RESEARCH REPORT **RR 90/225**

DEPARTMENT OF TRANSPORT

Guidelines for enforcing rideability quality control on road contracts

31 March 1992

TITEL/TITLE: GUIDELINES FOR ENFORCING RIDEABILITY QUALITY CONTROL ON ROAD CONTRACTS			
VERSLAG NR: **REPORT NO:** RR 90/225	**ISBN:**	**DATUM:** **DATE:** 31 March 1992	**VERSLAGSTATUS:** **REPORT STATUS:** Final
NAVORSINGS NR/RESEARCH NO: RR 90/225			

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SINOPSIS:

Die reisende publiek ervaar padrygemak as die belangrikste maatstaf van plaveiselgehalte. Dit is dus noodsaaklik om oppervlakongelykhede reeds tydens die konstruksiefase uit te skakel om sodoende openbare mening aangaande padgehalte te verbeter, om die effekte van dinamiese aslaste te verminder en om voertuigloopkoste te minimiseer. Die effektiwiteit van die huidige stelsel van kwaliteitbeheer, die 3-meter reihout, word bevraagteken in hierdie verband. Hierdie verslag rapporteer opsommenderwys oor Interim Verslag IR 90/225 en oor die resultate van veldtoetse om die beste haalbare rygehaltevlakke op nuwe paaie te meet. Aanbevelings word gemaak vir die aard en grense van 'n bonus-boete skema, gebaseer op hierdie haalbare rygehaltevlakke.

SYNOPSIS:

The travelling public perceives pavement rideability as the primary measure of pavement quality. It is thus necessary to minimise surface unevenness at the construction stage in order not only to improve the public's perception of the quality of the road, but also to lessen the effects of dynamic loading on the pavement and to decrease vehicle operating costs. The present system of quality control of unevenness, the three metre rolling straight-edge, has been questioned as to its effectiveness in this regard. This report summarises the results of Interim Report IR 90/225 and reports on the results of field tests conducted to establish the achievable riding quality levels on new roads. Recommendations for the properties and limits of a bonus penalty scheme based on these achievable riding quality levels are put forward.

TREFWOORDE:
KEYWORDS: Riding quality, surface tolerance, bonus penalty scheme, construction tolerance

VERSLAGKOSTE:
REPORT COST:

DISCLAIMER

The views and opinions in this report are those of the author and do not represent Department of Transport Policy.

TABLE OF CONTENTS

LIST OF TABLES

1. INTRODUCTION

The travelling public perceives pavement rideability (the severity of vibrations experienced by vehicle occupants) as the primary measure of pavement quality. While characteristics of the vehicle play a part in the overall perception, deviations in the road surface levels from a perfect plane are the prime source of the vibrations felt. It is thus necessary to minimise the surface unevenness at the construction stage in order to improve the public's perceptions of the quality of the newly constructed road but also to lessen the effects of dynamic loading from excitations created in suspension systems and to minimise vehicle operating costs.

The present system of quality control on surface evenness used in South Africa has been questioned as to its effectiveness. Roads are being constructed to meet the specification but are apparently of measurable poor riding quality. The current feeling is that the 3 m rolling straight edge is not a suitable instrument for determining the quality of the finished product.

There is no current incentive for the contractor to produce a road of a quality above the minimum necessary to meet the specification. There are an increasing number of countries that have instituted or are considering the institution of a bonus for work that exceeds the minimum specification and to attach penalties to work below the minimum specification. The results indicate a general increase in the quality of roads built under such schemes.

This report investigates the best achievable riding quality levels on new roads using the rod-and-level method as described in RDAC Interim Report 90/225 (Guidelines for enforcing rideability quality control on road contracts). Four road contracts were tested: Two concrete pavement contracts, and two asphalt paving contracts. Roughness and rideability in terms of QI and PSI were calculated using the RMSVA statistic determined from the road profiles surveyed. A proposed bonus penalty scheme based on achievable riding quality limits is proposed.

2. SUMMARY OF INTERIM REPORT

2.1 BACKGROUND

Attempts have been made to exercise control over the finished quality of a road ever since the Romans started building them. Various methods have been proposed since then. In 1909, an engineer in the United States proposed that a 10 foot (3 m) straight plank of wood should be used to determine the roughness of the road[1]. Since then the process has developed into the rolling straight edge but the principle and the base length have remained the same. The field of riding quality has developed considerably from a rough art into an exact science. Theoretical models, such as Quarter Car Simulations[2] have been developed that give consistent and repeatable results. The input for such models is an estimate of the exact road profile determined by rod-and-level survey techniques at short intervals or similar direct measurement of the road profile using an infinite reference plane. The routine measurement of riding quality is commonly done with response-type roughness meters calibrated to standard values from Quarter Car simulations.

