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Road Performance Goes Under The Microscope

Asphalt Institute develops prediction tool for pavement performance

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The Asphalt Institute, Lexington, Ky., adopted an action item in its Strategic Plan of 1996 to develop a lifecycle program for asphalt pavements. The program was divided into two phases. Phase One involved a survey of state departments of transportation (DOTs) and local governments to determine what type of data might be available. Phase Two called for the development of a database to store and analyze the data and make it available to user agencies. So far, survey results show, among other things, asphalt pavements are performing better than previously thought.

A database was developed in February and March of 1998 for the implementation of Phase Two. A 32-bit, Window-based program, the Pavement Performance Program, was created with Microsoft Visual Basic programming language and uses the Microsoft Jet Engine Database Version 2.0. It can be accessed through other programs that use this same database engine, such as

Microsoft Access. The program is being referred to as the institute's Present Condition Rating (PCR) program.

Phase One was discontinued after 18 months because of insufficient data. An initial service life for interstate highways was determined based on limited data in this study. This data did not include a PCR at the time it was rehabilitated nor was information made available to indicate how other pavements were performing with equal age and conditions of the same system. Phase One indicated that states did not maintain uniform records across state lines that could be readily used.

Five climatic conditions are studied

The pavement performance program allows the retrieval of specific PCR data record groups that can be plotted in an XY scatter graph. It also performs a linear regression on the selected data points and plots a linear regression curve, whose equation is then displayed below the graph along with the calculated correlation coefficient.

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Trends seen based on preliminary data

Phase Two PCR research found:

- The typical service-life equation is not a good representation of the decay life of a system of roads or streets.
- Initial and rehab service periods are longer than those currently stated by most agencies.
- Environment appears to have a more pronounced effect on life performance than was previously thought.
- Adjustments in lifecycle cost analysis should be re-considered by agencies in most cases, based on historical data.
- For roads with less traffic, more engineering analysis should be used for design standards and maintenance applications where performance varies.
- All asphalt pavements are being extended well beyond their expected life by timely maintenance and surface restorations.
- Asphalt pavements are in much better shape than most agencies generally perceive.
- In general, most asphalt pavement on mainline roads and streets is well above a PCR of 70, which indicates the need for surface restoration according to guidelines for this study.

The predicted service life, based on the linear regression, is also displayed for a PCR of 70. Major rehabilitation would be expected to occur at a PCR of 60 or, in some states, 50. Currently, the program indicates only the data for a PCR of 70, but future plans call for adding the information to show these multiple data points.

The program uses five climatic conditions - wet freeze, wet no-freeze, dry freeze, dry no-freeze, or all climatic conditions. The traffic, or functional, classification is divided into six different classes. Class I represents the basic residential street. The classification progresses upward to Class VI, which is heavy interstate. The construction level is composed of new, rehabilitation or both; and 54 service life equations can be developed from the data using the various traffic, construction and climatic conditions for a PCR of 70.

Initial service life equations show asphalt pavements are not only performing according to design life - normally 20 years - but can be maintained longer with routine maintenance, which may include crack pouring, surface treatments, milling and overlays of nominal aggregate size. Maintenance is not normally thought to add structural value to the pavement, but merely restore surface for ridability, safety and environmental protection from the elements.

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Preliminary data also indicates a significant difference in pavement performance for various climatic conditions. The rehabilitation, or second phase performance, is also out-performing estimated design periods, which are normally 15 years. For major rehabilitation, often referred to as reconstruction, pavements are also lasting beyond their planned design life. A much longer life than that anticipated by the estimate of design life is seen for the total range of rehab projects.

As additional pavement sections are added to the database, including Superpave concepts and new quality control specs, asphalt pavements are expected to show even longer performance periods with less maintenance. The data will be available for further analysis not only by this program, but also by other procedures as well. By the end of 1998, the database was expected to comprise approximately 800 pavement sections. Ultimately, there will be several thousand for the complete analysis of all criteria with respect to time.

Design variables follow AASHTO lead

Over 35 state agencies use the American Association of State Highway & Transportation Officials (AASHTO) pavement design procedures, or some modification of them. Many larger city and county agencies also use this design procedure, or a standard section, for various streets and roadways based on it. All formal procedures, regardless of the source, attempt to address the common issues of design variables. Since the AASHTO procedure is used the most, it is a common reference on some of the major issues.

One of the first considerations in design is the "design reliability," a statistically based factor that indicates how valid the design is for the input values. AASHTO provides a range of reliability factors based on traffic, as do other formal design procedures (See Table 4).

