different at 17 bpm. Uphill heart rate increased 30 bpm beyond that required for the synthetic rope.

Increasing the slope (Drag steep) produced additional demands on the heart. Both heart rate and task time were significantly different by rope type. The differences in the heart rates were numerically smaller (12-18 bpm) indicating the increased exertion effect of the slope on moving the body up the slope.

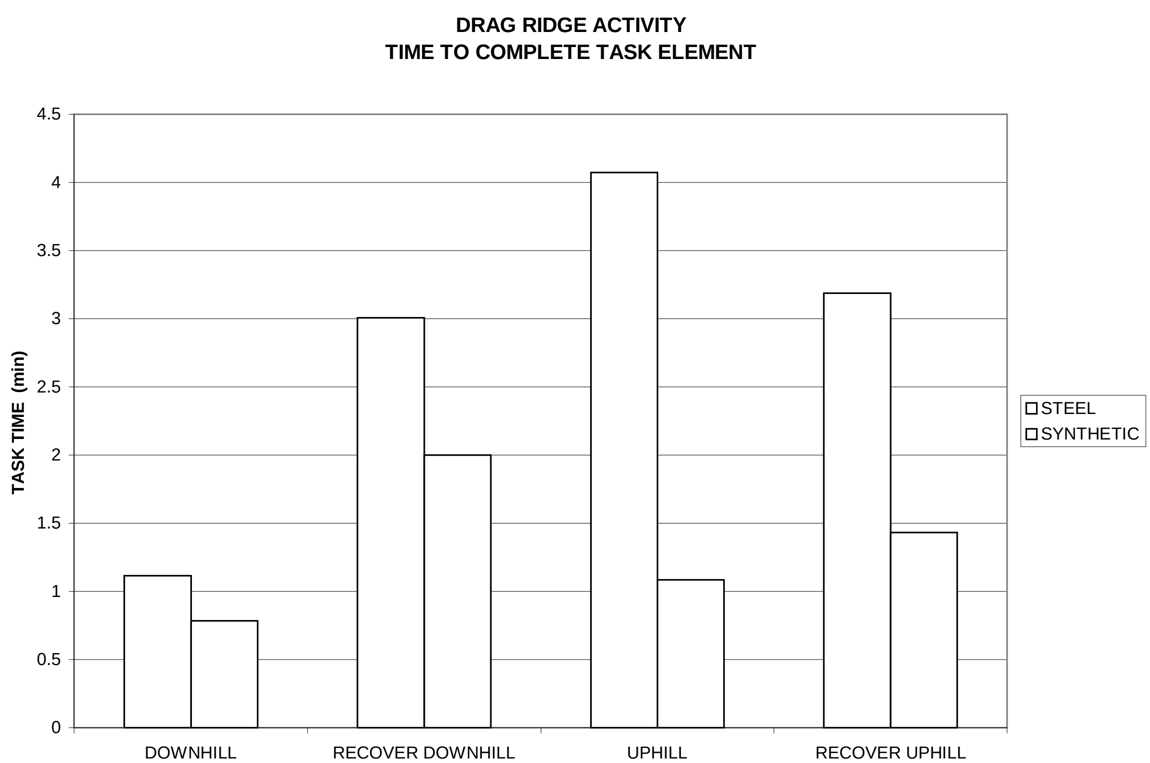

Figure 4. Task time for Drag Ridge activity.

Carrying the coils on the road also produced significant differences in time and heart rate. The numeric difference was about 15 bpm, which still is a 20 percent increase in base heart rate associated with the steel. Carrying reduced required heart rates by 20 bpm compared with dragging the rope along the road. Carrying on the ridge produced similar results with about a 15 bpm reduction in heart rate compared to pulling.

All heart rates and task times for Carry Steep activity elements are statistically different. With the synthetic rope, it took about one minute to carry or drag the segment, uphill or downhill. Downhill times with the steel are similar to this. However, carrying uphill took twice as long, and dragging uphill averaged 5.4 minutes. One worker did not complete the carrying downhill due to safety concerns related to balance and footing with the steel coil.

Climbing and Rigging

Climbing and rigging involved the following elements:

Climb 50 feet,
Pull up strap and block,
Rig strap and block,
Pull up strap and shackle,
Rig strap and shackle,
Pull up guyline,
Unhook guyline,
Rig guyline.

Analysis focused on the guyline elements as the rope type was the factor of interest. Pulling up the synthetic guyline averaged 0.5 minutes less, and unhooking the guyline averaged 0.6 minutes less than the steel guyline. It took about the same time to rig the guyline , independent of the rope type. Heart rates averaged 3, 13, and 12 bpm less with the synthetic for the 3 elements, respectively.

The more experienced workers had lower task times. Their heart rates were also 20 bpm less, averaging 140 bpm, a 100 percent increase of the standing resting rate. Anxiety with the less experienced workers could have been a factor. Total climb and rig time was about 11 minutes with the steel, and 9 minutes with the synthetic for the experienced group, with an additional 5 minutes for the inexperienced, primarily in the climbing element.

