Chapter 12

Roadway Materials and Material Sources

"Select quality roadway materials that are durable, well-graded, and perform well on the road. Maintain quality control."

LOW-VOLUME ROAD surfaces and structural sections are typically built from native materials that must support light vehicles and may have to support heavy commercial truck traffic. In addition, low-volume roads should have a surface that, when wet, will not rut and will provide adequate traction for vehicles. The surface of native soil roads is also an exposed area that can produce significant amounts of sediment, especially if rutted (*Photo 12.1*).

Roadway Materials

It is usually desirable and, in many cases, necessary to add subgrade structural support or to improve the roadbed native soil surface with materials such as gravel, coarse rocky soil, crushed aggregate, cobblestone, concrete block, or some type of bituminous seal coat or asphalt pavement, as shown in *Figure 12.1*. Surfacing improves the structural support and reduces road surface erosion. The selection of surfacing type depends upon the traffic volume, local soils, available materials, ease of maintenance, and, ultimately, cost.

A range of options exists for improving the structural capacity of the roadway in areas of soft soils or poor subgrades. These commonly include:

- Adding material of higher strength and quality over the soft soil, such as a layer of gravel or

Photo 12.1 A rutting road caused either by soft subgrade soil or inadequate road drainage (or both).

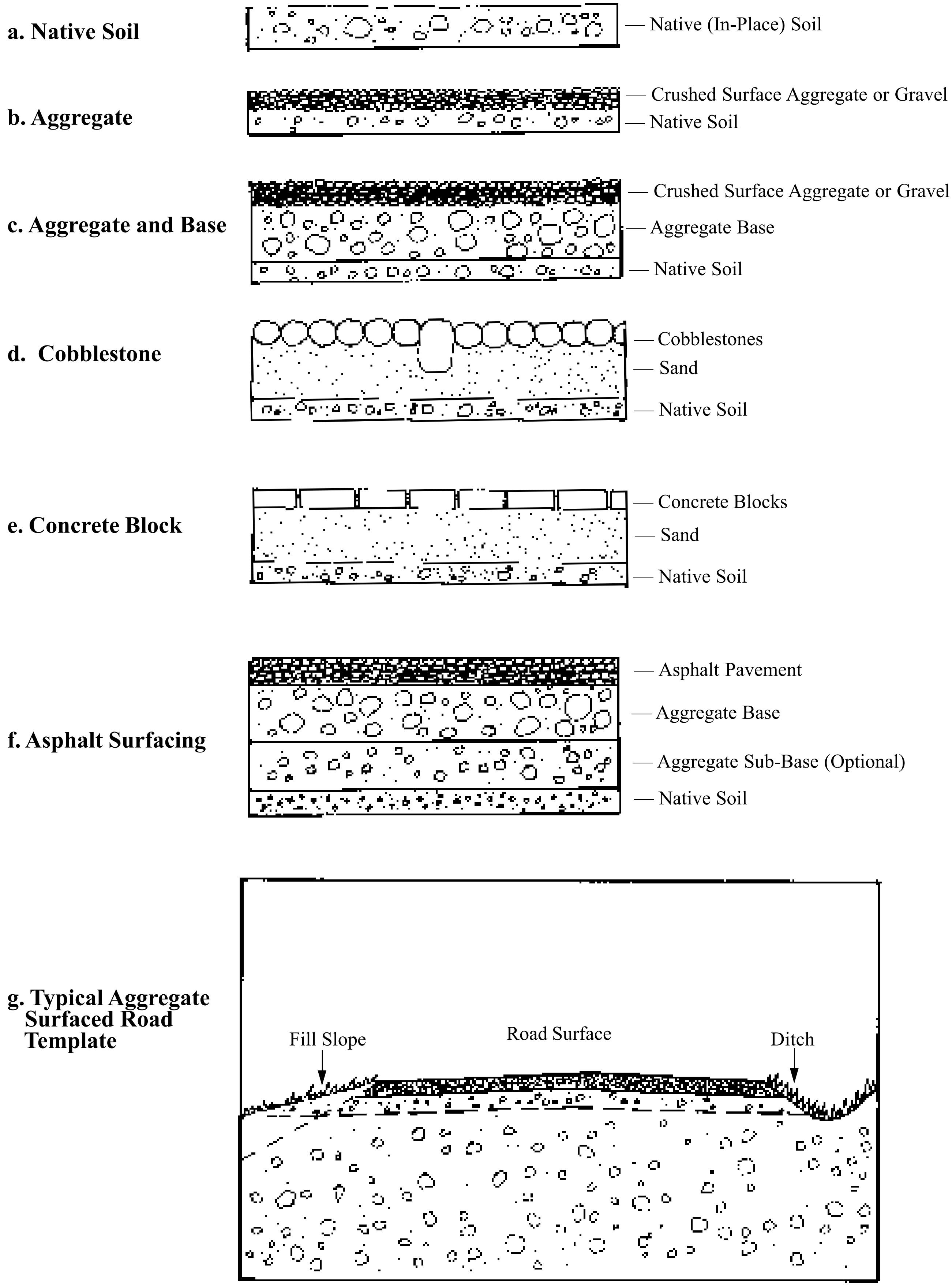


Figure 12.1 Commonly used low-volume road surfacing types and structural sections.

crushed aggregate;

- Improving the soft soil in place (in-situ) by mixing it with stabilization additives such as lime, cement, asphalt, or chemicals;

- Bridging over the soft soil with materials such as geotextiles or wood pieces (corduroy);

- Removing the soft or poor soil and replacing it with a high quality soil or rocky material;

- Limiting the use of the road during periods of wet weather when clay soils are soft;

- Compacting the native soil to increase its density and strength; and

- Keeping moisture out of the soil with effective roadway drainage or encapsulating the soil to keep water out.

