

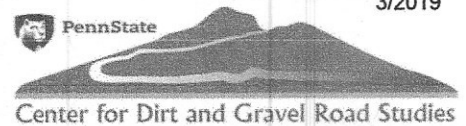
Technical Bulletin

Crown & Cross-Slope



PennState

3/2019



Center for Dirt and Gravel Road Studies

CROWN AND CROSS-SLOPE – This bulletin illustrates basic methods to drain water from the road surface using three (3) different surface templates. Crown describes the side to side, or the cross-sectional shape of a road surface. Typically road segments are either center-crowned, in-sloped, or out-sloped. The degree of the side slope is typically measured in percent or degrees, or expressed as inches of fall per foot of road width.

THE PURPOSE OF DRAINING THE ROAD SURFACE

When standing water is allowed to penetrate the road surface, through retention in puddles or potholes, the road surface and the road base become soft and weak. Flowing water that is allowed to concentrate on the road, such as in wheel tracks, causes damage and material loss from erosion. The purpose of surface drainage is to cause the water to leave the road as thin and non-erosive sheet flow in a direction and pattern chosen to suit various terrain and traffic conditions.

TYPES OF ROAD SURFACE TEMPLATES

1. **Centerline crown:** A surface shape that sheds water to both sides of the road from a highpoint at the road center (Figure 1).
- **In-slope:** A surface configuration that drains water from the entire width of the road toward the cut-bank or up-slope side. Commonly used on steep side-hills for safety. Super-elevation of curves (banked curves) is a form of in-sloping that both supports traffic and drains the road surface..
- **Out-slope:** Out-sloped road surfaces drain water from the entire width of the road toward the fill-bank or down-slope side. Elimination of road ditches on both sides of the road is possible with this surface shape. This shape best mimics natural drainage patterns and allows minor overland sheet flow is to flow across the road (Figure 2). Out-sloping is useful on low volume roads where side-slopes are gentle and concerns about winter icing are minimal.

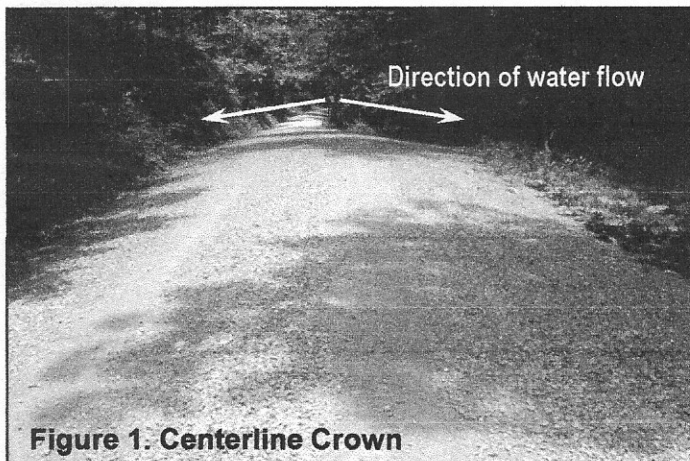
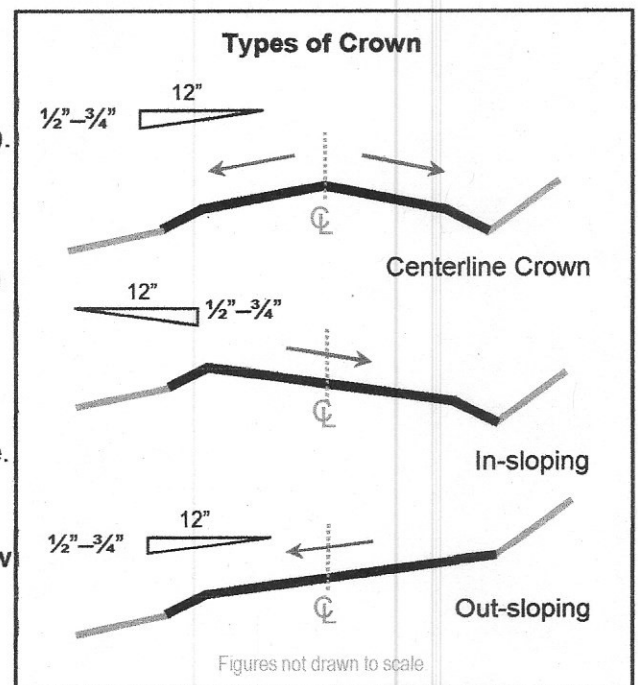


