REPORT

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Excavator Mobile Anchoring Methods

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Figure 1 - Excavator mobile anchor

Summary

Excavators can be used to anchor skylines and tailropes in cable logging operations. The method used to attach these load-bearing ropes and the positioning of the excavator can greatly affect its stability.

Liro Limited investigated the effects of a number of commonly used attachment and machine positioning methods on anchor stability. This report provides an overview of the modes of anchor failure and methods to improve stability. In addition, a list of points to consider when securing and shifting an excavator is presented.

Introduction

In recent years, the use of excavators as mobile anchors in cable logging operations (Figure 1) has increased in New Zealand. Excavators have the ability to lift the working ropes over obstacles during line shifts, which reduces the delays sometimes encountered when using a non-mobile anchor. Excavators also

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have the ability to form access tracks while minimising sidecasting of soil, and can use the boom and bucket to dig themselves out of trouble if stuck.

An important consideration with any cable logging operation is deflection. This can be increased by suspending the working ropes from the top of the dipper arm. Excavators of adequate size, situated and rigged correctly, can make strong and reliable anchors. However, if best practices are not adhered to, the anchorage capacity may be compromised creating a hazardous situation.

How do excavator anchors fail?

The mode of failure will depend on the attachment height and location, the angle of the dipper arm, and orientation of the boom.

Assuming that the excavator hydraulics do not creep and the track-gear brake is locked on, there are three main modes of anchor failure. These are:

1. sledging forward - this may occur when the load-bearing rope(s) are attached to the bucket (which is positioned on the ground).

2. overturning forwards - this can occur when the load-bearing rope(s) are attached high on the dipper arm, with the boom parallel to the direction of pull. The rear of the excavator will start to lift off the ground. If the boom remains in line with the direction of pull, the excavator will overturn forwards (Figure 2).

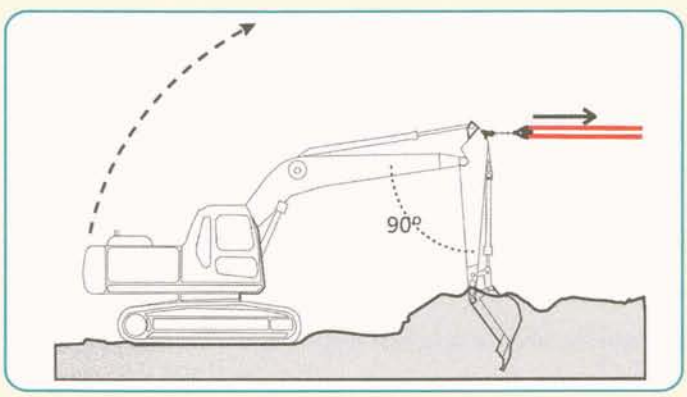

Figure 2 - Failure due to overturning forward

3. overturning sideways - this can occur when the load-bearing rope(s) are attached high up the dipper arm, but the boom is not in line with the direction of pull.

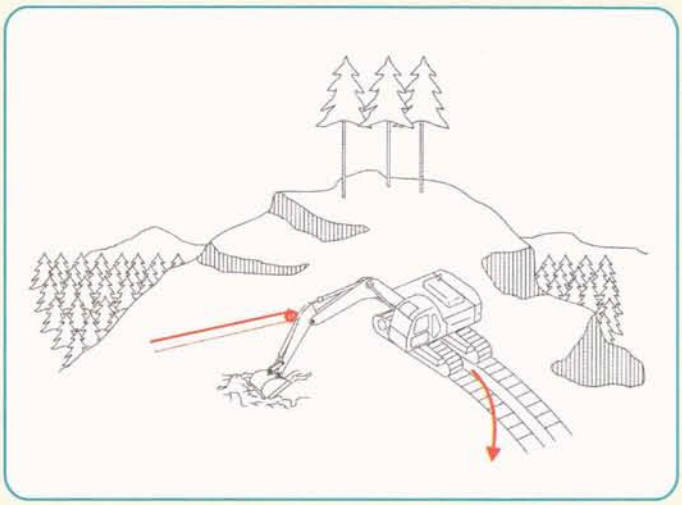

Figure 3 - Failure due to sliding sideways

In reality, an excavator is likely to fail through a combination of these three modes. If for instance, the excavator is on a side slope, the base of the excavator can become unweighted so it can slide sideways (in the direction of least resistance). This may result in the boom no longer being in-line with the working ropes, allowing the excavator to be pulled over on to its side (Figure 3).

