Basics of a Good Road

2014

Cornell Local Roads Program

New York LTAP Center

Basics of a Good Road - 2014

revised by

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Preface

Highway officials at the local level must have a thorough understanding of the technical aspects of road building. Decisions often determine whether public funds are invested wisely or poorly. Experience, either learned personally or by observing someone else, can only go so far toward providing the sound basics for making decisions. Experience, combined with sound technical training, will provide a basis for informed action.

The Basics of a Good Road workbook provides a general overview on the topics of design, soils, pavement structure, drainage, signage, and managing your highway department. This manual has been written to accompany a training course, also called, Basics of a Good Road. This edition represents a substantial update by Paul Male, P.E., currently the City Engineer for Saratoga Springs. He is also the course instructor. The previous version of Basics of a Good Road was written by Paul Cooney, P.E., L.S., who has retired from instructing the course. Ron Nichols, SUNY Alfred, and Lynne Irwin, Cornell Local Roads Program, wrote and instructed the original course. This version of the worksbook has been updated to meet the requirements of the National MUTCD and the New York State Supplement to the National MUTCD.

The course is intended for local highway officials, particularly at the rural town and village levels, who may be newly elected or newly appointed to their jobs. The purpose of the course, Basics of a Good Road, is to introduce new highway superintendents, foremen, and other local roads officials to the topics of soils, drainage, design, paving, signs and safety, and highway department organization. The one-day training course is offered in various locations throughout New York State by the Cornell Local Roads Program.

The Cornell Local Roads Program offers additional courses covering many of these topics in more detail. These one-day courses are offered regularly across New York State. For more information on how to receive notices about dates and locations, call (607) 255-8033, or visit the CLRP website at *www.clrp.cornell.edu*. Courses include:

- Powers and Duties of Local Highway Officials
- Reducing Liability for Local Highway Officials
- Road Safety Fundamentals
- Roadway and Roadside Drainage
- Small Highway Department Management
- Snow and Ice Control Operations for Local Highway Officials
- Work Zone Traffic Control for Local Roads

Support for the training activities of the Cornell Local Roads Program is provided by the New York State Department of Transportation, the Federal Highway Administration, Cornell University, and by local officials through their workshop registration fees. Responsibility for content and accuracy of this manual is solely that of the Cornell Local Roads Program.

Cornell Local Roads Program
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1 - Introduction

This workbook, *Basics of a Good Road*, is divided into six sections, as follows:

- **Geometric design** - definitions, traffic, road geometry, loading
- **Soils** - classification, compaction, geotextiles
- **Pavement structures** - materials, repair methods
- **Drainage** - frost action, ditches, gutters, culverts
- **Traffic signs** - signs, work zone safety
- **Managing your highway department** - record keeping, planning, training

If you are a newly-elected or newly-appointed local highway official, there are a lot of things to think about. Many people will offer you advice. Even if you worked for the highway department in another capacity before becoming the superintendent, you now have more responsibility. To get you started, here are the "Ten Commandments of a Good Road" for you to consider.

TEN COMMANDMENTS OF A GOOD ROAD

1. Get water away from the road
2. Build on a firm foundation
3. Use the best materials available
4. Compact all materials well
5. Design for winter maintenance
6. Build for traffic loads and volumes
7. Pave roads only when they are ready
8. Build from the bottom up
9. Protect your investment
10. Keep good records

The specifics for each Commandment are listed below. These ten basic tips will help you maintain your roads and keep them in good condition.

1. Get water away from the road

The importance of drainage cannot be overemphasized in road construction and maintenance. Water affects the entire serviceability of a road. Too much water in the base and subgrade materials weakens the road. Water allowed to remain on top of a road weakens the surface, and, combined with traffic, causes potholes and cracking. If improperly channeled, water causes soil erosion and a breakdown of pavement edges. Whether it is mud in the spring or frost heaves in the winter, the presence of excess water in a road is nothing but trouble.

A good surface drainage system is the best way to lessen water damage on a road. Proper surface drainage prevents water from infiltrating the pavement surface and removes water from the driving lanes to the side ditches, which carry the water away from the roadway.

A surface drainage system has four main components:

- **Road crown** - The road crown, and the superelevation of the road surface, allow surface water to run into the side ditches.
- **Shoulders** - Shoulders are an extension of the road surface and allow for the passage of surface water to the ditches.
- **Ditches** - Ditches are used to carry water away from the roadway. They need to be kept clean and protected from erosion. Water left in the ditch can sometimes leak back into the base and subgrade. Water collected and carried to the ditch has to be directed away from the roadway at frequent intervals, sometimes using a culvert.
- **Culverts** - Culverts usually channel water from one side of the road to the other, helping to control the flow of water and slowing it down to reduce erosion.

Highway superintendents are guided by the principles that:

- Water runs downhill
- Water needs outlets at the bottom of all grades
- Puddles mean problems

Except for water needed for soil compaction, dust control and vegetation, water is the highway superintendent's worst enemy.

2. Build on a firm foundation

A highway wears out from the top, but falls apart from the bottom. This is another way of saying that the road base determines the service life of a road. The base supports everything above it, including traffic.

Without adequate support, the road will deteriorate rapidly. A good road requires a suitable foundation composed of stable material. A road material is stable if it has little change in strength with a change in moisture content, and does not deform excessively under repeated loads whether the material is wet or dry.

3. Use the best materials available

The supply of natural good quality aggregates is beginning to disappear. Blended or crushed gravel is typically a more expensive alternative. The quality of soils used by a highway superintendent often depends on local availability and budget. In deciding what to use, consider the long-term consequences of using lower quality material. Using inferior base material may require excessive maintenance during the road's life and perhaps expensive rehabilitation. The adage "pay me now or pay me later" applies to road building.

4. Compact all materials well

The more dense the material is, the stronger it is. When soil is improperly compacted, future traffic loads or changes in moisture content can cause deformation and failure of the roadway.

Compaction is achieved by pressing soil particles together, which expels some of the air from the mass, making the material denser. Well-graded soils, having a fairly even distribution of particle sizes, will compact more easily than poorly-graded soils. Crushed or angular particles will lock together when compacted. They are more stable than rounded particles of similar size. A certain amount of moisture is necessary for good compaction.

5. Design for winter maintenance

In areas that receive substantial snowfall, roads that are designed for winter maintenance will be adequate for the rest of the year. Consider the following:

- If the traveled way is wide enough to allow a snow plow and a school bus to meet, it should be wide enough for the rest of the year.
- If the ditches and the roadside areas are wide enough to store snow, chances are they will accommodate spring thaws and heavy water flows.
- Longitudinal grades should be a minimum of one percent for drainage purposes, but not be greater than ten percent, if at all possible. If the road is steeper, it is difficult for heavy equipment to maneuver, especially in the wintertime.
- Good road design can make a road safer. Sight distance should be considered in designing a road. As a rule of thumb, a driver should be able to see 75 to 100 feet up the road for every 10 mph. Signs should be used to warn drivers of conditions when sight distances are not adequate.

6. Build for traffic loads and traffic volumes

Thin ice on a pond may support a young skater, but it will crack and break apart under the weight of an automobile. Similarly, a road built to serve residential traffic will break down when it starts carrying a number of large trucks. Roads, like bridges, should be designed with the expected future traffic type and volume in mind.

A rule of thumb is to design a road to accommodate the largest vehicle that will use the road under normal operations. If in doubt, design the road for the largest piece of town equipment that maintains it in all kinds of weather (i.e., a fully loaded snow plow).

Highway superintendents can get information and guidance from the New York State Department of Transportation or the Cornell Local Roads Program on the type and thickness of pavement mixes to apply to a gravel road. Generally speaking, a low-volume road with some truck traffic may provide good service with a chip seal or sand seal. As traffic volumes and weights increase, cold-mix asphalt and hot-mix asphalt pavements may be better alternatives.

7. Pave roads only when they are ready

Some highway officials make the mistake of paving over a road that is not properly prepared in their haste to get rid of a dusty, gravel road. The result may be a complete waste of money. Paving will not cure other problems the gravel road may have. It must be built of well-compacted layers of free-draining soil, be able to carry expected traffic loads, and drain well. The cost of rebuilding the mistake is much more than doing it right the first time.

Generally, the gravels used for the surface of a road are NOT good for use as a road base Most surface gravels hold too much water to be used as a base, due to their higher fines content.

8. Build from the bottom up

A road that has a poor base and poor drainage cannot be adequately improved with a top dressing of new gravel or new pavement. It may be necessary in some cases to dig out the old road, put in new materials, and build up the road in layers. Before doing anything to correct a road surface problem, highway superintendents should take into consideration what is causing the problem underneath. Improper drainage, insufficient depth of base, or poor quality materials may be the culprits. These should be corrected before spending money on the surface.

9. Protect your investment

Roads and bridges need regular maintenance to keep them from deteriorating. Increased weight and frequency of traffic on roads combined with adverse weather conditions means an increased rate of road and street deterioration. Regular road and bridge maintenance preserves your road investment and prevents costly major rehabilitation later on. Maintenance activities include:

- **Roadway surfaces** - blading and shaping, patching, resurfacing; dust control; snow and ice removal
- **Drainage** - cleaning and repairing culverts and ditches
- **Roadside** - cutting brush, trees, and grass; grooming shoulders; repairing and preventing roadside erosion; maintaining guiderail
- **Bridges** - channel clearing; repair of rails, decks, and structure; cleaning and painting
- **Traffic services** - maintaining signs, cutting vegetation to maintain visibility
- **Special projects** - emergency work such as removing slides, repairing washouts, and repairing retaining walls, to name a few

10. Keep good records

Highway superintendents know their roads like the back of their hands. Most of them are walking history books when it comes to the roads they manage everyday. This knowledge is of little use, however, when the highway superintendent is ill, moves, or retires.

Good record keeping makes roadwork much easier for everybody. It will be easier to draw up budgets and to show citizens plans for roadwork. Recording what type of work was done on roads or bridges, when, and what materials were used, can help a lot in making decisions later on. Towns can start by doing an inventory of all roads and bridges, listing length, width, surface types, culverts, problem areas, and other items. Placing these items on a map helps. Next comes listing and prioritizing needed improvements, putting a price tag on them, and taking care of a few problems each year.

2 - Geometric Design

FUNCTIONAL SYSTEMS FOR RURAL AREAS

The roadways making up the functional systems for rural areas include:

- **Principal arterials** - major interstate systems, and major federal and state highways, linking states and major population centers.
- **Minor arterials** - less traveled state and county highways linking smaller cities and major towns.
- **Rural collectors** - both major and minor collectors that typically serve regional intra-county travel. They link the smaller population centers with the rural areas.
- **Local roads** - connecting businesses and farms to the smaller communities and individual homes. They are mainly used by local residents in the course of their normal business.
- **Very low-volume roads** - local roads with an average daily traffic of fewer than 400 vehicles per day.

The following table lists the typical distribution of traffic volume and lengths of each functional class of road. As you can see, the local road system accounts for a small percentage of the total road traffic, but it represents the vast majority of the road mileage.

Table 1. Typical distribution of functional systems

Systems	Range	
	Traffic volume (%)	Length (%)
Principal arterial system	40-65	5-10
Principal arterial plus minor arterial street system	65-80	15-25
Collector road	5-10	5-10
Local road system	10-30	65-80

Source: A Policy on Geometric Design of Highways and Streets, American Association of State Highway and Transportation Officials, 2001

Classification of very low-volume local roads can be done using the primary land use along the roadway length. This allows highway departments to have appropriate standards for roads tailored to the way they are used.

Rural low-volume road classifications:

- Rural major access
- Rural minor access
- Rural industrial/commercial access
- Rural agricultural access
- Rural recreational and scenic
- Rural resource recovery

Urban and low-volume road classifications:

- Major access streets
- Residential streets
- Industrial commercial access streets

Source: Guidelines for Geometric Design of Very Low-Volume Roads, American Association of State Highway and Transportation Officials, 2001

TRAFFIC COUNTS

The life of a road is affected by the number and the weight of the vehicles using it. In general, the more vehicles using a road, the faster it will deteriorate. Also, a road carrying heavier vehicles will deteriorate at a faster rate than a road carrying lighter vehicles. In designing a road, attempting to evaluate the safety of an existing road, or projecting distress of a road is not enough. More precise and quantitative values of vehicle numbers and weight should be used in order to do engineering estimates.

Data are currently available from the New York State Department of Transportation (NYSDOT) for state highways. Some data on vehicle counts for local roads are also available from county highway departments. However, local agencies often have to do their own traffic counts.

DESIGN VEHICLES

Volumes and types of vehicles are prime considerations in making decisions involving your highway system. The number and weight of the vehicles greatly affects the life and performance of the road. When designing or rehabilitating your highway you must have a good idea of the number of equivalent 18,000-pound, single axle loads (ESALs) the road will bear. Making traffic counts is necessary to find out the average daily traffic (ADT) and ESAL in order to determine if your road is wide enough and its pavement thick enough. Remember, it takes approximately 10,000 autos to equal one 80,000-pound truck! One loaded dump truck, or an 18-wheel semi, typically applies two to three ESALs to the road.

TERMS AND DEFINITIONS

Most standards for roads (lane widths, shoulder widths, curve radii, pavement thicknesses, etc.) are keyed to the traffic volumes and prevailing speed that the road serves. Let's look at some of the terms that are used.

Average daily traffic (ADT)

The average number of vehicles passing a given point in a 24-hour period. When using the ADT, one should correct the results obtained by adjusting for such factors as season, month, or day of the week. Traffic can vary, day-to-day, such that the traffic on a rural road during the week might be double the average on the weekend.

Peak hour traffic

Traffic volume during a time interval shorter than one day is a better value to use in design if traffic volumes are relatively high. A period of one hour is often used and considered appropriate. Hourly traffic varies over the day and at different times of the year. On high volume roads, the peak "hour" may last as long as two hours (7:30-9:30 a.m. or 3:30-5:30 p.m.).

Capacity

The maximum hourly volume that a given roadway can carry is termed the capacity of the road. Most roads in rural areas have peak hour traffic which is substantially less than their capacity. A few local roads in suburban and urban areas may operate near capacity for an hour or a portion of an hour each day. Such roads can be widened, by adding lanes, to increase the capacity.

Level of service

As traffic volumes go up, the number of conflicts and restrictions on vehicle speed and maneuverability go up. While a two lane road has more capacity, it still is prone to restrictions on the free flow of traffic as the volume approaches the capacity of the highway. The *Level of Service* (LOS) is a measure of the ability of traffic to maneuver freely and move at speeds controlled by legal requirements or driver's desires, rather than concerns of moving around and with other vehicles. The LOS is reported as a letter from *A*-*F*, with *A* being free flow with no restrictions and *F* being forced flow with backups and traffic jams common.

30th hour volume

To have a road that will serve the public well, the capacity should not be exceeded very often nor by very much. On the other hand, to use the maximum peak hour traffic of the year would be wasteful. The compromise in design is to use the 30th highest hourly volume (30th HV). This means the design value will be exceeded in 30 hours during the year. At all other times the actual hourly traffic will be less than the 30th highest hourly volume. The 30th HV will run approximately 15 percent of the ADT for rural arterial roads. The maximum hourly volume will run about 25 percent of the ADT. Roads with a large seasonal fluctuation may need a design hour volume (DHV) different than the 30th HV.

Design hour volume

For urban roads, the trend of high morning and afternoon rush hour traffic means that the DHV traffic will be calculated more realistically if the peak hour for each week is recorded and then averaged for the year. For urban roads, the DHV is approximately 11 percent of the ADT. The design hour volume is used to design new highways, and can be used to determine deficiencies in existing roads. For a given DHV, an existing road should meet certain specifications on ride quality, alignment, and geometry if it is to be considered safe. Roads with existing traffic that exceed what the road was designed for should be looked at in terms of safety.

Directionality

During the peak hour traffic on rural roads, 55 to 70 percent of the traffic might be in one direction, indicating that opposing traffic is still light even at peak hour. Thus, some turning movements and passing movements might be no problem even at peak hour volumes.

Operating speed

Operating speed is the speed at which drivers are observed operating their vehicles during free-flow conditions. The 85th percentile of the distribution of the observed speeds is the most frequently used measure of the operating speed associated with a particular location of geometric feature.

85th percentile speed

The speed at or below which 85 percent of the vehicles travel. This normally will not conform to the posted speed limit. This speed is often called the *prevailing speed*. When better information is not available the 85th percentile speed is often used as the design speed for evaluating existing roads.

Table 2. Minimum desirable geometric design standards for very low-volume (ADT ≤ 400) local rural roads

Design feature	Critical criteria	Minimum standard
Design speed	Major and minor access Other land uses	45 mph 35 mph
Minimum stopping sight distance (high-risk areas are those near intersections, curves and other road hazards)	Low speed, ADT < 250, low-risk Low speed, ADT < 400 or high-risk High speed, ADT < 250, low-risk High speed, ADT < 400 or high-risk	170 feet 205 feet 260 feet 300 feet
Minimum radius for horizontal curves (assumes 4 percent superelevation)	Low speed, ADT < 250 Low speed, ADT < 400 High speed, ADT < 250 High speed, ADT < 400	205 feet 300 feet 420 feet 560 feet
Maximum percent of grade	Low speed, rolling terrain High speed, rolling terrain Low speed, mountainous terrain High speed, mountainous terrain	10 percent 8 percent 14 percent 11 percent
Total pavement width (including shoulders)	Major and minor access Industrial, agricultural and resource recovery Other land uses	20 feet 22 feet 18 feet
Clear zone width*	Preferred (or new construction) Acceptable when safety is okay	6 feet 0 feet

Notes:

- *Higher levels may be warranted. The values given here are distilled from detailed information available from AASHTO. They can be used as guides for understanding if a roadway design is appropriate.*
- *Urban streets have different needs.*
- *Existing roads without evidence of safety or functional problems may be rehabilitated on the same alignment.*
- ** Clear zones for existing roads are generally considered adequate if there is no history of accidents and other safety issues are not compromised.*

GEOMETRY

The layout of a road has a tremendous influence on the ability of the road to handle traffic. Higher volume roads need to have greater widths and longer sight distances to improve safety and keep capacity high. On the other hand, widening a road when not justified, costs money and does not improve the nature of the road. For very low-volume roads (fewer than 400 ADT), new standards available from AASHTO can be used to upgrade these roads without undo expense.

PERCENT OF GRADE

Percent of grade is defined as the amount by which the grade line rises or falls in a unit of horizontal distance. The percent of grade is usually expressed as a percentage, that is, as the rise or fall in the horizontal distance of 100 feet. If the grade line rises 2 feet in 100 feet, it has an ascending, or upgrade, of 2 percent (written as +2.0 %). If the grade line falls 1.83 feet in 100 feet, it has a descending, or downgrade, of 1.83 percent (written as -1.83 %).

To find the percent of grade of a culvert that is 30 feet long, you need to determine the difference in elevations between the inlet elevation and the outlet elevation. If the difference between the two elevations is found to be 1.5 feet, the percent of grade is calculated as follows:

$$\frac{\Delta \text{elevation}}{\Delta \text{distance}} = \frac{1.5 \text{ feet}}{30 \text{ feet}} = 0.05 = 5.0\%$$

SIGHT DISTANCE

There are three sight distances used in design:

- Stopping sight distance
- Passing sight distance
- Intersection sight distance

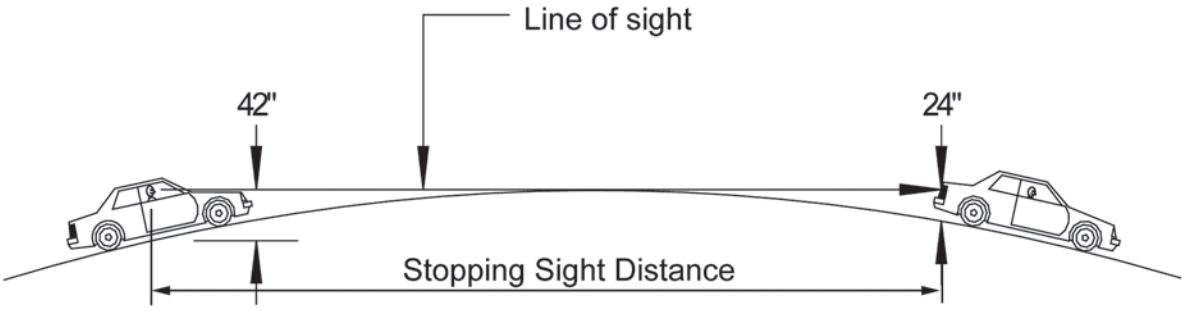

Figure 1. Measuring stopping sight distance on a crest

The **stopping sight distance** is the distance it takes for a vehicle to stop and it increases with vehicle speed. It is based upon an average driver eye height of 42" and an object height of 24" (the taillight of a car) (Figure 1). The distance includes the distance traveled during perception, reaction, and braking, assuming wet pavement. The distance needed to stop may need to be increased on a downhill grade (and may be decreased on an uphill grade). On horizontal curves, it is measured along the centerline of the driving lane (see Figure 2).

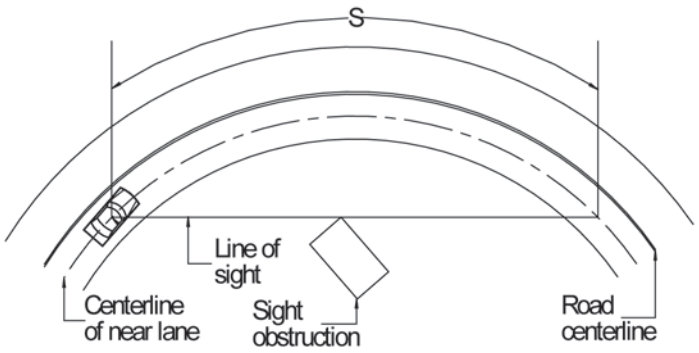

Figure 2. Measuring stopping distance (S) on a horizontal curve

The **passing sight distance** is the distance needed for overtaking, passing, and returning to the travel lane without interfering with an oncoming vehicle. Passing sight distance is only a consideration for two-lane two-way roads, since the affected vehicles are traveling in opposing directions. **Passing sight distance** is considerably longer than **stopping sight distance**.

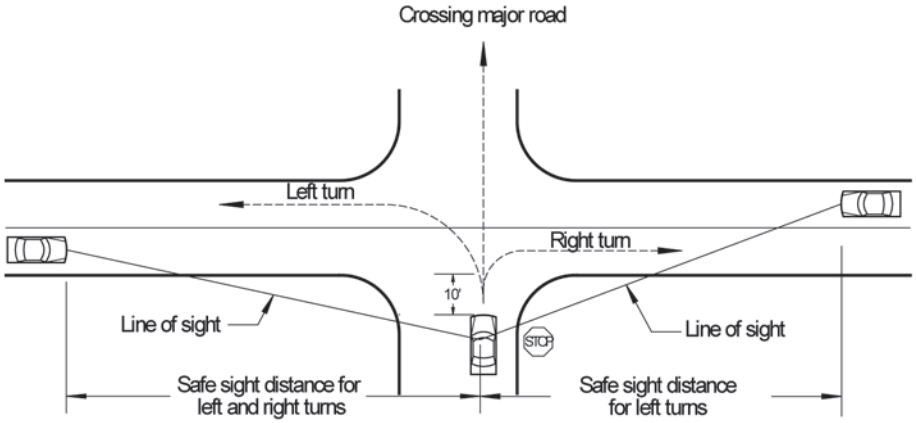

Figure 3. Sight distance at intersections

The **intersection sight distance** (see Figure 3) is the distance a driver at an intersection needs be able to see to tell whether it is safe to proceed. In addition to traffic speed, the intersection sight distance depends on the maneuver being made (through movement, left or right turn) and the traffic control used at the intersection.