Figure 1. Centerline Crown

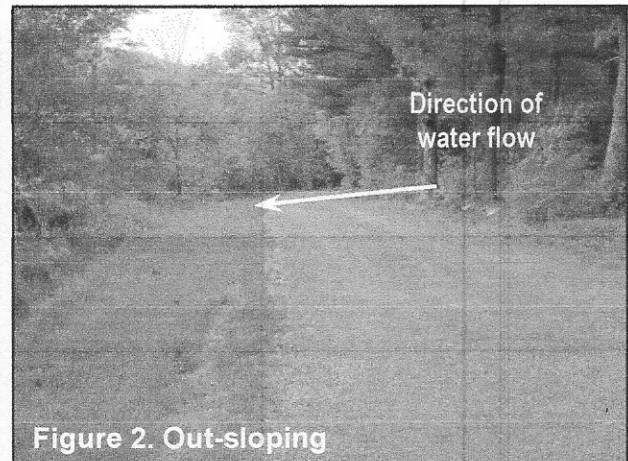


Figure 2. Out-sloping



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MAINTAINING ROAD CROWN

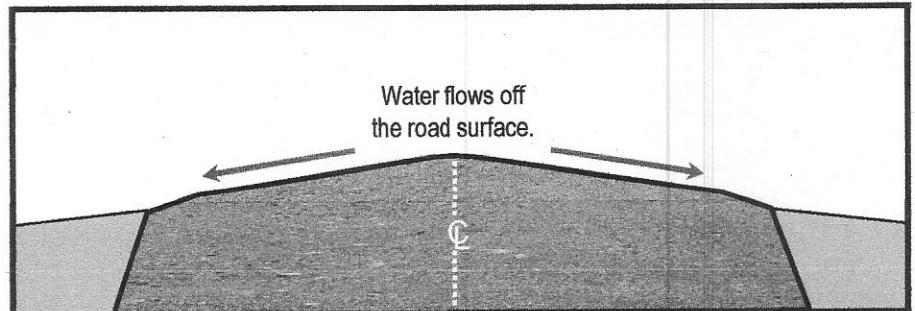
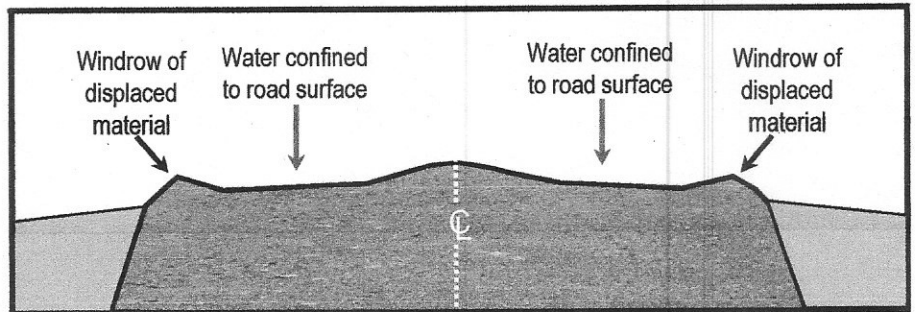
Compaction, abrasion, and displacement of aggregate caused by traffic, as well as disturbance from snowplowing, inappropriate grading technique, and forces from flowing water work to deform the road surface. Over time, fines, which bind the coarse aggregate together, are lost. The unbound coarse material is displaced by traffic and accumulates along the edge of the road. This traps water on the traveled surface, allowing the water additional time to saturate and soften the road. Compaction in the wheel tracks and windrows formed by displaced surface stone changes the shape of the surface cross-section. Additionally, water trapped on steeper road segments accumulates volume and velocity, eroding the driving surface, further changing the road's cross-sectional shape. This increasingly restricts the ability to shed water from the road surface (see Illustration 1). The process starts slowly, but if maintenance is not completed on a timely basis the damage to the road can be severe.

*Note - Specific procedures for re-establishing crown during maintenance operations are detailed in the *Grading Sequence with a Carbide-Tipped Blade* Technical Bulletin.

Illustration 1. A Center-crowned road that has become misshapen over time. The desired "A" shaped road surface has become a "W" shape, due to compaction of the wheel tracks and displacement of aggregate into windrows at the road center and road edges. Water ponds on the road surface and softens the road. Or, drainage is forced to travel on the road surface causing erosion, loss of road material, and an increased need for maintenance.

*Note - Additional methods of controlling this concentrated flow on the road surface are shown in the other Technical Bulletins.

