Intech Associates
CONSULTING ENGINEERS

IN ASSOCIATION WITH

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Rural Transport Project 2

RRST GUIDELINES

RURAL ROAD PAVEMENT AND SURFACE CONDITION MONITORING

March 2007

FOREWORD

These Guidelines have been prepared as an assignment by Intech-TRL under the South East Asia Community Access Programme (SEACA0P) funded by DFID under support for the Vietnam Ministry of Transport second Rural Transport Program (RT2).

The Guidelines synthesize the knowledge and experience developed under the Rural Road Surfacing Research (RRSR); including the Rural Road Surfacing Trials (RRST) and Rural Road Gravel Assessment Programme (RRGAP), as well as from other sources.

Local and international experience and knowledge has also been compiled and contributed to develop recommendations on good practices for rural road pavement and surfacing monitoring.

As part of the short-term monitoring programme for RRST-I, Intech-TRL has already adopted or designed condition assessment forms suitable for various surfacing types and these form the basis to develop formal guidelines and approved forms.

In addition to updated versions of these forms Intech-TRL have included the following as part of the Guidelines:

- Guidance on how to use the monitoring forms
- Guidance on the use of monitoring equipment such as the DCP and MERLIN
- Specifications for equipment
- Advice on planning and undertaking monitoring surveys
- Guidance on the collation and QA of collected data
- Advice on the storage and management of the data within the RRSR database
- Advice on the interpretation of the data and its links to maintenance requirements

The Guidelines also include appropriate diagrams, photographs and examples of collected data sets.

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RURAL ROAD PAVEMENT AND SURFACE CONDITION MONITORING

TABLE OF CONTENTS

ABBREVIATIONS

ADT	Average Daily Traffic
ARRB	Australian Road Research Board
ASEAN	Association of South East Asian Nations
Bmb	Bamboo
BRC	Bamboo Reinforced Concrete
CAFEO	Conference of ASEAN Federation of Engineering Organisations
CBR	California Bearing Ratio
CSIR	Council for Scientific and Industrial Research (South Africa)
DCP	Dynamic Cone Penetrometer
DFID	Department for International Development
DST	Department of Science and Technology, Ministry of Transport
DVD	Digital Video Disk
EDCs	Economically emerging and Developing Countries
esa	equivalent standard axles
FHWA	Federal Highways Association (US)
FM	Fines Modulus
FWD	Falling Weight Deflectometer
GMSARN	Greater Mekong Subregion Academic and Research Network
HDM4	Highway Development and Management Model
HQ	Headquarters
IFG	International Focus Group
ILO	International Labour Organisation
IRI	International Roughness Index
ITST	Institute of Transport Science and Technology
Km	kilometre
LCS	Low Cost Surfacing
M	metre
MERLIN	**M**achine for **E**valuating **R**oughness using **L**ow-cost **IN**strumentation
MoT	Ministry of Transport
OM	Operations Manual
PCU	Passenger Car Unit
PDoT	Provincial Department of Transport
PIARC	World Road Association
PMU	Project Management Unit
PPC	Provincial Peoples Committee
PPMU	Provincial Project Management Unit
QA	Quality Assurance
RITST	Research Institute of Transportation Science & Technology
RRGAP	Rural Road Gravel Assessment Programme
RRSR	Rural Road Surfacing Research
RRST	Rural Road Surfacing Trials
RTU	Rural Transport Unit
RT1	Rural Transport 1st Project
RT2	Rural Transport 2nd Project
RT3	Rural Transport 3rd Project
SEACAP	South East Asia Community Access Programme
SOE	State Owned Enterprise
TG	Technical Guidelines
TRL	Transport Research Laboratory
VOCs	Vehicle Operating Costs
VPD	Vehicles per day
WAN	Wide Area Network
WLC	Whole Life Costs

1 INTRODUCTION

1.1 Background

Since 1998 DFID and World Bank have funded with the Ministry of Transport (MoT) two Rural Transport Projects (RT1 and RT2) in Vietnam and are in the process of initiating a third (RT3), In addition, since 2003 cooperation between the MoT, World Bank and DFID has resulted in the implementation of a significant Rural Road Surfacing Research (RRSR) programme. The aim of the RRSR programme is to establish a range of sustainable road surfaces that better use local resources, minimising Whole-Life-Costs and supporting the Vietnam Government's poverty alleviation and road maintenance policies.

The technical assistance work of the RRSR has been undertaken by Intech-TRL in conjunction with their local partners ITST. The various technical aspects of the RRSR are co-ordinated by a Ministry of Transport Steering Committee under the direction of the Department of Science and Technology (DST). The main element of the RRSR programme so far has been two Rural Road Surfacing Trial programmes (RRST-I and RRST-II) in which a range of alternative options have been identified, designed and incorporated into an extensive trials programme involving the construction so far of 41 trial roads in 12 provinces throughout Vietnam with varied physical characteristics.

The programme has included not only the stabilisation of local soils by lime, cement and bitumen emulsion but also more innovative options for Vietnam such as bamboo reinforced concrete, fired clay brick, concrete brick and cobble or dressed stone surfacing. An important aspect of the trials design has been the incorporation of control sections constructed using existing standard Vietnamese rural road options such as unsealed gravel or hot bitumen sealed water-bound macadam. Many of these trial roads contain sections that have been selected for long-term monitoring and a detailed listing of these is included as Appendix A to this document.

RRST-I comprised trials roads in the following provinces:

Mekong Delta region	Tien Giang
	Dong Thap
Central Coastal region	Thua Thien Hue
	Da Nang

Construction of this phase was largely completed in 2005 and monitoring of the performance of these trials has commenced.

RRST-II comprised trials roads in the following provinces:

Central Highlands;	Gia Lai
	Dak Lak
	Dak Nong
Red River Delta:	Hung Yen
	Ninh Binh
Northern Highlands:	Tuyen Quang
	Ha Tinh
	Quang Binh

The construction phase of the second RRST-II programme was completed in mid 2006 and an initial As-Built survey was undertaken in August 2007.

1.2 Guideline Users

These Guidelines and the technical Appendices are primarily intended for use by the following Vietnamese rural road practitioners:

1. Central or provincial managers who have a responsibility or interest in the management of rural road assets.

2. Researchers who have an interest in updating or amending existing rural road Whole Life Cost Models.
3. Those who undertake, or who propose to undertake, rural road monitoring surveys, including the ongoing monitoring of the RRSR trials.

The Guidelines may also be of interest to a wider regional or international audience, although it is recommended that due recognition be given to local road environment conditions when transferring technology or recognized good practice from its original setting.

1.3 Guidelines Structure

These Guidelines comprise a short introductory text which briefly outlines the monitoring objectives and the key information collection procedures. Guidance is also given on the programming of RRSR monitoring surveys and the effective management of the resultant data.

Following a listing of existing RRSR monitoring sections there are a series of Appendices giving detailed information on the key monitoring procedures, together with any appropriate standard forms. These Appendices may be utilised as stand-alone field or training documents for each particular monitoring procedure.

Accompanying this guideline as an aid to future training is a DVD containing related presentations on this document and its companion guidelines on Maintenance and Construction, given at a workshop in Hanoi in March 2007.

2 MONITORING OBJECTIVES

2.1 General

The condition monitoring of roads may be carried out for a number of objectives, the most common of which are as follows:

Research. The development of new pavement or surfacing options requires that their performance be proven to be suitable, or otherwise, within the road environment constraints within which they are designed to operate. Their deterioration characteristics need to be identified in order to establish their Whole Life Costs and also to define the limits of their appropriate usage. The regular monitoring of appropriately selected road sections in conjunction with assessments of the governing road environments is an essential part of this process.

Maintenance. Effective management of rural road assets requires that relevant information on maintenance needs is available in order to prioritise appropriate interventions. This is particularly important in the typical case where maintenance budgets are severely limited and also where maintenance budget allocation requires factual justification to either central funding or donor-related sources. The adoption of some form of general road monitoring programme would be an invaluable tool in this context.

Specific Problems. It is not uncommon within the sub-tropical and tropical regions for roads to suffer from accelerated deterioration, or even failure, in response to one or more of the following factors of; harsh climatic conditions, poor initial construction design or control, high axle loads or inadequate maintenance funding. In such cases it may be necessary to assess specific failures to identify the exact nature of problems and hence appropriate solutions. The general road monitoring procedures detailed in this document may be usefully adapted for this purpose.

Each of the above general objectives may require a slightly different approach bearing in mind the scope of the survey required. This document concentrates on the needs of the RRST programme.

2.2 The RRSR Context

The current RRSR monitoring requirements are firmly placed within the research context, as defined previously, although there may in addition be specific problem situations arising from time to time that require particular attention. There may also be an increasing requirement to look more carefully at developing maintenance related monitoring programmes to be associated with any new rural road investment programmes that are scheduled to come on stream in the future.

3 STANDARD PROCEDURES

3.1 General

Pavement deterioration is a complex phenomenon which can manifest itself as distress of various inter-related kinds; hence the requirement to collect data for a range of variables during the performance monitoring stage. A monitoring programme needs to recover a collection of time series data, the analysis of which can then be used to provide robust evidence to explain the observed performance and provide confidence in the findings and derived recommendations.

Pavement condition is normally monitored in terms of surface condition, material strength, riding quality (by surface roughness), deformation (by rutting), in situ moisture condition and deflection (relating to pavement strength).

3.2 Surface Condition

Visual surveys using standard procedures, such as those given in Overseas Road Note 18[1] can be carried out to record changes in the pavement condition. Visual survey information can be used to diagnose mechanisms of pavement deterioration. This enables better evaluation of the deterioration mechanisms to be made.

On the RRST programmes, visual condition information is collected for 5m blocks of monitoring section on cracking type and extent together with other defects such as pot-holing, corrugations, edge wear, and erosion. Information is collected on standard field forms utilising defined codes. The exact nature of the information to be collected is governed by the general pavement type.

Appendix B contains relevant field forms and guides for the collection of data for the following pavement types:

1. Unsealed surfacing
2. Sealed flexible pavements
3. Concrete slab pavements
4. Block pavements

3.3 Strength

On the RRST monitoring sections the strength of the pavement layers is assessed, where appropriate, using a Dynamic Cone Penetrometer (DCP). The DCP is an instrument designed for the rapid in-situ measurement of the strength of road pavements constructed with unbound materials. It consists of a small steel cone mounted on a rod which is driven vertically into the road using repeated blows of constant force provided by a weight falling through a fixed distance. Details of the DCP apparatus and procedures are contained in Appendix C.

Continuous assessments can normally be made to a depth of 800mm, although the DCP also has the capability to add extension rods if deeper strength profiles are required. Where pavement layers have different strengths, the boundaries can be identified and the strengths

[1] Overseas Road Note 18. A guide to the pavement evaluation and maintenance of bitumen-surfaced roads in tropical and sub-tropical countries. TRL, 1999.

of the individual layers can be found. A typical test takes only a few minutes and the instrument provides a very efficient method of obtaining sub-surface information that would otherwise require test pitting. There are limits on the appropriate use of the DCP and these are outlined in Appendix C.

Correlations have been established by various authors between measurements with the DCP and the California Bearing Ratio (CBR), so that results can be interpreted and compared with CBR specifications for pavement design. Correlations can also be made with pavement resilient modulus, although these are very much dependant on material type and some caution is required.

Data from the DCP surveys can now be analysed using a computer programme (UKDCP) developed by TRL, and downloadable from www.transportlinks.com .

The DCP test is suitable for assessing the strength of unbound materials only, and it is not appropriate for bitumen bound or cement concrete pavement layers, or for materials with particle size larger than about 25mm, as this would risk damage to the instrument and anyway provide inappropriate measurements.

3.4 Roughness

A number of roughness measuring methods are available, which are classed on the basis of how accurately they measure the longitudinal profile of the road surface and hence the accepted sector standard of International Roughness Index (IRI). Response-Type Road Roughness Measuring Systems (RTRRMS), are devices where roughness is measured directly but need calibration or processing to convert the data into units of IRI. The **M**achine for **E**valuating **R**oughness using **L**ow-cost **IN**strumentation (MERLIN) falls in to this group of devices and is the designated apparatus for use on the RRST monitoring sections.

The MERLIN does not record the absolute profile but measures the mid-chord deviations over a predetermined base length for a section of road and then relates a statistic from the frequency of those deviations to the IRI using a predetermined correlation. The instrument, which is low cost and simple to fabricate, simple to operate and reliable, is described in detail by Cundill (1996)[2].

Appendix D provides details of the MERLIN, procedures for its use and interpretation.

3.5 Shape Deformation and Erosion

Deformation in terms of rutting measured by using a 2-metre straight edge is included within the surface condition procedures (Appendix A). However, for the RRST unsealed sections direct measurement of shape and erosion is undertaken using engineering level measurement techniques. The repeated level surveying of designated pavement cross-sections allows time-related comparisons to be made regarding shape deterioration, erosion and material loss.

Appendix E provides details of the procedures to be followed.

3.6 Sampling and Laboratory Testing

Laboratory work for standard RRST monitoring will normally be limited to moisture content testing of gravel or stabilised shoulders, as a general check on moisture condition in relation to in situ DCP testing. Appendix F outlines the appropriate procedures.

In some condition surveying cases where specific pavement deterioration problems have occurred, it may be necessary to excavate inspection pits and take samples for a more extensive suite of materials tests, and observe pavement layer and subgrade conditions. These procedures are outside the scope of this guideline, but some advice on relevant testing is contained within the RRST Construction Guidelines handbook.

[2] Cundill M A, The MERLIN road roughness machine; User guide. TRL Report TRL 229, 1996.