At every location along a road, drivers should be able to see at least the stopping sight distance. At every intersection, the intersection sight distance is the minimum distance that should be visible. On most low-volume roads the passing sight distance is not as critical but should be provided if traffic volumes warrant it. The Cornell Local Roads Program workbook *Road Safety Fundamentals* provides details on the acceptable sight distances and how they impact the safety of a road.

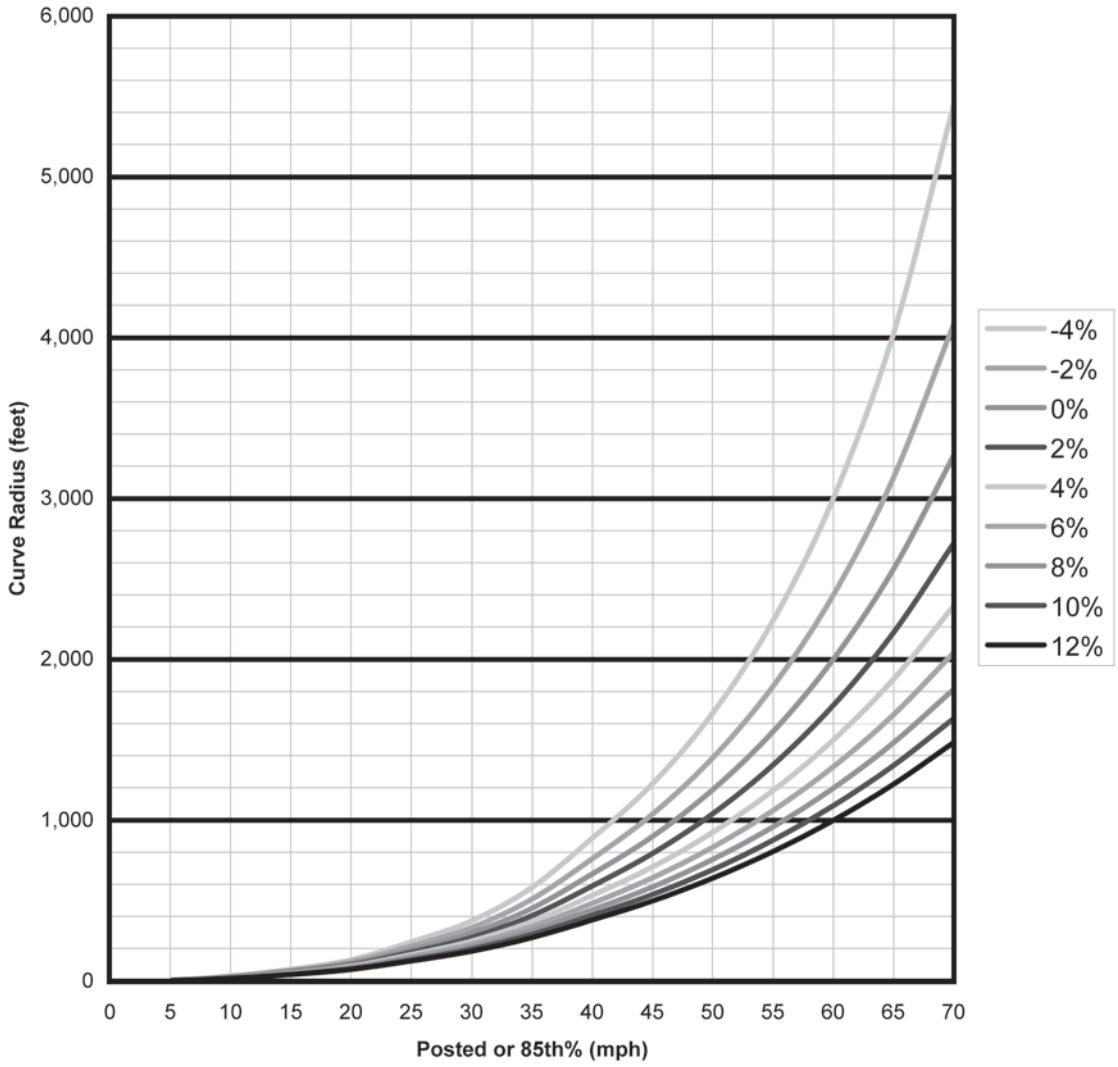

Figure 4. Recommended speed on curves, as influenced by curve radius and superelevation

SUPERELEVATION (BANKING)

With a horizontal curve, the road often has to be superelevated (banked) in order to help keep the vehicle on the road when it travels at the design speed. For a sharp curve, the superelevation is greater than it is for a gradual curve. A properly designed curve will balance the forces on a vehicle as it rounds a curve and will provide a comfortable ride. In areas where ice and snow are factors, there are limits to the amount of superelevation that should be used. Too much bank on a curve

can cause vehicles to slide to the center of the curve if the road is icy. A reasonable maximum superelevation is ½ inch-per-foot for asphalt surfaces, and ¾ inch-per-foot for aggregate surfaces. The amount of superelevation on a curve cannot be changed suddenly, but should be run out at the beginning and at the end of the curve. The runout distance varies depending upon the amount of superelevation. To measure banking on existing roads a ball bank indicator can be used.

Measure the superelevation slope of pavement using 6-foot rule and hand level $\Delta y / \Delta x$ to set feet / foot. Use 10-foot 2" x 4" straight edge to set Δy.

Example: R = 1000, Slope = 0.04, Speed = 52 mph, Post at 50 mph

Take flatter slope if grades vary. Based on friction factor of 0.6. This graph will get you in the ball park. The completed curve should be ball-banked for confirmation.

DEGREE OF CURVE

As a curve gets tighter, with a smaller radius, there is more need to provide superelevation to help vehicles stay in their respective lanes. While radius is a commonly used measure of the sharpness of a curve, there is another term used known as the *degree of curve*. The degree of curve is inversely proportional to the radius. For example, a large radius has a small degree of curve. Conversely, a smaller radius has a higher degree of curve. Knowing the degree of curve or the radius, one can find the other with the following calculations:

$$D = \frac{5729.58}{R} \quad R = \frac{5729.58}{D}$$

Where D = Degree of curve
R = Radius of curve in feet

While the radius is not easy to measure in the field, the degree of curve can be readily determined from the following rule:

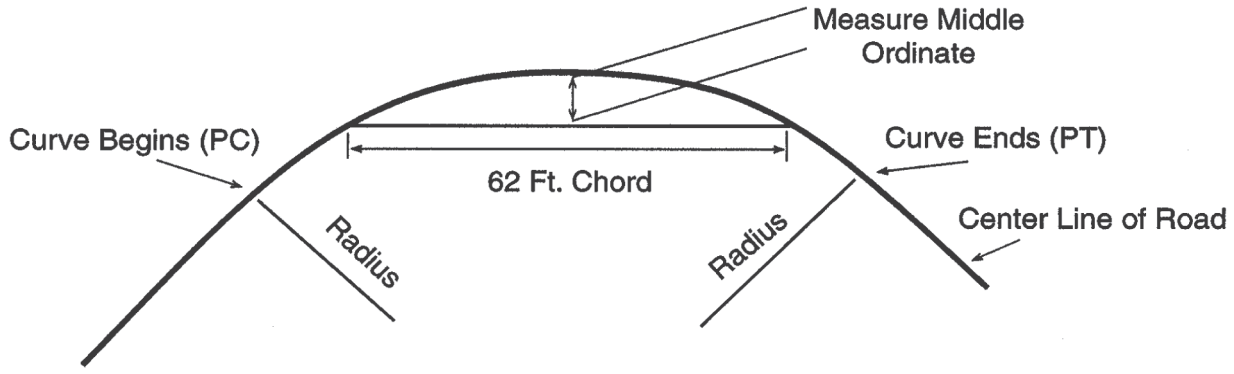

Figure 5. Determining the degree of curve in the field

Measure the middle ordinate in *inches* to a chord of 62 feet. The result is the degree of the curve (see Table 3).

Table 3. Conversion of degrees to radii (curves)

Middle ordinate (inches)	Degree of curve (D)	Radius in feet (R)
2	2	2865
4	4	1432
6	6	955
8	8	716
10	10	573
12	12	478
14	14	409

CLEAR ZONE

To save lives, the forgiving roadside concept was developed in the late 1960s. The concept provides a clear zone adjacent to the pavement without any obstructions. This allows a driver to safely recover and steer back on to the road if the vehicle wanders off the pavement for any reason. The wider the clear zone, the more forgiving the roadside. A 30-foot clear zone is much more forgiving and more desirable than a 5-foot clear zone. Achieving a clear zone on existing low-volume local roads with tight right-of-ways may be difficult.

For most existing low-volume roads, the existing clear zone is adequate when there is no experience of safety problems. Where possible, at least 6 feet of clear distance beyond the edge of the traveled way should be provided. A wider clear zone may be needed on the outside of curves and where other safety hazards exist.

On existing roads, the desired clear zone width is often difficult to achieve because of right-of-way or terrain constraints, but improvements should be made where they are needed. Focus your efforts on locations where run-off-road crashes have occurred. If you need additional right-of-way, you may have to secure an easement or acquire property from the adjacent property owner.

3 - Soils

Once you have established the design characteristics of your roadway you must consider the materials and conditions that go into its structure. The first of these is soil. Subgrades are the naturally occurring soils in a given area. Different types of soil have different properties which determine how a type of soil will perform.

TYPES OF SOIL

Normally soils will consist of a combination of several of the following components.

- **Gravel** - Rounded, subrounded, or angular particles of rock that will pass a three-inch square opening sieve (75 mm) and be retained on a #10 sieve (2.0 mm).
- **Sand** - Particles that will pass the #10 sieve (2.0 mm) and be retained on the #200 sieve (75 μm). Natural sand usually has rounded to subrounded particles, while manufactured sand is usually highly angular.
- **Silt** - Material passing the #200 sieve (75 μm) that is nonplastic and exhibits little or no strength when dried.
- **Clay** - Fine-grained material, typically smaller than 5 μm that can be made to exhibit plasticity (putty-like property) within a wide range of water contents and exhibits considerable dry strength.
- **Fines** - The portion of a soil passing a #200 sieve.

Usually, the makeup of a soil is determined using a sieve analysis. This analysis consists of taking a sample of soil and passing it through a series of sieves, and measuring the volumes retained on each sieve. The sieve analysis ensures that the makeup of the soil is appropriate for its intended use. The sizes of the sieve openings are shown in Table 4.

Table 4. Sizes of sieve openings

Sieve	Opening
3 inch	75 mm
#10	2.00 mm
#40	0.425 mm
#200	75 μm

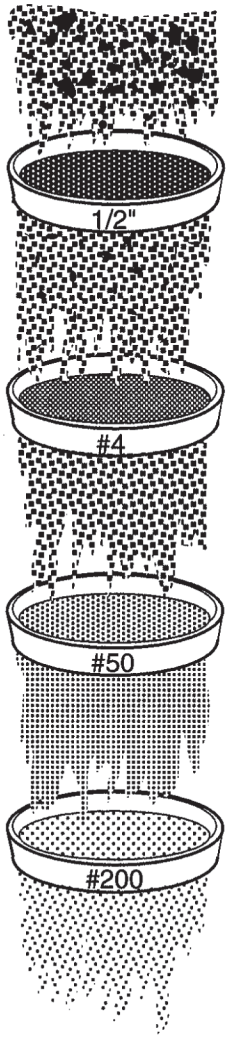

Figure 6. Sieve analysis

Figure 6 provides a visual explanation of how the various components of soils are retained on the various sieves.

Table 5. Recommended gradations for aggregate surface and base

50-70%	Gravel (1" maximum particle size)
25-40%	Sand
0-8%	Fines (for a base material)
8-15%	Fines (for an aggregate road surface)

Table 5 shows the recommended gradations for aggregate surface and base materials for gravel, sand, and fines. The percentages are determined from sieve analysis. Too much of one component can be detrimental to the road surface or base. Note that the recommended amounts of sand and gravel are the same for both surface and base materials. Only the fines content changes. However, a good surface gravel will not make a good base material.

Gravel vs. gravel

It is a bit misleading since we use the term *gravel* to define both the particles of a certain size, as well as, a mixture of various particles used in construction. The reason for this dual use stems from the fact that the gravel-sized particles are the most critical component of our gravel mixture. To help remember, keep the following two definitions in mind:

Gravel (as a component of a mixture) - Gravel-sized materials range in size from just larger than the openings in a #10 sieve (2 mm) to 3 inches across. The particles provide the strength in the overall mixture of particles used in road building.

Gravel (as a mixture) - Gravel is a mixture of particles of various sizes and gets most of its strength from the larger particles. Sand is needed to fill in the voids and help make the mixture stable after compaction. Fines (silt and clay) are not needed for base gravels, but are critical to the success of surface gravel mixtures. Too many fines will result in poor behavior in the presence of traffic and excess water.

VISUAL - MANUAL IDENTIFICATION

- **Gravel** - Identified by particle size. The particles may have an angular, rounded, or subrounded shape. Gravel size particles usually occur in varying combinations with other particle sizes.
- **Sand** - Identified by particle size. Gritty grains that can easily be seen and felt. No plasticity or cohesion. Size ranges between gravel and silt.

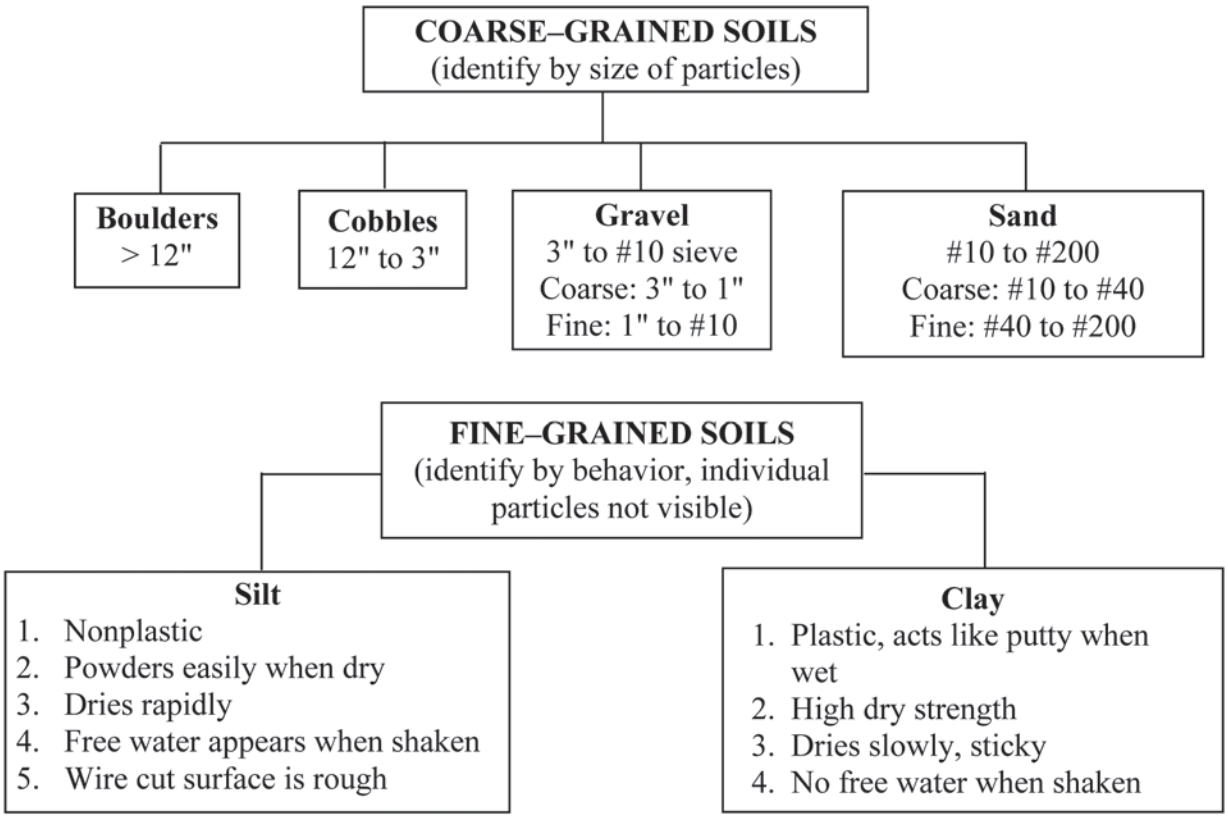

Figure 7. Identification procedure chart

- **Silt** - Identified by behavior. Fines that have no plasticity. May be rolled into a thread but will easily crumble. Has no cohesion. When dry, can be easily broken by hand into powdery form.
- **Clay** - Identified by behavior. Fines that are plastic and cohesive when in a moist or wet state. Can be rolled into a thin thread that will not crumble. When dry, forms hard lumps which cannot be readily broken by hand. Clay is often encountered in combination with other soil sizes. If a sample exhibits plasticity or cohesion, it contains clay. The amount of clay can be related to the degree of plasticity or cohesiveness; the higher the clay content the greater the plasticity.
- **Marl** - A white or gray calcium carbonate paste. May contain granular spheres, shells, organic material or inorganic soils. Reacts with weak hydrochloric acid.
- **Muck** - Black or dark brown finely divided organic material mixed with various proportions of sand, silt, and clay. May contain minor amounts of fibrous material such as roots, leaves, and sedges.
- **Peat** - Black or dark brown plant remains. The visible plant remains range from coarse fibers to finely divided organic material.
- **Organic clay** - Dark clay with microscopic-sized organic material throughout. May contain shells and/or fibers. Has weak structure, exhibits little resistance to kneading.

- **Organic silt** - Dark gray silt with microscopic size organic material dispersed throughout. May contain shells and/or fibers. Has weak structure which exhibits little resistance to kneading.
- **Fill** - Manmade deposits of natural soils and/or waste materials. Document the components carefully since presence and depth of fill are important engineering considerations.

PERMEABILITY

Permeability is the ability of soil to allow water to pass through it. Soil that allows water to flow through it quickly has a high permeability. As Table 6 indicates, a gravelly soil with few fines has a permeability many times greater than a silty soil. This means that a gravel material will drain water much faster than a silty soil. Small changes in the percentage of fines will have a large effect on soil permeability. The term *fines* refers to soil particles smaller than the #200 sieve.

Table 6. Typical soil permeability rates

Material	Permeability (feet/day)	Permeability (meters/day)
Gravel	30,000	9000
Sand	3,000	900
Fine sand and silt	3.0	0.9
Silty clay	0.003	0.0009

Note: Numbers have been rounded for clarity

Mixtures of gravel, sand, silt, and clay tend to have the permeability of the finest component.

The time required to drain a soil also depends on the distance the water must flow. It is sometimes necessary to install underdrains to reduce the distance and decrease the drainage time. Soils that are high in gravel and sands are excellent candidates for underdrains, dry wells, and infiltration basins. Conversely, soils that have high clay and silt contents are not suitable for infiltration-type devices.

CAPILLARITY

Capillarity is the ability of soil to move water by "wicking" action, including upward, against gravity. This is similar to what happens when a sponge is set in a plate of water. As time goes on, the water will rise up into the entire sponge. Soils with high capillarity cause problems with roads. As you can see in Table 7, sands and gravel do not have strong capillarity. Conversely, those soils with high concentration of silts and clays have high capillary capability.

Mixtures of gravel, sand, silt, and clay tend to have the capillarity of the finest component.

Table 7. Height of capillary rise

Soil type	Height of rise (feet)	Height of rise (meters)
Gravel	Nil	Nil
Coarse sand	0.5	0.15
Fine sand	1 to 3	0.3 to 0.9
Silt	3 to 30	0.9 to 9
Clay	30 to 90	9 to 27

Note: Numbers have been rounded for clarity

FROST-SUSCEPTIBILITY

Frost-susceptibility refers to the tendency of some soils to form ice lenses during the winter months. This is due to an interaction between permeability and capillarity. As the ground freezes, water is pulled toward the freezing front if the soil has sufficient capillarity. The freezing water may form thick ice lenses if the soil permeability will allow it.

- Clean materials, those having very little silt and clay fines, do not have enough capillarity to support the growth of ice lenses, and are not frost-susceptible.
- Clay soils have very low permeability, so they are not able to support the growth of ice lenses during the relatively short period of time that freezing conditions exist.
- Silty soils have the best combination of permeability and capillarity to support the formation of ice lenses. Pure silt (rock flour) can develop ice lenses that are several inches thick under optimum conditions. A mixture of gravel and sand, with enough silt (i.e., a dirty gravel) will also be very frost-susceptible.

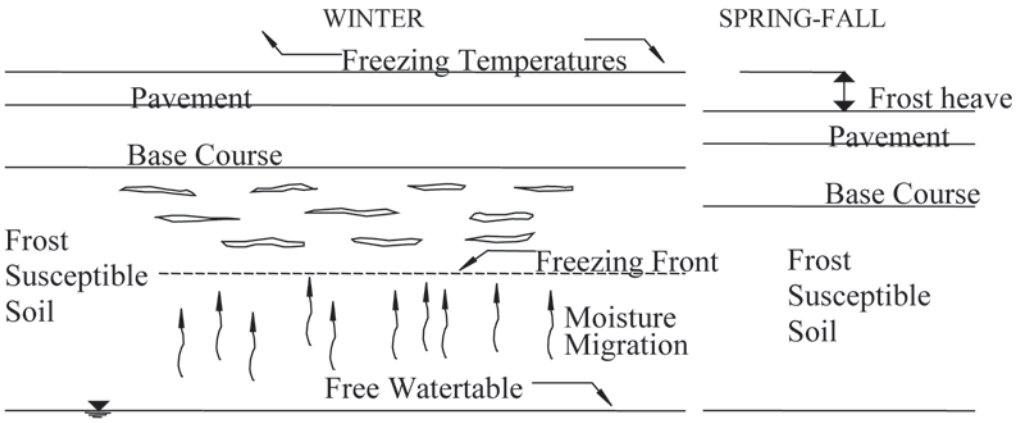

Figure 8. Frost heaving in winter

Table 8 describes the classification of various materials with regard to their frost susceptibility. When the ice lenses in the soil melt (during spring thaw), the material loses its stability and it becomes very weak. Because of this, you do not want to use frost-susceptible materials in the upper layers (base course) of a road.

Frost-susceptibility does not necessarily lead to *frost action* (the growth of ice lenses). For frost action to occur, all of the following must be present: a frost-susceptible material, freezing temperatures, and water available. Ways to prevent frost action will be discussed further in Chapter 5 on drainage.

Table 8. Classification grouping for frost-susceptible soils

Frost-susceptibility	Group	Description
Low	F1	Gravelly soils containing 3-20% finer than 0.02 mm by weight
Medium	F2	Sands containing 3-15% finer than 0.02 mm by weight
High	F3	a. Gravelly soils containing more than 20% finer than 0.02 mm by weight b. Sands, except very fine silty sands containing more than 15% finer than 0.02 mm by weight c. Clays with plasticity indexes of more than 12 d. Varved clays existing with uniform subgrade conditions
Very high	F4	a. All silts including sandy silts b. Very fine silty sands containing more than 15% finer than 0.02 mm by weight c. Clays with plasticity indexes of less than 12 d. Varved clays existing with nonuniform subgrade conditions

Source: U.S. Army, Corps of Engineers

DESIRABLE PROPERTIES FOR AGGREGATES

Using a NYSDOT approved material, carefully selected to be appropriate for the particular application (base course, chip seal, cold-mix, or other application) offers the best assurance of getting a good quality, durable product.

