End-Result Specifications for Warranted Asphalt Pavements

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Long-term pavement performance is highly dependent on its initial condition. High initial roughness leads to higher maintenance and rehabilitation costs, to shorter service life, and to significant reduction in riding quality. A performance-based specification applicable for new and rehabilitated warranted pavements is developed and presented here. The primary purpose of this specification is control of the initial longitudinal roughness of pavements, which will lead to smoother pavements and hence satisfactory long-term performance. In this specification, pavement roughness is measured by using Class I or calibrated Class II profilometers, such as infrared and laser profilometers. Tests are performed on each asphalt layer before the next layer is constructed. Three criteria are considered in the specification: surface tolerance, roughness indices, and repeated waves. It should be noted that this specification focuses on the functional performance of pavements and does not directly address their structural performances. A user-friendly software is developed to implement this specification. The software is capable of simulating straightedge inspections, calculating roughness statistics, and performing frequency analyses, such as power spectral analysis. With the software, a pavement section can be evaluated, tested, and analyzed in few minutes. Highway agencies as well as contractors will benefit from implementing this specification. Highway agencies will benefit by being able to achieve the goal of having safe, smooth, and economic pavements, and contractors will benefit by reducing maintenance cost during maintenance and warranty periods. Also, contractors will get quick results and meaningful feedback to the paving operation. A payment structure, including bonus payments for extended service lives, is included in the specification. This payment structure is based on the long-term effects of the initial roughness on the pavement life-cycle costs. The bonus program will encourage contractors to achieve higher levels of quality.

Several factors influence the ride quality of pavements as felt by highway users. These factors include vehicle characteristics and speed and pavement characteristics. Workmanship quality is one of the major pavement-related factors that influence the as-built pavement smoothness. A previous study conducted to investigate the causes of substandard riding quality of a newly constructed eight-lane, 29-km freeway (*1*) indicated that the main cause of the problem was related to poor workmanship and lack of smoothness acceptance specification. The project smoothness specification was limited to surface tolerances as measured with a 3-m straightedge, which was not able to identify the unacceptable riding quality of the project. In this study, the as-built pavement smoothness was evaluated with a 3-m rolling straightedge, a Mays Meter, a TRRL pump integrator, and a laser profilometer. Results of the tests confirmed that the pavement does have an acceptable level of roughness. The measured surface tolerances were found to be less than 4 mm and the 400-m international roughness index (IRI) values ranged from 1.1 to 1.2 mm/m. However, several complaints about the overall riding quality were received.

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Another round of testing and analysis was performed. Analyses included surface tolerance, roughness indices, and frequency analyses. Neither the surface tolerance nor the roughness indices were able to identify this problem. On the other hand, frequency analyses were found to be superior in identifying the problem. It was found that the major source of the discomfort is associated with 10-m repeated waves. Figure 1 presents a sample of the pavement profile measured with the laser profilometer, and Figure 2 shows the power spectral density (PSD) graph of the same section. As can be observed from the PSD graph, there is a very pronounced peak at a wavelength of 10 m (frequency = 0.1 on the horizontal axis). A life-cycle cost analysis was performed to quantify the long-term effects of the initial substandard smoothness of the project. Results of the analysis showed that the project life-cycle cost is increased by a present worth value (PWV) of 30 million US dollars. The study concluded that smoothness acceptance specifications are essential and could save million of dollars. Also, considerations should be given to the method of collecting roughness data as well as to the evaluation criteria. Similar problems were reported in North Carolina. Five-meter repeated waves were found to be the primary cause of the poor rideability of two major resurfacing projects in the state. Also, data from other projects in the state indicated the existence of similar waves in rough-riding areas (*2*).

COMPONENTS OF PAVEMENT SMOOTHNESS

Three criteria contribute to pavement smoothness: surface tolerance, longitudinal roughness, and repeated waves. These criteria are, in some cases, correlated, but they cannot replace each other. A pavement with no repeated waves and acceptable surface tolerance could feel rough because of its high longitudinal roughness. On the other hand, a pavement with acceptable surface tolerance and low longitudinal roughness could feel rough because of the existence of repeated waves (*1,2*). Figure 1 presents an example of this type of pavement. The profile of a pavement section with acceptable surface tolerance (less than 4 mm) and low IRI (1.1 mm/m) is indicated. Even with these acceptable tolerance and IRI levels, the ride over this section is felt as that over a concrete bridge with poor joints. Therefore, it is important to consider the three components in the evaluation of the as-built pavement smoothness.

Surface Tolerance

Surface tolerance is commonly used to evaluate the initial pavement smoothness and the quality of workmanship. Profilographs and straight-edges are used to measure the vertical deviations from a

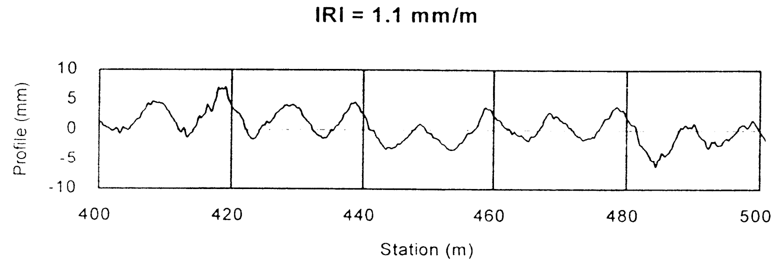


FIGURE 1 Repeated wave problem (*1*).

moving, fixed-length reference plane (surface tolerance). The measured tolerances are then compared with a maximum allowable value (3 to 4 mm). Areas with tolerance exceeding the allowable limit are identified and the appropriate remedial work is performed. This type of testing is time consuming, insensitive to the ride quality felt by the users, cannot address the roughness associated with wavelengths longer than the straightedge base length, and can be misleading, as indicated in Figure 3 (*3*).

The North Carolina Department of Transportation conducted a study to investigate asphalt pavement roughness and to recommend construction quality control measures (*2*). In this study, several roughness measuring devices were considered, including rod and level, different base-length rolling straightedges, and California and Rainhurt profilographs. Measurements of California and Rainhurt profilographs and the straightedges were compared. The ratio of the recorded to true amplitudes was used as the basis of these comparisons. The desired ratio is 1 for all wavelengths; however, the ratio ranged from 0 to 2 for all devices, as indicated in Figure 4. The study concluded that both California and Rainhurt profilographs have poor response to disturbances with wavelengths in the range of 5 m. A straightedge of appropriate length and equipped with a graphical device could do better than the profilographs. However, the study did not address how to determine the appropriate straightedge length.

