

APPENDIX 8. ROCKING STATE FOREST ROADS

Issue: Road surfacing is often the most expensive item associated with road management (over half of all project costs on many Districts). Surfacing is a non-renewable resource. Current formal engineering procedures for road surfacing types and depths are impractical to use for low-volume roads, thus the need for guidance consistent with state forests plans and objectives.

Objective: To present an empirical system for management of low-volume road gravel road surfacing that integrates planning, design, construction, production, maintenance and repair.

Northwest Oregon State Forests Forest Management Plan Direction (January 2001):

ACCESS—Main access roads are surfaced with rock to provide for all-weather use and to minimize impacts from rainfall and runoff. Secondary spur roads are built to the same maintenance standards but may have lesser specifications for width and surfacing. FMP p. 2–58

ENERGY AND MINERALS—Survey, evaluate, and identify aggregate rock sources important for the long-term management needs of northwest Oregon state forests. FMP p. 4–94

LAND BASE—Minimize the amount of forest land used for roads, road corridor clearings, landings, and mineral extractions by ensuring that construction and development specifications are designed to efficiently meet management activity objectives. FMP p. 4–96

Forest Practices Rules—OAR 629-625-0700

Wet Weather Road Use

- 1. The purpose of this rule is to reduce delivery of fine sediment to streams caused by the use of forest roads during wet periods that may adversely affect downstream water quality in Type F or Type D streams.*
- 2. Operators shall use durable surfacing or other effective measures that resist deep rutting or development of a layer of mud on top of the road surface on road segments that drain directly to streams on active roads that will be used for log hauling during wet periods.*
- 3. Operators shall cease active road use where the surface is deeply rutted or covered by a layer of mud and where runoff from that road segment is causing a visible increase in the turbidity of Type F or Type D streams as measured above and below the effects of the road.*

SUMMARY PROCEDURES: This guidance includes information on design, construction, aggregate production and maintenance and repair. Guidance is summarized on the following two pages, with the rest of the guidance providing more detail. Since aggregate is so expensive and there is also high aquatic risk from inadequate surfacing near streams, review of aggregate design work by the Engineering Supervisor and/or Unit Forester is essential.

A. Aggregate Surfacing Design

- 1) Determine road classification and/or near term use
- 2) Segment road and classify subgrade material and any existing aggregate
- 3) Categorize in-place subgrade material strength(s) using Table 1 (pg. 4)
- 4) Identify drainage conditions and drainage effectiveness, rated 0, 1 or 2 (pg. 4-5)
- 5) Determine construction period and compaction level, also rated 0, 1 or 2 (pg. 5)
- 6) Start with initial strength value, and add drainage or compaction effectiveness factors (each 0, 1, or 2) to get constructed subgrade strength (as constructed) from Table 2

- 7) Consider available aggregate surfacing materials (hardness, durability, gradation)
- 8) Determine aggregate depth for spur roads.
- 9) Consider use of sub-base and base reinforcement.
- 10) Consider use of geosynthetics for separation, drainage and/or reinforcement.
- 11) Add depth (to base course) for collector and mainline road classifications.
- 12) Use two-layer road rocking (base plus surface) new collector and mainline roads.
- 13) Add a 5 to 20 percent aggregate reserve to stockpiles for unexpected conditions.

B. Aggregate properties and production

- 1) Determine available quarries or rock sources.
- 2) Use the Unified Rock Classification System (URCS) to classify rock source materials and where necessary evaluate testing information.
- 3) For ODF quarries, prepare a quarry management plan and track reserve stockpiles.
- 4) Use gradation specifications based on aggregate durability and surfacing type.
- 5) Monitor rock production by visual observations. Routinely test gradation with sieve analysis, and where necessary conduct other aggregate tests.

C. Construction Practices

- 1) Verify subgrade materials used for surfacing design and identify any changed conditions after initial excavation begins and make local adjustments for aggregate depth.
- 2) Monitor moisture conditions. Avoid working when too wet or dry to effectively compact.
- 3) Grade, shape, drain and compact subgrade for maximum strength
- 4) Modify surfacing requirements when actual subgrade materials or construction practices are different from the design.
- 5) Use appropriate compaction equipment and methods for subgrade and road surfacing.
- 6) Apply aggregate in uniform depths and widths.
- 7) Process (uniformly mix and compact) aggregate in lifts not exceeding 6 inches in depth at time of placement. Avoid separation of materials.
- 8) Monitor aggregate processing and compaction. Make any corrections by loosening and processing until visual deformities cease.
- 9) Apply water during extended drying periods where necessary (most commonly used for surfacing courses and for rock products produced during dry periods and hauled directly to construction sites).
- 10) Consider use of aggregate stabilizing agents for dust abatement or improved surface course performance.