Be sure you know what you are getting

Many agencies use Item 4 gravel for base construction. Item 4 as an official state specification has not been available since 1973! There is a very close equivalent in section 304, type 4 of the NYSDOT *Standard Specifications*. However, research done by the *Cornell Local Roads Program* showed that materials that meet section 304, type 4 are prone to frost susceptibility.

The reasons for this makes sense if you examine the name of the material: Subbase Course. Item 304 refers to a subbase gravel material that should not be used as a base course just under the road surface. NYSDOT uses only asphalt concrete materials for base courses. If you want a base gravel, you need to order one.

Section 667 of the NYSDOT *Standard Specifications* is the section covering local road gravel base (and surface) courses. The material specified is cleaner that section 304 and is not as susceptible to frost action.

Actual soils or aggregates used on a project will not be 100 percent of any one particular component, but will include a range of sizes. Terms such as *sandy gravel* or *silty clay* are used to describe mixed materials. In the term **silty sandy gravel** the most abundant component would be gravel, the sand sized particles would be the next most abundant component, and silt would be the *least* abundant component. Thus, a silty gravel and a gravelly silt are not the same material. The distribution of particle sizes will help determine the soil permeability, strength, and density.

Well-graded or dense-graded soils have an evenly distributed range of sizes. These soils compact well into a dense material with relatively few voids. Open-graded soils are soils with mostly one particle size. These soils have a large void volume in the structure after compaction. Desirable properties for aggregates depend on the use of the material.

Base course materials

- Granular material with angular particles
- Well-graded with 0 percent to 8 percent fines
- High stability
- High permeability
- Nonplastic
- Not frost-susceptible

Aggregate road surface

- Granular materials
- Well-graded with 8 percent to 15 percent fines to act as a binder
- May be slightly frost-susceptible

Asphalt mix aggregates

- Hard materials that will wear well
- Angular in shape
- Well-graded
- Carefully controlled gradation

Chip seal aggregates

- Hard materials that will wear well
- Cubical in shape
- Open-graded and single size
- No fines

Cleanliness

Aggregates containing foreign matter (vegetation, shale, soft particles, clay coatings, or clay lumps) are unsatisfactory. Specifications should place limits on the amount of each of these materials. Clean soils will have less than 5 percent fines; dirty soils will have more than 12 percent fines.

Toughness

Aggregates must be able to resist a certain amount of crushing and abrasive wear during manufacture, placing, and from traffic. Aggregates at the pavement surface require greater toughness. The Los Angeles Abrasion test is used to measure toughness by rotating a specified amount of aggregate in a steel drum with a standard weight of steel spheres. A measure of weight of abrasive loss is used to determine if the material is satisfactory.

Soundness

Aggregates must be durable and should not deteriorate or disintegrate under the action of weather. Shale is a typical unsound material. Water enters it and freezes, then expands and fractures the shale. The soundness test uses a solution of magnesium sulfate, and the sample of aggregate is put through a number of soaking/drying cycles. The percent loss by weight of each size fraction of material is determined and used as a measure of soundness.

Particle shape

Particle shape influences the workability of asphalt concrete and the compactive effort necessary to obtain required density. Angular or irregular particles interlock and resist movement during compaction. For hot or cold-mix asphalt concrete, the asphalt content is a critical factor in the stability of dense-graded mixes. A mix of crushed stone and natural sand is often used. The crushed material gives strength, and the rounded sand particles provide workability. Sometimes crushed sand must be used to attain sufficient stability.

Polishing

Polishing is the tendency of some aggregates to become slippery over time. This is most important in surface courses such as chip seals, asphalt concrete, and portland cement concrete since we want these surfaces to provide good *skid resistance*.

Tire wear will cause some aggregates to polish. Limestone and dolomite have a high tendency to polish. Most granites, traprock, and sandstones are rough, and resist polishing.

There is no convenient test to measure polishing. However, both limestone and dolomite are carbonate minerals, and are soluble in acid. (The fizz is carbon dioxide gas being released.) Thus to avoid polishing, most specifications for hot-mix aggregate call for a major percentage of acid insoluble particles. For good skid resistance it would also be wise to require acid insoluble aggregates for chip seals.

Absorption

For use in asphalt mixes, a small amount of absorption is desirable. This will allow the aggregate to absorb some asphalt, forming a link between the asphalt film and the aggregate. Highly porous aggregate is not desirable since it absorbs too much asphalt. Burnt slag and other synthetic aggregates are highly absorptive, but they have a rough surface texture which makes them attractive for use in asphalt mixes.

Affinity for asphalt

Quartzite and some granites are undesirable aggregates for asphalt mixes because they allow water to separate the asphalt film from the aggregate. This is called *stripping*. Aggregates such as limestone, dolomite, and traprock do not allow the stripping of the asphalt film.

Table 9. Primary size ranges of standard aggregate (NYSDOT)

Size designation	Primary sieve sizes	
	Maximum	Minimum
Screenings	¼ inch	—
#1B	⅛ inch	#80
#1A	¼ inch	⅛ inch
#1ST	½ inch	¼ inch
#1	½ inch	¼ inch
#2	1 inch	½ inch
#3A	1½ inches	1 inch
#3	2 inches	1 inch

STABILITY

Stability is a measure of strength or bearing capacity. It depends on the size of the soil particles and their ability to work as a unit. Sand is very stable when it is contained, but will not hold its shape without containment. Clay will hold its shape fairly well, but reacts poorly when wet or disturbed. This is why it is important to have a good mixture of soils to allow them to act as a unit.

COMPACTION

It is necessary for the in-place soil in a road structure to possess certain properties. The subgrade and base course should have adequate strength, should be relatively incompressible so that future settlement is not significant, should be stable against volume change as water content varies over time, and should possess good permeability. Proper selection of fill material and proper placement can ensure that these desirable features are met.

Table 10. Allowable bearing capacity of soils

Soil	Allowable bearing capacity, tons/ft^2
Medium soft clay	1.5
Medium stiff clay	2.5
Sand, fine, loose	2
Sand, coarse, loose; compact fine sand; loose sand-gravel mixture	3
Gravel, loose; compact coarse sand	4
Sand-gravel mixture, compact	6
Hardpan and exceptionally compacted or partially cemented gravels or sands	10
Sedimentary rocks (hard shales, sandstones, and limestones) in sound condition	15
Foliated rocks (schist or slate) in sound condition	40
Massive bedrock (granite, diorite, gneiss, and trap rock), in sound condition	100

The properties of high strength, low compressibility, and stability are normally associated with good compaction (high density). It is important that embankments be properly compacted. In order to compact a soil well, with the least effort, use the proper equipment, have the soil at the optimum moisture content, and compact it in thin lift thicknesses.

Compaction equipment

Vibratory compactors are most effective on sand and gravel soils. Steel drum rollers tend to break down the individual grains of soil creating fines and lowering the permeability of the soil. For granular soils that have a tendency to break down, the rubber tired vibratory rollers are more suitable.

Sheepsfoot rollers are best used on silty and clay soils. With these rollers, the ideal lift thickness is approximately 6 inches. Smooth drum rollers have limited effective depth and should be used where only thin layers or surface zones need to be compacted.

Moisture content

The easiest and best way to obtain proper compaction of soil is to have the proper moisture content. If the moisture in the soil is too high or too low, even a great deal of effort will not attain the proper compaction. Figure 9 shows a typical moisture density curve for a silty subgrade. The moisture density curve for various soils will depend on the makeup of the soil.

The curve shows the dry density for various amounts of added moisture for samples made using the same compactive effort. As the moisture content increases, the moisture actually aids with compaction by acting as a lubricant. The moisture content at the peak of the density curve is called the optimum moisture content. Beyond this point the added moisture just takes up space and decreases the density of the soil. If there is too much moisture, the soil cannot be compacted properly. The zero air-voids (ZAV) curve shows the maximum density possible if there were no air voids. In real soils, the matrix of the soil always has some voids. As moisture increases, the saturation of the soil approaches 100 percent and the density approaches the ZAV curve.

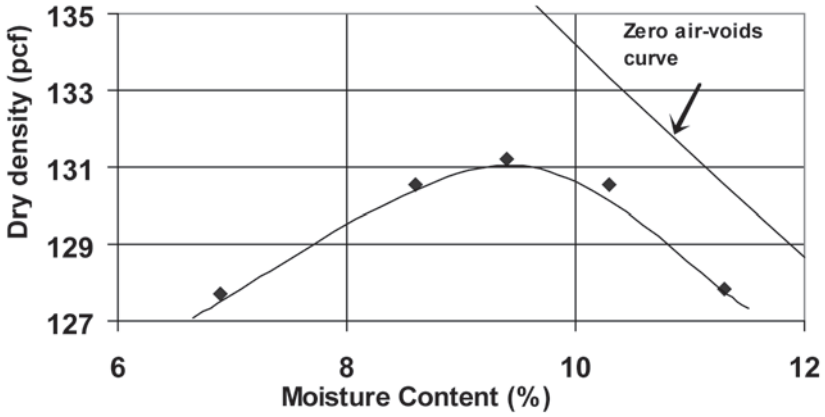

Figure 9. Moisture density curve

The dry density or dry unit weight of soil is the value used to measure compaction. The units are pounds of dry soil in a cubic foot of volume. The moisture content of a sandy soil should be about 8 percent for best compaction. If the soil is too dry it should be wetted down. If it is too wet it should be allowed to dry out.

Table 11 shows ranges of optimum moisture for some soils. Coarse crushed stone does not exhibit an optimum moisture content. It is best compacted dry or damp, with a vibratory roller.

Table 11. Range of optimum moisture contents for compaction for some soils

Soil	Optimum moisture content
Sand	6 - 10%
Sand-silt	8 - 12%
Silt	11 - 15%
Clay	13 - 21%

Table 12 - Characteristics of soils pertinent to roads

Description	As a base[1]	Frost susceptibility	Permeability
Well-graded gravels or gravel-sand mixtures, little or no fines	Good	None to very slight	Excellent
Poorly graded gravels or gravel-sand mixtures, little or no fines	Poor to fair	None to very slight	Excellent
Silty gravels, gravel-sand-silt mixtures	Fair to poor	Slight to medium	Fair to poor
Clayey gravels, gravel-sand-clay mixtures	Poor	Slight to medium	Fair to impervious[2]
Well-graded sands or gravelly sands,little or no fines	Poor	None to very slight	Excellent
Poorly graded sands or gravelly sands,little or no fines	Poor to unsuitable	None to very slight	Excellent
Silty sands, sand-silt mixtures	Poor to unsuitable	Slight to high	Fair to impervious[2]
Clayey sands, sand-clay mixtures	Unsuitable	Slight to high	Poor to impervious[2]
Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity	Unsuitable	Medium to very high	Fair to poor
Inorganic clays of low to medium plasticity, gravelly, sandy, silty, or lean clays	Unsuitable	Medium to high	Impervious[2]
Organic silts and organic silt-clays of low plasticity	Unsuitable	Medium to high	Poor
Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	Unsuitable	Medium to very high	Fair to poor
Inorganic clays of high plasticity, fat clays	Unsuitable	Medium	Impervious[2]
Organic clays of medium to high plasticity, organic silts	Unsuitable	Medium	Impervious[2]
Peat and other highly organic soils	Unsuitable	Slight	Fair to poor

Source: U.S. Army, Corps of Engineers

Notes:

[1] Value as a base directly under bituminous pavement.

[2] To be completely correct the phrase practically impervious should be substituted for the word impervious.

SOIL IDENTIFICATION IN THE FIELD

For professional evaluation of your soils, send soil samples to a reputable laboratory. However, with experience you will be able to estimate the general suitability of a gravel mixture by feel. Simple field tests offer a quick way to identify soil types. These tests are used to determine gradation, presence or absence of plasticity, and the optimum moisture content. Results of these tests are tentative, and soil classification for engineering design purposes should rely on laboratory test results. Samples must be selected to be truly representative of the overall soil mass. Generally, increasing the number of samples helps improve the quality of the test data.

Gradation refers to the relative amounts of gravel, sand, silt, and clay. For gravel surfaces a certain amount of silt and clay is needed to minimize raveling and seal the surface. For gravel bases that will be surfaced, less silt and clay is desirable. It is very difficult to visually estimate the amount of fines in a gravel. You should rely on a test to determine this.

Do-it-yourself gradation tests

Pick up two or three double handfuls of soil. Spread the material on a flat surface. Discard stones larger than approximately ¼ inch. Add enough water so that you can pack the material into a ball, but not so much as to make it mushy. Pick up a handful of the moist material, and squeeze it. It should contain enough sand to look and feel gritty.

Look at your hand. *For use in gravel roads* the mixture should contain enough silt and clay to stain your hand slightly, but not leave it muddy. It should hold its shape while moist. If dried, the ball should still retain its shape and resist breaking. *For use in base courses* the moist material should not stain your hand. If dried, a ball of this material should pulverize easily in your hand.

If the soil is wet, you can determine the percentage of fines by placing the soil in a glass container (like a canning jar). Add enough soil to fill the container ¼ full. Add water until the soil is just covered. Mark this level with a rubber band. Fill the jar ¾ full with water, and stir or shake vigorously. Let it settle approximately 1½ minutes. Mark the height of the soil with another rubber band. The difference between the two rubber bands represents the approximate percentage of fines.

Do-it-yourself plasticity tests

Pick up a lump of moist soil and knead it, removing as many large-grained particles as possible. Add enough water so you can mold the material into a ball easily, about golf-ball size. If the material clings to your hands, it is too wet!

Divide the ball in half, and then in half again. Roll the small portion into a snake-like shape approximately one-half inch in diameter. A nonporous surface such as a Formica counter or a sheet of glass works well for this purpose. If you cannot form a “snake” at all, the soil is nonplastic, and is probably silt or fine sand. If it does not roll easily, add a drop or two of water.

Continue rolling until the smallest possible “snake” is achieved before it crumbles. Measure the diameter of the thinnest “snake.” *If the material is suitable for gravel roads*, the diameter should be less than ⅜ inch. About ¼ inch is desirable. This material will be suitable for base courses.

Some clays will hold a "snake" smaller than ⅛ inch. If the diameter of the "snake" is less than ⅛ inch, it is probably too plastic and the road will likely soften when wet.

Now take the other portion of the soil you set aside earlier and knead it into a ball. Let it air dry, then crush it. Take a small jagged segment and try to squeeze it between your thumb and forefinger. *Silt* will turn to powder, and *clay* will be hard as a rock.

Soil clues summary

- **Clays** - A tough "snake" that dries slowly; a crusty dry residue that is difficult to remove from your hands; very hard and strong when dry.
- **Silts** - A weak or crumbly "snake;" powdery residue on your hands that is easily wiped or washed off; very weak and friable when dry.
- **Silt or clay mixtures** - Conflicting reactions to the tests.
- **Silt or gravel with few clay fines** - Enough clay to stain your hand when kneading a wet sample, but not enough to form a lump.
- **Sand or gravel with silt fines** - Any mixture with dusty or fairly gritty fines; weak and friable when dry.
- **Clean sands and gravels** - Water added works in immediately without making mud; does not stain your hands; no dry strength.

Remember! Results of these tests are tentative. Soil identification for designing a road or for major rehabilitation should depend on professional laboratory testing.

4 - Pavement Structures

VEHICLE LOADS

Both the size and the number of repetitions of vehicle loads are important in determining how well a road surface will hold up. Figure 10 shows the pressure immediately below the contact point of a tire. The load is spread out over a larger area as it progresses down through the pavement. If the pavement is sufficiently thick, then the stress will be so small as to minimize deflection. As one would expect, the larger the load, the thicker the pavement should be.

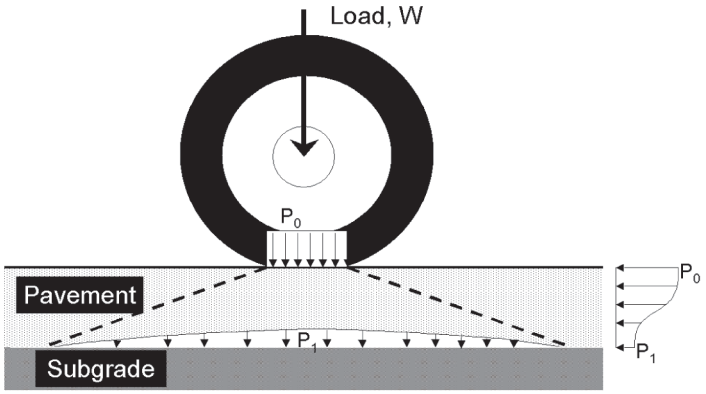

Figure 10. Subgrade stress due to a wheel load

Figure 11 shows how a pavement will deflect under a wheel load. As the pavement flexes, it will go through a combination of tension (pulling) and compression (pushing) stresses. These stresses, when repeated a number of times, will cause the pavement to crack due to fatigue. If the deflection is large, very few repetitions are needed before the pavement cracks. For a small deflection, many more repetitions of load are needed to cause cracking.

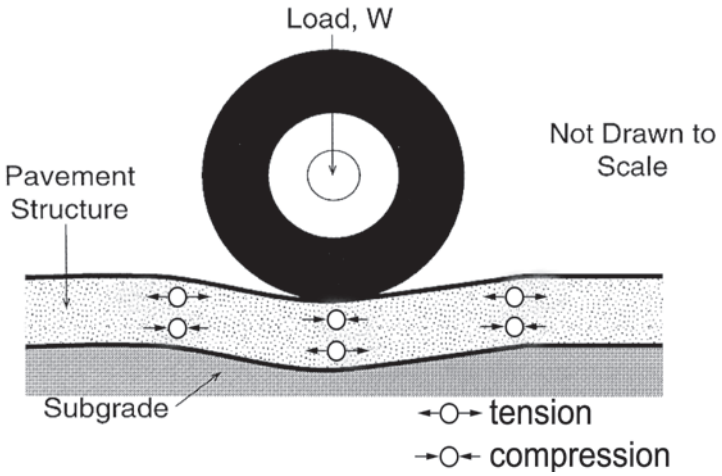

Figure 11. Pavement deflection

The tendency for a pavement to deflect is closely related to the amount of moisture in the subgrade soils. If the subgrade soils are wet, there will be a great deal of deflection under the wheel loads. The deflection will be much less for the same soil when it is well drained. The large deflections and associated cracking during the spring thaw are due to excessive moisture content of the subgrade when the ice in the frozen soil melts.

ROAD SURFACES

Road surfacing includes everything from gravel to asphalt to portland cement concrete. As a highway superintendent you must match the surface to the expected use of the roadway.

Gravel surfaces are generally warranted when traffic does not exceed 10-20 vehicles per day, and there are virtually no heavy trucks. Surface treatments such as chip seal on gravel may also be used on such low-volume roads, if the road has a history of maintenance problems.

Asphalt paving is warranted once volumes and loads exceed that allowed on gravel roads. Asphalt paving can be either cold mix or hot mix.

Remember, you should not surface treat or pave a gravel road with asphalt without changing the gravel material. Gravel roads are typically heavy with fines and make a poor base for a paved surface.

PAVING AGGREGATE ROADS

When to improve an aggregate road with a surface treatment is a frequent dilemma. Making the decision is often intuitive.

Sealing an aggregate road eliminates the need for frequent grading and addition of aggregate to replace surface loss. On top of this is the often overlooked vehicle operating cost. This cost will vary per mile driven depending upon the type of road surface. For aggregate surfaced roads, the operating cost is often substantially more than for bituminous roads in the same condition.

Careful analysis has shown that the total cost for an aggregate road and a surface treated road are identical with an average daily traffic (ADT) of eight. If the ADT is greater than eight, it is more economical to have a surface treatment.

Keep in mind that this represents total cost and not just the cost for the highway agency. The total cost is the road construction and maintenance cost plus the vehicle operating costs. If total cost is considered, many aggregate roads should perhaps be paved. The public is unaware that their costs would actually be less if some of these roads were surface treated. The problem, of course, is budgeting the money to upgrade the road.

Table 5 (page 16) shows that there is a substantial difference in the aggregate that should be used for a gravel road versus that which should be used as a base under a surface treatment. The aggregate surface needs to have more fines plus some plasticity to bind it together. When a surface treatment is placed over such a material, it will make an inferior base course. The bituminous surface will keep water in the base, and the high fines and plasticity will make the base soft. As a consequence, unless the old aggregate surface is covered with a new base course, or unless the old surface is chemically stabilized to bind it together, then the surface deflections will be large and the durability of the surface treatment will be reduced.

SURFACE TREATMENTS

A surface treatment is not considered a structural layer. Like shingles on a roof, a surface treatment gives a waterproof cover and provides resistance to abrasion, but it adds very little structural support. A good, clean, non-frost-susceptible base, and good drainage are essential to have a long-lasting surface treatment.

A surface treatment will:

- Provide long-lasting, economical surfaces for granular base roads having light to medium traffic volumes
- Provide waterproofing
- Provide good skid resistance
- Restore weathered surfaces
- Control dust

The correct grade of asphalt emulsion for a surface treatment will:

- Be fluid enough to spray properly
- Retain proper consistency to wet the applied aggregate
- Cure and develop adhesion quickly
- Hold aggregate tightly
- Not bleed or strip with changing weather conditions

Aggregate

The aggregate for surface treatments should be cubical in shape and as uniform in size as possible. The surface treatment should have one layer of stone. The largest particle size should be no more than twice the size of the smallest. NYSDOT-approved #1ST crushed stone is recommended for surface treatment construction.

The aggregate should be clean and angular in shape. Flat particles will be completely covered by the asphalt. Aggregate that is slightly damp will adhere better to the asphalt emulsion.

A new granular base course should be primed before applying the surface treatment. Priming should be done several days in advance, to allow it to cure.

Slurry seals

Slurry seals are used to seal the road surface and prevent moisture intrusion. They will fill cracks or improve smooth areas to restore the surface texture.

One of the problems with slurry seals is that all traffic must be kept off the surface until the slurry is completely cured. Under ideal conditions the curing time is a few hours. But, weather, drying conditions, and slurry thickness will vary the curing time. Use of polymerized asphalt will reduce the curing time, but it increases the cost.

Chip seals and slurry seals should be applied before Labor Day in New York State to ensure that the emulsion will cure properly before cold weather sets in. Also, surface treatments should not be placed prior to Memorial Day to be sure the ground temperature is warm enough.

COLD-MIX ASPHALT CONCRETE

Cold-mix asphalt concrete is a mixture of aggregate and emulsified asphalt. After the water from the emulsion has evaporated from the mix the emulsion forms a film which binds the particles like asphalt cement in hot-mix.

The use of emulsified asphalt permits the stones to be coated when cold, hence the name "cold-mix." The aggregate does not need to be dried or heated, which saves energy and money. In fact, the asphalt emulsion will generally mix better with the aggregate when the stones are damp on their surface. However, the aggregate must not be excessively wet (dripping). Always use NYSDOT-approved aggregates for cold-mix.

Cold-mix can be produced in a central plant like hot-mix, or large mixing machines can blend the asphalt emulsion and aggregate directly on the surface of the road. In the latter case the material is sometimes called *motor-pave*, *road-mix*, or *bituminous stabilized base*.

Because cost savings is often a factor in choosing cold-mix over hot-mix, sometimes the durability of the product is compromised. This is because quality control outside the central mixer is not as strict as with hot-mix. If low-quality aggregates are used, or if poor gradation control is exercised, the cold-mix pavement may not last as long as hot-mix.