Attachment height

Attaching the working ropes to the bucket (Figure 4) only relies on the excavator's weight, coefficient of traction, and the bucket resistance, to overcome the sliding effect. For instance, a 19 tonne excavator located on dry, loose ground will have an anchorage capacity of only 11 tonnes. This anchorage capacity would not be suitable to oppose the resulting forces of medium to large hauler working ropes, while maintaining a reasonable factor of safety.

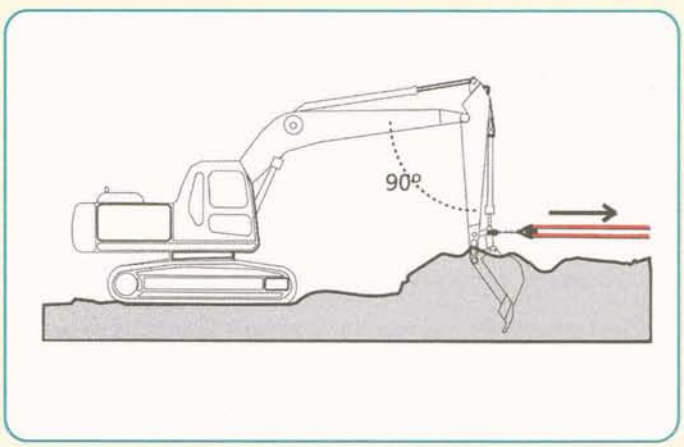

Figure 4 - Working ropes attached to the bucket of an excavator

To increase the anchorage capacity, the working ropes should be attached higher up on the dipper arm. Provided that the boom is in-line with the direction of pull, some of the load from the working ropes will force the bucket down into the ground. This will reduce the likelihood of the machine sledging forward.

However, the higher up the dipper arm that the load-bearing rope(s) are attached, the greater the tendency for the excavator to fail by overturning forwards. Therefore, a compromise is required between greater deflection (through a higher attachment position), and mobile anchor stability. Table 1 shows the tension required to overturn an excavator, with the load imposed horizontal to the point of attachment, for a range of attachment heights.

(a) 19 tonne Excavator

Attachment height (m)	Load-line tension at overturn (tonnes)		
	Dipper arm at 90°	Dipper arm at 110°	Dipper arm at 130°
3	49	56	62
4	37	44	49
5	30	36	42
6	25	31	37

(b) 30 tonne Excavator

Attachment height (m)	Load-line tension at overturn (tonnes)		
	Dipper arm at 90°	Dipper arm at 110°	Dipper arm at 130°
3	80	91	99
4	60	71	79
5	48	59	67
6	40	51	59

(c) 40 tonne Excavator

Attachment height (m)	Load-line tension at overturn (tonnes)		
	Dipper arm at 90°	Dipper arm at 110°	Dipper arm at 130°
3	120	134	146
4	90	104	116
5	72	86	98
6	60	74	86

Table 1 - Estimated overturn resistance for (a) 19t, (b) 30t, and (c) 40t excavator anchors with the load-line anchored to the top of dipper arm (0° slope angle)

Angle of the dipper arm

The effective length of an excavator anchor (from the bucket to the back of the tracks) has a significant effect on its resistance to overturning (providing the excavator does not screw, or slew sideways). The further the boom is extended forward (increasing the dipper arm angle), the greater the overturn resistance (Table 1). This is because the effective length of the excavator increases as the boom is extended (Figure 5). Also, a greater proportion of the load is transferred down the dipper arm to the ground (under the bucket).

