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SURFACING OF STEEP LOW VOLUME ROADS

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INTRODUCTION

In mountainous terrain, constructing a short, steep road may be less expensive than a longer road with a gentle grade. An important factor in the hauling cost over a steep road is the traction provided by the road surfacing material. If traction is insufficient for logging trucks to climb the grades unassisted, then an assist vehicle can significantly diminish the benefit of reduced construction costs.

This Technical Release discusses the requirements of aggregate road surfacing materials for providing adequate traction for standard rubber-tyred logging trucks on steep grades. The paper provides a summary of information available in the literature, and obtained from interviews with the United States Forest Service and Bureau of Land Management engineers as well as logging contractors and Oregon State University faculty. Literature on the traction characteristics of rock aggregate is minimal, and this is reflected in the lack of consensus among engineers about what will and will not work. This paper outlines some areas of concern. Greater detail about traction and other aspects of operating on steep roads is given by Anderson (1985).

GENERAL REQUIREMENTS

The design surface for a low volume road must satisfy three requirements to be acceptable :

(1) It must be feasible to place and prepare the surface. This includes compaction of the subgrade, and spreading and compaction of the surfacing material.

(2) The road surface must provide adequate traction and wheel load support during the design life of the road.

(3) The surface must be maintainable for normal wear and tear during the design life of the road. Maintenance to the road surface is confined primarily to blading, but the road surface must also provide a working platform for routine drainage ditch maintenance.

CONSTRUCTION

Placing, spreading and compacting surface material on steep grades can be troublesome. If conventional dump trucks are used to haul in aggregate surfacing material, they may require traction assistance to rough-spread the aggregate while dumping on adverse grades. A motor grader which is usually used for fine spreading of surfacing material to design thickness may also require traction assistance on adverse steep grades. The need for traction assistance will vary with grade, and the amount of material being carried by the blade while spreading. The steeper the grade is, the less material can be carried by the blade without traction assistance, hence more passes will be

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required to achieve proper spreading. Gradation of the surfacing material can also influence the need for traction assistance since the material carried by the blade should include all of the particle size range. The larger the particles are, the more material must be carried by the blade when spreading.

Compaction of the road surface increases the supporting capacity of the road, and also improves the traction potential. However, a practical upper limiting grade for self-propelled vibratory rollers seems to be about 20%. At steeper grades, either a tractor towed roller, or tractor assistance is required which increases constructions costs (Pearson, 1984).

TRACTION AND WHEEL SUPPORT

Crushed rock aggregate is the major surfacing material used on low volume roads that must remain open or be used in wet weather. On roads with gentle grades, the primary purpose of the crushed rock is to distribute surface wheel loads to the subgrade at low enough stress levels that subgrade bearing capacity failure and the associated rutting does not occur during the design life of the road. On roads with steep grades, subgrade support during the design life of the road is important, but of greater immediate importance is the traction provided by the road surface.

Experience in Oregon shows that traction problems start occurring on crushed rock surfaced roads at about 16% (1 in 6¼) on straight alignment (Pearson, 1984 and Rebar, 1984) and about 12% (1 in 8 1/3) on curves (Ward, 1984). For steep roads, it is necessary that an aggregate surface be dense and well bound. This can be achieved by careful control of the production, placement, and compaction of the crushed rock aggregate mix. However, a practical upper limit to the grade on which crushed rock aggregate can be used without traction assistance appears to be 18% to 20% (1 in 5½ to 1 in 5).

On grades between 20% and 25% (1 in 5 and 1 in 4), there is some question as to the feasibility of crushed rock aggregate. One contractor added a layer of fine crushed rock to an aggregate surface road on a 24% grade to improve traction, but was unable to haul without traction assistance. About 25%, most experienced engineers feel that crushed rock aggregate is not a viable option because its traction coefficient is too low. Additionally, it is a commonly held opinion that normal 25 mm minus, or 35 mm minus crushed rock aggregate cannot be compacted on grades about 25%. It has also been observed that pit-run rock will segregate with the coarse particles coming to the surface, leaving an even lower traction coefficient than the crushed rock.

The upper grade limit to unassisted adverse hauling appears to occur with a native soil surface. One logging contractor watered, graded, and compacted an unsurfaced road (in non-plastic sandy silt soil) every night to enable unassisted adverse hauling on a 26% grade. A suggestion has been made that wheel load support along with maximum traction can be provided on steep grades by placing a depth of pit-run rock covered by a soil surface layer.