Good evaporating conditions are necessary to get the water out of the mix after it is compacted. Some agencies prefer to use open-graded aggregates to enhance the water evaporation. Careful attention must be given to ensure that the open-graded layer can drain well, at the edge of the road, because trapped water from rainfall will rapidly weaken the layer. Usually open-graded cold-mixes are covered with a surface treatment within a few days after construction to protect the layer from rainfall.

Late season construction can lead to failures of cold-mix pavements. In the fall, temperatures are cool, and the daily evaporation rate is often less than the precipitation. Freezing weather will break asphalt emulsions, and then water remains in the mix. Poor bonding of the particles of aggregate results, and surface raveling can become a problem.

Cold-mix requires at least 14 days of good drying weather before a surface treatment is placed upon it. Thus it is necessary to construct the cold-mix by mid-August in order to complete the entire project before Labor Day.

PURCHASING COLD-MIX ASPHALT CONCRETE

Standard Specifications, Construction and Materials, NYSDOT, 2002, Section 405, provides a good specification for open-graded cold-mix pavement. Medium setting emulsions should be used in the mix.

NYSDOT does not publish a specification for dense-graded cold-mix. In such cases the local highway agency must rely on the asphalt supplier to recommend a mix design. In the absence of good specifications and without quality control, there is very little to ensure that money is being wisely spent. Highway officials, particularly those who do not have extensive experience, should be cautious and careful under such circumstances.

HOT-MIX ASPHALT CONCRETE

Asphalt concrete is a mixture of clean, durable, crushed aggregate and asphalt cement. Nearly all hot-mix asphalt concretes are made with dense-graded aggregates. The current NYSDOT Sections 402 and 403 provide detailed specifications for this type of surface. More details can be found in the Cornell Local Roads Program manual, *Asphalt Paving Principles*.

Standard mixes are HMA mixes that have been in use for many years and provide pavements with excellent service lives in most instances. These mixes can be found in *NYSDOT Standard Specifications, Section 403*. Be aware, NYSDOT intends to eliminate these mixes sometime in the future and proceed to full Superpave implementation.

The name Superpave comes from "SUperior PERforming PAVEments". The Superpave mix design system was developed through research performed during the Strategic Highway Research Program (SHRP). The paving system consists of a new asphalt binder grading specification, a new mix design method, and new HMA paving performance specifications.

At the batch plant the aggregates are dried and heated to about 300ºF. They are screened into primary size fractions, and the various fractions are recombined by weight according to carefully determined formulas. Asphalt cement, which has been heated to promote coating of the aggregate, is metered into a pugmill, and the batch is mixed for 60 to 90 seconds.

The mix is hauled to the job site in covered trucks to keep it hot. When placed through a paving machine its temperature should be in the 250º to 325ºF range. The mix is immediately compacted with a heavy roller to reduce the air void content to a minimum. This ensures that water, air, and sunlight cannot enter the pavement. All three reduce the longevity of asphalt pavements.

As the mix cools, the film of asphalt on the surface of each aggregate particle becomes very viscous. This binds the particles together, making the surface layer strong and abrasion-resistant. Once the mix has cooled below 185ºF the binder becomes so viscous that it is difficult for rollers to compact the mix.

The process of determining the proper amount of asphalt cement to add to a given dense gradation of aggregate is called mix design. Mixes designed according to Superpave criteria (*NYSDOT Standard Specifications, Section 402*) are rapidly replacing mixes designed using Marshall criteria in New York State. Samples of the mix are tested in a specified way to ensure that they will have adequate strength and durability.

Asphalt concrete is typically used in one of four ways:

- Base courses
- Binder courses
- Shim courses (truing and leveling - T&L)
- Surface courses

Base course

A base course typically will have a very large maximum particle size, up to 1½ inches (37 mm). Some agencies prefer to use dense-graded base courses, others prefer open-graded base courses. If open-

graded materials are used, careful attention must be given to allow the layer to have free drainage from its edges, otherwise water may become trapped in the layer, leading to its early failure.

Binder course

Binder courses are dense-graded, with a maximum particle size of about one inch (25 mm). Such materials provide a strong, low-permeability layer beneath the surface course. A binder mix is not considered suitable for traffic, however, because it is so coarse-textured that tire noise would be excessive.

Shim course (truing and leveling - T&L)

Shim mixes are very fine-grained. Basically, they are a mix of sand and asphalt. They are used for leveling ruts and for preparing an old surface to receive an overlay. They can be placed to a feather edge when necessary.

Surface course (top)

Surface course mixtures are designed to be strong and highly skid resistant. To reduce polishing, high friction aggregates are blended into the coarse aggregate.

Purchasing hot-mix asphalt concrete

Local road agencies should purchase hot-mix asphalt concrete according to the specifications of NYSDOT. NYSDOT invests a great deal of effort to ensure the highest quality in state-approved mixes.

Ordering standard mixes is relatively easy. The following table shows the standard mixes and their intended uses.

Table 13. NYSDOT standard mixes

Asphalt mix type	Nominal maximum particle size	Standard mix type numbers	Intended use
Base	1½" (37.5 mm)	Type 1	Dense graded base for general use
	1½" (37.5 mm)	Type 2	Open graded base for permeable base
Binder	1" (25 mm)	Type 3	Dense graded binder for general use
Shim	⅛" (3.2 mm)	Type 5	Fine mix for shimming ruts and leveling
Surface	½" (12.5 mm)	Type 6	Dense graded top course
	¼" (6.3 mm)	Type 7	Fine dense graded top course

Source: New York State Department of Transportation Standard Specifications, Section 403

Ordering Superpave mixes is a bit more difficult. This is due to different needs for the mix plant and the paving construction operations. The mix plant needs to know the mix type, maximum particle size, expected traffic volume, coarse aggregate friction requirements, and the asphalt binder to be used. The paving crew needs to know the mix type, compaction requirements, coarse aggregate friction requirements, and quality control adjustments.

For low-volume roads in New York State use *words* to order what you want. The numbers on any tickets can be checked versus NYSDOT specifications. Although there are lots of choices, on low-volume roads the number of variations is relatively small.

Mix type - These are the same mix types as for the standard mixes. The choices are: base (dense or open graded), binder, shim, and surface.

Maximum particle size - Again, this is similar to the standard mixes. Generally for each mix type there are only one or two choices for each mix type.

Traffic volume - This is the total number of ESALs expected over the life of the pavement. Since the specifications are written to cover state highways, there are a total of five levels of traffic in the Superpave system. For local roads the "< 0.3 million and 0.3 to 1.0 million" ESAL ranges are the most common traffic volumes. Ordering a higher traffic level mix will actually create problems. The mixes for higher traffic levels are harsher and prone to raveling if there is not enough traffic.

Coarse aggregate friction - For local roads the only critical item is if the mix will be placed on the surface. If the mix is a surface mix the friction of the particles needs to be higher.

Compaction requirements - There are four compaction levels but for low-volume roads the two choices are: density monitoring with a nuclear gauge or just measuring the number of roller passes.

Binder type - Asphalt cement, now called Performance Graded (PG) binders, is selected on the basis of climate and traffic at the location where it will be used. An example of a PG binder designation is **PG 64-28**. The first number, 64, is the high temperature in degrees Celsius that the pavement is expected to reach. The second number, -28, is the lowest service temperature expected. PG 64-28 asphalt is *soft* enough to resist low temperature thermal cracking down to a temperature of -28°C (-18°F), but *stiff* enough to prevent a pavement from rutting due to traffic during a very hot week when pavement temperatures reach 64°C (147°F).

NYSDOT has narrowed the potential PG binders down to just a few. Following are the common grades of PG binders used in New York State. Minor changes in the naming scheme are due in 2014.

Table 14. Common grades of PG binders used in New York State

Grade	Use
PG 58-34	New pavement, very cold environment
PG 64-22	Common general purpose grade, standard mixes
PG 64-28	Upstate New York
PG 70-22	Normal paving, downstate
PG 76-22	High traffic conditions, downstate

Generally, only one or two different binders will be used in a given area. Talk with the asphalt mix supplier to choose the right binder.

To order from a hot mix plant, you need to know the mix type, maximum particle size, traffic volume, coarse aggregate friction, and binder type. You should let the contractor know what the compaction requirements are. As shown in Table 14, there are not that many choices for low-volume roads. To order a binder on a low-volume road in upstate New York, you might ask the plant for the following:

- *Binder course, 19.0 millimeter, < 0.3 million ESAL, no friction requirement, PG 64-22 Binder*

You could then let the contractor know if you want the density measured with a nuclear gauge. If not, assume the number of roller passes will control the density.

Table 15. NYSDOT Superpave mixes for low-volume roads

Asphalt mix type	Nominal maximum particle size	Superpave mix numbers	Intended use
Base	37.5 mm	402.37Y90R	Dense graded base for general use
	37.5 mm	402.01Y90R	Open graded base for permeable base
Binder	25 mm	402.25Y90R	Dense graded binder for higher traffic volumes
	19.0 mm	402.19Y90R	Dense graded binder for lower traffic volumes
Shim	3.2 mm	402.01Y90R	Fine mix for truing and leveling
	3.2 mm	402.05890R	Fine mix for shimming
Surface	12.5 mm	402.12Y30R	Dense graded top course
	9.5 mm	402.09Y30R	Fine dense graded top course

Source: New York State Department of Transportation Standard Specifications, Section 402
Key to Superpave Mix Numbers
'Y' is the compaction method, needed to order mix, and is replaced with a '7' or '8' in the mix #:
7: Density monitoring with a nuclear gauge (for example: 402.01790R)
8: Controlled by the number of roller passes (for example: 402.05890R)

Paving with hot mixes

Figure 12 shows how the temperature of a mix drops when the mix is placed. As this figure shows, a 2-inch pavement laid on a base at 60ºF cools to 185ºF in about 18 minutes if the mix is initially at 300ºF. At a base temperature of 90ºF, cooling takes 23 minutes. The temperature of the base is important. It determines how much time a crew has to place and roll the mix. Air temperature is also important. The two determine how late in the season one can pave and expect good results.

Hot-mix with a nominal maximum size of ¾-inch (19 mm) is commonly used for rural, local roads. Mixes with a nominal maximum size of ½-inch (13 mm) are popular for urban, local roads. The latter mix is preferred in the urban environment. It has a finer texture resulting in less tire noise. In rural areas, where speeds tend to be higher, the coarser mix provides for better drainage beneath the tire.

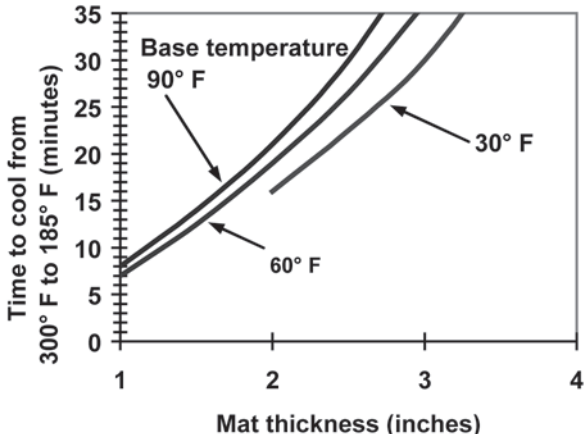

Figure 12. Time/temperature relationship of asphalt mixes

As a rule, Columbus Day (October 12) should be the end of the hot-mix paving season in New York State. Any later and you run the risk of not having enough time to allow you to compact the mix properly.

PAVEMENT MAINTENANCE

Figures 13 and 14 show the benefits of routine maintenance every year, or as necessary, as opposed to the strategy of waiting and doing nothing until it is too late. The five basic treatment strategies include:

- Routine maintenance
- Preventive maintenance
- Defer action
- Rehabilitation
- Reconstruction

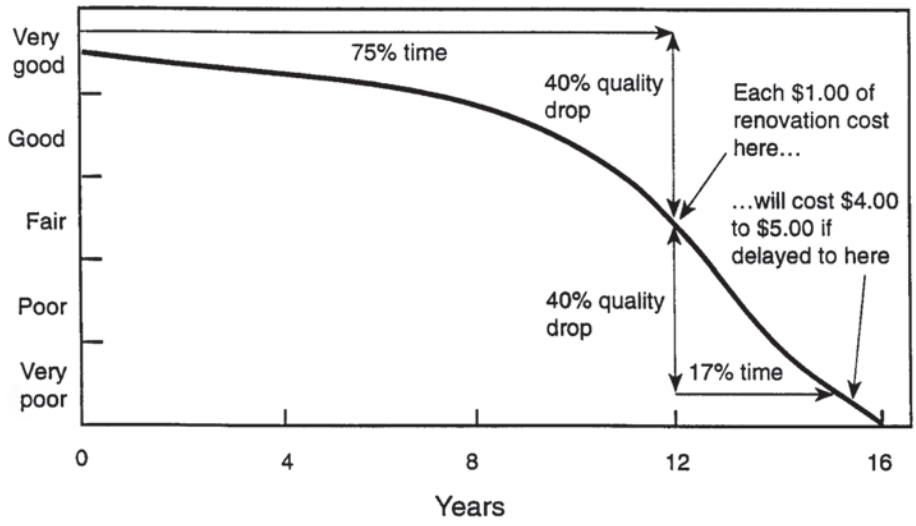

Figure 13. Pavement deterioration/rehabilitation cost relationship

Usually by the time you resort to rehabilitation or reconstruction, it is too late. The costs to bring the road back to a usable condition are five or more times higher than if routine and preventive maintenance had been done on a regular basis.

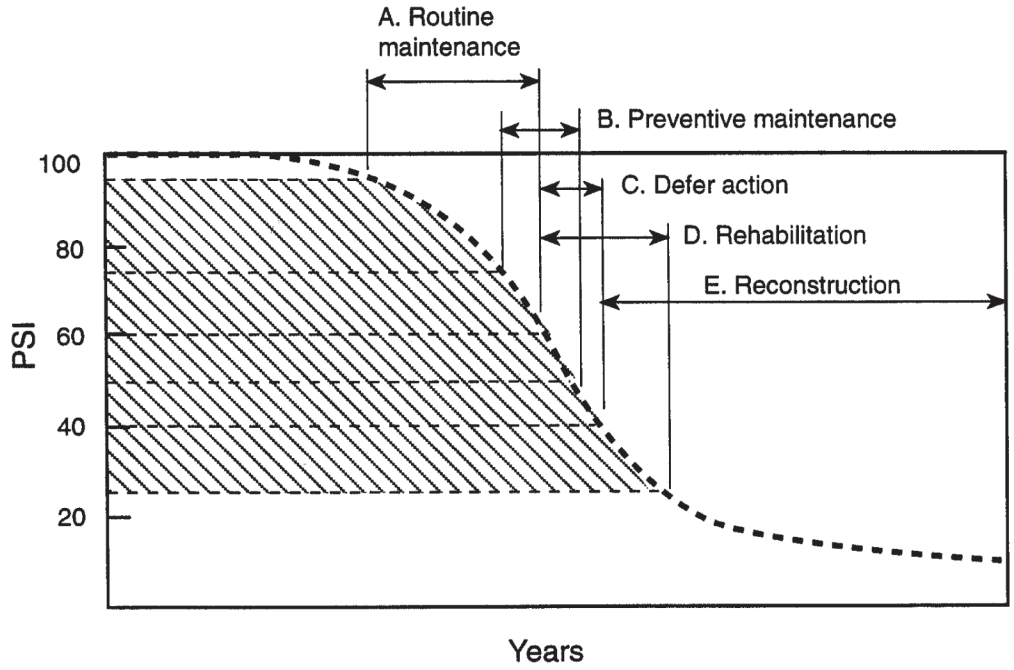

Figure 14. Conceptual relationship between the five treatment strategies
(PSI = pavement serviceability index, a measure of ride quality)

MAINTENANCE REPAIR

One of your most common complaints is potholes. Potholes are evidence of a pavement that is approaching the end of its useful life. The proper repairing of potholes is costly and time consuming. Usually potholes are caused by drainage problems in the subbase and occur most frequently in the spring. The best way to repair potholes is to solve the drainage problem.

Experience and testing has shown that the better the material you use to repair the pothole the longer it will last. Many new products have arrived on the market to repair pavements. Although they cost more than standard cold-mix, they last far longer.

Emergency patching of potholes, when they form in the late winter, is only a temporary measure. Later, when plant materials are available and the weather is conducive, you must remove the temporary patch and make a permanent repair. If you do not do this, the pothole will usually reappear next year.

Detailed information can be found in the two manuals, *Manual of Practice: Materials and Procedures for Repair of Potholes in Asphalt-Surfaced Pavements*, and *Materials and Procedures for Sealing and Filling Cracks in Asphalt-Surfaced Pavements*, published by the Federal Highway Administration. These are both available on the Web: *www.fhwa.dot.gov/research/publications/technical*.

PAVEMENT REPAIR ALTERNATIVES

There are a number of pavement repair alternatives that can be done from nothing to total reconstruction. The alternatives range from no funding to major funding to reconstruct a road.

One of the major responsibilities of a highway superintendent is to regularly observe what is happening to your various roads. Are they showing little wear? Are they showing serious structural problems? Are they at the end of their useful life? Once you determine that there is a problem, you need to establish the probable cause of the pavement distress or failure.

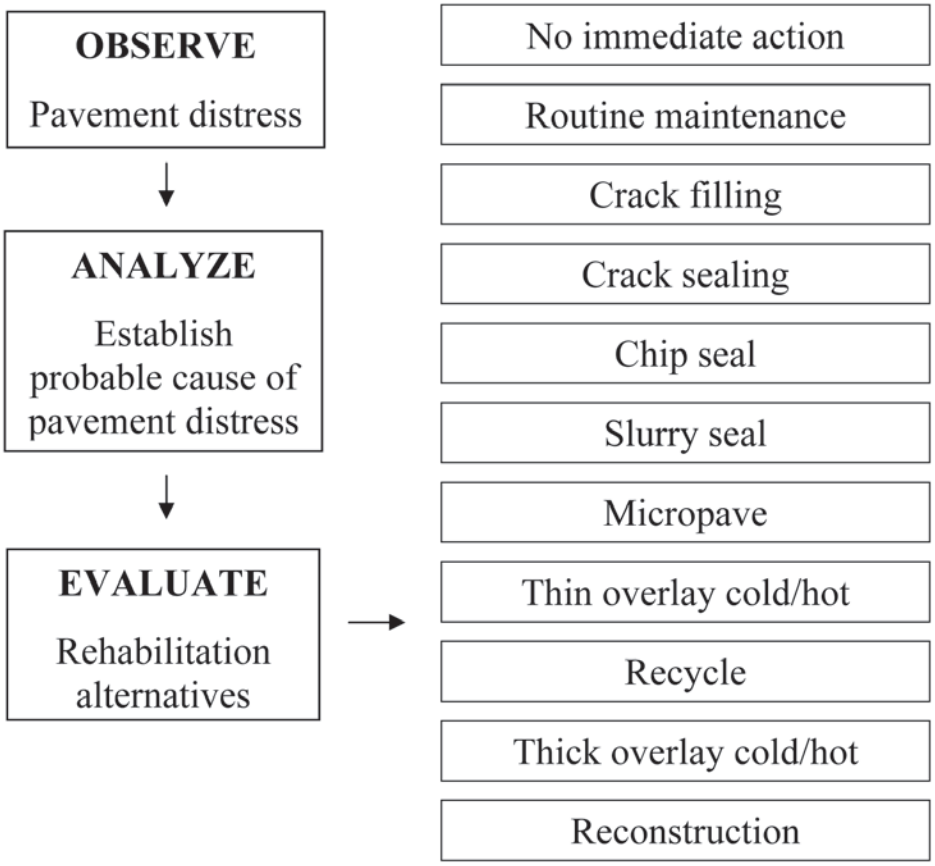

Figure 15. Pavement repair alternatives

There are a variety of options available to you once the problem is identified. Solutions include:

- **Crack filling** - Applying asphalt crack filler into pavement cracks to prevent the intrusion of surface water into the pavement structure.
- **Crack sealing** - Used prior to new overlays or to extend the life of an existing surface by sealing against the intrusion of surface water. Crack sealing involves a hot asphalt with fibers, applied as a thin film over cracks and designed to maintain flexibility in all weather conditions.

- **Chip seal** - A surface treatment in which a pavement surface is sprayed with asphalt emulsion and then immediately covered with aggregate and rolled. Chip seals are used primarily to seal the surface of a pavement with non load-associated cracks and to improve surface friction, although they also are commonly used as a wearing course on low-volume roads.
- **Slurry seal** - A mixture of sand and asphalt emulsion that is applied as a very thin layer to seal fine cracks and improve surface friction.
- **Microsurfacing** - A tough and durable surface treatment material which can restore the original service properties to worn but structurally sound pavements. Its properties are based on a blend of selected crushed aggregates and sophisticated chemical formulation of asphalt cements, emulsifiers, adhesives, and natural latex.
- **Overlays** - One or more courses of asphalt construction on an existing pavement. The overlay generally includes a leveling course, to correct the contour of the old pavement, followed by a uniform course or courses to provide needed thickness. Pavement condition and estimates of future traffic dictate the thickness of overlays.

  A **thin overlay** is used to correct minor surface deficiencies, will prolong good pavement performance, smooth the surface, and make the road safer for drivers. A **thick overlay** is necessary for correcting structural deficiencies to strengthen the pavement structure enough to accommodate the traffic using it for the selected design period. A **tack coat** should always be used to bond any overlay to the old pavement surface.

- **Recycling** - All types of asphalt pavements can be recycled. A candidate for recycling will have severe cracking and disintegration, such as potholes. Frequently the poor condition is due to the pavement being too thin and weak for the traffic. Poor drainage can also accelerate the rate and amount of pavement deterioration.
- **Reconstruction** - Pavement reconstruction is essentially "take it up, throw it away, and start over." The existing pavement is such that it can no longer serve a useful purpose and other treatments are not cost effective.

ROAD SECTIONS

Every municipality should have a typical cross section for the types of roads in its jurisdiction. These sections can be used by crews to rehabilitate or reconstruct a road or to construct new roads in subdivisions. The thickness of the layers would be based on local experience.

Figures 16 and 17 show a section for a paved road and a gravel road. For the most part, the sections are similar. The basic difference is the cross slope from the centerline across the pavement and shoulder to the ditch.

The paved road has a slope of ¼ inch/foot on the traveled way, and a slope of ¾ inch/foot for the shoulder. The gravel section has a slope of ¾ inch/foot on the traveled way and a slope of 1½ inches/foot for the shoulders.

