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Federal Highway Administration

# ROAD BUSINESS

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Vol. 2 No. 2 Spring 1987

*The short time available to us during New Hampshire's spring and summer seasons is extremely valuable. Frequently, we are tyring to get twelve months of work done in a four month period. This issue of* Road Business *has been put together as a special report for all the individuals who will be involved in the maintenance and construction of New Hampshire's rural roads. The articles below will be of particular interest to you if you are involved in bridge maintenance, pothole repair, paving projects, or road drainage problems. In our next issue we will return to our usual format featuring "On The Road In New Hampshire."*

**SPECIAL REPORT**

## Winter Is Never Over In NH

*Linseed oil for the protection of concrete structures*

The problem of protecting bridge decks, parking ramps, curbs, sidewalks, and other concrete surfaces from the ravages of winter is as old as the use of concrete itself. In spite of its smooth, rock-hard appearance, small, almost microscopic pores exist in the concrete surface. During the warmer months, moisture evaporates rapidly from these pores with no harm to the surface. In the winter, however, freezing water can cause measurable surface damage. At lower temperatures, water in the pores freezes and remains solid until the temperature rises enough to permit thawing. Several freeze-thaw cycles may occur during an average winter day. Since water expands when frozen, the effect of repeated freeze-thaw cycles is to initiate scaling and later spalling of the top surface. This is particularly true for concrete less than four years old.

The problem is aggravated by the use of most de-icing agents. These agents react with concrete and markedly accelerate the deterioration process. In particular, chlorides will penetrate concrete and cause corrosion of reinforcing steel. As the level of chlorides in concrete becomes excessive, the rate of corrosion increases. Reducing the ease with which clorides penetrate concrete surfaces is an effective means of preventing corrosion of rebar and subsequent concrete deterioration.

The scaling and pitting which beset concrete surfaces, often after a single winter, point up a problem which urgently demands a solution. Two possible approaches to this problem are the use of air-entrained concrete and protective coatings, such as linseed oil.

Prominent among the corrective measures suggested is the use of air-entrained concrete. This material contains myriads of tiny air bubbles distributed more or less evenly throughout the mass. The air bubbles help to inhibit scaling and spalling due to freeze-thaw cycles and the use of de-icing chemicals. Today practically all new concrete highway construction uses air-entrained concrete.

Air-entrained concrete failures occur frequently enough to be a source of serious concern to highway maintenance engineers. Plausible explanations, such as incorrect quantity of entrained air, improper formulation, inferior quality of aggregate, excessive trowelling of the top

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**—ALSO IN THIS ISSUE—**

# Asphalt Paving Materials

*by Thomas J. McLean, P.E.*

***Editor's note:** The information below has been requested by many road agents around New Hampshire. It is one of the best short introductions to pavement materials we have come across and we are happy to bring it to you in this special report issue of* Road Business. *It has been edited and reprinted with permission from the Center for Local Government Technology, Oklahoma State University.*

Asphalt is man's oldest engineering material. It was in use as an adhesive and waterproofing agent more than 5,000 years ago. Natural deposits of asphalt were used in ship building, water tanks, and for masonry and highway construction. While natural deposits still are present in many areas of the world, almost all asphalt produced and used in the United States is refined from petroleum. The asphalt produced is of many types and grades, from solids to thin liquids (see diagram below). Petroleum asphalt for use in pavements is usually called paving asphalt or asphalt cement to distinguish it from asphalt made for nonpaving uses, such as roofing. At normal temperatures, paving asphalt is a sticky, semi-solid, highly viscous material. It is composed chiefly of complex hydrocarbon molecules. Because of its adhesive quality, it sticks to aggregate particles and can be used to bind them into asphalt concrete. Paving asphalt is waterproof and is unaffected by most acids, alkalies and salts. It is a thermoplastic material, softening as it is heated and hardening as it cools. The unique combination of characteristics and properties of asphalt make it a very versatile construction material.

Rapid-curing (RC), medium-curing (MC), and slow-curing (SC) are designations of cutback asphalt types. Rapid-curing (RC) cutback asphalt is manufactured by blending asphalt cement with a specific amount of solvent (cutter stock) which will rapidly evaporate after using, leaving only the asphalt cement. The solvent (cutter) used in producing RC cutback is a material with a low boiling point such as gasoline or naptha. Medium-curing (MC) cutback asphalts are produced by blending asphalt cement with an intermediate boiling point solvent such as kerosene. The kerosene solvent evaporates more slowly than the gasoline solvent used in (RC) cutback, thus, the designation medium-curing. Slow-curing (SC) cutback asphalt may be produced by blending asphalt cement with a high boiling point gas oil or may be extracted as a residual material during the petroleum refining process.

