LOGGING INDUSTRY RESEARCH ORGANISATION
NEW ZEALAND
ISSN 1171-6932
REPORT
Vol. 20 No. 22 1995

STUMP ANCHORAGE CAPACITY ON TWO CONTRASTING SOIL TYPES

Jason Smith
Shane McMahon

Figure 1 - A stump being tested

ABSTRACT

Testing of a range of radiata pine stumps showed that stumps on a clay soil were approximately twice as strong as comparably sized stumps on a sandy soil. Furthermore, diameter at breast height (D.B.H.) was a poor indicator of the anchorage capacity of individual stumps. This was more pronounced on the sandy soil, where D.B.H. had a smaller effect on anchorage capacity.

Because of the variability in stump anchorage capacity, there appears no easy solution to identifying suitable anchor stumps on weak and/or shallow soils. Therefore, it is very important to ensure that safe rigging practices and hauler operation are being employed, and that anchor stumps are routinely inspected for signs of weakening.

INTRODUCTION

Stumps used as anchors for skylines and guylines must withstand cyclic loadings in excess of the wire rope safe working loads. They should also withstand peak or shock loadings that may occur during equipment failure and fouling of the drag. Typically, stumps are selected by contractors based on stump location, soil conditions, past experience, and belief that the bigger the stump the better.

The trend towards shorter rotations, more cable logging operations, and increased emphasis on safety, has heightened the need for more quantitative information on how anchor stumps behave. Earlier work by Liley (1985) on a gravel soil at Golden Downs Forest, highlighted that stump anchorage capacity generally increases with stump diameter. To determine if this is true for other soils, this study focused on two contrasting soil types where cable logging is commonly used.

This report summarises the main findings of that study, focusing on the application of the results to selecting appropriate anchor stumps.

ACKNOWLEDGMENTS

LIRO acknowledges the assistance of: Carter Holt Harvey Limited, Auckland; Rayonier New Zealand Limited, Gisborne; the Department of Natural Resources Engineering, Lincoln University; the Resource Monitoring Unit, New Zealand Forest Research Institute, Rotorua; and Brian Tuor (Cable Logging Specialist).

METHODOLOGY

Experimental design

In working situations, a variety of site, stand, and cable system factors affect the anchorage capacity of stumps. These include: the physical properties of the soil; the size, age and form of the tree; ground slope; position of the tree on the landscape; and the nature of the pulling force. To accurately define anchor stump behaviour under the influence of all of these factors requires the testing of an unrealisable number of stumps. We simplified the test conditions in this study, by focusing on only two of these factors - soil type and diameter at breast height (D.B.H.).

Stumps were tested at two sites during September and October 1994. Soil, ground slope, tree position and stocking variability within each site was minimised by appropriate stump selection. Loads were applied at the same height on the stump, loading rates were similar for all stumps, the pull direction was uphill, and the range of pull inclination was minimised.

Study sites

Two sites with contrasting soil types were chosen (Table 1): Whitford Forest, south east of Auckland, and Mangatu Forest, north west of Gisborne.

The clay soil at the Whitford site formed from weathering of greywacke bedrock. In contrast, the soil at the Mangatu site consists predominantly of sand formed by weathering of volcanic ash and underlying mudstone.

Tree Selection

The trees tested at each site were selected before being felled. This ensured that a range in D.B.H. was tested, and allowed unsuitable trees (such as heavy leaners, malformed or wind damaged trees) to be excluded from the sample. Table 1 summarises the stand characteristics and stumps selected.

Stump heights at the two sites ranged from 50 cm to 75 cm, measured from the downhill side. Stumps were tested within 30 days of felling. Prior to testing, each test

Table 1 - Summary of stand characteristics and stump selection

Study site	Soil type	Stocking (stems/ha)	Age at harvest (yrs)	No. of stumps tested	D.B.H. range tested (cm)
Whitford	clay	138	29	54	38 - 68
Mangatu	sand	350	25	64	29 - 76

stump was notched according to OSH (1989), 30 cm above the ground on the downhill side.

Stump Pulling System

Design of the pulling system required that loads approaching 100 tonnes could be applied to the stump to ensure that the larger stumps could be loaded until failure. The initial pulling force was applied by a mechanical winch mounted on the rear of a Komatsu D65 (Whitford) and a D7 Caterpillar (Mangatu). Using a six-block purchase system, a maximum load of 102 tonnes could be applied to a 35 mm wire rope strop looped over the stump. Applied loads were measured every ¼ second using a Husky Hunter field computer and loadcell shackled between the strop and the purchase system.

Once the test commenced, the winch applied the load at a constant rate until stump failure occurred. Usually, it took between 10 and 20 seconds for the maximum load on the stump to be reached.

RESULTS

Stump Failure

The majority of stumps tested (87%) failed by uprooting. Uprooting occurred relatively slowly, comprising displacement in the direction of pull, and rotation (Figure 2a).

