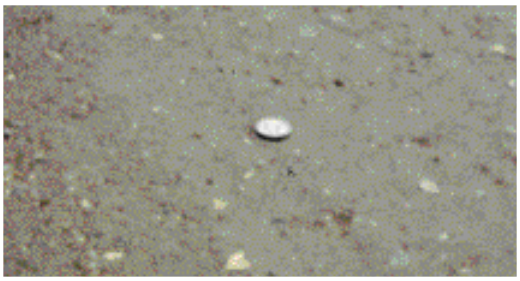
Section III: Surface Gravel

What is Good Gravel?

The answer to this question will vary depending on the region, local sources of aggregate available and other factors. Some regions of the country do not have good sources of gravel (technically called aggregate). A few coastal regions use seashells for surface material on their unpaved roads. However, this section of the manual will discuss the most common sources of material. They are quarry aggregates such as limestone, quartzite and granite; glacial deposits of stone, sand, silt and clay; and river run gravels that generally are a mix of stone and sand. One thing should be stressed: it pays to use the best quality material available. (31)

Difference in Surface Gravel and Other Uses

Too often surface gravel is taken from stockpiles that have actually been produced for other uses. For instance, the gravel could have been produced for use as base or cushion material for a paved road. There are two major differences between surface gravel and base (cushion) material. Good gravel for base courses will generally have larger top-sized stone and a very small percentage of clay or fine material. This is necessary for the strength and good drainability needed in base gravels. This material will not form a crust to keep the material bound together on a gravel road. It will become very difficult to maintain. Other gravel could have been produced simply as fill material for use at building sites. This material often has a high content of sand-sized particles which make it very drainable. This is a desirable characteristic in fill material since water can quickly flow through it and drain away from under building foundations and parking lots. But the same material will remain loose and unstable on a gravel road.What a gravel road needs is sufficient fine material that has a plastic or "binding" characteristic.



Notice the good blend of stone, sand and fine-sized particles tightly bound together on this road surface.

Good Gradation

Gravel is a mixture of three sizes or types of material: stone, sand and fines. This will be discussed further in the next section.Without a good blend of these three sizes, the gravel will perform poorly. Unfortunately, poor performing gravel will often be blamed on the maintenance operator. But the operator cannot make good gravel out of bad gravel. Bad or poorly graded gravel can not be changed to good gravel without additional costs, but it is often well worth it.

One common practice of improving surface gravel is to add new, clean, virgin fine gravel. Good surface gravel needs a percentage of stone which gives strength to support loads — particularly in wet weather. It also needs a percentage of sand-sized particles to fill the voids between the stones and give stability. But a percentage of good, plastic fines are also needed to bind the material together which allows a gravel road to form a crust and shed water. In many regions of the country, this is a natural clay which gives the gravel a strong cohesive characteristic and keeps a reasonably tight surface especially during periods of dry weather. Some of the fine material in surface gravel will be lost, under traffic action, in the form of dust that rises from the surface and simply blows away. This can be compensated for by specifying a higher percentage of fines in the new gravel. However, no gravel surface will perform like pavement! There will be some loose aggregate or "float"on the surface of virtually all gravel roads. But striving to get as good a material as budgets and local sources allow will improve the performance of a gravel road.

Example of a good blend of material for gravel surfacing. (Courtesy of Road Research Ministry of Roads/Transportation,Sweden)

Benefit of Crushing

In a few cases the gravel may simply be loaded onto trucks without processing. This is often referred to as "bank run" or "pit run" gravel. There are few natural deposits of material that have an ideal gradation without being processed. In some areas of the country it is still common to process gravel simply by screening to a maximum top size. A great benefit is gained from processing the material by crushing. This means that a good percentage of the stone will be fractured in the crushing process. The broken stones will embed into the surface of a gravel road much better than rounded, natural-shaped stone. It also means that the material resists movement under loads better and gives better strength or stability. This will vary throughout the country, but bank run gravels are nearly always improved through the crushing process. Quarry gravels are considered very good material since they are composed of virtually all fractured particles.