D. Maintenance and Repair

- 1) Inspect roads during heavy use and commercial operations (more frequently during wet-season periods). Maintain and inspect highest use roads more frequently.
- 2) Use reserve aggregate for corrective maintenance during initial heavy uses.
- 3) Perform maintenance only as needed – frequent grading wears out rock and may release fines.
- 4) Rutting is normal for gravel roads, so grade only when needed to protect water and the road. Remove ruts over 1½” deep and provide a safe running surface.
- 5) Plan to add rock by use (for logging **plus** rock hauling)

- 6) Use correct materials for road maintenance and repair (original aggregate or open graded repair aggregate).
- 7) High impact areas (landings, severe pumping) may require removal of deteriorated materials and replacement.
- 8) Perform highest level work for high traffic roads or where needed for resource protection.
- 9) Limit use of dirt roads to appropriate moisture conditions, and stop use prior to wet season.
- 10) Cease heavy-hauling during rapid thawing cycles, significant snowmelt, flooding and/or conditions when soils are saturated (uncommon on well drained roads).
- 11) Preserve unused reserve aggregate for uses on other roads.

Determining roads to rock by road functional use/classification

- A) Mainlines should be surfaced for all-season weather use, and should be resurfaced in part based on actual traffic and resource protection.
- B) Collectors should normally be surfaced for all weather use unless there is a compelling reason for not surfacing, and should be resurfaced in part based on actual traffic.
- C) Spurs should be surfaced where surfacing is likely to increase timber sale value by more than the cost of the rock, as necessary for planned future forest management activity, or for timing restrictions. In addition, purchasers should also have this option (at their discretion). Spurs should be surfaced with the minimum rock necessary for the immediate use. Very steep spurs (sustained grades over 18%) have marginal traction when rocked, if rocking is essential use a 3/4 inch minus traction lift for these roads.
- D) Administrative roads should be lightly surfaced or unsurfaced.

AGGREGATE SURFACING DESIGN: Surfacing depth is based on: 1) road strength, 2) traffic types and road use, and 3) current condition of existing roads. This design method considers effective road drainage (and compaction) as the primary factors affecting road strength. **For new roads, the design starts with initial soil strength, then adjusted for drainage and compaction effectiveness to determine the surfacing depth for spur roads. Design for summer (dry) building conditions unless there is a sound resource management reason for not doing so.** The aggregate depth is increased for higher use based on road classification (collectors or mainlines) and based on actual traffic if possible.

Properties of the roadbed: The properties that effect performance of the road subgrade include soil strength and drainage (moisture content), and on existing roads, the thickness and quality of the existing aggregate. These properties often vary along the road. Important properties and how they vary along the road should be evaluated during layout or design work. Break roads into segments based on significant differences in either subgrade material or drainage conditions. Short spurs often have a single segment. Longer roads typically have segments that vary between 200 and 2000 feet. Remember, two compacted inches of rock saved per station is about 12 yards. For a one mile road, this is a savings of \$5,000 to \$15,000. Also, surfacing designs are based upon the worst-case conditions that are anticipated during active road use. High traffic continual use roads require more design information than roads planned for seasonal-controlled use only.

Subgrade Material is most simply characterized by Unified Soil Classification System (USCS) and Unified Rock Classification System (URCS), at least for engineering properties. Existing

soil surveys are a source of information that may be used for initial planning. The final soil evaluation should be made in the field during design processes. Examine exposed soils in nearby road cuts and by local landforms and recognize how they change over the length of the road by landscape position. Also, it is important to use local knowledge of past performance.

Landforms with typically higher strength materials include ridgetops, and full-bench road sections. Old roads that have been modified by previous uses may also have higher strength values. Weaker soils are often found on benches and flats next to streams, with the weakest materials in wetlands. During field layout, identify seeps, wetlands, saturated soils and other wet areas. Soil strength evaluation is performed for the bearing surface only (upper 12" depth). Initial material strength is summarized in Table 1.

