

# INDEPENDENT STUDY

## LESSON 1

### KEY EQUIPMENT CONCEPTS

1 Hour

**TABLE OF CONTENTS**

**Contents**

Instructions for the Participants ..... 2

Overview ..... 2

Learning Outcomes ..... 2

Pavement Profile ..... 3

Equipment for Smoothness Measurements ..... 6

    Straightedge ..... 6

    Profilographs ..... 7

    Response Type Road Roughness Measuring Systems (RTRRMS) ..... 11

    Inertial Profilors ..... 13

Reference Devices ..... 16

    Rod and Level ..... 16

    Inclinometer-based Devices ..... 17

    Differences in Profile Measured by Inertial Profilors and Reference Profilors ..... 18

Synopsis ..... 21

References ..... 22

## **INSTRUCTIONS FOR THE PARTICIPANTS**

The participants are expected to read and complete these materials before the classroom portion. Please bring them to the classroom portion with you. The instructor will be reviewing these materials.

## **OVERVIEW**

Studies have shown that roughness is one of the biggest priorities of highway users. Additional studies have shown that pavements that are built smooth stay smoother longer and provide a longer pavement life. Most State highway agencies (SHAs) have some type of smoothness specification that is used to evaluate the smoothness of newly constructed or rehabilitated pavements. Many agencies also have incentives or disincentives for new construction and rehabilitation, which are based on pavement smoothness. Increasingly these agencies are turning to inertial profilers as the most reliable instrument for construction acceptance testing.

In this independent study, you will learn the basic concepts associated with various types of equipment used to collect longitudinal profile data.

## **LEARNING OUTCOMES**

This document contains the independent study material for Lesson IS1: Key Equipment Concepts. You should complete this material before attending the first classroom training session. It will take approximately 1 hour to complete this independent study lesson.

The overall learning outcomes for Lesson IS1 are:

- Identify different types of equipment used to measure pavement smoothness along with both the positive and negative aspects of their operation.
- Identify the basic components of an inertial profiler.
- Explain the advantages of measuring smoothness with an inertial profiler.

## PAVEMENT PROFILE

A profile is a two-dimensional slice of the road surface taken along an imaginary line. The longitudinal profile shows the variation of the profile of the pavement in the longitudinal direction. Figure 1 illustrates the longitudinal profiles that can be measured along a road surface. As shown in this figure, the longitudinal profile can be measured along any continuous imaginary line along the pavement surface. If the measurement is repeated, the same profile can only be expected if the same imaginary line is followed.



Figure 1. Profiles on a road surface

For any line drawn on a physical surface, a “true” profile exists. That “true” profile includes components of the aggregate texture, the surface texture of the roadway, the roughness of the roadway, and the grade of the roadway. The requirements for measuring the profile depend on the use of the data.

Let us consider the following example. You have decided to purchase a stereo system. In purchasing that stereo system, you will decide on the quality of the system based on the gain plot for the stereo system. The gain plot will tell you how the sound is distorted over a range of wavelengths. To know that you have a high quality stereo system, you

will look for a system with a gain of 1 over the range of wavelengths that people normally hear. It is not important to have a gain of 1 for sound waves that are either too short (or high pitched) or too long (or low pitched) for you to hear.

In the same way, we are interested in measuring aspects of the roadway profile which are felt by the user and attributed to pavement roughness. This measurement requirement then excludes the need for measuring the texture of the pavement surface (too short to impact ride) and the pavement grade (too long to impact ride). The surface texture and smaller features (such as the aggregate texture) impact the friction and noise characteristics of the pavement, but do not impact the roughness. Pavement grade and changes in pavement grade are large features which the user does not attribute or observe as roughness.

Accurately measuring the features of the longitudinal profile that are relevant to roughness provides several benefits. The first is that they allow us to prepare a plan for repairing some of the more significant features contributing to the roughness. For instance, accurately measuring the roughness on an existing pavement prior to construction of a rehabilitation treatment can allow us to determine appropriate steps to correct this roughness in order for the completed surface to be as smooth as possible. These measurements also allow us to identify where the bumps and dips occur in the completed surface which can allow for preparation of a grinding plan to correct them as needed.

Further, identifying the bumps and dips in the pavement surface can also help us identify causes from the construction process that are contributing to their development. For instance, a bump on a rigid pavement surface that occurs at 50-ft intervals may be indicative of a sagging stringline used in the paving process. A recurring bump on an asphalt surface may help the contractor identify the dump truck driver who always bumps the paver in the process of transferring material. Once we understand the cause for these features, construction practices may be improved providing for a higher quality roadway in the end.

**Question #1**

What is a pavement profile?

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**Question #2**

List two reasons why accurately measuring the pavement profile is important.

1. \_\_\_\_\_  
\_\_\_\_\_
2. \_\_\_\_\_  
\_\_\_\_\_

**Do not turn this page to continue with the lesson until you have answered these questions!**

## EQUIPMENT FOR SMOOTHNESS MEASUREMENTS

### Straightedge

Smoothness specifications based on straightedges were very widely used in the past and are still being used to determine smoothness of pavements for construction acceptance purposes in some cases. Smoothness specifications that are based on a straightedge indicate the maximum permissible deviation below the straightedge. A common specification that is used is a maximum deviation of  $\frac{1}{8}$  inch for a 10-ft straightedge. As shown in Figure 2, the straightedge is placed on the pavement surface and the deviation between the bottom edge of the pavement and the pavement surface is checked to see if the deviations are within the specified value.