Emulsified asphalt is a combination of water, asphalt cement, and an emulsifying agent. Since asphalt cement will not dissolve in water, it exists in small ($^1/_{25000}$ in. to $^1/_{2500}$ in. diameter) globules suspended in the water-emulsifying agent mixture. The emulsifying agent (commonly soap) prevents the asphalt spheres from coalescing. When an emulsion is mixed with an aggregate or spread thinly on a surface, the interfacial balance is disturbed and the water and asphalt phases separate. On aggregate, the asphalt globules coalesce into a continuous film that cements the aggregate particle while the water drains off and/or evaporates. There are two types of emulsified asphalt. Anionic emulsified asphalt is an alkaline, water-phase product in which the surface of the asphalt droplets carry a negative change. Best results are obtained when this type of emulsion is used with electro-positive aggregates such as limestone and dolomite. Cationic emulsified asphalt is acidic and the asphalt droplets carry a positive charge; therefore, best results are obtained when it is used with electro-negative aggregates, such as sand, and other siliceous aggregates. Some emulsions require that the aggregates be pre-wet. Anionic and cationic emulsions are incompatible and cannot be mixed or stored together.

In an asphalt-aggregate mixture used in paving, aggregates normally constitute 90% to 95% by weight of the total mixture. It is fairly obvious that the nature and quality of the aggregate will have a considerable effect on the resulting pavement. Hard, durable aggregate is required for strong, high-quality wearing courses where strength requirements are not as high as for the surface course. Locally available and lower-cost aggregates can be used in base courses and thus reduce the pavement cost. Particles of aggregate larger than about ¼ inch (particles retained on a ¼-inch sieve), called coarse aggregate, are normally obtained from crushing rock and screening gravel. Particles smaller than about ¼ inch, called fine aggregate, are obtained from natural sand or fine screenings from rock crushing operations. Sometimes a mineral filler such as rock dust is added to the fine aggregate.

**Types of Asphalt Pavement Construction**

Plant Mix: asphalt paving mixtures prepared in a central mixing plant are known as plant mixes. Asphalt concrete is considered the highest quality type of plant mix.

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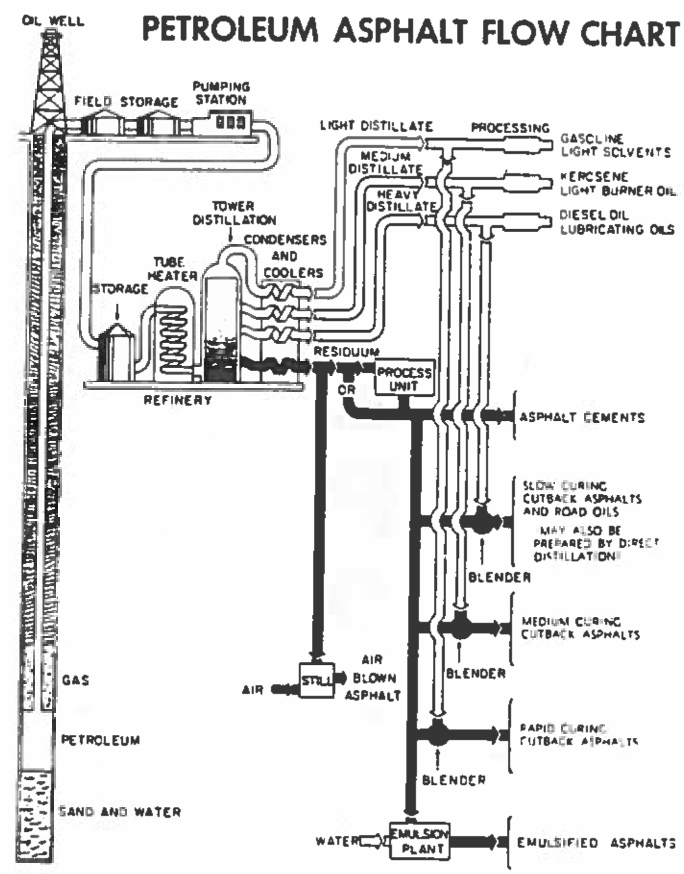
*Petroleum Asphalt Flow Chart—Reprinted with permission from The Asphalt Institute*

*There are many types and grades of asphalts, from solids to thin liquids.*



*Protection of Concrete...*
*continued from p. 1*

surface, etc., are often offered when air-entrained concrete fails in service. The fact remains that failures continue to occur and while more vigilant and costly inspection at the time of placing the concrete may obviate some of these difficulties, it could not entirely eliminate the possibility of human error.

Protective coatings are harmless, easily applied, low-cost materials, which can be applied in thin coats to seal the pores of the concrete and thus prevent the entrance of water and corrosive solutions. These are a practical means of correcting the trouble at its source. Although we will primarily review linseed oil as a protective coating, various other substances, such as synthetic resins, silicates, and silicones have also been suggested as protective coatings for concrete. One major manufacturer of synthetic resins has recently undertaken an advertising campaign in national magazines to call public attention to the problem and to highlight the need for winter roadway protection.

The water-repellency characteristics of linseed oil films suggested, many years ago, its application for this purpose. The Portland Cement Association and the Salt Institute have pointed out the value of linseed oil as a protective coating for non-air-entrained concrete. Others have even suggested the use of boiled linseed oil for additional protection with non-air-entrained concrete. A number of state, county, and municipal highway departments have used and are still using linseed oil for both types of concrete.

