A STUDY OF PAVEMENT SERVICEABILITY
WITH THE IDAHO BUMPOMETER
IDH-RP009(1)

Research Division Idaho Department of Highways

SYNOPSIS

The Construction Division has reported undesirable roughness in the construction of asphalt pavements for the past several years.

This roughness in many instances appears to be the result of a vibration or harmonic roughness of the pavement surface.

A Chevrolet Sedan with a recorder installed in the trunk to continually record on tape the space between the axle and frame of the vehicle was constructed to determine if this roughness could be measured and its cause determined. The device will record apparent roughness at speeds of 20 to perhaps 70 mph on smooth pavements and from NO to 30 mph on very rough pavements.

The device does not appear to measure bumps of less than 1/16" amplitude and 4 to 5 feet spacing. However, bumps with spacings of 5 to 7 feet are sometimes discernible. Irregularities in profile are readily evident at higher speeds.

General rideability of a pavement seems to be best determined at a speed of 50 mph unless an exceptionally rough pavement is being tested when speeds of about 30 are apparently more indicative.

Roughness measurements are made by the method used for the California Profilograph, i.e., the sum of the vertical displacements of all recorded bumps per mile. Measurements are made in increments of about 500 feet and the unit figure per mile computed.

The dervice appears to be a worthwhile instrument for use by construction personnel to determine the relative smoothness of their pavements. The past three years Interstate and other projects gave roughness indices as follows for about 100 miles of road.

Less than 15 - 33%

15 - 25 - 33%

25 - 40 - 23%

Over 40 - 10%

Older projects gave indices from 30 to 165 as averages. Surface treatments tested were about 60. Some projects even twenty years of age gave indices of about 50 and others were well over 100. Results of tests made this past season are included as well as samples of the tape for various roadway conditions.

It is recommended the device be used by the Construction Division to aid them in determining roughness during construction of the pavement while corrections are yet possible. It is also recommended that the device be checked to determine if it has any merit in checking the condition of the highway when making sufficiency ratings. This can be done on a sampling basis.

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Introduction

Pavement performance is of the utmost importance to the Department of Highways. One measure of pavement performance is the smoothness or rideability of the pavement throughout its life. Changes in smoothness of the pavement surface reflect changes occurring within the pavement structure somewhere from the wearing course down into the basement soil. The smoothness rating can only have merit if compared with a standard or an original, "As Constructed" rating. The Construction Engineer wishes to know if his pavements are being constructed to an acceptable degree of smoothness. The Maintenance Engineer wishes to know how the pavement is changing in rideability or smoothness during the lifetime of the pavement. The Design Engineer, Naterials Engineer and others wish to know the expected service life of the pavement structure with regard to an acceptable smoothness rating.

Pavement serviceability was one criteria that was thoroughly investigated at the AASHO Road Test in Ottawa, Illinois.

Using this information the AASHO Committee on Design has proposed methods using the serviceability concept for design. Smoothness of the pavement and changes in smoothness are a part of these measurements for serviceability.

During the past three seasons the Construction Division has complained that the pavements being constructed were sometimes subject to a roughness which gives an unsatisfactory ride and they believe it may cause a loss of serviceability to the pavement. Considerable discussion and disagreement as to the relative roughness of these pavements has resulted from different individuals evaluating the pavement by means of driving an automobile over the pavement.

It has become increasingly evident that the 10' straight edge with a 1/8" in 10' tolerance is obsolete for use in obtaining the quality of pavement surface desired. The need for the means to measure and control pavement smoothness during construction operations is more critical than ever due to the faster highway speeds being constructed into our roads today. Profilometers and Roughometers give a good measure of rideability of the pavement after it is built, but this is too late to make any change during construction of workmanship or construction practices to obtain the desired ride.

A simple device is needed which will measure the smoothness of the pavement and which can be used during construction.

This device should be capable of measuring repetitive minor deviations from the true plane occurring at distances of less than 10'
and often 3'- 4', as well as those that are occurring at distances

of 15' to perhaps 50'. The device should be capable of picking up harmonic vibrations which are evident at some vehicle speeds.