While the time savings appear to be small with the climb and rig activity, there are potential gains in safety. At times, lift trees (intermediate or tail trees) are rigged unguyed or under guyed (in violation of OR-OSHA regulations) due to the effort required, not in rigging, but in getting the rigging down or up the slopes to the trees. The above drag / carry analysis puts the numbers to what any hooktender will tell you he knew from day one. Additional time savings are likely possible with the use of synthetic jack support lines and synthetic based blocks.

Skidding Bull Line

The outhaul element was the focus of the difference in rope type. Heart rates, on average, were about the same. However, task time was 0.5 minutes faster with the synthetic rope (Figure 3). Heart rates were lower for all elements when using the synthetic rope. There appears to be an exertion carry-over effect into the next element, ie, when hooking the turn. A similar effect appears in the tree rigging with the unhook guyline (from the pass rope) element. Both activities occur right after the line pulling element.

Still heart rates are 70-85 bpm higher than our initial heart rate of 70 bpm. Heart rates increased 10 – 15 bpm with sustained activity (over the first turn) during the 5 turn sequence. ANOVA analysis showed significant differences in average heart rate for rope types and gender (main effects) and slope gradient, distance pulled, uphill/downhill (covariates).

The time savings associated with each turn is about 10 percent for 400-500 foot skids. This could amount to about 4 additional turns per day. While load size is an important factor, this could be about 1 MBF more per day, at a benefit of $ 50-100 per day to the contractor.

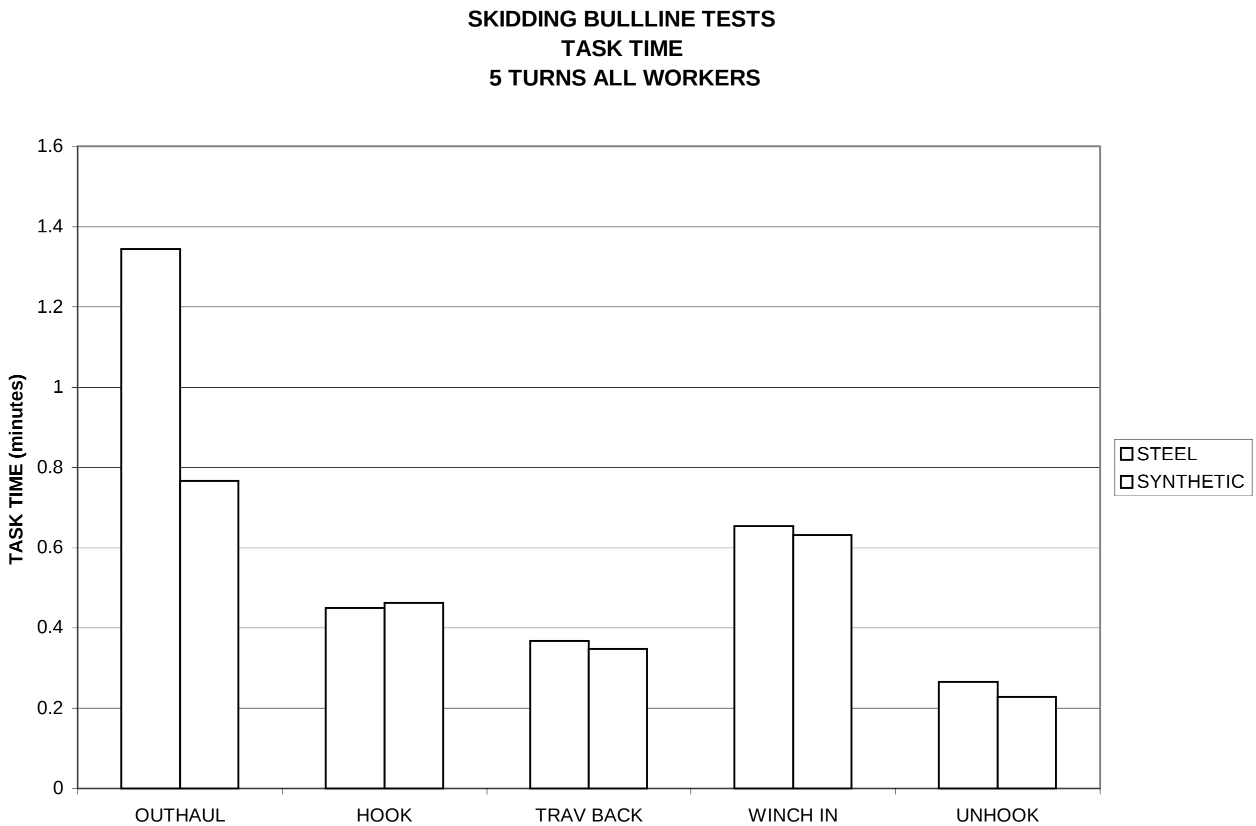

Figure 5. Skidding Bull line task time by activity element.

Subjective Analysis

Numeric results of the subjective analysis are informative, but the reader is directed to Appendix A which contains the text of the worker comments. Comments related to the synthetic rope include "Much easier, almost the same as just walking without anything", "pretty steep, rope no problem". Comments also noted tendency for pulled synthetic rope to catch on slash, tendency to tangle easier than steel (climb and rig). Overall, synthetic rope was well received, especially by those who have cut their hands on a jaggered bull line.

