Advantage

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Contents

Improving road performance by using appropriate aggregate specifications for the wearing course

Abstract

For optimal performance, a road's wearing course ("running surface") should use suitable aggregates. FERIC reviewed the characteristics of the wearing course material used by several member companies in eastern Canada and compared the results with company specifications and those of roads authorities. Most aggregates failed to meet either type of specification. The report describes the characteristics of aggregates suitable for use in a wearing course, and recommends how to improve road performance through proper specification of aggregates.

Keywords:

Aggregate, Wearing course, Running surface, Unpaved roads, Forest roads.

Authors

Glen Légère
and
Steve Mercier
Eastern Division

Introduction

The performance of *unpaved* roads relates directly to the quality of the aggregates used as a wearing course ("running surface"). Optimizing the specifications used for the production of the aggregates that will form a road's wearing course and monitoring their performance are thus critical. Forestry companies looking to improve aggregate quality often use specifications designed for the base course layers of *paved* roads since these are often the only relevant specifications in the available literature. However, this material is designed to drain under asphalt pavements and thus lacks the cohesion required for use in gravel roads. Using inappropriate specifications or poor-quality materials will lead to increased surface distress (e.g., loose material, potholes, washboards, dust), thereby increasing road maintenance and transportation costs and possibly compromising traveler safety. This report reviews the required aggregate characteristics (specifications) for the wearing courses of forest roads. The specifications used by several FERIC members were also assessed to evaluate how well forest companies are meeting their own and recommended specifications during road construction.

Choosing a specification designed for unpaved roads

The production of crushed aggregate is expensive, but using bad wearing-course material can even be costlier when road maintenance and trucking productivity are considered. Specifications designed for base-course layers typically lack sufficient fines (i.e., the particles passing through a 0.075-mm sieve) to provide good interlocking (cohesion) between particles in the wearing course.

The fines content required for base courses is generally 2 to 8% (MTO 1993), but the specifications for wearing courses require no less than 4% fines and can recommend values as high as 15% (Selim 2000).

It is also important to consider the *properties* of the fines, since these materials help to bind the coarser materials together, especially during dry weather. A good wearing course requires fines that are "plastic", and these are typically natural clays with a plasticity index of 4 to 9 (AASHTO 2001). This contrasts with the base course, in which plastic materials are undesirable because they impede drainage and are susceptible to frost heaving and deformation. In a wearing course, they help reduce the loosening of material ("ravelling") and also help waterproof the surface, thereby improving drainage and yielding a harder, drier running surface in moderate rains. The running surface will also retain moisture better in dry weather, improving cohesion and thereby reducing gravel loss and corrugation. However, wearing courses with excessive quantities of plastic fines become dusty when dry and easily rutted and slippery when wet. If the road is improperly drained, this becomes a significant problem during the spring break-up and during periods of prolonged, heavy rain. Silts should be kept to a minimum, since they provide little cohesion, are slippery when wet, and erode easily.

The requirements for the largest materials may also differ. Most base course specifications recommend that 100% of the material pass through a 1-in. (25.4-mm) sieve, but allow up to 20% by weight to be retained by a ¾-in. (19-mm) sieve. In contrast, Selim (2000) recommends that 100% pass through the finer sieve (19 mm) for wearing-course material. In the wearing course, an overly high percentage of coarse material may create a rougher surface and accelerate the production of washboards and loose aggregates. Figure 1 presents the general function of each particle size in an aggregate mixture.

When choosing a source of material and producing aggregates for use in the wearing course, avoid undesirable substances (such as organic matter and silt) and favor materials with the following physical properties: good resistance to wear, high soundness (resistance to weathering), good particle shape (angular particles interlock better), and a high percentage of fractured faces in the aggregate particles (RTAC 1987). FERIC plans to investigate the impact of these properties and present the results in a future report.