Various soil stabilization materials such as oils, lime, cements, resins, lignin, chlorides, enzymes, and chemicals may be used to improve the material properties of the in-place soil. They may be very cost-effective in areas where aggregate or other materials are difficult to locate or are expensive. The best soil stabilization material to use depends on cost, soil type, performance and local experience. Test sections are often needed to determine the most desirable and cost-effective product. However, many soil stabilizers still need some type of wearing surface. A stabilized road surface improves traction and offers erosion protection as well as structural support.

Photo 12.2 Stabilize the roadway surface with crushed rock (or other surfacing) on steep grades, in areas of soft soil, or in erosive soils.

Gravel, pit run rock, select material, or crushed aggregate are the most common improved surfacing materials used on low-volume roads (*Photo 12.2*). Aggregate is sometimes used only as "fill" material in ruts. However, it is more desirable to place it as a full structural section, as shown in *Figure 12.2*. The roadway surfacing aggregate must perform two basic functions. It must have high enough quality and be thick enough to provide structural support to the traffic and prevent rutting, and it must be well graded and mixed with sufficient fines, preferably with some plasticity, to prevent raveling and washboarding.

Necessary aggregate thickness typically ranges from 10 to 30 cm, depending on soil strength, traffic, and climate. Specific aggregate thickness design procedures are found in the Selected References. Over very weak soils (CBR less than 3), aggregate thickness can be reduced with the use of geotextile or geogrid subgrade reinforcement. Also, geotextile layers are useful over soft soils to separate the aggregate from the soil, keep it uncontaminated, and extend the useful life of the aggregate.

Figure 12.3 presents some of the physical properties and tradeoffs of various soil-aggregate mixtures, first with no fines (no material passing the #200 sieve, or .074 mm size), second with an ideal percentage of fines (6-15%), and finally with excessive fines (over 15 to 30%). *Figure 12.4* shows the typical gradation ranges of aggregates used in road construction, how the materials, ranging from coarse to fine, best perform for a road, and the approxi-

Figure 12.2 Aggregate options to prevent rutting.