TABLE 1. Initial Subgrade Soil Strength (wet season in place)

Unconfined Compressive Strength (t/ft²)	Strength Category	Description	Unified Soil Classification
4	Strong	full bench in rock well graded gravels	GW, GM
3	High	other gravels	GP, GC
2	Average	well graded sands and typical forest soils	SW, SM
1	Low	poorly graded sands, normal clays	SP, SC, CL*
0.5	Weak (pumping)	silts and soft clays	CH*, ML, MH*
0.25	Very Weak	organic, wetland soils	OL*, OH*

* Effective drainage and compaction difficult, use 0 or 1 for condition ratings

Drainage effectiveness is categorized by three categories and is determined by drainage of the road as it will be constructed. When evaluating drainage, also identify stream crossings and segments that will drain to streams versus draining onto the forest floor. Some conditions can be well drained, others cannot. These are noted during segmenting of the road as described below:

Well drained (+2) Used for roads that are effectively drained. This means that there can be no seeps, springs or wetlands in the segment. In addition, positive road drainage is accomplished by:

- A. Road grades, ditch lines (ditch bottom at least 2 feet below road surface), cross drainage relief and/or cross slopes of at least 4%.
- B. Subgrades are well shaped and compacted. Cross slopes are uniform with ruts removed and concentrations of organic materials are removed.

Intermediate drainage (+1) applies to roads with drainage and cross slopes of at least 2%, and for roads that must be constructed during wet weather (not the ODF design standard). Ground water concentrations are drained and/or geotextiles membranes are used for wicking, separation and reinforcement.

Poorly drained (0) is used where drainage is ineffective or impossible, often for old roads with grades under 2%.

Compaction is accomplished with construction equipment and 3 ratings are also used, based on the likely relative subgrade density as the road is constructed. Moisture content and use of specialized compaction equipment are critical to achieve high relative density.

Well compacted (+2) means that specialized compaction equipment must be used during periods when soils are near optimum moisture content (***fine grained soils must be dry to moist, this normally occurs in summer and early fall***). This is the design standard for new mainlines and collector roads. For fine-grained soils (silts and clays) a tamping compactor and 6 inch lifts must be used. For coarse grained soils without many fines, vibratory equipment is required to obtain the well compacted condition, and moisture content is not as critical. Compaction should continue until there is no visual deflection. During compaction, it is essential that the road cross section be reestablished, with cross slopes $\geq 4\%$, (crowned, insloped or outsloped). A rating of +2 requires control of construction activity and moisture content. In western Oregon, controlled conditions for soils are limited to drier construction season periods only. **For silts and clays, a lab test must be used to monitor moisture content during compactive efforts if designed with a rating of 2.**

Mid level compaction (+1) includes roads where loaded trucks or tracked equipment are used for compaction. This also includes when work is performed during conditions when soils are moderately wet or dry. Trucks and tracked equipment must be routed over the entire road cross section. Mixing dried ravel material from cut slopes and ditches can be used to improve and dry out wet soils. Note that roads constructed during wet periods or in the winter are not well compacted (the category that follows). Again as with the well compacted condition, it is necessary to insure the road cross slopes are re-established during compaction. This is the design standard for spur roads.

Not well compacted (0) includes all roads in fine grained materials that are constructed during the wet season or wet periods. This also includes any organic (wetland type) soil during any time of the year.

Determining depth of surfacing for spur roads: Spurs should be rocked using the depth indicated in Table 2. **The depth should be just sufficient to allow completion of heavy equipment operations without loss of traction or production of significant turbidity.** Begin with the Soil strength Number (0.25 to 4), and add drainage and compaction factors if appropriate. The drainage and compaction factors are 0, 1, or 2, and for typical conditions are a given a 1. The final strength rating varies from 0.25 to 8, and if less than a whole number round down. This relative strength is related to the unconfined compressive strength. Numbers in this table may be changed as additional field evaluations are conducted. Spurs should be surfaced with a single (base-type) course, though for steep roads (over 12%) should include a traction lift (2 to 3 inches of well graded 3/4 inch minus aggregate).

Determining aggregate depth for mainlines and collectors: Mainline and collector roads require increased base course depths primarily due to heavy traffic. In addition, these roads also require a stable running surface due to the increased loading and higher vehicle speed. Therefore, it is recommended that 2 layer aggregate systems are used for mainline roads and for higher traffic level collector roads. The 2 layer system consists of a base course plus a surface (wearing) course. The surfacing course is typically constructed from finer, well-graded aggregate (Table 5). The surface course provides stability by sealing the road surface. Aggregate depth for mainline roads is increased by at least 4 inches (above spur depth) and is increased by 2 inches (above spur depth) for collector roads.

