A STANDARD FOR ROAD ROUGHNESS MEASUREMENT

IOWA STATE HIGHWAY COMMISSION

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FOR

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Materials Department
Iowa State Highway Commission

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GENERAL

The problem of specifying what shall be the maximum roughness to be permitted in road construction is one affected not only by what is desirable and reasonable but also by what is possible in the present stage of the art of construction. What has actually been done in construction is shown very well by the wide range of roughness values and the averages obtained in roughness measurement of all kinds of roads during the past three years.

The measurements are in turn affected by the problem of maintaining the reliability and consistency of the roughometer, so that the question may arise as to whether the measurements are sufficiently reliable for use in determining the extent of fulfillment of specifications.

A further question may be asked by some as to whether the roughometer actually measures the roughness of the roads. Confidence in the nature of the figures obtained is necessary to satisfactory specification.

The specification of road roughness may also bring about a need for very quick measurement of each project in the early stages of construction in order to satisfy the contractors and engineers.

Thus, it appears that any specification for road roughness should probably be based upon (1) the best or the average which can be accomplished in actual practice, and supported by (2) reliable measurement, (3) valid measurement, and (4) quick and early measurement.

RELIABILITY OF THE ROUGHOMETER

Whenever immediate successive tests of a road are made the averages for each run are ordinarily within a fraction of 1% of each other. If the road is measured in quarter-mile sections, the roughness for each section will not always be identical in successive tests, probably because no driver can follow exactly the same course each time, but the averages for all the sections will be almost identical.

When successive tests are spaced a week or a month apart, or even between noon and evening on one day, the results will not be as close, but with proper care the averages will ordinarily be within probably 2% or 3% of each other, depending upon conditions.

Maintainence of a certain standard from year to year is largely a matter of how much time, effort, and money is spent in servicing the different parts of the roughometer.

The roughometer consists essentially of a standardized system of springs, damping devices, and load with a method of detecting the amount of variation as it travels over the roads. It is an anilog computer, and the variations in the measurements can be affected by changes in (1) the system itself or (2) in the detecting system.

Erratic changes in the readings can therefore be due to any of the following:

1. Changes in the load-deflection characteristics of the springs. For greatest precision the springs should be removed once a year for testing. Actually, with the system of transport which we have the springs are in use only during actual measurements. Thus, the springs are normally in use only a fraction of each day, thereby prolonging their life and maintaining uniformity.
2. The sealed bearings of the spring shackles may become loose but can be replaced for about $25 and one-day's work.
3. The action of the damping devices, which can be affected by the level of the oil, the depth of adjustment of the pistons, or the condition of the ball or universal joints connecting the damping devices to the machine. Due to the difficulty of keeping the original ball joints in adjustment they have been replaced with needle-bearing universal joints requiring no adjustment. Incidentally, the amount of damping can be changed to compensate for any change in the load-deflection characteristics of the springs by changing the size of the orifices in the pistons or baffle plates of the damping devices. This also furnishes a means of calibrating the roughometer to maintain a certain standard.
4. The roundness of the tire must be maintained within about 0.020" on the radius by occasional grinding of the rubber.

5. The mechanical integrator, which is part of the detection system, operates very well when it is new or in good condition. When it becomes worn after considerable service it will begin to slip, thereby giving readings that are too low. One improvement which was made at the beginning of the present season is the installation of a microswitch requiring only 10% as much mechanical power to operate as the original switch; it is expected that this will make the integrator wear much longer without servicing than before. Incidentally a digital integrator now under development is expected to give virtually 100% indication without change at any time. Thus, one important source of possible erratic variation may be eliminated.

In any event, each of the above five sources of erratic behavior can be controlled when understood. With the proper servicing, the roughometer can be a very dependable instrument, entirely suitable to testing for specification fulfillment.

VALIDITY OF THE ROUGHOMETER

There are several points which confirm the validity of the roughometer. The first of these is the graphic record which the roughometer makes. Examination of the record shows that, while it is not a true profile of the road, it certainly gives a movement that is definitely related to the profile in a direct variation. Further evidence could be produced, time and effort permitting, by a detailed comparison of the graphic record with a surveyed profile.

The validity is further confirmed by the fact that the roughometer typically detects changes in construction procedures at various points on the roads quite independently.

As for what the roughometer measures, many have stated without supporting evidence that it measures only "surface texture" or just quick rises in the surface known as "bumps". That it measures considerably more is shown by the fact that in many cases where a high roughness reading is obtained with the roughometer the inspectors there had been extremely conscientious in using the ten-foot surface checker. These inspectors typically state that the checker had revealed almost no rises higher than 1/8" within any ten-foot length on any part of the road.

The meaning of this is that the roughometer has responded to rises in the surface over a length of more than ten feet. The roughometer frame is heavy and can not rise quickly, on a relative inertia basis, with the longer variations in the road. The roughometer registers these rises fully or partially up to a limiting length. This is also shown on the graphic records.