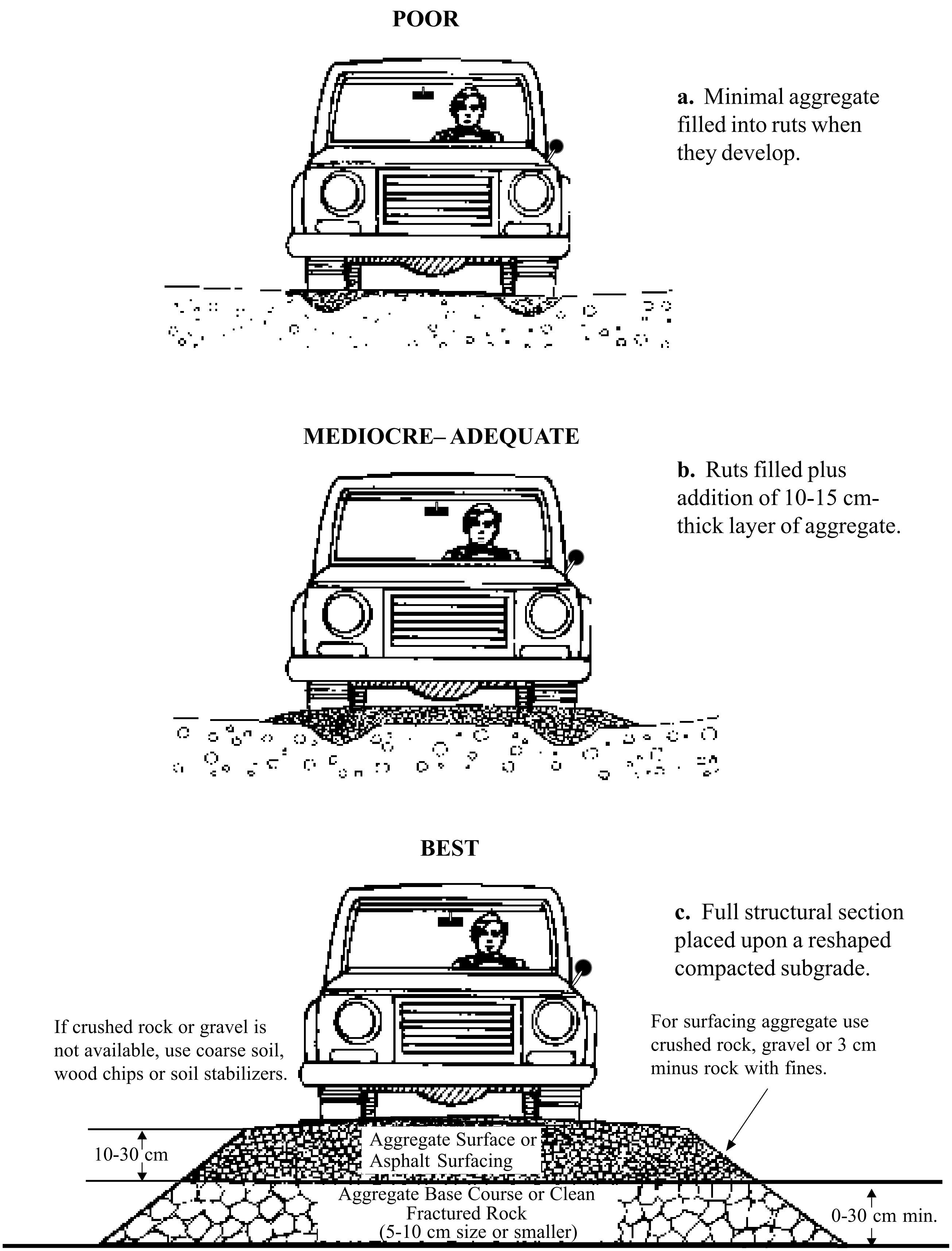
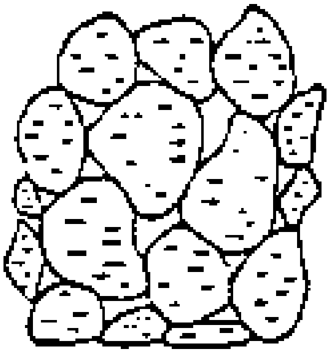
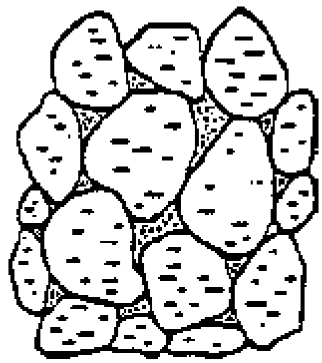