3.7 Traffic Counts

The rapidly developing transport sector in Vietnam demands that regular updating of traffic patterns should be an integral part of the overall monitoring and evaluation of the RRST surfacing and pavement options.

Simple traffic count procedures suitable for use by district or commune staff have already been developed and successfully employed on RRST-I and RRST-II roads. These procedures, involve the use of simple field data forms followed by the adaptation of the counts into equivalent Average Daily Traffic (ADT) figures using established conversion factors (Overseas Road Note 20, TRL)[3]. ADT is the total annual traffic in both directions divided by 365. Hence it is an average 24-hour daily traffic volume. This statistic for the RRST programme includes all motorised and non motorised traffic, bicycles and animal carts.

The use of ADT criteria has been adopted because of its greater relevance to pavement deterioration that the more traffic capacity and socio-economic related Passenger Car Unit (PCU) figure.

Details of procedures are detailed in Appendix G.

4 ADDITIONAL PROCEDURES

4.1 Axle Load Surveys

The importance of reliable axle load information for pavement evaluation for research and design purposes is emphasised by the widely accepted engineering principle that for light and medium flexible pavements, the degree of pavement damage caused by an axle load is proportional to approximately the fourth power of the axle load. This implies that the even a small percent of heavily overloaded trucks can often cause more pavement damage than the rest of the traffic combined.

Adequate information on axle load distributions can be obtained by road-side surveys of axle loads which can conveniently be made using portable wheel or axle weighing devices. Such surveys have already been undertaken as part of the RRST programme in the Mekong and Central Coastal regions, details of which can be accessed in the SEACAP 1 Final Report, Appendix C[4].

It is appreciated that because of the cost involved, and the current scarcity of suitable equipment, axle-load surveys will not be part of the standard monitoring programme for RRST roads. Nevertheless it should be considered for specific problem or "at risk" areas with routes frequented by heavy trucks.

4.2 Deflection Surveys

The least expensive method of measuring deflection is the deflection beam. This is a mechanical device that measures the maximum deflection of a road pavement under the dual rear wheels of a slowly moving lorry with a standard load. Maximum deflection under a slowly moving wheel load is a good indicator of the overall strength of a pavement and has been shown to correlate well with long term performance of pavements under traffic. Where stresses in the lower layers of the pavement are too high, the pavement will deteriorate through the development of cracks and ruts. Under these circumstances the deflection will be correlated with rut depth.

Apart from the maximum deflection, there are other parameters and indicators from the deflection bowl that can be used to identify structural differences between control sections and sub-sections within the trial. The radius of curvature (ROC) of the deflection bowl can be used to estimate the relative properties of the upper layers of the pavement. Deflection values at the extremes of the deflection bowl are indicators of the relative strength of the sub-grade.

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[3] Overseas Road Note 20. Management of rural road networks. TRL 2003.

[4] SEACAP 1 Final Report, Volume 2. Intech-TRL 2007.

The Falling Weight Deflectometer (FWD) procedure has the advantage of being able to apply impact loads which more accurately simulate the effect on pavements of vehicles moving at normal traffic speeds, than the slowly moving load applications associated with the deflection beam. FWD surveys were undertaken on all RRST-I monitoring sections in July 2006 and their methodology is reported in the SEACAP 1 Final Report, Appendix F.

It is appreciated that the current costs of FWD surveying may prohibit their regular use on RRST monitoring surveys, nevertheless they should be considered for occasional surveys and in particular on RRST-II roads that have not yet been so surveyed.

5 PROGRAMMING

5.1 RRST Monitoring

It is proposed that standard RRST monitoring surveys, with the exception of traffic counts, should be undertaken on RRST road at six-monthly intervals. These surveys should ideally coincide with the changes between dry and wet season conditions. Traffic counts are recommended for a yearly or two-yearly cycle, although advice should be taken from PDoT officials as to their exact survey intervals, bearing in mind the patterns of provincial transport development. Figure 5.1 illustrates the layout of typical RRST monitoring sections.

5.2 Other Monitoring Requirements

Non-standard survey procedures such as axle-load, Benkelman Beam or FWD surveys should be considered on the basis of specific need and the availability of equipment and budget. In general however it is recommend that axle-load and FWD (or Benkelman Beam) surveys should be undertaken at least twice on each trial section within a 10 year monitoring period; once within 12-18 months of road completion.

6 INFORMATION MANAGEMENT

6.1 Management Process

The management of data recovered from monitoring surveys falls into a number of logical steps, namely:

Quality control checks on fieldwork data. Completed field data forms should be checked for completeness and the amendment or exclusion of obvious gross errors.

Calculation. Field data such as DCP blows/mm or raw MERLIN data.

Data transfer into electronic format. Quality checked and calculated data should then be transferred onto the relevant EXCEL spreadsheets or ACCESS tables within the RRSR database. Summary forms and plots should also be produced where appropriate. There is additional option of using the DFID-TRL UKDCP programme to calculate and interpret DCP-CBR field data.

Final Quality Assurance. All entered data should be cross-checked by a suitably qualified and experience road engineer who has knowledge of monitoring procedures, the RRST programme and its objectives.

6.2 Interim Management Arrangements

The RRSR database is currently held in electronic and hard copy form at the Intech-TRL office in Hanoi. This is a project office and arrangements need to be put in place for transfer of these data to the organisation that will be responsible for the envisaged Long Term Monitoring of the selected RRST-I and RRST-II trial roads. If there will be a delay in the appointment of the Long Term Monitoring organisation, then interim arrangements will be required to provide local safe custody and integrity of the various components of the RRSR database, including additional resources for the transfer and training of operatives.

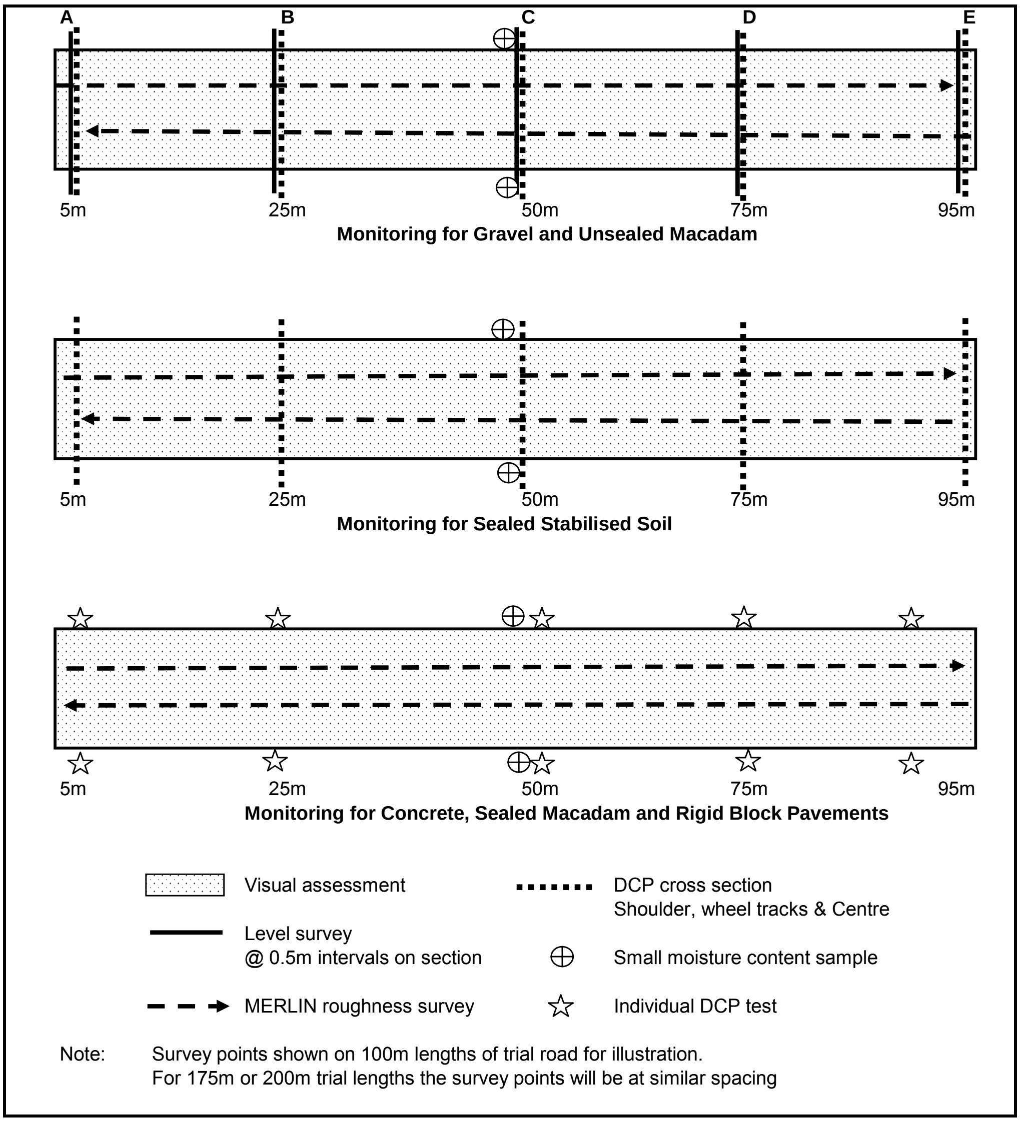

Figure 5.1: Schematic Layout of Monitoring Schemes

RRST GUIDELINE
RURAL ROAD PAVEMENT AND SURFACE CONDITION MONITORING

APPENDIX A

RRST Monitoring Sections

Province	Road	Section Reference	Monitoring Chainage		Section Type	Monitoring Length(m)	Design	Monitoring Reference
			From	To				
Hue	Thong Nhat	H02	0.200	0.400	Trial	200	CC03	H02
Hue	Thong Nhat	H03	1.775	1.875	Control	100	CC02	H03
Hue	Thong Nhat	H04	0.600	0.700	Control	100	CC04	H04
Hue	Thong Nhat	H06	0.800	1.000	Trial	200	CC05	H06
Hue	Thong Nhat	H07	1.000	2.000	Trial	200	CC06	H07
Hue	Thong Nhat	H09	1.300	1.500	Trial	200	CC06	H09
Hue	Thong Nhat	H11	1.600	1.775	Trial	175	CC07	H11
Tien Giang	My Phuoc Tay	TG02	1.100	1.300	Trial	200	MD01	TG02
Tien Giang	My Phuoc Tay	TG03	1.300	1.500	Trial	200	MD02	TG03
Tien Giang	My Phuoc Tay	TG05	1.600	1.800	Trial	200	MD03	TG05
Tien Giang	My Phuoc Tay	TG06	1.800	2.000	Trial	200	MD04	TG06
Tien Giang	My Phuoc Tay	TG07	2.000	2.100	Control	100	MD05	TG07
Tien Giang	My Phuoc Tay	TG08	2.100	2.200	Control	100	MD06	TG08
Tien Giang	My Phuoc Tay	TG09	2.200	2.400	Trial	200	MD10	TG09
Tien Giang	My Phuoc Tay	TG10	2.400	2.500	Control	100	MD11	TG10
Dong Thap	Tan Thuan Tay	D02	0.133	0.308	Trial	175	MD01	D02
Dong Thap	Tan Thuan Tay	D03	0.308	0.483	Trial	175	MD02	D03
Dong Thap	Tan Thuan Tay	D05	0.583	0.758	Trial	175	MD03a	D05
Dong Thap	Tan Thuan Tay	D06	0.758	0.933	Trial	175	MD04	D06
Dong Thap	Tan Thuan Tay	D07	0.933	1.033	Control	100	MD05	D07
Dong Thap	Tan Thuan Tay	D08	1.033	1.123	Control	90	MD06	D08
Dong Thap	Tan Thuan Tay	D10	2.065	2.265	Trial	200	MD07	D10
Dong Thap	Tan Thuan Tay	D11	2.265	2.465	Trial	200	MD08	D11
Dong Thap	Tan Thuan Tay	D12	2.465	2.665	Trial	200	CC01	D12
Da Nang	Binh Ky	DaN02	0.190	0.365	Trial	175	CC08	DaN02
Da Nang	Binh Ky	DaN03	0.365	0.540	Trial	175	CC09	DaN03
Da Nang	Binh Ky	DaN04	0.540	0.715	Trial	175	CC10	DaN04
Da Nang	Binh Ky	DaN05	0.715	0.815	Control	100	CC03	DaN05
Da Nang	Binh Ky	DaN06	0.815	0.915	Control	100	CC11	DaN06