Recycled Asphalt

As more of our asphalt pavements wear out, many of them are recycled. This is usually done by milling or crushing. Sometimes the material is available for use on a gravel road. It can be a good surface, but there are pitfalls. In this material, the bituminous portion of the old pavement becomes the binder. When placed on a road in hot weather, the recycled asphalt can take on the characteristic of pavement. But it will be a weak pavement. It will often develop potholes and will be hard to maintain with simple blade maintenance. To help overcome this problem,the material should be placed at a minimum three inch compacted depth and only on a road that has a strong subgrade. A better option is to mix the recycled asphalt 50/50 with virgin gravel. This will generally provide a material that still has a good binding characteristic, but remains workable for maintenance and reshaping. Recycled asphalt has also been mixed with crushed, recycled concrete and the performance has been good.

The Benefit of Testing Aggregates

It is very important to understand that all gravels are not the same. One can tell a little about them by visual inspection or by running your hands through the material but real quality can only be determined by testing.

Reasons For Testing

All managers and decision makers in local government need a good understanding of the benefit of testing aggregates in order to work towards better quality in road and street maintenance. Not everyone needs to understand how to do the testing. Testing requires special knowledge and equipment which is generally not available or affordable to most local governments. We simply need to recognize the benefits of knowing more about the aggregate that is used in construction and maintenance operations. This knowledge gives power to decision makers to specify good materials, to know when to accept or reject materials, and to communicate better with crushing contractors, consultants, DOT, and others involved in the business of building and maintaining roads.

Often an objection is raised to sampling and testing because the cost is too high. This claim can be countered with the argument that if several thousand tons of aggregate are going to be purchased or crushed, is it not wise to invest a few hundred dollars in testing the material to insure that the right aggregate is used? It is a good practice to test the aggregate before placing it on the road.Also, if the tests fail, you can work with the crushing contractor to try to blend and improve or reject the material. This becomes even more critical in producing material for pavement or base.

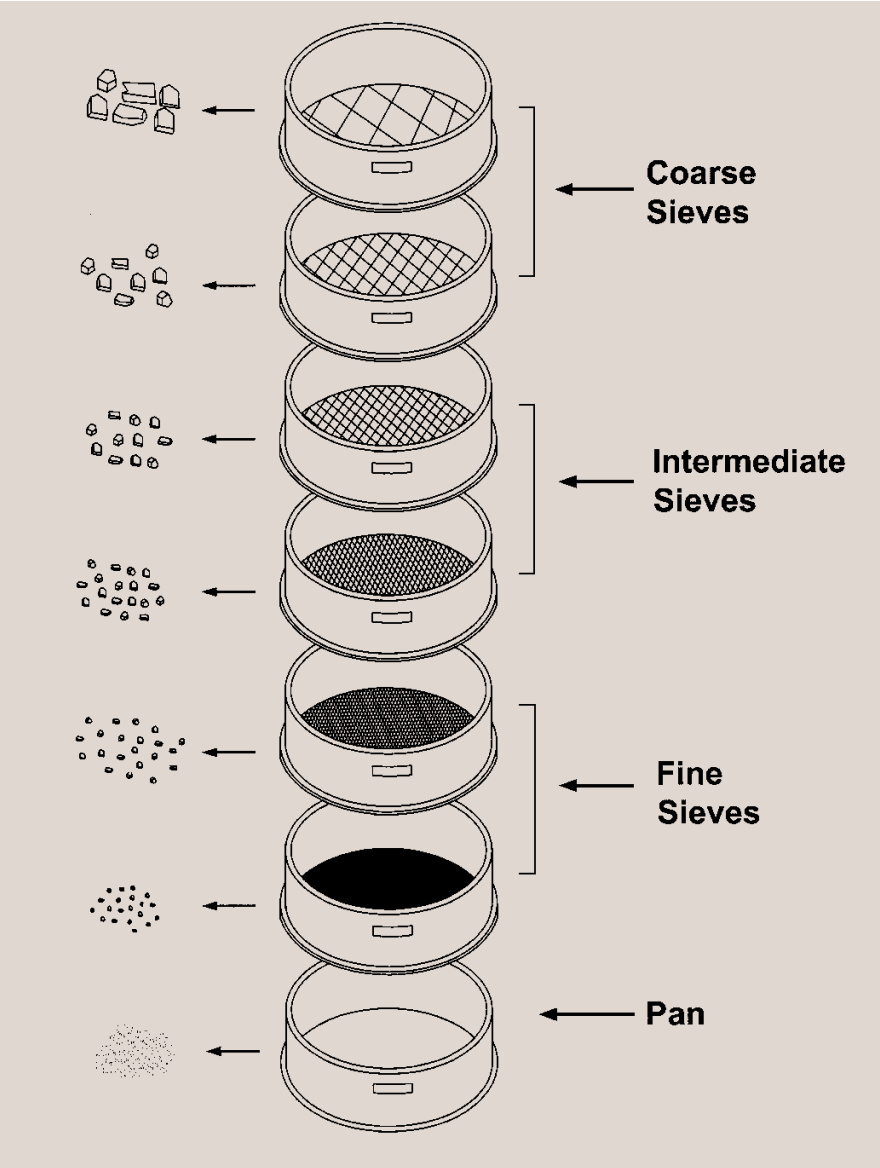


Figure 9: Stack of sieves used for testing the gradation of aggregate.

Sampling

Another issue critical to testing aggregate is obtaining a good sample of the material to be tested.Knowing how to get a good representative sample from a crushing operation, a stockpile, a windrow, or a paving operation is absolutely critical to getting good test results from a lab. Poor sampling techniques have led to more controversy in aggregate testing than any other factor. Every effort must be made to make sure that the sample brought to a lab is truly representative of the material in the field. It is wise to follow national standards such as

ASTM for aggregate sampling.A good video titled Sampling Aggregates, produced for the Michigan DOT, covers several interesting topics on the subject. This video should be available from any state's LTAP center. It is always advisable to work with an experienced sampler if you are not familiar with sampling.

What then are the benefits of testing aggregate? The primary concern here should be gradation of material. (18, 31, 34)

Table 1. Example of Gradation Requirements and Plasticity for Two Types of Materials.

Requirement Sieve	**Aggregate Base Course** Percent Passing	**Gravel Surfacing** Percent Passing
1"	100	
3/4"	80-100	100
1/2"	68-91	
No. 4	46-70	50-78
No. 8	34-54	37-67
No. 40	13-35	13-35
No. 200	3-12	4-15
Plasticity Index	0-6	4-12

From *South Dakota Standard Specifications*. (16)

Sieve Analysis

Gravel is made up of three groups of aggregate: stone, sand,and fines. Depending on what the material is to be used for, the ideal blend of these three groups varies greatly. For example, good surface material for a gravel road would need more material passing a #200 sieve than a good base material. There is also a difference in the need for plastic or cohesive material.Surface gravel needs some good natural clay which gives a "binding characteristic." The chart adjacent is an example of one state's base and gravel surfacing specifications. Most states have their own specifications and therefore it is highly recommended that state specifications be consulted.

Local governments are not held to these specifications when doing their own construction and maintenance work without state or federal funding and oversight. Yet, it is wise to be familiar with them and follow them whenever possible. Even if you choose to modify the specifications to suit a local material source or project, it is best to begin with a state specification.

Notice the major differences in the above specification in the top-sized material and the smallest sized material. The base course requires 100% of the material to pass a 1 inch sieve, but allows up to 20% of the stone to be retained on the 3/4 inch sieve. While this could make excellent base gravel, it would likely perform poorly if used as gravel surfacing. There would be too much large stone resulting in very difficult blade maintenance.

Also, the high percentage of coarse material would make a rough driving surface. Yet, a percentage of large stone is needed for strength in the base course.

Fines and Plasticity Index

Notice also the difference in the fine material and the plasticity index (PI). While gravel surfacing allows 4% and up to 15% of the material to pass a #200 sieve, base course can have as little as 3%, but not more than 12% passing the same sieve. More importantly, the PI can fall to 0 in base course and rise to no more than 6. The same index can rise as high as 12 or be no less than 4 in surface gravel. There is good reason for this. Good surface gravel needs a percentage of plastic material, usually natural clays, which will give the gravel a "binding" characteristic and hence a smooth driving surface. This is critical during dry weather. During wet weather, the surface may rut a bit, but will quickly dry and harden in sunny and windy weather. However, any great quantity of plastic fines in base gravel will cause problems. If moisture gets under the paved surface, the base will lose its strength and stability and cause rutting or even failure of the pavement. Too often the same gravel is used for both base work and surface gravel. Generally, it will be good for one purpose or the other, but will not work for both applications.

Appendix D contains a sample of a complete Screen Analysis and PI Worksheet typical of those used by testers across the country. Once again, it should be stressed that only by sampling and testing the aggregate can one really determine the quality of the material. Simple visual inspection can be misleading. One thing in particular that is very hard to determine without testing is plasticity. This is a laboratory test which, in simplified terms, tells you whether the fines are clays or silts. If you are not familiar with this testing, the whole process may appear very confusing. Yet, it really pays to increase your knowledge of these matters in order to be a better manager.

Every local road/street department manager has a big job and there is never enough money to cover all of the needs. It is imperative that money should be spent wisely.

Reduced Blading and Maintenance Costs

By spending some money to test material for quality, overall maintenance costs will be reduced. Good gravel that has good gradation and plasticity will compact well. It will develop a tightly bound surface that needs less maintenance. Problems with excess washboarding,rutting in wet weather, or loosening (floating) in dry weather, will be greatly reduced. It is well worth the effort to better understand the benefits of aggregate testing.

Process for Obtaining Good Gravel

An agency must strive to locate and use good gravel even if it costs a little extra. The long term benefits in terms of less maintenance will often pay for the extra cost. The initial cost should not be the primary consideration when purchasing gravel.

Establish Specifications

Gravel for local roads is often bought from a local supplier at a negotiated price for an estimated quantity. There may be some assurance that the gravel will perform well on the road based on past experience. However, material sources can change rapidly as the material is removed. The only real assurance of getting good quality material is to establish a specification and then sample and test the product to make sure these specifications are met.

A local agency generally would not be held to state specifications when doing maintenance work.However, this is what crushing contractors and aggregate suppliers are usually familiar with.

If one is confident in knowledge of surface gravel and wishes to change the specifications, that is fine; but it is wise to use the state specification as a benchmark to work from. For example,

These two roads show remarkable contrast in surface condition due to the quality of gravel. They carry virtually the same volume and type of traffic in an agricultural community. The top photo shows a good surface gravel with a nice blend of material,particularly some plastic fines which keep the surface tightly bound.The bottom photo shows a road surface that has too much stone and sand in proportion to the fine material. Consequently, the gravel remains loose and is hard to maintain.

state specifications may show a Class I Surface Aggregate designation for surface gravel. You may want a higher minimum requirement for plasticity or perhaps a smaller top size on the rock. State clearly in your specification that you want a Modified Class I Surface Aggregate and then clearly indicate what your modifications are. It is wise to familiarize yourself with your state specifications.

Communicate with Suppliers

Many problems are quickly solved when people make an effort to explain clearly what their problems or needs are. In regard to the specifications just discussed, many commercial aggregate suppliers can provide test data from their stockpiles to show the gradation of their material. They may have further data such as plasticity index, percentage of fractured faces, soundness, etc. You simply have to ask for it.It is wise to occasionally sample to verify their data. Good suppliers welcome this.

Good material is seldom the cheapest. An interesting example in Lawrence County, South Dakota, is a case in point. Local materials crushed to the state's Gravel Surfacing Specification did not perform well.After developing a modified specification and communicating clearly to crushing contractors what was needed,some very high quality surface gravel was produced. Some good natural clay material was mixed as the gravel was being crushed. The result was good surface gravel that has a very nice blend of stone, sand and good plastic fines which make a strong, tightly bound gravel surface. The material was more expensive up front, but resulted in reduced frequency of blade maintenance and longer intervals between regraveling. Total expense of maintenance over a five-year period was considerably less than purchasing cheap gravel,blading it more frequently and having to regravel more often. None of this is possible if the manager does not understand what good gravel is or does not communicate and cooperate with the supplier to provide it.

Handling Gravel

It is not common for maintenance operators or field supervisors to be involved in actually producing the gravel that is used on their roads. Yet it is very helpful to understand how the material should be handled from the time it is taken from the quarry face or the gravel bank in a pit. There are certain problems that can arise from the time the material is first removed from the earth until it is finally placed on the road.It may be wise to visit the site where your gravel is being produced to see if it is being handled well.

Pit/Quarry Operations

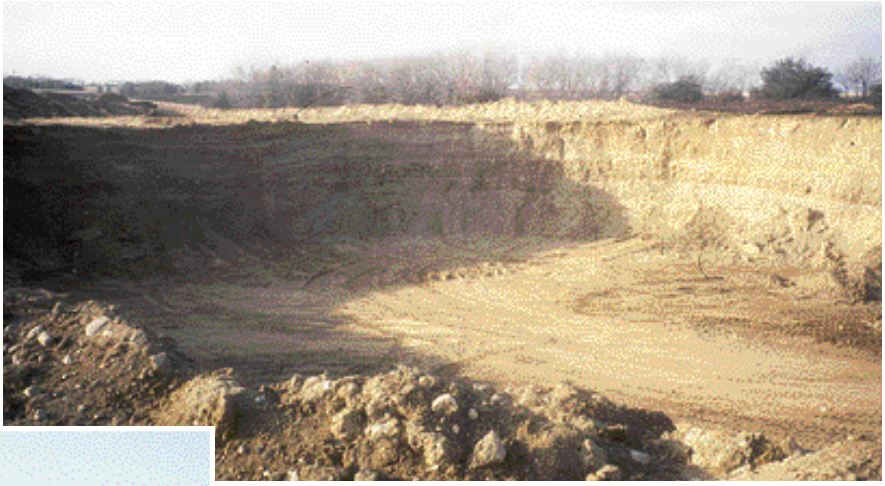
It is very important to remove topsoil and vegetation from the surface of the material source before beginning to process the material. Topsoil will contain organic matter which is never good for a road surface. Furthermore, in some agricultural regions of the country, the spread of noxious weeds can occur when parts of growing plants

Here is an example of a poorly managed pit operation.The top soil pile shown at the center of the photo was not placed far enough beyond the working face of the pit. As additional material was removed from the face of the pit, materials from the top soil pile fell into the working area. This will lead to contamination of the gravel with organic material and,even worse, noxious weeds.

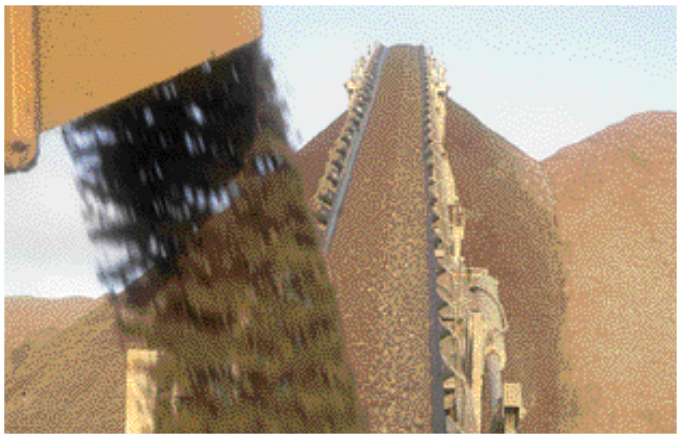
and/or the seeds are hauled out with the gravel and spread on rural roads. Several states have laws which allow authorities to quarantine material sources and stockpile sites to prevent the spread of weeds. Under these laws, the gravel cannot be removed even though your agency may already have ownership of it. It becomes very hard to guarantee that all problems have been eliminated before beginning to remove material again. The solution is to make sure the topsoil is removed and placed well out of the way.

