

# Aggregate Gradation

## Getting the Road Surface Right

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Construction of forest roads is an expensive undertaking. The road corridor needs to be located, the formation excavated and shaped, culverts placed, and aggregate spread and compacted to create a strong road surface. For many forest road engineers, this latter element is the most problematic. The winning or purchase of a suitable aggregate and transporting the material to the forest road site can cost over \$60/m<sup>3</sup>, often representing 60-70% of the total cost of road construction. Forest managers faced with the need to control roading costs inevitably seek to reduce the cost of aggregate by substituting with lower-cost and/or locally available materials. However, when choosing low-cost aggregates for forest roads it is important that the right material is selected, or else money may be poorly spent.

### Forest Road Pavements

Public low-volume roads are constructed using unbound flexible pavements - an arrangement that uses multiple layers of unbound granular material that are capped by a thin asphalt or chip-sealed layer. Pavements for forest roads differ in that they commonly consist of a single improved layer placed over the compacted natural soil. These two different design approaches have a significant impact on the type of aggregate required for the road pavement.

The aggregate used for low-volume sealed roads (the base and sub-base layers in Fig.1) is coarse, granular material designed to provide structural strength and stability, and to provide resistance against capillary action (the drawing-up of ground water by fine-grained soils). These layers are relatively porous and require a sealed surface layer to protect from the ingress of water that can significantly weaken the underlying natural soil. By comparison, the

aggregate used for an unsealed forest road (the improved layer in Fig.1) needs coarse particles for structural strength and stability, but also needs fine-grained particles to bind the aggregate into a dense and relatively impermeable layer. The improved layer aggregate is more susceptible to capillary action; however, this problem can be somewhat managed by the use of deep water table drains.

### Aggregate Gradation Standards

The difficulty faced by forest road engineers is that most readily available aggregate gradation standards have been designed for low-volume sealed roads. These aggregates are not suited for use on forest roads. A good example is the TransitNZ M/04 basecourse standard (TransitNZ 2006) - a standard specification for aggregate used in public road construction. This standard mandates a maximum particle size of 40mm and a fines component between 0-7% (fines are silt and clay particles passing the 0.075mm sieve). This design has insufficient fines to bind the larger particles together. Furthermore, the maximum particle size may not be adequate under the loading applied by log trucks, as low-cost aggregate tends to break down under heavy traffic.

Forest road engineers need to search harder to find a more appropriate design standard for forest roads. To find a national design standard for unsealed roads, you need to look back to the Main Highways Board (1938) standard. The MHB design uses a multi-layer approach with a coarse, granular basecourse similar to the TransitNZ M/04 standard and capped by a surfacing aggregate with maximum particle size of 19mm and 10-20% fines. This design produces a dense and relatively impermeable unsealed road pavement - it would seem that some of the expertise our previous

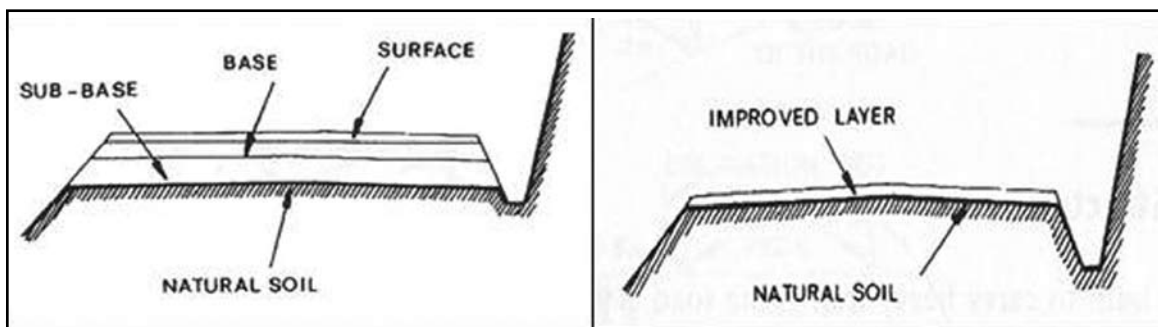


Figure 1. The typical design of a low-volume sealed road (left) and the typical design of an unsealed forest road (right). (Sessions, 2007).

generations developed in unsealed road design has been lost as sealed roads became the norm. However, the down-side of the MHB design is that the surface aggregate is too small for heavy traffic and the multi-layer design is more costly to construct and maintain. An aggregate design specifically developed for low-cost unsealed haul roads is needed.