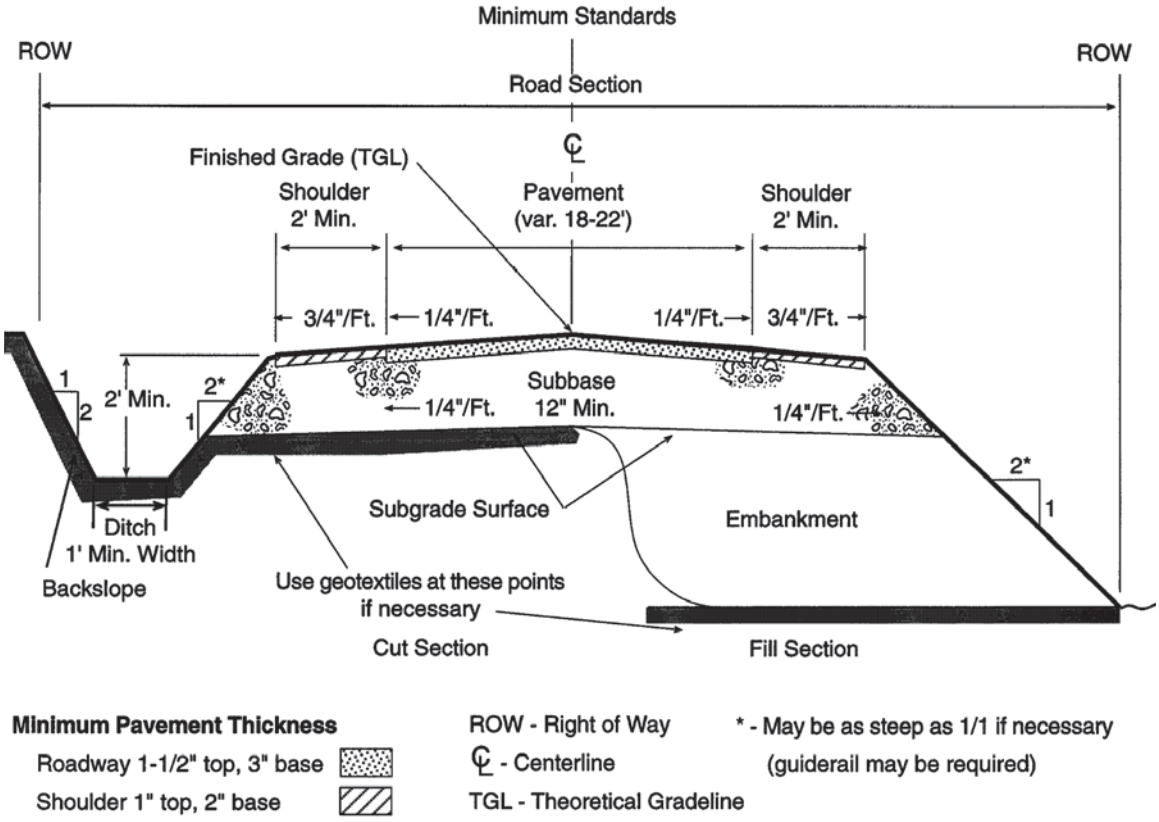

Figure 16. Desirable minimum dimensions for PAVED surfaces

The paved section has flatter slopes because water flows more easily across the blacktop surface. The gravel section is steeper in an attempt to move the water faster and prevent it from moving vertically through the gravel material. Excess water that is introduced into the surface gravel and base gravel will cause future problems with the road.

If your municipality has not adopted typical road sections, present your Board with proposed sections for adoption. These sections will then be required for all new subdivision streets and provide uniformity in construction. If you have poor soils, consider using a thicker subbase course or consider a subbase with a section of crusher run above the gravel. If you have heavy truck traffic, be sure to beef up the pavement section.

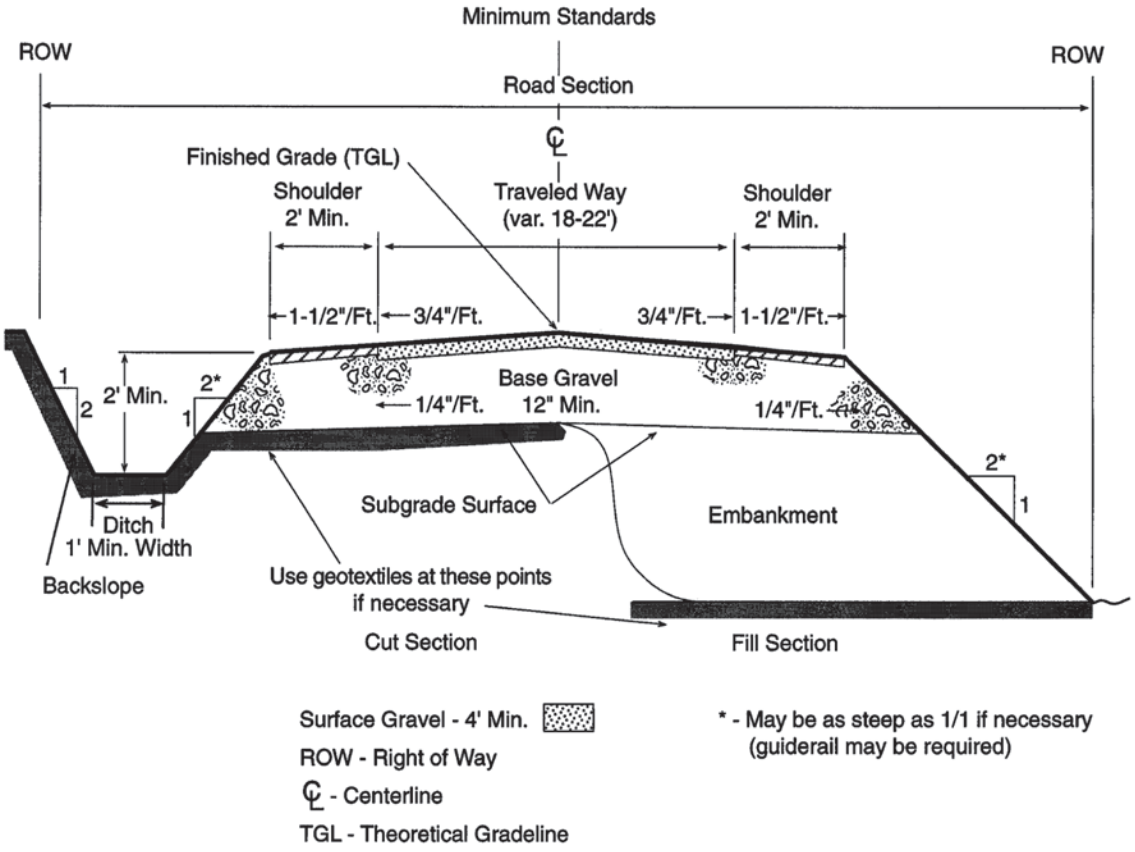

Figure 17. Desirable minimum dimensions for GRAVEL surfaces

GEOTEXTILES

Soil is the foundation of all roads. Vehicle loads are transmitted directly to the roadbed. If adequate support does not exist, severe rutting or washboarding will result.

When roadbeds are composed of fine-grained materials (i.e., sand, silt, and clay), the stability is dependent on the moisture content. In areas where there is poor drainage it is almost impossible to keep the roadway from rutting. Even if gravel is added at these locations the roadway may experience rutting shortly after a rainfall. Installing a geotextile, or fabric as it is sometimes called, along with 12 inches of “clean” gravel, will eliminate the problem in most cases. If your loads are very heavy you will want to make the gravel course 18 inches thick. The base course of crushed stone and surface paving are then added.

An option to help alleviate this problem is to install geotextiles. Figures 16 and 17 reference geotextiles under the gravel base “as necessary.” Geotextiles are materials used to separate layers of soils and to prevent fines from migrating into the base gravel material. Geotextiles are woven or non-woven. The woven textiles resemble burlap and come in a variety of colors and styles.

The non-woven textiles are made under heat and pressure from various polymers and have a texture similar to felt.

Geotextiles are generally used to separate fines in the subgrade from migrating into the base gravel. Generally, woven geotextiles are used for separation, erosion control, and reinforcement, while non-woven geotextiles are used primarily for paving and drainage applications. They can also be used to reinforce and stabilize the roadway from rutting.

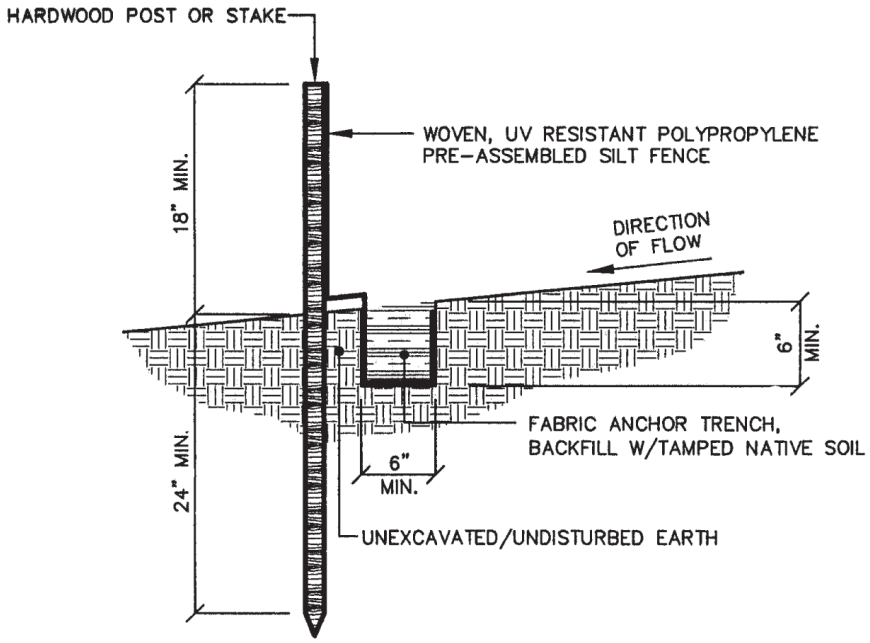

Figure 18. Silt fence detail

Notes:
1. Post or stake to be spaced at ten feet on center, maximum. In high runoff areas closer spacing may be required. To be positioned on the downstream side of fence.
2. Silt fence shall be installed prior to any clearing, grubbing, or grading on the site.
3. A maximum of 100 LF of silt fence shall be installed per 0.25 acre of drainage area.
4. Inspect all erosion & sediment control barriers daily. Maintain the integrity of the barriers throughout the construction. Repair or replace barriers, as required. Barriers shall be removed when the site has been stabilized and the grass growth deemed acceptable.

Silt fences

Another use of geotextiles is to use them as erosion control devices for silt fences. Figure 18 shows standard detail and notes for a silt fence used in an erosion control application.

This detail is used to control soil erosion while working in an area that is subject to soil washing out of the construction site. If your municipality is an MS4 (municipal separate storm water sewer system) community, you will be required to provide erosion control when working on road and highway projects.

Remember in today's society there are many local citizens who watch your every movement to ensure that you are constructing your projects in accordance with all state and local rules and regulations.

5 - Drainage

You have probably heard the expression realtors use regarding property, “It’s location, location, location.” In a highway it’s “drainage, drainage, drainage.” If you can drain it, you can maintain it!

Drainage cannot be over emphasized. Water can saturate your base, erode your slopes and ditches, ruin road surface and shoulders, and during the freeze-thaw cycle, destroy the entire road structure.

This chapter reviews the need to provide a “way out” for water and how to solve road problems attributed to drainage issues.

VEHICLE LOADS

First let’s talk about vehicle load effects on saturated subgrades. Recall Figures 10 and 11 on page 29. We are going to apply those loads to a subgrade that is too wet! This is a common occurrence during the spring.

Figure 19 shows a cracked pavement with lots of access for water to get into and saturate the base. Figure 20 shows the effect of a load wheel on such a pavement. The next step is potholes and premature failure.

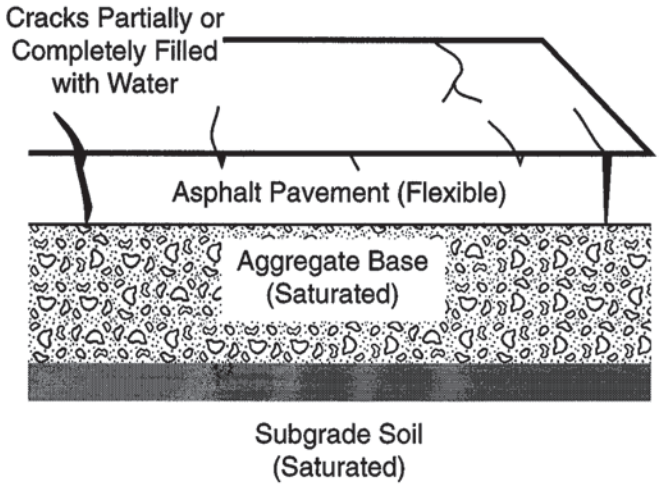

Figure 19. Unloaded asphalt cement pavement

Since we cannot eliminate water from our roads, we must remove the water. Water as rain, snow, runoff, or other source has detrimental effects on our pavement structure. Water can:

- Reduce soil strength
- Erode surface soils
- Freeze and expand
- Create potholes

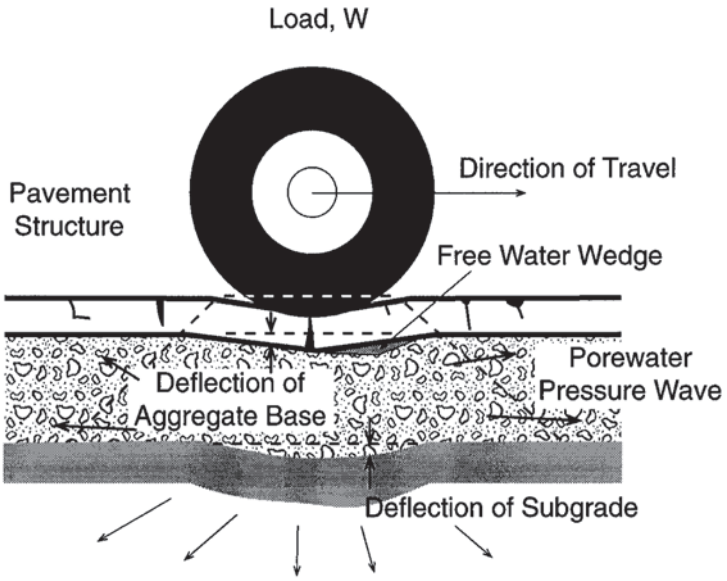

Figure 20. Action of free water under dynamic loading

SURFACE WATER

Surface water is the water flowing or standing on the earth's surface. As far as a roadway is concerned we need to think in terms of how we can quickly cause surface water to run off the road and away from it.

A number of things will help to drain the water off the road surface:

- Road cross-section/crown
- Eliminating depressions
- Ditches
- Culverts
- Sealing cracks and filling potholes

ROAD CROWN

The cross slope should be between ⅛ and ¼ inch-per-foot for asphalt roads, and between ½ and ¾ inch-per-foot for aggregate roads. The cross slope on the shoulder is a little steeper than the road itself, because the shoulder is usually a rougher surface and needs the steeper slope to drain properly.

Potholes in aggregate surface roads can be directly related to road crown. Roads with no crown will experience the most severe pothole problems. Gravel roads with a ¾ inch-per-foot crown will have fewer pothole maintenance problems.

For asphalt paved shoulders, the slope should be ¾ inch-per-foot. For aggregate surfaced shoulders, the slope should be at least one inch-per-foot. The slopes should not exceed these limits or cars may not be able to steer correctly on the shoulder.

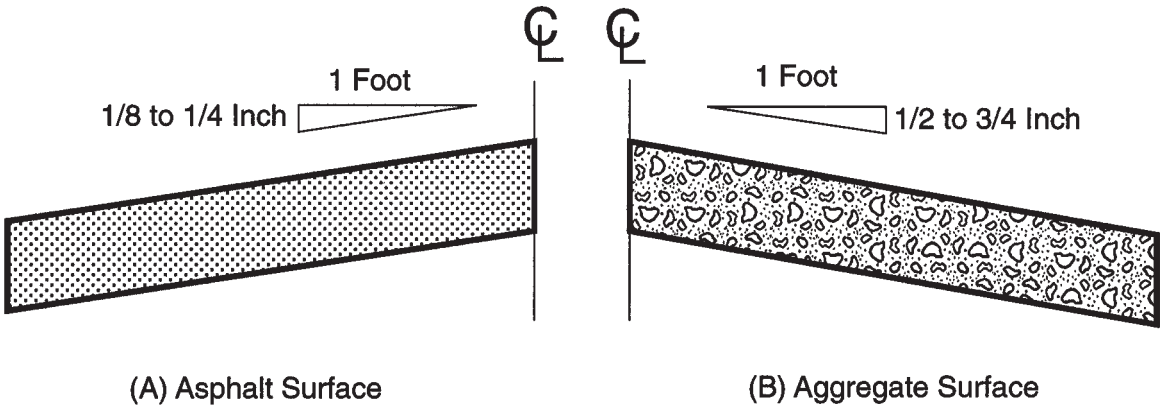

Figure 21. Proper crown for road sections

ELIMINATING DEPRESSIONS

Depressions in the roadway prevent proper drainage and cause pools of water to stand on the road surface after a rain. This standing water seeps into cracks and enters the base and subgrade soils, weakening the structure.

For open-graded mixes, water will permeate the mix and cause weathering and raveling of the surface. Vegetation growing along the shoulder or a ridge of sand left from winter road sanding will cause pooling of the water. These conditions should be eliminated by blading the edge of the road with a motor grader.

DESIGN STORM & STORM RETURN PERIOD

When designing a road drainage system, the amount of runoff that will be needed to be handled must be accounted for in the design. The concept of a *design storm* can be used to determine the amount of runoff.

The design storm is the average time between storms of equal magnitude. Sometimes this average time between storms is called the *storm return period*. A storm which has a 1/25 (4 percent) chance of occurring in a given year is called a 25-year storm. A 50-year storm would be one with a 1/50 (2 percent) chance of occurring in a given year. Since 4 percent is twice 2 percent, a 25-year storm is twice as likely to occur in a given year as a 50-year storm.

If a 50-year storm occurs in a given year, it does not mean another 50-year storm will not occur for 50 years. Each year the chances of a given storm are the same. The size of ditches, culverts and other drainage items should be based upon their ability to handle a given design storm (or storm return period). A greater design storm value (in years) leads to a longer average time between flooding events.

What storm should be used for design? While a larger drainage ditch or culvert pipe seems advantageous, the extra cost may not be justifiable. During heavy rains some flooding will occur. No drainage system can handle every flood. The objective of a highway department is to build a storm system to survive the storm. Table 16 shows the design years for different classifications of roads.

Table 16. Design years for various road types and drainage items

Road type	Culvert	Driveway	Ditches
Town roads/Village streets with low traffic	10	5	5
Town roads/Village streets with high traffic	25	10	10
County roads with low traffic	25	10	10
County roads with high traffic	50	25	25
Arterials (State and very important roads)	100	50	50

Table 17. Maximum allowable flow velocities for various types of ditch linings

Type of lining	Maximum velocity (ft./sec.)
Natural soil linings	
Rip-rap sides and bottoms	15-18
Clean gravel	6-7
Silty gravel	2-5
Silty sand, clay	2-3
Vegetative linings	
Average turf, erosion resistant soil	4-5
Average turf, easily eroded soil	3-4
Dense turf, erosion resistant soil	6-8
Gravel bottom, brushy sides	4-5
Dense weeds	5-6
Dense willows	8-9
Paved linings	
Gravel bottom, concrete sides	8-10
Mortared rip-rap	8-10
Concrete or asphalt	18-20

DRAINAGE DITCHES

Things to know about ditches:

- Keep a uniform grade and check for accuracy - generally one percent minimum
- Keep the shoulder a constant width
- Inspect annually and clean as necessary
- Use fiber mats, seed, and mulch to assist vegetation growth where necessary
- Always dig upstream!

Get easements, if necessary, to allow room for ditches

SIZING A CULVERT

There are several different ways to determine the proper size of a culvert pipe. More details are available in the *Cornell Local Roads Program* workshop manual *Roadway and Roadside Drainage*. The flowing rules of thumb are only guides. There are several sources of help including the Soil and Water Conservation Districts (SWCD). The contact information for each County SWCD is listed in Appendix 4, pages 80-81. In addition, County Highway Departments may have an engineer on staff who can assist, or a consulting engineer may be engaged.

Existing pipes

If the current pipe is adequate and there is no history of flooding, the pipe is probably properly sized. Be sure there are no significant changes in land use that could increase runoff from upstream.

New pipes

For new pipes, small drainage areas can be designed using simple methods. If the watershed area is less than 20 acres, the minimum pipe size should be 8 inches plus the number of acres. As an example, if a watershed is 14 acres, the pipe should be at least 22 (8 + 14). inches in diameter You would round up to the next larger size and use a 24-inch diameter pipe. No pipe less than 18 inches in diameter should be used for a culvert. No pipe less than 12 inches in diameter should be used for a driveway.

Check size of nearby pipes

Look upstream and downstream, and measure the area of the pipes bringing flow to the culvert and the first pipe downstream. The area of the new culvert should be somewhere near the area of the upstream pipes or the downstream pipe. In a driveway this is very simple. If the upstream driveway pipe is 18 inches in diameter and the downstream pipe is 24 inches, the new driveway pipe should be either 18 or 24 inches. If enough cover is available, put in the 24-inch pipe. If there is more than one pipe feeding a culvert you need to be more careful. GET HELP!

CULVERT INSTALLATION AND MAINTENANCE

Culverts are used through roads and driveways to carry stream flow and stormwater runoff so vehicles do not have to drive through flowing water.

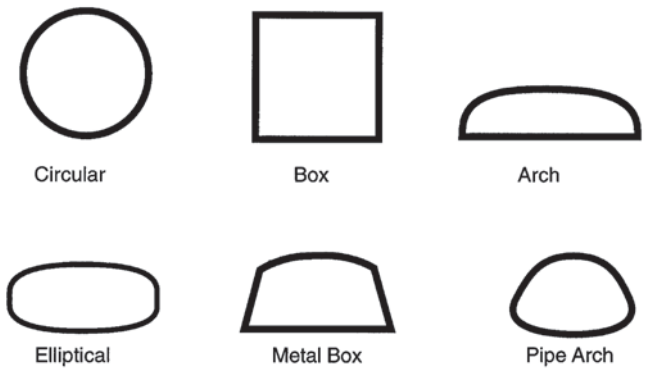

Figure 22. Commonly used culvert shapes

Potential problems

- Sediment problems can develop in waterways downstream of road crossings due to excavation or backfilling operations during installation of culverts.
- Damaged culverts or culverts filled with sediment cannot carry the designed quantity of flow, so water may overtop the roadway, causing erosion and safety problems for vehicles driving through flowing water.
- Significant erosion problems can develop at the outlet of culverts if not properly designed or installed.
- Improperly sized culverts can cause upstream flood problems from water backing up at the road crossing.
- Water quality problems can be created from improper grade control during installation of culverts.

Guidelines

- Culverts should be designed with adequate capacity to carry the ten-year frequency storm runoff, minimum requirement by town regulations, or sized to handle the rates used to design upstream structures. Check with your Soil and Water Conservation District (see Appendix 4, pages 80-81).
- For small watersheds (less than 20 acres), culverts may be sized using the following rule of thumb: culvert diameter (inches) = 8 + acres of drainage. For example, a culvert draining 13 acres of land would need to be at least 21 inches in diameter. Again, check with your Soil and Water Conservation District.
- The design of culverts for watersheds larger than 20 acres should be referred to a professional who is trained in hydrology and hydraulics.

- Culverts draining water from road ditches, areas adjacent to the road, and the road surface itself should be spaced at distances no greater than 500 feet apart.
- All culverts should be a minimum of 18 inches in diameter.
- A minimum of one foot of fill over a culvert is recommended.
- The bottom width of a trench for installing the culvert should be the width of the culvert plus two feet. The trench side walls should be at a 1:1 slope or flatter.
- Properly compact the soil around and over the culvert pipe in six-inch layers to prevent seepage along the pipe and reduce settlement of the road over the culvert. The excavated material should be used for the backfill (to assure uniform frost heave).
- Provide needed erosion control.
- Stabilize the inlet and outlet to protect from erosion.
- Install or conduct maintenance operations during the summer months when streams and brooks are at low flows and when erosion and sedimentation problems are minimal and can be easily solved.