In spite of the limitations of the rolling straightedge inspection, it is simple and easy to understand. It does not require expensive equipment or operators with engineering training. Also, contractors and highway agencies are familiar with this type of inspection.

Roughness Analysis

Longitudinal roughness is typically expressed in terms of roughness indices (summary statistics). Several roughness indices are available, such as the IRI and the present serviceability index (PSI). Previous studies (*4,5*) indicated that these indices are highly correlated. IRI, which was developed by the World Bank in 1982, is determined by using the reference quarter car simulation model. This model has standard tire, suspension, and damper properties. The model is driven over the measured profile at a constant speed (80 km/h) and the vertical movements of the sprung and unsprung mass are calculated. IRI is determined as the summation of the vertical movements along a base length (mm/m or m/km). Base lengths in the range of 100 to 1000 m are typically used. IRI is a repeatable, stable measure of roughness. The method of measuring a pavement profile can vary; however, with an acceptable level of accuracy in measuring the profile, IRI is considered to be a device-independent index.

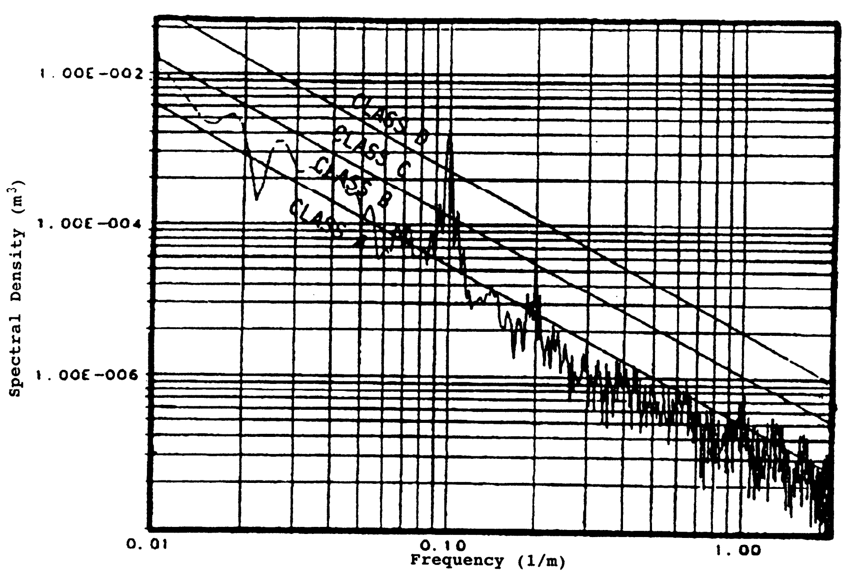


FIGURE 2 PSD graph.

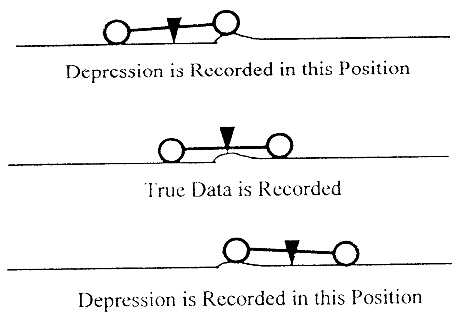


FIGURE 3 Limitations of straightedge inspections (*3*).

Because of the very good correlation between IRI and other roughness indices, IRI can be incorporated in the pavement design and life-cycle analysis. However, it cannot be used to detect the existence of repeated waves. Also, it does not address the discomfort associated with these waves. For example, a pavement section with a repeated-wave problem, as indicated in Figure 1 (IRI_{400m} = 1.1 mm/m), could have the same IRI value as a pavement section with a few randomly distributed bumps. However, a ride over the first pavement section is expected to be uncomfortable compared with that over the second pavement section.

Frequency Analysis

The longitudinal pavement profile may be regarded as a stochastic process made up of an infinite number of sinusoids with different wavelengths and amplitudes. Frequency analysis is the technique of separating the sinusoids from each other and determining their amplitudes. This type of analysis gives much more information about profiles than any other analysis method. It contains information about all wavelengths that can accurately be measured, not a limited range of wavelengths. Also, it indicates whether the profile is dominated by long or short wavelengths and whether there are some harmonies with very high amplitudes that may have a negative effect on the users (repeated waves). Repeated waves reduce the pavement smoothness and affect its long-term functional performance. Also, they may affect the pavement structural performance only if they are severe enough to increase the dynamic or impact loading of heavy trucks. Previous studies (*1,6*) indicated that frequency analysis, such as power spectral analysis, is the best method for detecting the existence of repeated waves.

Although PSD analysis is superior in identifying repeated-wave problems, it cannot be used to evaluate the pavement roughness or to predict its performance. Also, it cannot be incorporated in the pavement design or life-cycle analysis. PSD analysis gives only a general idea about the pavement roughness.

PERFORMANCE-BASED SPECIFICATION

Technical Specification

In this specification, Class I or calibrated Class II profilometers are used to measure the right and left wheel-path profiles of each asphalt layer. Construction of the following layer cannot be commenced until the previous layer is approved. Three types of analyses are performed on the measured profiles, as follows:

- Rolling straightedge simulation,
- Roughness indices, and
- Frequency analysis.

The rolling straightedge simulation is performed to control the surface tolerance, and the roughness indices analysis is performed to evaluate the construction quality, predict the long-term functional performance, and estimate the pavement service life (PSL). In this specification, IRI is used for this purpose; however other roughness indices, such as PSI, can be used instead. Two base lengths are considered in the specification: 100 and 1000 m. The 100-m IRI is used to evaluate the construction quality, and the average 1000-m IRI of the final layer is used to evaluate the long-term functional performance and to estimate PSL. Figure 5 presents an example of the estimated PSL, and Table 1 indicates the recommended initial and terminal 1000-m IRI values as a function of the highway class. PSL is used to select the appropriate payment adjustment factor (PAF) as indicated in Table 2. It should be noted that each highway agency has different needs; therefore the values in Tables 1 and 2 should be evaluated and modified accordingly to satisfy the agency needs.