Numerically, synthetic rope was considered 20 percent easier downhill and 15 percent easier uphill when pulled off the skidder bull winch. Climbing and rigging with the synthetic was considered 30 percent easier. Pulling on the ridge and steep slopes was 25 to 30 percent easier between uphill and downhill. Carrying the synthetic was considered 10 percent easier than pulling it. Drag Ridge, downhill was thought to be 50 percent easier with synthetic and 148 percent easier going uphill. Downhill drag with steel was stated 35 percent easier on the ridge than the road, reflecting the influence of gravity on the mass of the wire rope.

Material Testing Results

Laboratory testing to determine yield to failure values, "Breaking Strength", for the synthetic rope material were conducted in the Knudson Forest Products testing lab in OSU's Richardson Hall. The tests were conducted initially to the specifications of the Cordage Institute. This standard calls for load cycling the sample to 20 percent of its rated breaking strength 10 times, then loading to failure.

For the 5/8-inch synthetic "AmSteel" 12 strand braided rope, the certified (3/9/2001) minimum ultimate load was 51,741 pounds. Two tests were conducted with the following results:

Test	Failure Load (pounds)	
3	48,972	
4	49,582	
average	49,277	95.2 percent of certified minimum

After discussion with the manufacturer, a second series of tests were conducted with 10 load cycles to 50 percent of the certified minimum load, then to failure. Three tests were conducted with the following results:

Test	Failure Load (pounds)	
1	50,043	
2	49,832	
3	50,125	
average	50,000	96.6 percent of certified minimum

This apparent failure to meet certified minimum load is of concern and is being addressed by the manufacturer. It should not be considered a serious deficiency but one suitable for remedy by changed strength tables or different rope constructions. The other benefits of heart rate reduction, positive worker opinion, and potentials for safer and more economical logging operations exceed the rating issue which can be addressed. It should be noted that lab tests with synthetic rope already include the end connector (spliced eye) while wire rope strengths must be reduced from lab values when typical end connectors are used, eg, a 5% reduction for using a spliced eye in wire rope.

Splicing, End Connectors, and Used Rope

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. Figure 6. below shows a sample test for a 5/8-inch rope comprised of a long splice cycle loaded ten times to 20 percent of breaking strength, then to failure. Based on a limited number of laboratory tests with 9/16, 5/8, and 3/4-inch AMSTEELBLUE ropes, we can make the following observations regarding the physical properties of these synthetic ropes:

- The testing protocols allow for a buried eye-splice as the end connectors for the test samples and the ropes nearly always break at the end of the splice. Thus, the reported ultimate rope strength is the strength of the eye-splice end connector.

- Ropes break violently but with little lateral movement (snapback). Failures occur linearly and may leave one strand unbroken.

- Compressive fittings of any type (rope clips, pressed ferrules, etc.) are not recommended by the manufacturer with these ropes. However, we tested two low temperature epoxies in poured sockets to failure. Failure occurred in the rope at the point where the rope entered the socket. More testing is needed.

- While the final elongation of rope sections at loads are similar to specifications, the Test section has considerable elongation due to the buried eye-splice end connectors. These eye-splices would need to be pre-conditioned to about 50 percent of the rope's rated ultimate strength to take all of the "stretch" out of the rope segment.

- Tucked and buried long splices had ultimate strengths similar to specifications.

- Water (soaked overnight) had no effect on ultimate strength.

- Knots did not develop strengths as with other forms of rope and failed immediately or to a loading, at best, of 10-50% of the rated breaking strength. Knots are not recommended in logging.

- Pre-tensioning guylines or other lines with manual methods needs additional development, although we used “twisters” to pre-tension samples and did not find significant reductions in ultimate breaking strength.

- The ultimate strength of synthetic ropes above is comparable to steel wire rope but the exact breaking strength may depend on test procedures (rate of cycling to a prescribed percent of ultimate strength); quality of fiber materials, and the construction of the rope itself. Our cycled (per American Cordage Institute (1997)* test protocols) and uncycled tests produced similar breaking strengths. Design factors (formerly called Factor of Safety) may need to be developed for synthetic ropes.

The current project did not plan to test abrasion or degradation in synthetic ropes, but we did obtain a sample of AMSTEEL 815 synthetic rope used three years as a guyline for tail trees and intermediate support trees. The 9/16 inch rope was markedly increased in diameter (more than double) and had dirt and debris among the fibers and strands. Yet the residual strength of the test sections was more than 65% of the original specifications.

