Toward Measuring Pavement Conditions to Optimize Roadway Treatments

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INTRODUCTION

Pavements are typically the biggest asset owned/managed by the local agencies in the United States. Hence, optimizing roadway treatments is a key issue faced by these agencies. Every three years, the County of San Luis Obispo, California, sets out to measure the quality of the County's 1,100 miles of paved roads. This is done using MicroPaver Field Inspector, software developed by the Army Corps of Engineers. Pavement distresses (such as cracks and weathering) are input into the application, and a pavement condition index (PCI) value is returned, from 0 (worst) to 100 (best). In 2013, one of the authors was placed on the team charged with performing the analysis for that survey cycle. This paper documents the methods utilized to analyze the pavement that were learned during the survey. Data on historical pavement treatments undertaken by the County were also acquired and matched with historical PCI values to generate trends relative to each treatment. This analysis is also included in this paper.

DATA ACQUISITION

Methodology

The key characteristic of the MicroPaver surveying method is to survey one-tenth of the road network, using 2,500 square feet as a per-sample size. This causes the placements of the samples to vary depending on road width. Narrower roads have farther-apart samples compared to wider roads. For instance, a road of 25' width will have a sample of length 100' every 1,000', whereas a road of 50' width will have a sample of 50' length every 500'.

Another consideration is the length of a segment. Roads are divided into segments to help facilitate user (i.e., person collecting the data) interaction. Quite often, segments are divided using significant crossroads. In places where crossroads are far apart, mile posts are used. Users know where in a segment they are located through the use of a foot-resolution odometer that can be reset at the start of each segment.

Within each sample, the quantity of a variety of different distresses is acquired using a measuring wheel. For example, longitudinal and traverse cracks are measured through rolling the wheel along the lengths of the cracks. With alligator or block cracks, a length and width is measured and multiplied to find the area. Potholes are measured through counts. Other distresses include: edge cracks, rutting, patching, railroad tracks, weathering, and bleeding. All distresses are split into three categories (low, medium, high), depending on severity. Quite often, more than one severity level of the same distress exists in the same sample area.

These values are then entered into MicroPaver Field Inspector, where the program's algorithms generate a PCI value for the sample. Upon completing a section, a section PCI is returned as a weighted average of the section's samples' PCIs and each samples' representation in the section. This section PCI can be compared against past years' as a check – if the PCI has gone up and there has been no work done on the road, then perhaps the assessor was too lenient on the severity of the distresses. This check is mostly used at the start of the process, where the surveyors' rankings of different severity levels need to be calibrated. .

Procedure
At the beginning of the summer season, and several times more throughout the summer, the survey vehicle was calibrated using two known posts located one mile apart. Once calibrated, the vehicle (equipped with a warning beacon and cautionary sign) was ready for surveying. The survey vehicle is depicted in Figure 1. The pair of surveyors then used the vehicle as a "super" measuring wheel, pulling over at marked intervals (such as "1000 feet," "2000 feet," etc.). At the determined interval, an arrow was sprayed onto the ground to denote the start of the sample. One surveyor would then run across the street with a measuring wheel to assess the width of the road. The other surveyor then measured a length appropriate with the width to mark out an area of size of 2,500 square feet. At the end of the sample, another arrow was placed to denote the area to be analyzed.

FIGURE 1 San Luis Obispo County Survey Vehicle *Source: Kevin Carstens*

In this sample area, the distresses were then split among the two surveyors, often either by type or by side of the road. The wheels utilized had the ability to measure lengths and widths, and automatically multiply them and calculate the total area measured. Therefore, often distresses were split by having each surveyor tackle one area-based distress at a time and one longitudinal-based stress at a time. For instance, one might measure edge cracking and alligator cracking, while the other measures longitudinal/traverse cracking and patches. After collecting data on all of the distresses, the surveyors returned to the car to input their values into MicroPaver. To expedite this process, one would enter the values into the laptop, while the other drove to the next sample.

Two teams were sent out to start at the northern border of the County and work towards the south. Each team had a copy of the County's roadmap, and highlighted each segment completed. These highlights were then exchanged at the end of each day to ensure that the two teams did not overlap. Every so often, both teams would report back to the County offices to upload their data to the mainframe.

Since both teams operated out of the County headquarters, located in the City of San Luis Obispo, and the furthest points in the County were over two hour's drive away, the survey was done using a ten-hour, four-day workweek, rather than the usual eight-hour, five-day workweek.

DATA ANALYSIS

Using data from the current survey cycle (2013), and two survey cycles before (2007), the changes in roadway conditions were charted. A database of roadway treatments for 2007 to 2010 was then added and the difference in the change in roadway conditions across the six years by treatment type was compared.