Earlier this decade, local authorities in Pennsylvania, USA also found that existing aggregate design standards for unsealed haul roads were inadequate. The Centre for Dirt and Gravel Roads was subsequently established at Penn State University, and a 'Driving Surface Aggregate' (DSA) was developed (PSU 2006). This aggregate uses a maximum particle size of 40mm and has 10-15% fines. Again, the maximum particle size may be on the small side, but the overall design is sound. A similar aggregate gradation using a 65mm maximum particle size may be the best approach for forest haul roads. Figure 2 below compares the TransitNZ M/04 and the DSA gradation envelopes (modified for 65mm maximum particle size).

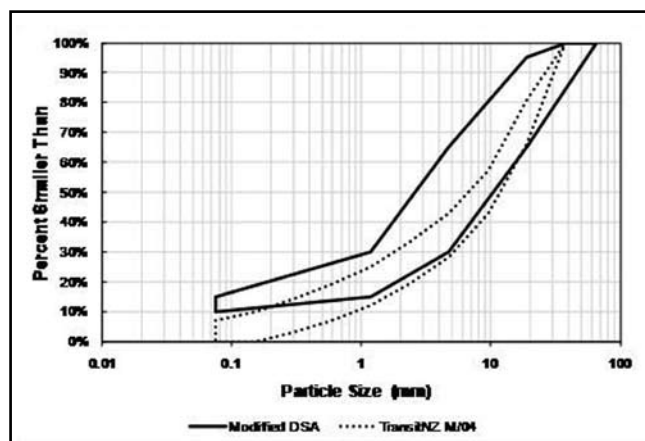


Figure 2. Comparison between Transit NZ M/04 Basecourse and the modified Penn State Driving Surface Aggregate.

## Aggregates used on New Zealand Forest Roads

Testing of 26 aggregates sourced from quarries and in-forest stockpiles around various New Zealand forest regions was completed over the last year and a half at the School of Forestry. In all cases, the selected aggregates were being used for the improved layer on forest haul roads. Analysis of the sieve test data shows that the maximum aggregate size ranged from 19mm to 100mm. The range of fines was from 1.4% to 15.7%. A summary of representative grading curves for these aggregates is shown below in Figure 3. The shaded zone indicates the gradation envelope for the DSA specification.

These results show that wide variation exists in the gradation of aggregates used on forest roads. Furthermore, many of the tested aggregates are poorly-graded (falling well below the envelope for the modified DSA), using material

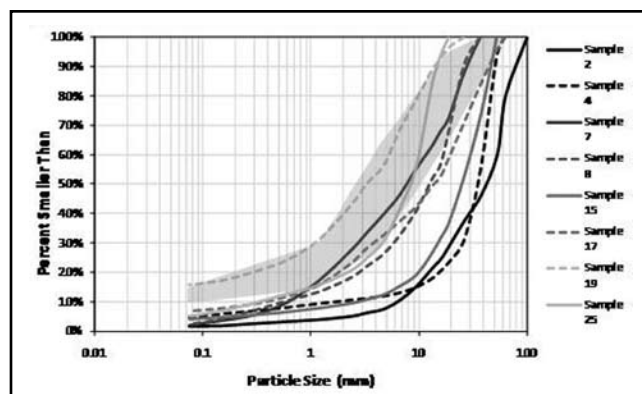


Figure 3. Gradation of samples of New Zealand forest road aggregates.

that is too coarse and has insufficient fines to produce an effective improved layer.

The consequence of using aggregates that are poorly-graded is that rainwater can penetrate the road surface and permeate into the subgrade soil. The soil will eventually become saturated and will exhibit significant losses in bearing strength. The coarse particles within the aggregate will be forced into the softened subgrade by heavy traffic and, with as little as 8% intermixing of subgrade fines, the aggregate strength can be severely degraded (Jorenby and Hicks 1987). In this case, money spent on aggregate is money poorly spent.

## References

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