During 1960, the Department of Highways borrowed the Oregon State Highway Department's Bureau of Public Roads' Roughometer and tested numerous highways under construction at that time as well as older roads in service. This device, when operated at a speed of about 15 mph gave a roughness index in inches per mile. It was the opinion of Engineers within the Department, however, that the index did not necessarily correlate with their opinion of the rideability of the road surfaces. During the summer of 1961, the Department borrowed the California Profilograph and again tested several of the pavements that had previously been tested with the Bureau of Public Roads' Roughometer as well as other pavements under construction at that time. The California device is hand-pushed and can be operated at a speed of about 2 - 3 miles per hour. It traces on a paper the profile of the road as taken from a 25' straight edge. This device appeared to give a better correlation with the rideability of the road surface than did the Roughometer, however, its slow speed of operation was undesirable and if it is to be operated on a Statewide basis, it would in all probability necessitate the construction of several devices.

One major advantage of the California Profilograph is the pencil trace of the roughness of the road surface. This trace permits a review of the pavement profile to determine exactly where the roughness occurred. In this way it is possible to determine if roughness occurs at construction joints or if it is a repetitive roughness due to some harmonic motion occurring in the paving operation.

A check on costs for these devices as well as the Chloe Profilometer which was designed from the AASHO Road Test gave cost figures of about \$3,000.00 for the California Profilograph and about \$6,000.00 for the Chloe Profilometer with the Bureau of Public Roads' Roughometer costing around \$9,000.00 if equipped electronically to record the pavement roughness.

Development of Idaho Bumpometer

Due to the fact that the roughness problem continued to plague Engineers in the Department, and it was believed necessary to do something quickly, it was decided to modify a Chevrolet Sedan to form a Roughometer which would record an index of pavement roughness on tape. The sedan was modified to measure the space between the rear axle and the frame continuously and record this distance on tape for both sides of the vehicle. It was hoped this device would permit measurement of roughness at any speed and thereby permit measurements at a speed where harmonic roughness appeared to be most pronounced. This device, as constructed, including new tires, new shock absorbers, and the turning of all tires round, and balancing them dynamically, cost \$510.00.

The initial machine was constructed with electric drive for the tape. This, however, caused some difficulty since the operator of the vehicle had to maintain a constant speed which is very difficult. Also, should it be desired to make tests at different speeds, the horizontal scale for distance traveled varied and any variation in speed during a test would prevent direct measurement for location of any indicated roughness. For this reason, it was decided that it would be necessary to drive the tape

by direct drive. This was accomplished by means of an odometer cable connection to the transmission. An odometer was provided to give better accuracy for speed and mileage traveled.

The Idaho Bumpometer, if the word may be used, permits roughness to be measured at speeds varying from approximately 20 mph to over 70 mph if desired. The tape will record at the same horizontal scale for any speed. The space between axle and frame is recorded in a direct ratio of 1" to 1". The device permits selection of speed for test, i.e., slow speeds on rough roads, faster speeds on smooth roads and when repetitive vibration occurs it permits more careful examination of the cause of the surface roughness, by testing at several different speeds. High speeds of the vehicle permit evaluation of the profile of the highway or both longitudinally and transversely. By testing and evaluating the pavement in question at several different speeds, one can sometimes find what appears to be a sympathetic or harmonic vibration in the road surface. The pen trace indicates where the problem exists and may reveal the cause, i.e., poor construction joints, harmonic vibration or profile variations. Since the equipment has been mounted in an automobile it permits the transfer of the vehicle between Districts and Projects rather quickly. The use of the machine to obtain roughness readings of the prime coat before paving, during construction of pavement courses as well as of the final finished course, determines whether or not roughness has been carried through from the base or if it is caused by paving construction practices.