Additionally, possible factors affecting the data were separated out, such as climate, urbanization, traffic volume, and topography of the road setting. The County was divided into fifteen analysis areas, such as the Cambria Area (urban, mountainous, coastal climate, high traffic) and the Paso Robles Area (rural, hilly, inland climate, low traffic). One analysis zone, Los Osos, was discounted from the study due to a multi-year sewer project generating atypical values. This categorization was critical, as San Luis Obispo County's geography leads to micro climate conditions where the temperature vary significantly over short distances (See Figures 2 and 3).

FIGURE 2 San Luis Obispo Climate Zones *Source: SLO County EnergyWise Plan*

Figure 2 depicts the two different climate zones in San Luis Obispo County, as determined by Pacific Gas and Electric (PG&E). Zone 4 is characterized by "summers [that] are hot and dry with a large daily temperature swing" [1]. Zone 5 is characterized by "summers [that] are warm with afternoon winds blowing until sunset, which naturally cools the region. The air is usually moist. Fog and cloud cover commonly blocks the sun in the morning and evenings" [2]. In the winter, both regions are cool, but not severely cold [1,2].

Figure 3 below shows an estimate of where the different analysis zones were bordered. As mentioned before, these borders were determined to try and best group together similar roads by a variety of factors such as level of urbanization and climate. The red areas approximately depict incorporated cities, where the County is not responsible for maintaining roadways.

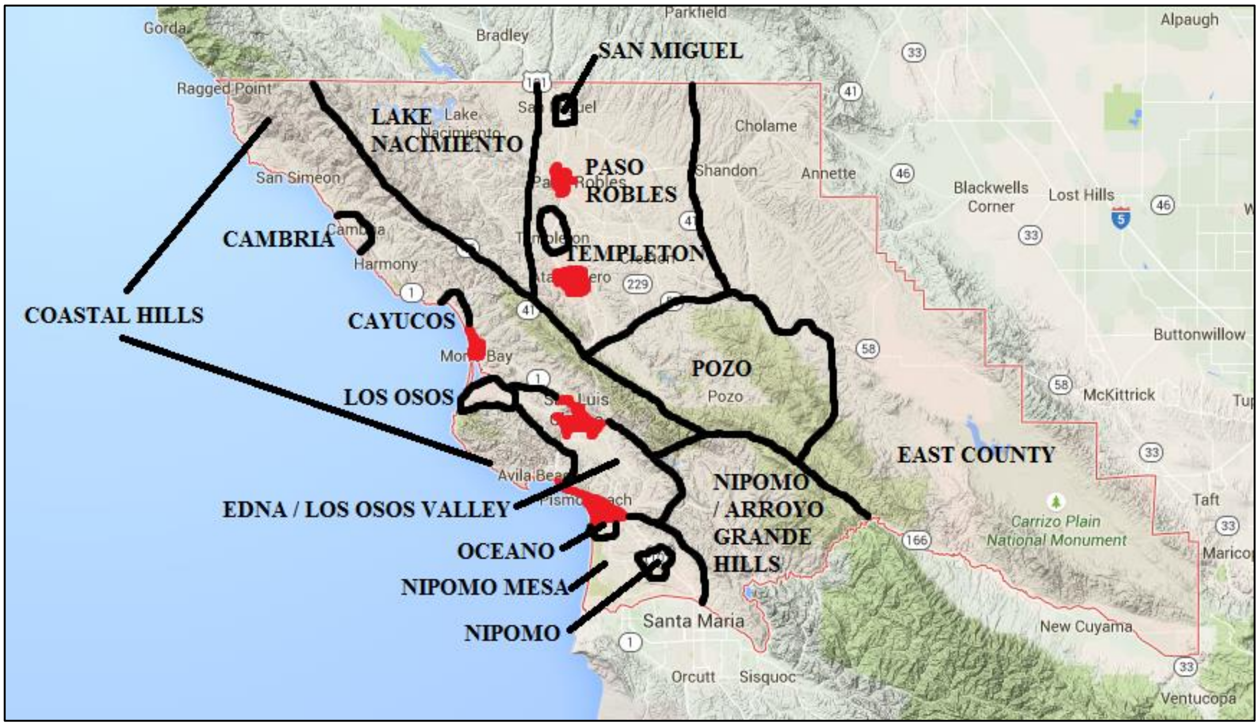

FIGURE 3 Map of Analysis Zones *Sources: Google Maps, Kevin Carstens*

After breaking the data into each of these analysis zones and by treatment type, Table 1 was developed. This table contains information both by analysis zone and treatment, and as weighted averages of the two most pertinent factors, climate and urbanization. These were determined to be the most critical factors, as the climate most affects weathering (inland areas have greater daily temperature swings) and urbanization most directly correlates with traffic levels.