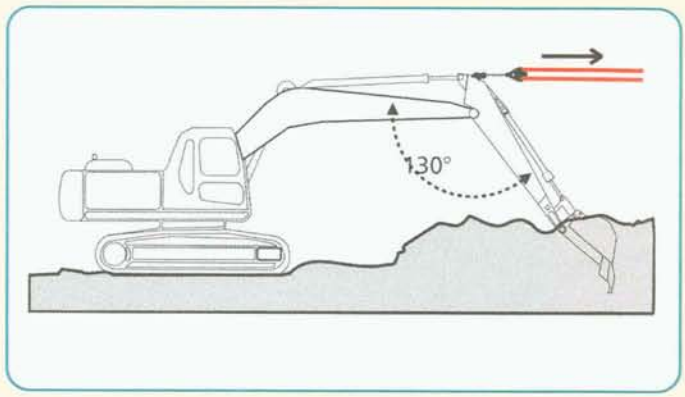

Figure 5 - Increasing the excavator's anchorage capacity by positioning the dipper arm further forward than 90°

Table 1 also shows the effect of three dipper arm angles (90°, 110°, and 130°) on anchorage capacity for a range of excavator weights. If the dipper arm angle is much greater than 130°, the anchoring effect of the bucket reduces as the soil tends to fail through shearing. Positioning the bucket behind a stump can help further reduce the chances of the excavator sledging forward.

A dipper arm positioned at 90° or less, results in the excavator hydraulic rams carrying 100% of the load from the hauler working ropes (Figure 6). The tension generated from medium to large haulers working ropes can easily cause the excavator hydraulic rams to weep (slowly fail). If the hydraulic hoses are overloaded, hydraulic failure may be instantaneous. Although hydraulic rams are equipped with relief-valves, these valves are only designed for standard use and could fail if subjected to external forces from the working ropes. Lock-valves fitted to the boom and dipper arm rams' are one solution to minimise failure.

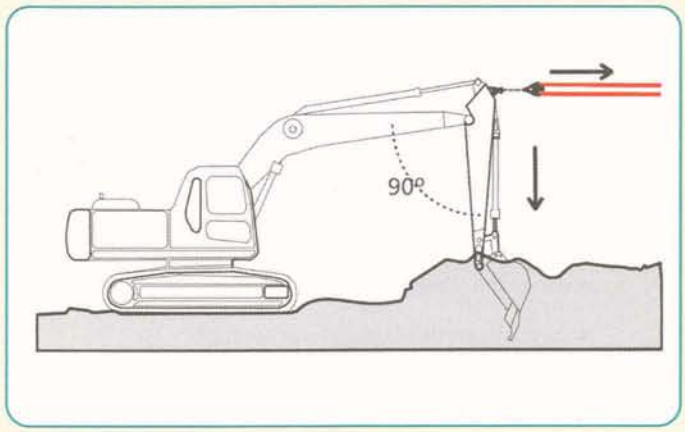

Figure 6 - Positioning the stick at 90° or less, means anchor stability depends on the hydraulic rams

Track-gear orientation

Mobile anchors are often sited on undulating or difficult terrain. The operator should always attempt to position the machine as level as possible, although it is unlikely the excavator will always be parked on perfectly flat ground.

If not parked level, there will be a tendency for the excavator to slide sideways downhill when the applied load approaches the overturning resistance of the excavator. This sideways movement can be minimised by:

(i) Orientating the tracks at 90° to the line of pull (as the track frame is generally longer than wider) to increase the effective width of the excavator

(ii) Positioning the tracks against a bank, to oppose likely sideways movement (Figure 7). This method is more effective when the tracks are orientated parallel with the bank (in-line with the direction of pull).

(iii) Attaching a strop from the rear of the undercarriage to a notched stump opposite the line of pull from the working ropes. The strop can be tensioned by driving the excavator forward before positioning the bucket on the ground (Figure 7).