Table 2. Minimum Aggregate Depth for Low Traffic Road Based on Modified Strength

As-modified Strength	Depth without geotextile	Depth with Geotextile
≥ 7	0	X
6	4	X
5	6	X
4	8	X
3	10	8
2	14	10
≤ 1*	**	***

- X - not applicable**
- * - indicates likely wetland crossing, evaluate relocation options**
- ** - must use on site rock or geotextile for reinforcement**
- *** - consult with geotechnical specialist or state forests engineer**

AGGREGATE PROPERTIES AND PRODUCTION: There is a range of useable aggregate specifications based on what the quarry is capable of producing. Ideal aggregate has hard, dense angular fragments with at least 3 sharp edges. It is well graded with a compact (not elongated/arrow) shape. Well-graded aggregate is superior because it can be compacted to a higher density than other materials and keeps water away from the subgrade, both resulting in a higher strength road surface. Single course aggregates should be well-graded and meet the specifications shown in Table 3, unless they are of marginal durability where the open graded (few fines) specifications shown in Table 4 are appropriate. Marginal, lower durability aggregate should not be used as a surface course on segments that drain to streams, but is usually acceptable as a base course, or for spurs that are not draining to streams. Use larger aggregate if the durability is marginal, as it is longer lasting. For this design method, *durable aggregate* is defined by strength bearing particles (large and intermediate sizes) with an unconfined compressive strength ≥ 9,000 psi. *Marginal durability aggregate* is defined by strength bearing

particles with and an unconfined compressive strength ranging from 4,500 to 9,000 psi. These may be estimated by the URCS, as there is no perfect laboratory test to determine these values now. **Durable aggregate road surfacing** must be used for active use roads segments draining into streams. If non-durable aggregate is used on spurs or on other roads with light winter use, traffic must be controlled and the road periodically evaluated for FPA wet weather rule compliance (visible turbidity in Type F or D streams).

Table 3. Standard gradation specifications for a single course well-graded aggregate

Sieve size	Percent Passing			
	4 inch*	3 inch	2 inch	1.5 inch**
4	95-100	100		
3		95-100	100	
2	70-90		95-100	100
1.5		70-90		95-100
1	50-80		70-90	
3/4		50-80		70-90
1/4 or #4	30-50	35-60	50-80	40-60
#10	20-40	25-50	25-50	30-50
#40	5-15	5-15	5-20	10-20

* Standard for spur if quarry can produce it

** Standard for l-layer surfacing on higher use roads

Table 4. Standard gradation specifications for marginal durability base or single course aggregate (fewer fines)

Sieve size	Percent Passing		
	4 inch*	3 inch	2 inch
4	95-100	100	
3		95-100	100
2	70-90		95-100
1.5		70-90	
1	50-70		70-90
3/4		50-70	
1/4 or #4	15-50		20-60
#10	0-30	0-30	0-30
#40	0-10	0-10	0-10

* Standard for spur if quarry can produce it

For the surface course of a higher use road (Table 5), aggregate should contain 8-16 percent plastic fines (not just rock flour) if possible as estimated by examining the percent passing the #40 sieve (should be sticky). Without plastic fines, a surface stabilizer may be needed to prevent loss of fines during heavy summer use. Steep spurs ($\geq 12\%$ adverse grades) should receive a thin

vener of aggregate (Table 5 specs.) to increase traction. Finer graded aggregates (1-inch and 3/4-inch minus) are better at sealing the surface and allow higher speeds and easier grading. However, they will break down under traffic more quickly than the coarser materials, so they must be durable quality and obtained from the better rock sources.

Table 5. Standard gradation specifications for durable surface course aggregate

Sieve size	Percent Passing		
	1.5 inch	1 inch	3/4 inch*
2	100		
1.5	95-100	100	
1	80-95	95-100	100
3/4	70-90	75-95	90-100
1/4 or #4	40-60	50-75	50-75
#10	25-40	25-50	30-55
#40	8-16***	8-16***	8-16***

*** Use the higher very fine percentage for road grades over 15 percent

Table 6. Gradation specifications for repair aggregate (excess fines in existing aggregate)

Sieve size	Percent Passing		
	1.5 inch	1 inch	3/4 inch*
2	100		
1.5	95-100	100	
1	80-95	95-100	100
3/4	60-80	80-95	90-100
1/4 or 4	20-50	20-40	30-60
#10	10-30	10-30	10-30
#40	0-10	0-10	0-10

Aggregate production: There are many ways to produce aggregate and rock products for road construction and maintenance activities. In some cases, rock of sufficient quality can be obtained by excavation into a road cut or other exposure. This can be placed on the road as is, or improved through processes such as blasting, ripping, screening, crushing, sorting and/or mixing.

