Some Approaches in Treating Automatically Collected Data on Rutting

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New methods of collecting data on pavement rutting have enabled a more extensive use of this distress for pavement maintenance. However, rut depth is merely an indicator of road rideability and does not itself provide enough information on the cause of pavement rutting. A statistical analysis of longitudinal variation of rut depth may indicate whether a certain layer is deformed, compacted or abraded. Traffic and environmental data seem to be needed for feasible analyses. Measurements repeated three times a year or more will certainly indicate if rutting can be attributed to studded tire wear, and one may also infer from these measurements when deformation during hot days occurs. Deep-lying deformations may be related to wet seasons or freeze-thaw cycles. Finally, by comparing certain properties of transversal profiles, such as how wide and how far apart the wheel tracks are, one may have a good basis for taking the right maintenance actions as the distress itself reflects the cause of it. In order to do so, it is imperative that the resolution be adequate both transversally and longitudinally. If this is the case, the profile evaluation method seems to be most appropriate when climate, subgrade, pavement and traffic data are scarce.

An appropriately designed, constructed, and maintained road will eventually wear down due to climate and traffic. This ageing can be recognized in flexible roads as fatigue cracking and pavement rutting. In a very generic way, one may consider the former distress typical for asphalt concretes with hard binders and, consequently, one associates rutting with soft binders.

Pavement rutting usually refers either to deformation or compaction by heavy wheel loads in one or more layers. Abrasion by studded tires is often included in this definition, largely because the adverse effect on traffic seems similar, that is, one may quantify the maximum rut depth as a term in the serviceability index (PSI). In this context, rutting will refer to the phenomenon of longitudinal depression of the road surface, whatever its cause.

However, the cause of rutting is not unimportant. Different causes will most certainly engender different maintenance actions. Furthermore, assuming that the maximum depths are the same, ruts caused by compaction of a deep-lying layer are not as severe for traffic as are deformation ruts near the surface. Ruts from studded tire wear may be very difficult to master, because they are often narrow and have steep edges. The extra wear and tear on pavements and tires inherent in such ruts make repair actions feasible when they are shallower than the other causes of rutting.

Over the years, rut depth has been considered in assessing the quality of road sections and whether to take maintenance actions. Typically, a rut ½ inch deep would yield routine maintenance, and a rut ¾ to 1 inch deep would render an overlay. Some confusion prevails regarding the definition of the depth. In the AASHO road test, for instance, a rather short (4 foot) straightedge was used. By increasing the base (length of the straightedge), up to 30% greater depths may be recorded (*1*). The accuracy and frequency of measurements may also affect the result. It is evident, however, that manual measurements are extremely tedious and that rut depth is of little significance in the PSI formula as long as it is fairly moderate. Therefore, a visual estimate is often considered sufficient for rating purposes, especially where relatively hard binders are used and rutting is of little or no significance.

In regions where softer binders are used, typically where great temperature differences occur, rutting may be the dominating distress, as well as a good indicator of the state of the road. In sections with much studded tire traffic, ruts develop which are directly related to the number of passing studded tires. Low-volume roads with thin asphalt-bound layers are also susceptible to rutting. Carefully estimating the extent, severity, and type of rutting for these road categories is essential to sound pavement management.

In the wake of tedious manual measurements, various types of equipment have been developed, many of which are electromechanical. Ultrasonics, interferometers, and lasers have recently been used either to obtain a reliable profile (standing still) or to acquire data at high speeds on entire roadnets. Much of the data can be stored and treated in ways that make it possible to judge road distress more delicately than as a mere value of maximum depth within a profile.

It is important to determine the initial cause of a rut. In some cases, this may be simple, especially if construction, maintenance, climate, and traffic data are known. However, in most cases, different factors combine to cause ruts, making a mathematical model desirable that contains all possible combinations.

This modeling provides several options that use the parameter depth. Depth, as such, is often considered the third dimension, with length and width the first and second dimensions. Time is generally denoted as the fourth dimension. Relating these dimensions to depth may indicate the type of distress. Using all four dimensions might provide feasible guidelines for further maintenance strategies.