To apply a protective coating of linseed oil costs around $.10 per square yard for materials. While application costs can vary, estimates indicate that this will not exceed an additional $.10 per square yard when readily-available, efficient spreading equipment is used.

Double-boiled linseed oil is preferred to raw oil because of its more rapid dryng and film-forming characteristics. To decrease the viscosity and facilitate spreading, it is common practice to mix the oil with an equal volume of mineral spirits.

When the mixture is used, it is customary to apply two coats, the first at .025 gallons per square yard. When this has thoroughly dried, it is followed by a second coat applied at the rate of .015 gallons per square yard.

For more information on using boiled linseed oil as a protective coating on concrete surfaces, see the directions printed on page 3 of this newsletter.

The above article was written for *Road Business* by Harvey S. Goodwin, Assistant Bridge Maintenance Engineer, NH DOT ■

# Directions For Using Boiled Linseed Anti-Spalling Compound

*Protect your concrete surfaces*

Linseed anti-spalling compound protects concrete surfaces in two ways: by penetrating the porous surface of the concrete to a depth of approximately ⅛"; and by combining with atmospheric oxygen to form a protective coating through which destructive moisture and salt solutions cannot penetrate.

**Uses:** Linseed anti-spalling compound is used to protect roads, bridge decks, sidewalks, curbs, abutments, endposts, concrete handrails, and all exposed concrete surfaces from de-icing agents. Usually, it is not applied to the undersides and backsides of structures which are less exposed to chlorides.

For more information, see the article on the front page of this newsletter.

**Material:** 50% double boiled linseed oil and 50% petroleum spirits (AASHTO M-233-79 Type II).

**Time of Application:** Surfaces should be cleaned and washed annually in the spring of the year and oiled every two years. Linseed anti-spalling compound can be used on new and old concrete.

The oil is most effective if applied to new concrete upon completion of the initial curing period, usually considered to be about 28 days after placement. However, it has been successfully applied to new concrete after 2 weeks curing.

Linseed anti-spalling compound can be applied to concrete of any age. However, it is most effective in preserving sound concrete surfaces.

**Pre-application conditions:**

(1) The concrete should be dry and the solution should not be applied within 24 hours of a rainstorm.

(2) Remove sand and debris from joints, drains and bridge shoes (use high pressure water wash and let dry 24 hours).

(3) New concrete should be at least two weeks old. Ideally, it should be 28 days old.

(4) The ideal atmospheric temperature at the time of application is 70 degrees Fahrenheit or above. Successful applications have been made, however, at temperatures as low as 35 degrees Fahrenheit.

**Application:** Two coats are recommended, applied as follows:

1st Coat: 0.25 gal. per sq. yd.
(40 sq. yds. per gal.)
2nd Coat: 0.15 gal. per sq. yd.
(67 sq. yds. per gal.)

Application may be by spray or hand but should be uniform. The coverage of *each* coat shall *not* be more than 50 square yards per gallon of the mixture. When applying the mixture to concrete surfaces, the contractor should take all necessary precautions to ensure that the mixture does not contaminate adjoining asphalt pavements. The mixture will cause a potential safety hazard by making the asphalt pavement slippery. Also, the petroleum based linseed oil mixture may have a tendency to weaken the asphalt.

Complete drying should be permitted between coats. At temperatures of 70 degrees Fahrenheit or above, drying is complete within a few hours. At lower temperatures, proportionately longer drying times are required.

**CAUTION:** Linseed anti-spalling compound has a flash point around 120 degrees Fahrenheit. While not dangerously flammable, it nevertheless should not be heated.

Care should be exercised to cover the concrete surface completely; including all edges, which are sometimes missed in spraying. Maximum protection is afforded only when coverage is complete.

The preceding information has been provided by Harvey S. Goodwin, Assistant Bridge Maintenance Engineer, NH DOT. ■

*Paving Materials...*
*continued from p. 2*

It consists of well-graded, high-quality aggregate and asphalt cement. The asphalt and aggregate are heated separately from 250 to 325 degrees Fahrenheit, carefully measured and proportioned, then mixed until the aggregate particles are coated with asphalt. Mixing is done in the pugmill unit of the mixing plant. The hot mixture, kept hot during transit, is hauled to the construction site, where it is spread on the roadway by an asphalt paving machine. The smooth layer from the paver is compacted by rollers to proper density before the asphalt cools.

Asphalt concrete is but one of a variety of hot-asphalt plant mixes. Other mixes, such as sand asphalt, sheet asphalt, and coarse-grade mixes are prepared and placed in a similar manner. However, they have one common ingredient—asphalt cement.

Asphalt mixes containing liquid asphalt also may be prepared in central mixing plants. The aggregate may be partially dried and heated or mixed as it is withdrawn from the stockpile. These mixes are usually referred to as cold mixes, even though heated aggregate may have been used in the mixing process.