A small proportion of the stumps (13%) rapidly failed by slabbing and shearing; all of these occurring at Whitford. Slabbing failure occurred after some forward displacement and rotation of the stump. This caused the holding wood above the

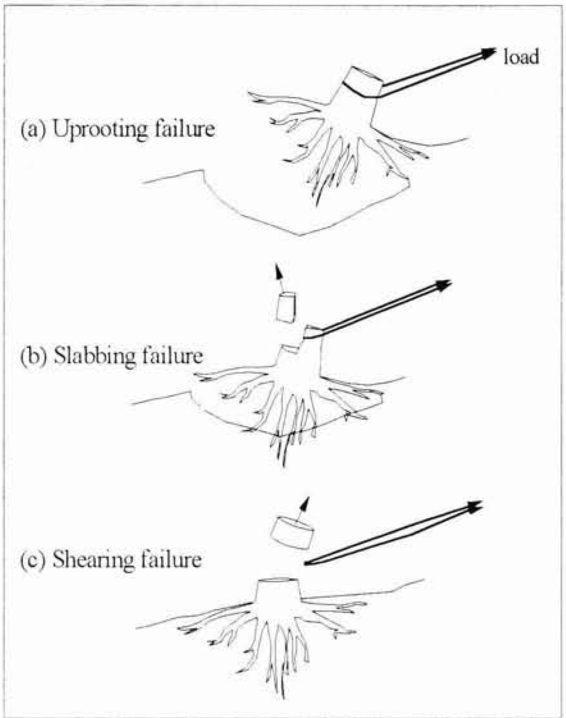


Figure 2 - The three types of stump failure

notch to slab off (Figure 2b). Shearing failure occurred when the wire rope strop cut through the stump before there was any appreciable forward displacement and rotation (Figure 2c). Stump height was increased from 50 cm to 75 cm to provide more holding wood above the notch. This eliminated the occurrence of slab failure, and slowed the rate of shearing failure.

Figure 3 shows D.B.H.s plotted against peak loads for all stumps. The effect of soil type can be seen, with each data set being defined by a different line of best fit.

The results show three main trends:

1. Overall, stumps on the clay soil were approximately twice as strong as stumps of comparable size on the sandy soil.

2. Stumps with similar D.B.H. values had considerably different stump anchorage capacities. For example, 50 cm D.B.H. stumps had peak loads ranging from 20 to 40 tonnes at Mangatu, and 45 to 75 tonnes at Whitford.

3. Larger stumps could have the same anchorage capacity as smaller stumps. For example, at Whitford, a 60 cm D.B.H. stump failed at a similar load to a 50 cm D.B.H. stump. This was more pronounced at Mangatu, where some 60 cm D.B.H. stumps failed at loads similar to some 40 cm D.B.H. stumps.

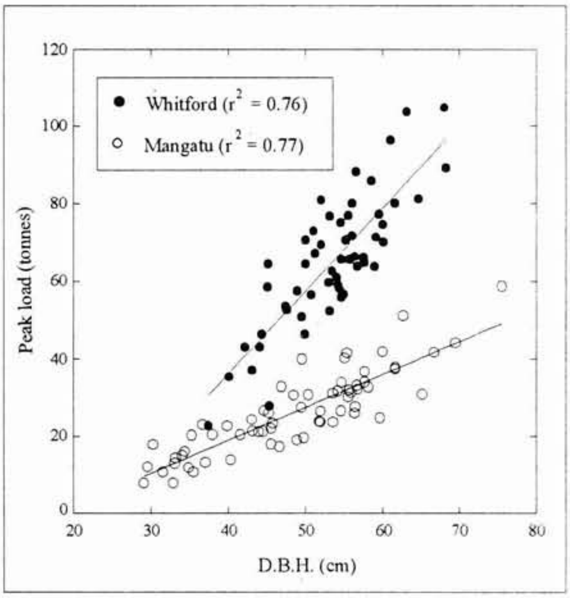


Figure 3 - D.B.H. versus peak loads for the two sites

DISCUSSION

Effects of Soil Type

Stumps on the clay soil of Whitford were approximately twice as strong as those of comparable size on the sandy soil at Mangatu. Two likely reasons for this result are differences in soil cohesion and depth to bedrock at the two sites.

Soil cohesion holds soil particles together due to chemical bonding and water tension in the voids. As clay sized particles have higher cohesion than sand sized particles, the higher the clay content of a soil, the higher the soil cohesion is likely to be. A good indication of how cohesive or strong a soil is can be gained by simply digging a hole. If it is difficult, it is likely that the soil is strong. However, if there are a lot of stones in the soil it is likely that the soil will be weaker than it appears.

The depth of soil overlying weathered bedrock will also affect stump strength by restricting downward root growth. Bedrock fragments were seen at the base of the root balls at Mangatu, and soil profile descriptions confirmed the presence of weathered bedrock within a metre of the soil surface.