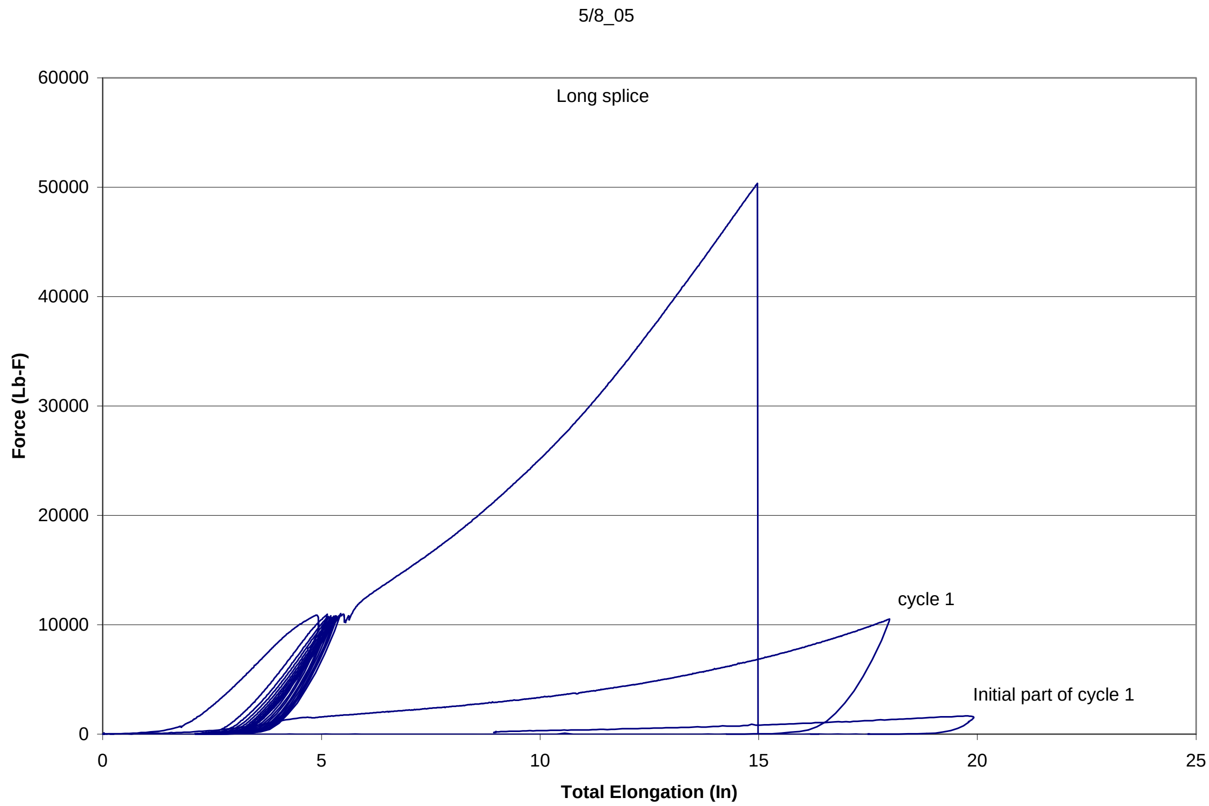

Figure 6. Sample test of a long splice with 5/8” AMSTEEL-BLUE rope

Economic Benefits

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 two to six times that 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 incorporated into the logging and forestry sector as well as other sectors currently using steel wire rope. However, it is clear that gains in effectiveness can offset the costs of synthetic rope at current prices.

For example, based on initial results from the skidder winch line trials (5 turns per worker), it is projected a 10 percent increase in productivity on a daily basis might be possible for a single machine operator setting his own chokers. Coupling this result with a recent skidder productivity study (Kellogg, et al, in review), this could amount to an additional 4 turns per day for 400-500 foot skids. While load size is an important factor, this could be about 1000 board feet (1 Mbf) additional production per day, at a benefit of $ 50 – 100 per day to the contractor.

If synthetic rope could increase payloads for cable systems or allow access to difficult terrain, substantial benefits might be attributed to the synthetic rope through reduced costs by replacing the need for more expensive harvest systems or additional roading. Gains might also come during cable equipment set-up, faster manual work, use in helicopter logging, balloon logging and many applications not yet considered. The light weight and high strength of synthetic rope provides the potential to increase skyline payloads. The benefits will be greatest at low deflections where the ratio of total line weight to net payload is greatest. Table 1. illustrates the potential benefits of using synthetic rope (AMSTEEL-BLUE) and wire rope (independent wire rope core, EIPS). Two rope diameters are compared for a 1500-ft span, zero chord slope, where a load is fully suspended at midspan. The maximum payload that brings each rope up to its design load (1/3 of breaking strength) is calculated. At low deflection (4%) the synthetic rope provides a 67% increase over the fully suspended payload for the 5/8-inch wire rope and 31% for the 1-inch rope. The percentage increase declines as the deflection increases.

Table 1. Potentials of Synthetic rope to increase payloads compared to steel wire rope.

	5/8-inch diameter rope			1-inch diameter rope		
Deflection (percent)	Steel Payload (pounds)	Synthetic Payload (pounds)	Percent Increase	Steel Payload (pounds)	Synthetic Payload (pounds)	Percent Increase
4	1645	2743	67	4096	5373	31
8	3779	5512	46	9450	10814	14
12	5824	8177	40	14581	16052	10

Planning for cable systems using steel wire rope is commonly done using LoggerPC or similar software. It seems appropriate and necessary to incorporate synthetic rope into such analytical tools in the future.