Table A.1: RRST-I Monitoring Sections

Province	Road	Section Reference	Monitoring Chainage From	To	Section Type	Monitoring Length(m)	Design	Monitoring Reference
Tuyen Quang	Lang Quan	Lq1	0.750	0.950	Trial	100	NH5	TQ(1)-1
Tuyen Quang	Lang Quan	Lq2	1.000	1.100	Trial	100	NH1d	TQ(1)-2
Tuyen Quang	Lang Quan	Lq3	2.100	2.200	Control	100	NH7	TQ(1)-3
Tuyen Quang	Lang Quan	Lq4	3.000	3.100	Trial	100	NH2c	TQ(1)-4
Tuyen Quang	Lang Quan	Lq5	3.775	3.875	Trial	100	NH2d	TQ(1)-5
Tuyen Quang	Y La	Yl2	0.300	0.400	Trial	100	NH5	TQ(2)-1
Ha Tinh	Chu Le	CL1	0.100	0.200	Control	100	NH7b	HT(3)-1
Ha Tinh	Chu Le	CL2	2.600	2.700	Trial	100	NH2b	HT(3)-2
Ha Tinh	Hong Loc	Hl1	0.050	0.150	Control	100	NH7a	HT(2)-1
Ha Tinh	Hong Loc	Hl2	1.710	1.810	Trial	100	NH2b	HT(2)-2
Ha Tinh	Hong Loc	Hl3	2.700	2.800	Trial	100	NH1b	HT(2)-3
Ha Tinh	Thac Minh	Tm1	0.100	0.200	Trial	100	NH1a	HT(1)-1
Ha Tinh	Thac Minh	Tm2	1.300	1.400	Trial	100	NH2a	HT(1)-2
Ha Tinh	Thac Minh	Tm3	2.050	2.150	Trial	100	NH5	HT(1)-3
Ha Tinh	Thac Minh	Tm6	4.000	4.100	Control	100	NH7c	HT(1)-4
Ha Tinh	Thac Minh	Tm7	5.700	5.800	Control	100	NH7b	HT(1)-5
Quang Binh	Cam Lien	CmL2	0.900	1.000	Trial	100	NH4b	QB(2)-1
Quang Binh	Cam Lien	CmL3	1.005	1.105	Trial	100	NH2b	QB(2)-2
Quang Binh	Cam Lien	CmL4	2.000	2.100	Trial	100	NH4b	QB(2)-3
Quang Binh	Cam Lien	CmL7	5.900	6.000	Trial	100	NH5	QB(3)-1
Quang Binh	Cam Lien	CmL8	6.000	6.100	Control	100	NH7	QB(3)-1
Ninh Binh	Dong Huong	Dh1	1.300	1.400	Control	100	RR12	NB(1)-1
Ninh Binh	Dong Huong	Dh2	1.500	1.600	Trial	100	RR3	NB(1)-2
Ninh Binh	Ninh Van	Nv4	3.700	3.600	Trial	100	RR10	NB(4)-1
Ninh Binh	Yen Trach	Yt2	1.000	1.100	Control	100	RR12	NB(2)-1a
Ninh Binh	Yen Trach	Yt2	0.600	0.700	Control	100	RR12	NB(2)-1
Ninh Binh	Yen Trach	Yt3	1.300	1.400	Trial	100	RR5	NB(2)-2
Ninh Binh	Yen Trach	Yt4	1.800	1.900	Control	100	RR12	NB(2)-3
Ninh Binh	Yen Tu	Ynt1	0.200	0.300	Trial	100	RR10	NB(3)-1
Ninh Binh	Yen Tu	Ynt2	1.100	1.200	Control	100	RR12	NB(3)-2
Hung Yen	Hung Long	Hlg2	1.200	1.300	Trial	100	RR9	HY(3)-1
Hung Yen	Hung Long	Hlg3	1.800	1.900	Control	100	RR15	HY(3)-2a
Hung Yen	Nhat Quang	Nq1	0.650	0.750	Trial	100	RR6	HY(2)-1
Hung Yen	Nhat Quang	Nq2	1.050	1.250	Trial	200	RR7	HY(2)-2a
Hung Yen	Nhat Quang	Nq3	2.600	2.700	Control	100	RR15	HY(2)-3
Hung Yen	Nhat Quang	Nq4	4.000	4.100	Control	100	RR12	HY(2)-4
Hung Yen	Thuy Loi	Tl1	0.050	0.150	Trial	100	RR7	HY(4)-1
Hung Yen	Tan Hung	Th1	1.250	1.350	Trial	100	RR2	HY(1)-1
Hung Yen	Tan Hung	Th2	1.350	1.450	Trial	100	RR4	HY(1)-2
Gia Lai	Ia Pnol	Ip1	0.400	0.500	Trial	100	CH5	GL(1)-1
Gia Lai	Ia Pnol	Ip2	1.900	2.000	Trial	100	CH1	GL(1)-2
Gia Lai	Ia Pnol	Ip3	2.200	2.300	Trial	100	CH6a	GL(1)-3
Gia Lai	Ia Pnol	Ip4	3.000	3.200	Control	200	CH9	GL(1)-4
Gia Lai	Xa Trang	Xtr1	0.900	1.000	Trial	100	CH6	GL(2)-1
Gia Lai	Xa Trang	Xtr2	1.700	1.800	Control	100	CH9	GL(2)-2
Gia Lai	Xa Trang	Xtr3	2.060	2.160	Trial	100	CH2a	GL(2)-3
Gia Lai	Xa Trang	Xtr4	2.200	2.300	Trial	100	CH9	GL(2)-4
Dak Lak	Buon Ho	Bh3	8.800	8.900	Trial	100	CH5	DL(2)-1
Dak Lak	Buon Ho	Bh4	9.700	9.800	Trial	100	CH4	DL(2)-2
Dak Lak	Buon Ho	Bh5	11.500	11.600	Trial	100	CH3	DL(2)-3
Dak Lak	Buon Ho	Bh6	13.200	13.300	Trial	100	CH3	DL(2)-4
Dak Lak	Cu Ne	Cn1	0.150	0.250	Trial	100	CH5	DL(1)-1
Dak Lak	Cu Ne	Cn2	1.600	1.700	Control	100	CH8b	DL(1)-2
Dak Lak	Ea Soup	Es1	0.220	0.320	Trial	100	CH2b	DL(3)-1
Dak Lak	Ea Soup	Es2	1.200	1.300	Control	100	CH8b	DL(3)-2
Dak Nong	Kien Duc	Kd01	0.045	0.145	Trial	100	CH7	DN(1)-1
Dak Nong	Kien Duc	Kd02	1.600	1.700	Trial	100	CH7a	DN(1)-2
Dak Nong	Kien Duc	Kd04	5.850	5.950	Trial	100	CH7	DN(1)-4
Dak Nong	Kien Duc	Kd05	6.900	7.000	Trial	100	CH2b	DN(1)-5
Dak Nong	Kien Duc	Kd06	0.060	0.160	Trial	100	CH7b	DN(2)-1
Dak Nong	Kien Duc	Kd07	0.800	0.900	Control	100	CH8	DN(2)-2
Dak Nong	Kien Duc	Kd08	1.200	1.300	Trial	100	CH7	DN(2)-3
Dak Nong	Kien Duc	Kd10	2.700	2.800	Trial	100	CH7	DN(2)-4
Dak Nong	Kien Duc	Kd11	3.250	3.450	Control	100	CH9	DN(2)-5a
Dak Nong	Kien Duc	Kd03	4.000	4.100	Trial	100	CH7	DN(1)-3
Dak Nong	Kien Duc	Kd11	3.675	3.775	Control	100	CH9	DN(2)-5b
Dak Lak	Ea Soup	Es1	0.150	0.230	Trial	80	CH2b	DL(3)-1a
Gia Lai	Xa Trang	Xtr2	1.500	1.600	Control	100	CH9	GL(2)-2a
Tuyen Quang	Y La	Y12	0.600	0.700	Trial	100	NH5	TQ(2)-1a
Ninh Binh	Dong Huong	Dh1	1.400	1.500	Control	100	RR12	NB(1)-1a
Ninh Binh	Yen Trach	Yt3	1.500	1.600	Trial	100	RR5	NB(2)-2a
Ninh Binh	Yen Trach	Yt4	1.600	1.700	Control	100	RR12	NB(2)-3a

Table A.2: RRST-II Monitoring Sections

RRST GUIDELINE
RURAL ROAD PAVEMENT AND SURFACE CONDITION MONITORING

APPENDIX B

SURFACE CONDITION SURVEY

RRST GUIDELINE
RURAL ROAD PAVEMENT AND SURFACE CONDITION MONITORING

APPENDIX B

SURFACE CONDITION SURVEY

This appendix contains field data sheets and associated codes to be used for assessing the surface condition of the following general pavement groups:

1. Unsealed surfaces
2. Sealed flexible pavements
3. Concrete pavements
4. Block paving options

Some examples of completed field sheets are also included.

Surface Condition Survey Form I: Unsealed Pavement Condition Assessment

RRST Pavement Condition Monitoring
Un-Sealed Pavement Condition Assessment **Form U F.1** **Road** ______

Inspector ______

Pavement ______ **Form** ______ **Date** ______ **Start Point** ______

		Left Hand													Right Hand														
		Carriageway									Shoulder				Carriageway									Shoulder					
Chain	Block	Thickness	Visual Appearance	Loose Material	Corrugations	Erosion	Ruts	Potholes	Shape		Cracks	Erosion	Run-off	Drain	Thickness	Visual Appearance	Loose Material	Corrugations	Erosion	Ruts	Potholes	Shape		Cracks	Erosion	Run-off	Drain	Photo	Comment
0	1																												
5	2																												
10	3																												
15	4																												
20	5																												
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190	39																												
195	40																												
200	41																												

RRST Pavement Condition Monitoring
Un-Sealed Flexible Pavement Condition Assessment
Condition Codes (Version F.1)

Carriageway

Thickness		As measured (mm)
Visual Appearance	1	Good surface shape - no aggregate protrusion
	2	Some deterioration/aggregate protrusion
	3	Up to 75% of surface intact
	4	75 to 50% of surface intact
	5	Extensive surface deterioration, up to 75%
	6	<25% of surface intact
Loose Material	1	Negligible
	2	<15mm loose thickness
	3	15-50mm loose thickness
	4	>50mm loose thickness
Corrugations	1	Negligible
	2	<15mm deep
	3	15-50mm deep
	4	>50mm deep
Erosion	1	Negligible
	2	Slight (material loss 5-20mm, area <10%)
	3	Moderate (material loss 5-20mm, area 10-50%)
	4	Severe (material loss > 20mm, area>10%)
	5	Total (material loss > 20mm, area>50%)
Ruts		Maximum (mm)
Potholes *(Record porthole extent)*	0	None
	1	1
	2	2-3
	3	>3
Shape	1	As built: 4%
	2	Good: 2-4 %
	3	Flat: <2 %
	4	Uneven
	5	Bowl shape (-ve)
	6	Super-Elevation

Shoulder

Cracks	0	No cracks
	1	Isolated individual
	2	Several individual
	3	Space interconnected (> 250mm)
	4	Close interconnected <250mm
	5	Severe crocodile/crumbling
Erosion	0	None
	1	Slight (material loss 5-20mm, area <10%)
	2	Moderate (material loss 5-20mm, area10-50%)
	3	Severe (material loss > 20mm, area>10%)
	4	Total (material loss > 20mm, area>50%)
	5	Shoulder failure
Run-off	1	Unimpeded
	2	Impeded by crossfall
	3	Impeded by debris/vegetation

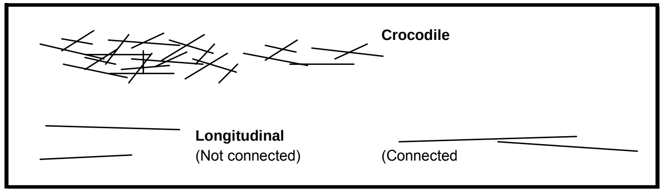
Drainage

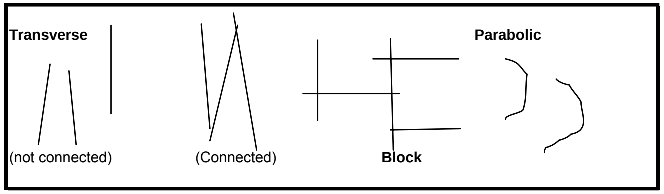
Condition	0	No side drain
	1	Good shape and level -clean
	2	Adequate shape and level - minor silting only
	3	Defects /silting evident but can function
	4	Significant defects/silting - drainage impaired
	5	Serious scouring/defects - no longer effective

Additional

M	Maintenance required
R	Repair required

Carriageway Cracking





Version F.1

Surface Condition Survey Form II: Sealed Flexible Pavement Condition Assessment

RRST Pavement Condition Monitoring
Sealed Flexible Pavement Condition Assessment **Form S F.1** **Road**

Pavement **Form** **Date** **Start Point** **Inspector**

		Left Hand														Right Hand															
		Carriageway										Shoulder				Carriageway										Shoulder					
		Cracks														Cracks															
Chain	Block	Type	Intensity	Position	Width	Extent	Ruts	Potholes	Aggregate Loss	Surface Texture	Edge	Cracks	Erosion	Run-off	Drain	Type	Intensity	Position	Width	Extent	Ruts	Potholes	Aggregate Loss	Surface Texture	Edge	Cracks	Erosion	Run-off	Drain	Photo	Comment
0	1																														
5	2																														
10	3																														
15	4																														
20	5																														
25	6																														
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190	39																														
195	40																														
200	41																														

RRST Pavement Condition Monitoring
Sealed Flexible Pavement Condition Assessment
Condition Codes (Version F.1)

Cracks

Type	0	No cracks
	1	Crocodile
	2	Longitudinal
	3	Transverse
	4	Block
	5	Parabolic
Intensity	0	No cracks
	1	Single
	2	>1 not connected
	3	>1 connected
	4	Interconnected (crocodile)
	5	Interconnected (loose)
Position	0	No cracks
	1	Edge
	2	Wheel track
	3	All carriageway
Width	0	No cracks
	1	<1mm
	2	1-3mm
	3	>3mm
	4	Spalling/crumbling

Extent		Crocodile cracks	Other cracks
	0	No cracks	No cracks
	1	0-10%	<1m
	2	10-50%	1-5m
	3	>50%	>5m