Figure 12.3 Physical states of soil-aggregate mixtures. *(Adapted from Yoder and Witczak, 1975)*



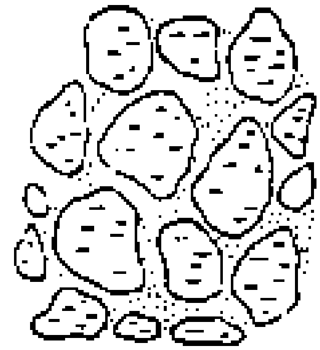
Aggregate with no Fines

- Grain-to-grain contact
- Variable density
- High Permeability
- Non-Frost Susceptible
- High stability when confined, low if unconfined
- Not affected by water
- Difficult to compact
- Ravels easily



Aggregate with Sufficient Fines for Maximum Density

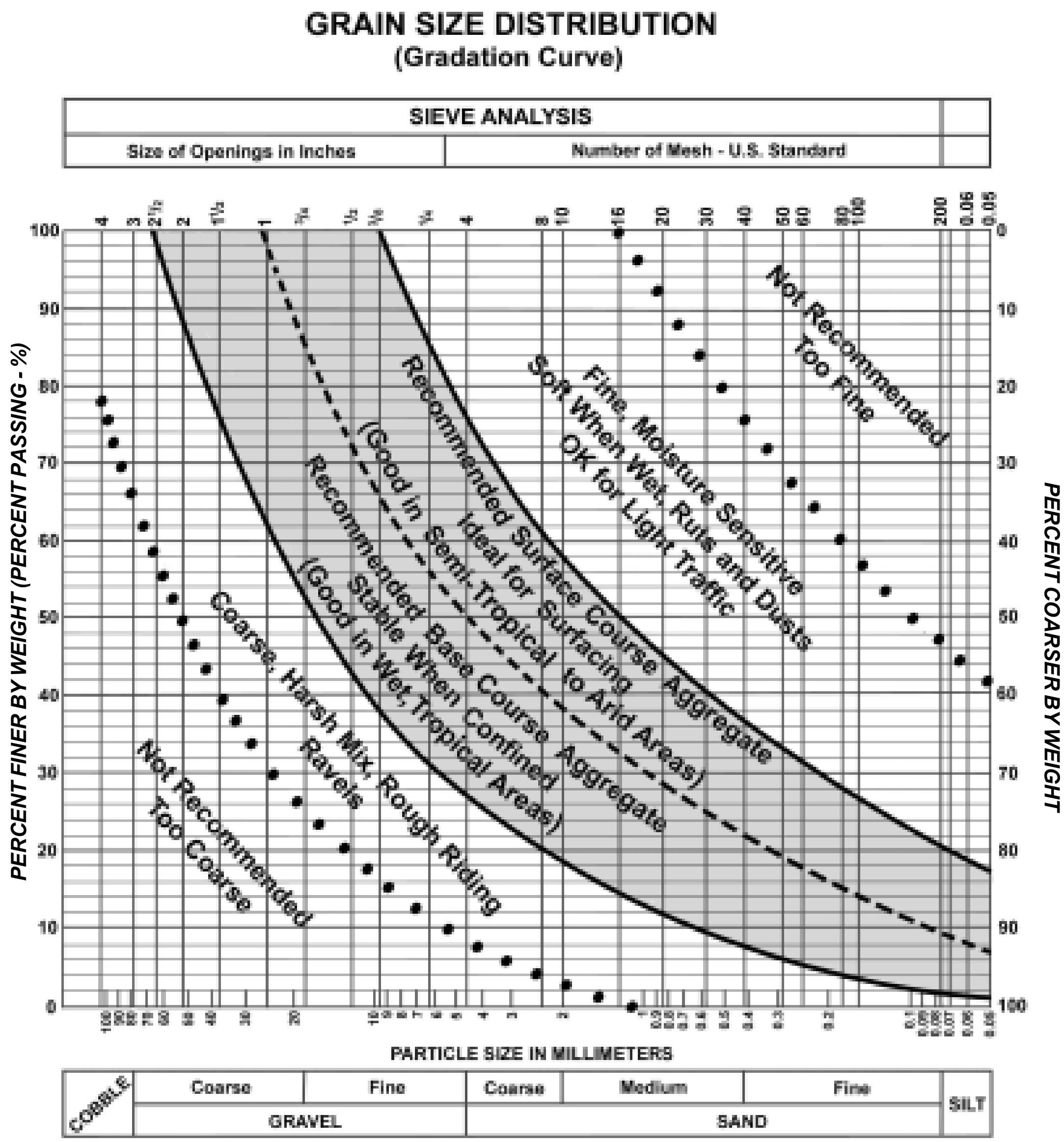
- Grain-to-grain contact with increased resistance against deformation
- Increased to maximum density
- Low permeability
- Frost susceptible
- Relatively high stability in confined or unconfined conditions
- Not greatly affected by adverse water conditions
- Moderately easy to compact
- Good road performance