2.2 INSTRUMENTS AVAILABLE FOR QUALITY CONTROL

The following instruments are used for quality control on road contracts:

(i) 3 metre rolling straight edge[3]

(ii) California Profilograph[4]

(iii) APL Trailer[5]

Each of the above instruments measure surface tolerance with only the APL Trailer having a direct correlation to what the road user feels. The rolling straight edge and the California Profilograph can distinguish a poor quality road from a good quality road in terms of adherence to surface tolerance but due to their short baselengths the correlation to what the road user feels is not clear.

2.3 OVERSEAS SPECIFICATIONS

Table 2.1 shows the tolerances used for testing pavements using the 3 m rolling straight edge. The maximum number of counts allowed varies with different countries, surface treatments and materials.

TABLE 2.1: SURFACE TOLERANCES USED OVERSEAS

Country	Road Layer	Specification	Other equipment used
South Africa	Wearing Course: - Concrete - Asphalt	 4 mm Freeways: 4 mm Other Roads: 6 mm	Use of the California Profilo-graph
Belgium	Wearing Course Base Course Road Base	4 mm (refusal at 7.5 mm) 7 mm 10 mm	Use of the APL Trailer for contractual acceptance (Penalty Scheme)
France	Wearing Course Road Base	3 mm 10 mm	Use of the APL Trailer
Germany	Wearing Course	4 mm (penalty if > 4 mm) 6 mm (low speed flexible pavements)	
United Kingdom	Wearing Course Base Course	Class A Max 20 values* > 4 mm and 2 values > 7 mm Class B (>50 km/h) Max 40 values > 4 mm and 4 values > 7 mm Class A Max 40 values > 4 mm and 4 values >7 mm Class B(>50 km/h) Max 60 values > 4 mm and 6 values > 7 mm refusal at any value of 10 mm * (values measured over a 300 m section)	
Norway	Wearing Course: - Asphalt - Concrete Base Course Road Base	Primary Secondary 4 mm 6 mm 4 mm* - (also less than 15 val. >3 mm per 100 m) 6 mm 8 mm 6-12 mm 8-16 mm	
Spain	Wearing Course: -Asphalt -Concrete Base Course Road Base	 5 mm 3 mm 8 mm 10 mm	In overlay and strengthening projects, bonuses of 2-3% can be granted if deviations below the straight edge are less than 3 mm
Sweden	Wearing Course Base Course Road Base	6 mm 9 mm 12 mm **Using a 5 m straight-edge**	
United States	Wearing Course	5 mm	California Profilograph

2.4 BONUS-PENALTY SCHEMES

2.4.1 The United States of America

As each state is virtually autonomous in terms of its highways and road policy, a number of different specifications exist. The AASHTO specification is used by many states and consists of two possible test methods. Method 1 specifies the use of the 10 foot straight edge to be used at locations selected by the Engineer. Method 2 specifies the use of a California type profilograph for all pavements where the design speed exceeds 40 mph.

Method 1: The variation from the testing edge of the straight edge shall not exceed 5mm or 3mm (3/16 or 1/8 of an inch) depending on the type of road.

Method 2: The maximum allowable Profile Index is 10 inches per mile. If the Profile Index on any one day's paving exceeds 15 inches per mile, the contractor is obliged to suspend paving activities and to take corrective measures as found necessary by the Engineer.

The Contractor will receive full contract price for all sections with a Profile Index of less than 10 inches per mile. If the Profile Index exceeds 10 inches per mile but does not exceed 15 inches per mile, the contractor has the option of either grinding or otherwise correcting his work or accepting a reduction in the contract price. If the profile index is less than 7 inches per mile, a bonus is paid. A maximum bonus of 5% can be awarded and a maximum penalty of 10% can be incurred.

2.4.2 Belgium

The APL trailer is specified for the testing of concrete pavements[5]. The threshold for the CP values are specified in the contract. The contractor is subject to a penalty scheme as follows:

1. On each hectometre of surfacing for which the CP value is calculated to be between 70 and 100, using a base length of 15 meter (APL 72), a penalty equalling 2% of the price of that hectometre of surfacing is deducted.

2. On each hectometre of surfacing for which the CP value calculated, (using a base length of 2.5 m, APL 25) is:

    a. between 35 and 45, a penalty of 1% of the price of that hectometre of surfacing is deducted.

    b. between 45 and 50, a penalty of 2% of the price of that hectometre of surfacing in deducted.

The two penalties are cumulative, and the entire finished road surface is checked using the APL trailer.