Additional

M	Maintenance required
R	Repair required

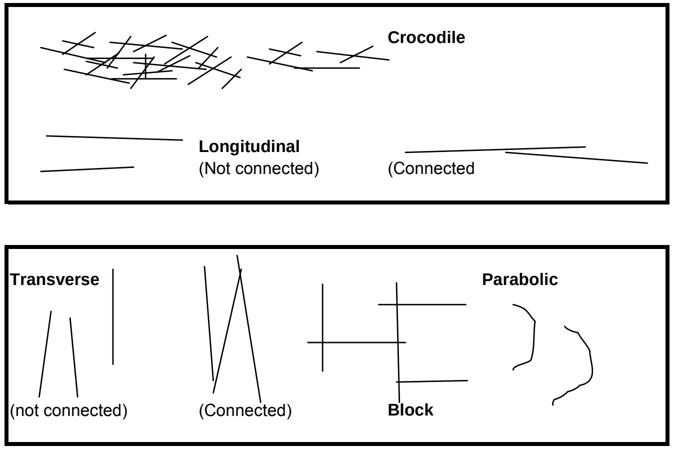
General Carriageway

Ruts		Maximum (mm)
Potholes	0	None
	1	1
	2	2-3
	3	>3
Aggregate Loss Extent	0	None
	1	0-10%
	2	10-50%
	3	>50%
Surface Texture	1	Smooth - intact seal
	2	Slightly coarse - fine aggregate shows
	3	Coarse - chippings dominate
Edge Failures >150mm	0	None
	1	0-10%
	2	10-50%
	3	>50%

Shoulder

Cracks	0	No cracks
	1	Isolated individual
	2	Several individual
	3	Space interconnected (> 250mm)
	4	Close interconnected <250mm
	5	Severe crocodile/crumbling
Erosion	0	None
	1	Slight (material loss 5-20mm, area <10%)
	2	Moderate (material loss 5-20mm, area10-50%)
	3	Severe (material loss > 20mm, area>10%)
	4	Total (material loss > 20mm, area>50%)
	5	Shoulder failure
Run-off	1	Unimpeded
	2	Impeded by crossfall
	3	Impeded by debris/vegetation

Carriageway Cracking



Drainage

Condition	0	No side drain
	1	Good shape and level -clean
	2	Adequate shape and level - minor silting only
	3	Defects /silting evident but can function
	4	Significant defects/silting - drainage impaired
	5	Serious scouring/defects - no longer effective

Version F.1

Surface Condition Survey Form III: Concrete Pavement Condition Assessment

RRST Pavement Condition Monitoring
Concrete Pavement Condition Assessment **Form C1.1** **Section** ____

Road ____ **Form** ____ **Date** ____ **Start Point** ____ **Inspector** ____

Chain	Block	Joint Condition	Left Hand – Carriagway – Cracks: Type	Intensity	Position	Width	Extent	Surface	Potholes	Edge	Shoulder: Cracks	Erosion	Run-off	Drain	Right hand – Carriagway – Cracks: Type	Intensity	Position	Width	Extent	Ruts	Potholes	Edge	Shldr: Cracks	Erosion	Run-off	Drain	Photo	Comment
0	1																											
5	2																											
10	3																											
15	4																											
20	5																											
25	6																											
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175	36																											
180	37																											
185	38																											
190	39																											
195	40																											
200	41																											

RRST Pavement Condition Monitoring
Concrete Pavement Condition Assessment
Condition Codes (Version F.1)

Block Seals

Condition	1	Satisfactory
	2	Minor cracks (width <3mm)
	3	Severe cracking (width <3mm)
	4	Depressed joint seal
	5	Loss of seal

Cracks

Type	0	No cracks
	1	Crocodile
	2	Longitudinal
	3	Transverse
	4	Block
	5	Parabolic

Intensity	0	No cracks
	1	Single
	2	>1 not connected
	3	>1 connected
	4	Interconnected (crocodile)
	5	Interconnected (loose)

Position	0	No cracks
	1	Edge
	2	Wheel track
	3	All carriageway

Width	0	No cracks
	1	<1mm
	2	1-3mm
	3	>3mm
	4	Spalling/crumbling

Extent		crocodile cracks	Other cracks
	0	No cracks	No cracks
	1	0-10%	<1m
	2	10-50%	1-5m
	3	>50%	>5m

Additional

M	Maintenance required
R	Repair required

General Carriageway

Surface	1	Good
	2	Crazed cracking
	3	Surface stripping

Potholes	0	None
	1	1
	2	2-3
	3	>3

Edge	1	Clean-sharp
	2	Minor degradation
	3	Cracking
	4	Block spalling

Shoulder

Cracks	0	No cracks
	1	Isolated individual
	2	Several individual
	3	Space interconnected (> 250mm)
	4	Close interconnected <250mm
	5	Severe crocodile/crumbling

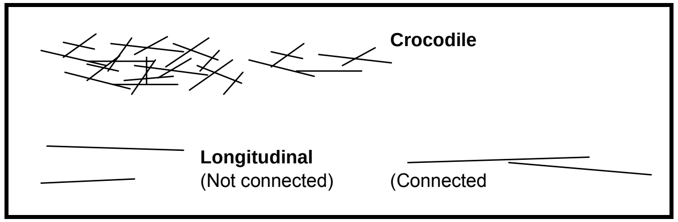
Erosion	0	None
	1	Slight (material loss 5-20mm, area <10%)
	2	Moderate (material loss 5-20mm, area10-50%)
	3	Severe (material loss > 20mm, area>10%)
	4	Total (material loss > 20mm, area>50%)
	5	Shoulder failure

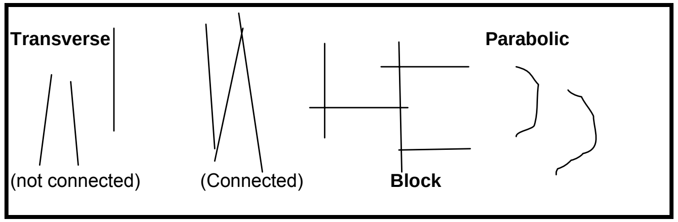
Run-off	1	Unimpeded
	2	Impeded by crossfall
	3	Impeded by debris/vegetation

Drainage

Condition	0	No side drain
	1	Good shape and level -clean
	2	Adequate shape and level - minor silting only
	3	Defects /silting evident but can function
	4	Significant defects/silting - drainage impaired
	5	Serious scouring/defects - no longer effective

Carriageway Cracking





Version F.1

Surface Condition Survey Form IV: Block/Brick Pavement Condition Assessment

RRST Pavement Condition Monitoring
Block Pavement **Form B1.1** **Road** ____________

Inspector ____________

Pavement ____________ **Form** ________ **Date** ________ **Start Point** ________

		Left Hand														Right Hand															
		Carriageway										Shoulder				Carriageway										Shoulder					
Chain	Block	Cracks	Crack Extent	Bock Condition	Joint Condition	Depressions	Ruts	Potholes	Shape	Kerb Condition	Seal	Cracks	Erosion	Run-off	Drain	Cracks	Crack Extent	Bock Condition	Joint Condition	Depressions	Ruts	Potholes	Shape	Kerb Condition	Seal	Cracks	Erosion	Run-off	Drain	Photo	Comment
0	1																														
5	2																														
10	3																														
15	4																														
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25	6																														
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190	39																														
195	40																														
200	41																														

RRST Pavement Condition Monitoring
Block Pavement Condition Assessment
Condition Codes (Version F.1)

Cracks	0	None
	1	On joints only
	2	On blocks only
	3	Across blocks & joints - transverse
	4	Across blocks & joints - longitudinal
	5	Across blocks & joints - longitudinal & transverse

Crack Extent	0	No cracks
	1	0-10% or total area <1m2
	2	10-50% or total area 1-5m2
	3	>50% or total area >5m2

Block Condition	1	Solid
	2	0-5% Loose of broken
	3	5-10% Loose or broken
	4	10-25% Loose or broken
	5	25-50% Loose or broken
	6	>50% Loose or broken

Joint Condition	1	All sound condition
	2	0-5% Cracked or missing
	3	5-10% Cracked or missing
	4	10-25% Cracked or missing
	5	25-50% Cracked or missing
	6	>50% Cracked or missing

Depressions *(Record depression extent*	0	None
	1	1
	2	2-3
	3	>3

Ruts		Maximum (mm)

Potholes *(Record porthole extent)*	0	None
	1	1
	2	2-3
	3	>3

Shape	1	As built: 4%
	2	Good: 2-4 %
	3	Flat: <2 %
	4	Uneven
	5	Bowl shape (-ve)
	6	Super-Elevation

Kerb Condition	1	Solid
	2	0-5% Loose of broken
	3	5-10% Loose or broken
	4	10-25% Loose or broken
	5	25-50% Loose or broken
	6	>50% Loose or broken

Seal Condition	0	No seal
	1	Intact
	2	0-5% Cracked or missing
	3	5-10% Cracked or missing
	4	10-25% Cracked or missing
	5	25-50% Cracked or missing
	6	>50% Cracked or missing

Shoulder

Cracks	0	No cracks
	1	Isolated individual
	2	Several individual
	3	Space interconnected (> 250mm)
	4	Close interconnected <250mm
	5	Severe crocodile/crumbling

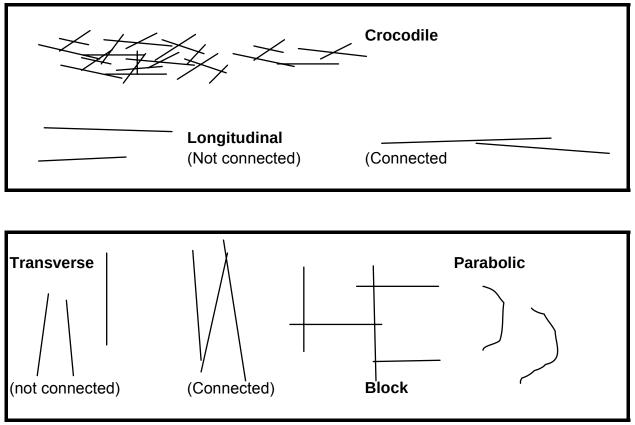
Erosion	0	None
	1	Slight (material loss 5-20mm, area <10%)
	2	Moderate (material loss 5-20mm, area10-50%)
	3	Severe (material loss > 20mm, area>10%)
	4	Total (material loss > 20mm, area>50%)
	5	Shoulder failure

Run-off	1	Unimpeded
	2	Impeded by crossfall
	3	Impeded by debris/vegetation

Drainage

Condition	0	No side drain
	1	Good shape and level -clean
	2	Adequate shape and level - minor silting only
	3	Defects /silting evident but can function
	4	Significant defects/silting - drainage impaired
	5	Serious scouring/defects - no longer effective

Cracking



Additional

M	Maintenance required
R	Repair required

Version F.1

Data Sheet Examples

RRST Pavement Condition Monitoring
Un-Sealed Pavement Condition Assessment **Form UF1.1** **Road** **My Phuc Tay**

Pavement T10 **Date** 27/7/2006 **Start Point** 2.400 **Inspector** **NEE/PGT**

		Left Hand												Right Hand													
		Carriageway								Shoulder				Carriageway								Shoulder					
Chain	Block	Thickness	Visual Appearnace	Loose Material	Corrugations	Erosion	Ruts	0	Shape	Cracks	Erosion	Run-off	Drain	Thickness	Visual Appearnace	Loose Material	Corrugations	Erosion	Ruts	Potholes	Shape	Cracks	Erosion	Run-off	Drain	Photo	
0	1		3	2	2	0	10	0	3	0	0	3			3	2	2	0	10	0	3	0	0	3			Drain not needed
5	2		3	2	2	0	10	0	3	0	0	3			3	2	2	0	10	0	3	0	0	3			
10	3		3	2	2	0	10	0	3	0	0	3			3	2	2	0	10	0	3	0	0	3			
15	4		3	2	2	0	10	0	3	0	0	3			3	2	2	0	10	0	3	0	0	3			
20	5		3	2	2	0	10	0	3	0	0	3			3	2	2	0	10	0	3	0	0	3			
25	6		3	2	2	0	10	0	3	0	0	3			3	2	2	0	10	0	3	0	1	3			
30	7		3	2	2	0	10	0	3	0	0	3			3	2	2	0	10	0	3	0	1	3			
35	8		3	2	2	0	10	0	3	0	0	3			3	2	2	0	10	0	3	0	1	3			
40	9		3	2	2	0	10	0	3	0	0	3			3	2	2	0	10	0	3	0	0	3			
45	10		3	2	2	0	10	0	3	0	0	3			3	2	2	0	10	0	3	0	0	3			
50	11		3	2	2	0	10	0	3	0	2	2/3			3	2	2	0	10	0	3	0	0	3			
55	12		3	2	2	0	10	0	3	0	0	2/3			3	2	2	0	10	0	3	0	0	3			
60	13		3	2	2	0	10	0	3	0	0	2/3			3	2	2	0	10	0	3	0	0	3			
65	14		3	2	2	0	10	0	3	0	0	2/3			3	2	2	0	10	0	3	0	0	3			
70	15		2	2	2	0	15	0	3	0	0	2/3			2	2	2	0	15	0	3	0	0	3			
75	16		2	2	2	0	15	0	3	0	0	2/3			2	2	2	0	15	0	3	0	0	3			
80	17		2	2	2	0	15	0	3	0	0	2/3			2	2	2	0	15	0	3	0	0	3			
85	18		2	2	2	0	15	0	3	0	0	2/3			2	2	2	0	15	0	3	0	0	3			
90	19		2	2	2	0	15	0	3	0	0	2/3			2	2	2	0	15	0	3	0	0	3			
95	20		2	2	2	0	15	0	3	0	0	2/3			2	2	2	0	15	0	3	0	0	3			
100	21		2	2	2	0	15	0	3	0	0	2/3			2	2	2	0	15	0	3	0	0	3			

RRST Pavement Condition Monitoring
Sealed Flexible Pavement Condition Assessment **Form SF1.1** **Road** T6

Pavement My Phuoc Tay **Form** **Date** 05/01/2006 **Start Point** 1.800 **Inspector** Pham Gia Tuan