Aggregate production normally requires crushing and screening to produce consistent (reliable products) for road surfacing uses. Procedures for management of major quarries include:

1. Thorough field investigation of the rock source.
2. Classify source materials using the Unified Rock Classification System (URCS) to determine best potential products and uses.
3. Perform topographic surveys of the rock source development area(s).
4. Prepare a geologic model that displays materials distribution, plan and profiles, cross sections and initial volume calculations.
5. Verification of the geologic model by sub-surface testing (excavation, drilling)

6. Develop a quarry management plan, including aggregate/rock specifications and any special development requirements.
7. Test aggregate/rock during production, including visual and sieve analyses.
8. Monitor aggregate performance during uses.

Testing: All tests other than gradation and the URCS have limitations and can be expensive. These other laboratory tests are appropriate only where you have a specific question about the aggregate and feel a specific test can answer your question, or to determine compliance. Other tests are more appropriate for purchased rock, as we do not have control over the quarry. The two most valuable tests are the Oregon Air Degrade (TM-208) and the LA Abrasion (AASHTO T-96). Durable material should have a value under 30 percent for either of these tests. Consult the State Forests Engineer or Area Geotechnical Specialists for advice when needed.

CONSTRUCTION PRACTICES: Aggregate requires compaction after placement on the road. The standard conversion from loose in-truck rock to in place compacted inches by road width is shown in crushed rock Table 7 (compaction factor 1.3)

Table 7. In-truck aggregate required for compacted depth.

		Finished Surface Width (feet)						
		10	12	14	16	18	20	
Rock Depth	inches	1	5	5	6	7	8	9
	2	9	11	12	14	16	17	
	3	14	16	19	21	23	26	
	4	18	22	25	28	31	35	
	5	23	27	31	35	39	43	
	6	28	33	37	42	47	52	
	7	32	38	44	49	55	60	
	8	37	43	50	56	63	69	
	9	42	49	56	63	70	78	
	10	46	54	62	70	78	86	
	11	51	60	68	77	86	95	
	12	55	65	75	84	94	104	
	13	60	70	81	91	102	112	
	14	65	76	87	98	110	121	
	15	69	81	93	105	117	129	
	16	74	87	100	112	125	138	
	17	78	92	106	119	133	147	
	18	83	98	112	126	141	155	
	19	88	103	118	133	149	164	
	20	92	108	124	140	156	173	

This volume change during aggregate placement and compaction is due to air space caused by fluffing when loaded and subsequent air space removal due to compaction. The conversion from pit-run rock compacted yardage to truck yardage is 1.3 to 1.4 based on conditions of the particular pit-run source.

It is essential to reevaluate the subgrade and drainage conditions prior to rocking. In addition to the practices described on page 2, ensure that the surface (wearing) course depth for higher use roads is between 4 to 6 inches. The surface course wears out over time and depth should be based upon expected loadings over 3 to 10 year time intervals. Use staged construction methods, applying 2-4 inches lifts in the locations with the highest traffic or that show the most wear first, and then completing the project in later years to get surfacing depths over time when funds are limited. Where minimum surfacing depths are used, it's important to monitor road performance during the initial heavy road use. Aggregate must be held in reserve (stockpiled) and used to correct any problems occurring during road use by adding reserve rock to these soft spots. As a general rule, reserve aggregate should be at least 5% for spur roads and as much as 20% for mainline and collector roads. Reserve rock for mainlines and collectors should be surface course aggregate, for spurs it should be the aggregate used on that road

Geotextiles: Use geotextiles for separation where effective drainage is not possible, including where aggregate is placed on organic soils, in wetlands, flat grades (which we should not have on new roads). Geotextiles should also be used for silts and clays than cannot be effectively compacted. For spurs, use a geotextile if the final strength rating from Table 2 is no greater than 2. Even when well-compacted, silts under mainlines and collectors may pump under wet weather use, so geotextiles should be considered. Another geotextile use is to help recycle aggregate from temporary or unneeded roads. In addition, consider geotextiles when roads must be constructed or repaired outside of normal construction periods (wet periods). Specifications for separation geotextiles are shown in Table 7.

