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STEEP GRADES FOR TEMPORARY ROADS

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INTRODUCTION

In the Pacific Northwestern United States and in other countries around the Pacific Rim such as Indonesia (Fraser, 1979), steep temporary roads are being built for timber harvesting due to a combination of environmental and economic pressures. How steep a road grade is practical for steep temporary roads? Some roading engineers in New Zealand recommend that the maximum grades on short spur roads should only exceed 13% for very short lengths (Cornelius, 1979). In Oregon, roads in the 30% to 35% grade range are now being constructed as temporary roads when a combination of construction, maintenance and user needs indicate it to be the best solution.

Figure 1 - Truck being assisted up 32% grade

The running surface for the road pictured was about five metres wide. To preserve as smooth and firm a surface as possible for the log trucks, the crawler tractor avoided travelling in the log truck wheel tracks. On the return trip, the trucks were able to back down the hill unassisted because the wheel tracks had been left in good condition by the crawler tractor.

These steep roads are being built for environmental and economic reasons. The steep topography and unstable soils of the Pacific Northwestern U.S. have led to the use of expensive road construction techniques. The techniques include the elimination of road construction on fill material on hillsides steeper than 50% to 60% sideslope and the removal of excess excavation to disposal areas. Both of these measures are intended to reduce landslides and damage to fish bearing streams.

These measures, coupled with the steep side slopes from 40% to 120%, have resulted in expensive roads. Roads in the Oregon Coast range that are built on side slopes can cost from US$150,000/km to US$375,000/km. Ridgetop roads in the same area may only cost about US$60,000/km.

Environmental and economic considerations favour the construction of ridgetop roads since excavation, transported material and drainage structures are minimised. In order to stay on ridgetops though, it is often necessary to build steep roads. Between 1972 and 1982, 20% of the roads built in one area of the Coast range have been steeper than 16% grade (Sessions, 1985).

WHAT ARE THE LIMITS OF VEHICLE OPERATION ON STEEP ROADS?

Log trucks common to the Coast Range have engines that can develop 225 to 350 kW and are equipped with power trains with overall gear reductions of from 90 to 1 to 130 to 1, therefore these trucks are not torque limited. These log trucks are similar in wheelbase dimension and payload to the 5 axle trucks used in New Zealand (Gordon, 1979) and generally require assistance on adverse grades steeper than 16 to 20% grade, depending on surface type. Moist, well compacted soil generally provides the best traction. However, crushed rock aggregate is often used because of concerns about wet weather haul.

Experience in the Pacific Northwestern U.S. has shown that trucks can be assisted on adverse grades of 30% to 35% grade when a crawler tractor can be used as an assist vehicle (Anderson and Sessions, 1985). The practical limit for assisting trucks on grades would also depend on the type of assist vehicle and on the haul vehicle used. It is not known from experience if 35% grade is the maximum for assisting log trucks.

Mathematical models can be used to predict gradeability of log truck and assist vehicle combinations. The results from using one model (Anderson, Sessions 1985) are displayed in Figure 2. This model shows that the maximum theoretical gradeability is somewhere between 35% and 45% grade depending on the coefficient of traction that the crawler track and log truck can develop.

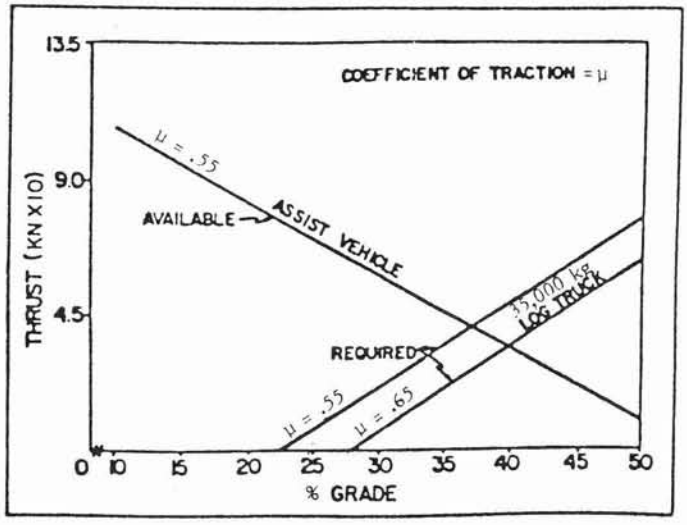

Figure 2 - The effects of coefficient of traction on log truck gradeability.

