EVALUATION OF THE STRUCTURAL ADEQUACY OF BITUMINOUS PAVEMENTS FOR COUNTIES AND MUNICIPALITIES IN MINNESOTA

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This paper presents the results of a cooperative study between the Minnesota Department of Transportation and a number of the counties and municipalities in Minnesota. It is sponsored by the Minnesota Local Road Research Board. The purpose of the project has been to make flexible pavement evaluations techniques available and usable by the local agencies. The procedures are now available in Minnesota. The evaluation procedures include the Benkelman beam to evaluate the pavement strength and load carrying capacity, surface condition surveys, and roughness measurements with the Brokaw Roadmeter to determine present serviceability index. In addition, detailed traffic analyses are being made on specific roads in the three counties and municipalities. The vehicle weights and distributions are being determined to compare with similar distributions on primary roads. A procedure developed by the Minnesota Department of Transportation (Mn/DOT) is used for converting traffic weights and distributions to predict equivalent 80 kN (18,000-lb) single axle load applications. The project includes evaluation of about 193 km (120 mi.) of bituminous pavements in each of three counties and one 1.6 km (1 mi.) segment in each of six municipalities. The paper will demonstrate the relevance of the pavement evaluation techniques on low volume roads and how the results can be used to set up a pavement inventory system. This system can then be used to lay out a maintenance schedule for the participating counties and municipalities. All of the procedures presented are usable and available to the counties and municipalities in Minnesota. The results of the study are making it possible for the local engineers to make decisions on when maintenance is needed on a given road and what the most appropriate procedure would be. The data obtained give the engineer factual information about the road to aid his judgment in making maintenance decisions.

The cost of 2.54 cm (1 in.) of asphaltic concrete overlay is now approximately $10,000 per 1.6 km (1 mi.). Pavement engineers, therefore, want to make sure that the pavement to be overlaid is really in need of that overlay. Also, the engineer would like to be assured that with the investment in an overlay or some other type of maintenance the structure there will withstand the expected traffic. Questions such as "Will the additional investment last long enough to be justified?" or "Will a 5.08 cm (2 in.) overlay last 10 or 20 years, 10 or 20 months, or 10 or 20 days?", should be answered. Another question that could be asked, "Is a 5.08 cm (2 in.) or 10.16 cm (4 in.) overlay necessary or could one get by with just a leveling course or some other type of surface treatment?" There are many criteria and factors that will be involved in making the decision on a particular road. In fact, the decision that is made on a given road will not only depend on its condition but also on the condition of other roads under the same jurisdiction.

In the last few years maintenance has become a much more important part of pavement engineering because fewer new roads are being constructed. With the many miles of surfaced roads that are now in existence, it is necessary to be able to judge which ones should be maintained and what maintenance procedures are most appropriate. For all except the very smallest of jurisdictions, some type of a maintenance management system should be used to establish priorities.

It is with this in mind that the steering committee of the Minnesota Local Road Research Board has chosen the subject of pavement maintenance management. During the last few years, work has been done to present rating systems and procedures which will make it possible to quantify some of the parameters needed to help make a judgment as to proper maintenance procedures.

So far, four presentations have been developed and been presented around the State of Minnesota.(1) These are: 1) Surface condition rating system; 2) Rideability; 3) Traffic; and 4) Strength.

The surface condition rating system presents a procedure for evaluating the characteristics of the bituminous surface only. By observing these and putting them into a rating scheme, it has been possible to determine if a given pavement is in need of a surface treatment or seal coat or some other type of resurfacing.

The presentation on rideability describes methods by which the roughness of the pavement can be converted into a rating from 0 to 5. This is defined in terms of the present serviceability concepts developed at the AASHTO Road Test.

In the traffic presentation, a method is described which makes it possible to calculate the load effect on the pavement in terms of equivalent 80 kN (18,000-lb) single axle loads.

The strength of the road is defined using two procedures. The first considers the type or strength of the embankment and the thickness of the pavement section layers. The second uses the Benkelman beam deflection test which gives a direct measure of the strength of the road at the time of the test. With these procedures it is possible to estimate the life of the road under the predicted traffic and also determine what the allowable load should be on that road during the critical spring period.

Each of the procedures presented uses concepts and equipment that are readily available to the counties and municipalities in the State of Minnesota. The procedures presented are either those used directly by Mn/DOT or are slightly modified from procedures which are used on the trunk highway system. It is recognized that there are other factors that will govern when and what is done to a particular pavement section. However, the parameters that are presented will help in the decision makers by making available more specific information on which to base their judgment.

This paper is a brief resume of each of the parameters and procedures which have been presented. A method of summarizing this information into usable form is then suggested.