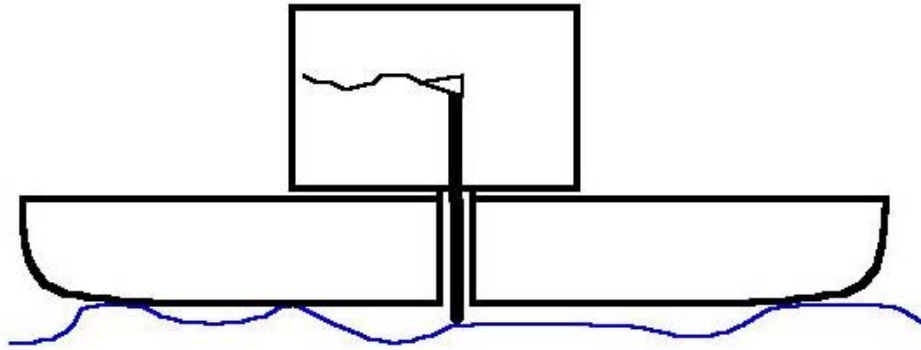


Figure 2. Sliding straightedge.

Another type of straightedge that is used is the rolling straightedge. A schematic sketch of the rolling straightedge is shown in Figure 3. As shown in the figure, the rolling straightedge is basically a sliding straightedge with wheels positioned at either end and on the measurement device. The straightedge is pushed along the pavement surface, and a pointer at the middle of the straightedge shows the displacement at the center of the straightedge from the line established by the two wheels of the device.

The rolling straightedge is easy to operate. It is also easy to understand the measurement method and results from the straightedge. Because the straightedge involves few mechanical parts, it is simple to repair and there are few requirements for its proper operation. In other words, it is possible to simply place the device on the pavement surface and begin pushing to obtain measurements.

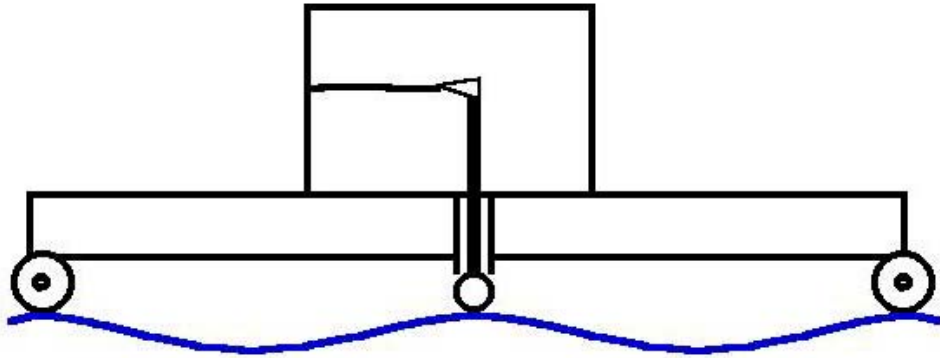


Figure 3. Rolling straightedge.

However, as illustrated in Figure 3, the rolling straightedge will not be able to detect a repetitive wavelength that is present on the roadway. The rolling straightedge shows a varying response to different wavelengths that are present on the roadway. The measurement of the rolling straightedge distorts some of the features in the pavement surface that contribute to pavement roughness (*I*). Further, this device is slow to operate requiring the operator to walk the pavement surface for the length to be measured.

### Profilographs

A profilograph consists of a rigid beam or frame with a system of support wheels at either end, and a center wheel. The support wheels at the ends establish a baseline from which the deviations of the center wheel can be evaluated. The center wheel is linked to a strip chart recorder or a computer that records the movement of the center wheel from the established baseline. The profilograph is pushed along the pavement, and 2 to 3 miles can be measured in an hour.

Mechanical profilographs record the data on a strip chart recorder. The output from the strip chart recorder has to be analyzed in order to obtain the smoothness results. The evaluation of the output from the strip chart recorder can be performed either manually or electronically. In the manual method, a technician evaluates the profilograph output to determine smoothness results and bump locations. In the electronic method, the output of the strip chart recorder is scanned and the data reduction is performed by a computer program and the results can be printed.

Computerized profilographs can analyze the data using computer programs to generate the profile index (PI) of the section and indicate the high points in the profile. The computerized profilograph eliminated the need for analyzing the profile in the office after the test was conducted in the field. The computerized profilograph was able to perform the trace reduction in the field immediately after the test was performed. This significantly increased productivity and reduced variability in trace reduction since the trace would always be interpreted the same.

The profilograph consists of frame segments, wheel assemblies, steering mechanism, and a recorder. The frame can be disassembled for transportation in a pick up or a van. The assembly time for the unit is reported to be 10 minutes, with the components being assembled using quick connect features and toggles. Figure 4 shows a photograph of the twelve-wheel truss type California profilograph which is most commonly used. Two other types of profilographs are illustrated by Figure 5, a beam type California profilograph, and a plan view of the Rainhart profilograph is shown in Figure 6.



Figure 4. Truss type California profilograph.



Figure 5. Ames profilograph. (2)