Ergonomic Results

The objective of the worksite redesign grants is to reduce workloads in specific occupations with innovative solutions. The use of synthetic rope to replace wire rope in some logging applications certainly fits this objective. A number of difficult and dangerous logging jobs use wire rope as an integral part of their daily operations. These include but are not limited to:

Chokersetters
Rigging Slingers
Hooktenders
Chasers
Climbers
Cat Hookers (chokersetters behind ground-based logging operations)
Helicopter Hookers
Helicopter Chasers
Truck Drivers
And so forth…..

The tasks using wire rope among these occupations involve pulling, carrying, climbing, lifting, and throwing wire rope in a variety of awkward positions. Just for emphasis, it is common to carry a 150 foot guyline on steep slopes to help rig trees. The wire rope for a common size weighs about 111 pounds while the comparable synthetic version is less than 18 pounds. This difference is significant for a person (man or woman) weighing one hundred and fifty pounds or so.

Improved measures of workload reduction may be needed to help assess differences between logging tasks as the overall heavy workloads run the pulse rate to high levels where maximum values may not be meaningful. This pilot research tends to demonstrate this effect. Our use of heart rate reserve as a percentage increase in heart rates over the resting rate helped our analysis but did not resolve the concerns. Thus, we also looked at task duration at high levels and improved recovery rates for use of synthetic rope over steel wire rope. While our sample size is small, it includes women and some age distribution of workers. Our results favoring synthetic rope over steel wire rope are statistically significant using various measures and approaches.

Finally, many aspects are ergonomic differences are subjective and depend on the workers themselves. We elect to report the comments of the workers on the use of synthetic rope versus steel wire rope in Appendix A. in their full measure as an important view of the differences.

Funded Future Research

Research with new developments generally stimulates many additional questions. 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 commenced July, 2001 and will run for two years.

Project 1: Field Applications Of Synthetic Ropes

The Synthetic Rope Research Team will now take the ropes to the field for trials with industry in the following applications.

- Static lines as guylines, etc. with 3 industrial logging contractors
- Establish wear and damage criteria for users
- Verify ergonomic potentials with ground-based logging with Student Logging Crew and logging contractors
- Test new rope formulations with different coverings and braiding construction
- Test the use of synthetic ropes to replace wrappers on log trucks with three firms including one woman log truck driver
- Produce an illustrated user's guide for synthetic rope applications in logging
- Summarize ergonomic and workload reductions from using synthetic ropes.

Project 2: End Connectors And Running Line Applications In Logging

Several major areas from the first project suggest the need for further research and development on synthetic ropes in logging. We will also test, develop, and evaluate new products and uses.

- Evaluate end-connectors comparable to those now available for wire rope

- Use synthetic rope in running line applications and develop design criteria for cable harvesting software
- Conduct materials properties tests for running line applications
- Evaluate manufacturer’s rope coverings for running line applications
- Assess winchline mechanics and spooling issues of synthetic rope
- Identify operating limits and procedures for running lines
- Work with a carriage manufacturer to develop slack-pulling and tensioning device for spooling
- Assess the ergonomic benefits from running line applications
- Estimate the economic benefits from using synthetic rope with running lines.

Both of the projects above involve the rope manufacturer, companies that make end connectors, a carriage manufacturer, and many logging industry cooperators.

Project Summary

With the dwindling logging workforce pool and an aging, but highly experienced labor force, the industry needs to take steps to attract, retain, and protect workers. Additionally, productivity increases and cost reductions are always welcomed in the competitive logging industry. Synthetic rope as a replacement for wire rope in selected applications (lift tree guylines and lift lines) appears immediately warranted from this study. Additional applications are possible based on future research on durability and longevity.

The results of the heart rate monitoring shows logging is a high exertion activity. The range of trials conducted reflect the day to day activities associated with cable logging and also pulling bull line off the skidding winch. Even numerically small reductions in heart rates can have large reductions in exertion levels. Fatigue is a major ‘cause’ associated with industrial accidents. Incorporating synthetic ropes into the logging industry may be one the most innovative manual labor improvements since the introduction of the chainsaw.

We expect to learn a great deal about logging applications with synthetic ropes with exciting research in the next few years. Great promise exists for improvements in logging safety, worker ergonomics, and economic efficiency. Quantification and description of safe applications, limitations, and useful life/replacement criteria may lead to industry-wide implementation and benefits. These areas of research, with foundations in the wire rope and cable harvesting research of the 1960’s and 1970’s, will advance the field with 21st century materials and applications. As with the case of many logging activities, innovation can then be advanced further once the rope is in the hands of practitioners.