		Left Hand														Right Hand															
		Carriageway										Shoulder				Carriageway										Shoulder					
		Cracks														Cracks															
Chain	Block	Type	Intensity	Position	Width	Extent	Ruts	Potholes	Aggregate Loss	Surface Tuxture	Edge	Cracks	Erosion	Run-off	Drain	Type	Intensity	Position	Width	Extent	Ruts	Potholes	Aggregate Loss	Surface Tuxture	Edge	Cracks	Erosion	Run-off	Drain	Photo	Comment
0	1	0	0	0	0	0		0	0	2	1	2	5	1		0	0	0	0	0		0	0	2	1	2	5	1		0	
5	2	0	0	0	0	0		0	0	2	1	2	5	1		0	0	0	0	0		0	0	2	1	2	5	1		5	
10	3	0	0	0	0	0		0	0	1	1	2	2	1		0	0	0	0	0		0	0	1	1	2	3	1		10	
15	4	0	0	0	0	0		0	0	1	1	2	2	1		0	0	0	0	0		0	0	1	1	2	3	1		15	
20	5	0	0	0	0	0		0	0	1	1	2	2	1		0	0	0	0	0		0	0	1	1	2	2	1		20	
25	6	0	0	0	0	0		0	0	1	1	2	5	1		0	0	0	0	0		0	0	1	1	2	2	1		25	
30	7	0	0	0	0	0		0	0	1	1	2	2	1		0	0	0	0	0		0	0	1	1	2	4	1		30	
35	8	0	0	0	0	0		0	0	1	1	2	2	1		0	0	0	0	0		0	0	1	1	2	4	1		35	
40	9	0	0	0	0	0		0	0	1	1	2	2	1		0	0	0	0	0		0	0	1	1	2	4	1		40	
45	10	0	0	0	0	0		0	0	1	1	2	1	1		0	0	0	0	0		0	0	1	1	2	1	1		45	
50	11	0	0	0	0	0		0	0	1	1	2	1	1		0	0	0	0	0		0	0	1	1	2	1	1		50	
55	12	0	0	0	0	0		0	0	1	1	2	2	1		0	0	0	0	0		0	0	1	1	2	2	1		55	
60	13	0	0	0	0	0		0	0	1	1	2	2	1		0	0	0	0	0		0	0	1	1	2	2	1		60	
65	14	0	0	0	0	0		0	0	1	1	2	2	1		0	0	0	0	0		0	0	1	1	2	2	1		65	
70	15	0	0	0	0	0		0	0	1	1	2	2	1		0	0	0	0	0		0	0	1	1	2	2	1		70	
75	16	0	0	0	0	0		0	0	1	0	2	2	1		0	0	0	0	0		0	0	1	1	2	2	1		75	
80	17	0	0	0	0	0		0	0	1	0	2	1	3		0	0	0	0	0		0	0	1	1	2	1	3		80	
85	18	0	0	0	0	0		0	0	1	0	2	1	3		0	0	0	0	0		0	0	1	1	2	1	3		85	
90	19	0	0	0	0	0		0	0	1	0	1	1	3		0	0	0	0	0		0	0	1	1	2	1	3		90	
95	20	0	0	0	0	0		0	0	1	0	1	1	3		0	0	0	0	0		0	0	1	1	2	2	1		95	
100	21	0	0	0	0	0		0	0	1	0	1	1	3		0	0	0	0	0		0	0	1	1	2	2	1		100	
105	22	0	0	0	0	0		0	0	1	0	1	1	3		0	0	0	0	0		0	0	1	1	2	2	3		105	
110	23	0	0	0	0	0		0	0	1	0	1	1	3		0	0	0	0	0		0	0	1	1	2	1	3		110	
115	24	0	0	0	0	0		0	0	1	0	1	1	3		0	0	0	0	0		0	0	1	1	2	1	3		115	
120	25	0	0	0	0	0		0	0	1	0	1	1	3		0	0	0	0	0		0	0	1	1	1	1	3		120	
125	26	0	0	0	0	0		0	0	1	0	1	1	3		0	0	0	0	0		0	0	1	1	1	1	3		125	
130	27	0	0	0	0	0		0	0	1	0	1	1	3		0	0	0	0	0		0	0	1	1	1	1	3		130	
135	28	0	0	0	0	0		0	0	1	0	1	1	3		0	0	0	0	0		0	0	1	1	1	1	3		135	
140	29	0	0	0	0	0		0	0	1	0	1	1	3		0	0	0	0	0		0	0	1	1	1	1	3		140	
145	30	0	0	0	0	0		0	0	1	0	1	1	3		0	0	0	0	0		0	0	1	1	1	1	3		145	
150	31	0	0	0	0	0		0	0	1	0	1	1	3		0	0	0	0	0		0	0	1	1	1	1	3		150	
155	32	0	0	0	0	0		0	0	1	0	1	1	3		0	0	0	0	0		0	0	1	1	1	1	3		155	
160	33	0	0	0	0	0		0	0	1	0	1	1	3		0	0	0	0	0		0	0	1	1	1	1	3		160	
165	34	0	0	0	0	0		0	0	1	0	1	1	3		0	0	0	0	0		0	0	1	1	1	1	3		165	
170	35	0	0	0	0	0		0	0	1	0	1	1	3		0	0	0	0	0		0	0	1	1	1	1	3		170	
175	36	0	0	0	0	0		0	0	1	0	1	1	3		0	0	0	0	0		0	0	1	1	1	1	3		175	
180	37	0	0	0	0	0		0	0	1	0	1	1	3		0	0	0	0	0		0	0	1	1	1	1	3		180	
185	38	0	0	0	0	0		0	0	1	0	1	1	3		0	0	0	0	0		0	0	1	1	1	1	3		185	
190	39	0	0	0	0	0		0	0	1	0	1	1	3		0	0	0	0	0		0	0	1	1	1	1	3		190	
195	40	0	0	0	0	0		0	0	1	0	1	1	3		0	0	0	0	0		0	0	1	1	1	1	3		195	
200																															

RRST Pavement Condition Monitoring
Concrete Pavement Condition Assessment **Form C1.1** **Section** T3

Inspector Pham Gia Tuan

Road Tan Thuan Tay **Form** **Date** 05/01/2006 **Start Point** 1.300

Chain	Block	Joint Condition	Left Hand Carriageway Cracks Type	Intensity	Position	Width	Extent	Surface	Potholes	Edge	Shoulder Cracks	Erosion	Run-off	Drain	Right hand Carriageway Cracks Type	Intensity	Position	Width	Extent	Surface	Potholes	Edge	Shldr Cracks	Erosion	Run-off	Drain	Photo	Comment
0	1	1	0	0	0	0	0	1	0	1	1	0	2		0	0	0	0	0	1	0	1	1	0	3			
5	2	1	0	0	0	0	0	1	0	1	1	1	2		0	0	0	0	0	1	0	1	1	0	3			
10	3	1	0	0	0	0	0	3	0	1	1	2	2		0	0	0	0	0	3	0	1	1	1	3			
15	4	1	0	0	0	0	0	3	0	1	1	2	2		0	0	0	0	0	3	0	1	0	1	3			
20	5	1	0	0	0	0	0	1	0	1	1	2	3		0	0	0	0	0	1	0	1	0	1	3			
25	6	2	0	0	0	0	0	1	0	1	0	0	3		0	0	0	0	0	1	0	1	0	3	3			
30	7	1	0	0	0	0	0	1	0	1	0	0	3		0	0	0	0	0	1	0	1	0	2	3			
35	8	1	0	0	0	0	0	1	0	1	0	0	3		0	0	0	0	0	1	0	1	0	2	3			
40	9	2	0	0	0	0	0	1	0	1	0	3	3		0	0	0	0	0	1	0	1	0	2	3			
45	10	1	0	0	0	0	0	1	0	1	0	3	3		0	0	0	0	0	1	0	1	0	2	3			
50	11	2	0	0	0	0	0	3	0	1	0	2	3		0	0	0	0	0	3	0	1	0	2	3			
55	12	1	0	0	0	0	0	3	0	1	0	2	3		0	0	0	0	0	3	0	1	0	2	3			
60	13	1	0	0	0	0	0	1	0	1	0	3	3		0	0	0	0	0	1	0	1	0	1	3			
65	14	1	0	0	0	0	0	1	0	1	0	3	3		0	0	0	0	0	1	0	1	0	2	3			
70	15	1	0	0	0	0	0	1	0	1	0	2	3		0	0	0	0	0	1	0	1	0	2	3			
75	16	1	0	0	0	0	0	1	0	1	0	2	3		0	0	0	0	0	1	0	1	0	0	3			
80	17	1	0	0	0	0	0	3	0	1	2	2	3		0	0	0	0	0	3	0	1	0	1	3			
85	18	1	0	0	0	0	0	3	0	1	2	2	3		0	0	0	0	0	3	0	1	0	1	3			
90	19	1	0	0	0	0	0	1	0	1	3	2	3		0	0	0	0	0	1	0	1	0	1	3			
95	20	1	0	0	0	0	0	1	0	1	3	2	3		0	0	0	0	0	1	0	1	0	1	3			
100	21	2	0	0	0	0	0	3	0	1	1	1	1		0	0	0	0	0	3	0	1	1	1	1			
105	22	1	0	0	0	0	0	3	0	1	1	2	1		0	0	0	0	0	3	0	1	1	1	1			
110	23	1	0	0	0	0	0	1	0	1	1	1	1		0	0	0	0	0	1	0	1	1	1	1			
115	24	1	0	0	0	0	0	1	0	1	1	1	1		0	0	0	0	0	1	0	1	1	1	1			
120	25	1	0	0	0	0	0	1	0	1	1	1	1		0	0	0	0	0	1	0	1	1	1	1			
125	26	2	0	0	0	0	0	1	0	1	1	1	1		0	0	0	0	0	1	0	1	0	1	1			
130	27	1	0	0	0	0	0	1	0	1	0	1	1		0	0	0	0	0	1	0	1	0	1	1			
135	28	1	0	0	0	0	0	1	0	1	1	1	1		0	0	0	0	0	1	0	1	0	1	1			
140	29	1	0	0	0	0	0	1	0	1	1	1	1		0	0	0	0	0	1	0	1	1	1	1			
145	30	1	0	0	0	0	0	1	0	1	1	1	1		0	0	0	0	0	1	0	1	1	1	1			
150	31	2	0	0	0	0	0	1	0	1	1	0	1		0	0	0	0	0	1	0	1	1	1	1			
155	32	1	0	0	0	0	0	1	0	1	0	0	1		0	0	0	0	0	1	0	1	1	1	1			
160	33	1	0	0	0	0	0	1	0	1	0	0	1		0	0	0	0	0	1	0	1	0	1	1			
165	34	1	0	0	0	0	0	1	0	1	0	0	1		0	0	0	0	0	1	0	1	0	0	1			
170	35	1	0	0	0	0	0	1	0	1	0	0	1		0	0	0	0	0	1	0	1	0	0	1			
175	36	2	0	0	0	0	0	1	0	1	0	0	1		0	0	0	0	0	1	0	1	0	0	1			
180	37	1	0	0	0	0	0	1	0	1	0	0	1		0	0	0	0	0	1	0	1	0	0	1			
185	38	1	0	0	0	0	0	1	0	1	0	0	1		0	0	0	0	0	1	0	1	0	0	1			
190	39	1	0	0	0	0	0	1	0	1	0	0	1		0	0	0	0	0	1	0	1	0	0	1			
195	40	1	0	0	0	0	0	1	0	1	0	0	1		0	0	0	0	0	1	0	1	0	0	1			
200																												

RRST GUIDELINES
RURAL ROAD PAVEMENT AND SURFACE CONDITION MONITORING

APPENDIX C

IN SITU STRENGTH TESTING BY DCP

THE DCP EQUIPMENT

1 INTRODUCTION

The TRL DCP (Dynamic Cone Penetrometer SOI0026) is an instrument designed for the rapid in-situ measurement of the structural properties of existing road pavements constructed with unbound materials (Figure C1). Continuous measurements can be made down to a depth of approximately 850mm or, when extension shafts are used (Figure C2) to a recommended maximum depth of 2 metres. Where pavement layers have different strengths the boundaries can be identified and the thickness of the layers determined.

Correlations have been established between measurements with the DCP and CBR (California Bearing Ratio) so that results can be interpreted and compared with CBR specifications for pavement design. A typical test takes only a few minutes and therefore the instrument provides a very efficient method of obtaining information.

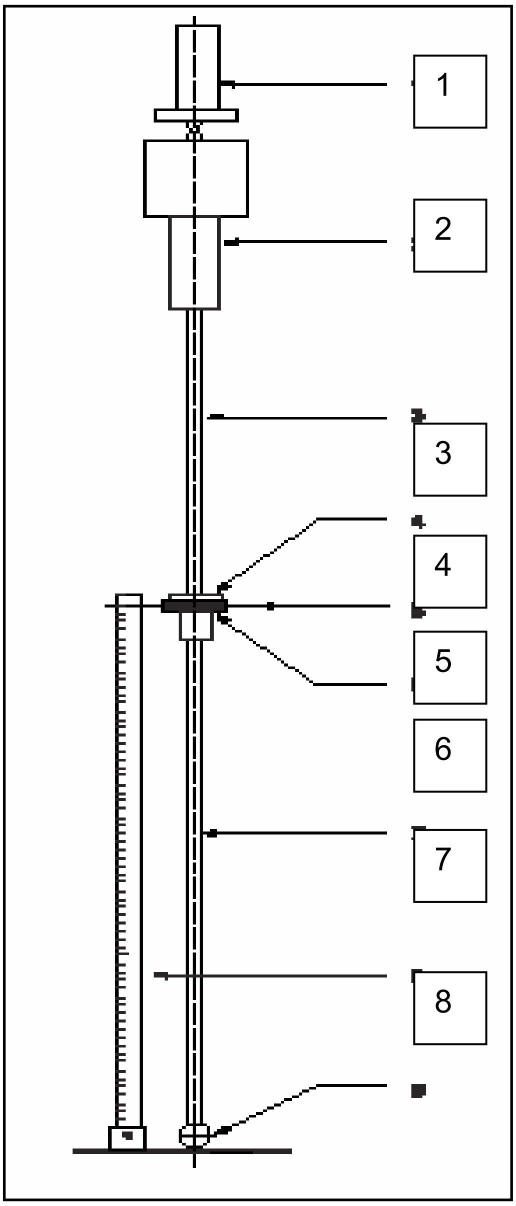


Figure C1: The Assembled DCP

1. Handle
2. 8kg Hammer
3. Hammer shaft
4. Coupling
5. Handguard
6. Clamp ring
7. Standard shaft
7.1m rule
8. 60 degree cone

2 ASSEMBLY

The design of the DCP uses an 8kg weight dropping through a height of 575mm and a 60^0 cone having a diameter of 20mm.