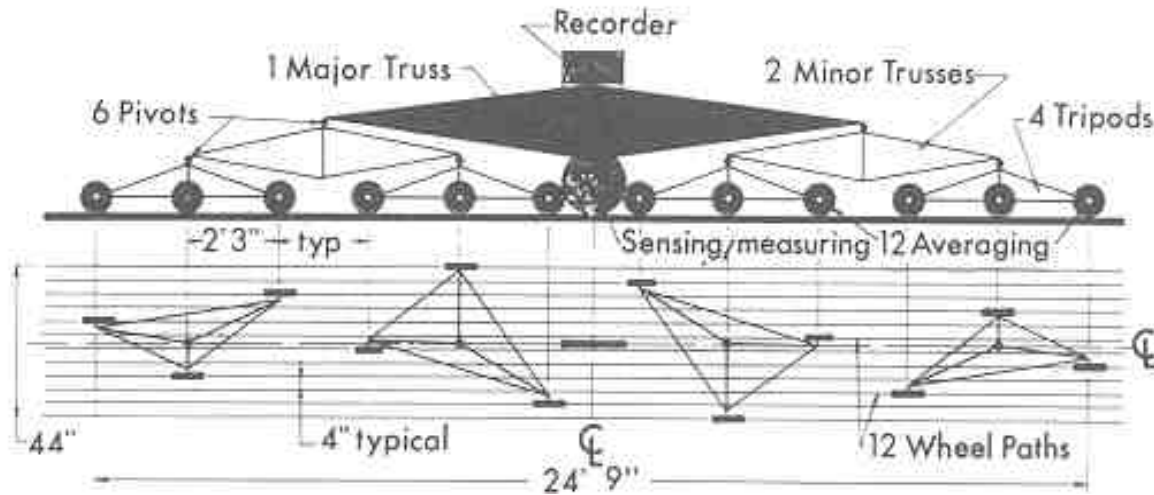


Figure 6. Rainhart profilograph (3).

A plan view of the common California profilograph is shown in Figure 7. As shown in Figure 7, the beam length of the profilograph is 25 ft, while the overall length is 32.5 ft. There are two support wheel systems at either end of the profilograph. Each wheel system consists of six wheels, with four wheels on one side of the truss and the other two wheels on the other side of the truss. The profilograph is pushed along the pavement by an operator who steers the front support wheels in the unit using a steering wheel located at the center of the unit. Profile traces are recorded to a horizontal scale of 1:300 (i.e., 1 in. = 25 ft) and to a vertical scale of 1:1.

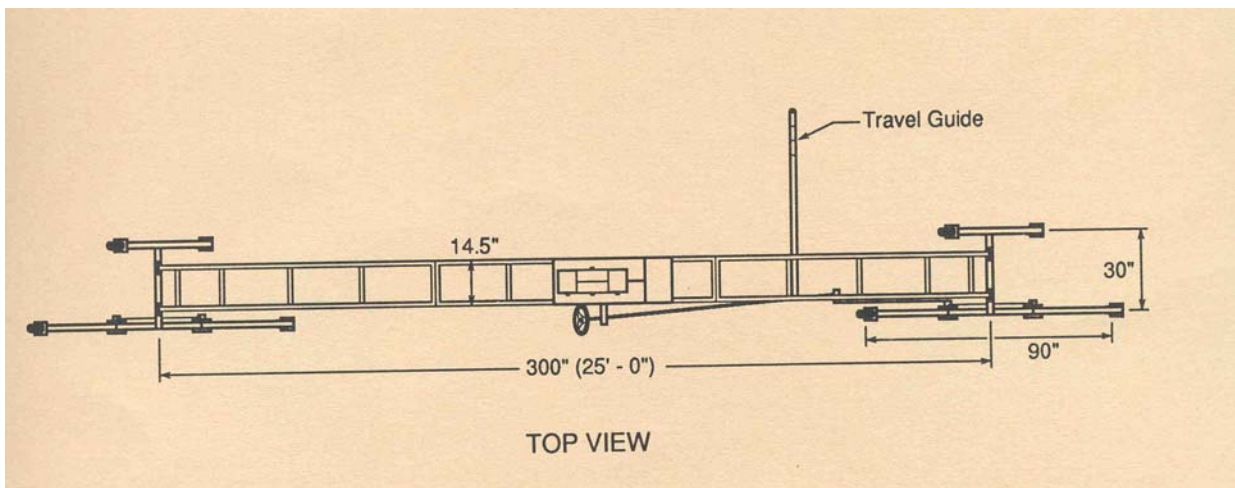


Figure 7. Plan view of California profilograph (3).

***Advantages and Disadvantages of Profilographs***

As with the rolling straightedge, the profilograph is fairly simple to operate and its measurement principle is fairly simple to understand. These devices are somewhat more complicated than the straightedge; however, with few parts, repairs are also fairly simple to complete with the potential exception of repairs to the computer or automated measurement system.

There have been questions raised about how well a profilograph measures wavelengths that are related to ride quality. Kulakowski and Wambold (4) reported that profilographs have varying response to wavelengths present on roadways. They report that profilographs measure some wavelengths correctly, amplify some wavelengths, and that some wavelengths are hardly measured. Figure 8 shows the actual and desired frequency response of a 12-wheel California Profilograph. (4) As shown in this figure, the California profilograph amplifies some of the features in the profile and attenuates others. The line labeled as “Desired” in the figure illustrates the feature lengths that impact ride quality.

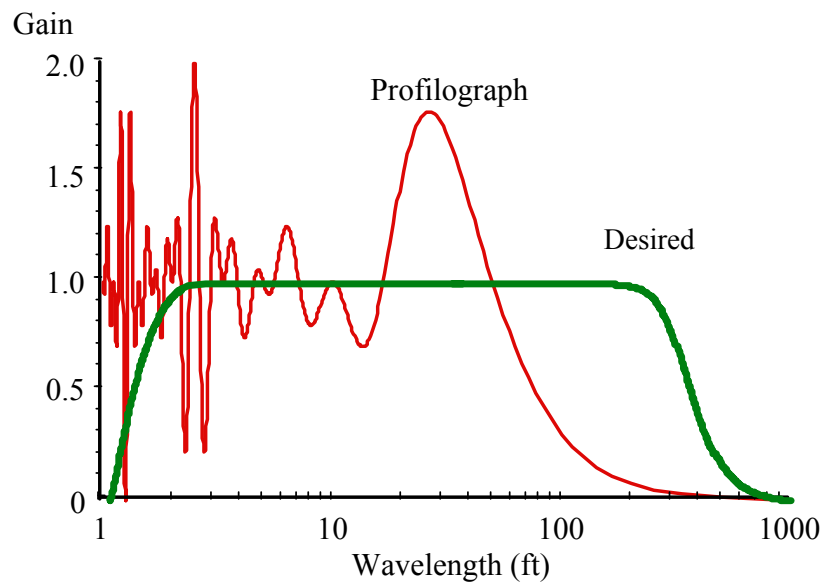


Figure 8. Desired and actual frequency response of 12-wheel California style profilograph.