EARLY MEASUREMENT

Effort has already been made toward the measurement of the construction in the early stages. During both last year and this year many projects have been measured as soon as the first two or three miles were completed.

However, the quickest measurement of all will be obtained by providing each resident engineer with one or more small manual roughometers so that one can be easily available for each job at all times.

There is every reason to believe that this type of roughometer will give a reliable reading suitable for testing the early construction. It can be made to give a graphic record and a definite average index in inches per mile on the same standard scale as with the regular roughometer for any length desired. It is ideal for early testing inasmuch as it could be used on portland cement concrete within 48 hours after pouring and on asphalt immediately following the rolling operations. The machine is light, and the cost is low.

STANDARDS FOR ROUGHNESS

Measurements during the past three years have been made on all kinds of roads in Iowa. These have shown a range from 50 to 150 inches per mile and have permitted the concluding of averages for various kinds of roads.

From the ranges and the averages it has been possible to establish some informal standards. For example, it has been desired to have all asphalt roads measure less than about 60 to 65 inches per mile and all portland cement roads measure less than about 90 or 100 inches per mile. On this basis the contractors have been considered commendable when meeting these figures.

While the contractors, engineers, and inspectors have all been extremely cooperative in trying to meet the standards the results have been variable. In many cases the standards were exceeded, but in other cases the contractor often claimed that he had legitimate obstacles of one kind or another that kept his crew from doing the best work.

SPECIFICATIONS FOR ROUGHNESS

Specifications as to what amount of roughness shall be permitted in the construction of the roads, with penalties for failure of fulfillment, would best take into account the many obstacles that might be encountered on any particular road. That is, there is no more reason to expect, for example, the same construction results on two different ten-mile projects than to expect their contract price to be equal, unless the conditions are identical. Each contractor determines his costs through a process of estimating which takes into account the many different factors and conditions for any particular project. These are factors which affect his costs, but in exactly the same way there are factors which will effect the quality of the construction and therefore the roughness. For example, two ten-mile projects may be of equal length, but there the similarity ends. One may be perfectly straight and on flat terrain; the other may wind its way through and over hills from one end to the other. Now, it is apparent that one of these roads will measure rougher than the other when completed, and no one will have any doubt as to which it will be.

The point here is that it is not possible to tell how good a job any particular contractor did on any particular project unless some consideration is given to the conditions with which he had to work. If a contractor ends up with an average of 100 inches per mile on one job he may have done excellent work if there were many natural obstacles. On the other hand, if he makes 80 inches per mile on another job he may have done very poorly.

THE STANDARD ROUGHNESS

A standard for each project, in contrast to any single standard for all roads, can be determined by taking into account the lengths and sizes of curves and hills relative to the straight, flat lengths in each project. This can be according to a simple schedule of allowances, and each Resident Engineer or County Engineer could therefore determine the standard roughness for each of his projects in a matter of minutes by examining the plans. The schedule of allowances could be originated by measuring a number of hills and curves to determine their ranges and averages to find out what is good and acceptable work for them. Other allowances, such as for season of the year, rain, city work, hand work, etc., could be made if desired. Also, as the art of road construction improves the allowances can be changed.

EXAMPLE OF DETERMINATION OF STANDARD ROUGHNESS

The standard roughness can be determined for a non-existant example if we were to accept the following schedule for, say, portland cement concrete roads:

Flat terrain	85 inches per mile
Slopes 0 to 2.9%	90 " " "
" 3 to 6%	95 " " "
Curves 2° to 10°	92 " " "
Curves & slopes 0 - 2.9%	95 " " "
" " " 3 - 6%	100 " " "

The plans for Project FIH-22(3) in Hoot Hoot County, 7.340 miles, have shown the following compositions, for which the following allowances can be made:

	Miles	Allowance	Product
Flat paving	2.03	85	172.55
Slopes 0 to 2.9%	1.89	90	170.10
" 3 to 6%	2.35	95	223.25
Curves 2° to 10°	.78	92	71.76
Curves & slopes 3 - 6%	.29	100	29.00
	7.34		666.66

$$\text{Standard Roughness} = \frac{666.66}{7.34} = 91.0 \text{ inches per mile}$$

In other words, the contractor on this project will have done good work if his road averages 91 inches per mile or below, but it will be poor work above that figure. If the average is above 91 inches per mile the contractor can not claim that he was handicapped by the irregular terrain, for this has already been taken into account.

RECOMMENDATIONS

It is recommended that the system of roughness standards for variable terrain be given a trial. Standards for curves, hills, and level paving could be determined without delay or interruption of present measuring. The standard for each project could be shown on each roughness report so that the measured roughness could be evaluated by comparison. After a period of time, consideration could be given to the desirability of establishing actual specifications incorporating the variable standards.