The instrument is assembled as shown in Figure C1. and should be supplied with appropriate tools such as: two 13-17mm AF Spanners, Tommy Bar, 3mm AF Hex Wrench and a bottle of 'Loctite 242' used for securing handle/top rod and bottom rod/cone joints.

Some instruments are usually split at the top rod/anvil joint for carriage and storage. Later models are split at the lower rod/anvil joint to facilitate the use of extension shaft sets. <u>It is important that joints are checked regularly during use as operating the DCP with any loose joints will reduce the life of the instrument considerably.</u>

3 OPERATION

After assembly, the first task is to record the zero reading of the instrument. This is done by standing the DCP on a hard surface checking that it is vertical and then entering the zero reading in the appropriate place on the test sheet (Figure C3).

The DCP needs three operators, one to hold the instrument, one to raise and drop the weight and one to record the results. The instrument is held vertical with the weight touching the handle, but not lifting the instrument. The operator then lets it fall freely (with out lowering it by hand). If during the test the DCP leaves the vertical, no attempt should be made to correct this as contact between the bottom shaft and the sides of the hole will give rise to erroneous results.

It is recommended that a scale reading should be taken at increments of penetration of about 10mm. However it is usually easier to take a reading after a set number of blows. It is therefore necessary to change the number of blows between readings according to the strength of the layer being penetrated. For good quality granular bases readings every 5 or 10 blows are normally satisfactory but for the weaker sub-base layers and sub-grade readings every 1 or 2 blows may be appropriate. There is no disadvantage in taking too many readings, but if too few are taken, weak spots may be missed and it will be more difficult to identify layer boundaries accurately hence important information will be lost.

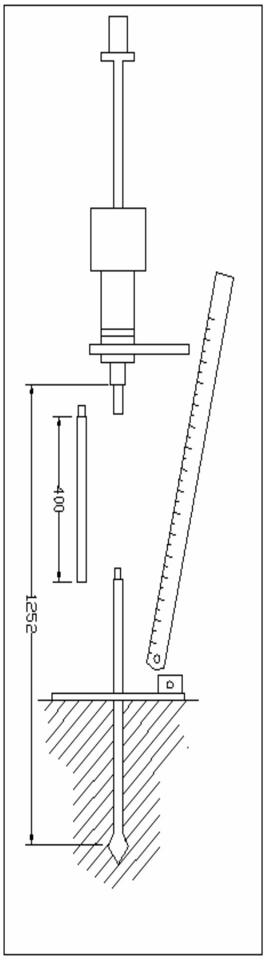


Figure C2: Extension Shaft

When the extended version of the DCP is used the instrument must be driven into the pavement to a depth of 500-600mm before the extension rod is added. To do this the meter rule has to be detached from its base plate and the bottom shaft split to accept the extension. After re-assembly a penetration reading should be taken before the test is continued.

After completing the test, the DCP is removed by gently tapping the weight upwards against the handle. Care should be taken as if this is done too vigorously damage may result.

Little difficulty is normally experienced with the penetration of most types of granular or lightly stabilised materials. It is more difficult to penetrate strongly stabilised layers, granular materials with large cobbles and very dense, high quality crushed stone. The instrument has been designed for strong materials and therefore the operator should persevere with the test. Penetration rates as low as 0.5mm/blow are acceptable but if there is no measurable penetration after 20 consecutive blows it can be assumed that the DCP will not penetrate the materials. Under these circumstances a hole can be drilled through the layer using an electric or pneumatic drill or by coring. The lowers of pavement can then be tested in the normal way. If only occasional difficulties are experienced in penetrating granular materials it is worthwhile repeating any failed tests a short distance away from the original test point.

The DCP can be driven through both single and double surface dressings but it is recommended that thick bituminous surfacing or concrete paving should be cored prior to testing the underlying layers.

SITE/ROAD	DATE
	TEST NO
SECTION NO/CHAINAGE	DCP ZERO READING mm
DIRECTION	TEST STARTED AT
WHEEL PATH	

No OF BLOWS	TOTAL BLOWS	READING mm	No OF BLOWS	TOTAL BLOWS	READING mm	No OF BLOWS	TOTAL BLOWS	READING mm

Figure C3: Standard DCP Field Sheet

If the DCP is used extensively for hard materials, wear on the cone itself will be accelerated. The cone is a replaceable item and it is recommended by many authorities that replacement be made when the diameter has reduced by 10 percent. However other causes of wear can also occur hence the cone should be inspected before every test. Typically the cone will need replacing after about 10 holes in hard material and in the absence of damage other than shoulder wear this is the recommended practice.

4 INTERPRETATION OF RESULTS

The results of the DCP test are usually recorded on a field test sheet similar to that shown in Figure C3 and the results can then either be interpreted by hand calculator or transferred to a standard EXCEL-type spread-sheet and processed by computer, Figure C4. Alternatively, there is now available a DFID funded TRL computer programme that can be used to calculate not only layer depths and CBRs but other related relationships and plots. This programme may be downloaded via www.transport-links.org, Figures C5-C6 show example screens.

The boundaries between layers are easily identified by the change in the rate of penetration. The thickness of the layers can usually be obtained to within 10mm except where it is necessary to core (or drill holes) through materials to obtain access to the lower layers. In these circumstances the top few millimeters of the underlying layer is often disturbed slightly and appear weaker than normal.

Relationships between the DCP readings and CBR have been obtained by several authors. The relationship derived by Kleyn and Van Heerden is based on the largest data set and is the one currently used by the TRL.

1. Kleyn and Van Heerden (60^o cone) $Log_{10}(CBR) = 2.632 – 1.28\ Log_{10}(mm/blow)$
2. Smith and Pratt (30^o cone) $Log_{10}(CBR) = 2.555 – 1.145\ Log_{10}(mm/blow)$
3. Van Vuuren (30^o cone) $Log_{10}(CBR) = 2.503 – 1.15\ Log_{10}(mm/blow)$
4. TRL, Road Note 8 (60^o cone) $Log_{10}(CBR) = 2.480 – 1.057\ Log_{10}(mm/blow)$

Agreement is generally good over most of the range but differences are apparent at low values of CBR, especially for fine grained materials. It is expected that for such materials the relationship between DCP and CBR will depend on material state, therefore the precise values are needed. It is advisable to calibrate the DCP for the materials in question. The user should consult the references for advice.

A number of estimated relationships between CBR and MR (Modulus of Resilience) are reported in the Vietnamese specification for the design of flexible pavements (22TCN-274-01; Guidelines for the Design of Flexible Pavements). These are:

Powell W.D (1984- TRL):

$Eo = 17.6\ (CBR)^{0.64}$ MPa (1MPa = 145 psi)
$= 176\ (CBR)^{0.64}\ daN/cm^2$

Heukelom and Klomp:

MR(psi) = 1500 x CBR (1 psi = 6.9KPa)

MR – Modulus of Resilience

Carbro Intern

MR = 4.(CBR) + 10 MPa (1MPa = 145 psi)

Croney and Croney

Eo (MPa) = 6,6 CBR
Eo (daN/cm^2) = 660 CBR
1 daN/cm^2 = 0,01 MPa

Note
Pa = 1N/m2
1N/cm^2 = 0.1 daN/cm^2
1MPa = 1000Pa = 1000N/10000cm^2 = 0.1 N/cm^2 = 0.01 daN/ cm^2

Typical values are showed in Table C1 for comparison, although it must be emphasised that these **correlations should be used with extreme caution and for general guidance only**, as experience has shown they can vary significantly between material types. .

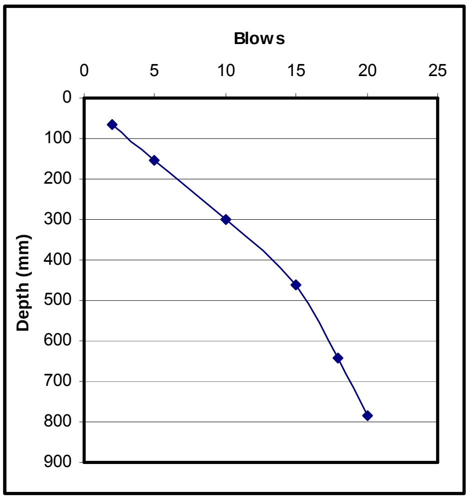
DCP-CBR	Equivalent Modulus of Resilience (daN/cm2)		
	Carl Bro	Powell(TRL)	Croney
1	140	176	152
2	180	274	303
3	220	356	455
4	260	427	606
5	300	493	758
6	340	554	909
7	380	611	1061
8	420	666	1212
9	460	718	1364
10	500	768	1515
12	580	863	1818
15	700	996	2273
20	900	1197	3030
25	1100	1381	3788
30	1300	1552	4545
35	1500	1713	5303
40	1700	1866	6061
45	1900	2012	6818
50	2100	2152	7576
75	3100	2790	11364
100	4100	3354	15152

Table C1: DCP-MR Correlations

HUE DCP FIELD SHEET								
Site/Road		Phu Loc Road			Date		19/11/2002	
Test No.		PL.07			Operator		Ph¹m Gia TuÊn	
Site Location					Zero Reading (C^0)		107.0	
Test Location		RS			Depth of Start		0.0	
No.Blows	Total Blows	Pen (mm)	Correct Pen	Pen	Pen/blow	LogP	No	CBR
a	b	c	d	e	f	g	h	j
		107						
2	2	174	67.0	67	33.5	1.5250	0.8680	7.4
3	5	259	152.0	85	28.33333	1.4523	0.9449	8.8
5	10	406	299.0	147	29.4	1.4683	0.9280	8.5
5	15	570	463.0	164	32.8	1.5159	0.8777	7.5
3	18	750	643.0	180	60.0	1.7782	0.6005	4.0
2	20	890	783.0	140	70.0	1.8451	0.5297	3.4

Formulas for Excel

a	b	c	d	e	f	g	h	i
Input	$b^n=a^n+a^{n-1}$	Input	$d^n=c^n-c^0$	$en=d^n-d^{n-1}$	f = e/a	g=log10(f)	h=2.48-1.057*g	i=10*h