Asphalt mixtures made with emulsified asphalt and some cutback asphalts can be

*continued on p. 4*

*Principal Uses of Various Types of Asphaltic Products*

*Reprinted with permission from The Asphalt Institute and the University of Oklahoma*

| Type Construction | Asphalt Cements | | | | | Rapid-Curing (RC) | | | | | | Medium-Curing (MC) | | | | | | Slow-Curing (SC) | | | | | | Emulsified | | | | | Inverted Emulsions | Cationic Emulsions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 40/50 | 60/70 | 85/100 | 120/150 | 200-300 | 0 | 1 | 2 | 3 | 4 | 5 | 0 | 1 | 2 | 3 | 4 | 5 | 0 | 1 | 2 | 3 | 4 | 5 | RS-1 | RS-2 | MS-2 | SS-1 | SS-1h | | |
| Plant-Mix Hot Laid | | X | X | X | X | | | | | | | | | | | | | | | | | | | | | | | | | |
| Modified Hot Laid | | | | | | | | | | X | X | | | | | X | X | | | | | X | X | | | | X | | | |
| Cold Laid-Macadam Aggr. Type | | | | | | | | | X | X | X | | | | | X | X | | | | | | X | | | | X | | | X |
| Cold Laid-Graded Aggr. Type | | | | X² | X² | | | | | | | | | X | X | X | | X¹ | X¹ | | X | X | | | | | X | | | |
| Penetration Macadam Large Voids | | | X | X | X | | | | | | | | | | | | | | | | | | | | | | | | | |
| Small Voids | | | | | | | | X | X | | | | | | | | | | | | | | | X | | | | | | |
| Mixed-In-Place Macadam Aggregate | | | | | | | | | X | X | X | | | | | X | X | | | | | | | | | | X | | | X |
| Open Graded Aggregate | | | | | | | | X | X | X | X | | | | X | X | X | | | | | X | X | | | | X | | | X |
| Dense Graded Aggregate | | | | | | | | | | | | | | X | X | X | | | | X | X | X | | | | | X | X | X | |
| Surface Treatments With Cover Aggregates | | | | X | X | | X | X | X | X | X | | X | X | X | | | | | | | | | X | X | | X | | X | X |
| Seal Coats | | | | | X | | | X | X | X | X | X | X | X | | | | | | | | | | X | X | | X³ | | | |
| Black Seal, Fog or Color Coat | | | | | | | | | | | | | | | | | | | | | | | | | | | | X⁴ | | |
| Tack Coat | | | | | | X | X | | | | | | | | | | | | | | | | | | | | X⁴ | | | |
| Prime Dust Laying | | | | | | | | | | | | | | | | | | X | X | | | | | | | | X⁴ | | | |
| Soil Treatment Mixtures | | | | | | | | | | | | | | X | X | X | X | | | X | X | X | X | | | | X | X | X | |
| Membrane Envelope | X⁵ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Hydraulic Structures Membrane Linings-Canals & Reservoirs | X5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Hot Laid, Graded Aggr. Mix for Groins, Dam Facings, Canal and Reservoir Linings | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Curbs Graded Aggregate Mix | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Blocks Graded Aggregate Mix | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Crack Filling | | | | | | | | | | | | | | | | | | | | | | | | X | | | X³ | | | |
| Expansion Joints | Blown Asphalts, Mineral-Filled Asphalt Cement and Performed Joint Compositions | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Roofing | Blown Asphalts | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Miscellaneous-See Note 6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

¹ In combination with powdered asphalt
² With water or liquifier ordinarily not exceeding 3%
³ Slurry mix
⁴ Water diluted
⁵ Also 50-60 pen, blown asphalt and prefabricated panels
⁶ Specially prepared asphalts used for pipe coverings, battery boxes, automotive undercoating, electrical wire coating, insulation, tires paints, asphalt tile, wallboard, paper sizing, water-proofing, floor mats, ice cream sacks, adhesives, phonograph records, tree grafting compounds, grouting mixtures, etc.

*Paving Materials . . .*
*continued from p. 3*

spread and compacted on the roadway while quite cool. Such mixtures are called cold-laid asphalt plant mixes. They are hauled and placed in normal warm-weather temperatures. To hasten the evaporation of emulsification water from cutback solvents, these mixtures, after being placed on the roadway, are sometimes processed or worked back and forth laterally with a motor grader before being spread and compacted.

Mixed-in Place (Road Mix): emulsified asphalt and many cutback asphalts are fluid enough to be sprayed on and mixed with aggregate at moderate to warm-weather temperatures. When this is done on the area to be paved, it is called mixed-in-place construction. Although mixed-in-place is the more general term, and is applicable whether the construction is on a roadway, parking area, or airfield, the term "road mix" is often used when construction is on a roadway.

Mixed-in-place construction can be used for surface, base, or sub-base courses. As a surface or wearing course, it usually is satisfactory for light and medium traffic. However, mixed-in-place layers covered by a high-quality asphalt plant mix surface course make a pavement suitable for heavy traffic service. Advantages of mixing-in-place include:

1. Utilization of aggregate already on the roadbed or available from nearby sources and usable without extensive processing; and

2. Elimination of the need for a central mixing plant. Construction can be accomplished with a variety of machinery often more readily available, such as motor graders, rotary mixers with revolving tines, and traveling mixing plants.

Asphalt Spray Applications: many necessary and useful purposes are served when paving asphalt—temporarily in a fluid condition—can be sprayed in uniform and controlled amounts onto a surface.