When higher reliability factors are used, the pavement design is proportionally thicker. Most agencies will select the 85 to 90 percent reliability for the upper traffic levels. A reliability factor of 87.5 percent is fairly common for most high traffic designs. Having heavier traffic than expected in the design period often negates the design more than any other factor. Designing at 95 percent reliability or above is prohibited by cost for most agencies. Lower volume roads and streets typically specified by ordinance or standard sections fall into a 50 to 70 percent range of design reliability.

The preliminary data from the performance program shows a wider variation in the performance life of Classes I to III than for Classes IV to VI. The level of maintenance may not be as high for the lower volume roads, which could contribute to a wider band in the performance curve.

The institute's traffic classification is presented in Table 2. All facilities were placed into the appropriate traffic classification based on equivalent single axle load (ESAL) design zone.

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Environment affects pavement performance

Environmental factors can and do affect pavement performance, and extreme moisture and temperature variations appear to be the most common factors. When both are present, this combination can affect the strength and durability, as well as the load carrying capacity, of the structure. Prolonged exposure to these extreme conditions destroys the structural capacity of the roadway.

Aging effects under the various environmental conditions are normally degrading to the structural coefficients that are originally assigned to the materials. This has to be taken into consideration in long-term pavement performance. Level of maintenance is extremely important as environmental factors are considered, and may be an issue in the spread of performance on lower volumes of roadways.

The loss of serviceability - a decrease in PCR - can be the result of both traffic and environmental factors. Appropriate and timely maintenance, which may include crack sealing, cross-slope, shoulder and general drainage improvements in conjunction with some surface restoration, can retard environmental effects on the loss of PCR.

The pavement sections for climatic conditions of dry freeze and dry no-freeze appear to have the best overall service life, based on this preliminary data. Right now the study is short on projects from the dry no freeze region. The projected service life for a PCR of 70 is presented for the classifications that have a significant amount of data (See Table 3). As more data is collected, current values are expected to change. Normally, as the R2 of the correlation equation increases, the projected service life decreases up to a given point.

Table 1. Summary of maximum pavement deductions

Cracking	Distortion	Disintegration	Drainage	Roughness (Ride)
35	20	10	10	PCR = 100 - deducts

Table2. Traffic classifications

Traffic	ESAL	Type of Class Street or Highway	Approximate Range-Number of Heavy Trucks for Design Life
I	5 X 103	• Parking lots, driveways • Light traffic residential streets • Light traffic farm roads	< 7,000
II	104	• Residential streets • Rural farm and residential roads	7,000-15,000
III	105	• Urban minor collector streets • Rural minor collector streets	70,000-150,000
IV	106	• Urban minor arterial and light industrial streets • Rural major collector and minor arterial highways	700,000-1,500,000
V	3 X 106	• Urban freeways, expressways and principal arterial highways • Rural interstate and other principal arterial highways	2,000,000-4,500,000
VI	107	• Urban interstate highways • Some industrial roads	7,000,000-15,000,000

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For some of the cells, there's not enough data to make a valid correlation. The categories of all climatic conditions and both categories for the construction level should provide an overall estimate of the life expectancy of each roadway facility, before major rehabilitation or reconstruction will be required.

Service life decay curve proves atypical
The typical and traditional polynomial curve often used to illustrate the decay or service life of pavements was not seen in the performance equations. A typical logarithmic decay curve was found to provide the best-fit curve (See Figure 1). The pavements do not drop by the purported 40 points of PCR in the 12 percent time remaining, as alleged. Perhaps this is due to timely maintenance by agencies.

Data collection methods vary by state
All state DOTs have implemented some form of a pavement management system according to Federal Highway Administration (FHWA) directives. National Center for Highway Research Programs (NCHRP) Synthesis 203, Current Practices in Determining Pavement Condition, summarizes state agency procedures and shows what measurements are made in determining the pavement conditions. This data indicates most states use some measure of deducts combined with ride or roughness measurements. It also shows that none of the states have rated their pavements in the same manner. As a result, the Asphalt Institute used a detailed rating form in existence for over 30 years and adopted by many agencies for use in determining PCR.

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The Asphalt Institute rating system, Informational Series (IS-169), contains practically all forms of asphalt pavement defects on a weighted scale with major load-associated defects assigned a deduct value of 10. Minor and environmental defects are assigned a deduct value of five. This system has proven reliable because it offers a detailed breakdown of the defects. A summary of the deduct values are shown in Table 1. The rating from this system is a numerical value usually in a range of 40 to 100. This rating value is subjective - as most ratings values are - implying that the pavement is at this condition at the time and under the existing conditions of traffic and environmental factors. In a subjective rating, no attempt is made to project what any existing defect will have on future performance.