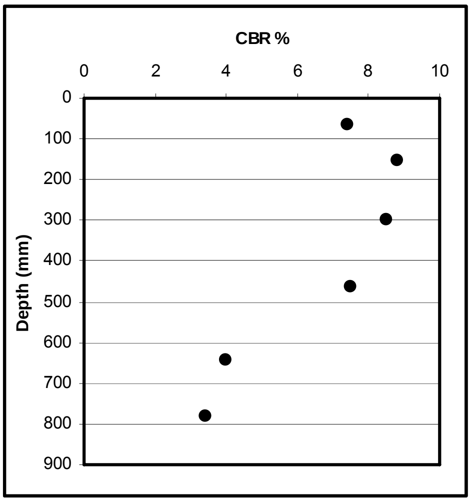


Figure C4: Typical EXCEL Calculation Sheet and Plots for DCP Data

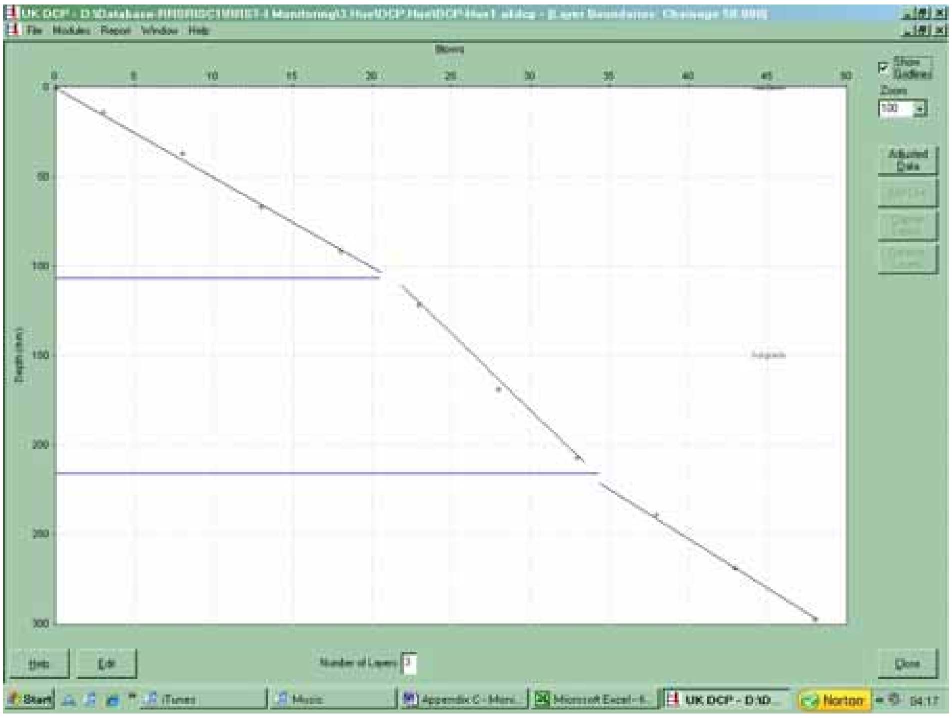


Figure C5: UKDCP Analysis Sheet

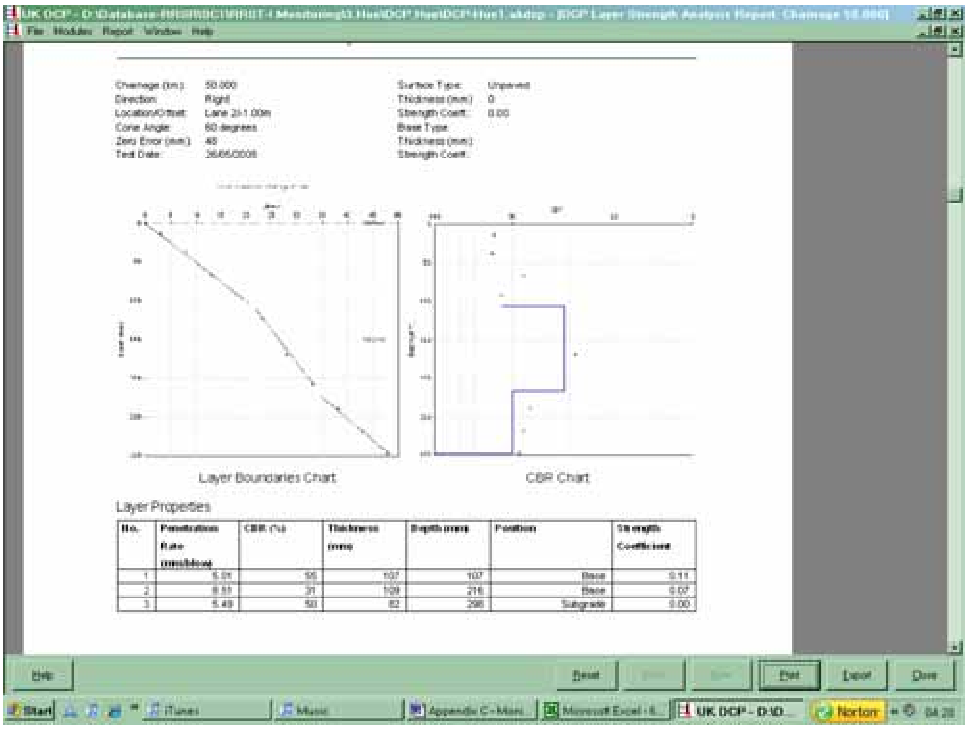
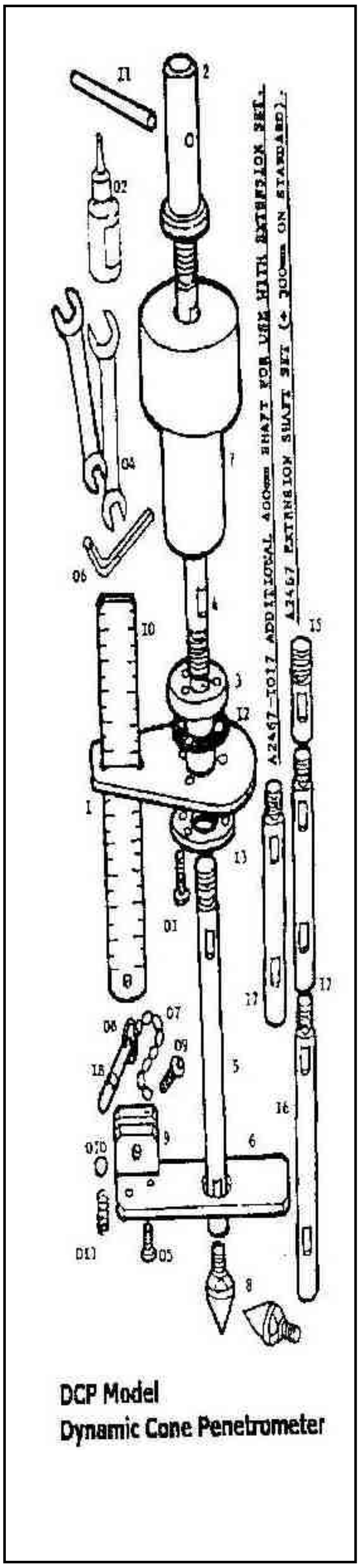


Figure C6: UKDCP CBR Report Sheet



Item	Part Code	Description
1	SOI0026 1	Hand Guard
2	SOI0026 2	Handle
3	SOI0026 3	Coupling
4	SOI0026 4	Hammer Shaft-890mm
5	SOI0026 5	Standard Shaft (lower) 910mm
6	SOI0026 6	Base Plate
7	SOI0026 7	Weight
8	SOI0026 8	Cone 60^o
9	SOI0026 9	Clevis Block
10	SOI0026 10	Rule Rabone
11	SOI0026 11	Tommy Bar
12	SOI0026 12	Damping Washer
13	SOI0026 13	Support Ring
14	SOI0026 14	Case
15	SOI0026 1015	Upper Extension Shaft-70mm
16	SOI0026 1016	Lower Extension Shaft-785mm
17	SOI0026 1017	Extension Shaft-400mm
18	SOI0026 18	Rule Pin
01		Button Headscrew M5x20 (3pack)
02	SOI0026 02	Bottle Loctite
04	SOI0026 04	Spanner 13-17AF
05	SOI0026 05	Countersunk Screw M5x16(X2)
06	SOI0026 06	Hex Wrench
07	SOI0026 07	Chain
08	SOI0026 08	Key Ring
09	SOI0026 09	But:HD:Socket Screw M5x15 (pack)
010	SOI0026 010	Steel Ball
011	SOI0026 011	Spring

Figure C7: Typical Parts List for a DCP Kit

RRST GUIDELINES
RURAL ROAD PAVEMENT AND SURFACE CONDITION MONITORING

APPENDIX D

MERLIN ROUGHNESS SURVEYING

MACHINE FOR EVALUATING ROUGHNESS
USING LOW-COST INSTRUMENTATION
- MERLIN Guide -

1 Introduction

The Merlin (Plate1) is a device for deriving the International Roughness Index for paved and unpaved roads (**MERLIN** - **M**achine for **E**valuating **R**oughness using **L**ow-cost **IN**strumentation). A detailed explanation of its development can be found in Cundill 1991 (TRL Research Report 301). The device is suitable for both paved and unpaved roads.

Plate 1: The MERLIN Equipment

MERLIN has now been successfully manufactured in Vietnam based on the TRL design and used for Rural Road surface evaluation for the Rural Road Surfacing Trial Project. A Vietnam made MERLIN costs USD200. While a UK made machine would cost more than USD1,000.

This document presents some basic specifications and instructions on how to use this MERLIN.

2 MERLIN Description

The MERLIN device works by transferring an expression of surface roughness onto a standard recording chart by means of the calibrated movement of a central foot and lever. The principal components of the MERLIN are as shown in Figure D1.

The Merlin can be operated in one of two different modes. The mode of operation depends on the location of the measuring foot (see below). By changing the position of the foot the magnification factor can be set to either 5:1 or 10:1, this dictates how far the chart pointer moves compared to the measurement probe. That is, when the Merlin is set to 5:1 magnification the pointer moves approximately 5mm on the chart for every 1mm the probe moves. Therefore for very rough surfaces the Merlin needs to be set to 5:1 magnification and for smooth surfaces the Merlin should be set to 10:1 magnification Figure D2

3 Merlin Calibration

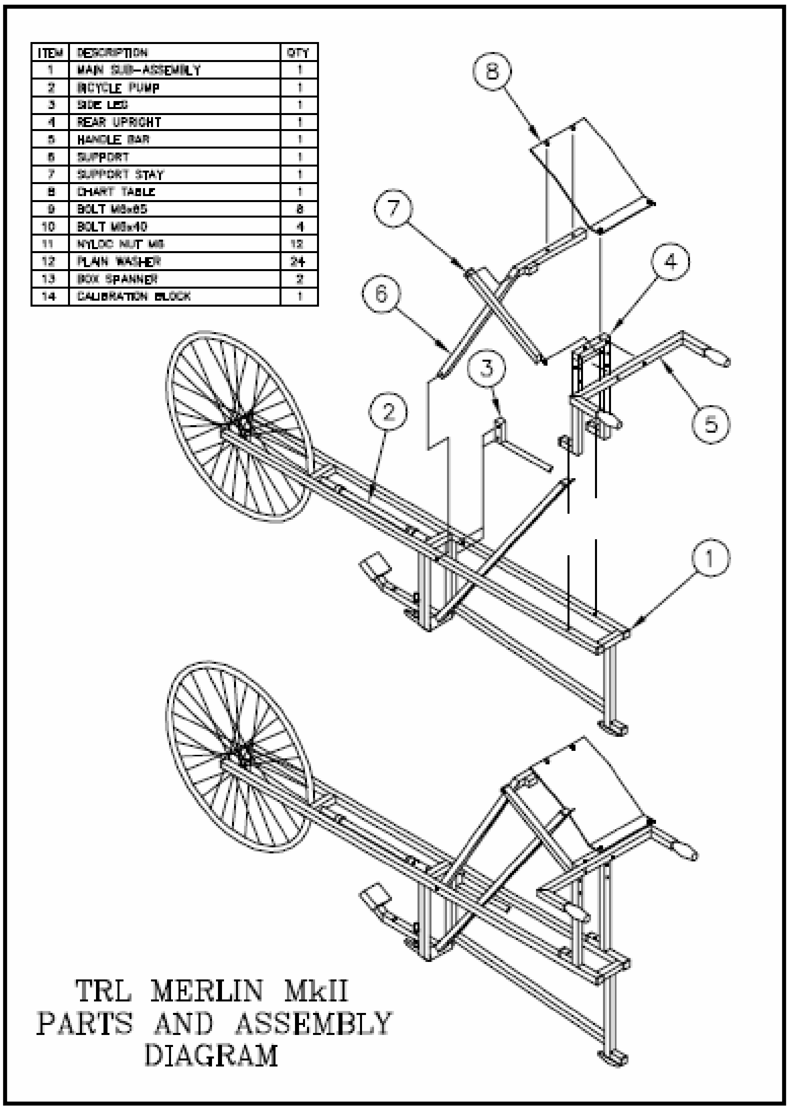
Prior to use the Merlin must be calibrated to produce a scaling factor (Sf), this will correct any discrepancy in the magnification between the probe and the chart pointer. Determination of the Sf is given in detail in TRL Report 229 and is briefly described below.

Calibration is a simple procedure. Place the Merlin on a flat surface, make a mark on the edge of the Merlin chart next to the pointer. A calibration block (usually made from machined metal) of known thickness (T), usually about 6 mm, is then placed under the probe and a second mark is made on the Merlin chart next to the new position of the pointer. The distance between these two marks, measured in mm, is the displacement (S).

The Scaling factor, $Sf = \dfrac{10 \times T}{S}$ When MERLIN in 10:1 Magnification (equation 1)

$$Sf = \frac{5 \times T}{S}$$ When MERLIN in 5:1 Magnification

For example, if a block of metal of thickness 6.5 mm, produces a Merlin pointer displacement of 32.5 mm when set in the 10:1 position, then T=6.5, S=32.5, hence Sf = (10x6.5)/32.5 = 2.



ITEM	DESCRIPTION	QTY
1	MAIN SUB-ASSEMBLY	1
2	BICYCLE PUMP	1
3	SIDE LEG	1
4	REAR UPRIGHT	1
5	HANDLE BAR	1
6	SUPPORT	1
7	SUPPORT STAY	1
8	CHART TABLE	1
9	BOLT M8x65	8
10	BOLT M8x40	4
11	NYLOC NUT M8	12
12	PLAIN WASHER	24
13	BOX SPANNER	2
14	CALIBRATION BLOCK	1

Figure D1: The MERLIN Equipment

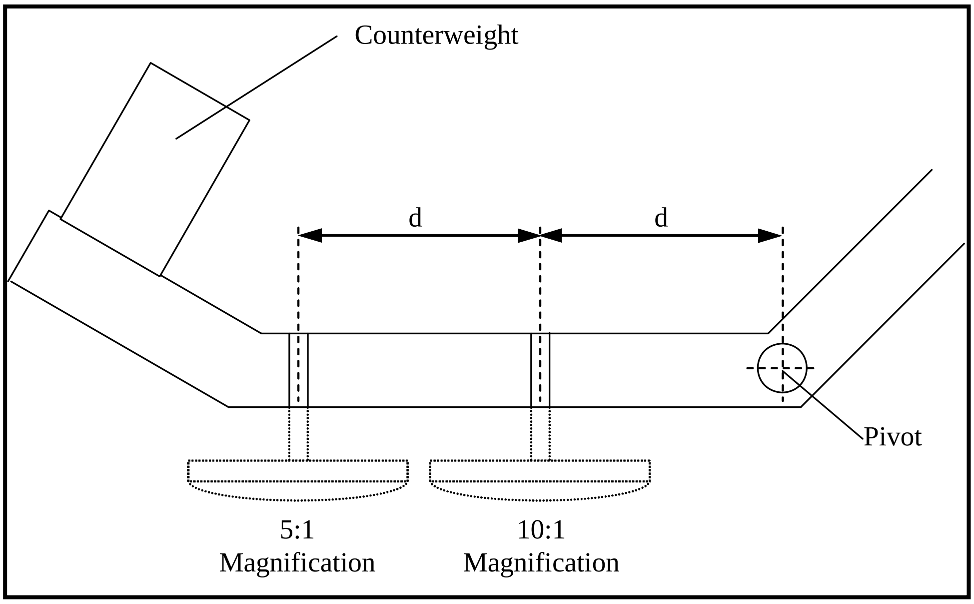


Figure D2: Alternative Probe Positions

4 Survey Operation

Plate 2

Plate 3

1. Merlin Calibration; as per section 3 above.

2. Place the Merlin on one wheel track. Put a mark (x) in pointer position cell on the chart and also mark (x) in the small counting check box (Plates 2 and 3).