The third type of analysis considered in the specification is frequency analysis. PSD analysis is performed to detect the existence of repeated waves. Repeated waves can be cured only by preventing their formation. Therefore, if repeated waves are detected, the causes

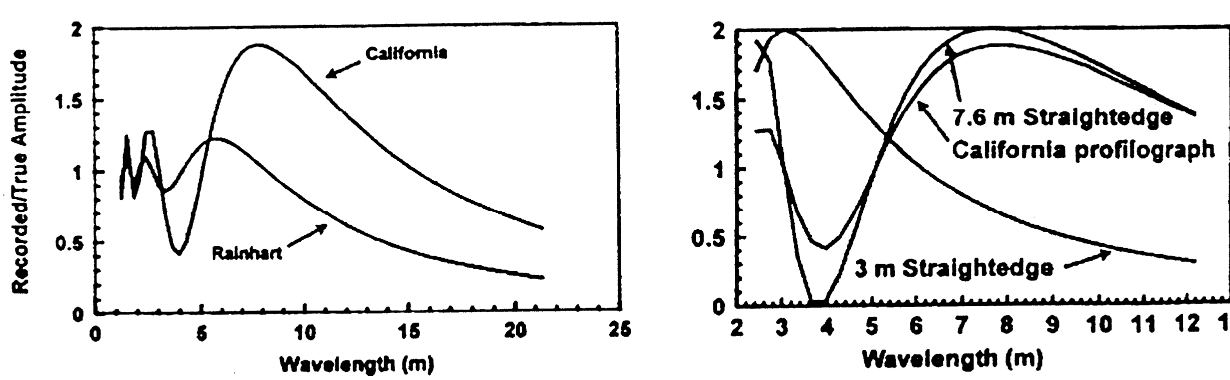


FIGURE 4 Profilographs and straightedge responses (*2*).

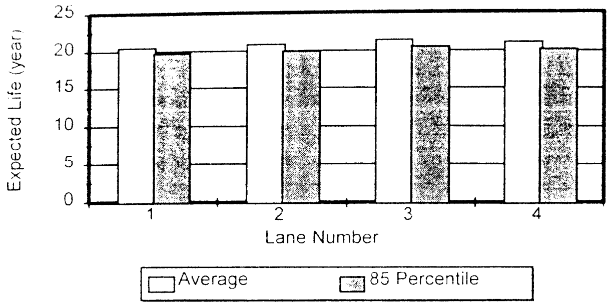


FIGURE 5 Expected service life (based on roughness testing).

should be investigated and corrected. The most common construction-related causes of repeated waves include (7) the following:

- Fluctuation in the material stiffness in front of the paver screed as a result of variation in the material head or temperature;
- Incorrectly set hopper flow gates;
- Haul truck driver holds the brakes while the truck is being pushed by the paver;
- Haul truck bumps into the paver;
- Reflection of the waves in the underlying surface;
- Roller operator turns or reverses the roller too abruptly;
- Improper operation of the vibratory roller (frequency, amplitude, and speed);
- Screed is in poor mechanical condition; and
- Sagging in the string line.

If repeated waves are detected in any of the asphalt layers, other than the surface (final) layer, a layer removal is recommended to prevent their reflection on the surface. If repeated waves are detected in the surface layer, ride surveys conducted by selected panels are recommended to evaluate the detrimental effect of these waves on the users. The following are the main steps of the specification:

1. Test the first asphalt layer with Class I or calibrated Class II profilometers.
2. Perform rolling straightedge simulation analysis on the profiles of the left and right wheel paths. The maximum tolerance should not exceed 4 mm for the final layer and 6 mm for the other asphalt layers. Areas with tolerance exceeding the allowable limit should be identified, rectified, and retested. Level I analysis of the software is customized to simulate the 3-m rolling straightedge inspection and to report locations where the maximum allowable tolerance is exceeded. Also, the software permits the user to change the straightedge length and the maximum allowable tolerance (Level II analysis).
3. Calculate the 100-m IRI of the left and right wheel paths. The 100-m IRI should not exceed 1.2 for the final layer and 1.3 for the other asphalt layers. Two 100-m IRI readings in each section are allowed to exceed these values; however, only one 100-m IRI reading is allowed to exceed 1.35 for the final layer and 1.5 for the other asphalt layers. No 100-m IRI readings should exceed 1.6. Remedial work should be performed on the areas that do not meet these criteria. Tests should be repeated after the appropriate remedial work has been done. Level I analysis of the software is customized to perform this analysis and to report locations where the maximum allowable 100-m IRI is exceeded.
4. Perform PSD analysis on the left and right wheel-path profiles with the software.

TABLE 1 Recommended Initial and Terminal IRI Values (Final Layer Only)

Highway Class	Average 1000-m IRI	
	Initial	Terminal
Freeways/Expressways (Urban)	0.9± 0.05	3.2
Freeways/Expressways (Rural)	1.0± 0.05	2.8
Arterial	1.0± 0.05	3.2
Collector	1.2± 0.05	3.8
Local Roads	1.5± 0.1	3.8
Industrial Areas (all classes)	1.5± 0.1	4.5

TABLE 2 Price Adjustment Factors

Expected Service Life (%Designed Service Life)①	Contract Unit Price Adjustment Percent of Pavement Unit Bid Price (%)
125% or more	105
< 125% - 120%	104
< 120% - 115%	103
< 115% - 110%	102
< 110% - 105%	101
< 105% - 100%	100
< 100% - 95%	99
< 95% - 90%	97.5
< 90% - 85%	95.5
< 85% - 80%	93
< 80% - 75%	90
less than 75%	not acceptable

① = Expected Service Life/Designed Service Life

5. If repeated waves are detected, investigations should be made on the cause of the waves. Because repeated waves can be cured only by preventing their formation, a layer removal is recommended to prevent reflection of the waves on the pavement surface.

6. The layer under consideration has to meet the three criteria mentioned above before construction of the following layer can be started.

7. Repeat the same steps on each asphalt layer, including the final layer.

8. If all layers satisfied the three criteria mentioned above, the average 1000-m IRI of the final surface is calculated and compared with the limits indicated in Table 1.

9. If the average 1000-m IRI exceeded the limits indicated in Table 1, then the expected PSL should be estimated based on the initial roughness (the measured 1000-m IRI) and the terminal roughness obtained from Table 1. Level II analysis of the software performs this analysis.

10. If PSL is greater than the designed service life (DSL), then the contractor is eligible to receive a bonus payment, as indicated in Table 2.

11. If PSL is greater than 75 percent of DSL and no repeated waves are detected, then the pavement section can be approved. The appropriate PAF can be determined from Table 2.

12. If PSL is less than 75 percent of DSL and no repeated waves are detected, then a life-cycle analysis is recommended. The contractor should be charged for the PWV of the increase in the pavement life-cycle costs, considering only direct agency costs. However, if this value is greater than the value of the final layer, then the contractor can choose either to be charged for the value of the final layer or to replace the final layer. It should be noted that, in the life-cycle analysis, only direct agency costs are considered. However, a highway agency might include some lane rental cost, such as that used in Indiana's warranty project (*8*).

13. If repeated waves are detected in the final layer, records of the previous layers should be reviewed to make sure these waves are not reflected from the bottom layers.

14. If the waves are found to be reflected from the bottom layers, then a special study of how to repair the pavement is required.