The outlet of all culverts should be protected against erosion and undermining. One method of protection is a stoned outlet or plunge pool. For culvert sizes of 30-inch diameter or less, an outlet pool lined with 6 to 12-inch stone constructed 12 inches deep, two pipe diameters wide, and four pipe diameters long will provide adequate outlet protection. Outlet protection for all culverts larger than 30 inches in diameter should be designed by a professional engineer.

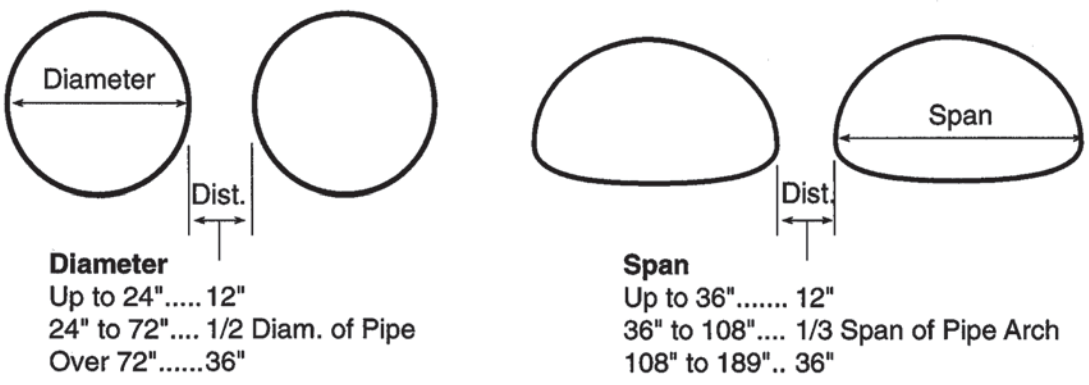

Figure 23. Minimum spacing allowed between multiple pipes

Calculating culvert length

You are rebuilding a section of road and replacing culverts. To figure the correct culvert lengths, here is a handy chart to help:

Table 18. Determining culvert lengths for culverts perpendicular to centerlines only (based on 2 horizontal to 1 vertical slope)

Width (in feet) of road at culvert location (including any shoulders). Culvert will be longer if skewed.

Depth of fill (in feet)	12	14	16	18	20	22	24	26	28	30
2	20	22	24	26	28	30	32	34	36	38
3	24	26	28	30	32	34	36	38	40	42
4	28	30	32	34	36	**38**	40	42	44	46
5	32	34	36	38	40	42	44	46	48	50
6	36	38	40	42	44	46	48	50	52	54
7	40	42	44	46	48	50	52	54	56	58
8	44	48	50	52	54	56	58	60	62	64
9	48	50	52	54	56	58	60	62	64	68
10	52	54	56	58	60	62	64	66	68	70

Example: Road width = 22 feet (including shoulders), Depth of fill = 4 feet. Using the chart, the culvert length must then be 38 feet.

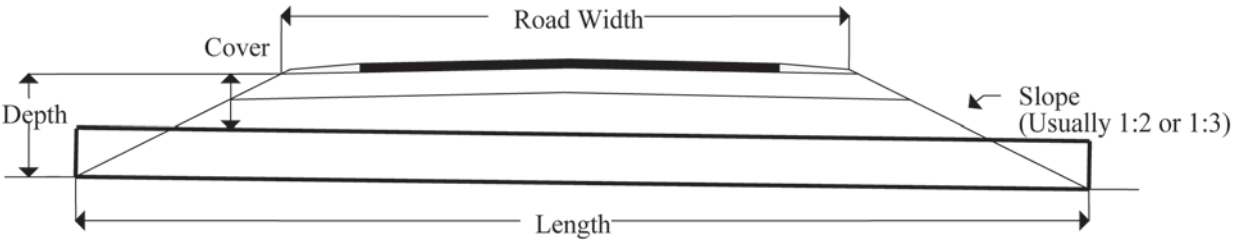

Figure 24. Determining culvert length

'Two horizontal to one vertical slope' refers to the slope of the fill from the shoulder to the bottom of the ditch. With a 2-to-1 slope, the vertical distance is 4 feet and the horizontal distance is 8 feet. With a 3-to-1 slope, the vertical distance is still 4 feet and the horizontal distance is 12 feet.

UNDERDRAIN

Where the water table is high, vertical trenches may be placed on each side of the roadway with drain pipe to lower the water table under the road as shown in Figure 25. Another solution may be to raise the roadbed in the affected area above the water table. Note that the drain tile pictured

will need an outlet in order for the collected water to drain as desired. The drain tile cannot dead-end in poorly drained soil, as this will not provide a satisfactory outlet for collected water.

Edge drains will work more effectively and last indefinitely if washed concrete sand is used as the backfill above and below the pipe.

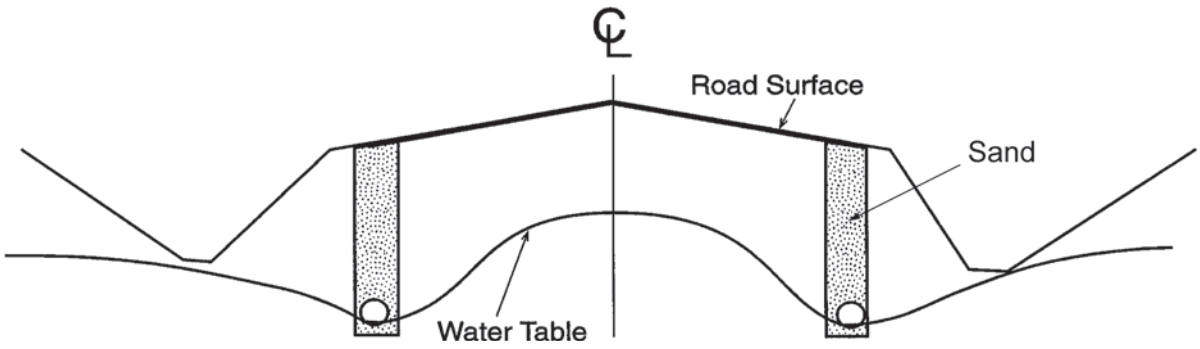

Figure 25. Edge drains

It is common during the course of a subsurface investigation for a highway or during construction to discover springs or other localized areas of seepage in the foundation areas of embankments. These sources of seepage must be tapped and adequately drained if the integrity of the foundation and stability of the embankment are to be maintained. Several typical strategies for accomplishing this objective are illustrated in Figure 26.

The key to successful use of the drainage control measures illustrated in Figure 26 lies in providing the proper combination of high drainage capacity with appropriate filter protection. Often this can be satisfactorily accomplished by constructing the local drains with a core of very high permeability aggregate within an envelope of filter aggregate or drainage fabric. Exercise care in the design, construction, and maintenance of the outlets of these drains.

Using sand to backfill underdrains

Backfilling underdrains needs to be done carefully to avoid crushing the pipe. In addition, the backfill material must be more permeable than the soil in order to allow the subsurface water to flow toward the pipe. This flow, however, will also pull fines toward the drain. This can lead to premature plugging unless a filter is used.

Two different filters can be used to increase the life of the subsurface drain and improve the flow characteristics. Option one is to use a filter fabric wrapped around the trench. In this case, the backfill is usually a pea stone sized gravel. The other option is to use only coarse sand as a backfill. If the gradation is right, the sand will be coarse enough to bridge over the slots in the slotted underdrain pipe and will still be able to act as a filter. No fabric is needed. NYSDOT coarse concrete sand (Section 703-07) meets these requirements for most of the silty gravels found in New York State.

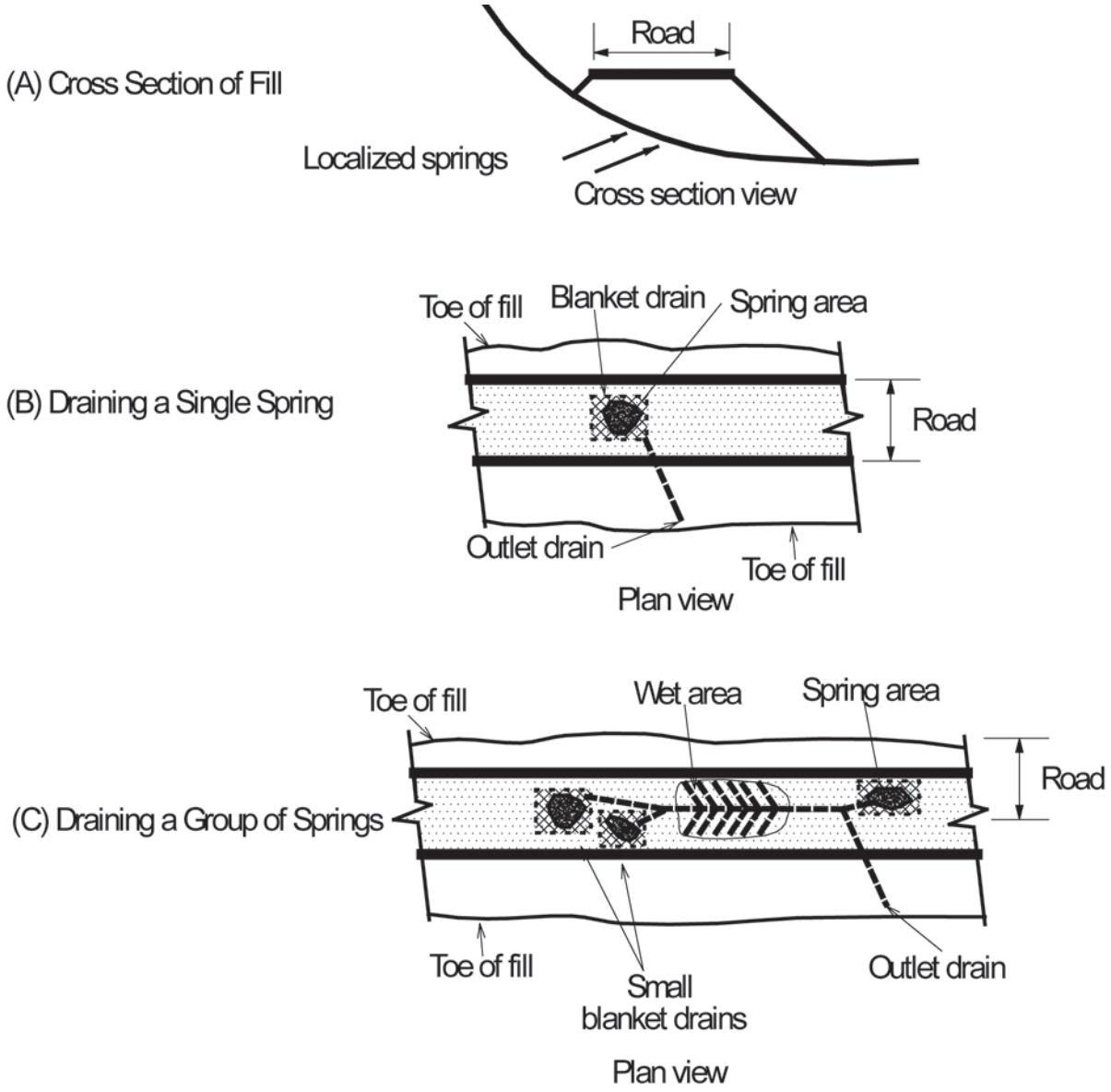

Figure 26. Localized surface drains

FROST EFFECTS ON CULVERTS

Frost heaves are a major problem in climates that have a freeze/thaw season. In New York State this period usually occurs anytime from February 15 to April 1. Sometimes a January thaw will cause frost heave damage to pavement surfaces.

As ice forms in wet soil the expansion and contraction can damage the roadway and culverts. Heave occurs when these three conditions are present:

- Freezing temperatures
- Frost susceptible soil
- Water in the soil

To prevent frost damage you must eliminate one of the three. We cannot control the weather, so we have to either replace the soil or eliminate the water.

Frost heaving causes flexural stress and formation of bending cracks. These will eventually have to be sealed. During the spring melt, the large volume of ice in the ice lenses melts, resulting in excess water in the subgrade. Due to its low permeability the subgrade cannot drain and it weakens. Large deflections and breakup of the road may result.

Water can rise by capillary action from the water table upward into the freezing zone. For some soils the height of rise is considerable, as shown in Table 7, page 19. The smaller the soil particle size, the higher the water will rise above the water table.

Water is pulled up from the water table to form ice lenses. The water is pulled up by capillary action in much the same way as kerosene rises in the wick of a lamp. Water freezes in the large voids first. Then it continues to rise through the smaller openings, allowing ice lenses to form. The depth of frost penetration depends upon a number of things, the most important of which are air temperature, amount of sunshine, surface color, snow cover, soil type, and moisture content.

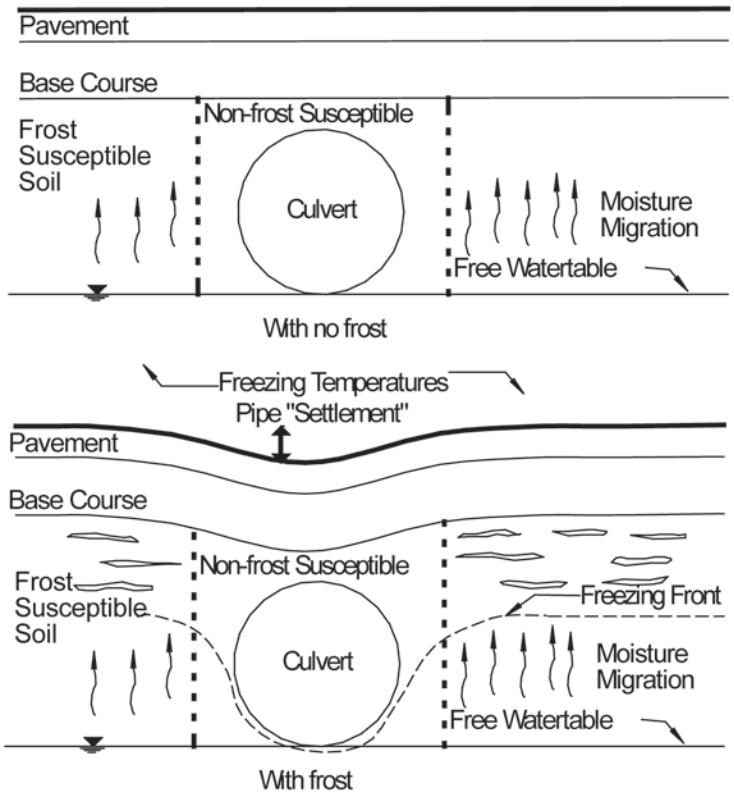

Figure 27. Culvert “settlement” in winter

When installing culverts across a road, consider backfilling the material from the top of the pipe to the bottom of the subgrade with native material. This provides a uniform layer and generally allows the soils to act together and move up and down as one unit. Backfilling with well drained sand or gravel around the pipe lets that area drain freely resulting in little or no vertical movement, unlike that to the left and right of the culvert.

Stormwater Regulations

As part of a Federal EPA program, all municipalities are required to have a general permit for any construction work that disturbs more than one acre of land. While this does not include maintenance activities, there is still a general requirement to maintain good housekeeping practices, even on maintenance activities. In addition, many urbanized areas will need to have a separate permit as a Municipal Separate Storm Sewer System (MS4). To determine if your municipality is in an MS4 area, contact the NYSDEC.

More details can be obtained from the NYSDEC web site: *www.dec.state.ny.us*. Help in developing these permits may also be obtained via the local SWCD.

A list of all of the SWCD offices in New York State, along with their contact information, can be found in Appendix 4, on pages 80-81.

6 - Traffic Signs

Once you have chosen the location of roadway work, selected the materials, decided on a riding surface, and installed your culverts, you still have one task remaining. That task is making sure your roadway and work zones are in compliance with Manual for Uniform Traffic Control Devices (MUTCD). Every highway department should have a copy of the MUTCD and use it to determine sign types and locations.

In New York State, the MUTCD is the combination of the 2009 Edition of the National Manual on Uniform Traffic Control Devices and the New York State Supplement to the National MUTCD. Both are available on the internet. Hard copies of the National MUTCD can be ordered from organizations such as the American Association of State Highway and Transportation Officials AASHTO), the Institute of Transportation Engineers (ITE), and the American Traffic Safety Services Association (ATSSA). Hard copies of the New York State Supplement are available from West Group Publishers: (1-800-344-5008 or *http://west.thomson.com*). When ordering from West Group, the Supplement should be referred to as "Transportation Title 17B (NYCRR)."

The MUTCD is the official document for direction and guidance in the use of traffic control devices. Its purpose is to establish uniformity throughout the state. It also provides consistency with the National MUTCD and promotes uniformity nationwide. Deviation from the MUTCD could greatly increase your liability in accident cases. It is your responsibility to follow the MUTCD without fail. It is not a legal excuse to say you cannot afford a copy or that you have never heard of it.

Table 19 shows the different sections of MUTCD that deal with the types, sizes, colors, and locations of all signs and pavement markings, and work zone safety.

Table 19. Sections of MUTCD that deal with signs, pavement markings, and work zone safety

Manual on Uniform Traffic Control Devices	
Part 1	General Provisions
Part 2	Signs
Part 3	Marking
Part 4	Highway Traffic Signals
Part 5	Traffic Control Devices for Low-Volume Roads
Part 6	Temporary Traffic Control
Part 7	Traffic Control for School Areas
Part 8	Traffic Control for Railroad and Light Rail Crossing
Part 9	Traffic Control for Bicycle Facilities

The *Traffic Sign Handbook for Local Roads, NYS Edition* (CLRP publication No. 11-07), available from the *Cornell Local Roads Program* (CLRP), is adapted from the MUTCD. The *Traffic Sign Handbook* is meant to be a field companion to MUTCD. It is a training manual, not a standard, specification, or regulation, nor may it be read into evidence in New York State courts.

New York State switched to the use of the National MUTCD and NYS Supplement in September of 2007. As your order new signs, be sure to upgrade to the newer standards. The NYS Supplement includes some signs not in the National MUTCD.

SIGNS

For a traffic control device to be effective, it must follow these basic principles:

- Fulfill a need
- Command attention
- Convey a clear, simple meaning
- Command respect
- Give adequate time for response

In addition, there are certain basic requirements for the use and placement of traffic control devices.

- Design - standard colors, shapes, etc.
- Placement - visible and in a non-hazardous location
- Operation - must be in accordance with regulations
- Maintenance - good visible signs during the day and at night
- Uniformity - consistent with regulations to provide uniform information to all drivers

The sign size, sign location in the right-of-way, height and longitudinal placement, and advance posting distance are all specified in the MUTCD. Failure to follow the specific placements of signs could result in liability to your municipality.

Retroreflectivity

In order for signs to be seen at night, they need to reflect the light of the passing vehicles back toward the driver. This is done with embedded beads, prisms, and other materials that are part of the sign sheeting. This *retroreflectivity* allows the driver to see a sign when the headlights of the vehicle strike it. If the sign cannot be seen at night, it has lost its retroreflectivity and should be replaced as soon as possible. In some cases, such as stop signs, the sign should be replaced immediately. All permanent traffic signs must be retroreflective so that they have essentially the same appearance day or night. Black portions of a sign face need not be reflectorized. Materials used for signs should provide nighttime visibility that is comparable to daytime visibility. In order to ensure that your signs retain their reflectivity for the longest time possible, consider purchasing the best sign material available. Examples of reflective sheeting include: engineering grade, high intensity, Type 7500, and several types of Diamond Grade.

Drive all your roads at least once per year, during a variety of weather conditions, and during the day as well as at night, and make a visual inspection of all your signs to be sure they are

effective, visible, legible, retroreflective, and meet all required standards. Replace all defective signs immediately. Keep clear and detailed records of these inspections and all sign maintenance and replacements. A new standard released in 2009 will mandate the minimum levels of retroreflectivity and allowable inspection and maintenance techniques.

There are three basic types of signs that affect vehicle and pedestrian movements. These include:

Regulatory signs

Regulatory signs inform the traveler of traffic laws or regulations such as speed limits, right-of-way designation, and stop signs. These signs should be placed whenever needed to meet this purpose, but unnecessary signing should be avoided. For example, STOP signs should not be used for speed control. Regulatory signs need a law or local ordinance to be enforceable.

Most regulatory signs are rectangular, taller than they are wide, with black text on a white background. There are a few exceptions, such as stop and yield signs.

Warning signs

Warning signs are used when necessary to warn traffic of existing or potentially hazardous conditions on or next to a roadway. This may call for reduced speed or a maneuver in the interest of the safety of the driver or other vehicles or pedestrians. Properly used, warning signs can significantly reduce crash rates involving the condition for which the warning sign is posted. Warning signs should only be used if needed. Unnecessary use tends to breed disrespect for all signs. If the condition requiring a warning sign can be removed, the sign should be removed once the hazard is gone.

Generally, all warning signs shall be diamond shaped, yellow with black lettering or diagrams. They must be erected in compliance with the MUTCD. Warning signs are *advisory only*, as opposed to regulatory signs which mandate compliance. Warning signs include railroad crossings, work zone signs, bicycle, handicapped, and schools.

Once a condition has been identified to require a warning sign, the location of the advance posting distance is determined by the prevailing approach speed and the action required to respond to the condition. There are two broad conditions for determining the advance posting distance.

- **Condition A** signs warn of conditions that require or may require speed reduction and lane-changing in heavy traffic. These signs are not typically found on most local roads.
- **Condition B** signs warn of conditions that require a driver to decelerate to a listed advisory speed. In the case of signs such as stop ahead or intersection, the advisory speed is 0 mph (or stopped).

Table 20 shows the advance posting distance for Condition A and B signs. Some signs do not fall into either condition. In those cases, the information on posting is provided by the relevant section of the MUTCD.

Table 20. Advance posting distances for Condition A & B signs (Table 2C-4 from the NYS Supplement)

Posted or 85th-Percentile Speed (mph)	Advance Placement Distance (ft)[1]																
	Condition A: Speed reduction and lane changing in heavy traffic[2]	Condition B: Deceleration to the listed advisory speed (mph) for the condition[4]															
		0[3]	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75
20	410	115	110	105	90	75	-	-	-	-	-	-	-	-	-	-	-
25	515	155	160	150	135	120	95	-	-	-	-	-	-	-	-	-	-
30	620	200	205	195	185	165	140	110	-	-	-	-	-	-	-	-	-
35	720	250	255	245	235	215	190	160	130	-	-	-	-	-	-	-	-
40	825	305	320	310	295	280	255	225	190	150	-	-	-	-	-	-	-
45	930	360	380	370	360	340	315	285	255	210	165	-	-	-	-	-	-
50	1030	425	455	450	435	415	390	360	330	285	240	185	-	-	-	-	-
55	1135	495	530	520	505	490	460	435	400	355	315	255	205	-	-	-	-
60	1280	570	605	595	585	565	540	510	475	435	390	335	280	220	-	-	-
65	1365	645	670	690	675	660	630	605	570	525	485	425	375	315	240	-	-
70	1445	730	785	775	765	745	720	690	660	615	570	515	460	400	325	260	-
75	1545	820	880	870	855	840	810	785	750	705	660	605	550	495	420	350	275

Notes:

1 The distances have not been modified to account for sign legibility.

2 Typical conditions are locations where the road user must use extra time to adjust speed and change lanes in heavy traffic because of a complex driving situation. Typical signs are Merge and Right Lane Ends. The distances are taken from the 2001 AASHTO Policy, Exhibit 3-3, Decision Sight Distance, Avoidance Maneuver E.