The initial hypothesis was that greater temperature swings and heavier traffic loads likely result in more rapid deterioration of pavements. However, after some inspection, there does not seem to be a significant difference based on the groupings, after controlling for small sample sizes. Therefore, the analysis going forward was directed at the weighted total line at the bottom of Table 1. A few of the treatment types have large enough sample sizes to be meaningful. Firstly, over the six years from 2007 to 2013, roads that were not treated at all declined by an average of 19 PCI points. The 62 sections that received a quarter-inch chip seal only declined by one point. The 32 sections that received a two-inch overlay improved by thirteen points, while the 17 sections that received a four-inch overlay improved by 37 points. Interestingly, the 17 sections that were completely reconstructed still declined by nine points over the six years. This is quite possibly due to the fact

TABLE 1 Change in PCI from 2007 to 2010 by Climate and Urbanization

Analysis Zone	Climate Zone	Rural or Urban	Pavement Treatment															
			None		Chip Seal 1/4"		Chip Seal 5/16"		Overlay Thin		Overlay 1"		Overlay 2"		Overlay 4"		Reconstruct Structure	
			Count	Average Change	Count	Average Change	Count	Average Change	Count	Average Change	Count	Average Change	Count	Average Change	Count	Average Change	Count	Average Change
Lake Nacimiento	4	R	13	-25	31	-14	0	-	0	-	0	-	10	-19	4	48	0	-
Paso Robles	4	R	60	-22	6	28	0	-	0	-	0	-	8	47	0	-	2	8
San Miguel	4	R	8	-24	0	-	0	-	1	62	0	-	0	-	0	-	2	50
Templeton	4	U	11	-16	14	7	0	-	0	-	0	-	1	14	0	-	0	-
Cambria	5	U	15	-13	0	-	0	-	0	-	0	-	1	-9	0	-	1	13
Coastal	5	R	33	-17	3	0	1	-2	0	-	0	-	1	20	0	-	0	-
Cayucos	5	U	4	-14	8	12	0	-	0	-	0	-	0	-	0	-	0	-
Edna/Los Osos Valleys	5	R	8	-25	0	-	0	-	0	-	1	25	1	33	0	-	0	-
Pozo	4	R	25	-13	0	-	0	-	0	-	0	-	0	-	0	-	0	-
Oceano	5	U	22	-22	0	-	0	-	1	18	0	-	0	-	0	-	0	-
Arroyo Grande and Nipomo Hills	5	R	26	-21	0	-	0	-	0	-	0	-	5	5	0	-	11	-30
Nipomo Mesa	5	R	32	-20	0	-	0	-	0	-	0	-	0	-	2	15	1	51
Nipomo	5	U	47	-19	0	-	0	-	0	-	0	-	3	16	0	-	0	-
East County	4	R	42	-16	0	-	0	-	0	-	0	-	2	58	0	-	0	-
Weighted Average Climate 4			159	-19	51	-4	0	-	1	62	0	-	21	15	4	48	4	29
Weighted Average Climate 5			187	-19	11	9	1	-2	1	18	1	25	11	11	2	15	13	-20
Weighted Average Rural			247	-19	40	-7	1	-2	1	62	1	25	27	24	6	37	16	-10
Weighted Average Urban			99	-18	22	9	0	-	1	18	0	-	5	10	0	-	1	13
Weighted Average Total			346	-19	62	-1	1	-2	2	40	1	25	32	13	6	37	17	-9

that for 11 sections in the Arroyo Grande and Nipomo Hills area, reconstructions took place right before the 2007 survey. For these points, the 2007 PCI measurement reads 100, which indicates a brand new road with no faults. Hence, those 11 sections declined monotonically while the other locations depict an increase in quality, then several years of decline.

CONCLUSION

With this data in hand, a pavement engineer can apply values to the results to run a cost-benefit analysis to determine which treatments to pursue. Obviously, the more expensive treatments (2" and 4" overlays) on average produce better results than the cheaper treatments (such as the ¼" chip seal), and even better results than doing nothing. However, the engineer will need to determine at which point the expense outweighs the benefits.

Future expansion of this work should include adding data points to the sparse treatment categories (such as the 5/16" chip seal), and a wider band of analysis years. This analysis only spans six years, while a comprehensive analysis would include the entire life-cycle of the pavement.

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