Aggregate with High Amount of Fines (>30 percent)

- Grain-to-grain contact destroyed, aggregate is "floating" in soil
- Decreased density
- Low permeability
- Frost susceptible
- Low stability and low strength
- Greatly affected by water
- Easy to compact
- Dusts easily

Figure 12.4 Gradation ranges of roadway surfacing materials and their performance characteristics. *(Adapted from R. Charles, 1997 and the Association of Asphalt Paving Technologists)*



NOTE: Gradation Ranges Shown Are Approximate.

The best roadbed surfacing materials have some plasticity and are well graded. They have gradations parallel to the curves shown above, and are closest to the "Ideal" dashed curve in the middle of the gradation ranges shown.

PRACTICES TO AVOID

- Construction operations or heavy traffic during wet or rainy periods on roads with clay rich or fine-grained soil surfaces that form ruts.
- Allowing ruts and potholes to form over 5 to 10 cm deep in the roadway surface.
- Road surface stabilization using coarse rock larger than about 7.5 cm. Coarse rock is difficult to drive upon or keep stabilized on the road surface, and it damages tires.
- Using surfacing materials that are fine grain soils, soft rock that will degrade to fine sediment, or clean, poorly graded coarse rock that will erode, ravel, or washboard.

mate limitations to the desirable gradation ranges. Note that the desirable percentage of fines in an aggregate can be sensitive to the climate or road environment. In semi arid to desert regions, a relatively high percentage of fines, such as 15 to 20%, with moderate plasticity, is desirable. In a high rainfall "wet" environment, such as tropical, coastal mountain, or jungle areas, a low percentage, such as 5 to 10% fines, is desirable to prevent rutting and maintain a stable road surface.

Ideally, aggregate surfacing material is (1) hard, durable, and crushed or screened to a minus 5 cm size; (2) well graded to achieve maximum density; (3) contains 5-15% clayey binder to prevent raveling; and (4) has a Plasticity Index of 2 to 10. The

RECOMMENDED PRACTICES

- Stabilize the roadway surface on roads that form ruts or ravel excessively. Common surface stabilization techniques include using 10-15 cm of crushed aggregate; local pit run or grid roll rocky material (*Photo 12.4*); cobblestone surfacing; wood chips or fine logging slash; or soils mixed and stabilized with cement, asphalt, lime, lignin, chlorides, chemicals, or enzymes.

- For heavy traffic on soft subgrade soils, use a single, thick structural section consisting of at least 20-30 cm of surfacing aggregate. Alternatively, use a structural section consisting of a 10-30 cm thick layer of base aggregate or coarse fractured rock, capped with a 10-15 cm thick layer of surfacing aggregate (*Figure 12.2*-BEST). Note that soft clay-rich tropical soils and heavy tire loads may require a thicker structural section. The structural depth needed is a function of the traffic volume, loads and soil type, and should ideally be determined through local experience or testing, such as using the CBR (California Bearing Ratio) test.

- Maintain a 3-5% road cross-slope with insloping, outsloping, or a crown to rapidly move water off the road surface (see *Figure 7.1*).