The figure shows the assist thrust needed by a loaded log truck and the assist thrust available from a crawler tractor as a function of grade. The log truck in this example would be a tractor/trailer combination in the 35 tonne weight range and the crawler tractor is given a weight of 25 tonnes. For this example, a coefficient of traction of .55 for both the log truck and the crawler tractor was assumed and the maximum grade climbing ability of this combination would be between 37% and 38% grade. This model is for straight ahead motion on adverse grades. The effect of travelling around curves would be to reduce gradeability due to resisting forces encountered in cornering. Safety is another factor that cannot be evaluated using this model. For longer assists or assists on surfaced roads, rubber tyred assist vehicles might be favoured. Skidders, graders and dump trucks all have served as assist vehicles.

Gradeability can also be improved by powering the steering wheels. Figure 3 shows the increase in gradeability that could be expected from a 6 x 6 powertrain versus a 6 x 4 powertrain.

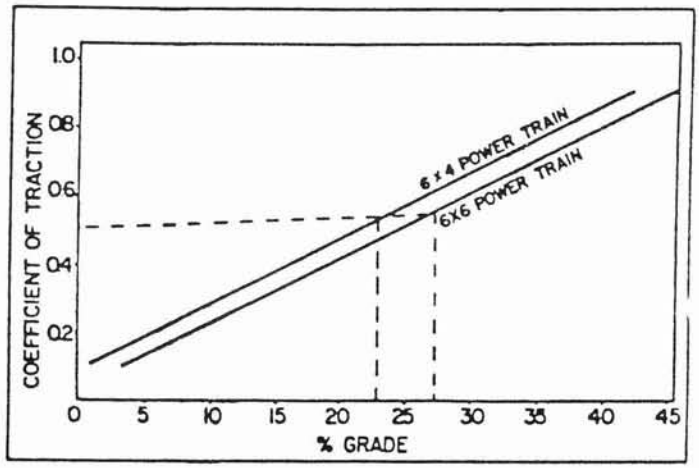

Figure 3 - Gradeability increase from powering the front wheels

For the coefficients of traction commonly found in the Oregon Coast Range, the increase in grade climbing ability would be between 4% and 4.5% grade using 6 x 6 powertrains.

FACTORS TO EVALUATE

Factors to evaluate when deciding on building a steep road that could involve assisting haul vehicles :

Savings in road cost

What is the difference in the cost of a steep road versus a road with a flatter grade? Will the steeper road grade result in significant cost savings and most important, will the savings be enough to offset the costs to assist the log truck?

Logging Production

Since the assist cost will probably be a fixed daily cost, will there be enough volume hauled per day to keep the unit cost of assists reasonable?

Need to keep the road open after harvesting

In practice, roads steeper than 20% generally are used just for log haul and then closed. The 32% road grade pictured in Figure 1 was used for only six to eight weeks and then it was closed. If the road will be used for other activities, gentler grades may be preferred.

Season of use

For steep unsurfaced roads, season of use is very important. In many areas, wet weather can rapidly make steep roads unusable.

Erosion hazard

The Oregon Coast Range has soils that are very rapidly drained and have high infiltration rates. Even when compacted, infiltration rates might vary from 13 mm to 50 mm/hour. Rainfall intensities are generally less than 50 mm/hr. Therefore, the potential for surface flow is not as great a problem as it may be in some areas.

CONCLUSION

In summary, steep roads are often a viable alternative for land management where economic and environmental pressures are high. Their advantage is greatest where limited volumes need to be transported and haul can be done during the dry season. In the design of steep roads, gradeability of log trucks and assist vehicles are important considerations. Models such as those developed at Oregon State University are useful to predict the theoretical limits of equipment. Steep roads have proved to be a valuable option in some cases and their use should be considered where they are practical and economical.

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LIRA NOTE

New Zealand's "Safety Code for Bush Undertakings, Part 5 - Transportation" states that ...

> *"26.1 The gradient of any road used for transporting logs or wood products shall be not greater than 1 in 5 on the steepest part ..." (1 in 5 = 20%).*

Therefore roads with gradients greater than 1 in 5 cannot be used for the transportation of logs or wood products in New Zealand without prior approval from the Department of Labour.

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