2.5 USE OF THE CALIFORNIA PROFILOGRAPH AS A MEANS OF TESTING PAVEMENTS FOR RIDEABILITY QUALITY CONTROL

The results of the field study as reported in Interim Report IR 90/225 showed that the California Profilograph is not entirely suitable as a testing instrument for rideability. Its frequency response and the lack of clear definition between pavements that show good riding quality, (3.5 PSI and above) make this instrument unsuitable for determining a basis for awarding bonuses and penalties. These results are corroborated by work performed by Dossey et al[6], which showed that the profilograph has an overall variability of 1.9 inches per mile (30 mm/km). The overall variability takes into account the variances of profilograph-operator interaction, repeatability of the profilograph, and operator and profilogram reader inherent variability. It is stated by the authors that for flexible pavements, "..... bonus categories would be meaningless". It therefore appears not to be in the country's interest to invest in importing or manufacturing profilographs due to these fundamental faults and variabilities. These funds could be better utilized in developing a more acceptable alternative.

The California Profilograph is subject to various design, interpretation and repeatability faults that render it unsuitable for use as a precise instrument for measuring the acceptance or failure of a road. To quote the Director, Office of Engineering and Highway Operations, Research and Development, Mr Thomas J. Pasko, Jr P.E. "..... Several Researchers have shown that none of these profilographs can produce accurate presentations of the pavement roughness profile. Amplitudes of some wavelengths in the pavement roughness spectrum are magnified while some are attenuated ..... In spite of these shortcomings, profilographs continue to be used since no inexpensive alternative is presently available.[8]" An expensive and more accurate alternative should be devised that will measure the true road roughness profile.

South Africa has only one profilograph at present. The proposal put forward by VKE[7] on the use of the Profilograph for Surface Test Specification shows that inconsistent results obtained for smooth concrete roads where a large scatter was observed around the smoother end of the scale, thus enabling a pavement of 3.0 PSI to achieve a higher bonus than one of 3.5 PSI.

2.6 CONCLUSIONS

In Interim Report IR 90/225, the 3 m rolling straight edge has been shown not to correlate well with what the road user feels. The effect of longer wavelengths, though felt by the road user, cannot be detected with the 3 m straight-edge. The increasing cost of buying, maintaining and calibrating the instrument cannot be justified by its lack of relevancy. It is recommended that the rolling straight-edge be discontinued as the primary instrument for measuring the contractual acceptance of new roads.

International acceptance of the IRI riding quality scale for defining riding quality will result in the increased use of profile measuring systems as opposed to straight-edge type profilometers. The only stable source of reference for measuring what the road user feels is the road profile itself and it is thus recommended that the true road profile be used for quality control. A study performed by Visser et al[9] has shown that road roughness statistics such as QI can be accurately determined using rod-and-level surveys with a spacing of 500 mm between points and an accuracy of 1 mm.

3. FIELD TESTING

3.1 INTRODUCTION

The purpose of the field investigation was to apply the method of testing roads as recommended in the Interim Report IR 90/225 and to determine the achievable standard of newly constructed roads. Four road contracts were investigated. Five 100m sections were randomly selected over each contract and levels taken of the inner wheel path at a spacing of 500mm. A precise automatic level and Invar staff were used. The reduced levels were analyzed by computer to produce the RMSVA roughness statistic, which was then converted to QI and PSI.

3.2 ACHIEVABLE RIDING QUALITY LEVELS

Analysis of the test results made it possible to establish the riding quality levels that are presently being achieved in the field in order to determine a possible base line for a bonus-penalty scheme. The four contracts investigated had totally different working conditions, pavement types and construction methods.

3.3 CONTRACT 1 - N2 (TONGAAT TO BALLITO)

The contract was a two lane dual carriage way freeway. The pavement was a dowelled jointed concrete pavement. It was a new construction in an rural area.

TABLE 3.1: RESULTS OF CONTRACT 1

Section No.	QI	PSI
1	21.0	3.56
2	23.0	3.44
3	16.6	3.85
4	22.7	3.46
5	30.5	3.01
Average	22.8	3.46

3.4 CONTRACT 2 - N2 (UMDLOTI TO TONGAAT)

The contract was a two lane dual carriage way freeway. The pavement was a plain jointed concrete pavement. It was also a new construction in a rural area.

TABLE 3.2: RESULTS FROM CONTRACT 2

Section No.	QI	PSI
1	24.0	3.38
2	14.1	4.02
3	16.5	3.86
4	20.3	3.60
5	26.7	3.22
Average	20.3	3.62

3.5 CONTRACT 3 - R103 (UITENHAGE TO PORT ELIZABETH)

The contract was a rehabilitation project on an existing road, a two lane dual carriageway arterial. The existing asphalt premix was milled out and replaced with a 40mm premix wearing course over the existing base. Construction took place whilst the road was under traffic. One lane of the carriageway was closed to traffic.

TABLE 3.3: RESULTS FROM THE CONTRACT 3

Section No.	QI	PSI
1	24.1	3.37
2	17.6	3.78
3	37.2	2.68
Average	26.3	3.2

Note: Only three sections were measured on this contract due to problems to accommodate traffic.