The table above shows the principal uses of various types of asphalt. This table and much of the information contained in this article is from The Asphalt Institute.

For further information on seal coats and other surface treatments the reader is referred to the December 1986 issue of *Road Business,* available at no cost from the Technology Transfer Center, 1-800-423-0060.

More information on asphalt paving materials is available in *The Asphalt Handbook.* A copy of the handbook can be purchased from: R. J. Joubert, The Asphalt Institute, 101 Amesbury Street, Lawrence, MA 01841—(617) 681-0455. ■

# Your Best Defense In The War Against Potholes

*The minimum 4" pavement thickness design*

Through collaboration and observations shared with other pavement engineers an interesting and significant performance observation came up. Once a pavement is 3½" to 4" in thickness it cannot pothole (in the strict classical sense of the bowl-shaped pothole that loses pavement and is deepened and enlarged by traffic as the granular base is eroded).

In accordance with the information and test results reported by Martin Ekse, Volume 29, AAPT, 1960; W. Phang, Volume 50, AAPT, 1981; and WASHO Test Road Report, Part 2, Test Data, Analyses, and Findings; nine aspects of the 4" pavement design exist:

(1) 4" minimum pavement has more strength than AASHTO or other criteria indicated by straightline coefficient usage.

(2) Distress cracking in a pavement expands and multiplies rapidly when pavements are thinner. The cracking breaks the pavement into many small pieces. However, there is less fragmentation with 4" plus pavements. Also, rutting and waviness which reflect base material stress and freeze/thaw effects are virtually eliminated on 4" plus pavements.

(3) There is often a great deal of strain with a 2½" design due to construction traffic in site-work or subdivisions. In these situations it is common for the design to have a 1½" thickness carrying all of the construction traffic for several years. This initial layer gets easily overstressed and even cracked on the underside before it is topped with only an additional 1" wearing surface. On the other hand, with a 4" design a 2½" layer carries construction traffic adequately. A final 1½" layer provides a wearing and exceptionally strong strengthening course, providing much more strength and longevity to the pavement.

(4) With a 4" design pavement strength adjacent to utility cuts and castings is more substantial.

(5) Added strength acquired through the use of the minimum 4" design, provides a safety factor for traffic growth and occasional overload situations. This is particularly helpful when an owner may not have control of the traffic volume or the funds available to strengthen the pavement.

(6) A minimum 4" design provides a pavement that will require surface maintenance only. Pavement treatments can be limited to individual crack sealing, liquid seals, and very thin overlays—thicker overlays are required only when traffic growth calls for it.

(7) The 4" minimum provides sufficient thickness for recycling by milling. When milling 1" from a 2½" surface to a 1½" in depth, little stock is left for construction traffic to travel on.

(8) Better overall pavement quality and density can be achieved by using more compactible layer thicknesses. This leads to less embrittlement and greater retention of flexibility with time.

(9) Although 2½" designs have been shown in tests to be sufficient, it should be kept in mind that test road data always reflects better performance than actual practice.

When a 4" pavement is overloaded by traffic and cracks, the pavement is thick enough to resist disintegration into small pieces and to resist the type of flaking out at the crack that occurs on thinner pavements. This is why you will rarely see overnight potholing occur on a pavement greater than 4" thick. If distress is occurring, it will be evident for several years while remaining safe and serviceable. Only total neglect and lack of maintenance over many years will cause it to eventually break down into surface ravelling. However, this surface ravelling or delimination only affects rideability and appearance. It is tolerable from a safety and auto damage point of view.

Once weakened, pavement thicknesses less than 3 to 4 inches can break into pieces and pothole very easily. This is because the pieces are small enough to be turned out by tire traffic. On thicker pavements (about 3½"+) the thick broken pieces act like big paving blocks and are virtually impossible to be rotated out of the hole by traffic. In other words, it fails but remains safe for traffic.

Thin pavements are sometimes best restricted to liquid asphalt surface treatments that require frequent maintenance treatments every few years. These asphalt surface treatments are only recommended for very low volume roads, particularly those that do not have significant truck traffic. Such thin pavements must have excellent drainage designed into them and be diligently maintained throughout their service life.

Potholes in thin pavements rapidly get deeper and larger as traffic and water work them. They are the type that most seriously affect safety and cause more damage to autos. An additional problem is the need to overcome the use of poor minimum standards in subdivision control work and new work submitted by consultants. Some of these standards still call for thin surface treatments and pavement thicknesses less than minimums recommended for permanent pavements. The *lack of permanence* built into these new pavements means the municipality is accepting *greater annual maintenance.* This problem is compounded when some consultants use the same minimum standards on other municipal projects within the community and, worse yet, simply copy them to use in other towns as proper standards.

If standards are used, they must be reasonably conservative to cover the weaker conditions and unforeseen circumstances such as variance in soil conditions, construction quality, utility settlement and lack of maintenance when budgets are cut regardless of the pavement's condition.

For a low maintenance permanent pavement, the thickness used by most all agencies is at least 3 inches. The Asphalt Institute has a firm policy of recommending a minimum pavement thickness of 4 inches even for low volume roads.