Few specifications for aggregate gradation have been designed for unpaved roads. However, many specifications for base courses exist, and these are generally similar among jurisdictions. Figure 2 compares one typical specification for *base courses* (Ontario's Granular "A"; MTO 1993) with a *wearing-course* specification used in South Dakota (Selim 2000) for unpaved roads. This figure shows that the recommended range of compositions for the wearing course has higher overall proportions of fines than the corresponding range for the base

Forest Engineering Research Institute of Canada (FERIC)

Eastern Division and Head Office
580 boul. St-Jean
Pointe-Claire, QC, H9R 3J9
(514) 694–1140
(514) 694–4351
admin@mtl.feric.ca

Western Division
2601 East Mall
Vancouver, BC, V6T 1Z4
(604) 228–1555
(604) 228–0999
admin@vcr.feric.ca

Find us Online!
www.feric.ca

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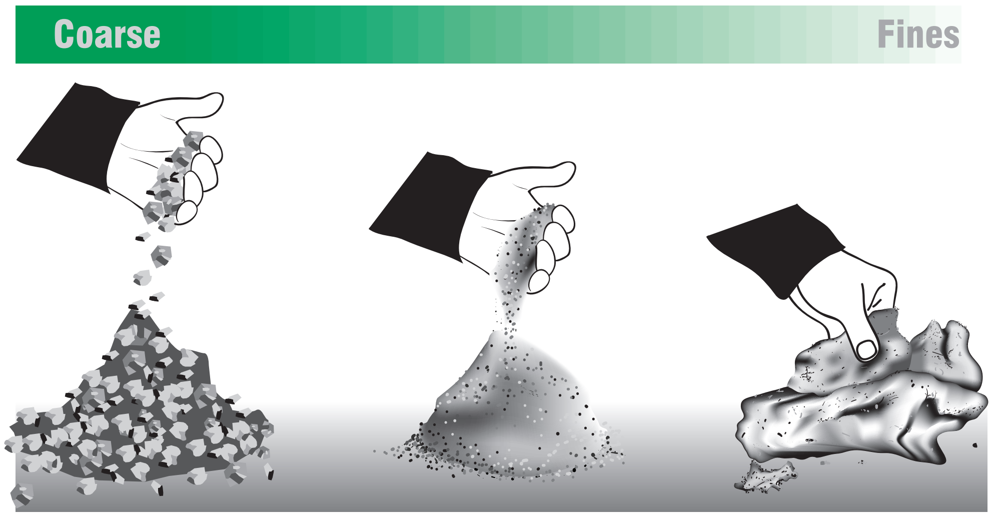
course. A literature review conducted by FERIC found that most specifications for wearing courses have similar criteria. Figure 2 also highlights the particle-size distributions that are prone to various surface-distress problems. Table 1 presents the potential causes of each type of surface distress.



Gravel
Increases strength, improves traction, reduces surface deterioration (less vulnerable to erosion).

Sand
Shares some properties with coarse materials and fines. Helps clay soils drain better and coarse materials retain moisture. Fills gaps in the gravel matrix.

Clay
Acts as a binder (cohesion) that holds the aggregates together and aids compaction.

Figure 1. Functions of wearing-course materials.