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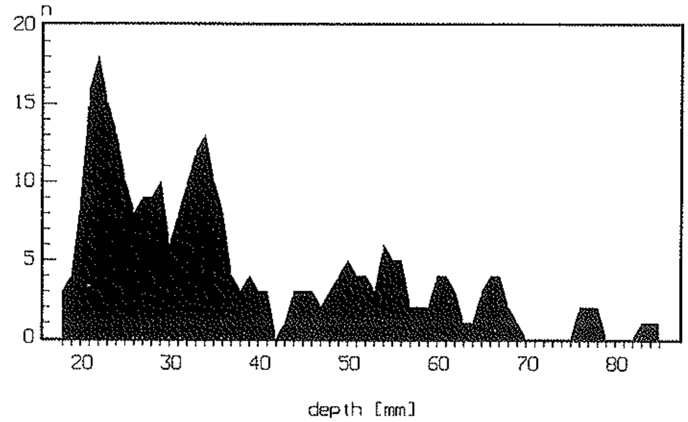

FIGURE 1 Frequency diagram of rut depth: low volume road.

VARIATION OF MAXIMUM RUT DEPTH ALONG A SECTION

The variation of rut depth along the road (i.e., along the third and first dimensions) can be utilized in an analysis because studded tire wear is lengthwise more uniform than are deformations, at least when no excessive traction, side, or braking forces are applied. Pavement deformation is a much more temperature-dependant variable, and therefore variation is likely to occur due to shadows and different materials in the road structure.

Because materials also vary lengthwise, a good record is required of what is in the road. If rutting results from deformations lying deep in the structure, a thin asphalt pavement might sustain a certain degree of deformation and then crack, giving way to even more deformation. A frequency graph of rut depths may show two maxima, one for the uncracked portion and one for the parts with thoroughly propagated cracks. If the process is allowed to continue, the asphalt layer will crack in all directions, a typical fatigue crack pattern will occur, and the bound layer will no longer be able to provide load distribution support to the underlying layers. In such cases, a third group of ruts may be agglomerated around a still deeper value, which is illustrated in figure 1. In this particular case, maximum depths were measured every meter over a 100 m section of road with no apparent variation of subgrade and pavement properties. A millimeter precision of classes and a moving average of three measurements is presented in the figure. Thus, the influence of macrostructure is suppressed.

A different example from a high-volume road is shown in figure 2. In this case the bound layers were roughly a foot (300 mm) thick together, and no cracking was evident. Consequently, the rut depth does not vary greatly, even though the average is as high as an inch (25 mm).

The differences in thickness in the examples above may be detected statistically by calculating the second, third and fourth moments of distribution. A low-volume road having a thin pavement yields high variance and skewness values but a low kurtosis. A high-volume road having a more symmetrical distribution is less skewed. It is understood that these quantities may also be useful in determining a criterion for overlay and routine maintenance, especially for thin pavements.

In the above examples, measurements were carried out manually along every meter of the sections. With automatically collected data, the sampling rate could be more frequent. It is not known if a higher sampling rate would improve the statistical data or if a lower resolution could be permitted without deteriorating it. An appropriate rate can be determined by autocorrelating various sample rates.

TIME-RELATED RELATIONSHIPS

A growth history can be obtained by relating rut depth to time. Classically, a new road will be aftercompacted by traffic,

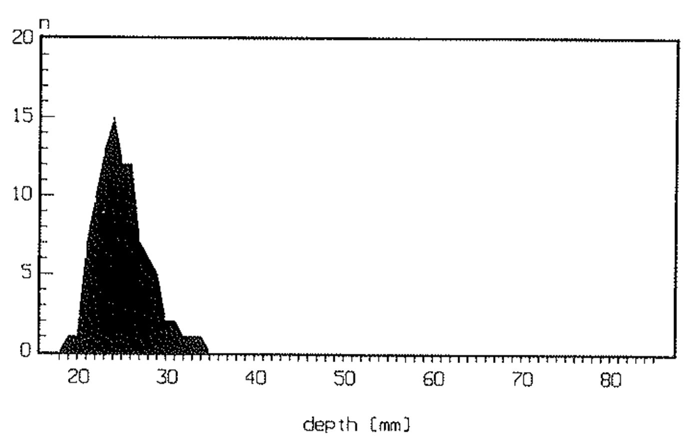

FIGURE 2 Frequency diagram of rut depth: studded tire wear.