The next area of concern is how the material is being removed from the face of the quarry or pit.Almost any material source will have variations in the layers of gravel. Good crushing contractors will remove the material by working a broad area of the face. This is essential to have material that is blended well as it goes into the crusher. Even a pit or quarry that appears to have very uniform layers of material will still have variations such as clay or silt seams which can suddenly change in thickness. This can really affect the overall gradation of the gravel.Good loader or dozer operators are key players in getting a good blend of gravel right at the start of processing.

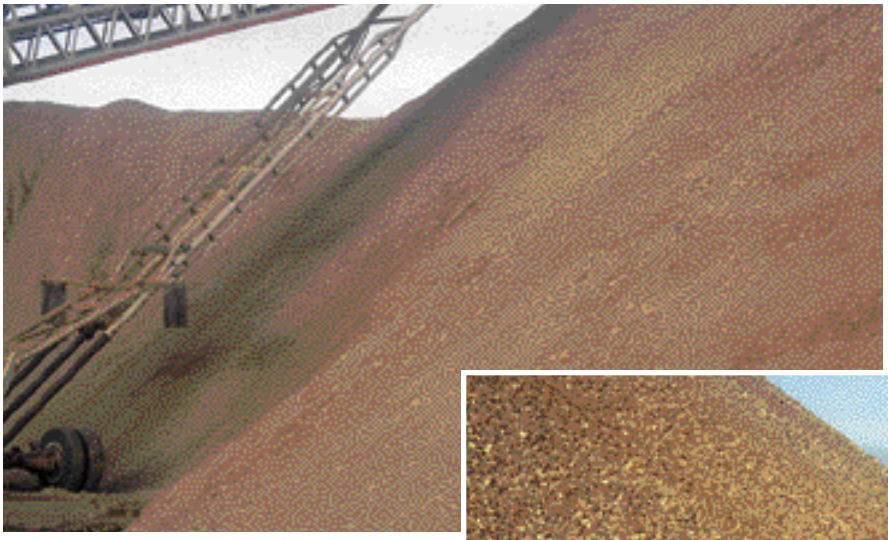
A very good example of working a gravel bank.Large loaders are being used to feed a crushing plant.Notice the good effort to work a broad area of the gravel bank.The operator virtually never takes a bucket of material from the same spot twice. This assures a good blend of material going into the crusher.



A good example of topsoil and vegetation that has been stripped from the surface of a gravel pit and placed beyond the working area. It can later be placed back over the bottom of the pit as part of the reclamation process. It will once again grow grass.



The discharge conveyor from a crushing plant is in the foreground. Notice how badly segregated the material is as it is carried up to the stockpile on a belt stacker. This invariably leads to problems illustrated in the following two photos.



Notice the dramatic difference in the two sides of the stockpile. The inside of the pile (top photo) has an excess of fine material while the back side has excess stone (bottom photo).This could have been prevented by eliminating segregation on the stacker belt.

Another problem commonly encountered is in the processing plant itself. These plants are made of different types and sizes and the detailed operation of each is beyond the scope of this manual.

The problem here is the segregation of material during processing.When segregation occurs, large-sized particles tend to group together and get isolated instead of being blended well with the rest of the material. This will lead to inconsistency in the material as well as difficulty in compaction.Surface areas containing an unusual amount of coarse particles will remain loose and unstable, while other areas, rich with fines, may rut excessively during prolonged wet weather. When a stockpile is segregated as badly as the one just illustrated,it is almost impossible to blend the material again before it is hauled out onto the road. One option would be to use a bulldozer and rework the stockpile to blend it. Some agencies require their stockpiles to be constructed in layers so that these problems do not occur in the first place. Work with suppliers to reduce these problems. Segregated material is always a problem.(18, 33)

This road is located about 50 miles from Cairo, Egypt.It displays segregation problems in several spots. (Photo courtesy of Ali Selim,SD LTAP, USA)

Loading From Stockpiles

Good loader operators who observe the stockpile and work hard to blend material evenly are essential in getting good gravel delivered to the road.In many small maintenance operations, every truckdriver may operate the loader to load his/her own truck. It then becomes important that every driver understand the need to observe the pile and load material uniformly. If large stockpiles have been placed with belt stackers, it is always best to work into the end of the pile and work the face of the pile uniformly. Again, as the loader places material in the trucks it is wise to get each bucket of material from a different location across the face of the pile. (18, 33)

A good example of loader operation — working uniformly across the end of the stockpile. Note also a very level stockpile site and a well maintained loading area on which the loader and trucks work.This demonstrates pride in doing a good job of handling material.