This particular form, seen in Table 1, was used to correlate the data available from the state DOTs. The procedure entails a survey of the data available within a particular DOT's pavement management system, and subsequently, an on-site rating of specific sections of pavement. Sufficient sites need to be rated to develop an accurate correlation. This procedure provides a standard for all pavement sections in the study. The states surveyed so far have been helpful and cooperative in providing existing, available data. Other states that do not have a rating system have provided project logs that can be used to establish the pavement's age. The pavement was then rated by an institute district engineer.

Anyone can submit a project for this study. Projects submitted for inclusion will require verification by the Asphalt Institute district engineer for pavement age and PCR. Many local agencies have data that can be added to the database directly because they are using this rating form in their current pavement management system. An update of this study should be made periodically, and the data can also be obtained from the Asphalt Institute's website as well as through written reports. This is an ongoing study with no end-point currently established.

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Table 3. Projected Service Life of Hot Mix Asphalt[1]

	Type of Construction			Climatic Conditions				
Traffic Class	**New**	**Rehab**	**Both**	**Wet Freeze**	**Wet No Freeze**	**Dry Freeze**	**Dry No Freeze**	**ALL**
I	•			X	X	X	X	24
I		•		X	X	X	X	X
I			•	X	X	X	X	18
II	•			X	X	X	21	20
II		•		X	9	X	17	13
II			•	X	9	X	20	17
III	•			9	X	47	27	23
III		•		20	10	32	25	19
III			•	16	11	39	27	21
IV				18	X	36	X	34
IV				41	34	X	35	46
IV				30	X	43	33	39
V	•			37	31	X	X	49
V		•		24	38	27	X	29
V			•	34	38	38	15	35
VI				X	X	X	X	X
VI				26	21	25	X	25
VI				32	21	29	X	28

1 Service life projected to a PCR of 70 indicates surface restoration be considered.
X = insufficient data.

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Table 4. Design reliability factors for various functional classifications

Functional Classification	Percent Recommended Level of Reliability Urban	Rural
Interstate & Freeways	85 to 99.9	80 to 99.9
Principal Arterials	80 to 99	75 to 95
Collectors	80 to 95	75 to 95
Local (Low Volume)	50 to 80	50 to 80

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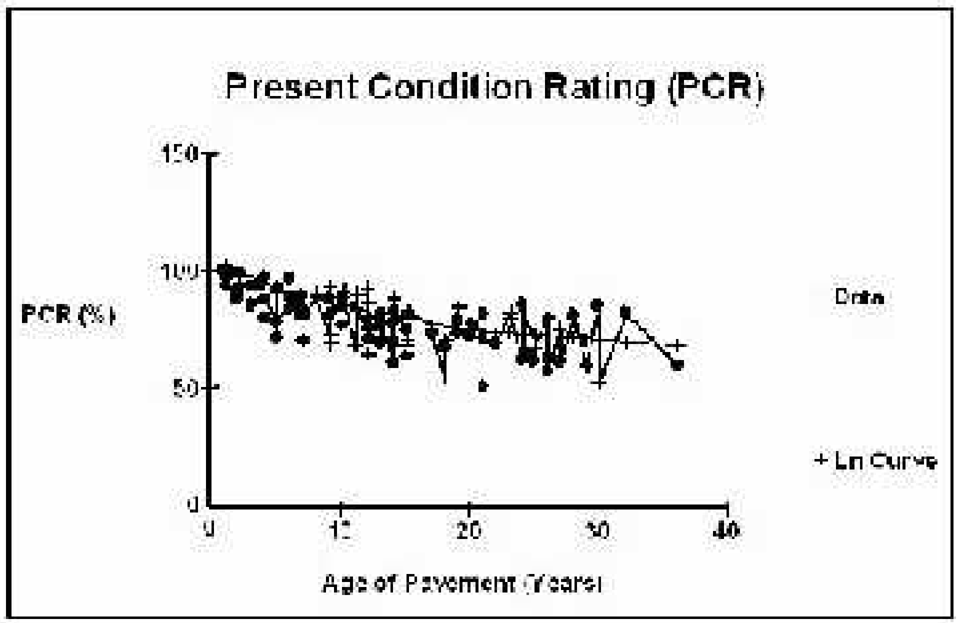

Figure 1. Typical service life decay

This graph displays the expected percentage of decay a pavement should show after a period of years - its service life decay. The curved line underneath the plotted information represents the service life equation engineers have established. The solid dots represent actual data and where it falls above or below the service life goal. The plus signs represent the logarithmic decay curve discussed in the article. Asphalt Institute engineers plan to unveil the service life equation at ACE '99 later this month, demonstrating how to predict when a pavement should be considered for resurfacing.

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