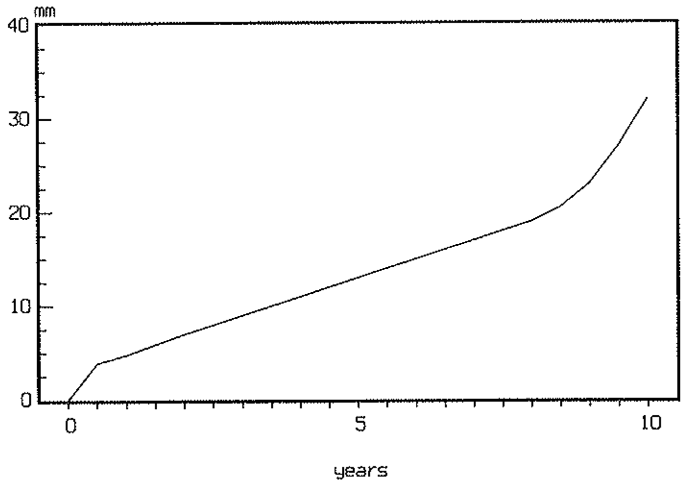

FIGURE 3 Classical rut growth.

that is, both granular and bound layers will be densified. Therefore, depths of ⅛ to ¼ inch develop relatively quickly, then the process slows. As ageing occurs, the asphalt layer becomes more brittle and susceptible to cracking. The cracked asphalt-bound layer cannot provide an adequte load distribution on the granular courses, and growth accelerates (see figure 3). Ruts caused by studded tire wear, however, are directly related to the number of studded tires passing the section, as illustrated in figure 4. This type of wear is even more apparent if measurements are made at least twice a year, before and after each stud season, which is the concept illustrated in figure 5. Figure 6, on the other hand, illustrates deformation caused by heavy loads and high temperatures. In a similar way, compaction and/or deformation of deeper-lying layers may be detected if rutting is recorded before and after a wet season. Figures 3 through 6 illustrate well-known concepts in rut growth. In reality, however, a combination of causes often makes it difficult to appraise the growth satisfactorily. Therefore, determining the causes by evaluating rut growth will require repeated measurements and a good backlog of previously-known relationships.

MEASURING THE RUTS TRANSVERSALLY

The profile transversal to the direction of travel represents the second and third dimensions. It contains information on the width of the ruts and on how far separated they are. Deformation is usually caused by heavy loads in vehicles whose tire configuration differs from passenger cars with studs. By carefully evaluating the profile, one may draw conclusions from this fact and act accordingly. This is probably the best way to trace the cause of ruts when earlier information on the state of the road is poor and when the pavement and underground materials are scarcely known.

Commercial vehicles are wider than passenger cars, therefore the outer distance from tire wall to tire wall is much greater. However, as implied by load, most trucks have dual tires on each side. The inner distance from tire to tire is therefore about the same as for passenger cars. To determine which vehicle category caused the ruts, the mean distance between tires can be measured. It can be assumed that a rut will be deepest in the center if it was due to the same type of vehicle. The vehicles passing the section, however, are

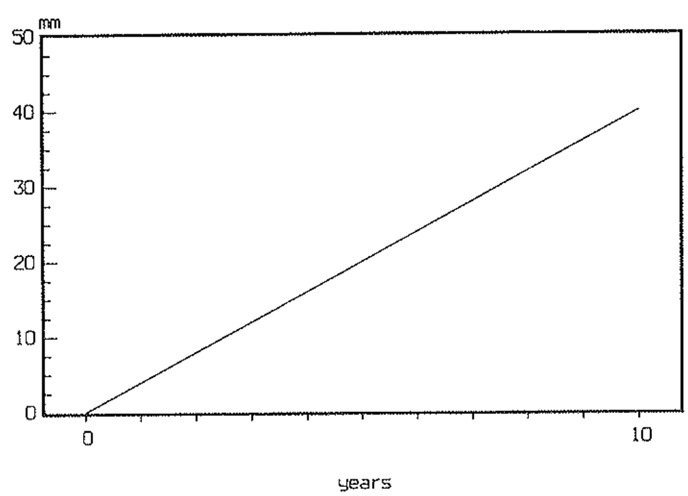

FIGURE 4 Studded tire wear growth.