Roadway Preparation

When fresh gravel is to be placed on a road, it is vital that the road be in good shape. For example, a washboard area needs to be cut out and reshaped prior to placing new gravel over it. Otherwise, the washboard distress will quickly reflect right up into the new surface and the problem quickly reappears. Another critical matter is to take care of any surface drainage problems. If the road has lost crown, has potholed areas, high shoulders or severe rutting, all of these problems need to be eliminated. Then fresh gravel can be placed at a uniform depth and the road becomes easier to maintain. Generally it is not wise to simply fill these problem areas with new gravel. It can become very expensive and the gravel will not have uniform depth.

This road has been badly damaged from a heavy haul. It would be useless to begin hauling and placing fresh gravel until the entire roadway has been reshaped.

Preparing a road for new gravel can be as simple as cutting out a few potholes or a washboard area to reshaping the entire cross section. Even if the existing road is smooth and hard, it is often wise to lightly scarify the surface to get a good bond. One final tip: be sure the crown and shape of the road is as close as possible to the way the road needs to look after regraveling is finished. That is the only way a completely uniform layer of new gravel can be placed.

Calculating Quantity

The procedure for determining how much gravel needs to be hauled to add a predetermined depth to a road is not always well understood. One thing that is often overlooked is the shrinkage in volume that occurs from ordinary compaction. Ordinary compaction means the shrinkage that occurs from the material being placed, absorbing moisture from rainfall and then having traffic passing over it. In many parts of the country, this will result in 30% or greater reduction in volume.

Keep in mind some people often calculate the volume of material only as it is carried in the truck or as it exists in the stockpile. Material in the stockpile is very loose and has very low density. Remember to allow for shrinkage when calculating how much gravel depth is needed after the job is compacted and finished. Calculation then should be made for the distance that each truck can spread its load. This is not always done in maintenance operations, but it is recommended.It's the only way to really know for sure how much material is being placed.Appendix C of this manual has two charts to help in calculating quantities.

Hauling and Dumping

Traffic control is sometimes neglected in rural areas while the work is being done. It is not common in most areas of the country to place signs during routine blade maintenance. It is a mobile work area and the warning lights on the machine give adequate notice that maintenance work is being done. But hauling and spreading gravel should be treated as a work zone and signed as such. The Manual on Uniform Traffic Control Devices (MUTCD) or the state's uniform signing manual should be used as a guide to select appropriate warning signs. (38)

These two photos depict a the good job of spreading done by a county highway department using tandem end-dump trucks. The skill of the drivers makes this job look easy. Notice also the grader is ready to begin processing the material.

Once hauling begins, it is wise to have a motorgrader present to process and place the gravel immediately. The skill of the truck drivers can really make a regraveling operation work smoothly. When drivers are able to dump the load evenly and within the correct length that was marked, the grader operator's job becomes much easier.

Windrowing, Equalizing and Spreading

Once the gravel is dropped on the road, the grader operator should pick up the material and place it in a windrow. This will usually take more than one pass. It is called equalizing. This accomplishes two important things when handling gravel. It gives a final blending and mixing of the gravel, and it makes a windrow of very uniform volume. Once equalized, the material should be spread by the grader evenly on the roadway. Care must be taken not to carelessly cast material off the edge of the roadway where it cannot be recovered.When the material is finally placed across the roadway, it leaves a uniform depth of well-blended material that becomes the new gravel surface for the public to drive on. It all works better when everyone understands his/her job. While it is not possible everywhere, adding water and using rollers for compaction invariably makes a better gravel road. It is recommended whenever possible. (32)

The motorgrader operator has done a good job of picking up the fresh gravel and equalizing it into a very uniform windrow.

Only after completely windrowing and equalizing does the operator begin to place the material at a uniform depth across the roadway.

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