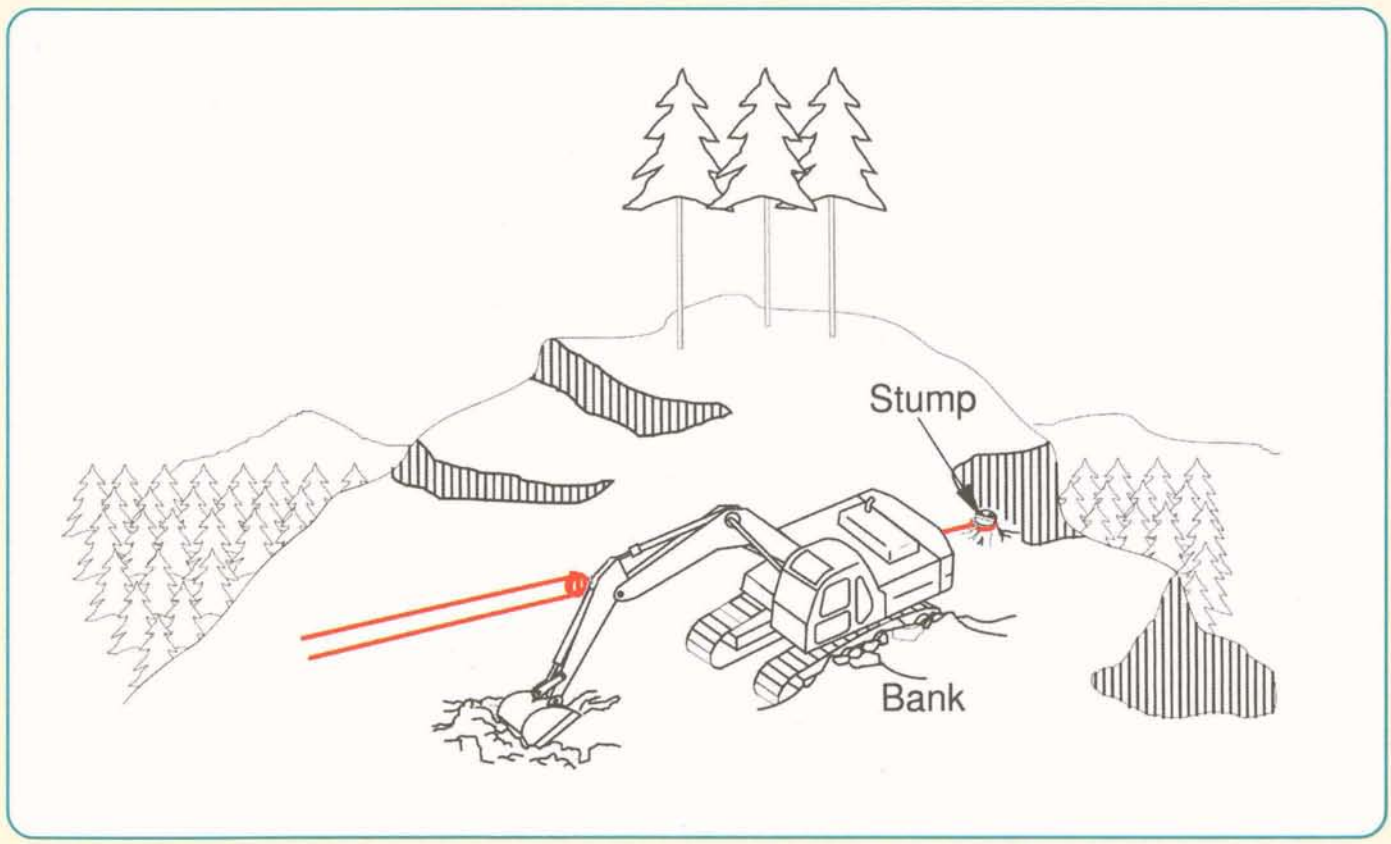

Figure 7 - Sideways movement of the excavator can be minimised by positioning the tracks against a bank, or attaching a strop to the rear of the undercarriage

Boom orientation

The orientation of the boom has a significant impact on the stability of a mobile excavator anchor. As a general rule, the boom should always be orientated in-line with the skyline or main load-bearing rope. The exception being where drags are being broken out laterally to the skyline. The resulting angle of pull from a loaded skyline often changes during break-out. In these situations, the excavator is often more secure with the boom positioned slightly to the break-out side of the unloaded skyline (Figure 8). However, do not over-compensate for any lateral force as anchorage capacity decreases as the angle between the line direction and the boom orientation increases (Table 2).