Summary of Parameters

Surface Condition Rating System

The surface condition rating system includes procedures and suggestions for making a set of surface condition ratings. This information can be summarized on a surface condition rating form.(1,2) The conditions considered under this scheme are: 1) General structural condition; 2) Surface wear; 3) Weathering; 4) Skid resistance; 5) Uniformity; and 6) Crack condition, a) opening, b) abrasion, and c) multiplicity. Each of these eight conditions can be given a rating from 0 to 5.

The general structural condition gives the rating of how good that pavement is performing structurally, The ride may be satisfactory, but it may still have some cracking and patching developing.

The surface wear is a measure of how much the pavement is being worn down by the effect of tires or how badly the pavement is bleeding.

The weathering gives a rating of how deteriorated the surface is due to the affects of temperature, water and wind.

The skid resistance rating is suggested as a means of estimating skid resistance when a number from a skid trailer is not available.

The uniformity rating gives an indication of how blotchy, streaked or nonuniform the surface looks generally.

The crack condition rating is a measure of the crack width, how much they are abraided and whether there are associated multiple cracks along with the transverse of longitudinal cracks. Descriptions for ratings of these parameters are given.(1,2) In the surface condition presentation, some examples are given showing pictures of pavements which have been rated at the various levels of these conditions.

It is important that those who would wish to use this rating system do some practice rating before surveying a system of roads.

The ratings can be recorded on the surface condition rating sheet (Table 1) and then entered in Table 14, which is a summary of the pavement conditions.

Rideability

For the pavement management procedures developed in Minnesota, the rideability has been defined using the present serviceability concept. With this concept the rideability is defined as the ability of a section of road to serve the traffic that it was designed for. The rating is actually an average of the opinions of a group of individuals on how well that road rides based on a scale from 0 to 5. In the rideability presentation, two procedures are suggested for determining the rideability of a given section of road: 1) Use of a rating panel; and 2) Use of the Portland Cement Association (PCA) Roadmeter.

The rideability can be estimated using as few as three raters. However, if more ratings or opinions are obtained, this will give a better estimate of the rideability. The following nine rules should be followed if the rating panel system is to be used.

1. Use the following descriptions to define the ride as related to the numerical ratings: 4 to 5 - Very Good; 3 to 4 - Good; 2 to 3 - Fair; 1 to 2 - Poor; and 0 to 1 - Very Poor. Ratings between these descriptions (eg., 2.4) can be used to indicate levels between those shown. The rater should ask himself how he would like to ride on a pavement like this all day. This guideline may not strictly apply to shorter county roads or city streets. However, an indication of how well that road is serving the public should be made.
2. The rater should disregard grade, alignment, right-of-way width, shoulders, ditch conditions, etc., and other conditions which do not directly affect ride or are governed by the structure of the pavement.
3. Ride the pavement sections at the posted speed limit.
4. Ratings should be made for each 0.8 km (1/2 mi.) in rural areas and 0.4 km (1/4 mi.) in urban areas as it is difficult to remember the level of ride for longer distances.
5. There should be no discussion of ratings during a session if there is more than one rater in a car. There could be some discussion after a session, but it should be remembered that there is no absolute right rating. Two people will not necessarily judge the ride in exactly the same way.
6. The average rating for each 0.8 km (1/2 mi.) or 0.4 km (1/4 mi.) should be recorded as the present serviceability rating for that portion of road. These distances need not be exact and if there are other limits which are appropriate they should be used.
7. Raters should go on practice runs periodically to help calibrate themselves. It would be good to have a series of roads in the area which are examples of high and low ratings to ride over periodically.
8. Ratings should be done in passenger cars in relatively good condition. The raters should also be in relatively good condition (not tired, etc.).
9. Ratings on roads in good condition (3.0 to 3.5) or higher need only be taken every two or three years, whereas those with lower ratings (less than 3.0) should be rated about every year.

Use of the PCA Roadmeter

The PCA Roadmeter is composed of a set of counters which accumulate the number of 3.2 mm (1/8 in.)

deviations between a car axle and frame from a null position when driving over a section of road. The rating is done using a standard automobile. The PSR is determined using a relationship between counts and serviceability established for that vehicle. There are ten Roadmeters available throughout the State of Minnesota, one in each Mn/DOT construction district and one in the Mn/DOT central office. When the Roadmeter is used it should be calibrated periodically. Rules to follow in the operation are included in an appendix to the rideability presentation. Usually a Mn/DOT district will be able to run Roadmeter ratings for counties or municipalities if enough lead time is allowed for scheduling. It may also be possible for three or four counties and/or municipalities to cooperate to obtain their own Roadmeter. The devices are available commercially or can be built and installed in any standard car using plans available from Mn/DOT.

After the present serviceability rating is determined either using a panel or the PCA Roadmeter, this value should be entered in the appropriate place on the Summary of Pavement Conditions Sheet (Table 14).