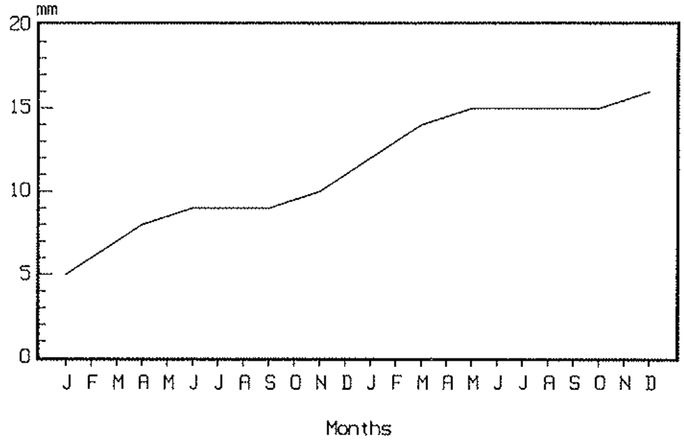

FIGURE 5 Studded tire wear growth: monthly measurements.

randomly distributed transversally over the lane. Thus, provided the section is passed by the same type of vehicle, one may determine the gauge by measuring the distance between the bottom points of the ruts. However, if the section is trafficked by various types of vehicles (as it is in most cases), using this distance would not suffice. For example, the wearing course may be deformed primarily by heavy traffic. In those ruts, studded tires wear down a few millimeters of the surface. Then, by taking the maximum-to-maximum depth distance between the ruts, studded tire wear will be indicated, albeit the deformation dominates.

A measurement based on worn or depressed areas may provide a better indication of the cause. This is done by determining the distance transversal to the direction of travel between the points where each rut profile area is divided in two equal halves. Thus, the distance between ruts can be determined based on the deformed or worn profile area of each rut, as shown in figure 7.

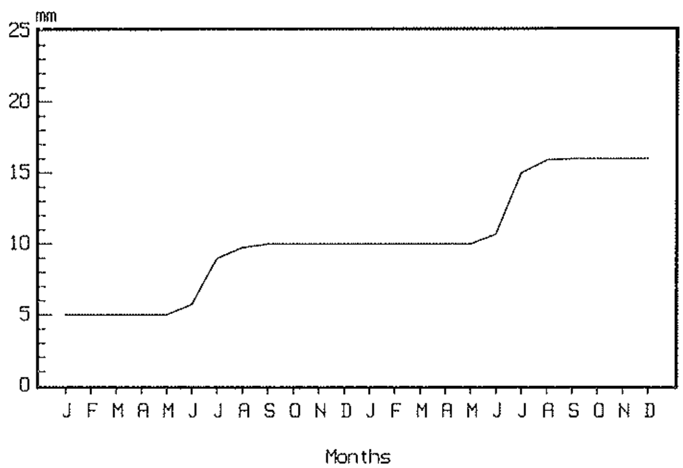

FIGURE 6 Deformation growth: monthly measurements.

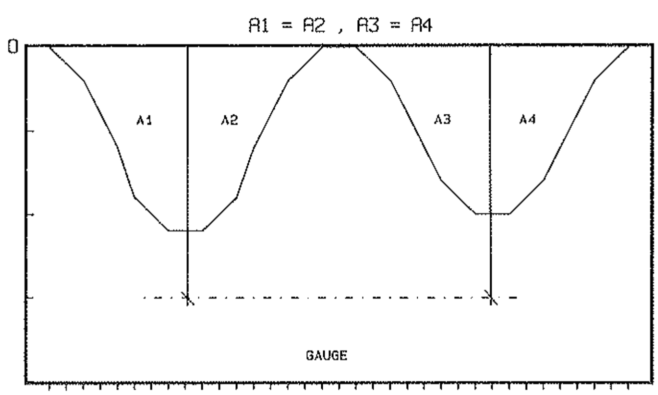

FIGURE 7 Definition of rut gauge.

