EVALUATION OF PAVEMENT SERVICEABILITY ON THE INTERSTATE SYSTEM IN OREGON

Gordon Beecroft, Oregon Department of Transportation
Lawrence C. Miller, Portland Cement Association

Measurements of road roughness using a PCA Road Meter have been made on the 1156 km (718 mile) Interstate System in Oregon annually since 1972. For purpose of comparison and analysis, the measurements are converted to present serviceability index (PSI) values using the ride measurements only. The highway system has been broken down into homogeneous sections based on the pavement structure and construction contract. Structural strip maps were prepared showing the material and thickness of each component of the pavement structure with date of construction and any subsequent overlays. The PSI ratings plotted on this strip map show the pavement performance trend for each section. The superior performance of some pavements has been documented and sections that will be in need of early rehabilitation identified. Analyses of PSI vs. age and PSI vs. heavy truck traffic have been made and compared with PSI values calculated from the Brokaw model equations. The goal of this work is to develop PSI trend curves as an aid to providing advance predictions of when rehabilitation of the pavement sections will be required. This simple and inexpensive method can be very useful in programming future overlay and rehabilitation projects in the management of the pavement system.

The present serviceability index (PSI) rating system was developed at the AASHO Road Test (1). The equations for calculation of PSI require an evaluation of AASHO slope variance, measurement of cracking and patching, and also measurement of rut depth on flexible pavements. The PCA Road Meter readings can be used as measures of the slope variance through correlations with the Chloe Profilometer and AASHO Profilometer. Through these correlations, the road meter readings can be used to provide the PSI(R) or ride portion of the PSI.

The slope variance or ride rating is the dominant variable in the PSI rating system. The ride portion of the PSI is essentially the total PSI until some significant deterioration of the pavement takes place. The deducts for cracking, patching, and rut depth have little effect until ride has deteriorated to a considerable degree. For most pavements, it appears that significant structural distress does not occur without a comensurate deterioration in ride. The reverse is indicated in that a deterioration in ride can usually be measured in advance of any appreciable visible structural distress.

The concept used in the Oregon study is that PSI ratings will be based on ride alone until some threshold number is reached at which measurements of cracking, patching, and rutting become significant. Tentatively, the PSI ratings suggested as thresholds are 3.7 for concrete and 3.3 for asphalt pavements. When the ride portion of PSI has reached this level, further deducts will probably reduce it to a level between 2.5 and 3.0. A sudden drop in the PSI from the previous year or visible distress in the pavement would also indicate the need for further measurements.

Project Description

The 1156 km (718 mile) Oregon Interstate system has been divided into sections for measurement based on pavement type, structural section, and construction contract. Each direction of travel on the divided highways is treated separately so the total length is 2312 km (1436 miles). Ride measurements are made on 67 sections of concrete pavement totaling 481 km (299 miles) and 200 sections of asphalt pavement totaling 1213 km (754 miles). The measured sections begin and end at mileposts so that the same places are measured each year. Measurements are made in the outside lane. A 1.6 km (1 mile) gap between sections is omitted for recording of data. The distance actually measured amounts to 73 percent of the total interstate system.

Measurements have been made by PCA staff in late August or early fall each year beginning in 1972. They are made at a constant speed of 80 km/hr (50 mi/hr) and four days are required for the rural sections. Measurements in the Portland urban area have been made several times, but not each year. Urban measurements are difficult due to heavy traffic, but can be made successfully at approximately 9 to 10 a.m. or 7 to 8 p.m. Since 1976, measurements have also been made annually by the Oregon State Highway Division, using a PCA-type road meter. The purpose of the dual measurements was to obtain a correlation between the two meters so the work could be carried on by either the PCA or the Highway Division. For purpose of this project, the PCA

staff readings have continued to be used. Although the same meter has been used through the nine years of record, it has been installed in several different cars which has led to some uncertainty of the calibration in recent years.