**Question #3**

What type of equipment has your agency used in the past for measuring construction acceptance?

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## **Response Type Road Roughness Measuring Systems (RTRRMS)**

Response Type Road Roughness Measuring Systems (RTRRMS) measure the response of the road on the vehicle or a special trailer equipped with a measuring system. Automobiles or standardized trailers have been used to house response type devices. The vehicle-mounted systems accumulate the vertical movement of the rear axle of the automobile with respect to the frame; while the trailer-mounted systems accumulate the movement of the trailer with respect to the frame.

These devices have primarily been used for pavement management purposes in the past. While they have not been used for construction acceptance testing, except in rare cases, they are discussed here because their measurement methodology is very intuitive.

One of the earliest response type devices was the Bureau of Public Roads (BPR) Roughometer. Thereafter, a variety of response type devices such as Cox Roadmeter, PCA Roadmeter, and Maysmeter were developed. These devices measure roads at speeds up to 50 mph. The American Society for Testing and Materials has developed ASTM Standard E1082 “Standard Test Method for Measurement of Vehicle Response to Traveled Surface Roughness” (5) that specifies procedures to be followed for measuring roughness with vehicle mounted response type systems. The ASTM Standard E1215 “Standard Specifications for Trailers Used for Measuring Vehicle Response to Road Roughness” (5) specifies standards and procedures to be used for measuring roughness with trailer-mounted roughness measuring systems. A brief description of the measurement principles and operating procedures for the BPR Roughometer and Maysmeter are presented next.

### *Bureau of Public Roads (BPR) Roughometer*

Figure 9 shows a sketch of the BPR Roughometer. The BPR Roughometer consists of a single wheel trailer that is towed by a car or a light truck. The wheel mounted on the trailer is supported by leaf springs. Variations in the pavement surface cause the wheel to move with respect to the frame of the trailer. These vertical movements are accumulated and the roughness for the pavement is given in terms of inches per mile. This device was operated at a test speed of 20 mph to collect data.

The measurements obtained by this device were susceptible to temperature, condition of bearings and mechanical components. This device also had a resonant frequency effect that produced incorrect results. Because of the slow operating speed of the equipment, many equipment modifications were made to increase the operating speed. However, the basic operational characteristics were altered at high speeds and the use of the device has gradually declined over time.

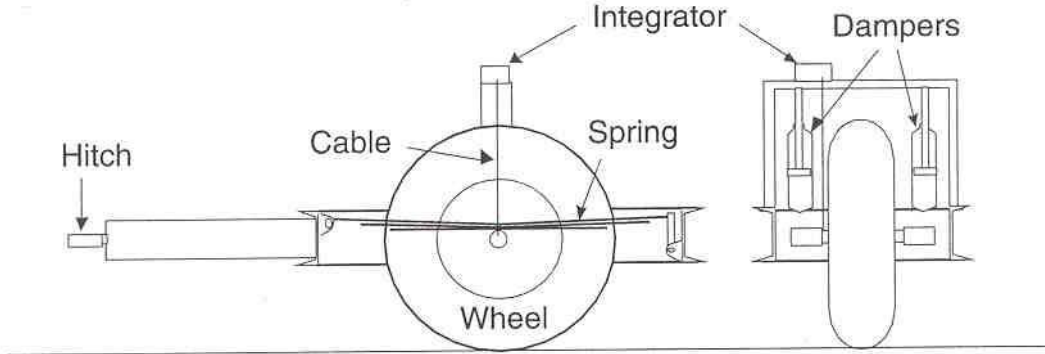


Figure 9. Bureau of Public Roads (BPR) Roughometer (1).

### *Maysmeter*

This device was mounted on an ordinary passenger car or a light truck. Figure 10 shows a sketch of a car-based Maysmeter.

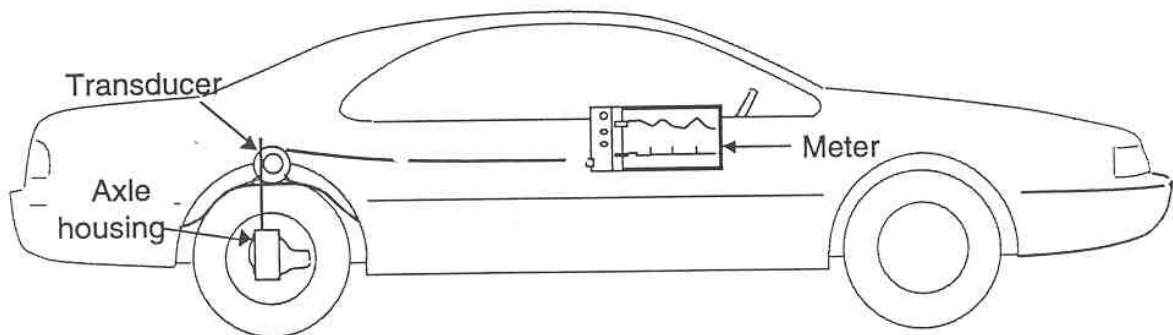


Figure 10. Car-mounted Maysmeter (1).

The Maysmeter measures the suspension motions of the vehicle by recording the relative movement between the axle and the body. The roughness measure that is obtained by this device is “inches” of accumulated suspension stroke, divided by the distance traveled, and is reported in units of inches per mile. The measure of vehicle response measured by the Maysmeter is very similar in its frequency content to the accelerations on the vehicle body, so it is highly correlated to ride vibration.