Traffic

On the Summary of Pavement Conditions Sheet (Table 14), there are four entries for traffic. The first is the AADT which is the total two-way average annual daily traffic. This value can be obtained either from a traffic flow map for the municipality or county, or by a traffic study on a road considered to have similar traffic, or if it is an existing road, on that given road. To calculate the one-way ADT, the two-way value is usually multiplied by 0.5 for two lane roads or 0.45 for four lane roads. The speed limit should also be recorded.

The equivalent 80 kN (18,000 lb) single axle loads ($\Sigma N18$) can be determined using one of the two methods available in Minnesota. The procedure is summarized on the calculation sheet (Table 2). The parameters that are required for this calculation are the AADT, the distribution of vehicles, the average effect of each vehicle at that location, and some indication of a growth factor. The AADT can be determined using a traffic flow map. The distribution of vehicles can be determined either by making a vehicle type study on the road being proposed for maintenance, on a similar road. An assumed distribution could also be used.

If a vehicle type survey is to be made, it is conducted for 16 hours on two consecutive weekdays other than Monday or Friday. The survey should be made from 6:00 a.m. to 2:00 p.m. on one day, and 2:00 p.m. to 10:00 p.m. on the next. Vehicles are classified according to the types listed in Table 3 which are used for classification by the Planning and Programming Section of Mn/DOT. The results of the 16 hour count are listed in Column 2 of Table 2. These values are then modified with the seasonal adjustment factors listed in Table 4. The appropriate factors are entered in Column 3. The seasonally adjusted number of each type vehicle (Column 4) is obtained by multiplying Column 2 by Column 3. The seasonally adjusted percentage is then calculated by summing Column 4 and taking each truck type as a percent of the total.

If it is not possible to run a traffic survey, then assumed percentages listed in Table 5 can be used. Some judgment should be used in modifying these values if it is felt there is some appropriate variation to use. The design lane AADT had been determined and entered in Column 6. The design lane distribution is then calculated for each vehicle type by multiplying Column 5 by Column 6 for each vehicle type.

The average effect of each vehicle type on the performance of the road is called the N18 factor. This can also be considered the number of equivalent 80 kN (18,000 lb) single axle loads on the average imparted to that pavement each time one of that type vehicle passes a location. Table 6 is a listing of average N18 factors for 62.3 kN (7-ton) and 80 kN (9-ton) roads in Minnesota. For specific situations, these factors can be modified in consultation with a knowledgeable traffic engineer. The N18 factor for each vehicle type is entered in Column 8 of Table 2. To calculate Column 9, which is the design lane daily N18 for each vehicle type, each entry in Column 7 is multiplied by the respective value in Column 8. The summation of Column 9 is then the total daily N18 at present for that road.

The number of years to be used for design is then entered along with an estimated percent growth on the bottom of Table 2. Time growth factors for 10 and 20 year periods are listed in Table 7 for various rates of growth. As indicated in the table, a growth of 0.5 percent is suggested for 62.3 kN (7-ton) roads and 3.5 percent for 80 kN (9-ton) roads. Again, if the conditions warrant it, other design periods and/or annual growth rates can be used. The time growth factor is an annuity factor and thus can be found in standard annuity tables.

The $\Sigma N18$ for the design period is then calculated by multiplying the daily N18 by 365 and multiplying that product by the time growth factor. This value should be entered in the appropriate location in Table 14.

Strength

The strength of a pavement section is defined using two methods. These include either the structure of pavement section or using a direct measure of strength which for the State of Minnesota has been defined using the Benkelman beam deflection test.

The definition of strength is related to the number of equivalent 80 kN (18,000 lb) single axle loads that the road can take before the serviceability is reduced to some level defined as failure. For most state highways, this level is taken as the PSR, or serviceability level of 2.5. However, for lower traffic municipal and county roads, this level may be taken as a serviceability level rating of 1.5.

Strength Defined Using Pavement Section. One method of measuring the strength is using the pavement structure. The pavement structure is made up of the embankment and the various layers of base and surfacing. In order to determine the structure by this method, it is necessary to know the type or strength of embankment and the thickness of the layers broken down into subbase, base and surface. This information can be obtained from records or by making borings.

For the embankment, the stabilometer R-value must be determined. If the R-value has not been run on the given soil in the laboratory, it can be estimated using the AASHTO classification or the textural classification with Table 8, which is Table F of the Mn/DOT Road Design Manual.(3)

The layer thicknesses are converted to granular equivalent thicknesses for the section using the G.E. factors listed in Table 9, which is Table D of the Mn/DOT Road Design Manual.(3) The granular equivalent can then be calculated with the following formula:

$$G.E. = a_1D_1 + a_2D_2 + a_3D_3$$

The values of a_1, a_2, and a_3 can be obtained from Table 9. If a pavement section is deteriorating, then some judgment has to be used to estimate what factor is appropriate for the layer. The R-value and granular equivalent thickness should be entered in the appropriate location in Table 14.