The Highway Division prepared a structural strip map for the major interstate highways on a scale of 1:63360 (1 in/mi) horizontal and 1:12 (1 in/ft) vertical. This map shows the structural section with the depth and description of each material layer and date of construction. Any subsequent overlays are shown above the original surface line with their date of construction. PSI measurements recorded on this map show pavement performance trends.

The information on the structural strip map was placed on individual pages for each homogeneous highway section measured to provide all information in a convenient loose-leaf notebook. All project identification information, the milepost limits of the highway section, and a graph of the PSI values vs. year are shown on the front. Traffic information is tabulated on the reverse side. This includes the average daily traffic (ADT) and the number of tractor semi-trailer and combination vehicles per day for each year since the pavement was opened to traffic. Provision is being made to enter the summation of 80-kN (18000-lbf) equivalent axle loads as a measure of traffic loading; however, this data has not yet been tabulated. The PSI values obtained from ride scores are tabulated and, for the portland cement concrete sections, they are compared with PSI values calculated from the Brokaw equations.

The Brokaw equations shown in Figure 1 were developed to predict the PSI of plain (non-reinforced) concrete pavement with short joint spacing and without dowels. The slope variance portion of the AASHO performance equation was broken into three component parts of roughness due to construction, roughness at transverse joints, and roughness between joints (2). The calculated PSI then becomes a function of the initial PSI, age, and the ADT of tractor semi-trailer and combination traffic. These equations were not intended to apply to reinforced concrete pavements and there does not appear to be any correlation for either the mesh-dowel pavements nor the continuously reinforced pavements included in this study. The ride quality of the concrete pavements has not declined appreciably during the period of the study whereas the values calculated from the Brokaw equations show a uniform annual decline. Although little has been required, joint maintenance has been performed as needed. The reinforced concrete construction and this nominal maintenance have provided pavements that retain a higher level of smoothness than that predicted by the Brokaw model equations. Comparisons with other appropriate equations can easily be made when they are developed.

Pavement Performance

This paper will be limited to a discussion of the findings on concrete pavements.

The sections of concrete pavement on which annual roughness measurements are made total 481 km (291 mi) and range in age from 4 to 22 years. All are 203 mm (8 in) thick. Pavements built prior to 1964 are all reinforced concrete of the mesh-dowel design (RC-MD). Reinforcement is welded wire mat with 7.35 mm diameter (No. 1 gage) wires at 152 mm (6 in) spacing longitudinal and 5.19 mm diameter (No. 4 gage) wires at 305 mm (12 in) spacing transverse. Doweled joints are spaced at 18.75 m (61.5 ft). There are 132 km (82 mi) with this design having an average age of 18.95 years. The average PSI of these pavements in 1980, as determined from ride meter readings, was 4.29 with a range of 3.86 to 4.60.

Typical performance of the reinforced concrete mesh-dowel pavements is shown by the example in Figure 2. The accumulated traffic on this section is given in Figure 3 which is the reverse side of the page for the project in Figure 2. The road meter readings for the years 1977, 1978, and 1979 are somewhat suspect because the meter was transferred to a different vehicle with apparently different suspension characteristics. If time permits, an analysis will be attempted to see if an appropriate adjustment factor can be devised for these years. The PSI ratings determined from the meter counts tend to be quite uniform during the years of service with perhaps a slight downward trend if the more questionable years are neglected. Although the truck traffic has been much heavier than was anticipated at the time of design, the ride quality of the pavement has remained reasonably high.

All but two sections of the concrete pavements constructed since 1964 are continuously reinforced (CRCP). Slab thickness is 203 mm (8 in) and typical reinforcement is 15 mm (No. 5) bars at 165 mm (6.5 in) longitudinal and 13 mm (No. 4) bars at 1.5 mm (60 in) transverse. Transverse bars were omitted on some of the more recent projects on which longitudinal bars were placed through tubes in the slipform paver. There is a total 349 km (217 mi) of continuously reinforced concrete pavement with an average age of 9.86 years. Using the road meter count, the average PSI of these pavements in 1980

Figure 1. Brokaw model equations for determination of PSI for plain jointed concrete pavements.