- Grade or maintain the roadway surface before significant potholes, washboarding, or ruts form (see *Figure 4.5*).

- Compact the embankment material, road surface material or aggregate during construction and maintenance to achieve a dense, smooth road surface and thus reduce the amount of water that can soak into the road (*Photo 12.5*).

- "Spot" stabilize local wet areas and soft areas with 10-15 cm of coarse rocky material. Add more rock as needed (*Figure 12.2*).

- Stabilize the road surface in sensitive areas near streams and at drainage crossings to minimize road surface erosion.

- Control excessive road dust with water, oils, wood chips, or use of other dust palliatives.

- Blend coarse aggregate and fine clay-rich soil (when available) to produce a desirable composite roadway material that is coarse yet well-graded with 5-15 % fines for binder (see *Figures 12.3* and *12.4*).

- Use project construction quality control, through visual observation and materials sampling and testing, to achieve specified densities and quality, well-graded road materials (*Photo 12.6*).

- On higher standard, high traffic volume roads (collectors, principals, or arterials) use appropriate, cost effective surfacing materials such as oils, cobblestone, paving blocks (*Photo 12.7*), bituminous surface treatments (chip seals) (*Photo 12.8*), and asphalt concrete pavements.

Photo 12.3 A road in need of maintenance and surfacing. Add roadway surface stabilization or do maintenance with grading and shaping of the surface to remove ruts and potholes before significant road damage occurs, to achieve good road surface drainage, and to define the roadbed.

Photo 12.4 A grid roller can be used to produce a desirable surfacing material when the coarse rock is relatively soft. Level and compact the roadway surface aggregate to achieve a dense, smooth, well-drained riding surface.

Photo 12.5 Compaction of soil and aggregate is typically the least expensive way to improve the strength and performance of the material. Compaction is useful and cost-effective both for the stability of fill embankments and for the road surface.

Photo 12.6 Here, a "nuclear gauge" is being used to check the density of aggregate. Use project construction quality control, gradation and density testing, etc., as needed to achieve the desirable materials properties for the project.

Photo 12.7 Concrete blocks (Adoquin) or cobblestone offer an intermediate alternative to aggregate and pavement road surfacing. These materials are labor intensive to construct and maintain, but are very cost-effective in many areas.

Photo 12.8 A chip seal road surface being compacted. A variety of surfacing materials can be used, depending on availability, cost, and performance.

surfacing applied to the road must be maintainable in order to prevent rutting and erosion. Significant deterioration of the road can occur if ruts, raveling, washboarding, or surface erosion are not controlled (*Photo 12.3*). Road damage can be greatly reduced by restricting road use during wet conditions if road management allows for this option.

Compaction is usually the most cost-effective method to improve the quality, including strength and water resistance, of subgrade soils and to improve the performance of aggregate surfacing. It increases the density and reduces the void spaces in the material, making it less susceptible to moisture. Thus, compaction is useful to protect the investment in road aggregate, maximize its strength, minimize loss of fines, and prevent raveling. Road performance has been excellent in some semi-arid regions with the use of blended local materials, very high compaction standards, and a waterproof membrane such as a bituminous seal coat.

Compaction can best be achieved with a minimum of effort if the soil or aggregate is well graded and if it is moist. Ideally, it should be close to the "optimum moisture content" as determined by tests such as the "Proctor" Moisture-Density Tests. Expansive soils should be compacted on the wet side of optimum. Hand tamping can be effective, but only when done in thin lifts (2-8 cm) and ideally at a moisture content a few percent above optimum.

The best compaction equipment for granular soils and aggregate is a vibratory roller. A tamping, or sheepsfoot roller is most effective on clay soils. A smooth drum, steel wheel roller is ideal for compaction of the roadway surface. Vibratory plates or rammers, such as "wackers", are ideal in confined spaces. No one piece of equipment is ideal for all soils, but the best all-purpose equipment for earthwork in most mixed soils is a pneumatic tire roller that produces good compaction in a wide range of soil types, from aggregates to cohesive silty soils.

