UNDERSTANDING UNPAVED ROAD MATERIAL PERFORMANCE - INTERPRETATION

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Unpaved road performance is linked to material properties, road shape and drainage, and to construction and maintenance quality and although all are controllable, using inappropriate materials will have the biggest impact on dust levels, slipperiness, and how quickly the road deteriorates due to washboarding, raveling, and erosion.

A finished road is only as good as the materials that form the riding surface. Most unpaved roads in the United States have some form of imported aggregate base and wearing course. Much of this imported aggregate comes from commercial sources that also supply contractors and various departments of transportation. Consequently, the aggregate supplied for unpaved roads will often meet the specifications of the supplier's greatest need; typically asphalt concrete, portland cement concrete, or aggregate base for paved roads. Many practitioners mistakenly believe that if materials meet the specifications for aggregate base in a paved highway, it will also work well as an unpaved road wearing course. This is an incorrect assumption! Aggregate base used in paved roads is confined by the chip seal, asphalt or concrete on the surface and gradings are optimized for strength alone as it is not directly exposed to traffic abrasion or the weather. A different set of material specifications is needed for unpaved road wearing courses to compensate for this lack of surface containment.

Unpaved Road Material Specifications

There are a range of recommendations, guidelines, and specifications available for unpaved road base and wearing course materials. These are not discussed here; instead readers are referred to their organizations' in-house specifications, or to the documents listed in the Library Section. Keep in mind that specifications often need to be adapted to suit local conditions and material availability.

Material Testing

Key material properties influencing unpaved road performance include the grading or particle size distribution, the fines content, the clay content, and the material shear strength. These are determined from basic material indicator tests including:

- A grading analysis (for example, AASHTO T 27 or ASTM C136)
- A plasticity test (Atterberg Limits [AASHTO T 89 and T 90 or ASTM D4318] or bar linear shrinkage [Caltrans CT 228 or Texas Tex-107-E]), and
- A strength test (for example, California Bearing Ratio [CBR, AASHTO T 193 or ASTM D1883]).

All of these tests are simple to do and cost very little (at a commercial laboratory, grading analysis and Atterberg Limit tests cost about $200 and $100, respectively, a CBR test costs about $700). In fact, the costs are negligible in terms of the costs of gravel replacement and selecting the correct chemical treatment and are potentially recovered many times over when better material selection results in extended life of the road and reduced maintenance requirements. The small savings enjoyed up front by skipping material testing will invariably mean higher costs later on because of early replacement of gravel and the need for more frequent maintenance. Most specifications are based on these or similar tests and typically provide an envelope of parameters for each, which the aggregate supplier or practitioner needs to meet.

Understanding How Material Properties Influence Performance

Many practitioners have difficulty in interpreting laboratory test results, especially with regard to understanding performance if a grading envelope and a single plasticity criterion cannot be met by an aggregate supplier or in gravel located on the road owner's property. The following simple three-step procedure, based on research in southern Africa and adapted for international use, can be used to interpret the results of the tests listed above, assess the applicability of local material specifications, and understand how unpaved roads are likely to perform if a particular material is used. The procedure can also be used to make a decision regarding material choice, road design specifications, and chemical treatment selection. This procedure is a guide only and NOT a new specification, nor is it intended that it replace existing specifications. It may need to be refined for particular situations and calibrated for local conditions.

Step 1 – Test Result Analysis

Grading Analysis

In this recommended approach, only four key sieve sizes are required for the grading analysis. These are the 1.0 in., #4, #8, and the #40 (25 mm, 4.75 mm, 2.36 mm, and 0.425 mm) sieves. The first three are used to check for the correct mix of coarse, intermediate, and fine particles using the following simple formula known as the grading coefficient (G_c):

G_c = ((P1.0 in. – P#8) x P#4) / 100 or

G_c = ((P25 mm – P2.36 mm) x P4.75 mm) / 100

Where P is percent passing

Although the grading coefficient is determined using material passing the 1.0 in. (25 mm) sieve, a maximum size of 1½ in. to 1¾ in. (40 mm to 45 mm) is preferable to provide adequate all-weather passability. The use of aggregates larger than this will reduce ride quality, make it noisy to travel on, and cause problems for the maintenance grader operator.