A - 1,2,3 Subgrades

$$PSI = 5.41 - 1.8 \log \left[1014/10^{0.56P_o} + 1.94\, TA^2/D^{5.47} + (A+1)^{0.58} - 1 \right] - 0.01\, A + 0.65 \log D - 0.62$$

A - 4,5,6,7 Subgrades

$$PSI = 5.41 - 1.8 \log \left[1014/10^{0.56P_o} + 1.11\, TA^2/D^{4.60} + (A+1)^{0.70} - 1 \right] - 0.01\, A + 0.65 \log D - 0.62$$

Nomenclature

- PSI - Serviceability Index following years of service (A) after construction.
- P_o - Serviceability Index constructed.
- T - 2-way average ADT of tractor semi-trailer and combination vehicles during years of service (A).
- A - Years of service after construction and to reaching PSI.
- D - Thickness of pavement in inches.

Subgrades - Classes according to AASHO M145.

Figure 2. Typical performance of mesh-dowel concrete pavement.

ROUTE: I-5 Southbound LOCATION: 234.80 - 227.68

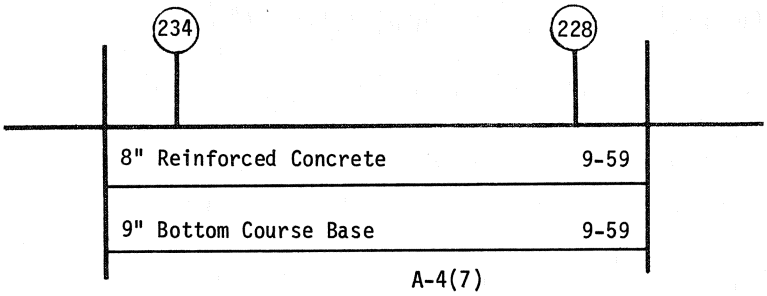
PROJECT: N. Albany Junction - Lebanon Road Section

CONTRACT NO: 5345 COUNTY: Linn PREFIX: 622-1082

CONTRACTOR: Roy L. Houck & Sons

PAVED BY: Roy L. Houck & Sons

RESIDENT ENGINEER: Dustin C. King



COMMENTS:

SUBSEQUENT WORK:

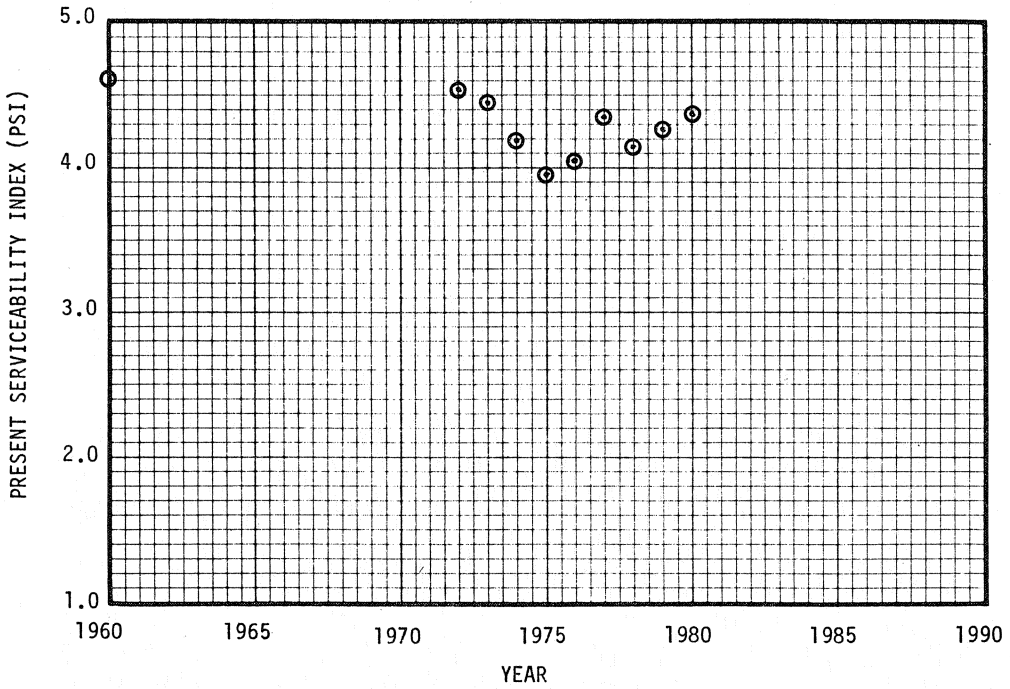


Figure 3. Traffic and loading data and measured and calculated PSI values for section shown in Figure 2.

OREGON DEPARTMENT OF TRANSPORTATION

ROAD METER SURVEY

Route: I-5 Southbound Location: MP 234.80 - 227.68

Year	ADT	Heavy Trucks Per Cent	Heavy Trucks Number	18-kip EAL in 1,000's Number	18-kip EAL in 1,000's Cumulative	PSI	Brokaw PSI
1960	6,700	14.0	940				4.50
1961	7,800	14.5	1,130				4.37
1962	9,700	14.5	1,410				4.26
1963	9,700	14.5	1,410				4.17
1964	10,700	13.1	1,400				4.07
1965	11,600	13.1	1,520				3.98
1966	12,500	13.1	1,640				3.89
1967	12,900	11.5	1,480				3.80
1968	13,500	11.5	1,550				3.71
1969	14,100	12.8	1,800				3.63
1970	15,100	12.3	1,860				3.54
1971	17,000	11.9	2,020				3.45
1972	18,200	12.3	2,240			4.53	3.36
1973	18,700	16.8	3,140			4.44	3.27
1974	16,700	16.9	2,820			4.19	3.16
1975	18,100	16.7	3,020			3.96	3.07
1976	20,900	16.2	3,390			4.05	2.97
1977	21,900	16.1	3,530			4.35	2.87
1978	23,200	16.1	3,740			4.14	2.78
1979	22,200	20.8	4,620			4.27	2.68
1980						4.38	2.58

734-1856(12-80)

was 4.52 with a range of 4.00 to 4.76.

Performance of the continuously reinforced pavements to date has veen very good and several have been outstanding. Figure 4 is typical of several sections near Pendleton which show superior performance to date. This pavement was opened to traffic in 1969 and has very high PSI values even after 11 years of service. The contractor on this project used an unusual float following the slipform paver which produced a very smooth surface. This very large float, which he called a "barn door", was dragged over the pavement as the final operation prior to texturing. This project illustrates the point that high quality construction with high initial PSI values should lead to higher ratings throughout the service life and extend the service life. Present truck traffic on this CRCP section is 1380 tractor semi-trailer and combinations per day.

One pavement with an unusual performance trend is shown in Figure 5. This pavement was built with a coarse broomed skid resistant texture that was so rough and severe that the initial PSI was only 4.05. The usual initial value for slipformed pavements has been around 4.70. Harsh broomed textures of this type are subject to comparatively rapid abrasion from studded tire traffic. As a consequence, the ride improved for a few years as the surface roughness caused by texturing wore down. Today the pavement is much smoother and PSI values are accordingly higher.

Advantages and Limitations

The purpose of this project is to determine the PSI trend curves for highway sections in order to predict in advance when pavement deterioration will reach the point where rehabilitation is necessary. The principal advantage of the road meter measurement system is its simplicity, ease, and speed of obtaining the data. Only one week each year is required to make the field measurements.