### ***Advantages and Disadvantages of Response Type Road Roughness Measuring Systems***

Although there are problems involving reproducibility and portability of data taken with response-type systems, one reason that they have been so popular in the past is that they

provide an economic way of obtaining the roughness of roadways. The measures they produce have been viewed by engineers as matching their experience for determining pavement quality in a meaningful way.

Response type road roughness measuring systems have features that affect the accuracy of data collection. The measurements obtained from response type systems are influenced by the properties of the vehicle such as suspension system characteristics, tire conditions, tire pressure, and vehicle weight. If the properties of the vehicle change over time, the response that is measured will vary. This raises concerns regarding accuracy and repeatability of RTRRMSs. As the roughness measurements may not be stable with time, measurements obtained by a RTRRMS cannot be compared with confidence to those made previously.

Because the measurements are dependent upon vehicle properties, the measurements obtained by a RTRRMS are seldom reproducible by another device. The output obtained from a RTRRMS that is installed in a particular vehicle will be different from the output obtained from the same RTRRMS that is installed in another vehicle.

The speed of travel affects the response of the system. If the same section is measured by the same device at two different speeds, the outputs that are obtained will be different. When roughness measurements are made with response-type systems, a standard speed is used to obtain measurements. However, the vehicle may not be able to always maintain this standardized speed due to existing traffic conditions.

As the response-type devices record only the response of the vehicle, no information regarding the location of rough spots on the pavement can be obtained from the recorded data.

### **Inertial Profilers**

Inertial profilers are intended to collect the portion of the longitudinal profile that affects ride quality. Inertial profilers can be classified into two types, high-speed profilers that are van-based, and lightweight profilers that are housed in a utility vehicle. High-speed inertial profilers collect profile data on pavements at highway speeds. The first high-speed inertial profiler was developed by Elson Spangler and William Kelley at the General Motors Research Corporation (6).

A schematic diagram of an inertial profiler is shown in Figure 11. The five principal components of an inertial profiler are a height sensor, an accelerometer, a distance measuring system, computer software and hardware, and a photocell (not shown in the diagram).

The height sensor records the height to the pavement surface from the vehicle. The non-contact height sensor types that are commonly used in profilers today are lasers.

The accelerometer that is located on top of the height sensor records the vertical movement of the height sensor. Data from the height sensor and the accelerometer are combined to determine the distance to pavement surface relative to an inertial reference frame.

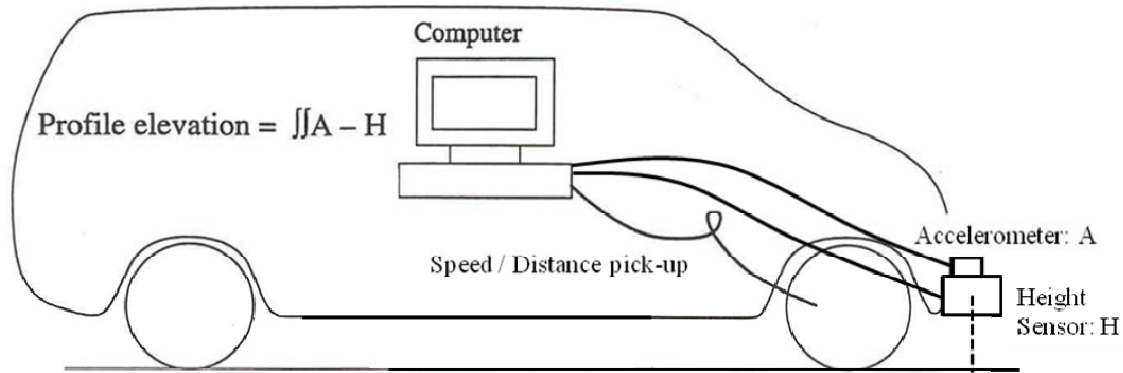


Figure 11. Components of an inertial profiler (1).

The distance measuring system keeps track of the distance with respect to a reference starting point.

A computer is used to compute the profile at each sampled point of the height sensor using the data recorded by the height sensor, accelerometer, and the distance measuring system.

A photocell is used to automatically initiate data collection at a pre-determined location. Two types of photocells, vertical and horizontal, are available. The vertical photocell can be used to automatically initiate data collection when the photocell detects a white reflective tape that is placed on the travel lane. The horizontal photocell is used with a traffic cone that has reflective markings to initiate data collection. The traffic cone is placed on the shoulder at the location where data collection has to be initiated. When the horizontal photocell detects the cone, data collection is initiated.

### ***Advantages and Disadvantages of Inertial Profilers***

The first and biggest advantage to the use of inertial profilers is that they provide a more accurate and precise measurement of the features of the longitudinal profile that are relevant to the assessment of pavement roughness.

These devices mounted on vans or trucks operate at highway speeds. Even those mounted on lightweight utility vehicles still operate at speeds of approximately 20 mph making them much faster for data collection than either the straightedge or the profilograph.

Commonly, the high speed devices (those mounted on a van or truck) will have additional equipment installed to measure other aspects of the pavement. For instance, additional height sensors may be used to measure the transverse profile or cameras may be installed to store images of the pavement surface or forward-video for logging roadway appurtenances. This ability makes these devices very versatile for use in both pavement management and construction acceptance.

While these devices offer a very good option for measuring longitudinal profile as it pertains to pavement roughness, they do have several disadvantages. First, the operational aspects of the equipment require that they be at their required operational speed for some distance prior to starting data collection. The requirement for this “lead-in distance” will be discussed further in the classroom section of the course.

These devices are complicated pieces of machinery requiring knowledgeable technical understanding for maintenance and repair. This course will assist operators in identifying when the equipment is not working properly, but the repair of the devices is beyond the scope of the subjects covered.

**Question #4**

Identify the five components of an inertial profiler and their purpose.