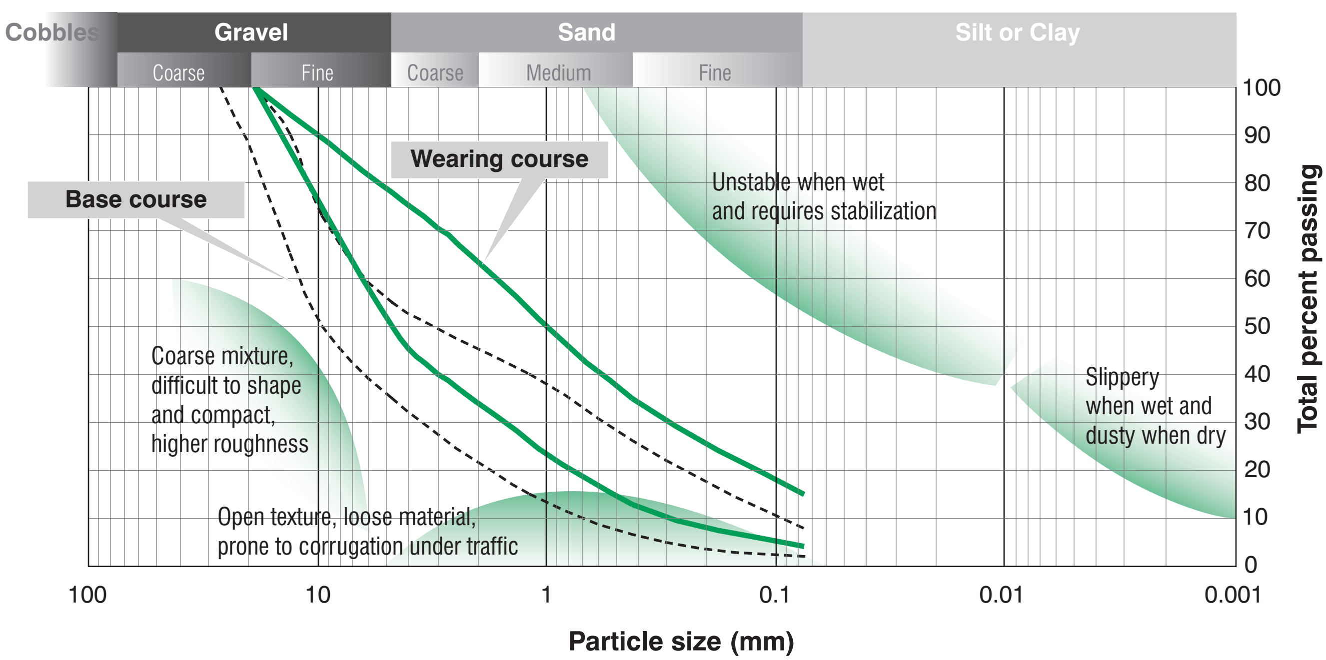


Figure 2. Typical specifications for the range of particle-size gradations for a base course and a wearing course, and ranges of size distributions that typically pose surface-distress problems. The latter ranges are adapted from Metcalf (1981).

Table 1. Surface-distress problems and their potential causes related to the construction material[a]

Surface distress	Description	Potential causes	Comments
Corrugation (washboards)	Closely spaced ridges and depressions at regular intervals, perpendicular to the direction of traffic.	Lack of cohesion and poor granular gradation. Initiated by traffic and made worse by loose aggregate.	These ridges are more frequent on hills, curves, areas of acceleration or deceleration, and in areas where the road is soft or potholed.
Potholes	Bowl-shaped depressions, usually less than 1 m in diameter.	Excessive moisture content, lack of a cross slope (poor drainage), poorly graded aggregate, or combinations of these factors.	Potholes grow faster when water collects inside the holes. The road then continues to disintegrate because of loosening of the surface material or the development of weak spots in the underlying soils.
Ruts	Surface depressions that form in the wheel paths, parallel to the direction of traffic.	Caused by high moisture content in the subsurface soil or base course, inadequate base-course or wearing-course thickness, or heavy traffic (weight and frequency).	Ruts develop as a result of repeated passes by vehicles, especially when the road is soft or wet.
Loose aggregates	Coarse particles broken free of the surface aggregate gather in berms, typically in the center of the road (between the wheel paths) and along the shoulders.	Lack of fine particles (binder) leads to a loss of cohesion. Fine particles are lost through erosion or dust production. Surface may also be loosened by grading when dry, without compaction.	Aggregates become loose as a result of repeated vehicle passes and heavy rains. Compaction at optimum moisture content during construction and after grading can reduce this problem.
Dust	Loss of small particles, fine enough to become airborne as a result of vehicle traffic or strong winds.	Traffic eventually loosens the larger particles from the finer binding particles or grinds the coarser materials into finer particles. In dry weather, wheel action works the fine particles loose and a dust problem develops. Winter sanding and excessive grading contribute to the problem.	Loss of fines may lead to other forms of surface distress and dust may cause a safety hazard for travelers as well as environmental concerns.

[a] Material characteristics alone do not explain surface distresses; the type of vehicles traveling on the road also has an impact.