3 Typical condition is the warning of a potential stop situation. Typical signs are Stop Ahead, Yield Ahead, Signal Ahead, and Intersection Warning signs. The distances are taken from the 2001 AASHTO Policy, Stopping Sight Distance, Exhibit 3-1.

4 Typical conditions are locations where the road user must decrease speed to maneuver through the warned condition. Typical signs are Turn, Curve, Reverse Turn, or Reverse Curve. The distances are determined by providing a 2.5 second PIEV time and a vehicle deceleration rate of 10 ft/second^2.

The values in Table 20 are suggested minimum advance posting distances on essentially level approaches for various approach speeds and, where needed, advisory speeds. Advance posting distances should be increased on downhill approaches since braking distances will be longer. On steep upgrades the values may be decreased. For further information see section 2C of the MUTCD or contact the NYSDOT Traffic Engineering and Safety office for your region, the *Cornell Local Roads Program*, your county highway superintendent, or a traffic engineering consultant.

Guide and information signs

Guide and information signs help drivers reach their destination. They include route markers, destination signs, and information signs. They have green, blue, or brown backgrounds and white legends.

Safe speed advisory signs

Advisory speed plates added to curve warning signs provide additional protection for the driver. The advisory speed plate may be used, with warning signs, to show the maximum recommended safe speed around a curve or through a hazardous location. See the MUTCD or the *Traffic Sign Handbook* for a list of signs that can be used with advisory speed panels. Do not use it alone, and do not use with any sign other than a warning sign. Mount it below the standard warning sign. Do not erect an advisory speed plate until the recommended safe speed has been determined by an accepted traffic engineering procedure. The procedure for determining maximum safe speed on horizontal curves, using a ball bank indicator, is described below.

Advisory speed panels are required if the advisory speed for the curve is less than the speed limit. For safe speed sign checks, you should estimate the approximate safe speed by making several trial runs along the curve. The test runs will determine the exact speed required to swing the ball off center to the degree specified for various speed ranges. This is a safe speed for the curve, and will provide you with an advisory speed to add to the warning sign. To perform this test in the field requires a driver and an observer to record the data. More information can be found in the *Traffic Sign Handbook*, or in the CLRP workshop manual *Traffic Signs and Pavement Markings*.

WORK ZONES

Work zones should be planned. Avoid the situation where you try to get something done ASAP without any regard to safety either for your personnel or the traveling public. A work zone plan is essential for any job, no matter how large or small. The work zone should be planned and supervised by an experienced supervisor. Your goal is to keep traffic moving safely and provide a safe place to work.

Work zone safety devices must be used correctly. They must meet the requirements of the MUTCD. They must plainly show the driver what to expect and where to proceed. Signs should be covered when not in use. Work zone signs, barrels, cones, etc., must match the situation. For example, don’t use a “flagger ahead” sign if there is no flagger.

Work zone warning signs are diamond shaped with a bright orange background and black lettering or symbols. Work zone guide signs are rectangular signs with orange backgrounds

and black lettering or symbols. These include detour signs, which are required by law whenever a road is closed to traffic. They must be erected in compliance with the MUTCD, and be reflectorized.

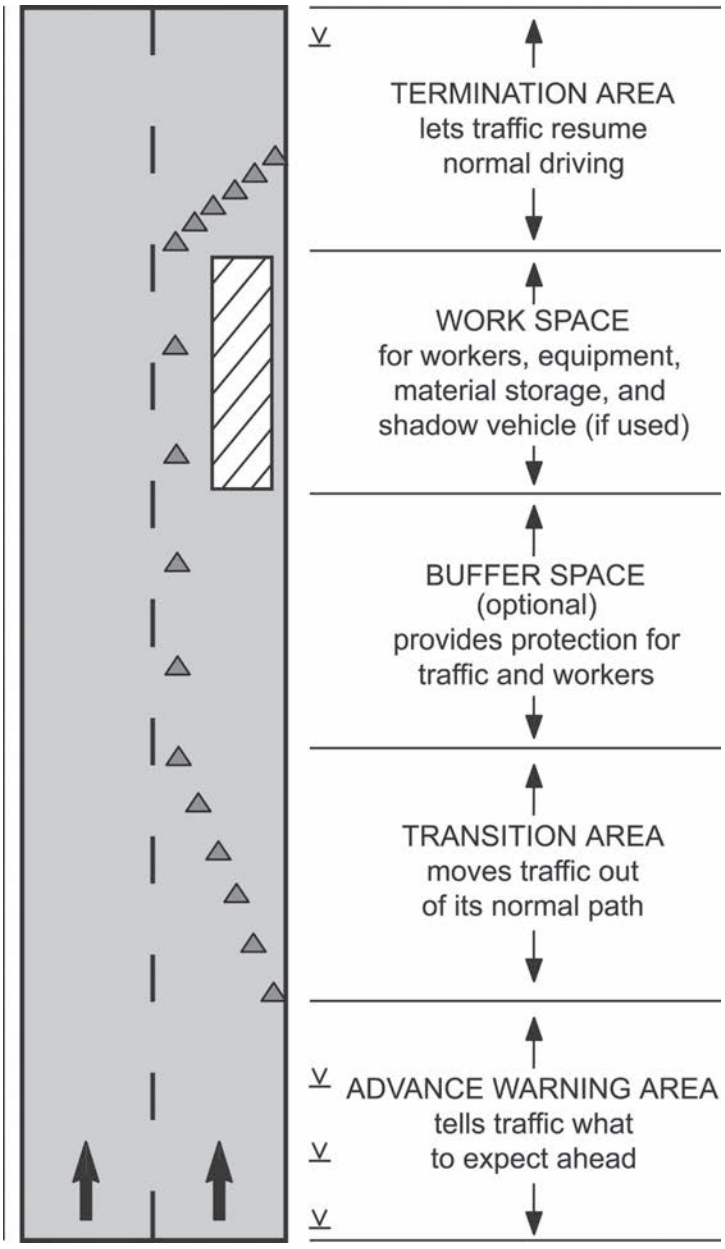

Figure 28. Five parts of a work zone

The *Cornell Local Roads Program* publishes the manual, *Work Zone Traffic Control for Local Roads*. This manual provides diagrams on setting up work zones for most rural applications. More details on work zone planning can also be found in the MUTCD.

The work zone can be divided into five zones (see Figure 28). Note that this figure shows one direction of traffic past the work zone. For two-way traffic, the same areas would apply from the opposite direction (see Figure 29).

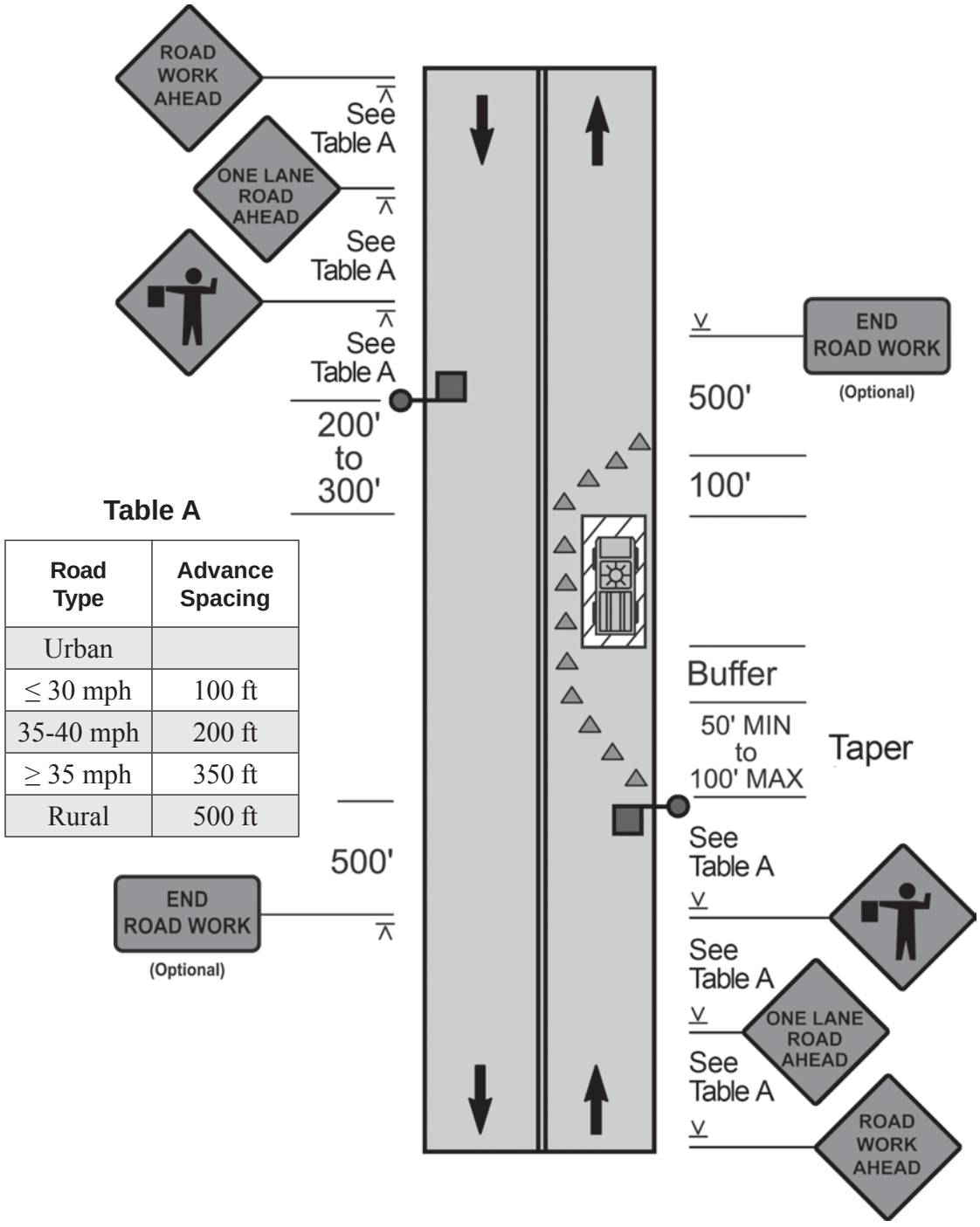

Figure 29. Example work zone layout

Typical rural, two-lane, two-way, medium duration, > 1000 cars per day

Your traffic control plan (TCP) should:

- Give advance notice
- Allow for drive error/inattention
- Move traffic away from hazards
- Move traffic away from workers

A typical two-lane work zone will look like Figure 29.

The advance warning area

The advance warning area is the most important since it tells the driver what to expect. This area:

- Gets the public's attention
- Provides the driver time to react
- Is repeated using three signs
- In rural areas, allows 500 feet between signs
- In urban areas allows 100, 200, or 350 feet between signs (depending upon the speed limit)
- Can (and should) be adjusted for field conditions

For lane closure of long duration on a fairly busy high-speed road, the advance warning signs would be a sequence of three. The first is a general warning, such as "road work ahead." The second sign gives more specific information about the hazard, such as "one-lane road ahead" or "right lane closed ahead" or "merge left." In rural areas, the spacing of these signs would usually be 500 feet. This would provide an advance warning distance of 1500 feet. Advance signs include:

- General warning
- Specific warning
- Specific instructions

The length of the time to complete the work and the type of operation influence the number and type of traffic control devices used. The five categories of work listed in the MUTCD include.

1. *Long-term stationary* is work that occupies a location more than 3 days.
2. *Intermediate-term stationary* is work that occupies a location more than one daylight period up to 3 days, or nighttime work lasting more than 1 hour.
3. *Short-term stationary* is daytime work that occupies a location for more than 1 hour within a single daylight period.
4. *Short duration* is work that occupies a location up to 1 hour.
5. *Mobile* is work that moves intermittently or continuously.

Long term stationary work may warrant the use of more barriers, changes in pavement markings and more extensive signage. The shorter term operations may involve less extensive signage. Mobile work zones may warrant the use of shadow vehicles or other specialized signage. The primary goal is the safety of the workers and traveling public. The crews placing the work zone signage should be thought about when developing the traffic control plan.

The transition area

The transition area moves traffic out of its normal path. Cones or barrels are often used to force traffic out of its normal path. Traffic must shift laterally a certain amount due to narrow pavement, reduction of the number of lanes, or a lane closure. The area where the actual shift is made is called the *taper*. The length of the taper is dependent on approach speed and the width of the shift.

The transition area should:

- Move traffic out of the normal path/flow
- Provide clear directions so that drivers know where to go
- Usually involve tapers
- Vary with speed and distance

The buffer space

The buffer space is an unoccupied space between the transition area and the work area itself. This area must be free of all equipment, vehicles, and construction materials. This buffer area provides room to stop for drivers who do not see or who do not follow the sign or flagger guidance. The length of this area can vary from 50 feet in urban low-speed situations to 500 feet or more for high-speed conditions.

Table 21. Guidelines for longitudinal buffer space length

85 percentile approach speed (mph)	Buffer space length (ft)
20	115
25	155
30	200
35	250
40	305
45	360
50	425
55	495
60	570
65	645

The length of the buffer should be adjusted to allow placement of the flagger or traffic taper in a visible location rather than on a curve, in the shade, etc. Along the buffer and work zone, the cone spacing, in feet, should be two times the speed, in miles per hour. For example, in a work zone with a 25 mph speed limit, cones would be 50 feet apart.

Remember, the buffer area is:

- A safety factor in case a driver does not stop
- The place where you can adjust for hills and curves
- A place where vehicles and/or equipment are not allowed

Table 21 provides guidance on determining buffer length.

In summary, the work area should:

- Delineate to keep traffic out
- Delineate to keep workers safe
- Deal with side roads

The termination area

The termination area advises drivers that they are past the work site and may resume normal driving. It is good practice to put an END ROAD WORK sign in this area. A short downstream taper is also recommended. Five cones in 100 feet are adequate.

The termination area:

- Lets drivers know the work zone is over
- Is usually a short taper
- Needs an END ROAD WORK sign if it is not obvious

Traffic control plan

Combining the five parts of the work zone results in a traffic control plan (TCP) for your operation. The TCP must address both directions of travel when appropriate. Figure 29 on page 63 shows what the TCP should look like for long duration, two-lane, two-way situations with normal volume of 55 mph traffic. The plan shown is for average conditions and can and should be adjusted to fit the specific operation for each day. For low-volume, low-speed situations, you could eliminate one advance sign. For high-speed, high-volumes, you may need more signs or you may need to position signs farther in advance of the work area. In urban situations, the spacing of the advance signs may be reduced.

Flagging

Flagging is one of the most important parts of a good work zone safety program. The basic functions of a flagger include:

- Guiding traffic safely through the work area
- Protecting the lives of the workers
- Avoiding unreasonable detours to motorists
- Answering questions courteously and intelligently

Advance warning signs must be in place, including a flagger ahead sign. This alerts the motorist that a flagger is directing traffic in and around the work zone.

The flaggers equipment must include:

- Stop/slow paddle at least 18" x 18"
- Safety vest with reflective markings. The vest may be orange, yellow, or yellow-green. Reflective markings must be visible from 1,000 feet away when lit by headlights, and be visible from any angle, not just the front and back. The vest must meet the requirements of Performance Class 2 or 3 of the ANSI/ISEA 107 Standard.
- Air-horn device
- Flashlight with glow cone (for night flagging)

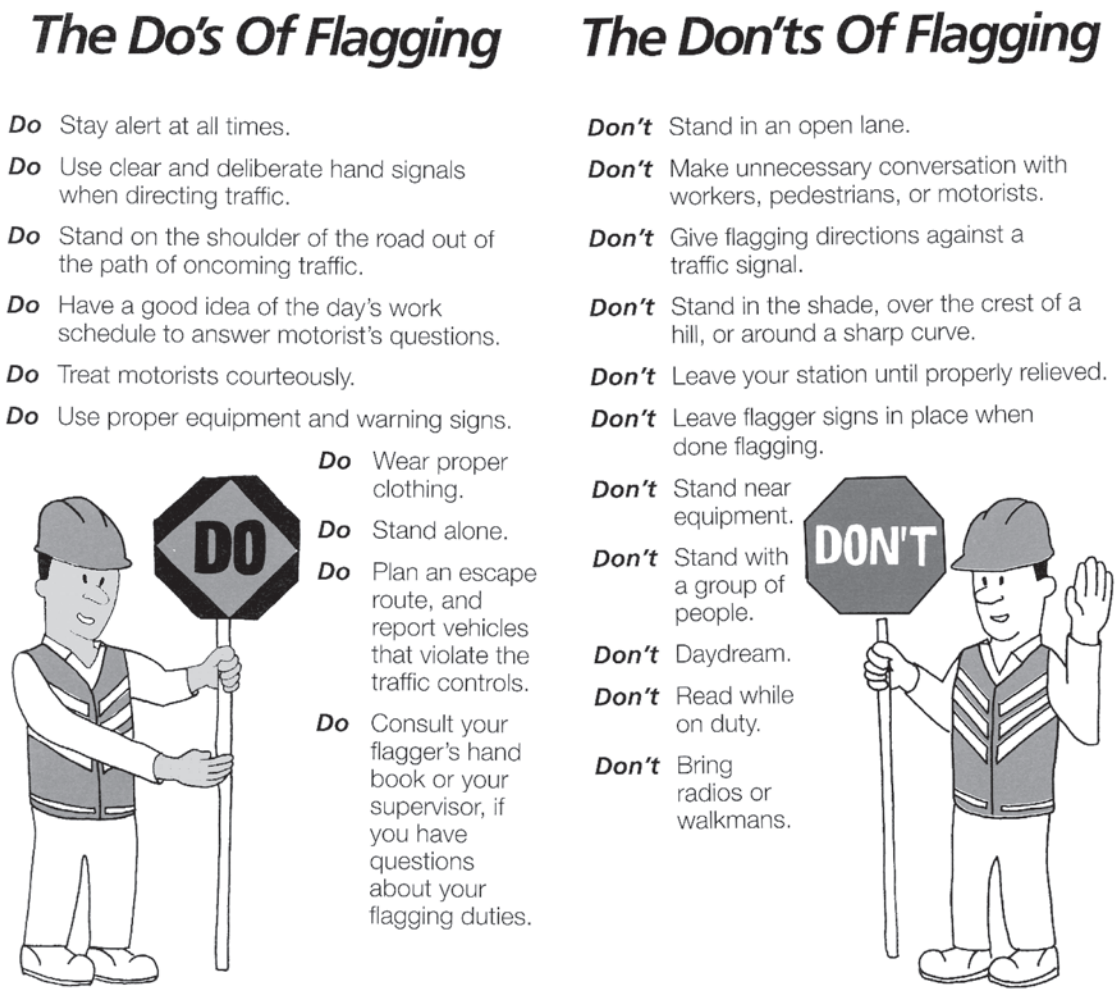

Figure 30. Do's and don'ts of flagging

The *Cornell Local Roads Program* offers a free publication, *Flagger's Handbook*; a short flagging tutorial on our website: www.clrp.cornell.edu; and flagging videos for your training needs. Each person in your department should be up to date on flagging procedures. It is recommended that your employees be required to review flagging materials on an annual basis.

Hints and hazards

Your exposure to being hit is the greatest when you are putting out or picking up traffic control devices, so be extra alert. When setting up the work zone signs, make sure that all devices are in place before you start any work. Put up the advance signs first, then position the flagger if there will be one, then the transition and work zone channelization. Pick them up in reverse order. Move with traffic whenever possible.

Summary

A properly developed and implemented traffic control plan will increase the safety of your employees, facilitate safe, convenient passage of traffic through the work area, and greatly decrease your liability exposure in the event of an accident.

You should prepare a traffic control plan for each activity and should be prepared to justify the plan selected. Then you need to communicate the plan to your workers. It is a good idea to document its implementation and its maintenance. Date it and indicate that you have discussed it with your crew. This way it becomes a permanent record.

A good time for refresher work zone safety training is just before your workers go out on the work site. A follow-up meeting can review successes or problems.

7 - Managing Your Highway Department

Once your roadway work is done in the field you have one more task. You have heard the expression, “It isn’t complete until the paperwork is done.” It’s trite, but true. It does not take long to forget details. Remember, the world’s worst pencil is better than the world’s best memory. At today’s hectic pace it is easy to lose track of events.

PLANNING AND DIRECTION

Have a plan for your efforts that covers today, tomorrow, this week, next month, and this year. Decide what standards you and your board want in place. It will help you keep your perspective and highlight your priorities. Also it will help in making budget requests to your Board. Your plan should include preventive maintenance work, regular maintenance, capital construction, and employee and equipment needs.

ORGANIZATION

Once you have a plan you have to decide how to make it work. Do not be afraid to delegate authority. Get input and feedback from supervisors and workers and use it! Decide on how to proceed with your operations. Review operations periodically to see if your plan is working. Don’t wait for someone else to tell you. Stick to your priorities!

TRAINING

Make every effort to keep yourself up to date but do not neglect staff training. It pays off and will make your job easier. Properly trained people do a better job and are more inclined to participate in planning. The Cornell Local Roads Program has numerous workshops, videos, and publications available to you and your staff for training purposes.

RECORD KEEPING

Good records are the foundation of any good risk minimization program. Since there is no way to eliminate liability or prevent suits, municipalities must do the next best thing. They must minimize their liability exposure. A good risk management program is a preventive program.

Devise a record keeping plan and stick to it. It must be complete and simple to use. Complicated forms will be ignored. Decide what you need to know and write it down. Convince your supervisors and staff to use the system on a daily basis. Periodically review the record keeping plan to see if it gives you the data you need.

While records and documents serve to provide a proper foundation for a maintenance program and provide a defense in a court of law, they can also reveal failure to eliminate known hazards. Concurrent with the establishment of a proper record keeping system, communication must be established to ensure that recorded defects go to the maintenance organization for action.

The importance of maintaining records cannot be overemphasized. They are used on the establishment of appropriate programs, allocation of resources, and defense of the agency against litigation. Written records are viewed by the courts more favorably than the oral testimony of witnesses seeking to recall facts from days long since passed.

The records themselves need not be long and detailed. Short, direct, and accurate records can be equally valuable.

At a minimum, records should include the following information:

- Date and time the complaint was made
- Name, address, and telephone number of the complainant
- Person receiving complaint
- Nature of the complaint (pothole, missing sign, debris, etc.)
- Exact location of the problem area
- Person/crew report was given to, with time and date
- Time and date repair was started and completed
- Description of defect the repair crew found and the action taken to repair
- Person/crew completing the repair

OTHER ISSUES

Besides organization and management, there are other issues that can affect the operations of a highway department. Listed below are a few that new superintendents should be aware.

Right-of-way

What is the standard right-of-way (ROW) for your municipality? Unless you have obtained roads by deed or dedication, the roads are probably "user-roads." This means that the only ROW you have available to you is what you actually maintain. Maintenance is defined as ditching, mowing, etc. within the ROW. If you do not use it then you do not own it, and have no right to use the property.

Many roads are designated as a 3 or 4-rod road (rod = 16½ feet). Many surveyors mark and show these roads as a 3-rod road. Even if it is shown as a 3-rod road, you must use it to claim ownership. The ROW is very important in highway maintenance. A typical section has 18-22 feet of pavement, 4 feet of shoulders, ditches, and grading back to natural grade. Many times there is not enough room in the user-road ROW to cut or clear ditches and then grade back at a reasonable grade. If you find yourself short of width, approach the property owners to obtain fee ownership or an easement for ditching and grading. See Appendix 5 for a sample easement.