Using the R-value and the granular equivalent thickness for a given pavement section, the present Mn/DOT design chart for flexible pavements can be used to estimate how much traffic the section should be able to withstand before the serviceability level has dropped to 2.5 or 1.5.

Estimation of Strength Using the Benkelman Beam Deflection Test. One of the direct measurements of strength using a load test is the Benkelman beam deflection test. For this test, a known axle load can be run over the pavement section and the deflection under that load measured. An advantage of this approach for estimating strength over the granular equivalent method is that moisture conditions and other local variations are taken into account. A disadvantage is that there are different levels of flexibility of pavements and, therefore, what would be a critical deflection level for one may not be for another.

The testing equipment and operational procedures for running the Benkelman beam deflection tests are given in Appendix A of the fourth part of Reference 1. The procedure outline gives the equipment and procedures required to obtain deflections every 152 to 305 m (500 to 1000 ft.).

With the deflections determined, it is then necessary to calculate the design deflection which represents a given section of road (usually taken as a mile). In order to do this, the following variables are considered: 1) Temperature; 2) Time of year; 3) Load; 4) Thickness of layers; 5) Strength of embankment; and 6) Variability measurements.

The temperature is corrected by using Table 10, which shows the temperature correction to 27°C (80°F) for deflections run at other temperatures. The deflections are corrected only for tests at a temperature less than 27°C (80°F).

Deflections are converted to a critical spring value using the factors in Table 11. The ratios are dependent upon the time of year and the thickness of the asphalt layer in the pavement section.

The axle load on the test vehicle used is typically a 62.3 kN (7-ton) or 80 kN (9-ton) axle. It is important to know what the load is. Then deflections can be calculated for other loads by taking an arithmetical ratio of the loads. Using the spring ratios, a spring deflection for that section of road is determined.

Table 12 shows allowable deflections for various thicknesses of bituminous surface and levels of traffic. The allowable spring axle chosen from the table, the axle load used for the deflection test and the design spring deflection are substituted into equation 1 to calculate the allowable spring axle load in tons.

$$L_A = L_B \times \frac{\text{allowable deflection}}{\text{design spring deflection}} \qquad (1)$$

Where:

L_A = Allowable axle load, kN

L_B = Test vehicle axle load, kN

This calculation can be made for each of the deflections run on the section of road.

It is also possible to estimate the life of a flexible pavement section based on the design spring deflection. If the deflection is run using an 80 kN (9-ton) axle load, 62.3 and 44.5 kN (7 and 5 ton) deflections for the same section of road can be obtained by multiplying 7/9 and 5/9, respectively. Equation 2 is the design equation presently used to predict pavement life based on the Benkelman beam deflection.

$$\text{Log } \Sigma N18 = 11.06 - 3.25 D_S \qquad (2)$$

Using the 80, 62.3 and 44.5 kN (9, 7 and 5 ton) deflections, it is possible to calculate a ΣN18 value for each of the load restrictions. The assumption in each case would be that the maximum deflection represents a situation where the load would be restricted to 80, 62.3 and 44.5 kN (9, 7 and 5 ton) during the critical spring period.

Table 13 shows the solution to the performance equation for various design spring deflections. As would be expected, if the road is restricted to a lower load during the critical spring period, it will theoretically be able to carry a greater number of total equivalent 80 kN (18,000 lb) single axle loads.

By comparing the number of ΣN18 predicted from the deflection tests with the number of years to accumulate that level of traffic from the previous calculations, the number of years of life to a serviceability level of 2.5 for that section of road can be estimated.

A worksheet has been developed which can be used to summarize the calculations for design spring deflections, allowable tonnages and estimated road life. The worksheet is set up to use each deflection measured. By using this procedure, the variation in pavement strength in terms of tonnage and predicted life can be observed. It is also possible to calculate the average and standard deviations of the deflections in 1.6 km (1 mi.) and calculate tonnages and road life for an average, plus two standard deviation values. This could also be done for the calculated tonnages within each 1.6 km (1 mi.). It is suggested that the latter procedure be used because it would then be possible to see what areas within the 1.6 km (1 mi.) are low in strength. It may be possible to upgrade the whole section by strengthening relatively short segments of the roadway, as shown by the example in Appendix 1.

Summary of Conditions

So far in this presentation, procedures have been summarized for determining the surface condition, calculating the traffic factor in terms of equivalent 80 kN (18,000 lb) single axle loads, determining the rideability in terms of serviceability rating of a pavement section, and estimating pavement life or strength using the pavement structure and a direct measure of strength of a pavement. Table 14 is an example of how this information might be summarized. An attempt has been made to put as much information as possible on one sheet of paper for a given pavement section. A brief discussion of how to fill out this table follows.

Under the heading of General description of the pavement section, the approximate date at which the evaluation is being done, year the road was constructed and the year it was overlaid are entered.