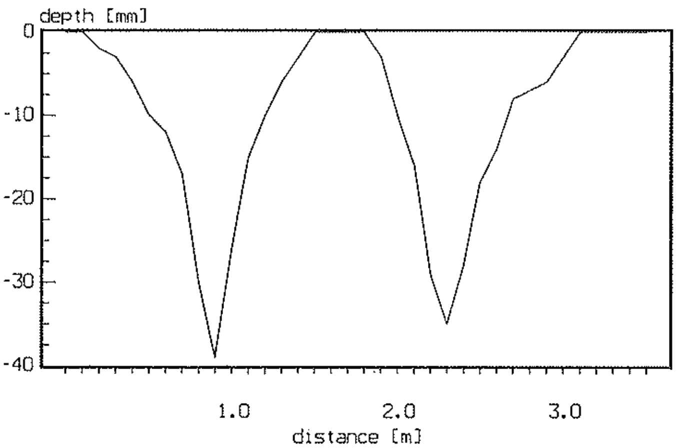

FIGURE 8 Profile of studded tire wear.

Another indicator of vehicle category is the width of the ruts. Naturally, ruts from heavy vehicles are wider because of their wheel configuration. Examples are shown in figure 8, which is taken from a lane dominated by passenger cars, and figure 9, which is a profile from a lane with slow and heavy traffic. The difference between these extremes is obvious. For most cases, however, it may be more difficult to discern the dominating cause. Often the road is repaired with materials whose properties differ from the original materials, often three lanes are made into four, and so forth. In such cases, the width of the ruts may complement the gauge mark determinations. The rut width can be determined as the gauge distance. A certain portion of the rutted (abraded) area around the middle of the rut can be considered (see figure 10). A studded tire rut is much narrower than a deformation rut of the same profile area; deep-lying deformations are even wider.

Widespread use of super single tires also affects these measurements. The ruts resulting from this category of vehicles

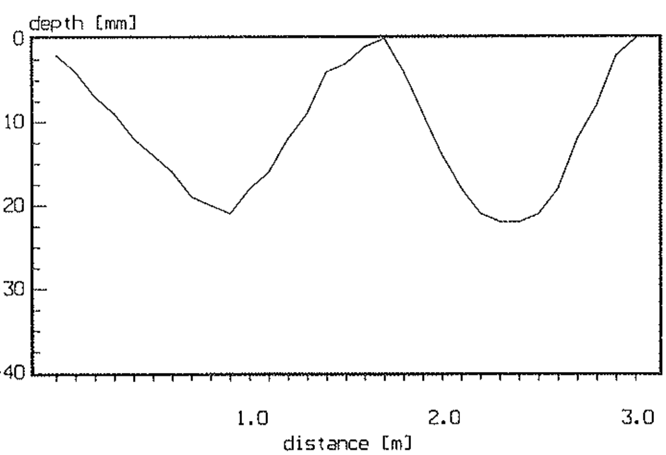

FIGURE 9 Profile of deformation.

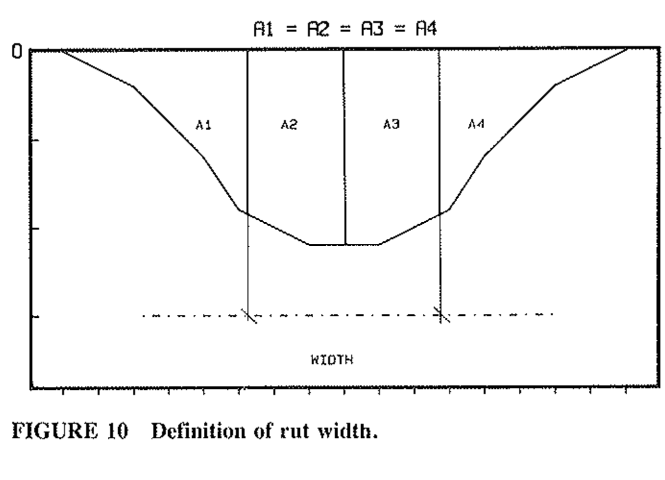

FIGURE 10 Definition of rut width.

are probably narrower than the standard dual-wheel load configuration and even wider than those from studded passenger cars. The distance between ruts, however, is greater than for any other vehicle category.