Technology Transfer

It is beyond the scope of this report to list all of the Technology Transfer outputs and events where the research in progress has been highlighted. Listed below find example presentations and articles of the kinds of technology transfer for the synthetic rope project (estimated audience impacted in parentheses):

Synthetic Rope Research at Oregon State University, Intermountain Forest Engineering Conference, 2000, Moscow, ID, April 2000. (176)

Synthetic Rope: Ergonomics and Productivity, Intermountain Forest Engineering Conference, 2001, Moscow, ID, April, 2001 (187)

Update on Synthetic Rope: First Look and Future Research, Intermountain Forest Engineering Conference, 2002, Moscow, ID, April 2002 (156)

Synthetic rope in logging. Olympic Logging Conference. Vancouver, BC. April 2000. (204)

Prospects for using synthetic rope in logging: First look and future research. International Mountain Logging Conference and Tenth Northwest Skyline Symposium, Seattle, WA, December 2001 (226)

Synthetic rope used in logging: Some Potentials. Council on Forest Engineering Annual Meeting, Snowshoe, WV, June, 2001, (128)

Synthetic Rope Research in FORWORKNET: Focus on Ergonomics in Forestry. Special issue of the Forestry Workforce Network. International Labor Organization Sectoral Activities Department. Geneva, Switzerland. December 2001(2,000)

The basis for productivity improvement in cable harvesting from human resources. FAO/ECE/ILO Joint Committee Seminar on New Trends in Cable Harvesting for Sustainable Forest Management in Mountainous Regions. Ossiach, Austria. June, 2001 (88)

Article in Logger's World, trade magazine of the logging industry, on synthetic rope research. March 2002, (>5,000)

The above presentations and publications were to loggers and other users of synthetic rope and do not include the brief one-evening programs for loggers where a portion of the program was devoted to synthetic rope research. Future plans will involve publishing synthetic rope research results in peer review journals in the forestry sector and safety sector.

Video

Accompanying this report is a short video with a description of the synthetic rope research. For the near term it can be made available with the written report through the Oregon Occupational Safety and Health Administration mechanisms. Once all research is completed, a more robust video will likely be produced to show the entire process of developing synthetic rope for use in logging. It would likely be made available through OR-OSHA and the OSU College of Forestry Media Center. Additional funding would be needed to complete the video project in future years.

Photo Gallery

Pictures of synthetic rope research are useful to those wishing to understand the potential and research and development effort. A photo CD with captions has been prepared to accompany this research report to Oregon OSHA.

Special Appreciation

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References

American College of Sports Medicine, 1990. The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness in healthy adults. Medicine and Science in Sports and Exercise. 22:265-274.

Anderson, L. and Temen, K.I. 1999. Cable thinning as a business partnership between landowner and contractor. P. 143-153 *in* Proc. of the International Mountain Logging and 10th Pacific Northwest Skyline Symposium, Sessions, J. and W. Chung, (eds.). Oregon State University, Corvallis, OR. 368 p.

Astrand, P-O and K. Rodahl. 1986. Textbook of work physiology: Physiological bases of exercise. McGraw-Hill, New York. 756 p.

Cordage Institute. 1997. Test methods for fiber rope. Standards CI 1500-97. Effective July 1997.Wayne, PA. 16 p. plus appendices.
*(A misprint in the Cordage Institute test methods should call for a cycle rate of “20 – 200 seconds” rather than the “2 – 200 seconds” found in the test procedures.)

Donohue, P.G. 2001. Dr. Donohue: Calculating exercise heart rate can be tedious, but is worth it. Corvallis Gazette-Times Column. September 1, 2001.

Durnin, J.V.G.A., and R. Passmore. 1967. Energy, work and leisure. William Heinemann, Ltd., London. 167 p.

Garland, J.J., J. Sessions, S. Pilkerton, and B. Stringham. 2001. Synthetic rope used in logging: Some Potentials. Council on Forest Engineering Annual Meeting, held July 16-19, 2001, Snowshoe, West Virginia. Council on Forest Engineering. Corvallis, OR. 5 p.

Garland, J.J. 2001 (contributing editor) FORWORKNET: Focus on Ergonomics in Forestry. Special issue of the Forestry Workforce Network. International Labor Organization Sectoral Activities Department. Geneva, Switzerland. December 2001. 28p.

Golsse, J-M. 1996. Initial tests of synthetic-fiber mainlines for cable skidders. Field Note FN-033. Forest Engineering Research Institute of Canada. Pointe Claire, Quebec, Canada. 2 p.

Jarmer, C. and J. Sessions. 1992. Computer based skyline analysis: LOGGERPC 3.0 - a new tool for logging planning. P. 128-134 *in* Proc. "Workshop on Computer Supported Planning of Roads and Harvesting", August 26-28, 1992, Feldafing, Germany, Sessions, J (ed.). Sponsored by IUFRO 3.05 and 3.06. Oregon State University, Corvallis, OR.

Kellogg, L.D., G.V. Milota, and M. Miller, Jr. 200x. Tractor thinning production and costs: Experience from the Willamette Young Stand project. Draft manuscript in review, Forest Research Laboratory, Oregon State University, Corvallis.

Pilkerton, S. Garland, J., Sessions, J., and B. Stringham. 2001. Prospects for using synthetic rope in logging: First look and future research, in Proceedings of the International Mountain Logging and 11th Pacific Northwest Skyline Symposium. 2001-A Forest Engineering Odssey. Eds. P. Schiess and F. Krogstad, College of Forest Resources. U. Washington. Seattle, WA. Dec. 10-12, 2001. CD ROM Media. 289p.

Macwhyte wire rope. 1984. Catalog G-18. Macwhyte Wire Rope Company. Kenosha, Wisconsin.

Oregon Occupational Safety and Health Administration (OR-OSHA). 2000. Worksite Redesign Program Guide, 2000. OR-OSHA, DCBS, Salem, OR. 13 p. (www.cbs.state.or.us/external/osha/grants)

Polar Electro Oy. 1998. Polar precision performance user’s guide: Software version 2.0 for Windows. Polar Electro Oy, Kempele, Finland. 147 p.

Takumi, Uemura. 1998. Application of super fiber rope as a guyline for a mobile tower yarder. P. 70-75 *in* Proc. of the IUFRO/FAO Seminar on forest operations in Himalayan forests with special consideration of ergonomic and socio-economic problems, Heinimann, H.R. and J. Sessions (eds.). Kassel University Press, GmbH. ISBN 3-933146-12-7. 160 p.

The American Group (now Samson Rope Technologies). 1997. Marine and industrial ropes (catalog MIRC-1097). Ferndale, WA. 39 p.

Appendix A

Subjective Comments from Workers on Selected Tasks

1999

Steel – Drag Ridge activity (150 feet @ 25 percent)

Coiled cable is better. 10

Uphill very difficult. Easier to coil and carry. 11

Uphill was harder. 12

Pulling downhill was <u>much</u> easier than pulling uphill through the brush – I barely made it uphill. 13

Synthetic – Drag Ridge activity (150 feet @ 25 percent)

Synthetic is much less difficult. 10

Rope slides easier over slash. 11

Steel – Drag Steep activity (150 feet @ 45 percent)

Compared to pulling it up the road it was about the same. Technique was different, ie., pulled entire length of rope on road. On the hillslope I could no (sic) pull entire 150 feet at all. Had to stop and pull slack then walk up the hill, stop pull slack… until I was at the end of the test distance. Total effort was slightly more difficult just different. If asked to pull entire length, I would not be able to do it. 8

Not much worse than the lower slope. 10

Very difficult pulling steel uphill w/ slash. 11

About the same level of difficulty as the lesser slope. 13

Synthetic – Drag Steep activity (150 feet @ 45 percent)

Compared to pulling wire on the road this was a piece of cake. I could pull the entire length of synthetic uphill with ease, essentially the same as walking up the hill. 8

Rope slides over slash easier. 11

Steel – Carry (coil) Ridge activity (150 feet @ 25 percent)

Footing was the most difficult part of this task. Slope was greater also. 8

Heavy cable makes it difficult to keep balance. 11

Synthetic – Carry (coil) Ridge activity (150 feet @ 25 percent)

Much easier than packing steel up road surface. 8

Synthetic is nicer, but the main difference is dealing w/ footing. 10

Very easy compared to steel – safer – can keep good balance in heavy slash/brush. 11

Steel – Carry (coil) Steep activity (150 feet @ 45 percent)

More difficult due to slope and footing. Downhill was similar. Uphill much more effort was required. 8

Slightly more difficult than packing on the road, but still easier than pulling line up slope. 10

Slash slope grade, irregular terrain make this very difficult. 11

Easier to carry the wire rope wrapped then pull the stretched rope. 12

Downhill was harder than uphill on road due to greater slope and slash – I had to watch my footing more. 13

Synthetic – Carry (coil) Steep activity (150 feet @ 45 percent)

Carrying coil of synthetic uphill and downhill was very easy compared to carrying steel on the road. 8

Coiled rope was easier to carry than dragging the full length of synthetic. 9

Synthetic rope was not a factor in the diff. (iculty ?) the change for me is dependent on slope. 10

Slightly more difficult due to slope, slash. 11

Slope and slash were more difficult, but rope was much easier. 13

Climb and Rig Intermediate Support Tree (Steel)

Again climbing was the same. Rigging, ie., pulling up cable (steel) associated lines and rigging was difficult compared to just climbing. Compared to pulling synthetic ropes and straps, this was much more difficult. 8

Climbing was the same as before. Lifting all rigging (steel and associated straps) was “difficult”. Compared to synthetic lifting the steel guyline and jack support line was much harder. Setting the jack support line in it’s block and pulling slack to lower eye to the ground was much more difficult than the synthetic. Closing the jack support block was much harder also. 8

Climb and Rig Intermediate Support Tree (Synthetic)

Climbing was essentially the same as baseline climb. Rigging the support made the task more difficult than just climbing. Pulling synthetic rope guylines and straps up to rigging point was much easier than steel. 8

Much easier to use than other tree straps. Much easier than cable. 11

Total task (climbing and rigging) was somewhat more difficult than just climbing. Lifting block was the same, but all other rigging / line was much lighter and required much less effort. Setting jack support line in it’s block and lifting entire assembly in order to insert pin was much easier than steel. 8

Synthetic seemed to tangle easier than wire rope. Synthetic tree straps seemed about the same as regular tree straps in ease. 9

2000 Crew Comments

Steel – Drag Road activity (300 feet @ 4 percent)

Base case - Going down was fairly simple, coming back it beeped (HR > 160) just about 30 feet after I started, much more difficult. 1

Base case – started beeping after 20 feet downhill, never below 100 on recovery before coming uphill, over 160 right after start. 2

Base case – going down was easy, going up got very difficult ¾ of the way up. 3

Base case – no problem going down, going up was a little tougher. 4

Base case - feeling it ¾ way down. Feeling it, ½ way up. 5

Base case - HR at 165 half-way down on downhill pull. Above 160 after 50 feet on uphill pull – had to stop and rest close to top on uphill pull. 6

As a base case, downhill somewhat difficult, uphill extremely difficult.

Synthetic – Drag Road activity (300 feet @ 4 percent)

Much easier, almost the same as just walking without anything. 1

Hardly like pulling anything. 2

Felt like leading a good horse. 3

Was able to pull with pinky finger up and down the road with (sic) trouble. 4

Walking – no significant drag downhill, slight tug uphill. 5

Felt like I was just walking. Slight resistance on uphill pull. 6

Very easy. 7

Steel – Drag Ridge activity (150 feet @ 25 percent)

About halfway up the hill I felt like the cable was stuck and I could not move it, very difficult. 1

Had to pull slack most of the way uphill. 2

Downhill easy, uphill over 160 bpm with 15 feet to go. 4

Uphill, 100 feet +/- reached 160+ beats per minute (bpm) with steady progress until last 20 feet +/- . 5

Had to pull slack practically the whole way. 6

Synthetic – Drag Ridge activity (150 feet @ 25 percent)

A bit more of a pull uphill, still easy though. 1

Was able to drag with no problem. 4

Noticeable resistance associated with slash interactions. 5

Slight pull uphill, but fairly easy steady pull. 6

Very easy. 7

Steel – Drag Steep activity (150 feet @ 45 percent)

Down was not so bad at all, up was quite a chore, almost maxed. 1

The hardest part was getting footing on the slope - I pulled slack about 50 feet from the top on the uphill pull. 6

Synthetic – Drag Steep activity (150 feet @ 45 percent)

A bit more difficult coming up then it was before. Quite a bit of friction on the rope. 1

Got caught on some things on the way up. 2

Could feel the rope on the way up when it got caught on things. 6

Both very easy as compared to base case. 7

Steel – Carry (coil) Road activity (300 feet @ 4 percent)

Not too bad. 1

My back started to hurt on the way up. 6

Synthetic – Carry (coil) Road activity (300 feet @ 4 percent)

Just as easy as walking up a driveway. 1

Same as walking up and down a road. 3

No problems. 4

Very easy. 7

Steel – Carry (coil) Ridge activity (150 feet @ 25 percent)

I went about 30 feet too far on the way down. Heavy cable. 1

Felt like my body weighed about 500 pounds. Had to stop and catch breath on uphill. 6

Synthetic – Carry (coil) Ridge activity (150 feet @ 25 percent)

Easy, however, HR got up to 160 briefly at the end. 1

Practically like walking. 6

Steel – Carry (coil) Steep activity (150 feet @ 45 percent)

Not too bad. Not very good footing. 1

Stopped after going about 90 feet downhill. Feet slipping and did not feel comfortable. 6

Synthetic – Carry (coil) Steep activity (150 feet @ 45 percent)

Pretty steep, ropes no problem. 1

Easy going down, a little more difficult walking up. 3

Very easy. 7

Climbing Only (BASE CASE for climb and rig)

My heart rate was fairly high, but I did not feel very worked. 1

First time climbing 50 feet – nervous during entire climb – especially on the way down. 2

Halfway = 160+ bpm. 3

Forearms cramped on the way down. 4

Halfway up – 160 bpm. 5

Not bad going up – nervous on the way down. 6

Nothing out of the ordinary. 7

Climb and Rig Intermediate Support Tree (Steel)

Climb and rig was the same, but the cable was extremely heavy. 1

Rigging not much more taxing. Pulling steel 5/8-inch up 50 feet is. 5
NOTE: All other workers pulled 1/2-inch cable up 50 feet).

I had a hard time climbing up today and pulling up the guyline was quite challenging. 6

Climbing portion was identical. Pulling rigging up made it difficult compared to just climbing. 7

Climb and Rig Intermediate Support Tree (Synthetic)

It is very high, and rigging that high can make me a bit nervous. 1

Same as climbing, but slightly more difficult. 3

Syn. Rope easier to pull up than even strap/shackle or strap/block (any steel). 5

Had trouble pulling block but syn. Rope was easy to haul up. 6

Climbing up was exactly the same, pulling rigging was the only difference. 7

Steel – Bull line winch (5 turns)

All in all it was not difficult. The steep long pull was tough because we ran out of cable on the drum. But all other pulls were really easy. 1

Short uphill pulls were not too difficult, long steep pulls very hard. All downhill very easy. 7

Synthetic – Bull line winch (5 turns)

Not so bad. 1

Both directions were easier than dragging cable on road. 7