15. If the waves are not reflected from the bottom layers, then subjective ride surveys performed by selected panels are recommended to evaluate the negative effect of these waves on the users.

16. If the results of the ride surveys are acceptable and the 100-m IRI values are within the limits, then 50 percent of the value of the final layer should be deducted from the contractor's fee.

17. If the ride survey results are unacceptable, the contractor should replace the final layer.

Figure 6 presents the main steps (flowchart) of the specification, and Tables 1 and 2 provide the supplementary information required for the specification.

PAF

Table 2 presents the recommended payment structure. In this table, PAFs with bonus payments for extended service lives are presented. For example, if a pavement is designed for 20 years and because of the high initial roughness the expected service life is only 17 years, then the expected increase in the project PWV is about 4.5 percent, which will be charged to the contractor. These PAFs are based on the long-term effects of the initial roughness. Life cycle analyses are used to quantify these long-term effects. In this analysis, only direct agency costs are considered. However, other costs such as delay costs can be considered. Several factors are involved in the life-cycle analysis, depending on local conditions. It is strongly recommended that each highway agency conduct this type of analysis and develop its own PAFs.

Warranted Pavements

During warranty periods, if any, pavement roughness and condition (distress) should be monitored (annually). Surface defects will be reported to the contractor to perform the appropriate remedial action. The measured roughness will be used to estimate the remaining service life (RSL) of the pavement section. A comparison will be made between RSL and the remaining designed life (RDL), which is calculated as follows:

$$RDL = PSL - ASP \qquad (1)$$

where PSL is estimated service life based on the as-built average 1000-m IRI, and ASP is total traffic to date (ESAL)/designed annual traffic (ESAL).

It should be noted that PSL and ASP are calculated in equivalent single-axle load (ESAL) units. Also, because PSL is used to select the appropriate PAF, it should be used to monitor the pavement performance during the warranty period. A pavement is considered to be performing satisfactorily if the estimated RSL is equal to or greater than RDL. In cases where RSL is less than RDL, the 100-m IRI will be used to identify locations where remedial work is needed and the contractor should perform the appropriate remedial work. If the area of the remedial work exceeds 30 percent of the total section area, then the remedial work should be applied on the entire section. Level II analysis of the software can be used for this analysis.

Example

The performance-based specification is used for the two warranted pavement sections (5-year warranty periods) indicated in Table 3.

Annual roughness surveys are performed on the sections. The survey results are used to calculate RSL as explained above. Also, the 1000-m IRI values are compared with the IRI limits (Table 4). These limits are calculated based on the initial (as-built) and terminal IRI (Table 1) values and RDL in ESAL units. For example, the average 1000-m IRI of Section 1 should not exceed 0.98 at the end of Year 1 [total traffic to date = 10 million ESAL (mESAL); RDL = 90 mESAL] to allow the section to have an average 1000-m IRI equal to or less than 2.8 at the end of the DSL (total traffic = 100 mESAL; RDL = 0 mESAL).

SOFTWARE

A user-friendly software is developed to implement this specification (*9*). In this software, two levels of analyses are available, Levels I and II. Level I is customized to implement the specification, and Level II is a flexible tool that allows the user to perform more detailed analysis. Three types of analyses are available in the software: straightedge simulation, roughness indices analysis (summary statistics), and frequency analysis.