The main limitation of using a PSI evaluation system based on ride scores is that some pavement defects to not affect ride to a serious degree. Scaled surfaces and surfaces which have suffered wheel track erosion may not reduce the measured ride quality to the point where restoration is indicated, though judgment may indicate such need. Joint roughness does affect ride but it is another defect which may become annoying or require excessive maintenance before the measured PSI indicates a need for correction. As mentioned earlier in the paper, the concept of the project is that the PSI determined from road meter count is a valid indication of the serviceability index until some threshold level is reached at which other defects such as cracking, patching, and rutting need to be taken into account to refine the PSI value.

The most difficult problem in making this system a reliable pavement rating procedure is with the difference in suspension systems between vehicles. There is a need for standardization when a meter is moved from one vehicle to another or when wheel alignment, shock absorbers, or tire balance is changed on a given vehicle. Road meter measurements have been made using four different PCA vehicles and two Oregon State Highway Division vehicles and difficulty has been experienced in correlation of the measurements from car to car. There is need for a calibration track close by for checking the road meter - vehicle combinations. The closest track available is in Iowa and the 1980 PCA test unit was taken there for calibration.

A benefit of this rating system other than being able to project ahead to needed rehabilitation or maintenance is the ability to compare different pavement designs over a period of time. Since 1973 all concrete pavements in Oregon have been placed on treated bases whereas earlier pavements were placed on granular bases. The performance of the two designs will be observed. Another subject of interest is the performance of asphalt overlays on concrete pavements vs. asphalt overlays on asphalt pavements. If there is a difference, it will be measured. It is also expected that any differences in performance of formed vs. slipformed pavements will become apparent. The tighter control of water content required for slipformed concrete is expected to exhibit better durability. The effect of other construction operations such as the use of rollers and spray bars should also show up if there is a difference in performance.

Conclusion

An annual survey with a PCA Road Meter provides a very useful measure of pavement performance and can contribute important elements for a pavement management system. The simplicity of the system along with the ease and speed of making the measurements make it attractive. If the ride meter calibrations can be made consistent year to year, the trend of the PSI can be easily followed on a graph. On this project, the PSI values as determined from road meter readings are being plotted against the year. For comparing one section to another, they can be plotted against equivalent 80-kN (18000-lbf) axle loads. For heavily constructed pavements, such as those on the Interstate System, the procedure of using the PSI determined from ride score only until some threshold value is reached at which time other defects will be taken into account appears to be a simple and useful concept for pavement evaluation. The measurements should also contribute to the development of better predictive models to estimate the future PSI for a given pavement, using projected heavy truck traffic or equivalent 80-kN (18000-lbf) axle loads as input.

References

1. AASHO Road Test, Report 5. Pavement Research, Highway Research Board. Special Report 61E, 1962.
2. Brokaw, M. P. Performance and Design of Concrete Pavements Without Dowels and Distributed Reinforcement. Portland Cement Association, 1971.

Figure 4. Superior performance of continuously reinforced concrete pavement near Pendleton.

ROUTE: I-84 Eastbound LOCATION: 188.04 - 204.42

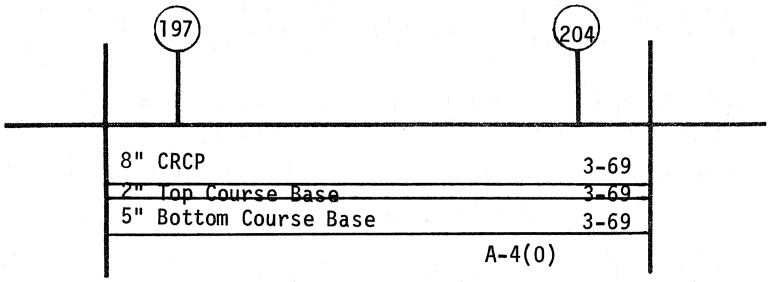
PROJECT: Stanfield Junction - Pendleton Section