Under the Structure, the type of surface base and subbase are listed along with the thickness of each. These can be obtained from either records in the office or by measuring with borings in the field. The granular equivalent factors are obtained using Table 9 as a guide. The granular equivalent for each of the layers is then calculated by multiplying the thickness by the respective factor. The total granular equivalent is calculated by adding up the values for each of the layers. The embankment R-value can be either obtained by running an R-value test on the soil in the lab or by estimating the R-value using either the AASHTO soil classification or a textural classification from Table 8.

The Traffic Factors listed are, first, the AADT which can be obtained, as indicated in the traffic presentation, either from a flow map or by making a 16 hour count. The speed of the section of road is the speed limit. The equivalent loads in terms of 80 kN (18,000 lb) single axle loads should be determined since construction or the last structural overlay. This can be done using the techniques and the calculation chart from the traffic presentation. The traffic to 20 years of age or any other age can be obtained using those procedures. The road conditions are defined using the present serviceability rating which is obtained either with the PCA Roadmeter or a panel using the procedures outlined.

The Surface Conditions are those obtained with the surface condition rating scheme which has been summarized.

The rut depth can be determined using either the A-frame or by running a stringline across the road and measuring the depressions in the wheel path.

The Strength and Life Predictions of Table 14 summarizes the two methods suggested for estimating the years of life with the existing pavement section. The first part uses the structure and the embankment strength to determine the first $\Sigma N18$ that this structure could withstand according to the present Mn/DOT Design Chart. This can be read directly from the chart when the granular equivalent and the R-value of the embankment are either measured or estimated. To determine the number of years to accumulate this $\Sigma N18$, a table or plot of the predicted accumulation of $\Sigma N18$ can be used which compares the predicted number of loads to 2.5 serviceability level with the accumulation predicted with time. This can be obtained using the calculations from the traffic presentation. In the next part of Table 14, Benkelman beam deflection information is used to predict the life of the pavement, again without any structural overlay or improvement. The $\Sigma N18$ predicted in this manner is the $\Sigma N18$ for the total life of the pavement. Therefore, if the pavement is presently 10 years old and its total life is estimated to be 22 years, it can be assumed there is 12 years left before the PSR will drop to 2.5. The 80, 62.3 and 44.5 kN (9, 7 and 5 ton) deflections are calculated as given in the fourth presentation. The $\Sigma N18$ values will be greater for the 44.5 kN (5 ton) deflection than for the 80 kN (9 ton) deflection because the lower deflection will result in a longer predicted life. The years to accumulate this traffic then can be obtained in the same way as for the prediction of life for the structure by looking at the relationship of the accumulation of traffic with years under the traffic level using the traffic calculations.

References

1. Eugene L. Skok, Jr., "Pavement Management System Seminars." Part I, "Surface Condition Rating System," 1975. Part II, "Calculation of Equivalent 18,000-Pound Single Axle Loads," 1975. Part III, "Determination of the Rideability of a Pavement Section," 1976. Part IV, "Determination and Use of Pavement Strength," 1976. Mn/DOT Investigation No. 645, "Research Implementation."
2. Eugene L. Skok, Jr., and Miles S. Kersten. Criteria for Sealing or Other Surface Maintenance on Bituminous Roads. Proceedings, First International Conference on Low Volume Roads, Transportation Research Board, Special Report 16, 1976.
3. P. C. Hughes. Development of a Rating System to Determine the Need for Resurfacing Pavements. Final Report, Minnesota Department of Highways, Investigation No. 189, 1971.

Appendix 1

Examples of several uses of pavement evaluation information.

Washington County - Spring Road Restrictions

A pavement evaluation implementation "pilot project" is under way, conducted by the Physical Research Unit of Mn/DOT. This "pilot project" concerns itself with some of the pavement attributes described in this paper and shows some of the benefits of measuring these attributes.

The pavement strength, as measured by the Benkelman beam, is of particular interest in Washington County. Benkelman beam measurements were taken at 0.16 km (0.1 mi.) intervals on about 200 km (125 mi.) of county collector routes.

In the 200 km (125 mi.) of road, there were 61 segments with different structure or traffic levels; of the 61 sections, 43 sections were posted with a spring restriction and 31 were tested with the Benkelman beam. Of the 31 sections, 14 62-kN (7-ton) sections were tested resulting in them all being increased to all season 80-kN (9-ton) roads, three sections were 53-kN (6-ton) and one was changed to a 62 kN (7-ton) road. Fourteen 44 kN (5-ton) sections were tested resulting in changing 7 to an 80 kN (9-ton) road, 3 to a 62 kN (7-ton) road and 4 remaining at 44 kN (5-ton). Traffic levels on all of these sections are low, so there is no danger of a reduced fatigue life because of the increased axle loads.