Materials Sources

The use of local materials sources, such as borrow pits and quarries, can produce major cost savings for a project compared to the cost of hauling materials from distant, often commercial, sources. However, the quarry or borrow pit material quality must be adequate. Sources may be nearby rock outcrops or granular deposits adjacent to the road or within the roadway. Road widening or lowering road grade in fractured, rocky areas may produce good construction materials in an area already impacted by construction. Rock excavation and production may be by hand (*Photo 12.9*), or with the use of various types of equipment, such as screens and crushers. Relatively low-cost, on-site materials can result in the application of considerably more roadway surfacing and more slope protection with rock since the materials are readily available and inexpensive. However, poor quality materials will require more road maintenance and may have poor performance.

Borrow pits and quarries can have major adverse impacts, including sediment from a large denuded area, a change in land use, impacts on wildlife, safety problems, and visual impacts. Thus quarry site planning, location, and development should usually be done in conjunction with Environmental Analysis to determine the suitability of the site and constraints. A **Pit Development Plan** should be required for any quarry or pit development to define and control the use of the site and the materials being extracted. A pit development plan typically defines the location of the materials deposit, the working equipment, stockpile and extraction areas (*Photo 12.10*), access roads, property boundaries, water sources, and final shape of the pit and back slopes. Materials source extraction can cause long-term land use changes, so good site analysis is needed.

In-channel gravel deposits or stream terrace deposits are often used as materials sources. Ideally, deposits in or near streams or rivers should **not** be used. Gravel extraction in active stream channels can cause significant damage to the stream, both on-site and downstream (or upstream) of the site. However, it may be reasonable to remove some materials from the channel with adequate study of the fluvial system and care in the operation. Some gravel bar or terrace deposits may be appropriate for a materials source, particularly if taken from above the active river channel. Equip-

Photo 12.9 **Develop quarries and borrow sites (materials sources) close to the project area whenever possible. Either hand labor or equipment may be appropriate, depending on the site conditions and production rates.**

Photo 12.10 **Quarries and borrow sites (materials sources) can provide an excellent, relatively inexpensive source of project materials. A site may require simple excavation, screening, or crushing to produce the desired materials. Control use of the area with a Pit Development Plan.**

ment should not work in the water.

Site reclamation is typically needed after materials extraction, and reclamation should be an integral part of site development and included in the materials cost. Reclamation work should be defined in a **Pit Reclamation Plan**. Reclamation can include conserving and reapplying topsoil, reshaping the pit, revegetation, drainage, erosion control, and safety measures. Often, interim site use, closure, and future reuse must also be addressed. A site may be used for many years but be closed between projects, so interim reclamation may be needed. Roadside borrow areas are commonly used as close, inexpensive sources of material (*Photo 12.11*). These areas ideally should be located out of sight of the road, and they too need reclamation work after use.

The quality of the local material may be variable or marginal, and the use of local material often requires extra processing or quality control. Low quality material may be produced at a cost much lower than commercially available material, but may not perform well. Zones of good and bad material may have to be separated. The use of local materials, however, can be very desirable and cost-effective when available and suitable.

RECOMMENDED PRACTICES

- Develop local borrow pits, quarries and pit-run material sources wherever practical in a project area. Ensure that Environmental Analysis has been done for the establishment of new materials sources.

- Use a **Pit Development Plan** to define and control the use of local materials. A Pit Development Plan should include the location of the site, extent of development, excavation, stockpiling and working areas, shape of the pit, volume of useable material, site limitations, a plan view, cross-sections of the area, and so on. A plan should also address interim or temporary closures and future operations.

- Develop a **Pit Reclamation Plan** in conjunction with pit planning to return the area to other long-term productive uses. A Pit Reclamation Plan should include information such as topsoil conservation and reapplication, final slopes and shaping, drainage needs, safety measures, revegetation, and erosion control measures (*Photo 12.12*).

- Reshape, revegetate and control erosion in roadside borrow areas to minimize their visual and environmental impacts (*Figure 12.5*). Locate materials sources either within the roadway or out of view of the road.

- Maintain project quality control with materials testing to guarantee the production of suitable quality material from quarry and borrow pit sources.

PRACTICES TO AVOID

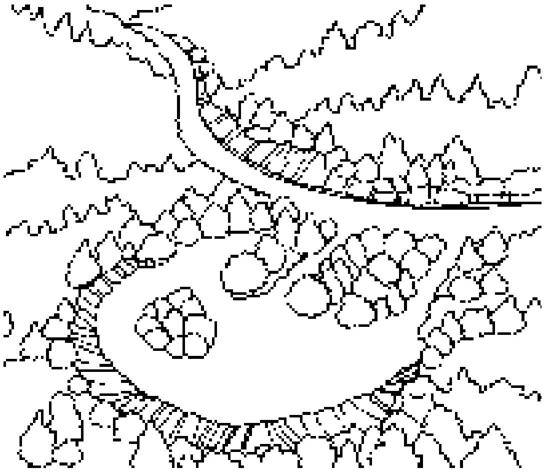
- In-stream channel gravel extraction operations and working with equipment in the stream.

- Developing materials sources without planning and implementing reclamation measures.

- Using low quality, questionable, or unproven materials without adequate investigation and testing.

Figure 12.5 Good and bad roadside quarry development practices. *(Adapted from Visual Quality Best Management Practices for Forest Management in Minnesota, 1996)*

Good Practices for Quarry Development



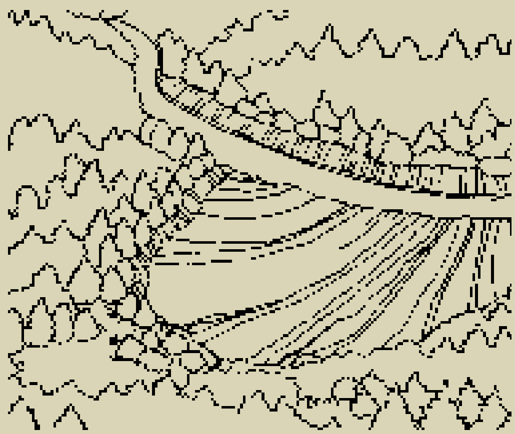
DO!

- Screen pit area from road
- Leave gentle slopes
- Reshape and smooth the area
- Leave pockets of vegetation
- Seed and mulch the area
- Use drainage control measures
- Replace Topsoil

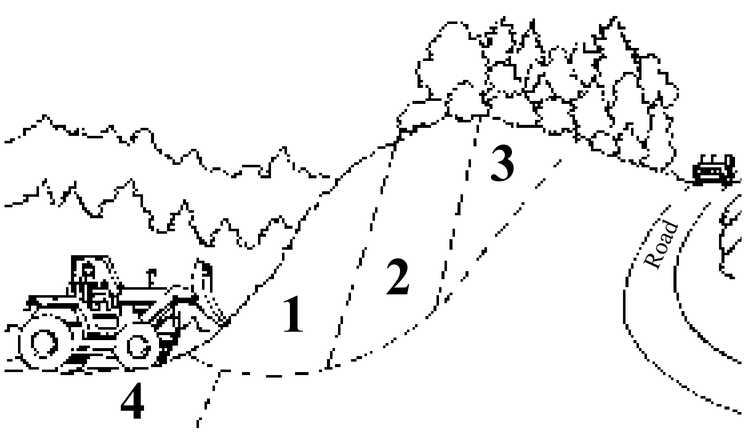
Poor Practices for Quarry Development

DO NOT!

- Expose large, open area
- Leave area barren
- Leave steep or vertical slopes



Ideal Location and Sequence of Excavation



Locate borrow areas out of sight of the road.
(NOTE: Safe backslope excavation height depends on soil type. Keep backslopes low, sloped or terraced for safety purposes.)

Photo 12.11 This roadside borrow area lacks drainage and erosion control. Roadside quarry development can be inexpensive and useful, but the areas should be hidden if possible, and the areas should be reclaimed once the project is completed.

Photo 12.12 A reclaimed and revegetated borrow site. Reshape, drain, plant vegetation, and rehabilitate borrow pits and quarries once the usable materials are removed and use of the area is completed.