The observation that "normal" crushed rock aggregate, pit-run rock, and soil all provide different traction potential leads one to the conclusion that grain size distribution is important in surfacing steep roads. Vischer (1979) reported a study of road grades ranging from near level to 16%, and reported that acceptable performance correlated with a compacted and oven-dried unconfined compressive strength of the surface material of 517 KPa (75 psi). Vischer contends that the unconfined compressive strength is more appropriate than the more traditional confined penetration tests (e.g. California Bearing Ratio) since the surface of a road is relatively unconfined. It is unclear that the unconfined compression test is the most appropriate test to use in evaluating road surface materials, but Vischer's work indicates that it is a reasonable index of performance.

Vischer was also able to show that the fraction of fine soil particles in a crushed rock aggregate influence the unconfined compressive strength (Figure 1). He used gradations obtained from successful roads, and the test results in Figure 1 to develop the suggested gradations shown in Figure 2.

Ames (1984) identified rock gradations that provided acceptable traction on grades from 14% to 20%. His band of gradations follows Vischer's band, but is somewhat wider (Figure 2).
The crushed rock gradations reported by Vischer and Ames, were developed from observations of the performance of fairly hard, durable rock. Softer, less durable

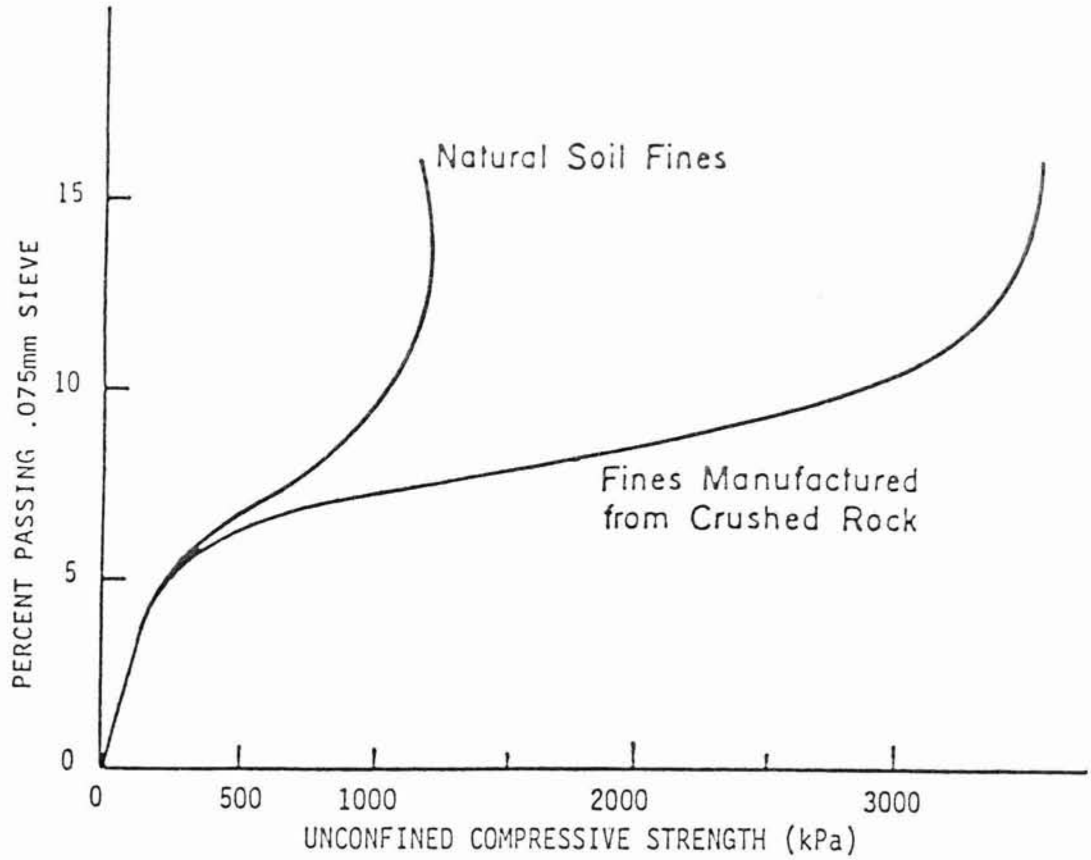

Figure 1 - Unconfined compressive strength of aggregate surfacing materials (Vischer, 1979)