According to The Asphalt Institute, the minimum permanent pavement thickness when using asphalt hot mix is 4 inches. The slab strength of a 4 inch thick pavement is substantially greater than that of a 2", 2½" or 3" pavement by many times: the load to produce a ⅛-inch deformation on the base is only 400 pounds on a 2 inch pavement; 3,900 pounds on a 4" pavement.

The information for this article was obtained, edited, and printed with permission from R.H. Joubert of The Asphalt Institute. ■

# New Video Loan Program for NH Towns

*The Technology Transfer Center is now able to lend video tapes to you at no cost. We currently have 27 tapes in our library. Soon, you will be mailed a complete video list containing titles and descriptions of all the tapes available. To get the program started, 10 of these tapes have been listed below. You can place your order by calling 1-800-423-0060, or by filling out the information request form in this newsletter. These tapes are VHS ½". Please limit your order to one tape per order and return the tape in two weeks so that others can also use it. A rating of excellent = *****

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Potholes, Cold Regions Research Laboratory (26 min.)****

(8) **Video Loan Order No. PA-201**
Subdivisions—A Local Dilemma (29 min.)****

(9) **Video Loan Order No. ST-203**
Worksite Safety: Night; Flagging; Traffic Control

- Night Safety at Worksites (12 min.)***
- Work Area Flagging (25 min.)***
- Selection and Use of Traffic Control Devices (30 min.)**

(10) **Video Loan Order No. ST-205**
Multiple Choice (24 min.)****

- six men in construction accidents and how they may have been prevented

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- Better Roads
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  Published twice monthly, this magazine carries articles of interest on construction activities in the northeast area. Constructioneer, 1 Bond Street, Chatham, NJ 07928.
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- Rural and Urban Roads
  Published bimonthly. Road construction and maintenance. Scranton Gillette Communications, Inc., 380 Northwest Highway, Des Plaines, IL 60016.

From Technotes, University of Maryland and Rural Technical Assistance News, ME DOT, Spring 1987. ■

# One Dollar Spent On Drainage Will Save Two Dollars On Maintenance

*Proper drainage is probably the most important element in road design*

Whether it is concrete, asphalt, or gravel, when a road fails, inadequate drainage is often the cause. Shoulders and embankments damaged by heavy rain or floods can allow water to stand on the road or seep back into the base, saturating it. Surface cracks allow water to penetrate and weaken the base. Poor design can direct water back onto the road or keep it from draining away. Too much water remaining on the surface, base, and subgrade combine with traffic action to cause potholes, cracks, and pavement failure.

To reduce water damage, build and maintain a good drainage system. **One dollar spent on drainage will save two dollars on maintenance.**

A proper drainage system has four major elements—roadway, shoulders, ditches, and culverts—which you must design, build, and maintain.

### Roadway and Shoulders

Design and build the roadway surface, base, and shoulder as a unit. One common gravel road construction method, the trench technique, causes poor drainage. This technique involves the shallow excavating of just the intended road surface, then filling the excavated surface with subbase and base material. The shoulders are not fully excavated and the original soil on the shoulder is covered with a thin layer of gravel.

The problem is that usually water can't penetrate beneath and through the shoulder subsurface material. These impermeable shoulders keep water from draining out of the roadway's base. Water is trapped and weakens the roadway.

For proper drainage and longer roadway life, excavate the shoulders to the same depth as the roadway and make them the same sub-base and base material (see the diagram on this page). Use a good draining gravel or crushed rock to remove any water which soaks through the surface or enters the subsurface from ditches.

The road surface should be crowned so water will run off to the shoulders. As a general rule, the roadway crown should be two and one-half inches higher than the shoulder for paved surface and five to six inches higher for gravel surfaces. Shoulders should slope as much or more than the road to keep water moving to the ditches. Shoulders extend the road surface, directing water flow to the ditches if they slope as much or more than the crown. If they slope less, water will build up at the joint between shoulder and road during heavy rain, flooding traffic lanes. Make sure the shoulder continues the road crown smoothly. For example, a paved roadway with an 11-foot lane and four-foot shoulder should have a total crown (from centerline to outside edge of shoulder) of not less than three and one-half inches.

Gravel roads subjected to frequent rains will need higher crowns to prevent the surface from absorbing too much water, becoming saturated, and not drying out. Traffic action on a saturated surface will cause potholes and ruts.

Good quality gravel absorbs only minimal amounts of water, sheds the rest, and dries out quickly. Poor drainage may be caused by gravel with a poor gradation of stones, sand, and fines. You can compensate partially for poor quality gravel with a higher road crown.

Steep roads may also require higher crowns since the water will tend to flow down the road, flooding traffic lanes, rather than across the crown.

Springs or seepage areas will require special treatment. You can use French drains (rock-filled trenches) or perforated pipes to drain this subsurface water into ditches or streams.

### Ditches

Ditches carry water away from the roadway and into streams or other natural waterways. To fulfill this function, ditches must be properly shaped for safety, maintenance, water-flow, and erosion control. The ditch should be at least one foot below the bottom of the gravel base in order to drain the pavement. Deeper ditches may be necessary to provide positive drainage patterns.