Stump Selection

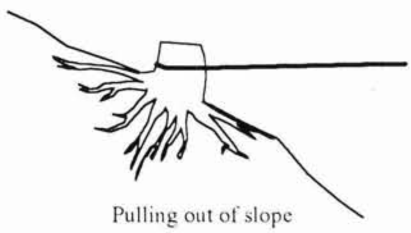
This study has shown that over a range of stump sizes, the bigger the stump the stronger it is likely to be. However, this may not be the case when selecting individual stumps. We minimised variations in aspect, inclination, soil properties, and tree characteristics, but still found that D.B.H was not always a good indicator of anchorage capacity. For instance at Mangatu, a 60 cm D.B.H. stump may have the same anchorage capacity as a much smaller 40 cm D.B.H. stump in the same setting. This type of problem was more noticeable at Mangatu, where D.B.H. had less of an effect on stump anchorage capacity.

In logging operations, aspects, slopes, rope inclinations, soil properties and loading rates are likely to be more variable than in our study. This will cause a greater variation in stump anchorage capacity, further reducing the accuracy of estimating individual stump strengths from predictive equations.

On weak and/or shallow soil, the concept of the bigger the better is less reliable than on stronger and/or deeper soils. Therefore, it should be recognised that large stumps on weak and/or shallow soil may not provide adequate anchorage capacity under peak load situations. If in doubt about likely stump strength, use multiple stump anchors or tie backs to increase anchorage capacity. Alternatively, anchor stumps can be eliminated from the system by using deadmen or mobile anchors.

When using stumps as anchors for either guylines or skylines, several basic rules of selection apply. These are:

- Avoid using heavy leaners for single anchors
- Do not use damaged stumps, including any obvious root damage
- Avoid stumps on wet and/or shallow soils
- Avoid old stumps
- Avoid pulling out of the slope.



Pulling out of slope

Other Safety Considerations

Several other steps to reduce the likelihood of stump failure are listed below. These should be adopted regardless of how confident you are in your stump anchors. Further information on safe rigging and operating practices is discussed by Liley (1983).

- Ensure notch depths are correct (OSH 1989), and notch as low as practical.
- Ensure adequate holding wood above the notch to reduce the chances of slabbing; we suggest at least 30 cm.
- Ensure that the guyline spread and inclinations are appropriate to the skyline direction and cable system being used (For instance, is the skyline being pulled laterally?).
- Check guyline anchor stumps daily and after peak loadings (drag fouling), looking for signs of stump movement. Also, check skyline anchor stumps if used over several days.
- Avoid situations that result in skyline and guyline overloading. Ensure good communication between breakerouts and the hauler operator to avoid overloading.
- Use tension monitors to determine the loads being applied to anchor stumps. This allows you to identify when recommended loadings are being exceeded. Also, monitors may warn the operator of uprooting or slabbing failure.

CONCLUSIONS

Tests were performed on a total of 118 radiata pine stumps to determine the effects of soil type and D.B.H. on stump anchorage capacity. Anchor stumps were loaded until failure, and the applied loads were measured.

Failure by uprooting occurred gradually as the stump moved laterally and rotated in the direction of pull. In contrast, failures by slabbing and shearing were rapid. Some lateral movement and rotation did occur prior to slab failure, but was generally absent for shearing failure.

The results show that anchor stumps on a clay soil at Whitford Forest were approximately twice as strong as those of comparable size on a sandy soil at Mangatu Forest. This difference is attributed to the lower soil cohesion and the presence of shallow weathered bedrock at the Mangatu site.

Over the ranges of stump sizes tested at each site, anchorage capacity increased with D.B.H. However, within the range of stump sizes there was considerable variation in anchorage capacity that did not conform to the overall trend. This was more pronounced on the sandy soil where D.B.H. had a smaller effect on anchorage capacity. Therefore, selecting anchor stumps on weak and/or shallow soils based on the bigger the better can result in unexpectedly weak stumps being selected.

Simple predictive equations or D.B.H. versus strength trends should not be used as the sole basis for selecting appropriate anchor stumps because they can be misleading. Where stump suitability is in doubt, skyline and guylines can be anchored to multiple stump anchors and tie backs, or deadmen (Liley 1983; OSH 1989).

Finally, safe rigging and operating practices must be followed at all times to reduce the risk of overloading stump anchors.

REFERENCES

Liley, W.B. (1983) : *Cable Logging Handbook*. New Zealand Logging Industry Research Association, Rotorua.

Liley, W.B. (1985) : Lift Resistance of Stumps. *New Zealand Logging Industry Research Association Report* 10(3): 4 p.

Occupational Safety and Health (1989) : *Safety Code for Bush Undertakings; Part 2 - Cable Logging*. Occupational Safety and Health, Department of Labour. 87p.

For further information, contact:

LOGGING INDUSTRY RESEARCH ORGANISATION
P.O. Box 147,
ROTORUA, NEW ZEALAND.

Fax: 0 7 346-2886 *Telephone: 0 7 348-7168*