Table 7. Standard Specifications for Separation Geotextiles

High Strength Option - 6 oz./yd² – Woven Fabric

Grab Tensile Strength	300 lbs.	ASTM D4632
Puncture Strength	110 lbs.	ASTM D4833
Mullen Burst	600 psi	ASTM D3786
Width	12.5 or 16 ft.	

Mid Strength Option - 4½ oz./yd² – Woven Fabric

Grab Tensile Strength	200 lbs.	ASTM D4632
Puncture Strength	90 lbs.	ASTM D4833
Mullen Burst	400 psi	ASTM D3786
Width	12.5 or 16 ft	

Some geotextiles can improve drainage. In areas with seeps and springs, a drainage geotextile should be used. These are normally non-woven, and have a specification called permittivity. For seeps and small springs, permittivity should also be specified, normally as greater than 0.2 sec⁻¹. A higher value is appropriate for larger springs or seeps. Except for wetlands, use of a drainage geotextile will change the drainage class from 0 to +1. Other geosynthetic products (such as geogrids and drainage fabrics) may be used for specific reinforcement or drainage applications.

Changed conditions: Determine if subgrade materials used for design are those observed during initial construction. Identify any changed conditions after initial excavation begins and make local adjustments for aggregate depth. This may be a decrease or increase in required aggregate depth, and should be added to or subtracted from the aggregate reserve. Changes due to purchaser action or inaction, including if the purchaser had a dry period in which to construct the road, but instead built it during a wet period are the purchaser's responsibility. The design depth should be recalculated and the purchaser is responsible for any increased aggregate required due to this condition. On the other hand, if the purchaser constructs the road during a dry period and encounters different subgrade conditions, seeps or springs, the increased aggregate required is an ODF responsibility and taken from the design reserve. Purchasers can choose to rock spurs designed for dirt surface at their cost. These spurs must be rocked and used to FPA standards (durable surfacing on those segments connected streams)

Application: Aggregate used for road surfacing must be applied in a uniform depth and width. The maximum depth lift that can be processed is 6 inches, 8 inches when applied over geotextiles. This often requires staking the road prior to rock spreading. Aggregate must be uniformly mixed and often requires application of water for processing and compaction. This is especially true for aggregate produced and applied during dry periods. Stockpiled rock retains water and will normally require less applied water for optimum moisture content.

Resurfacing roads: Over time, the road surface weakens while the subgrade increases in strength. Evidence of need for new rock includes 1) excess fines on the surface, *especially fines the color of the subgrade, not just rock flour*; 2) frequent grading required to correct ruts and imperfections; and 3) loss of traction (loss of stability when driven by field rig when surface is wet). Gradation tests can confirm worn surfacing. If over 25 percent of the sample passes the number 40 sieve then additional replacement aggregate is probably needed. Another indicator is the loss of rock to rock contact when observing the aggregate (just below the surface). **If surface runoff discolors Type F or D streams, hauling must cease until the situation is corrected.**

Only roads with active use planned for the current or next year should be resurfaced. Since new surfacing lowers traction during dry periods, resurfacing is best done in the fall after some rain but before the subgrade reaches mid winter moisture levels. Before a major re-rocking project it is essential to estimate the existing useful depth of aggregate. This is best accomplished by digging through the existing rock surfacing (use of road graders or excavators is recommended) and determining the effective rock depth (to aggregate/subgrade contact). Effective rock depth can be zero where the entire road surface has been punched into the subgrade. Use the same subgrade strength and drainage ratings as new roads, and use a compaction rating of +1 unless the subgrade is unusually dense. Existing roads should be resurfaced with surface course material so that the total aggregate depth equals the design depth in Table 2.

When treating a surfacing with too many or too few fines, use gradation as in Table 6. In very limited cases, re-rock segments that have failed (very deep ruts, wet) by removing and replacing contaminated surfacing. Cut out defects and add leveling and reinforcement rock for uniform depth. This requires waiting until it is dry enough to drain and re-compact. If this is not possible,

use a geotextile. Do not dump crushed rock into a very soft area (only purchasers can have this option with rock they buy).

