both city and country. Professor Owen also called for an international effort of cooperation as a possible way to create a global network of organizations that would focus responsibility for extending and improving the world's transport capabilities. He pointed out that this kind of road means a way to provide benefits for a better education, health, housing, labor, life. He ended by calling to our attention the disease of the mother world: an imbalance in terms of wealth, power, culture, attraction, and hope. But creating new hope for the isolated and forgotten in rural areas all over the world would be a challenging assignment entrusted to this international conference. This philosophical thought is in agreement with the Mexican position expressed by the Minister of Communications and Transport during the Ninth World Meeting of the International Road Federation held in Stockholm. There Mr. Felix stated, "If the future can, at times, be forboding it remains, undoubtedly, full of opportunity and promise." The optimistic spirit with which we all face the future, and the efforts made to shape it, assure us of such fine results. From this framework of hopes and fears we chose the right perspective for our theme. Low volume roads will possess strategic importance in the future. As a consequence, developing nations must take the lead in conceiving and applying those instruments appropriate to their own reality and needs as well as to fulfilling their own requirements.

Finally, three basic elements most certainly shape the framework of our actions to modify and improve human living conditions: liberty, justice, and respect for others. There pertinence and exercise characterize the true sense of progress. Their is no growth without freedom; no humanization without justice; no fraternity without respect. Together they comprise the highest goal of humanity: peace, with freedom, justice, and respect for others. Roads in the future should be roads to harmony. Indeed roads to peace. I do thank you very much.

*CALIBRATING AND STANDARDIZING ROAD ROUGNESS MEASUREMENTS MADE WITH RESPONSE TYPE INSTRUMENTS

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The UK Transport and Road Research Laboratory road roughness calibrating and standardizing beam was developed to provide a calibrating capability for response type road roughness measuring systems (RTRRMS). This development was based on past TRRL experience in the field of roughness measurement in developing countries. The concept of "ride comfort" as adopted in the developed world as a direct measure of the unevenness of a road surface as perceived by the road user was not applicable to the road conditions met in developing countries. In such countries ride comfort and level of service do not have the same importance as in the developed countries, as the greater need is for more roads to provide the basic means of transportation and communication which are operable through the year. Because of shortage of resources for building and maintaining all weather roads, a lower serviceability rating is tolerated by the user. However, the lower quality of the road surface manifests itself in higher vehicle operating costs through greater wear and tear of the mechanical components of the vehicles. Comfort to the vehicle rather than to the rider takes on a greater importance. There is very little evidence to suggest what measure of roughness is most appropriate to relate to the effects of "vehicle comfort." Measures in use have been generally selected on the basis of convenience, simplicity and past experience of investigators, and the most popular measure has been the output of RTRRM's which measure the displacement of the axle relative to the body of the vehicle induced by the roughness of the road it is traversing. The magnitude of these response type measurements varies according to the suspension characteristics of the vehicle used and also with time due to a change in these characteristics through usage. Such measurements are acceptable only if they could be calibrated to a given standard enabling measurements with different vehicles at different periods in time and space to be related to that standard. In spite of these serious drawbacks RTRRMS enjoy a great popularity with practicing engineers and researchers and are in widespread use throughout the world. It has been accepted that this method of measurement will prevail for some years to come and therefore the necessity to provide a viable and readily available calibration system is urgent.

An alternative to the RTRRMS measure of roughness is a profilometry based measure of roughness, and is an obvious candidate for providing a calibration reference for calibrating measurements of RTRRMS. A major requirement of any profilometer based system is that it should have the ability to accurately measure the longitudinal profiles of test sections of road, and also be able to be calibrated independently of other measuring systems. It also requires a method of processing the profile data to yield a single roughness statistic to describe the profile for subsequent correlation with RTRRMS measures.