Ditches should extend the shoulders with smooth transition to a shallow foreslope. Sides that are too steep may impede maintenance and cause vehicles to roll over. A gentle slope makes mowing and ditch cleaning easier, faster, and cheaper. Side slopes of four to one are desirable. Two and one-half to one should be near the maximum slope. Of course, flat slopes require a wider right-of-way.

It is very important that water flow through ditches and not stand. Standing water may saturate the subsurface material, beneath the roadway, preventing the road from draining during the next storm.

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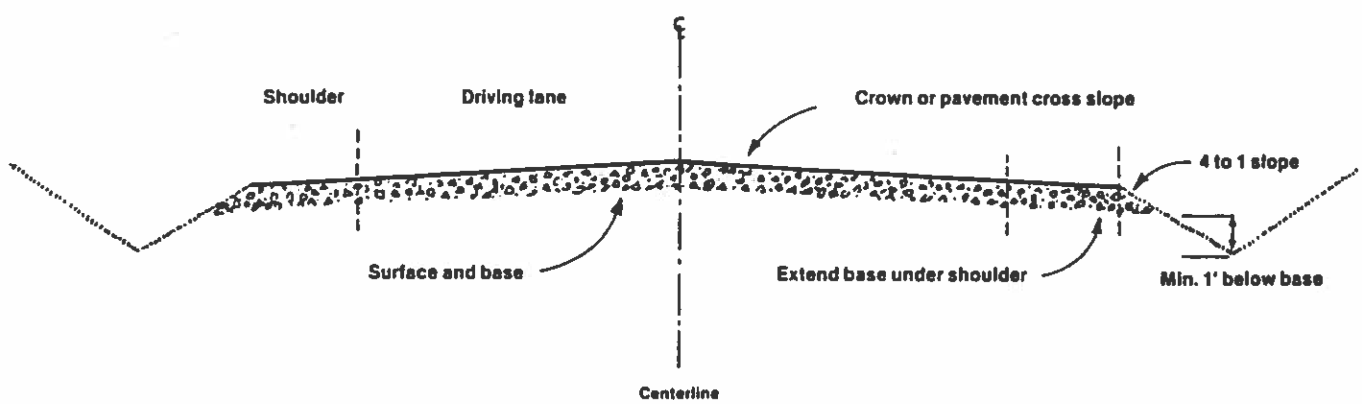

Proper Ditch

- safe
- higher capacity
- clean with grader
- blends into roadside
- easy to mow

Improper Ditch

- less capacity
- must be cleaned with backhoe
- cars can get stuck
- sides cave in

*Drainage...*
*continued from p. 7*

Standing water also reduces the ditch's capacity to handle run-off; the next storm could wash out the roadway. Ditches with a one percent gradient are desirable (one-half percent minimum) to insure proper flow.

The flow of water through ditches should not erode the ditch itself or weaken the adjoining shoulder.

Vegetation in ditches is necessary to help keep the soil in place and minimize erosion. Use paved ditches if steep slopes cause serious erosion.

### Culverts

Culverts channel water under the roadway from one side to the other. They help control water flow and slow it down to control erosion. In designing culverts, consider loads, cover, durability, capacity, placement, and gradient.

A culvert must be strong enough to support the fill material above it and the traffic that moves over it. Concrete culvert strength depends on wall thickness and the amount of steel reinforcement provided. **Steep culvert strength is determined by the depth of corrugations, gauge of steel used, and, to a great extent, the quality and compaction of backfill material on the sides of the pipe.** They should be covered with at least 12 inches of soil from the top of the pipe to the top of the subgrade. Arch and elliptical pipes or shallow box culverts can be helpful where there is limited depth of cover over the culvert.

A culvert must be durable and have sufficient hydraulic capacity to carry away a predetermined quantity of water in a given time. Design charts are available for each type of culvert. A complete design involves reviewing the topography, predicting runoff, sizing the waterway and culvert, and comparing cost to risk of flood damage. For roadway cross culverts, the minimum recommended size is 18 inches. When you decide to design a culvert, a professional advisor with local experience can save you construction costs and damage claims.

The capacity of a culvert can be improved by altering the entrance configuration. Beveling the edge of the inlet or using side-tapers and slope-tapers can help improve culvert capacity significantly.

Place culverts so they match existing contours; in the existing channel, if possible. Be extremely careful about changing culvert locations, capacities, or drainage patterns. Before replacing culverts located in established flood plains, you must also secure prior approval.

Culverts should slope enough so that water will flow at about two and one-half feet per second. A minimum drop of six inches across the road is desirable. This will keep sediment from accumulating in the pipe at the discharge end. Metal aprons or concrete headwalls improve the capacity, reduce erosion, and can shorten culvert length.

### Driveways

Poorly designed driveways can cause drainage blocks and flooding. Culverts should be required to maintain normal ditch drainage. An 18-inch minimum diameter is recommended.

Driveways should be built so that they either slope away from the road or are graded with the low point over the culvert. This prevents water from washing into the road from driveways.