Difference between boom and line orientations (°)	Percentage reduction in anchorage capacity (%)
5	9
10	17
15	26
20	34
25	42
30	50
35	58
40	64
45	71

Table 2 - Effect of boom orientation on anchoring capacity

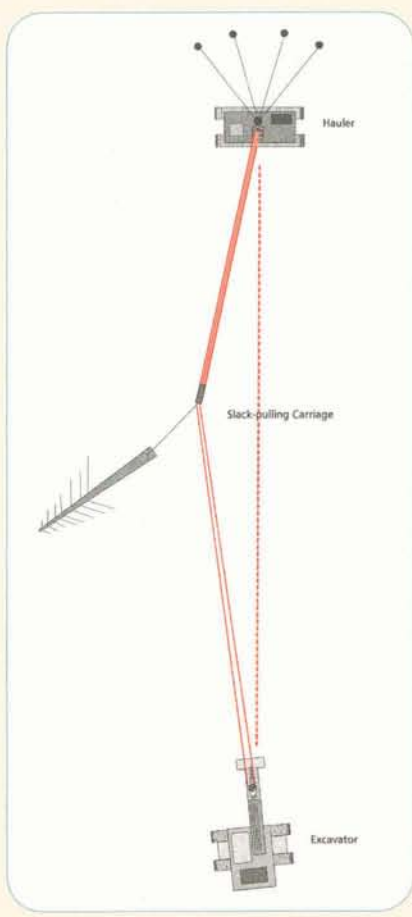

Figure 8- Resulting forces of trees being broken-out laterally to the working ropes

Conclusions

- The ability of an excavator to anchor working ropes in a cable logging operation depends upon:
  - excavator weight
  - rope attachment height and location
  - angle of the dipper arm (effective length of the excavator)
  - orientation of the track gear
  - orientation of the boom
  - angle of lateral pull from the working ropes.
- To increase resistance to overturning forward, the dipper arm can be extended so that the angle between the dipper arm and the ground (in front of the dipper arm) is in the range of 110°- 130°
- To increase lateral stability, the track gear can be orientated to maximise the resistance to any lateral (sideways) movement of the excavator base
- As a general rule, the excavator boom should be orientated in-line with the working ropes. However, when drags are being pulled laterally to the skyline, the excavator may be more secure if the boom is orientated slightly to the break-out side to oppose the lateral force.

Note: Although this report discusses the potential mechanisms of failure individually, a combination of failure modes is more probable. Therefore, all possible causes of failure should be considered at all times.

Points to consider when securing a excavator mobile anchor

- The controls' neutraliser lever is engaged.
- The excavator is positioned on level ground (when practicable)
- The working ropes are attached.
- The dipper arm is positioned in the range 110^0 to 130^0 to ensure there is a downward force proportionate to the forward force being applied.
- The boom is oriented parallel to the skyline (loadline).
  Exception: When drags are being pulled laterally to the skyline, the boom can be positioned to one side to compensate for the lateral forces imposed on the excavator.
- Something is done to prevent the base of the excavator moving sideways when under load from the working ropes. For example:
  - track-gear is oriented at 90^0 to the boom or
  - tracks parked hard-up against a bank and/or
  - a strop is tied between the back of the excavator base and a stump.

Points to consider when shifting the excavator

- Have a direct communication system with the hauler operator.
- Wear seat belt.
- When it is necessary to tension the working ropes during a line shift, ensure the boom is oriented in-line with the working ropes. Do not tension the working ropes to a degree that the operator of the excavator does not have total control.
- Have enough height in the ropes to clear any obstacles.
- Retreat to a safe position clear of the excavator before the working ropes are fully tensioned.

These points should not be treated as the sole source of information and should be used in conjunction with the relevant codes of practice and standards.