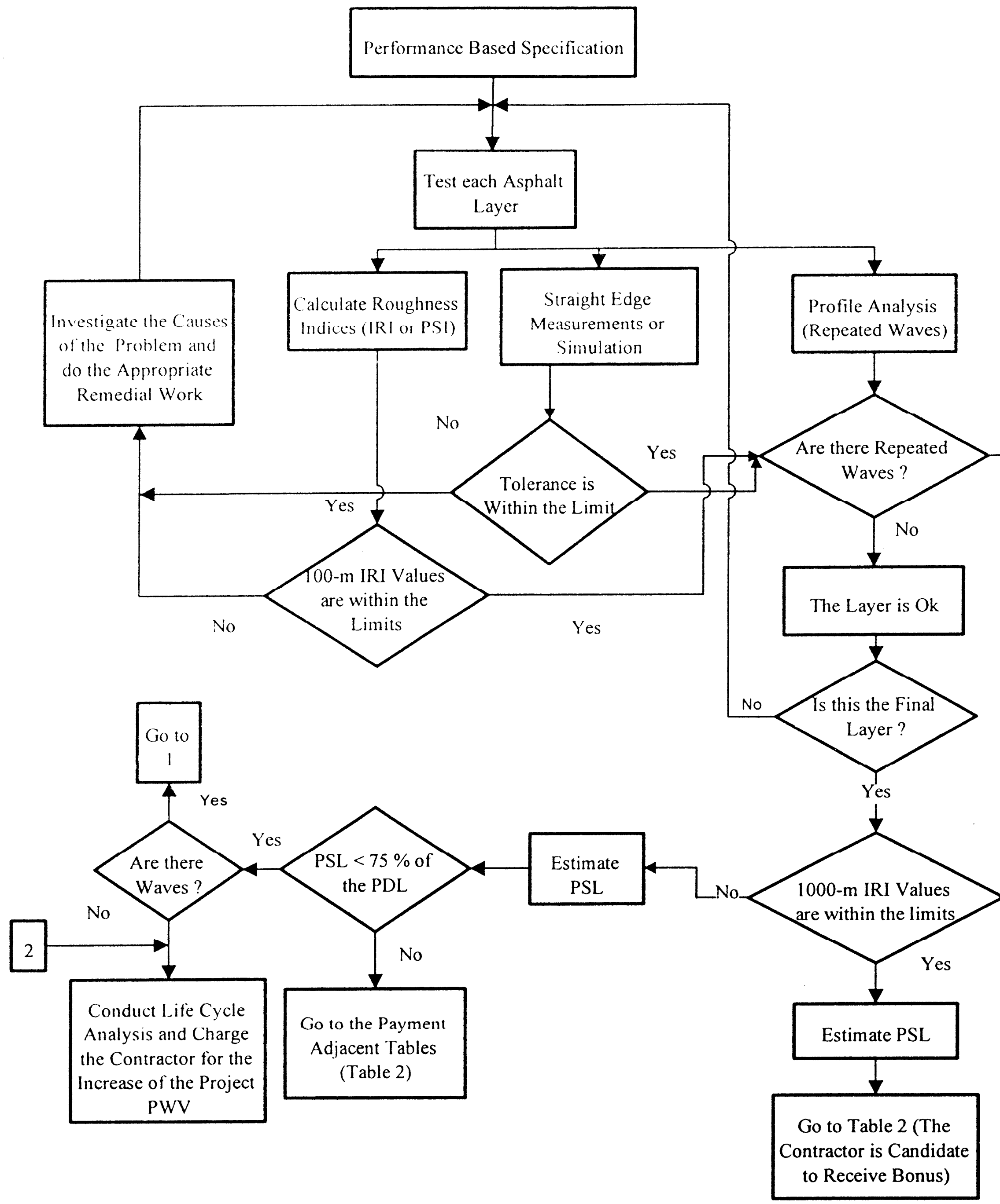


FIGURE 6 Performance-based specification. *(continued on next page)*

Straightedge Simulation

The software simulates the straightedge inspection by driving it over the measured profile at 150-mm intervals, the profile sampling rate. In Level I analysis, the straightedge length is fixed to 3 m and the software reports, in tabular and graphical formats, the maximum tolerance at each straightedge position. Also, it highlights locations where the preselected maximum allowable tolerance (e.g., 4 mm) is exceeded. In Level II analysis, the software permits the user to vary the straightedge length (from 3 to 20 m) and the maximum allowable tolerance. The software provides the option of reporting all tolerances along the straightedge length. Figure 7 presents a sample of the software output.

A verification study was performed to evaluate the accuracy of the straightedge simulation. In this study, comparisons were made between the measured and simulated tolerances. It was found that

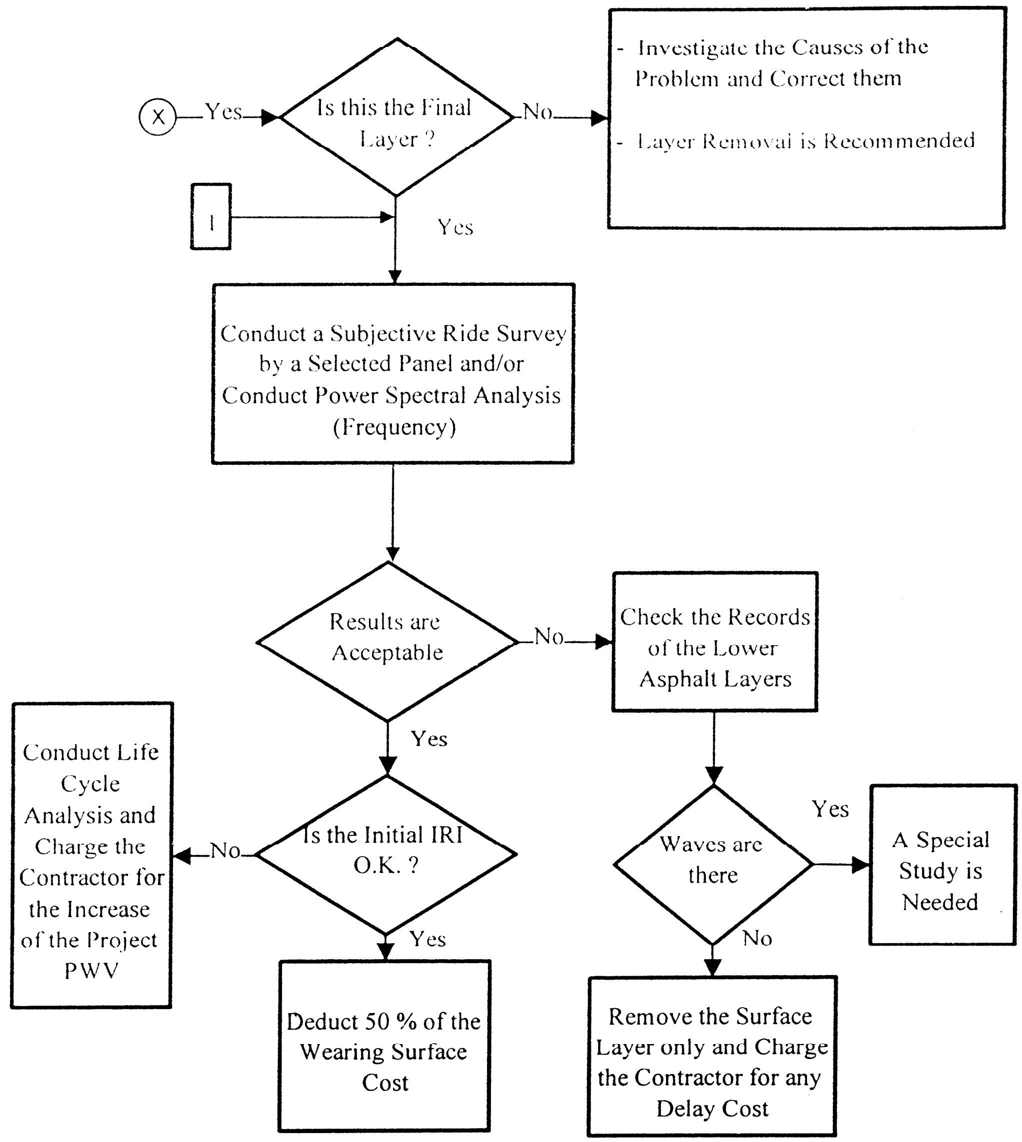


FIGURE 6 (*continued*)

the straightedge inspection can be simulated with an accuracy level of 95 percent. However, the simulated results were found to be shifted by a few meters. The cause of this shift is related to the method of initiating and ending the data acquisition. Because tests are performed at relatively high speeds (70 to 90 km/h), it is difficult to manually initiate the data acquisition at the exact starting point of the section. To overcome this problem, it is recommended that a photo cell be used to initiate and end the data acquisition.

Roughness Indices

In Level I analysis, the software calculates the 400-m IRI or PSI statistics and highlights locations where the maximum allowable IRI or minimum allowable PSI values are exceeded. In Level II analysis, the software quantifies the long-term effects of the initial roughness in terms of reduction or increase in the PSL. Level II analysis can also be used to monitor the pavement functional performance, especially for warranted pavements, and to estimate the RSL before a functional improvement is needed. Results of Levels I and II analyses are presented in tabular and graphical formats. Figure 8 presents a sample of the software output.

Frequency Analysis

The software allows the user to perform PSD analysis to detect the existence of repeated waves. Figure 9 presents a sample of the analysis results. Also, it allows the user to filter a profile to exclude or focus on a certain wave band. Figures 10 and 11 present examples of good and poor pavement sections, respectively. In both examples, the measured profile along with the filtered profiles are indicated. No

TABLE 3 Performance-Based Specification for Two Warranted Pavement Sections

Section Number	Activity	Design Life (years)	Annual Design Traffic* (mESAL)	IRI Limits (Table 1)		As-Built IRI
				Initial	Terminal	
1	Mill & Overlay	10	10	1.00	2.80	0.9
2	Recon-struction	20	10	1.00	2.80	0.9

* Zero annual growth factor is assumed

predominant wavelength is detected in the profile in Figure 10, whereas 10-m waves are detected in the profile in Figure 11.