Metric system

Currently, any community having a highway project designed or to be designed by the NYSDOT may be dealing with metric measurements and quantities on all plans and correspondence. Those communities not involved in state or federally funded or designed highway construction projects will still see the metric system being used. The manufacturers and distributors of highway

devices and materials will probably provide them in metric units. Other items may remain exactly the same, with dimensions mathematically converted to metric units. Your order for an 18-inch culvert may actually be a 450 mm pipe.

Plants producing asphalt pavement materials and dealing with DOT contracts eventually will have to provide the material in metric quantities. Operating the same plants in standard English units for municipal applications may create confusion and problems. Therefore, these plants may choose to operate under a full metric basis. If this occurs, municipalities and others will have to bid their paving jobs in metric units. If you are paying for "tons" of hot mix now, you may soon be paying for "metric tons."

Bridges

A bridge is a structure with a clear span of 20 feet or more. Some structures under 20 feet may be defined as a bridge depending on their construction. If you have any bridges in your municipality you must make certain who owns the structure and who is responsible for maintenance. There are three categories, one of which may apply to your bridges.

1. The municipality owns the entire structure and is responsible for all maintenance and repairs.
2. The municipality owns the roadway (deck and guiderail), and another municipality (town or county) owns the rest of the structure.
3. Another municipality (town or county) owns the entire structure.

NYSDOT inspects all bridges over 20 feet in New York State at least every two years. You should receive a report on any structures you own partially or wholly. For further information contact the NYSDOT Regional Bridge Engineer (see Appendix 3 for address).

Americans with Disabilities Act (ADA)

Title I of the Americans with Disabilities Act (ADA) became effective in July 1992. The new Act prohibits discrimination in the workplace against qualified individuals with disabilities *because of the disabilities*. The law bars discrimination in any activity or service operated or funded by state or local government. An estimated 2.5 million New York State residents are protected under the legislation.

For ADA information or technical assistance, contact the Regional Disability and Business Technical Assistance Center at the Northeast DBTAC in Trenton, New Jersey, at (609) 392-4004.

Government Accounting Standards Board (GASB 34)

The purpose of GASB 34 is to establish standards for financial accounting and reporting for state and local governments. It requires state and local governments to begin treating their infrastructure (roads, bridges, water and wastewater facilities, etc.) as capital assets and report their value in their annual financial statements.

The dates for compliance are based on community revenue:

- Communities with over $100 million in annual revenue ending June 15, 1999 must meet prospective reporting requirements for the fiscal year beginning after June 15, 2001 and start retroactive infrastructure reporting for the fiscal year beginning after June 15, 2006.

- Communities with between $10 million and $100 million in annual revenue must meet prospective reporting requirements for the fiscal year beginning after June 15, 2002 and start retroactive infrastructure reporting for the fiscal year beginning after June 15, 2007.
- Communities with less that $10 million in annual revenue must meet prospective reporting requirements for the fiscal year beginning after June 15, 2003. Retroactive infrastructure reporting will be optional for these smaller communities.

Hopefully you will have complied with the federal resolution by now. If you have not yet complied, you need to move quickly to stay in compliance.

One good benefit of this federal regulation is that each municipality should now have a good list of its infrastructure and the condition of each.

Compliance with GASB 34 starts with an accurate, complete and up-to-date inventory of significant infrastructure assets. Each inventory record should include description, year placed in service, method of acquisition (e.g., bond, cash, donation, etc.), funding source, cost or estimated cost, salvage value, and estimated useful life.

Government entities do not need to capitalize every infrastructure asset. To do so would be an unnecessary burden and would not materially affect financial results. GASB has established generally recommended threshold values for tracking and inventorying assets and higher threshold values for capitalization and depreciation. They are as follows:

Government size	Tracking/Inventory	Capitalize/Depreciate
Small (< $10 million)	$25,000	$100,000
Medium ($10-$100 million)	$50,000	$250,000
Large (> $100 million)	$100,000	$3,000,000

Examples of infrastructure expenditures that need to be capitalized and depreciated include:

- Water supply, treatment, pumping, storage, and distribution systems
- Wastewater collection, pumping, treatment, and disposal facilities
- Highways and rest areas
- Roads, streets, curbs, gutters, sidewalks
- Bridges, railroads, tressels
- Canals, waterways, wharfs, docks, sea walls, bulkheads, boardwalks
- Dams, drainage facilities
- Electrical systems and gas main lines, distribution lines, and tunnels
- Fiber optic and telephone distribution systems (between buildings)
- Lighting systems (traffic, outdoor, street, etc.)
- Signs
- Airport runways, strips, taxiways, and aprons

There is currently no legal requirement for municipalities to comply with this schedule or even to adopt GASB 34 at all. However, a municipality that does not comply may receive an adverse opinion from its auditor with respect to conformance with Generally Accepted Accounting Practices (GAAP). Whether this is significant may be a matter of judgment, dependent on particular circumstances, such as a municipality's desire to issue bonds.

INFRASTRUCTURE MANAGEMENT

Developing infrastructure management plans can meet the requirements of GASB34. More importantly, they can make the job of managing the highway department easier. Pavement, signs, bridges and drainage are areas where plans have been developed.

Pavement management systems (PMS)

PMS is a process that can be used year after year to manage the maintenance and improvements for a roadway network.

A PMS consists of a series of well-defined steps:

1. Assess the road network condition
2. Identify (trouble-shoot) road problems
3. Select repair alternatives
4. Assign repairs to roads
5. Prioritize repairs
6. Determine costs
7. Establish goals
8. Make long-range budget plans

Many highway superintendents do the first five steps of the process informally. They look things over to assess conditions and decide on repairs. However, some superintendents find it difficult to explain to board members what the road problems are and to convince them to appropriate the funds needed to fix these problems. Furthermore, through the informal process, all the knowledge of the road system stays in the head of the highway superintendent. When a new highway superintendent is elected, the long-range plans and strategy of the former superintendent may not be communicated to the new person. The knowledge of what has been done to various roads goes with the former superintendent. This history can be very valuable to the new superintendent.

Following a plan that you develop is what pavement management is all about. Computer software has been developed to do PMS. One example is the *Cornell Asset Management Program for Roads and Streets* (*CAMP-RS*) available from the CLRP and based on an older program (*RSMS*, originally developed by the New Hampshire LTAP center). Other PMS are available through private engineering firms and range in price and in complexity and style. The eight steps above are common to all pavement management systems. However, the steps are handled somewhat differently by each system.

Sign inventory

It is highly recommended that the municipality conduct an annual sign inventory to document the various signs on your roads. Inventory should include the following:

- Location of sign
- Type of sign (stop, warning, etc.)
- Size of sign
- Height of sign from the ground
- Distance off the shoulder or from the edge of pavement
- Date of installation or replacement
- Type of reflective material
- Visibility to drivers
- Reflectivity at night

This is one of the most important things you need to do as a highway superintendent. Maintaining records like these may prevent your municipality from being hit with a large liability claim.

Remember all your signs must be posted for the appropriate use in the correct horizontal and vertical position. This information can be found in the MUTCD. Failure to use this document for any reason is not an excuse. If you end up in court over an accident involving improper signage, the first question the opposing lawyer will ask is, "Are you familiar with the MUTCD?" The lawyer will have an expert witness ready to testify on the issues. Make sure you have the same preparation and documentation.

SUMMARY

Here is a list of things to do to help you with your job. These tips were suggested by experienced highway superintendents with new or inexperienced road managers in mind.

- Keep good records, including a daily diary. Write down why you decide to do or not do something, not just what you decide. (TIP: Make sure that your foremen complete inspection reports on time.)
- If everything looks good, and there are no problems, report that as well.
- Get to know your Board, Mayor, and other local government officials. Keep the lines of communication open. Develop a relationship with a potential advocate for your highway needs. Inform! Inform! Inform! (TIP: Conduct an annual road tour with your local officials.)
- Know the OSHA rules.
- Use the experience of others. Question the "same old way" of doing things. Talk with neighboring superintendents about rehabilitation, maintenance, drainage, and construction practices. Take advantage of new technology. (TIP: Learn sources of accepted materials by checking with the Office of General Services and the New York State Department of Transportation for advice.)
- Develop training goals for yourself, your foremen, and crews, and stick to them!

- Resist the temptation to reduce your road repair budget. There are always unplanned needs.
- Learn about funding issues and how your municipality's budgeting process affects the highway dollars. (TIP: Know the deadlines for applying for state and federal aid funds.)
- Establish a procedure to handle complaints. Teach it to all of your employees, and make sure that everyone follows it. Remember that there is no substitute for personal attention. (TIP: Return every call within 24 hours, and do not make promises you cannot keep.)
- Avoid the most common exposure to tort liability by having a regularly scheduled sign inventory and inspection routine. (TIP: Act on it!)
- Speak to every employee every day. Show you care about them. (TIP: Avoid being overly friendly with any individual employee.)
- Establish a sign inventory (can be part of GASB 34).
- Establish accepted work zones for projects in the right-of-way.
- Train all your employees to be flaggers.

Appendix 1 - Reference Publications

A Superintendent's Guide for Small Highway Department Management, Cornell Local Roads Program, CLRP No. 95-6

Asphalt Emulsion Manual, MS-19, Third Edition, Asphalt Institute

Asphalt Paving Principles, Cornell Local Roads Program, 2004, CLRP No. 04-3

Flaggers Handbook, Cornell Local Roads Program, 2008, CLRP No. 08-08

Geotextile Selection and Installation Manual for Rural Unpaved Roads, FHWA-RT-89-050

Guidelines for Geometric Design of Very Low-Volume Roads (ADT ≤ 400), American Association of State Highway and Transportation Officials, 2001, Washington, D.C.

Manual of Practice: Materials and Procedures for Repair of Potholes in Asphalt-Surfaced Pavements, FHWA-RD-99-168, Federal Highway Administration

Manual of Practice: Materials and Procedures for Sealing and Filling Cracks in Asphalt-Surfaced Pavements, FHWA-RD-99-147, Federal Highway Administration

McKinney's Consolidated Law of New York (Highway Law), West Group Publishers, Annotated 2006

National Manual on Uniform Traffic Control Devices, Federal Highway Administration, Washington, DC, 2009 mutcd.fhwa.dot.gov

New York State Supplement to the National Manual on Uniform Traffic Control Devices, New York State Department of Transportation, Albany, NY, 2011 www.nysdot.gov/portal/page/portal/divisions/operating/oom/transportation-systems/traffic-operations-section/mutcd

The Office of Highway Superintendent, Association of Towns of the State of New York, 2005

A Policy on Geometric Design of Highways and Streets, American Association of State Highway and Transportation Officials, Fourth Edition, 2009, Washington, D.C.

Pavement Maintenance, Cornell Local Roads Program, 2006, CLRP No. 06-5

Powers and Duties of Local Highway Officials, Cornell Local Roads Program, CLRP No. 97-6

Road Construction Materials, Cornell Local Roads Program, August 1988, Report #88-8

Road Safety Fundamentals, Cornell Local Roads Program, 2002, CLRP No. 02-07

Roadway and Roadside Drainage, Cornell Local Roads Program, 1998, CLRP No. 98-5

Selecting a Preventive Maintenance Treatment for Flexible Pavements, FHWA-IF-00-027, August 2000

Soils Manual, Asphalt Institute, MS-10, Second Edition

Standard Specifications, Construction and Materials, New York State Department of Transportation Office of Engineering, 2013

Traffic Sign Handbook, NYS edition, Cornell Local Roads Program, 2008, CLRP No. 11-07

Traffic Signs and Pavement Markings, Cornell Local Roads Program, 2008, CLRP No. 08-03

Work Zone Safety - Guidelines for Construction, Maintenance and Utility Operations (Work Zone Safety Pocket Guide), Cornell Local Roads Program, 2008, CLRP No. 08-07

Work Zone Traffic Control for Local Roads, Cornell Local Roads Program, CLRP No. 08-01

Appendix 2 - Sources

American Association of State Highway and Transportation Officials (AASHTO)
444 N. Capitol Street, NW (Suite 249)
Washington, DC 20001
(202) 634-5800
www.transportation.org

Asphalt Institute
2696 Research Park Drive
Lexington, Kentucky 40511-8480
(859) 288-4960
www.asphaltinstitute.org

Association of Towns of the State of New York
50 State Street
Albany, New York 12207
(518) 465-7933
http://nytowns.org

Better Roads Magazine
(Subscription free to public works officials)
3200 Rice Mine Road
Tuscaloosa, AL 35406
(800) 633-5953
www.betterroads.com

Cornell Local Roads Program
416 Riley-Robb Hall
Ithaca, New York 14853-5701
(607) 255-8033
www.clrp.cornell.edu

National Association of County Engineers (NACE)
25 Massachusetts Avenue, NW, Suite 580
Washington, DC 20001
(202) 393-5041
www.countyengineers.org

New York State County Highway Superintendents' Association
136 Everett Road
Albany, New York 12205
(518) 465-1694
www.countyhwys.org

New York State Association of Town Superintendents of Highways
125 State Street
Albany, NY 12207
(518) 426-1023
www.nysaotsoh.org

New York State Dept. of Transportation
50 Wolf Road (main office)
Albany, New York 12232
(518) 457-6195 (general information)
www.dot.ny.gov

Public Works Magazine
(Free to public works officials)
8725 W. Higgins Road, Suite 600
Chicago, IL 60631
(773) 824-2400
www.pwmag.com

Roads and Bridges magazine
(subscription free to public works officials)
3030 W. Salt Creek Lane, #201
Arlington Heights, IL 60005
(847) 391-1036
www.roadsbridges.com

Transportation Research Board
The National Academies
500 Fifth Street, NW
Washington, DC 20001
(202) 334-2934
www.trb.org

Appendix 3 - NYSDOT Regional Offices

Main Office
50 Wolf Road,
Albany, NY 12232,
(518) 457-6195
www.dot.ny.gov

Capital District (Region 1)
Albany, Essex, Greene, Rensselaer, Saratoga, Schenectady, Warren, Washington Counties
328 State Street
Schenectady, NY 12305
(518) 388-0388

Mohawk Valley (Region 2)
Fulton, Hamilton, Herkimer, Madison, Montgomery, Oneida Counties
Utica State Office Building
207 Genesee Street
Utica, NY 13501
(315) 793-2447

Central New York (Region 3)
Cayuga, Cortland, Onondaga, Oswego, Seneca, Tompkins Counties
State Office Building
333 E. Washington Street
Syracuse, NY 13202
(315) 428-4351

Genesee Valley (Region 4)
Genesee, Livingston, Monroe, Ontario, Orleans, Wayne, Wyoming Counties
1530 Jefferson Road
Rochester, NY 14623
(585) 272-3300

Western New York (Region 5)
Cattaraugus, Chautauqua, Erie, Niagara Counties
100 Seneca Street
Buffalo, NY 14203
(716) 847-3238

Central Southern Tier (Region 6)
Allegany, Chemung, Schuyler, Steuben, Yates Counties
107 Broadway
Hornell, NY 14843
(607) 324-8404

North Country (Region 7)
Clinton, Franklin, Jefferson, Lewis, St. Lawrence Counties
Dulles State Office Building
317 Washington Street
Watertown, NY 13601
(315) 785-2333

Hudson Valley (Region 8)
Columbia, Dutchess, Orange, Putnam, Rockland, Ulster, Westchester Counties
Eleanor Roosevelt State Office Building
4 Burnett Boulevard
Poughkeepsie, NY 12603
(845) 431-5750

Southern Tier (Region 9)
Broome, Chenango, Delaware, Otsego, Schoharie, Sullivan, Tioga Counties
44 Hawley Street,
Binghamton, NY 13901,
(607) 721-8116

Long Island (Region 10)
Nassau, Suffolk Counties
State Office Building
250 Veterans Memorial Highway
Hauppauge, NY 11788
(631) 952-6632

New York City (Region 11)
Bronx, Kings, New York, Queens, Richmond Counties:
Hunters Point Plaza
47-40 21st Street
Long Island City, NY 11101
(718) 482-4526

Appendix 4 - NYS Soil & Water Conservation Districts

NYS Soil and Water Conservation Committee
(518) 457-3738
www.agriculture.ny.gov/soilwater/contacts/county_offices.html

Albany	(518) 765-7923
Allegany	(585) 268-5840
Broome	(607) 724-9268
Cattaraugus	(716) 699-2326 (716) 699-2327
Cayuga	(315) 252-4171 (315) 252-0793
Chautauqua	(716) 664-2351 ext. 5
Chemung	(607) 739-4392 (607) 739-2009
Chenango	(607) 334-4632 (607) 334-8634
Clinton	(518) 561-4616 ext. 3
Columbia	(518) 828-4386 (518) 828-4385
Cortland	(607) 756-5991 ext.3
Delaware	(607) 865-7161 (607) 865-7162
Dutchess	(914) 677-8011 (914) 677-8199
Erie	(716) 652-8480 (716) 652-8830
Essex	(518) 962-8225
Franklin	(518) 483-4061 ext. 5
Fulton	(518) 762-0077 ext. 3
Genesee	(716) 343-2362
Greene	(518) 622-3620
Hamilton	(518) 548-3991
Herkimer	(315) 866-2520 ext. 3
Jefferson	(315) 782-2749 (315) 786- 0486
Lewis	(315) 376-6122
Livingston	(585) 283-0043
Madison	(315) 824-9849 (315) 824-9073
Monroe	(585) 753-7380
Montgomery	(518) 853-4015
Nassau	(516) 364-5860
New York City	(212) 431-9676
Niagara	(716) 434-4949 ext. 4
Oneida	(315) 736-3334 (315) 736-3335
Onondaga	(315) 457-0325
Ontario	(585) 396-1450 (585) 396-1455
Orange	(845) 343-1873
Orleans	(585) 589-5959 (585) 589-6504
Oswego	(315) 592-9663
Otsego	(607) 547-8337 ext. 4

Putnam	(845) 878-7918
Rensselaer	(518) 271-1740 (518) 271-1764
Rockland	(845) 364-2670
St. Lawrence	(315) 386-3582 (315) 386-2401
Saratoga	(518) 885-6900 ext. 3
Schenectady	(518) 399-6980 (518) 399-5040
Schoharie	(518) 295-8811 (518) 295-8600
Schuyler	(607) 535-9650
Seneca	(315) 568-4366 (315) 568-6346
Steuben	(607) 776-7398 ext. 3
Suffolk	(631) 727-2315 ext. 3
Sullivan	(845) 292-6552 ext. 101
Tioga	(607) 687-3553 (607) 687-2240
Tompkins	(607) 257-2340
Ulster	(845) 883-7162 ext. 5
Warren	(518) 623-3119
Washington	(518) 692-9940 ext. 3
Wayne	(315) 946-4136 (315) 946-4137
Westchester	(914) 995-4407 (914) 995-4423
Wyoming	(585) 786-5070
Yates	(315) 536-5188

Appendix 5 - Temporary Easement

This EASEMENT granted this ___ day of _____ Two thousand _____.

BETWEEN _____, residing at _____ hereinafter referred to as "Owner", and COUNTY/TOWN/VILLAGE/CITY of _____, New York, a municipal corporation of the State of New York, hereinafter referred to as "County", "Town", "Village", "City", acting by and through _____, the duly elected/ appointed Superintendent of Highways.

WHEREAS, the County/Town/Village/City of _____, acting by and through the Superintendent, desires and plans to provide for the construction, reconstruction, and maintenance of _____ (describe highway/bridge) _____, located in the Town/ Village/City of _____, County of _____, State of New York.

WHEREAS, in connection with such work, it will be necessary for the County/Town/Village/ City and their contractors and/or employees to temporarily occupy and use a portion of the lands of the Owner as hereinafter described.

WHEREAS, the term of this temporary easement shall commence on execution hereof and shall terminate on the _____ day of _____ Two thousand _____, unless extended in writing executed by Owner.

WITNESSETH, that Owner, in consideration of the sum of one Dollar ($1.00) lawful money of the United States of America, and other good and valuable consideration, paid by the County/ Town/Village/City do hereby grant and release unto County/Town/Village/City, its successors and assigns,

A temporary easement to enter upon and occupy any and all lands of the owner as described in the attached Exhibit A entitled "Easement Description" which is hereby incorporated into this document and made a part hereof. The Owner covenants and agrees that the County and their agents and employees, or contractor or contractors, may immediately enter upon the premises described herein for the purposes of construction, reconstruction and/or maintenance of said highway/bridge without becoming or being held liable for trespass or damages related thereto. The Owner does hereby waive any and all claims for damages for such entry or occupation.

The location of the highway centerline is as shown on the maps/plans prepared and approved for such construction and reconstruction as filed in the Office of the County Clerk of _____County.

Upon completion of said work of constructing, reconstructing, and/or maintaining said highway/ bridge, the County/Town/Village/City will leave any lands which have been occupied, pursuant to this Agreement, in a clean, neat, orderly condition, free of debris and ruts caused by such work as ordered by the Engineer in Charge for the project.

The property subject to the temporary easement granted herein is described in a deed(s) recorded in the Office of the _____ County Clerk in Book _____ of Deeds at Page ____. Owner shall in no way be held responsible for any personal injuries that may occur during, after, and/or as a result of said work.

The word "Owner" as hereinabove used shall be deemed to include the plural number.

IN WITNESS WHEREOF, the part of the first part ha hereunto set his/her/their hand(s) and seal(s) the day and year first written above.

IN PRESENCE OF _____ LS

_____ LS

State of New York }

}ss.

County of _____}

On this _____ day of _____, 20 ____, before me, the undersigned, a Notary Public in and for said State, personally appeared, _____, personally known to me or proved to me on the basis of satisfactory evidence to be the individual(s) whose name is subscribed to the within instrument and acknowledged to me that (s)he executed the same in his/her capacity, and that by his/her signature on the instrument the individual(s), or the person upon behalf of which the individual(s) acted, executed the instrument.

_____

Notary Public

Appendix 6 - Inspections and Getting Ready for Summer Checklist

ROAD NAME: _____ DATE:_____ BY: _____ SECTION: _____

ITEMS TO INSPECT	WORK NEEDED?	WORK TO BE DONE
Pavement		
❑ Potholes	❑ Yes ❑ No	
❑ Pavement edge dropoff repair	❑ Yes ❑ No	
❑ Shoulder cutting	❑ Yes ❑ No	
❑ Crack repair	❑ Yes ❑ No	
❑ Blade/regrade gravel surface	❑ Yes ❑ No	
Bridges and culverts		
❑ Pavement settlement	❑ Yes ❑ No	
❑ Pipes clear and open	❑ Yes ❑ No	
❑ Inlet/outlet damage	❑ Yes ❑ No	
❑ Other repairs	❑ Yes ❑ No	
Ditches and other drainage		
❑ Cleaning	❑ Yes ❑ No	
❑ Erosion	❑ Yes ❑ No	
Signs		
❑ Signs straight	❑ Yes ❑ No	
❑ Signs legible	❑ Yes ❑ No	
Guiderail		
❑ Plow damage	❑ Yes ❑ No	
❑ Post/bolts replacement	❑ Yes ❑ No	
❑ Ends	❑ Yes ❑ No	
Snow and ice clean up		
❑ Sand removal/sweeping	❑ Yes ❑ No	
Schedule and layout		
❑ Plow damage	❑ Yes ❑ No	
❑ Post/bolts replacement	❑ Yes ❑ No	
Trees and brush		
❑ Tree removal/trimming	❑ Yes ❑ No	
❑ Brush removal/trimming	❑ Yes ❑ No	
Other items		
❑	❑ Yes ❑ No	