A successful calibration system based on profilometry for use in developing countries needs to satisfy three important conditions. The calibration system/instrument must be easily transportable particularly from country to country. Appraisal studies undertaken by consultants for developing countries are usually of short duration. This means that unless the instruments can be easily transported to the country and the site, they will not be used by practicing engineers and consultants, however good they may be. Secondly the instrument must be reasonably simple to operate, and data management, analysis and interpretation available immediately after measurement. Manual data processing cannot be undertaken by field staff, therefore the generation of profiles alone in the field and the creation of a large data bank without the capability of instant computation, analysis and presentation of calibrated results is not acceptable as a viable method of calibrating roughness measurements. The last and equally important consideration is the cost of such an instrument. The instruments available at present are highly sophisticated, and very expensive to acquire, which effectively puts them out of the reach of practitioner.

These three conditions guided the TRRL's approach to the computation of a suitable numeric for correlation with RTRRMS measurements and the subsequent development of the beam as a viable roughness calibrating and standardizing instrument, independent of external computational requirements.

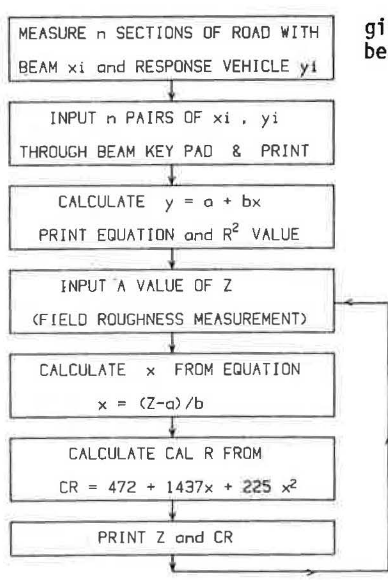
The Calibrating and Standarizing Process

Calibration of response type instruments is achieved through the computation of the root mean square of deviation (RMSD) of the road profile of the test section for base lengths of 1.8 meters using profile intervals of 300 mm.

The procedure for calibration is to select a number of sections of road approximately 200-300 meters in length, covering a range of roughness levels and containing as many road surface types as possible (a minimum of 10 sections is recommended). These sections are then profiled on the nearside wheelpath with the TRRL beam and the Root Mean Square of Deviation (RMSD) statistic computed for each section. The sections are also measured with the response type vehicle mounted roughness measuring instrument at a speed of 32 km/h. A linear regression of the form $y = a+bx$ is calculated using RMSD as the independent variable (x) and the RTRRMS measures as the dependent variable (y). This equation now constitutes the calibration equation for that particular RTRRMS.

Calibrated roughness measurements made with different instruments need to be standardized on a universally acceptable scale to achieve comparability between instruments and also transferability between countries. The standardization recommended is based on the response characteristics of the TRRL towed 5th wheel bump integrator. A standard reference roughness equation was developed by relating the towed 5th wheel bump integrator measurements to the root mean square of deviations of the road profiles. Figure 1 illustrates the relationship and the equation is:

Figure 1. Flow Diagram of the Operation of the TRRL Roghness Calibration Beam



$$ROUGHNESS = 472 + 1437\,(RMSD_{1.8/300}) + 225\,(RMSD_{1.8/300})^2 \ .....(1)$$

The above standard reference roughness equation will remain a permanent road roughness estimator through time and space.

Routine field roughness measurements can now be made with the response instrument. These routine measurements need to be calibrated and standardized in the following manner. Substitute each field measurement for y in the equation $y = a+bx$ and calculate x from $x = (y-a)/b$, to produce an estimate of RMSD as perceived by that particular RTRRMS. This estimated value of RMSD is then input to the standard reference roughness equation (equation (1) above), to produce a standardized roughness value. All the field measurements are standardized in this manner.

OPERATION OF THE TRRL ROUGHNESS CALIBRATION AND STANDARDIZATION BEAM

The TRRL beam has now been developed as a compact, self contained road roughness calibration and standardization system. The road profiles measured by the beam are processed automatically through its internal microprocessor and the root mean square of deviation is printed out at the end of the measurement of the test section. After measuring the required number of test sections, the operator is required to input the RMSD values for each section together with the RTRRMS measure through the built-in key-pad to compute the calibration equation. The equation is also printed together with the value of R^2. The equation is printed for the operators information only, although he does not need to use it. The R^2 value will be printed with a warning that the correlation is not satisfactory if the value falls below 0.90. After the equation has been computed and printed, the operator inputs his routine field roughness measurements in mm/km and the processor will print the calibrated standard measure of roughness which will be expressed in mm/km for a standard speed of 32 km/h.

A flow-chart of the operation of the beam is given in Figure 2 and an illustration of the beam is shown in Figure 3.

Figure 2. Flow Diagram of the Operation of the TRRL Roughness Calibration Beam

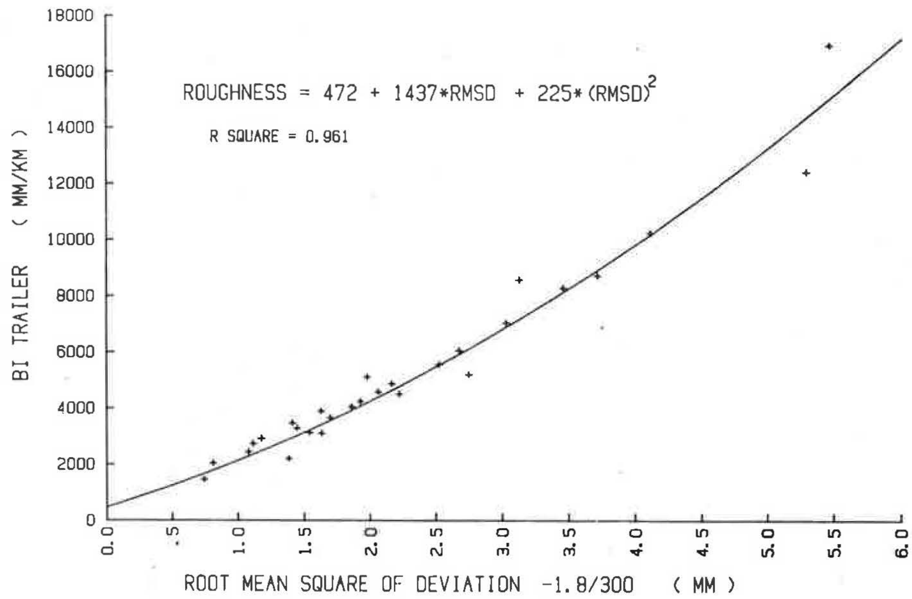
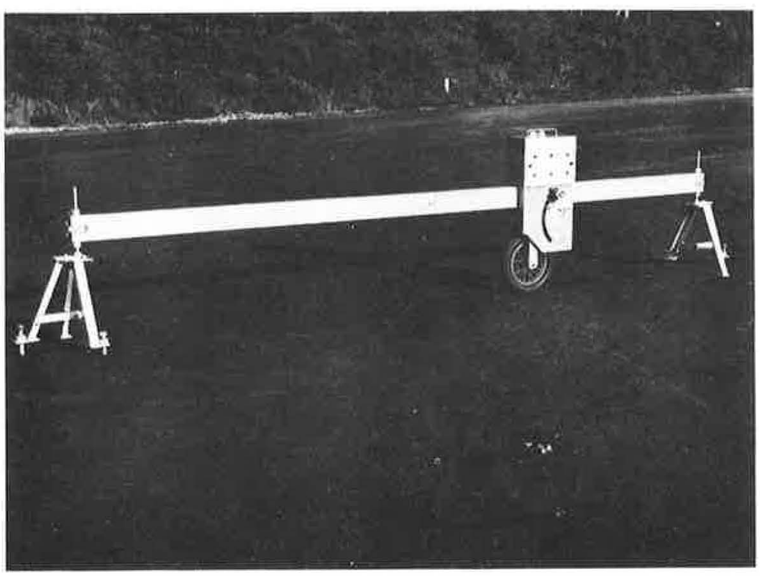


Photo 1. TRRL Roughness Calibration Beam



**This material was unavailable when TR Record 898 was printed. It is included here so that the content of Dr. Abaynayaka's conference presentation will be recorded.*