Clay County - Design Evaluation

Clay County, a participant in the project used the results to evaluate the effectiveness of their design for a 62 kN (7-ton) road. A portion of County State Aid Highway (C.S.A.H.) 10 was constructed in 1972 and evaluated as part of the "pilot project" in 1976. An evaluation of the pavement by Benkelman beam showed that the road was 80 kN (9-ton) over portions having a sand loam subgrade and 62 kN (7-ton) over a clay loam subgrade. The clay loam subgrade exists only on about 20 percent of the section, so the section could be upgraded to an 80 kN (9-ton) road by adding additional structure over the clay loam portion of the road. An adjoining segment of C.S.A.H. 10 was programmed for construction after the evaluation. The evaluation showed the predominant subgrade to be clay loam, indicating the design used would result in a 62 kN (7-ton) road. It also gives the county engineer the information to do a cost/benefit analysis for an 80 kN (9-ton) design based on the traffic volumes and loadings on C.S.A.H. 10.

Chisago County - Pavement Evaluation of a Heavy Move Route

An electrical power utility company (NSP) applied for a permit to move 4 transformers from a railroad siding to a substation site. Each of these transformers and the vehicle that would move them would have a gross weight of about 2000 kN (450,000 lb). As a condition of the permit, the move route was evaluated for rideability, strength with the Benkelman beam, and surface condition before and after the transformers were moved. The permit had a payment schedule to refund the county for any measurable loss of service from the road due to the moves.

Because of the vehicle used to move the transformers, there was no measurable loss of service. The vehicle was a trailer with 96 tires suspended hydraulically so that the downward force on each tire would remain constant and equal to the rest.

Tables

Table 1. Surface condition rating form.

Date ______________

Job Description ______________

Surface Sealed Before ☐ Yes ☐ No

	GEN. STR. CONDITION	SURFACE WEAR	WEATHERING	SKID RESISTANCE	UNIFORMITY	CRACK CONDITION		
						OPENING	ABRASION	MULT.
		☐ Excess Asphalt		Skid Number				
5	Good	None	None	Coarse / Gritty — Good	Good	Hairline	None	None
						1/16		
4	Long Crk.	Slight	Slight	Coarse / Gritty — Fair	Strkd.		Slight	Slight
						1/8		
3	Map Crk.	Moderate	Moderate	Agg. Sl. Pol.	Cr. Fill.		Moderate	Moderate
						1/4		
2	Allig Crk.	Severe	Severe	Agg. Pol.	Blotchy		Severe	Severe
						1/2		
1	Eros.	Abrasion	Erosion	Bleeding	Non Unif.	> 1/2	Abrasion	Erosion

Table 2. Calculation sheet for equivalent 18,000-lb. axle loads.

Date__________

Road Location __________ **No. Lanes** __________ **Design Lane** __________

Design Lane AADT; __________ **Map** ☐ **Count** ☐ **Other** __________

Vehicle Distribution; Assumed ☐ **Manual Count** ☐ **Machine Count** ☐ **Other** __________

1	2	3	4	5	6	7	8	9
Vehicle Type	16 hour Count	Adjustment Factor	Seasonally Adj. No.	Season. Adj. Percent	X Design Lane ADT	Design Lane Distribution	X N18 Factor	Design Lane Daily N18
1					X		X	
2					X		X	
3					X		X	
4					X		X	
5					X		X	
6					X		X	
7					X		X	
8					X		X	
9					X		X	
10					X		X	
Totals								

Design Number Years __________

Percent Growth __________

Design ≤N18 = 365 x (Daily N18) x (Time Growth Factor)

= 365 (   ) x (   ) = ☐

Table 3. Vehicle type definitions for equivalent load calculation.

Vehicle Type Number	Description
1	Passenger Cars
2	Panel and Pickups (under one ton)
3	Single Unit; 2-axle, 4-tire
4	Single Unit; 2-axle, 6-tire
5	Single Unit; 3-axle
6	Tractor Semitrailer Combination; 3-axle
7	Tractor Semitrailer Combination; 4-axle
8	Tractor Semitrailer Combination; 5-axle
9	Tractor Semitrailer Combination; 6-axle
10	Trucks and Trailers Combinations plus Buses

Table 4. Seasonal adjustment factors for vehicle types.

	Vehicle Type						
Data Taken	1 - 3	4	5	6	7	8 - 9	10
Jan.-April	1.45	0.81	1.68	0.88	0.87	1.01	0.95
May-August	0.96	0.78	0.76	0.77	0.73	0.96	0.90
Sept.-Dec.	1.27	0.78	0.92	0.73	0.91	0.95	1.07

Table 5. Assumed percent distributions.

Vehicle Type	62 kN (7-ton)	80 kN (9-ton)
1	76.5	78.1
2	15.2	10.0
3	2.0	1.4
4	3.7	3.9
5	1.0	1.3
6	0.1	0.3
7	0.1	0.5
8	0.5	3.0
9	-----	-----
10	0.9	1.5

Table 6. Average N18 factor by vehicle type.