PILOT IMPLEMENTATION

In 1996, Dubai Municipality, United Arab Emirates, conducted a pilot study to implement this specification. Profile measurements were performed with a K.J. Law Profilometer (Class I) equipped with three to five infrared sensors. A series of training sessions was provided to contractors and consultants to explain the contents of the specification. Results of the pilot study suggested that the high levels of quality included in the specification are achievable. In the first few implementations, contractors were not able to satisfy the specification requirements. However, after a few projects they were able to achieve higher levels of quality. Also, it was found that the condition of the bottom asphalt layers has a significant effect on the smoothness of the final surface. Pavement sections that experienced high IRI or repeated-wave problems in the bottom layers showed similar trends on the final surface.

In addition to the profile measurements, rolling straightedge inspections were performed to verify the results of the software simulation. Results of a comparison of the measured and simulated tolerances indicated that the straightedge inspection can be simulated with an accuracy of 95 percent.

ADVANTAGES OF THE PERFORMANCE-BASED SPECIFICATION

1. Tests are performed at 70 to 90 km/h.
2. With the software, long pavement sections can be analyzed in a few minutes.
3. Contractors obtain quick results and meaningful feedback to the paving operation.
4. All components that influence the riding quality and long-term pavement functional performance (surface tolerance, roughness, and repeated waves) are controlled.
5. Testing each asphalt layer before constructing the following layer allows early detection of construction-related problems, which reduces repair costs and improves the riding quality of the pavement.
6. Pavement functional performance can be easily and accurately monitored with annual testing.
7. It suits warranted projects.
8. Implementation of this specification will lead to better riding quality (smoother pavements), longer-lasting pavements, and huge savings in maintenance and rehabilitation costs.

SUMMARY

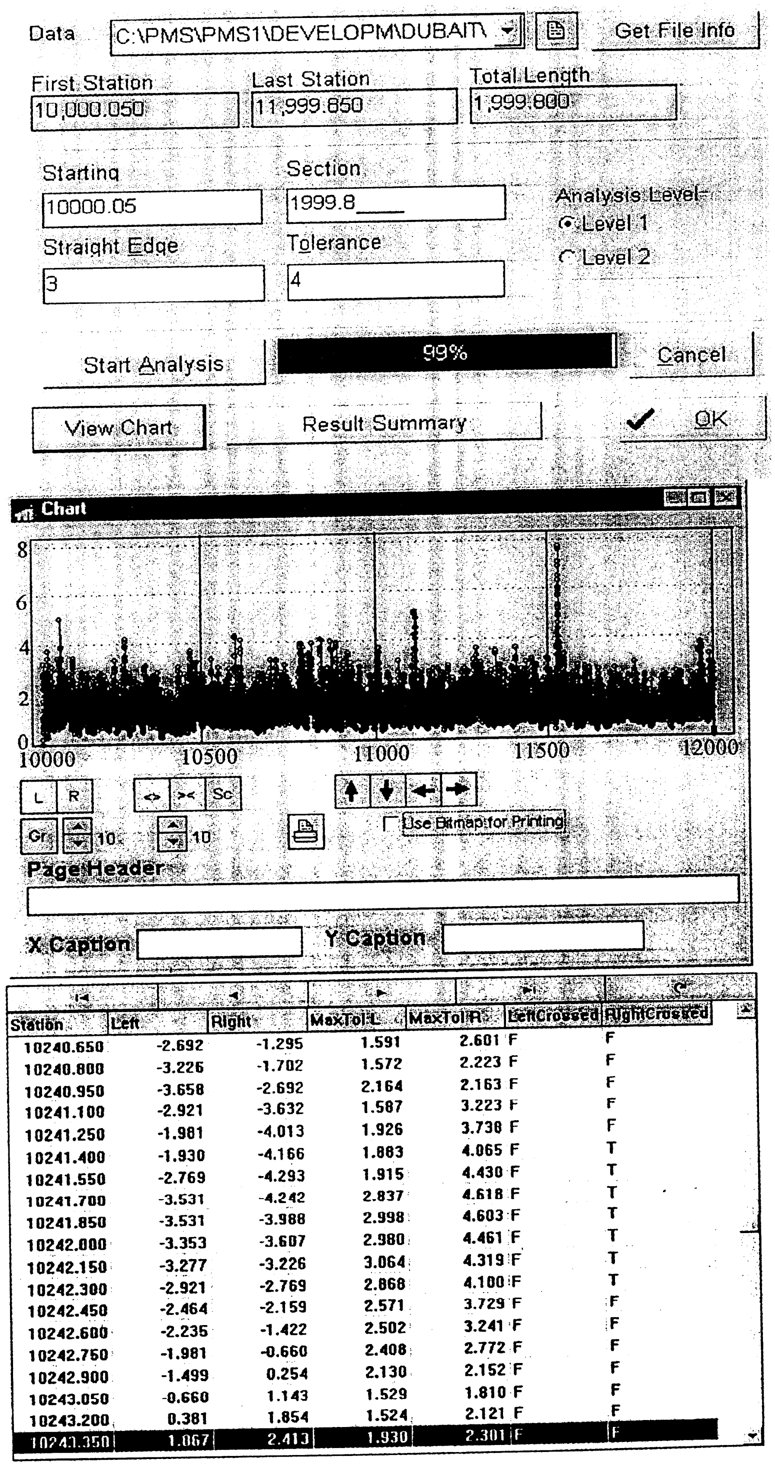
A performance-based specification applicable for new and rehabilitated warranted pavements is developed and presented. The primary purpose of this specification is control of the initial longitudinal roughness of pavements, which will lead to smoother pavements and hence satisfactory long-term functional performance. In this specification, roughness testing is performed on each asphalt layer before the next layer is constructed by using Class I or calibrated Class II profilometers. Three criteria are considered in the specification: surface tolerance, roughness indices, and repeated waves. It should be noted that this specification focuses on the functional performance of pavements and does not directly address their structural performance.

A user-friendly software was developed to implement the specification. The software is capable of simulating straightedge inspection, calculating roughness statistics, and performing frequency analyses, such as power spectral analysis. With the software, a pavement section can be evaluated, tested, and analyzed in a few minutes. A verification study was performed to evaluate the accuracy of the straightedge simulation. In this study, the measured and simulated tolerances were compared. It was found that the straightedge inspection can be simulated with an accuracy level of 95 percent.