3.6 CONTRACT 4 - (MITCHELL'S PASS - CERES)

The contract was the reconstruction and widening of an existing single carriageway road (with climbing lanes). The wearing course was a 50mm asphalt premix on top of two layers of bitumen treated base. Traffic accommodation was a major aspect of the contract as the road is a major route for transportation of produce out of the Ceres Valley. Traffic was controlled using Stop/Go boards whilst one lane was paved. Steep grades and constant transition between left and right super-elevations made paving conditions difficult.

TABLE 3.4: RESULTS FROM CONTRACT 4

Section No.	QI	PSI
1	49.9	2.14
2	50.1	2.13
3	50.3	2.12
4	41.6	2.47
5	47.3	2.23
Average	47.8	2.22

3.7 SUMMARY OF THE RESULTS

TABLE 3.5: AVERAGES OF ALL CONTRACTS

Contract No.	QI	PSI
1	22.8	3.46
2	20.3	3.62
3	26.3	3.28
4	47.8	2.22
Average without Contract 4	23.1	3.45
Average	29.6	3.15

4. CONCLUSIONS AND RECOMMENDATIONS

The field study showed that a ride quality of 3.0 PSI (approximately 30 QI) is achievable by most contractors. If we exclude the results of Contract 4 - Mitchell's Pass, the results show that a ride quality of 3.4 PSI is presently achievable. In the case of Mitchell's Pass, it is clear that the conditions under which the final surface was laid played a major role in the final riding quality.

The rideability achieved over different sections of a contract may vary substantially. To survey an entire contract is costly and time consuming and thus the principles of statistical quality control may thus be implemented to good effect. In order to apply such a method, the following factors must first be determined:

- The variability in smoothness of the pavement over the whole contract length.
- The risk to the client of accepting a substandard section of pavement.
- The risk to the contractor of being penalized for an entire kilometre when only a few metres of the pavement is at fault.
- The factors that affect all of the above, such as pavement type, construction conditions and geometric design.

In order to determine these factors, a large number of contracts would have to be surveyed and a data-base established.

If the use of the California Profilograph becomes part of the specification, then the following factors must be determined for South African conditions:

- The required number of passes in the same wheelpath to ensure that a fair estimate of the Profile Index is given.
- The length and wheel arrangement that is most suitable for South African conditions.
- The limits to be used for flexible pavements for bonus-penalty schemes.

However, the use of the Profilograph is **not** recommended as the accuracy and repeatability of the instrument does not warrant the investment required.

5. PROPOSAL OF A BONUS PENALTY SCHEME

5.1 PROPOSED SCHEME

It is proposed that a quality control scheme with the following elements be considered:

(i) The measurement of the true road profile along the entire contract in the inner wheel path of each paved lane at a spacing of 500 mm. The accuracy of the measurements must be within 1 mm. The measurements must be taken prior to the opening of the road to traffic, preferably as early as possible after the paving operation.

(ii) The quarter-car model, RMSVA program or similar be used to establish an objective roughness statistic such as QI based on the measured profile.

(iii) The contract is split up into 1 km sections in each lane and the average riding quality of each section determined. The bonus or penalty is then awarded for each section.

(iv) Full acceptance of the quality between **4.0 and 3.5 PSI**. Acceptance between **3.5 and 3.0 PSI** at a reduced rate. Riding qualities of below 3.0 PSI will not be accepted. Acceptance of over 4.0 PSI at an increased (bonus) rate.

(v) The bonus and penalty rates must be determined for different types and classes of pavement and based on increases or savings in construction, maintenance costs and user costs.

(vi) Mandatory rectification of high/low points irrespective of the riding quality must be enforced. A maximum single deviation of 7 mm in 3 m over each 1 km section to be the limit.

(vii) A 200 m section of the pavement is to be measured after each day of paving and the riding quality determined. If the riding quality is below 3.0 PSI, no further work is to be continued until the faults in the paving operation are rectified.

(viii) The measurements are to be performed by the Engineer or by suitably trained personnel on his behalf. If the contractor disputes the measurements taken, then an independent surveyor is to measure the section under dispute at the contractor's expense.

6. AMENDMENTS TO THE CSRA SPECIFICATION

It is suggested that the following clauses be amended or added to the CSRA specification.

Clause 8111 (c) **Testing of riding quality on pavements**

The pavement is to be measured using rod and level or similar to obtain a true profile of the pavement at a spacing of 500 mm between points to an accuracy of 1 mm. The Quarter Car Index (QI) is to be established by means of a suitable model. In any 3 m length of pavement, the deviation of any single elevation point from the slope between the first and the last points of that length shall not exceed the specified limit.

Clause 3405 (f), Clause 4213 (a) v and Clause 7122 (f)

The pavement is to be tested and the Quarter Car Index established as specified in Clause 8111 (c). The acceptance range and the rates of bonus/penalties are to be stated in the tender documents.

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