	Load Limit	
Vehicle Type	62 kN (7-ton)	80 kN (9-ton)
1	0.0004	0.0004
2	0.007	0.007
3	0.01	0.01
4	0.17	0.19
5	0.55	0.48
6	0.37	0.60
7	0.43	0.84
8	1.00	1.50
9	-----	-----
10	0.33	0.33

Table 7. Time growth factors for 10 and 20 years.

Annual Growth %	10 Years	20 Years
0	10.00	20.00
0.5[a]	10.23	20.98
1.0	10.46	22.02
1.5	10.70	23.12
2.0	10.95	24.30
2.5	11.20	25.54
3.0	11.46	26.87
3.5[b]	11.73	28.28
4.0	12.01	29.78
4.5	12.29	31.37
5.0	12.58	33.07
5.5	12.88	34.87
6.0	13.18	36.79

[a]Suggested annual growth for 62 kN (7-ton) roads.
[b]Suggested annual growth for 80 kN (9-ton) roads.

Table 8. Stabilometer R-values by soil type.[a]

AASHO Soil Type	Textural	Assumed R-Value	Comments
A-1	Sands Gravels	75	Excellent confidence in using assumed value.
A-1-b	Sands Sandy Loams (nonplastic)	70	If percent passing No. 200 sieve is 15 to 25 %, R-value may be as low as 25. In such cases, it is highly desirable to obtain laboratory R-values.
A-2-4 & A-2-6	Sandy Loams (nonplastic, slightly plastic, or plastic.)	30 (70 for LS and LFS)	Loamy Sands and Loamy Fine Sands commonly have R-value of 70. Laboratory R-values range from 10-80 for the entire A-2 classification. It is highly desirable to obtain laboratory R-values for the Sandy Loams. See Table 11 for sampling frequency.
A-3	Fine Sands	70	Excellent confidence in using assumed value.
A-4	Sandy Loams (plastic), Silt Loams, Silty Clay Loams, Loams, Clay Loams, Sandy Clay Loams	20	Laboratory R-value range from 10 to 75. It is highly desirable to obtain laboratory R-values. See Table 11 for sampling frequency.
A-6	Clay Loams, Clays, Silty Clay Loams	12	Laboratory R-values commonly occur between 8 and 20.
A-7-5	Clays, Silty	12	Data available are limited.
A-7-6	Clays	10	Laboratory R-values commonly occur between 6 and 18.

[a]Based on data collected by MHD through 1974.

Note: In using the above assumed R-values for flexible pavement design it is essential that the subgrade be constructed of uniform soil at a moisture content and density in accordance with Mn/DOT Spec. 2105. To minimize frost heaving and thaw weakening it is also essential that finished grade elevation be placed an adequate distance above the water table. This distance should be at least equal to the depth of frost penetration. In the case of silty soils in the distance could be significantly greater.

Table 9. Granular equivalent (G.E.) factors.

All bituminous and aggregate courses are converted to an equivalent thickness of Class 6 Aggregate Base (denoted as granular equivalent = G.E.) using factors listed below.

Material	Specification	G.E. Factors
Plant-mix surface	2341, 2361	2.25
Plant-mix surface	2331	2.00
Plant-mix binder	2331	2.00
Plant-mix base	2331	2.00
Road-mix surface	2321	1.50
Road-mix base	2321	1.50
Bituminous treatment base	(Rich) 2204	1.50
Bituminous treatment base	(Lean) 2204	1.25
Aggregate base	(Cl. 5, Cl. 6) 3138	1.00
Aggregate base	(Cl. 3, Cl. 4) 3138	0.75
Selected granular material		0.50[a]

[a]May be used in design when so approved by central office Soils Section.

Note: Where the subgrade consists of granular material the district materials and/or soils engineer may recommend the treating of the upper portion of the selected granular material with 2.5 cm (1 in.) or 5.1 cm (2 in.) of stabilizing aggregate (Spec. 3149.2C) or treating the upper 7.6 cm (3 in.) with 0.36 liter/m^3/cm (0.2 gal./sq. yd./in.) of asphalt emulsion, SS-1.

Table 10. Temperature correction to 26.7°C (80°F) for Benkelman beam deflections.

Range of Deflection in mm ≤ BB <	Temperature in Degrees Celsius				
	T < 1.6	1.6 ≤ T < 7.2	7.2 ≤ T < 12.8	12.8 ≤ T < 18.3	18.3 ≤ T < 23.9
.000 < .254	.127	.102	.076	.051	.025
.254 < .508	.178	.152	.102	.076	.025
.508 < 1.016	.254	.203	.152	.102	.051
1.016 < 1.270	.305	.254	.178	.127	.051
1.270 < 1.524	.381	.305	.229	.152	.076

Note: 1 mm = .04 in.

Table 11. Benkelman beam deflection ratio table.