Some provinces have developed wearing-course specifications for use on unpaved highway shoulders. For example, Quebec's MG20B wearing-course specification (MTQ 2000) requires a higher fines content (5 to 11%) than in the province's MG20 base-course specification (2 to 7%). Quebec forestry companies commonly use the MG20B specification for wearing courses.

Specifications used by FERIC members

FERIC surveyed several eastern Canadian members and collected wearing-course samples from their aggregate stockpiles. Sieve analyses were performed by FERIC or an independent lab, and the results were compared with nine base-course specifications (provided by provincial governments) and five wearing-course specifications (from various international sources). We found that:

- Most of the companies were using specifications designed for aggregates that would be used as the base course for paved roads. The provincial department of transportation typically provided these specifications.
- Only 14% of the samples met the companies' own specifications.
- Only 31% of the samples met one or more of the provincial base-course specifications.
- Only 11% met one or more of the five wearing-course specifications.
- None of the samples measured by FERIC that contained particles smaller than 0.075 mm had fines with adequate plasticity (i.e., had sufficient clay).

Implementation

FERIC's survey and lab work revealed that few (31%) of the aggregate samples used by our members were adequate for use as a base course and even fewer (11%) were adequate for use as a wearing course. Quality control during the production of crushed materials appears to be poor, since only 14% of the samples met the company's own specifications. The availability of clay particles may also be an issue, since few companies add fines to their mixtures and none add *plastic* fines. This report does not propose an optimal specification that companies should use; instead, it encourages readers to consider the most important characteristics when producing aggregates for use as a wearing course. Further tests must be done to better define the optimal specification for unpaved roads so as to meet different regional needs. Moreover, factors such as the gravel source, nature of the source material, crushing and screening methods, traffic type and intensity, and the effects of winter maintenance (sanding) can all affect the performance of a wearing course. Grading quality and frequency are also very important.

To produce optimal aggregate mixtures for use as a wearing course, FERIC recommends that companies:

- Choose a specification designed for wearing-course applications or adapted for regional conditions.
- Aim for a fines content of between 4 and 15% by weight (Selim 2000). These fines must contain clay minerals (i.e., plastic materials) to improve cohesion, and the plasticity index of

these materials should be between 4 and 9 (Selim 2000, AASHTO 2001). However, this rule of thumb should be tested and adapted to meet regional needs.

- Ensure that the maximum particle size is smaller than 19 mm (¾ in.). Where this is not possible, a maximum of 20% of the particles should be retained on a 19-mm sieve and 100% must pass through a 25-mm (1-in.) sieve.
- Monitor aggregate quality during crushing operations by taking regular samples for sieve analysis. The target particle-size distribution, sampling frequency, and method should be written into the contract with the aggregate provider.

References

AASHTO. 2001. Standard specifications for transportation materials and methods of sampling and testing. Part I—specifications. 21st ed. American Association of State Highway and Transportation Officials, Washington, D.C. Unpaginated.

Metcalf, J.B. 1981. Introductory pavement lectures: 1. Compaction, 2. Principles and application of soil stabilisation, 3. Flexible pavement design. Australian Road Res. Board, Victoria, Australia. Research Rep. ARR No. 47A. 33 p.

MTO. 1993. Material specification for aggregate—Granular A. Ont. Min. Transportation, Toronto, Ont. Ontario Provincial Standard Specification 1010. 4 p.

MTQ. 2000. Matériaux granulaires pour fondation, sous-fondation, couche de roulement granulaire et accotement. Ministère des Transports du Québec, Ste-Foy, Que. Norme 2102, Tome VII, Chapitre 2.1—Granulats. 2 p.

RTAC. 1987. Guidelines for cost effective use and application of dust palliatives. Road and Transportation Assoc. Can., Ottawa, Ont. 87 p.

Selim, A.A. 2000. Gravel roads: maintenance and design manual. U.S. Dep. Transportation, Federal Highway Administration, South Dakota Local Transportation Assistance Progr., Brookings, South Dakota. 64 p.