1. \_\_\_\_\_
2. \_\_\_\_\_
3. \_\_\_\_\_
4. \_\_\_\_\_
5. \_\_\_\_\_

**Question #5**

Under what circumstances might use of the inertial profiler not be the best measurement device for determining pavement roughness?

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**Question #6**

What brand of inertial profiler is your agency / company using?

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\_\_\_\_\_

\_\_\_\_\_

**Do not turn this page to continue with the lesson until you have answered these questions!**

## REFERENCE DEVICES

Reference devices are devices that provide the actual profile to a high degree of accuracy. These devices are generally slow to operate, but provide very detailed data. The purpose of a reference device is to provide measure the longitudinal profile against which the accuracy of the inertial profiler may be evaluated.

The Federal Highway Administration (FHWA) has developed a means for evaluating reference devices. (7) In order for a system to be sold as a reference device for use in evaluating an inertial profiler, it must have passed the review by the FHWA. The following provides a basic description of some potential reference devices.

### Rod and Level

One method for collecting reference data is using a rod and level. There are several different types of rod and level surveys available. The standard rod and level equipment are illustrated in Figure 12.

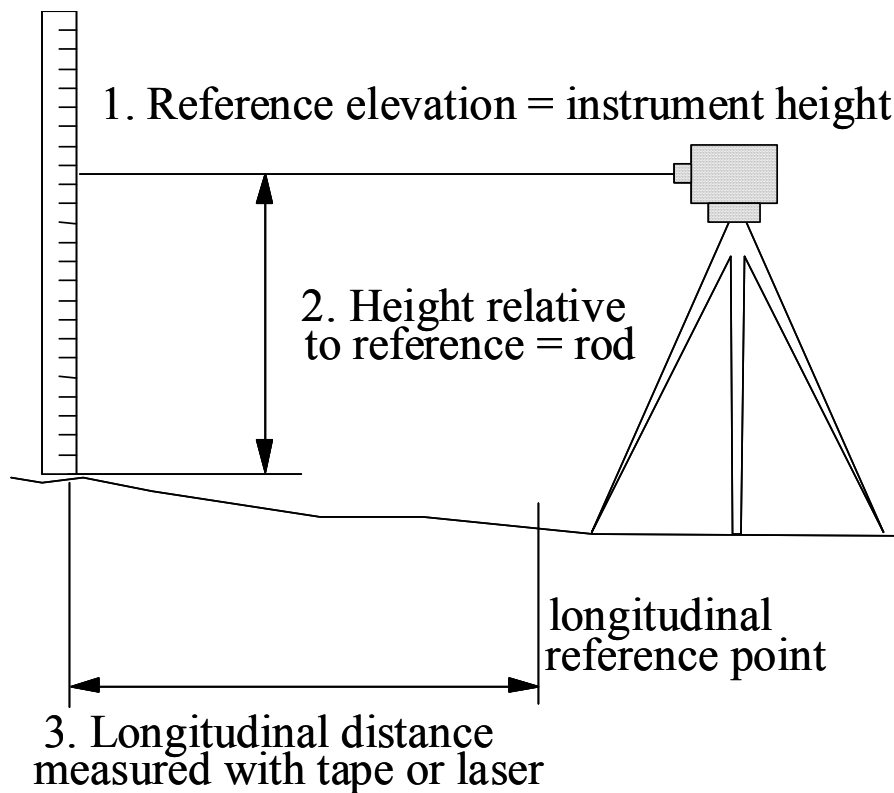


Figure 12. Rod and level survey used as reference

The rod and level survey equipment are difficult to use for a check of the inertial profiler as the requirement for measuring ride quality calls for data collected at 3-inch intervals or

smaller. Collecting survey data at 3-inch intervals is very time consuming and difficult to maintain accuracy. The ASTM standard E 1364, Test Method for Measuring Road Roughness by Static Level Method (5) describes the procedures to be followed to collect rod and level data at a test section. The most important factor when collecting rod and level data is to make sure that the resolution of the level meets the requirements outlined in the ASTM standard.

There are other procedures available for collecting elevation data which are more automated than the standard rod and level survey. These pieces of equipment have been developed by various manufacturers for use as reference devices. Most of these devices operate at very slow speeds making them inappropriate for regular use in collecting longitudinal profile data. However, because of the accuracy associated with these measurements, they are quite useful in checking that the inertial profiler is providing accurate data.

### Inclinometer-based Devices

Another type of device that is available for use to provide reference measurements are based on inclinometers. These devices will consist of two “feet” with one in front of the other which rest on the pavement surface. One such device is illustrated in Figure 13.

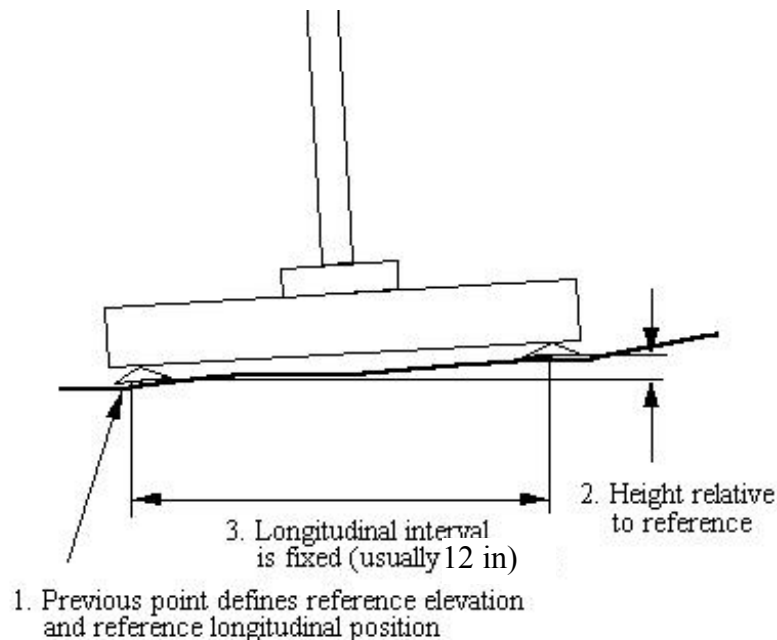


Figure 13. Example of inclinometer-based reference device

The inclinometer measures the angle between these two feet. The angle can be used to determine the relative change in elevation between the locations represented by the two feet. With some of these devices the foot at the back of the device is moved to the location of the front foot and the front foot is moved to a new location for the next measurement. With other devices a rolling inclinometer is used, but the operational characteristics are the same

as the static. The final elevation profile provides elevation measurements relative to the first point which is assumed to be at 0 ft.