CONTRACT NO: 7087 COUNTY: Umatilla PREFIX: 630-1097

CONTRACTOR: Rogers Construction Company

PAVED BY: Matich

RESIDENT ENGINEER: W. C. Ferguson



COMMENTS:

SUBSEQUENT WORK:

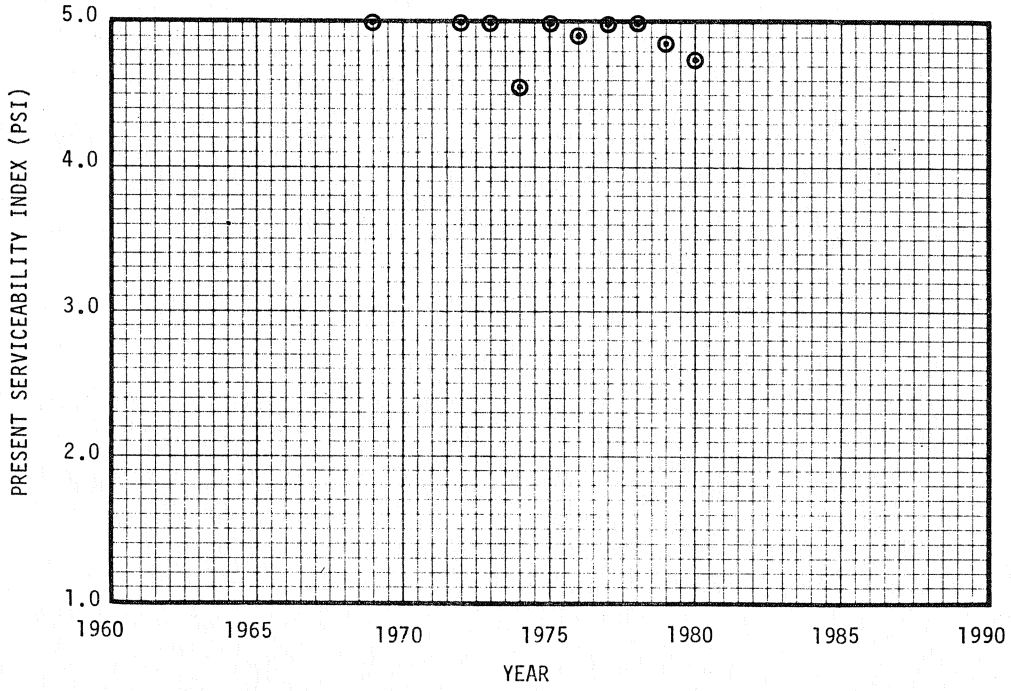


Figure 5. Section constructed with a harsh broomed texture. Ride improved as texture wore down.

ROUTE: I-84 Westbound LOCATION: 374.06 - 368.16

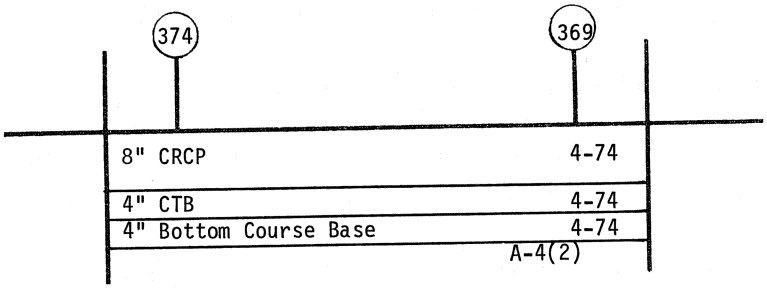
PROJECT: North Fork Jacobsen Gulch - North Ontario Interchange

CONTRACT NO: 7605 COUNTY: Malheur PREFIX: 623-1024

CONTRACTOR: J. C. Compton and Ross Brothers

PAVED BY: Gordon Ball

RESIDENT ENGINEER: P. F. Burnett



COMMENTS:

SUBSEQUENT WORK:

