Manual Line Loading Investigation

Place: Riksanlegget, Sjoa, NORWAY.
Date: 27-07-2006.
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Introduction

In order to better predict typical loading on throwlines (etc) used in river rescues, accurate estimates are needed regarding the loads that can be applied by people on such systems. This investigation considers several of the most commonly found systems, and enumerates their loadings on such lines. Note that for these purposes 'loads are quoted in kg', where 1kg ~= 9.81N in the vertical plane.

System description

An anchor (tree) was used to tether a load cell, via a triple loop of 25mm webbing. Various rope/mechanical systems were then attached to the load cell using an opposing anchor, and humans to load the system. The line used was a 10.4mm 'Type 5 polyamide' multi-core rescue line from Beal, conforming to EN 1891.
The loads were then measured via the load cell (A TEO 2 000kg FSD load cell, calibrated, max error =1% of FSD).

Image 1 "load cell & anchor"

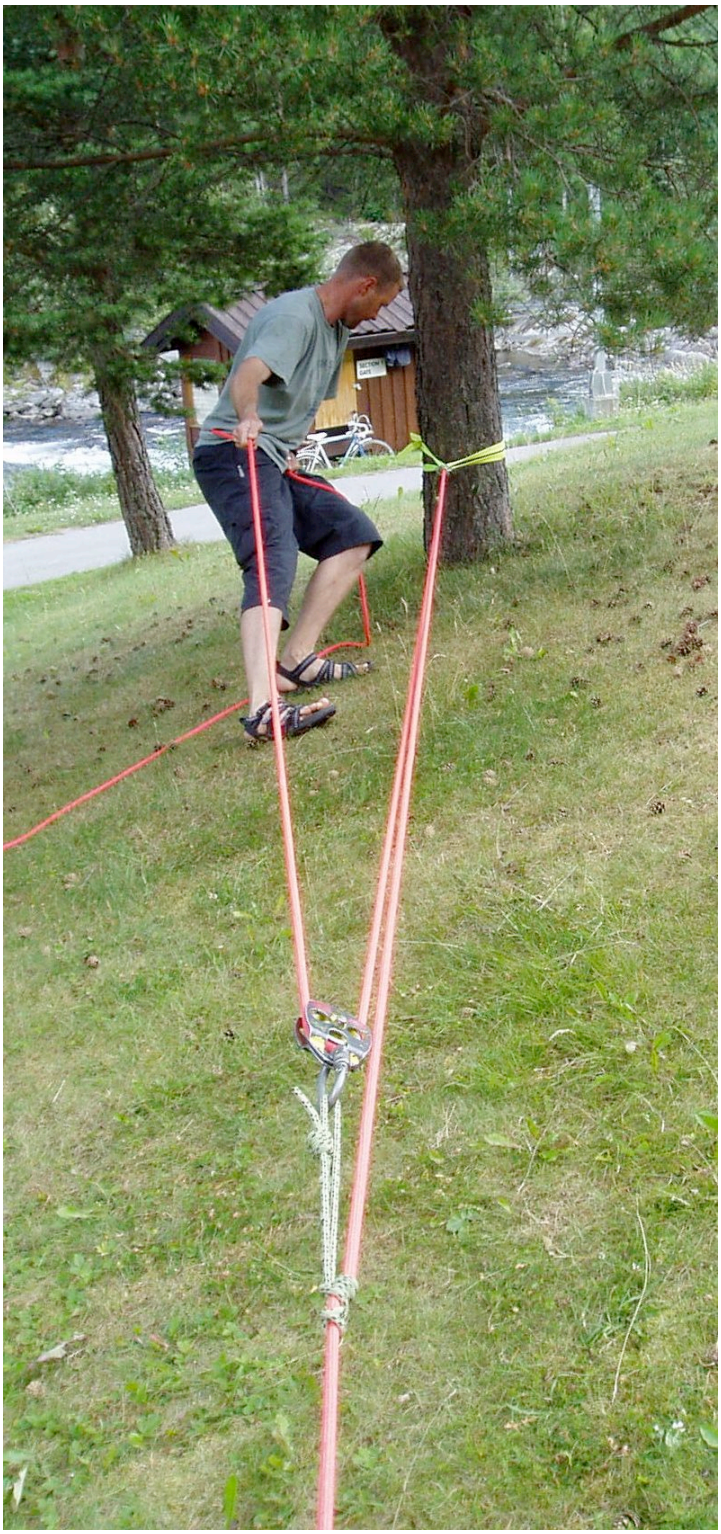

Image 2 “free standing person loading on Z-drag 3:1”