There are a number of manufacturers of the inclinometer based devices as illustrated in Figure 14. The operational speeds of these devices range from 0.5 to 2 mph depending upon the type of device being used.



Figure 14. Examples of rolling inclinometer-based profilers (8, 9, 10)

### **Differences in Profile Measured by Inertial Profilers and Reference Profilers**

The profile that is obtained from an inertial profiler does not look like a profile that is measured by a reference device. The agreement between the profile obtained with an inertial system and one obtained from a reference device is good in some respects, but not in others. Figures 15 and 16 show the profile obtained along the same roadway by a reference device and an inertial profiler, respectively. Although the profile shown in these two figures were obtained along the same road, the two plots are very different. The elevation profile that is obtained from the reference device that is shown in Figure 15 includes the grade of the road, and as seen in this figure the road has a negative grade. The profile that is obtained from an inertial profiler that is shown in Figure 16 does not include the grade of the road, but includes the features in the profile that affect the ride quality of the pavement. The profile that is obtained from an inertial profiler is “filtered” to show the profile features that are relevant to ride quality. This causes a profile that is obtained from an inertial profiler to look different from the elevation profile that is obtained from a reference device.

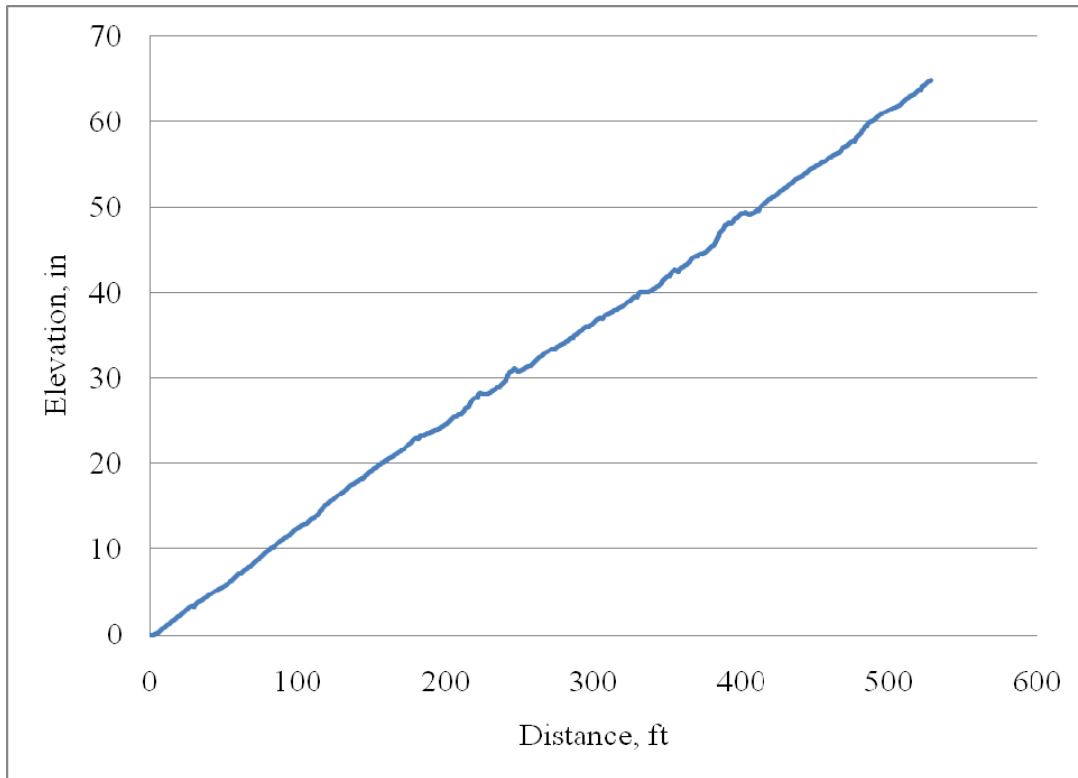


Figure 15. Elevation profile obtained from reference device measurements.