### Maintaining Proper Drainage

If maintenance is neglected even on a road that has been constructed with all the proper drainage design elements, flooding, washouts, and potholes are likely to occur. **To keep a road in good condition, maintain the road surface and shoulders as nearly as possible to the original design.** This involves smoothing and reshaping gravel roads with a motor grader. Surfaced roads may need periodic patching or overlays.

**Ditches clogged with debris or sediment should be cleaned to avoid overflowing and washouts.** If the ditch has been properly built, it will have sides with slopes gentle enough so that a grader can clean it. You will need a backhoe to clear a ditch with steep side slopes. This is more expensive and time-consuming than using a grader. It's important to mow vegetation and cut brush so that it will not obstruct water flow. Also, be careful to disturb the vegetation as little as possible when removing sediment from ditches to limit erosion. it may be necessary to reseed, mulch, or use other erosion protection methods on steep slopes or in areas sensitive to severe erosion. Sediments from eroding slopes can fill other road ditches and culverts or pollute streams and lakes.

Keep culverts free of sediment to avoid washing out roads and flooding adjacent property. Preventing sediment from building up in ditches is the best maintenance technique. Clogged culverts can be cleared using hand shovels or mechanized equipment.

Culverts must also be inspected periodically for cracks or corrosion that might lead to failure.

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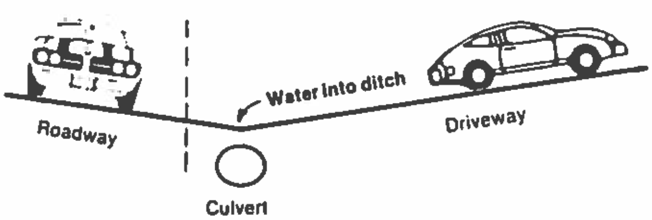
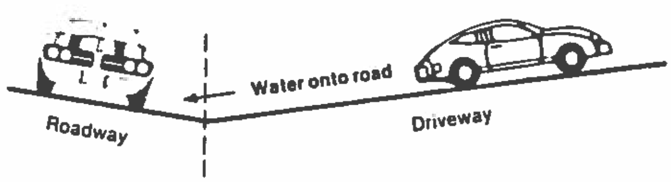



Proper Driveway




Improper Driveway

# Diagnostic Aid For Drainage Problems

| IF YOU SEE: | IT USUALLY MEANS: | YOU SHOULD: |
|---|---|---|
| **Scour at Inlet** | Pipe too small.<br>Pipe clogged.<br>Poor location. | Schedule for larger pipe.<br>Clean.<br>Relocate.<br>Until corrected, schedule for frequent cleaning and check for rust. |
| **Scour at Outlet** | Too much grade.<br>Pipe too small.<br>Pipe in poor condition. | Build stone apron at outlet end.<br>Check invert for wear or rust.<br>Schedule for repair/replacement. |
| **Standing Water** | Not enough crown on road. | Clean clogged drains.<br>Remove standing water by brushing.<br>Clean or deepen ditches.<br>Check drains often. |
| **Rusting/Corroding** | Water high in acid.<br>Scour from water flow. | Clean pipe.<br>Coat with asphalt.<br>Contact district for acid test for water. |
| **Edge Cracking** | Not enough shoulder.<br>Road too narrow. | Cut and stabilize shoulders. |
| **Alligator Cracking** | Sub-base is saturated.<br>Too much load on roadway. | Cut and shape shoulders.<br>Schedule for pipe placement.<br>Treat surface. |
| **Trash at Inlet** | Pipe clogged. | Clean trash away.<br>Clean ditches for 15 feet on both sides of inlet. |

*Drainage...*
*continued from p. 8*

**Summary**

Attention to proper drainage design and maintenance on rural roads is crucial and cannot be overemphasized. A proper drainage system has four elements—roadway, shoulders, ditches, and culverts—which, working together, prevent water from infiltrating the road surface, remove water from the driving lanes to the side ditches, and carry water away from the roadway. However, even roads with all the proper drainage design elements will flood, wash out, and develop cracks and potholes if maintenance is neglected.

Some quick tips for helping to design and maintain good road drainage:

- Build and maintain a roadway crown to drain water from the surface: one-fourth inch per foot of width for paved roads or one-half inch per foot of width for gravel roads.
- Avoid the trench technique of construction. Extend the roadway base to the outer shoulder edge.
- Use ditches with gentle side slopes to minimize erosion, aid maintenance, and improve vehicle safety.
- Design culverts to handle soil and traffic loads and appropriate drainage volume. Good design saves money.
- Maintain the pavement and culverts so they perform as originally intended.
- Keep ditches clean for efficient water flow.
- Inspect culverts regularly. Inspection after a heavy rain will give the most information on your drainage problems.
- Maintain natural surface water flow conditions and coordinate improvements with local drainage boards.

***References:*** Information and figure sources include: Oklahoma State University Fact Sheet D-1020, Kentucky Transportation Link Newsletter, Vermont Local Roads Program Fact Sheet T-610, and Wisconsin Transportation Bulletin Fact Sheet Number 4.

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