Case 1

Simple loading senario, 1:1 mechanical advantage via person pulling directly against the load cell.

Loading person (weight)	Load - Free standing	Load - Braced against tree
Åk (65 kg)	30	40
PV (75 kg)	40	60
JG (85 kg)	60	70
PV + JG combined	120	

Observation: On average a person is able to apply ~60% of their body weight to a line when free-standing. If a stance braced against/behind a stationary object is adopted, then the average loading rises to ~75% % of their body weight.

Case 2

Simple loading senario, 1:1 mechanical advantage with person pulling via a 'change of direction' pulley.

Observation: The above 'Case 1' experiment was repeated with a single pulley introduced into the system, to facilitate a change of loading direction but no modification in mechnanical advantage. This gave almost identical results, showing that the additional pulley has negligable effect (friction) on the system.

Case 3

Loading senario with a 3:1 mechanical advantage - person pulling via a 'Z' drag system.

Loading person	Load – Free standing	Load – 'bounce'	Load – braced against tree
ÅK	130 kg	150 kg	170 kg
PV	170 kg		200 kg
JG	180 kg	200 kg	230 kg

Observation: Due to the use of low friction pulleys, a near perfect x3 muliplication of the load is achived with the system. In addition the participants are better able to load the system since they are more stable whilst travelling 1/3 distance under pulling due to 3:1 system.

Case 4

Loading senario with a 3:1 mechanical advantage ('Z' drag) to tension the system initially, which is then 'locked off' (with a "rescue-cender"). A prussik was then attached to the middle of the span and loaded traversely to create a so-called 'vector pull'.

Initial load in line	With additional 'vector pull'.
85 kg	190 kg
100 kg	210 kg
120 kg	220 kg
150 kg	230 kg

Observation: The use of a 'lock off' device, such as a rescue-cender (or additional prussik) and then a 'vector pull' clearly demonstrates an effective load multiplier, with an average increase of doubling (x2) the initial loading.

Case 5

Loading senario with a 4:1 mechanical advantage - human pulling via a 'pig-rig'.

Loading person	Load – braced against tree
PV	250 kg
JG	280 kg

In addition the system was re-rigged with carabiners, instead on pullies, creating more friction in the system. This reduced JG maximium loading to 210 kg.

Observation: Due to the use of low friction pulleys, a near perfect x4 muliplication of the load is achived with the system. In addition the participants are better able to load the system since they are more stable whilst travelling 1/4 distance under pulling due to 4:1 system.

Case 6

Loading senario with a 4:1 mechanical advantage 'pig-rig') to tension the system initially, which is then 'locked off' (with a "rescue-cender"). A prussik was then attached to the middle of the span and loaded traversely to create a so-called 'vector pull'.

Loading human	Load – braced against tree	Load – with additional 'Vector pull'
JG	320 kg	350 kg

Note that JG used a harness to attach the line to himself, thus increasing traction to tension the system.

Conclusion

A single person with mimimal equipment, such as that carried in the back of a kayak can reasonably expect to be able to apply a load approaching 400kg (~4000N) to a teathered line (e.g line on a pinned kayak etc). Thus all equipment used within such systems must be able to withstand such loading.

Additional factors such as:

- Detoriation of equipment over time
- Adrenaline = ‘stronger’ rescuers
- Stronger/heavier than average rescuers
- Multiple rescuers.
- Additional ‘Mechanical Advantage’ from additional systems
- Shock loading upon failure of a single component within the system.
- Desired Factor-of-saftey.

should also be taken into account when designing components of such rescue system.

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