Illustration 2. Centerline crown with proper cross-slope. Road drainage flows without obstruction off the road surface into ditches or surrounding vegetation.



CROWN: PAVED ROADS VS. UNPAVED ROADS

Unpaved roads require more aggressive crown than do paved roads. Pavement resists infiltration of water and will shed water more quickly than an unpaved surface. The cross-slope of a paved road is typically 2%, or $\frac{1}{4}$ " of fall per horizontal foot of road width. A common problem is to shape a dirt or gravel road like a paved road. An unpaved road requires 2X to 3X the side-slope to guard against erosion and displacement.

On unpaved surfaces, the recommended cross-slope is between 4% and 6%, or $\frac{1}{2}$ " to $\frac{3}{4}$ " of fall per horizontal foot of road width. The steeper cross-slope creates less potential for water to concentrate and scour the road surface, or to penetrate and weaken the road base. This equals less loss of purchased road material therefore and a smoother road with longer intervals between maintenance grading operations. Over time, traffic and mother nature will wash out and drive out the crown, so grading is routine and on-going maintenance. Every road is different, and some roads will require more frequent grading than others. Road shoulders should be set at the same side-slope as the travelway, or slightly steeper. Pay attention to the elevation of your road shoulders. A shoulder only slightly higher than the road surface can trap a whole lot of water on your road and it will only get worse from there!

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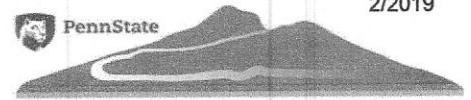
Surface Maintenance

For unpaved roads



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PURPOSE OF SURFACE MAINTENANCE FOR UNPAVED ROADS – To establish effective drainage, to smooth the road for vehicular travel, to reduce long-term maintenance costs and pollution impacts.

WHAT IS SURFACE MAINTENANCE?

Road surface maintenance is the periodic re-shaping of the road surface to ensure proper drainage and smooth traffic passage. The process may involve re-graveling, or the replenishment of surface material, and includes:

- Re-establishing crown and proper cross-slope (see Crown & Cross-Slope Informational Bulletin).
- Incorporating segregated stones back into the road surface (see Grading Sequence Technical Bulletin).
- Eliminating imperfections such as potholes, ruts, and washboards.

Timely maintenance using up-to-date surface maintenance techniques can improve road performance, lengthen maintenance cycles, reduce maintenance costs, and reduce pollution impacts.

WHY IS SURFACE MAINTENANCE NECESSARY?

The surface stones on an unpaved road are not bound with asphalt or concrete, as on a paved road, and are constantly moving due to traffic and weather. Vehicles differentially compact, displace, and segregate the mix. Freeze-thaw swells and breaks apart the road. Water trapped on the surface softens the road. Over time, the coarse stones, which provide support for traffic, are displaced and accumulate along the edge of the road. This resultant windrow traps water on the traveled surface. Water that cannot freely leave the road has more time to saturate the road surface and road base, breaking down the road's support structure. Additionally, water that accumulates on the road becomes increasingly erosive as it gains volume and velocity on steeper slopes, or forms potholes at low points on the road. The process starts slowly but if surface maintenance is not completed on a timely basis, the damage to the road can be severe.

BENEFITS OF SURFACE MAINTENANCE

- Limits water from flowing on, or laying on, the road.
- Creates a tightly packed road surface;
- Reduces dust generation caused by the grinding action of loose stones under traffic; and
- Minimizes loss of road material caused by traffic and erosion, to save money and reduce sediment and dust pollution.

INDICATORS THAT SURFACE MAINTENANCE IS NEEDED

- Excessive dust;
- Loose stone on the road surface or along the road edge (particularly in windrows – see Photo 1);
- Water flowing parallel with the road in the wheel tracks (see Photo 2);
- Holes or potholes (see Photo 3);
- Ruts or Wash-boarding;
- Loss of crown, even if other indicators are not yet present.



Photo 1

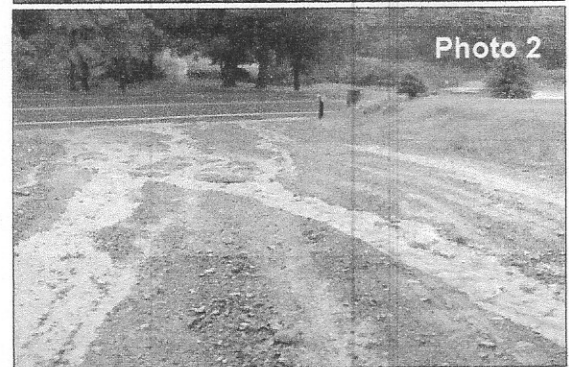


Photo 2

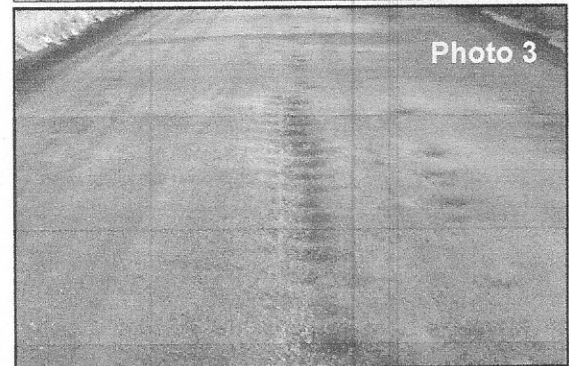


Photo 3



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ADVANTAGES OF A QUALITY AGGREGATE ROAD SURFACE:

A good road surface aggregate consists of a mixture of crushed hard stone designed specifically as a surface-wearing course. The mixture will have minimal amount of deleterious material such as clay, silt and organics. The gradation, or distribution of specific rock sizes, will create a dense and durable travel surface when compacted at optimum moisture. Driving Surface Aggregate, or DSA, is a good example of a quality surface aggregate. DSA information and specification can be found in the separate DSA Technical Bulletin.

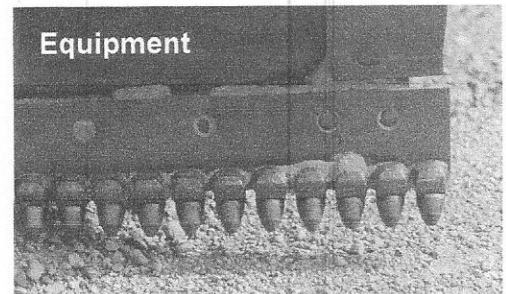
HOW IS SURFACE MAINTENANCE OF QUALITY AGGREGATE DIFFERENT?

Grading Equipment: A road surface made up of quality aggregate should always be graded and never bladed. The tight knit surface should not be disrupted with the use of a rake or drag. When grading, the equipment should cut deep enough (3"-4" +) to mix fines embedded in the road back in with larger stone retrieved from the road edge. A carbide toothed grader blade is ideal for this purpose.

Moisture: Moisture is critical to achieving maximum compaction (road density). Grading quality aggregate should be done when adequate moisture is present in the road to minimize segregation of stone sizes and maximize compaction density. Grade after extended wet weather periods, or add moisture to the road surface (see Photo 5). Compact the road following grading, before the road dries.

Compaction: Post grading compaction greatly extends the functional life of a re-graded road. This procedure minimizes the differential compaction and aggregate displacement caused by traffic and allows the road to maintain effective crown longer. The loss of fines, typically flushed from the road surface by the first rain storm on a freshly graded road, is reduced considerably. This reduces the loss of purchased road material and sediment pollution of nearby surface waters. A 10 ton vibratory roller is ideal for this application. However, smaller vibratory rollers and even static drum rollers will add to the durability of the road surface and the longevity of the grading job.

Re-graveling (surface replenishment): Whether doing a full overlay or a skim coat, it is best to reapply quality aggregate, so as not to contaminate or compromise the original aggregate mixture.



OTHER MAINTENANCE OPERATIONS

- Shoulder maintenance and ditch cleaning are often combined with surface grading as one operation. Material retrieved from the road shoulder is often displaced surface aggregate useful in reconditioning the road. Ditch material, often rich in organic debris, is not desirable road material. Combining ditch cleaning and shoulder maintenance with grading typically leads to some ditch material mixing into the road aggregate. This has the serious drawback of contaminating the quality surface aggregate and nullifying its desirable attributes.
- Potholes must be scarified at least 1" below the base, or bottom, of the hole. If a pothole is too deep to scratch to this depth with a carbide toothed grader blade, the hole should be scratched with a trenching bucket on a backhoe or excavator prior to the grading operation. Where numerous deep potholes exist, each road lane should be graded in two directions (with traffic and against traffic) prior to the final grooming pass and subsequent compaction.

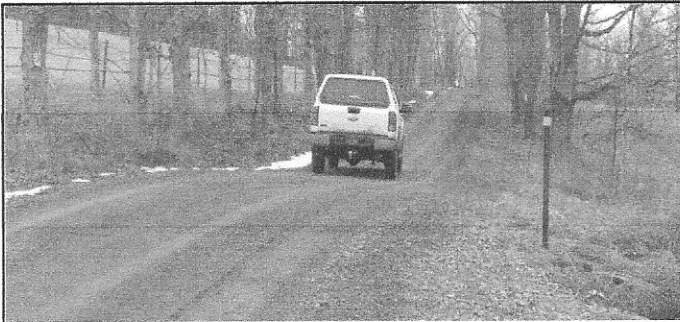
MAINTENANCE STRATEGIES

- Avoid doing road surface maintenance and road ditch maintenance on a schedule and together. Grade a road and clean ditches only when needed (see page 1 for grading indicators).
- If both surface grading and ditch cleaning are necessary, and separating the procedures is impractical, cut the road shoulder and blend that material back into the road before cleaning the ditch. Clean the ditch, remove the ditch material from the road, and dispose of the spoils appropriately.

Technical Bulletin

Surface Drainage Practices

Surface Drainage Practices – Road maintenance features designed to shed water from the travelway, including crown and cross-slope, grade breaks, and broad-based dips.



Grade Break - A small increase in road elevation on a downhill slope, which forces surface flow off the road.



Broad-Based Dip - A small increase in road elevation that directs all road drainage across the road to an outlet.

PURPOSE – To quickly move water from the travelway. To prevent linear flow and standing water on the road. To lengthen time between grading or re-graveling and to reduce pollution.

BENEFITS OF GOOD SURFACE DRAINAGE:

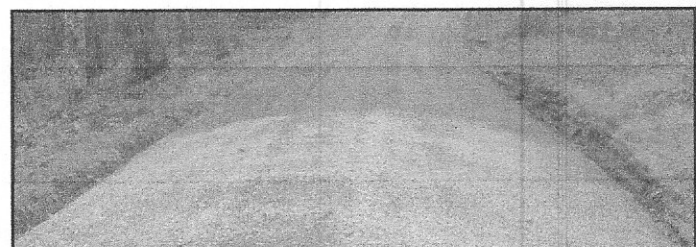
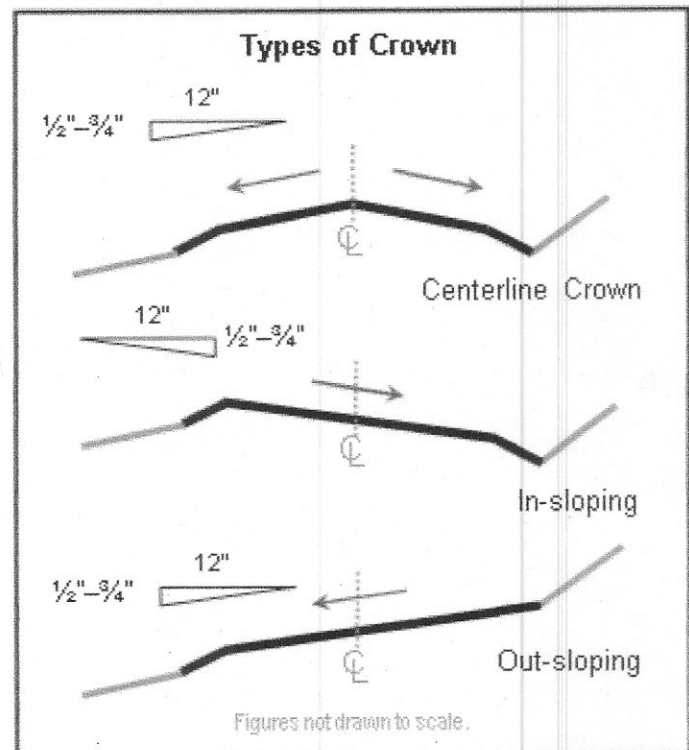
- Improves drivability and ride quality.
- Sheds water from road surface into ditches.
- Reduces surface material loss.
- Reduces base saturation, improving stability.
- Reduces long term maintenance cost and pollution of nearby surface water.

WHERE TO USE –

- Use crown and cross-slope on all roads.
- Use Grade Breaks (GB) and Broad-Based Dips (BBD) where road grade, topography, traffic, and ability to maintain are applicable.

CONSIDERATIONS –

- Crown and cross-slope is the road's first line of drainage defense and is a must.
- Maintenance of surface shape is necessary.
- Grade Breaks and Broad-Based Dips have slope limitations. A road can be too steep to use these practices.
- Traffic and vehicle type must be taken into account when considering a GB or BBD.
- Mark GBs and BBDs to alert grader operator.
- Center-crown, in-slope, or out-slope utilize the same 4% to 6% on unpaved roads and 2% to 4% on paved roads.



Center Crown – An “A” shaped high point on the road centerline to shed water to both sides of the road.

COMMON APPLICATIONS OF SURFACE FEATURES—

Center Crown

- Most common road shape. Splits drainage and traffic lanes.

Inslope

- Consider when a steep downslope bank exists.

Outslope

- Consider on low traffic/low speed roads with minimal downslope bank.
- Use to avoid concentrated drainage outlets.

Grade Break

- On low traffic and low maintenance public roads.
- To provide cover for shallow crosspipes.
- For access roads to prevent run-on flow.

Broad-Based Dip

- On very low traffic and low maintenance public roads where water on the road is acceptable.
- Where crosspipes or outslope are not practical.
- For access roads to prevent run-on flow.

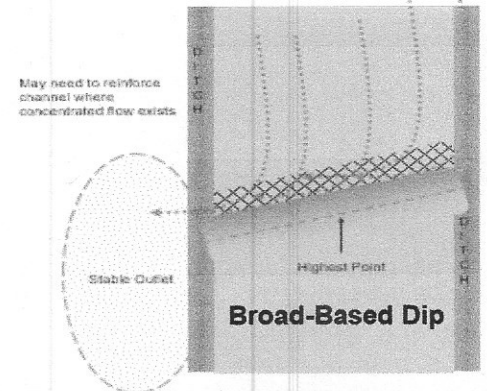
CONSTRUCTION AND MAINTENANCE NOTES —

- Surface drainage practices vary in methods of maintenance.
- The use of a motor grader is the most common way to establish and maintain surface crown and/or cross-slope.
- Adequate material, capable of being shaped and compacted, is a must to effectively create the desired shape in the road.
- Unpaved roads need 2X-3X more crown than do paved roads.
- A paver may be employed to establish the initial crown and/or cross-slope and to replenish gravel as needed.
- Imported material (fill) is required to establish a Grade Break (GB) and a Broad-Based Dip (BBD).
- In general, Grade Breaks and Broad-Based Dips are installed using earthmoving equipment other than a motor grader.
- Construct GBs and BBDs to accommodate intended vehicles, so as not to cause ground clearance issues.
- Mark locations of Grade Breaks and Broad-Based Dips, to avoid removing them when grading or snowplowing.

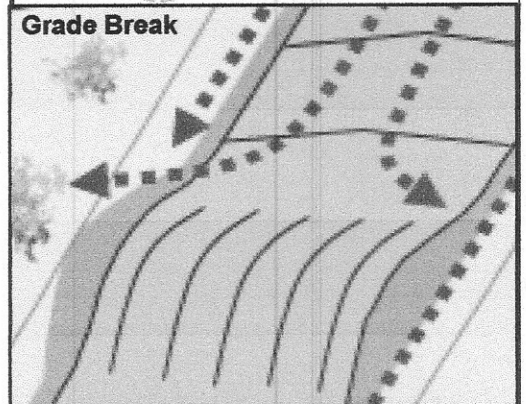
SURFACE DRAINAGE INFORMATION WORTH KNOWING —

- All practices are used to shed water from the road surface
- All practices are driven out over time and must be maintained
- All practices can be used on public roads and access roads
- All roads require crown and/or cross-slope
- Construct GBs and BBDs to create a reverse linear grade
- GBs and BBDs may calm traffic and extend surface life
- Grade breaks can be used with an associated crosspipe
- Broad-Based Dips may require a hardened flow channel
- Effective compaction extends the life of all surface features
- Roads with inslope and outslope shape suffer less surface damage during snowplowing than does a center crown road

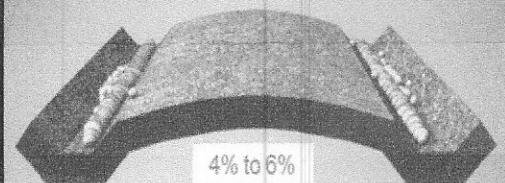
Common Surface Practices



Grade Break



Center Crown (surface cross-slope)



Top to bottom – Sketch of broad-based dip, illustration of grade break, proper slope for center crown