Deflection rations to approximate critical spring deflections from deflections taken during other nonfrozen times of the year for:

Plastic Embankments

Asphalt Surface Thickness	Date of Test				
Conventional Construction	Aug.- Sept.	July	June	May 16- May 31	May 1- May 15
≤ 8.9 cm	1.73	1.64	1.52	1.32	1.14
> 8.9 cm ≤ 14 cm	1.68	1.54	1.40	1.24	1.14
> 14 cm ≤ 20.3 cm	1.49	1.28	1.25	1.25	1.17
> 20.3 cm	1.37	1.16	1.14	1.18	1.13
Full-Depth Construction					
> 20.3	1.45	1.12	1.13	1.16	1.12

Semi-Plastic Embankments (L, Sil, and sl. pl. SL)

	Date of Test				
Asphalt Surface Thickness	Aug.- Sept.	July	June	May 16- May 31	May1- May 15
≤ 12.7 cm	1.46	1.52	1.45	1.35	1.16
> 12.7 cm	1.68	1.56	1.48	1.40	1.29

Non-Plastic Embankments (S, S & G, FS, and LFS)

	Date of Test				
Asphalt Surface Thickness	Aug.- Sept.	July	June	May 16- May 31	May 1- May 15
≤ 5.1 cm	1.88	1.83	1.76	1.41	1.30
> 5.1 cm ≤ 14 cm	1.48	1.57	1.50	1.36	1.21
> 14 cm ≤ 20.3 cm	1.10	1.05	.99	1.02	1.00

Note: Critical deflections correspond to maximum deflections which occur in the spring, during which the pavement is most likely to be damaged by heavy loads. This ratio table is based on a continuous ten year record (1964 to 1973) of measured rebound deflections taken throughout the year on various Minnesota pavements.

Note: 1 cm = 0.4 in.

Table 12. Allowable spring deflections.

Traffic						
	Two-way	HCADT[a]	<50	50-100	100-150	>150
	Two-way	AADT[b]	<500	500-1000	1000-3000	>3000
Bituminous Surface Thickness			Allowable Deflection, cm			
Less than 7.62 cm			0.191	0.178	0.154	0.114
7.62 cm to 15.24 cm			0.165	0.152	0.127	0.102
Greater than 15.24 cm			0.140	0.127	0.102	0.089

[a]HCADT - Heavy commercial average daily traffic volume (excludes passenger cars and 4-tired trucks).
[b]Use AADT only when HCADT is not known.

Note: 1 cm = 0.4 in.

Table 13. Solution to performance equation predicting equivalent loads to PSR = 2.50.

Deflection, mm	ΣN18	Deflection, mm	ΣN18
0.508	6,800,000	1.905	92,500
0.635	3,300,000	2.032	75,000
0.762	1,800,000	2.159	61,600
0.889	1,100,000	2.286	51,100
1.016	710,000	2.413	43,000
1.143	490,000	2.540	36,300
1.270	345,000	2.667	31,000
1.397	253,000	2.794	26,600
1.524	191,000	2.921	23,100
1.651	147,000	3.048	20,100
1.778	116,000	3.175	17,600

Equation: $\log \Sigma N18 = 5.88 - 3.25 \log D_s$

Where: ΣN18 = Equivalent 80 kN (18,000 lb) single axle loads.
D_s = Design Spring Deflection, mm.

Note: 1 mm = 0.04 in.

Table 14. Summary of pavement conditions.

GENERAL

Location ______________________________ Date ____________

Year Constructed __________________ Last Overlaid ____________

STRUCTURE Type Thickness in G.E. Factor G.E.

Surface, (D_1) __________ __________ __________

Base, (D_2) __________ __________ __________

Subbase, (D_3) __________ __________ __________

TOTALS - - G.E. = __________

Embankment R-Value ______ < ______ Laboratory / ______ Estimated

TRAFFIC

AADT __________

Speed __________

Equivalent Loads ($\sum$N18)

Since last O.L. or construction __________

Future

5 yr. ______ 10 yr. ______ 20 yr. ______

CONDITIONS

PSR ______ < ______ Roadmeter / ______ Panel

Uniformity __________

Surface Condition

Structural __________

Surface Wear ______ < ______ Abrasion / ______ Bleeding

Weathering __________

Skid Resistance ______ < ______ Number / ______ Rating

Crack Conditions

Opening __________

Abrasion __________

Mult. __________

Rut Depth, in. ______

STRENGTH AND LIFE PREDICTIONS

Structure

N18 from Design Chart ______

Years to accumulate
Assuming O.L. __________

Recommended Action __________

____

Est. Cost __________________

Benkelman Beam
Deflection Predictions

Spring	Defl. (.001 in.)	$\sum$N18	Yrs.
9 T			
7 T			
5 T			

Present Restricted Tonnage based on Mn/DOT 603 Procedure
__________ tons