It is believed that this specification will lead to higher levels of quality (smoother pavements), longer-lasting pavements, and huge savings in maintenance and rehabilitation costs. Highway agencies as well as contractors will benefit from implementing this specification. Highway agencies will benefit by being able to achieve the goal of having safe, smooth, and economic pavements, and contractors will benefit by reducing maintenance cost during maintenance and warranty periods. A payment structure that includes bonus payments for extended service lives is included with this specification. This payment structure is based on the long-term effects of the initial roughness on the pavement life-cycle costs.

TABLE 4 The 1000-m IRI Limits

Section Number	RDL (m ESAL)				
	90	80	70	60	50
1	0.98+0.05	1.06+0.05	1.14+.05	1.25+.05	1.37+.05
2	0.94+0.05	0.98+0.05	1.01+0.05	1.05+0.05	1.09+0.05



Station	Left	Right	MaxTol L	MaxTol R	LeftCrossed	RightCrossed
10240.650	-2.692	-1.295	1.591	2.601	F	F
10240.800	-3.226	-1.702	1.572	2.223	F	F
10240.950	-3.658	-2.692	2.164	2.163	F	F
10241.100	-2.921	-3.632	1.587	3.223	F	F
10241.250	-1.981	-4.013	1.926	3.738	F	F
10241.400	-1.930	-4.166	1.883	4.065	F	T
10241.550	-2.769	-4.293	1.915	4.430	F	T
10241.700	-3.531	-4.242	2.837	4.618	F	T
10241.850	-3.531	-3.988	2.998	4.603	F	T
10242.000	-3.353	-3.607	2.980	4.461	F	T
10242.150	-3.277	-3.226	3.064	4.319	F	T
10242.300	-2.921	-2.769	2.868	4.100	F	T
10242.450	-2.464	-2.159	2.571	3.729	F	F
10242.600	-2.235	-1.422	2.502	3.241	F	F
10242.750	-1.981	-0.660	2.408	2.772	F	F
10242.900	-1.499	0.254	2.130	2.152	F	F
10243.050	-0.660	1.143	1.529	1.810	F	F
10243.200	0.381	1.854	1.524	2.121	F	F
10243.350	1.067	2.413	1.930	2.301	F	F

FIGURE 7 Straightedge simulation analysis.

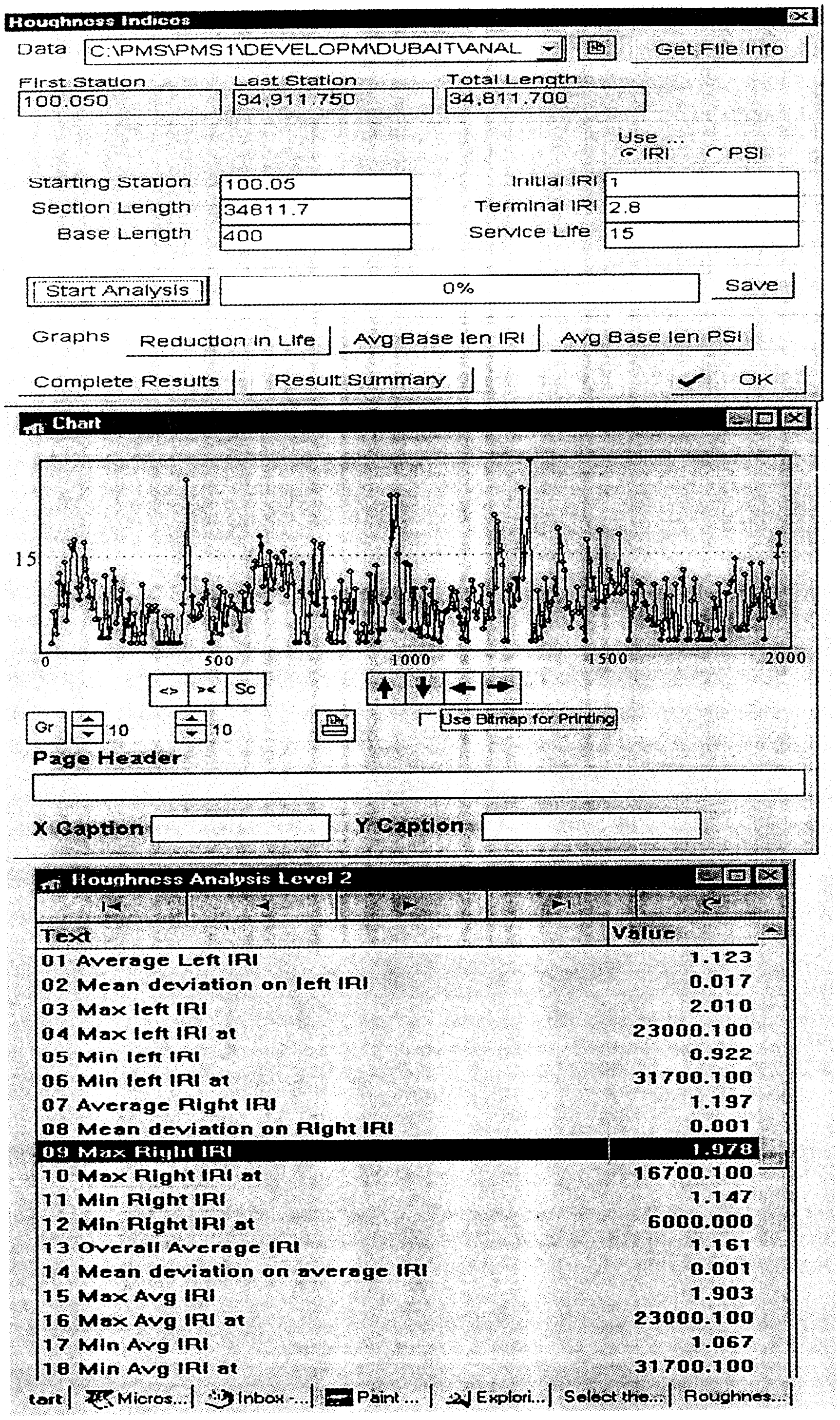


FIGURE 8 Roughness analysis.

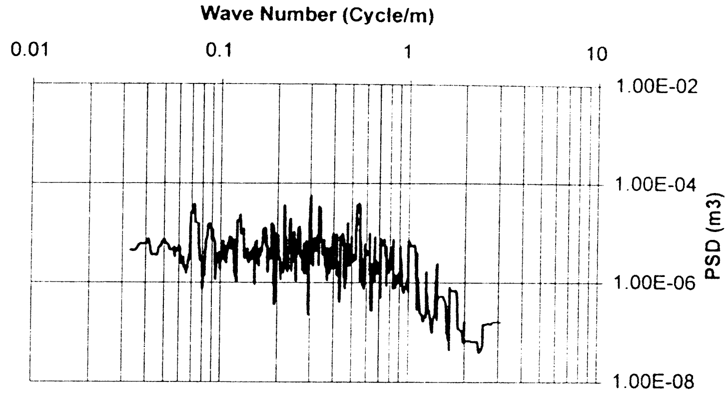


FIGURE 9 Sample of the PSD graphs.

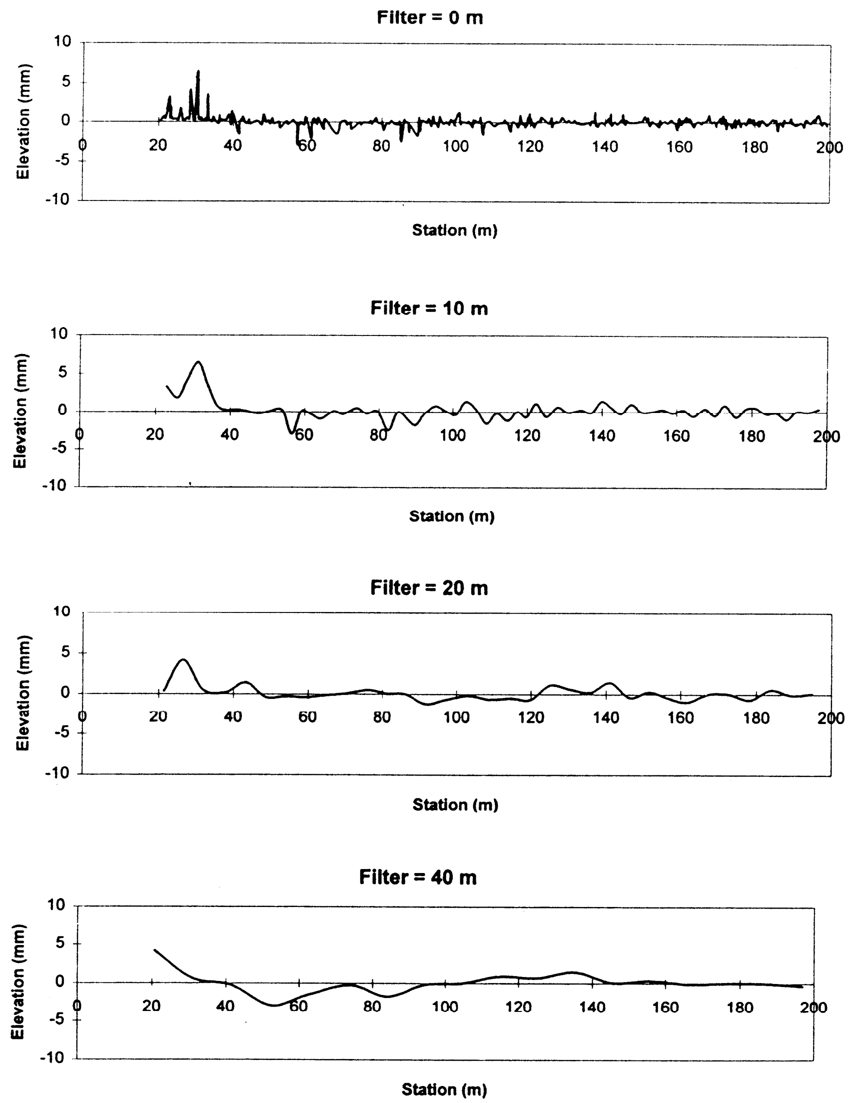


FIGURE 10 Example of a good pavement section.

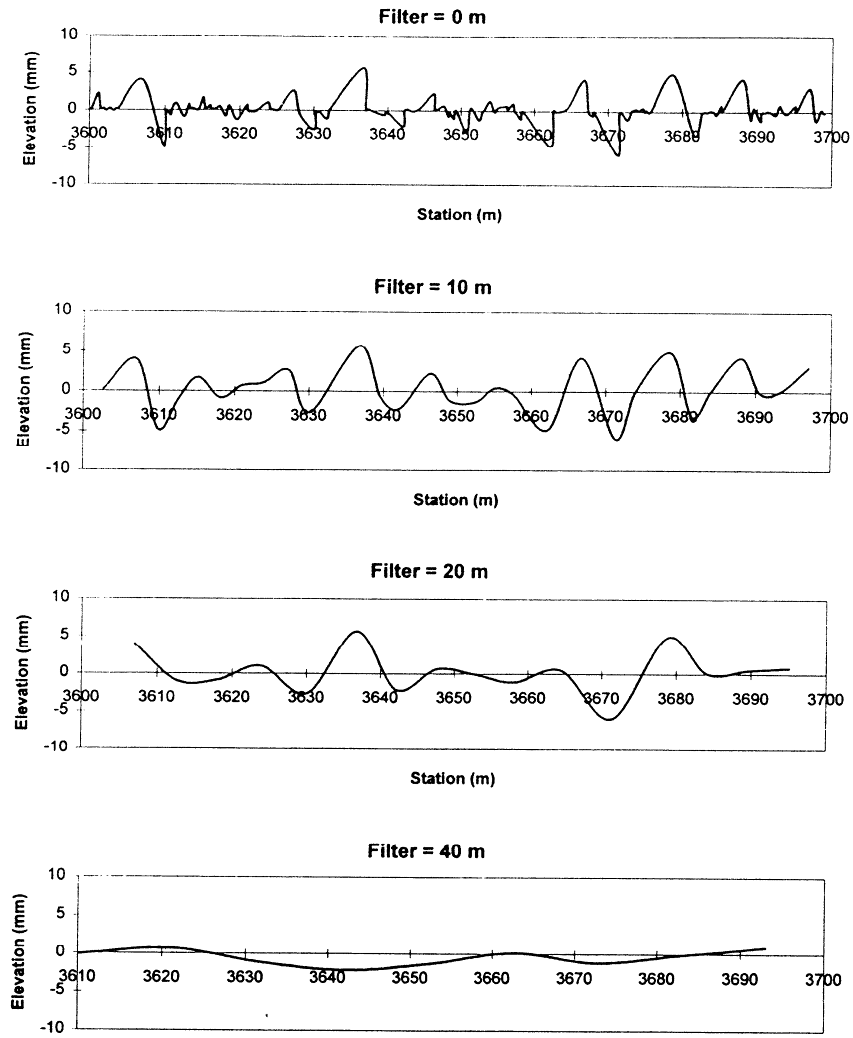


FIGURE 11 Example of a poor pavement section.

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