Aggregate wear rates: Heavy traffic wears out aggregate. For this design method, wear rates can be used to plan for rock replacement for mainline and collector roads. Traffic using mainlines and collectors should be tracked or estimated based on either volume or truck counts. This method is directly related to 18,000 pound equivalent single vehicle axle loads (ESAL). **This includes use by rock trucks.** Each 10 c.y. rock **truck is equivalent to approximately 3 MMBF.** Based on past experience, highest quality durable aggregate wears at a rate of 1 compacted inch per 10 MMBF and marginal durability rock wears at a rate of 1 inch per 3.5 MMBF. For each mainline or collector road, rate the durability of the aggregate based on URCS investigations, laboratory tests for durability and/or past experience. For high traffic roads, plan to replace surfacing course materials after 2 to 3 inches of rock wear occurs. Past experiences indicate that surfacing course replacement typically occurs on 1 to 7 year cycles, dependent upon axle loading (heavy traffic).

Tire Pressure: Many studies have shown that aggregate wear is greatly increased by higher tire pressures. This also reduces overall road surface performance. **Tire pressure for trucks using State forests roads should be limited to 75 psi.** This is a safe pressure for operating on paved roads. For rock trucks working only on ODF roads, consider limiting tire pressures to 50 psi (but only if they do not drive on paved roads during the work period).

Aggregate recycling is a technique that Astoria District has used with success. This makes sense for roads with no current wet season uses, and roads that are being vacated, **but only if durable rock was used on that road being closed.** Astoria has found aggregate recovery rates ranging from 75 to 92 percent. Also, recovery and quality of recovered rock was improved when geotextiles were used for subgrade/aggregate separation.

MAINTENANCE AND REPAIR: Work is needed periodically to protect the road investment and minimize environmental impacts. Maintain roads before they are deeply rutted (ruts that keep water from flowing off the road). **The purchaser is also responsible to bring a mainline or collector used for logging back to original condition if logging activity has damaged the surface.** Consider the following items when monitoring and planning for road maintenance operations:

1. Grade only when necessary. Frequent grading wears out aggregate and releases fines.
2. Rutting is a normal occurrence for gravel roads. Ruts and roughness are indicators of maintenance need. If ruts exceed 1½” in depth or direct water down the road, or, surface roughness affects the ability to travel the road it’s time to perform surface maintenance.
3. Re-establish positive road drainage (ditch lines, cross drainage, cross slopes, water-bars).
4. Avoid contamination of aggregate (logging debris, grass and grouser tracks).
5. Cut to depth to correct problems. Most surfacing failures are due to poor quality materials that may require removal or reprocessing to correct.
6. Add patch rock to soft and locally rutted locations.
7. Restrict heavy equipment to staging and landing areas.

8. Avoid working when too wet or too dry. Aggregate must be moist to grade to obtain uniform mix and to process rock. Aggregate processing often requires application of water for optimum moisture content.
9. For mainlines and collectors, compact aggregate for maximum density. Use specialized compaction equipment, such as vibratory rollers where necessary to restore running surfaces.

Winter weather: Snow removal by plowing should be allowed by permission only. Avoid disturbance of road surfacing by leaving a 1 inch layer of snow on the road surface. Provide drainage, avoid berms that direct water down the road surface. Avoid filling in ditch lines, culvert inlets and/or outlets. As a general rule, use of motor graders for snow removal is preferred as opposed to tracked equipment, such as a dozer.

Heavy hauling should be suspended during rapid thawing cycles, significant snowmelt or flooding. *Ceasing road use* is essential for all traffic (excluding that necessary to prevent more serious emergencies) during deep thawing period after the aggregate surface has frozen down to the subgrade. Traffic must also be controlled on all roads with marginal durability surfacing that have drainage to streams. This requires careful inspections by contract administrators during periods of moderate rainfall in order to comply with FMP water quality standards and Forest Practices wet season road use rules. All heavy uses must cease except for public safety or more serious resource damage emergencies.

Dry season stabilization: During dry weather, loss of fines as dust will destabilize the surface, affect driving safety, and affect air quality for persons living or recreating near the road. Water, magnesium chloride and lignin sulfate are most commonly used. Where available, water is cheapest in the short term and has the least environmental effects. Use of road water from a stream requires a road watering permit from the Water Resources Department. Magnesium chloride is generally considered to have minimal environmental effects if rainfall does not occur shortly after application. Lignin sulfate needs to be applied during dry periods.