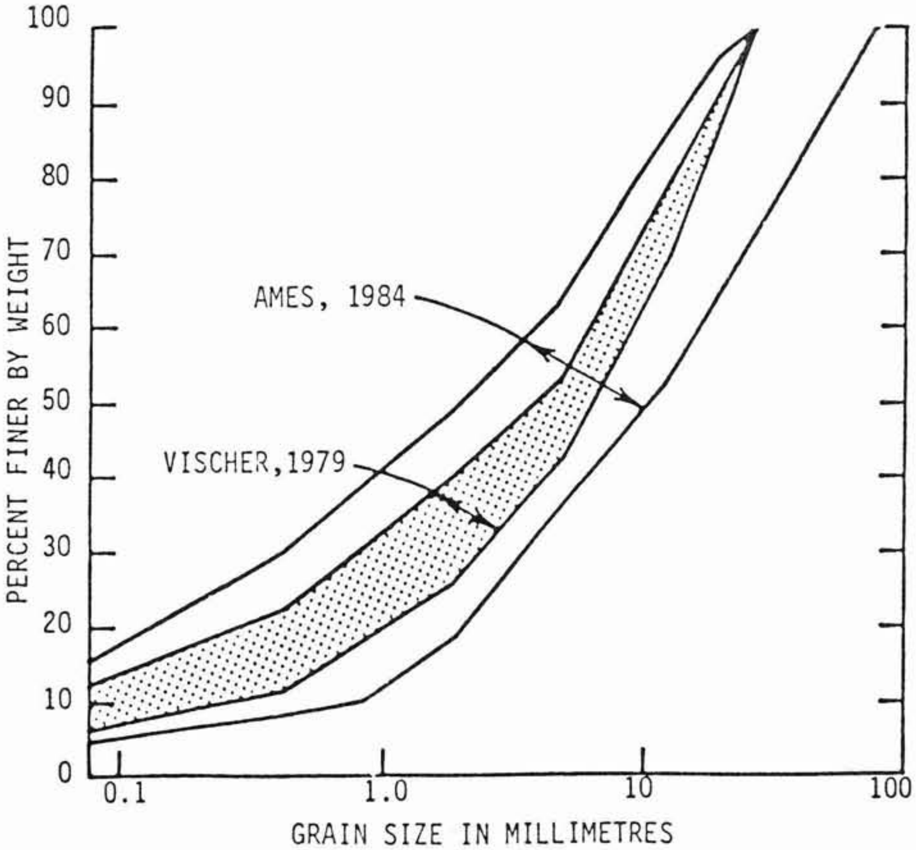

Figure 2 - Aggregate gradation for surfacing material

aggregates could well require a different gradation at the time of placement.

MAINTENANCE

Maintenance cost is often cited as one of the reasons that steep roads are used only with great reservation by some timber companies. This is especially true when less than ideal conditions exist in terms of weather and surfacing materials. Most road managers interviewed shared the opinion that maintenance costs increase markedly on grades about 16%, but no hard data could be found to support this contention. Despite maintenance problems, it is common for new spur roads to be constructed at grades in excess of 16% in the Pacific Northwest.

Maintenance of steep grade roads during hauling operations may include daily surface watering, blading, and compaction. Water trucks, graders, and compactors are less efficient for maintenance on steep grades just as they are for construction. The standard blading procedure used on most aggregate surfaced roads consists of working a depth of the surfacing material equal to two times the largest particle size (Williamson, 1984). Working this amount of material on steep grades may not be possible without traction assistance. Some road managers have reduced the maximum particle size used in crushed rock aggregate from 35 mm to 25 mm or even 15 mm to facilitate blading (Nagygyor, 1985).

Long term maintenance activities concentrate on keeping the road surface smooth, controlling erosion, and keeping the ditches and culverts open. As road grade increases, both the road surface and the ditchline require more maintenance. The problem is made more severe by the fact that a soil surface that provides adequate traction on a grade above 20% will likely be very erodible, and require substantial erosion control effort between periods of use. Erosion control can consist of combinations of water barring, grass seeding, and even surfacing with rock aggregate solely for erosion control.

SUMMARY

Steep roads are being considered as an option for log hauling in steep terrain. Present surfacing strategies provide general guidelines as to the appropriate surface for a given road, but they are still experimental. Research is needed to accurately predict the performance and cost of steep roads. In addition to needed research on the traction potential of various surfacing materials, and the short and long term maintenance requirements of steep roads, such issues as safety, and wear and tear on trucks and assist vehicles must be considered to fully develop the cost picture.

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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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