The percentage material passing the #200 (0.075 mm or 75 µm) sieve is also a useful indicator of how an unpaved road will perform and will influence the decision of what treatment to use. High percentages of material (that is, >20 percent) passing this sieve imply that the road will be dusty when dry and may become slippery when wet. Low percentages (that is, <10 percent), imply that the road will washboard and require regular grader maintenance. Many unpaved road wearing course specifications based on paved road base course specifications limit this fines content to about 5 percent in the mistaken belief that this will reduce dust. Determination of the percent passing the #200 sieve (usually done using a wet process as part of a standard grading analysis) is, however, not as simple as determining the percent passing the #8 sieve (which can be done dry if necessary when checking aggregates in the field). Consequently for understanding general performance, the #200 material is factored into the grading coefficient equation as part of the #8 sieve material. However, the percent passing the #200 sieve is required for optimal chemical treatment selection.

The angularity of the aggregate should also be checked during the sieve analysis. Cubicle material (Figure 1) has better interlock than rounded material (e.g., uncrushed alluvial aggregates [Figure 2]) and consequently rounded aggregate should be crushed to obtain at least two fracture faces to enhance interlock and prevent raveling.

Clay Content

The percent passing the #40 (0.425 mm) sieve is used together with the bar linear shrinkage (BLS), or plasticity index (determined from the Atterberg Limit tests if the BLS test cannot be undertaken), to optimize the clay content using the following simple formula known as the shrinkage product (S_p):

S_p = BLS x P#40 if the bar linear shrinkage is used, or

S_p = (PI x 0.5) x P#40 if plasticity index is used

(Note that using the bar linear shrinkage to determine the shrinkage product is more accurate than using the plasticity index, especially for silty non-plastic or slightly plastic materials. These materials often have a plasticity index of zero, and consequently also a shrinkage product of zero if the above formula is used. However, they will usually have some shrinkage [that is, BLS > 0], thereby providing a number to work with to better estimate expected performance).

Figure 1: Cubicle aggregate.

Figure 2: Rounded aggregate.

<u>Bearing Capacity</u>

The California Bearing Ratio (CBR) performed on material in the laboratory is the most commonly used bearing capacity test. No formulas are required to interpret the results from this test.

Step 2 – Test Result Interpretation

Optimal unpaved road performance will usually be achieved when the wearing course materials meet the following:

- The grading coefficient is between 15 and 35. Although not directly measured in the grading coefficient formula, a fines content (material passing the #200 sieve) of between 10 and 15 percent is typically required to meet optimal grading coefficient requirements.
- The shrinkage product is between 100 and 365 (or between 100 and 250 if dust is a major concern and no dust control treatment is planned). Many unpaved road specifications based on paved road base course specifications limit or exclude any clay in the mistaken belief that this will reduce dust.
- Assuming that the road has a quality base course with adequate CBR, the soaked CBR of the wearing course should be above a minimum of 15. If the traffic is predominantly trucks and the road is in a high rainfall area or storms of high intensity are common, a higher CBR may be desirable if passability problems are an issue. However, higher CBR materials tend to have low clay contents and consequently washboarding may be a problem. Therefore, a balance between CBR and shrinkage product needs to be determined for optimal performance for specific traffic type and volume.

When these optimal grading coefficient and shrinkage product limits are met, good performance is achieved as shown below in a simple performance prediction chart (Figure 3). The chart also demonstrates the likely consequences of not meeting the criteria.

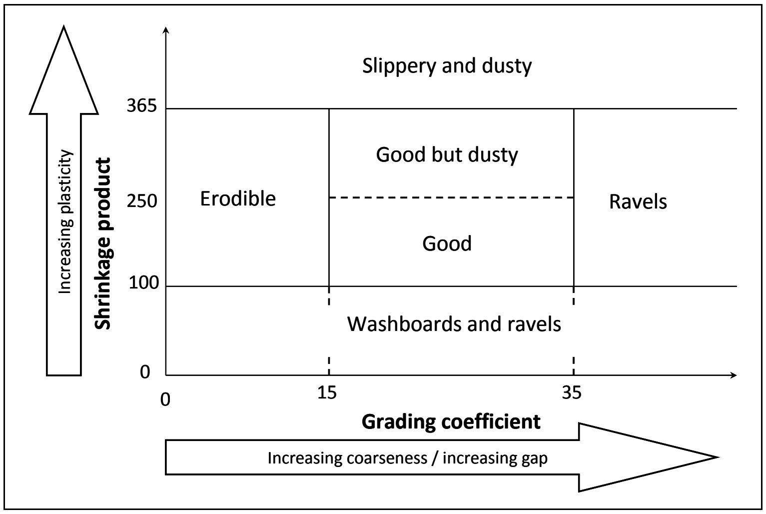

Figure 3: Material performance predictor chart (adapted from Paige-Green, 1989)

The factors that contribute to each of these predicted material performances are discussed below.