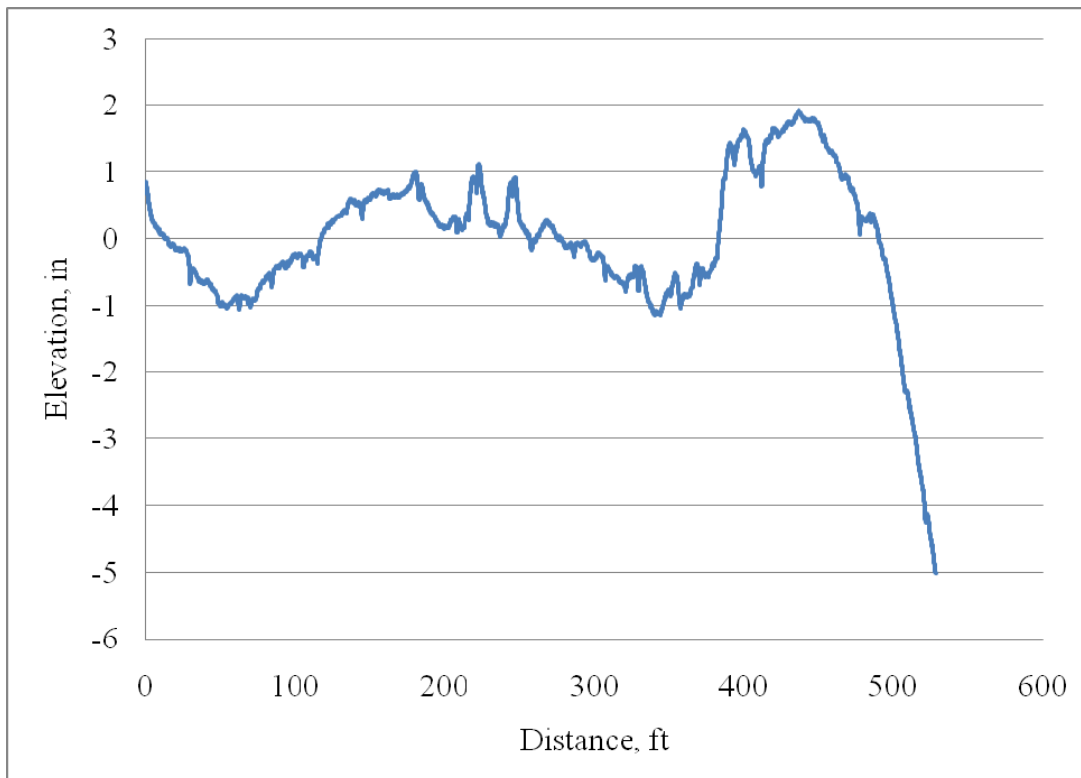


Figure 16. Profile measured by an inertial profiler.

**Question #7**

What is the purpose of taking measurements using a reference device?

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**Question #8**

What causes the difference in measurements obtained from a reference device and an inertial profiler even if both devices are very accurate?

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**Do not turn this page or proceed to second independent study lesson until you have answered these questions!**

**SYNOPSIS**

<b>Profiler Type</b>	<b>Advantages</b>	<b>Disadvantages</b>
Straightedge	<ul style="list-style-type: none"> <li>• Easy to operate</li> <li>• Easy to understand operating characteristics</li> <li>• Easy to repair</li> </ul>	<ul style="list-style-type: none"> <li>• Slow operational speed</li> <li>• Does not accurately measure some features which impact ride quality</li> </ul>
Profilograph	<ul style="list-style-type: none"> <li>• Easy to operate</li> <li>• Easy to understand operating characteristics</li> <li>• Easy to repair</li> </ul>	<ul style="list-style-type: none"> <li>• Slow operational speed</li> <li>• Does not accurately measure some features which impact ride quality</li> <li>• Requires assembly and disassembly for transport</li> </ul>
Response-Type Road Roughness Measuring Systems	<ul style="list-style-type: none"> <li>• Measure ride quality at higher speed than the straightedge or profilograph</li> <li>• Intuitive measure of ride quality</li> </ul>	<ul style="list-style-type: none"> <li>• Results are not reproducible between two pieces of equipment</li> <li>• Results are not repeatable – the same device may not get the same data twice</li> <li>• Results are speed dependent</li> <li>• Results cannot be used to identify locations of localized roughness</li> </ul>
Inertial Profilers	<ul style="list-style-type: none"> <li>• More accurate measurement of features relevant to ride quality</li> <li>• May be operated at highway speeds</li> <li>• Measurements are repeatable and reproducible</li> </ul>	<ul style="list-style-type: none"> <li>• Operating characteristics are not necessarily easily understood</li> <li>• Maintenance and repair must be performed by a knowledgeable technician</li> <li>• Requires distance to reach operational speed for data collection and time to stop after the project</li> </ul>
Reference Device	<ul style="list-style-type: none"> <li>• Collect accurate and repeatable measurements</li> </ul>	<ul style="list-style-type: none"> <li>• Slow to operate</li> </ul>

**REFERENCES**

1. Sayers, M.W. and Karamihas, S.M., *The Little Book of Profiling: Basic Information about Measuring and Interpreting Road Profiles*, University of Michigan Transportation Research Institute, Ann Arbor, Michigan, 1998.
2. [www.amesengineering.com](http://www.amesengineering.com) accessed July 9, 2010.
3. Scofield, L., “Profilograph Limitations, Correlations and Calibration Criteria for Effective Performance Based Specifications,” NCHRP Project 20-57, Task 53, National Cooperative Highway Research Program, Transportation Research Board, Washington, D.C., 1992.
4. Kulakowski, B.T. and J.C. Wambold, “Development of Procedures for the Calibration of Profilographs,” *Report FHWA-RD-89-110*, Pennsylvania Transportation Institute, State College, PA, 1989.
5. *Annual Book of ASTM Standards, Volume 4.03, Road and Paving Materials*, American Society of Testing and Materials, Philadelphia, PA, 1999.
6. Spangler, E. B. and Kelley, W. J., “GMR Road Profilometer—A Method for Measuring Road Profile,” *Research Publication GMR-452*, General Motor Research Laboratory, Warren, Michigan, 1964.
7. Karamihas, S.M., *Critical Profiler Accuracy Requirements*, University of Michigan Transportation Research Institute, Ann Arbor, Michigan, August 2005.
8. Smooth Road, [www.smoothroad.com](http://www.smoothroad.com) accessed July 9, 2010.
9. Australian Road Research Board, [www.arrb.com](http://www.arrb.com) accessed July 9, 2010.
10. International Cybernetics Corporation, [www.internationalcybernetics.com](http://www.internationalcybernetics.com) accessed July 9, 2010.