Quantifying these measures presents a method of determining rut cause without necessarily having data on traffic, road, and climate. Width and gauge can easily be determined by measuring systems currently in use, since the algorithms are very simple. However, readings must be taken sufficiently close transversally in order to obtain a profile detailed enough to trace the narrow studded tire rut. Examples of measurements are shown in tables 1 and 2. The first example is a section from a fast, leftmost lane dominated by passenger cars. The second is from a section where traffic often is congested, and thus the influence from heavy vehicles is larger. (Corresponding graphs are shown in figures 8 and 9, respectively.) The examples are excerpted from an unpublished study on wheel track rutting on various pavement types in the city of Stockholm. Roughly one hundred profiles were analyzed in the study, most of them from high volume roads. In order to validate these concepts, further research is needed under controlled conditions, employing a wide range of traffic compositions, as well as construction types and climate conditions.

CONCLUSION

New methods of collecting data on pavement rutting have enabled a more extensive use of this important distress category in pavement management. Rutting, as such, may be caused by several factors and combinations thereof. A simple maximum value of a transverse profile, known as rut depth, is merely an indicator of road rideability and will not provide information on the cause of rutting.

Rutting data must be treated statistically to see if the variation of depths follows a known rule for a certain reason. The reasons, as well as traffic data, must be known, or it will be difficult to differentiate studded tire wear from shallow

TABLE 1 CHARACTERISTICS OF A PROFILE FROM A SECTION WITH MUCH STUDDED TIRE WEAR

Measured profile at E4N, Left lane at Ulriksdal February 1984

Distance, [mm]:	100	200	300	400	500	600	700	800	900	1000
Depth, [mm]:	0	0	0	2	3	6	10	12	17	30
Distance, [mm]:	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000
Depth, [mm]:	39	26	15	10	6	3	0	0	0	0
Distance, [mm]:	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000
Depth, [mm]:	3	10	16	29	35	28	18	14	8	7
Distance, [mm]:	3100	3200	3300	3400	3500					
Depth, [mm]:	6	3	0	0	0					

Worn/Depressed Area, Left Rut:	179 cm^2
Worn/Depressed Area, Right Rut:	177 cm^2
Worn/Depressed Area, Total:	356 cm^2
Width of Left Rut:	29 cm
Width of Right Rut:	31 cm
Distance between ruts:	146 cm

TABLE 2 CHARACTERISTICS OF A PROFILE FROM A SECTION WITH SLOW TRAFFIC

Measured profile at 275W, Right lane at Brommaplan, July 1984

Distance, [mm]:	100	200	300	400	500	600	700	800	900	1000
Depth, [mm]:	2	4	7	9	12	14	16	19	20	21
Distance, [mm]:	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000
Depth, [mm]:	18	16	12	9	4	3	1	0	4	9
Distance, [mm]:	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000
Depth, [mm]:	14	18	21	22	21	18	12	8	2	0

Worn/Depressed Area, Left Rut:	187 cm^2
Worn/Depressed Area, Right Rut:	149 cm^2
Worn/Depressed Area, Total:	336 cm^2
Width of Left Rut:	50 cm
Width of Right Rut:	36 cm
Distance between ruts:	149 cm

asphalt layer deformation, since both causes have small longitudinal variations.

Measurements repeated preferably three times a year or more will indicate with certainty if the rutting can be attributed to studded tire wear. If pavement temperatures are known, one may also conclude when deformation in hot weather occurs and thus obtain criteria for restraining loads for certain pavement temperatures. Deep-lying deformations may be related to wet seasons or freeze-thaw cycles.

Finally, comparing certain properties of transversal profiles, such as how wide and how far apart wheel tracks are, one may have a firm basis for taking the right actions as the distress itself reflects the cause of it. In order to do so, both transversal and longitudinal resolution must be adequate. Provided that these criteria are fulfilled, this evaluation method seems to be most appropriate when climate, subgrade, pavement, and traffic data are scarce.

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