- Erodible materials are typically fine grained and have some plasticity. They generally perform well when used in roads on flat terrain or in areas of very low rainfall. In other areas they will quickly erode during rainfall, leaving channels in the road that are dangerous and unpleasant to drive over and expensive to maintain. Examples of roads built with materials falling in this area of the chart are shown in Figures 4 and 5. The eroded material usually ends up where it is not wanted (for example, blocking drains or flowing into streams or onto adjacent land).

Figure 4: Transverse erosion.

Figure 5: Longitudinal erosion.

- Materials that washboard (corrugate) and ravel are usually poorly graded or gap-graded (absence or insufficient quantities of certain sizes leading to poor aggregate interlock) and lack fines and plasticity. Consequently the particles do not bind together, leading to washboarding, raveling and, ultimately, gravel loss, and thus a poor and unsafe ride on a surface requiring regular maintenance. These materials are also prone to erosion during rainfall. Examples of roads built with materials falling in this area of the chart are shown in Figures 6 and 7.

Figure 6: Washboarding (corrugation).

Figure 7: Washboarding and raveling.

- Materials that ravel have some plasticity, but are gap-graded. The presence of clay usually limits washboarding but does not prevent raveling. Examples of roads built with materials falling in this area of the chart are shown in Figure 8. Windshield damage is a major problem on these roads.
- Materials that are slippery when wet and very dusty when dry typically have high fines and clay contents. Examples of roads built with materials falling in this area of the chart are shown in Figures 9 and 10. Increasing clay content also results in decreasing CBR, leading to poor passability in addition to the slipperiness (Figure 11).

Figure 8: Raveling.

Figure 9: Dusty when dry.

Figure 10: Slippery when wet.

Figure 11: Impassable.

- Well-graded materials with moderate clay contents will perform well, but may be dusty during dry conditions. Examples of roads built with materials falling in this area of the chart are shown in Figure 12.
- Finally, well-graded materials with some clay will perform well with a minimum of maintenance. Examples of roads built with materials falling in this area of the chart are shown in Figure 13.

Figure 12: Good but dusty.

Figure 13: Good material.

Step 3 – Material Selection Decision

If materials falling within the good performing area on the chart are readily available, the decision is easy. Use these materials to construct a good road and keep them good with a dust palliative or surface stabilizer. If they are not readily available the practitioner needs to decide on an appropriate course of action as follows:

- Weigh the consequences with the probability of occurrence:
  + Erodible materials can be used in flat areas and areas with low rainfall or low intensity rainfall events. Surface stabilizers may reduce the erosion problem, but are unlikely to prevent it.
  + Materials that washboard or ravel can be used on roads with low-traffic volumes traveling at low speeds. They can also be used if the road owner is prepared to regularly blade or drag the road. The costs of this maintenance should be compared with importing better gravel from elsewhere. If the road is generally only used to access residences, the homeowners may be willing to tow a simple tire drag themselves to smooth washboarding and raveled areas. Dust palliatives and surface stabilizers will retard the rate of washboarding, but won't prevent it. They will not prevent raveling.
  + Materials that are slippery or impassable can be considered on low traffic volume roads in low rainfall areas if the road can be closed during problem rainfall events. Some surface stabilizers can be used to modify or "waterproof" the clay particles causing the slipperiness.
  + Good but dusty materials can be used with appropriate speed restrictions or a suitable dust palliative.
- Use the material "as is," but adjust maintenance programs accordingly:
  + Blade the road more frequently to remove erosion channels or washboarding and redistribute raveled material.
  + Close the road during slippery or impassable conditions.
- Seek alternative aggregate suppliers who can provide the requested material.
- Blend two materials to meet the required grading coefficient and shrinkage product. This usually requires the addition of small amounts of clay if commercially obtained aggregate is used.
- Use a dust palliative or stabilizer at higher than normal application rates to provide additional binding to the material, but remember that it is usually cheaper to use fines to fill voids (that is, meet the grading coefficient and shrinkage product requirements) than to use a chemical.