Tests have indicated that the device repeats the trace satisfactorily at any single speed for distances of at least a mile. The perfectness of repetition of the trace is dependent upon the transverse position of the vehicle with regard to the highway and should the vehicle drive in a different transverse position, the trace naturally is somewhat different. Attached are several one—half reductions of paper traces of roughness measurements.

This bumpometer appears to be useful in evaluating pavement performance early during the construction period. It can be
operated on the pavement as soon as the pavement has cooled sufficiently to carry vehicular traffic. Should roughness be indicated, it may then aid in determining the cause of the roughness and
by adjustments to the paver or in construction procedures, determine
if the pavement smoothness can be improved. Another advantage, of
course, is the extremely low cost of the device.

Disadvantages of the machine include the fact that it is different than any other known roughometer or profilometer. Direct comparisons between the rating obtained from this device and other devices is a moot question. Also, any change in the suspension of the car due to changes in shock absorbers or to tires, tire wear, etc., may change the results. Nylon tires could not be used and it was necessary to change to a rayon tire in order to avoid a repetitive bump from the tire.

Other difficulties will occur when this particular vehicle is retired from service, in perhaps five years. Another automobile would no doubt give entirely different results than the existing

car. Also as the shock absorbers become worn, it will mean that roughness indices may be changing. The device, as constructed, cannot be considered of sufficient accuracy or of a type suitable for use in specifications. It will indicate a relative roughness, but not to the accuracy desired for this purpose.

The tape requires making direct measurements from the tape manually and in this regard is similar to the California Profilograph. The method of measuring is somewhat tedious and is subject to human error. The device has not been able to measure vibrations of small amplitude or closely spaced, that is, in the order of vibrations 4^{\ddagger} - 5^{\ddagger} between crests and perhaps $1/16^{\ddagger}$ or less total displacement.

Results of Operations with the Bumpometer During 1963 Season

Several projects were rated during construction in the 1963 construction season. Ratings were also made of nearly all of the projects constructed during the 1960-1961-1962 seasons and several older projects. Projects constructed during the last three years involved perhaps 100 miles or more of paving. Ratings were made on a sample basis for all of these roads. For projects constructed since 1960, it was determined that approximately 33% gave an index value of less than 15; 33% gave an index value of between 16 - 25 and 23% between 26 - 40. Only 10% gave index values in excess of 40 if the pavement consisted of a plantmix.

In comparison, Bituminous Surface Treatments gave index values of about 60 as compared to a very rough new plantmix with a reading ranging between 60 - 90. Pavements over 5 years in age rate

from a low of about 30 to approximately 165 for one about 30 years old. It was determined that roughness from the prime coat or first course does not reflect in the top course if construction is carefully controlled. In those instances where profiling of the base course has not been carefully controlled, profile irregularities do reflect through for the longer waves, i.e., 40 feet or more.

It has been possible to confirm that there are vibrations in some pavements with a 5° - 7° distance between crests at lower speeds of about 20 mph. These, however, cannot be too accurately measured, although the shape of the trace, that is, a square top and a square trough, is an indication.

The use of this device has increased the desire of some construction inspectors and contractor's personnel to get the best job possible. Just visual examination of the recorded roughness and comparison with other projects has given them an incentive to do better.

Future use of the device is recommended as follows:

The Construction Division use the Roughometer-Bumpometer to measure pavement roughnesses the first day or two of paving on their projects. This would indicate the natural profiling and performance of the individual project.

Should the rating be other than desired, an endeavor can be made to find the cause of the roughness and eliminate it. The machine would be able to make direct comparisons of the pavement section that is unsatisfactory and sections that are considered to be improved by changes in paving operations.

The device is also capable of determining profile smoothness of a highway should bluetopping be inaccurate or the Contractor's operations poor. The bumpometer should indicate the location and help determine the cause. The bumpometer ratings can be used as a means of competing for the best pavement within the District or within the State each season. If ratings are published with an award of a certificate or plaque for the best pavement, considerable interest in performance may be developed. Another possible use of the device would be to rate pavements for serviceability throughout the State. At the present time, the sufficiency ratings are determined by the roughness or rideability of the road surface as well as structural properties, on the basis of judgment alone. It may be possible to use the Roughometer as a means of determining the relative rating of the pavement. A trial chart has been made assuming that the rating of about 15 roughness index is the equivalent of 4.5 on the present serviceability scale of the AASHO Road Test and that a roughness index of 200 is the equivalent of a 1.5 present serviceability index. After placing the bumpometer roughness index values on a straight line between these two points and noting the pavement age, it indicates that the roughness index and serviceability index may have a general relationship that might be usable,

It is proposed that the device be turned over to the Construction Division or the Materials Laboratory for use on construction projects in future years and if desired that the Planning Survey may also use this device for assisting them with sufficiency ratings for pavement surfaces.

ROUGHNESS INDEX VALUES

Pavements Constructed Since 1960

Route	Section	M.P M.P.	Age In Years	Ave. All Readings Roughness Index			
I-15W I-15W I-15 I-15 I-15	American Falls West American Falls ByPass Pocatello Creek - Chubbuck Chubbuck Sep Fort Hall Fort Hall - Blackfoot	26.7 - 26.8 70.0 - 71.0 71.0 - 78.0	3 0 1 2 2	33 23 82 30 32			
I-15 I-15 I-15 I-15 I-15	Blackfoot River North Lava Section LavasNorth to Bonn. County I Bonn. County Line - Idaho Fa Hamer - Dubois		1 1 1 1	45 42 10 9 21			
I-15W US 20-26 SH 25	Raft River - Salt Lake Interd Gooding - Bliss Barrymore East	hange	2 0 1	17 25 40			
Pavements Constructed Before 1960							
US 191 US 191 US 91 I-15 SH 25 SH 25	Beach's Corner - Ucon (Mtce. & Resurf 1962) Bonn Jefferson Co. Line - North So. 1daho Falls Conn. I-15 - No. City Limits Hamer - Roberts Wendell - Jerome (BST) Jerome East - U.S. 93 (Mtce. Reconst 1950)			55 46 110 19 60 165			
SH 14 SH 16 SH 15 SH 15 SH 15 SH 15	Barbie's Cafe East Jct. 44 - North 4 Miles Spring Valley Ferncroft (Rmx) Jct. SH 52 - North Gardena - Banks	9.0 - 9.5 41.6 - 42.0 20.7 - 21.0 24.1 - 24.4	21 4 28 18 24 24	50 35 90 85 78 80			
SH 15 SH 15 SH 15 SH 15 SH 15 SH 15	Gardena - Banks Gardena - Banks Ferncroft (Rmx) Ferncroft North (CTB) Ferncroft North (CTB) Ferncroft North (CTB)	35.0 - 35.3 39.3 - 39.5 41.6 - 41.9 46.2 - 46.3 51.1 - 51.4 52.0 - 52.2	22 22 3 8 8	70 54 51 72 65 73			

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Route	Section	M.P M.P.	Age In Years	Ave. All Readings Roughness Index
SH 15 SH 15 SH 15 SH 15 SH 15 SH 15	Cougar Inn North (Mtce. Reconst 1955) Round Valley (CTB) Round Valley (CTB) Round Valley (CTB) South Cascade South Cascade	53.6 - 53.9 58.0 - 58.3 59.0 - 59.4 61.5 - 62.0 64.0 - 64.5 67.0 - 67.2	8 (29) 7 7 7 7 7	55 68 85 62 45 51
SH 15 SH 15 SH 15 SH 15 SH 15 SH 15	South Cascade North Cascade North Cascade North Cascade North Cascade North Cascade North Cascade	68.4 - 68.7 72.0 - 72.2 73.5 - 74.0 78.0 - 78.3 81.1 - 81.3 83.0 - 83.2	7 15 15 11 11	30 51 61 47 71 51

Plantmix unless otherwise noted.

Rmx - Roadmix

BST - Bituminous Surface Treatment CTB - Cement Treated Base