3. Lift and push the Merlin forward one half – wheel distance. Stop, lower the machine to

   rest on the surface and make further marks as above.

4. Continue this process for the length of the wheel track on the trial section and then survey the second wheel track. One Merlin sheet is used for each measurement of 1 wheel track section.

5. Having completed the survey (maximum of approximately 200 readings) then the IRI can be calculated. Figure D4 is a typical completed field-sheet

6. Note the number of readings (Number of marked cells in the small check box) e.g. 186 cells.

7. Calculate 5% of the total number of Merlin measurements; e.g. for 186 readings, 5% = (5/100)x186 = 9.3

8. Count in 9.3 of readings from each end of the distribution on the Merlin sheet and make one mark at each of these points.

9. Measure the distance between these two marks (in mm), e.g. L = 103mm.

10. Calculate the scaling factor Sf = 10 x T/ S = 10 x 8 / 93 = 0.86 (10:1 Magnification)

11. Calculate the Merlin D value. This is determined by multiplying the distance measured in c) by the scaling factor (Sf), which should already have been calculated in equation: D = L x Sf = 103 x 0.86 = 88.58

12. Calculate the IRI for each wheel path using:
    13. IRI = 0.593 + (0.0471xD) = 0.593 +(0.0471x88.58) = 4.8 mm/m

14. Calculate the average IRI for the section by taking the mean of the results for each wheel path. The final result should be a single IRI value (in mm/m) for the section. The above calculations can be easily set up as standard Excel sheet. Table D1 presents an example from Tien Giang, RRST-I. Table D2 summarises standard interpretations of IRI figures.

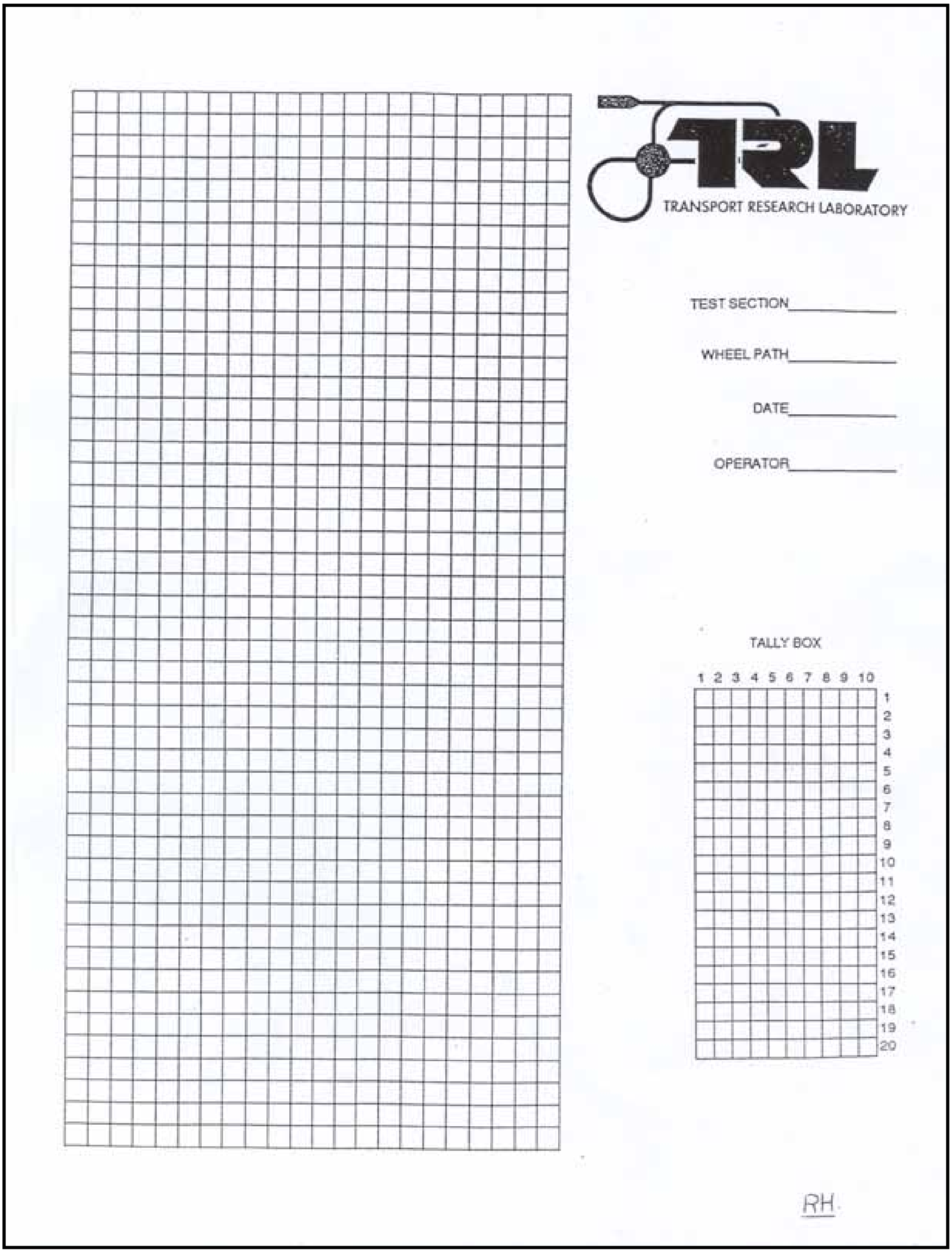


Figure D3: Typical MERLIN Field Chart

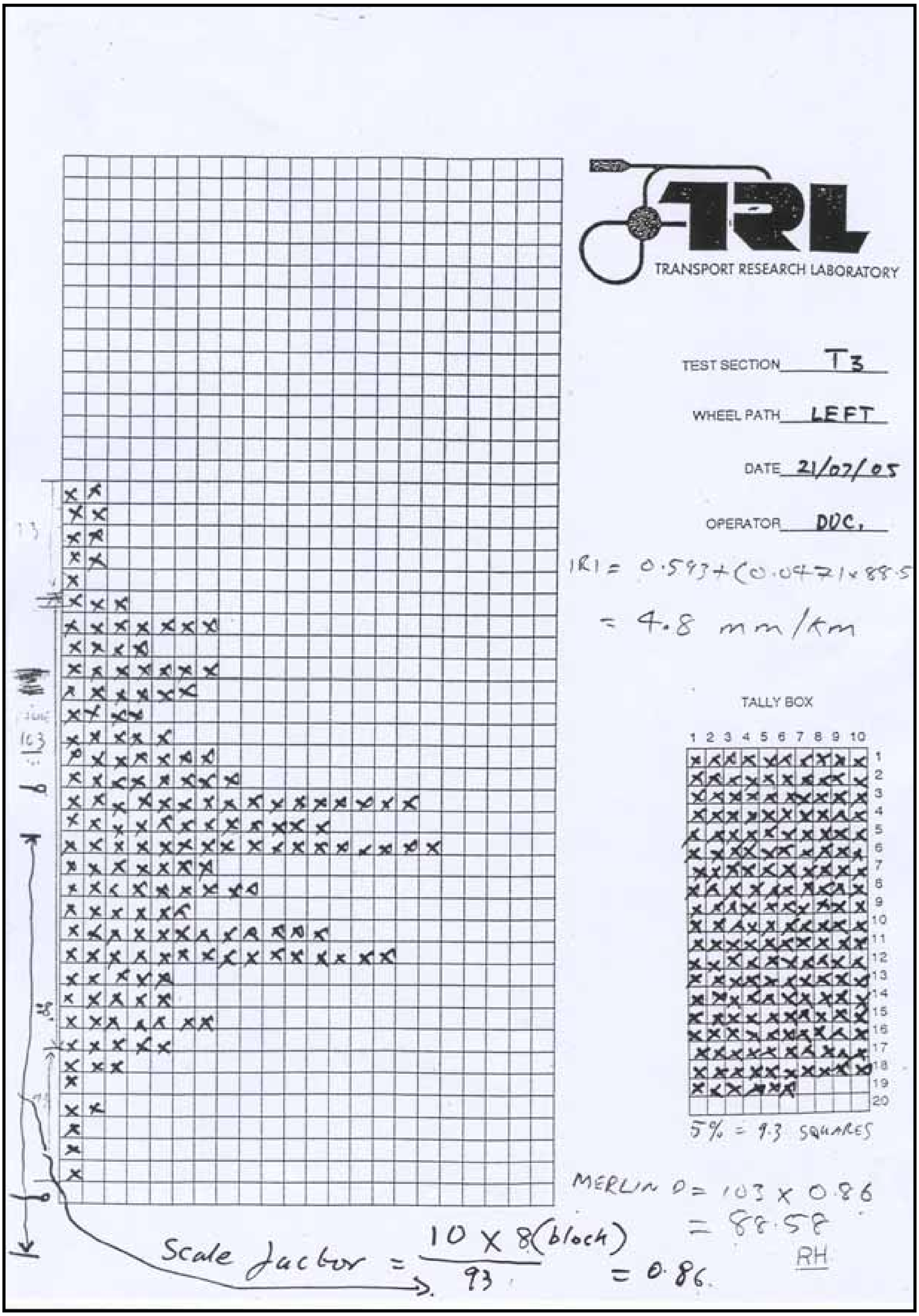


Figure D4: Typical Completed MERLIN Chart

No.	Road Name	Wheel Path	Date	S (mm)	Scaling Factor	D 1 (mm)	Dc 1 (mm)	IRI 1 (m/km)
	Tien Giang							
8	T2	RHL	28/07/2005	93	0.86	116.00	99.78	5.29
	Bamboo Reinforced concrete	CL						
		LHL	21/07/2005	93	0.86	121.00	104.09	5.50
9	T3	RHL	27/07/2005	93	0.86	98.00	84.30	4.56
	Steel Reinforced concrete	CL						
		LHL	21/07/2005	93	0.86	103.00	88.60	4.77
10	T4	RHL	28/07/2005	93	0.86	183.00	157.42	8.01
	Sand seal on DBM	CL						
		LHL	28/07/2005	93	0.86	190.00	163.44	8.29
11	T5	RHL	07/08/2005	93	0.86	190.50	163.87	8.31
	Sand seal on DBM	CL						
		LHL	21/07/2005	93	0.86	186.00	160.00	8.13
12	T6	RHL	07/08/2005	93	0.86	112.00	96.34	5.13
	Sand seal on Lime stab soil	CL						
		LHL	21/07/2005	93	0.86	125.00	107.53	5.66
13	T7	RHL	21/07/2005	93	0.86	170.00	146.24	7.48
	Pen Mac	CL						
		LHL	21/07/2005	93	0.86	166.00	142.80	7.32
14	T8	RHL	21/07/2005	93	0.86	204.00	175.48	8.86
	WBM	CL						
		LHL	21/07/2005	93	0.86	128.00	110.11	5.78
15	T9	RHL	28/07/2005	93	0.86	105.00	90.32	4.85
	Bamboo Reinforced concrete	CL						
		LHL	21/07/2005	93	0.86	118.00	101.51	5.37
16	T10	RHL	28/07/2005	93	0.86	103.00	88.60	4.77
	Natural Gravel	CL						
		LHL	21/07/2005	93	0.86	114.00	98.06	5.21

Table D1: MERLIN Spreadsheet for IRI Calculations

IRI (Roughness Range)	Road description
1.5 → 2.5	Recently bladed surface of fine gravel or soil surface with excellent longitudinal and transverse profile (usually found only in short lengths).
3.5 → 4.5	Ride comfortable up to 80-100km/h, aware of gentle undulations or swaying. Negligible depressions (e.g. < 5mm/3m) and no potholes.
7.5 → 9.0	Ride comfortable up to 70-80km/h but aware of sharp movements and some wheel bounce. Frequent shallow moderate depressions or shallow potholes (e.g. 6-30mm/3m with frequency 5-10 per 50m). Moderate corrugations (e.g. 6-20mm/0.7-1.5m).
11.5 → 13.0	Ride comfortable at 50km/h (or 40-70km/h on specific sections). Frequent moderate transverse depressions (e.g. 20-40mm/3m-5m at frequency 10-20 per 50m) or occasional deep depressions or potholes (e.g. 40-80mm/3m with frequency less than 5 per 50m). Strong corrugations (e.g. > 20mm/0.7-1.5m).
16.0 → 17.5	Ride comfortable at 30-40 km/h. Frequent deep transverse depressions and/or potholes (e.g. 40-80mm/1.5m at frequency 5-10 per 50m); or occasional very deep depressions (e.g. 80mm/1-5m with frequency less than 5 per 50m) with other shallow depressions. Not possible to avoid all the depressions except the worst.
20.0 → 22.0	Ride comfortable at 20-30km/h. Speeds higher that 40-50km/h would cause extreme discomfort and possible damage to the car. On a good general profile: frequent deep depressions and/or potholes (e.g. 40-80mm/1.5m at frequency 10-15 per 50m) and occasional very deep depressions (e.g. > 80mm/0.6-2m). On a poor general profile: frequent moderate defects and depressions (e.g. poor earth surface).

Table D2: Standard IRI Evaluations

RRST GUIDELINES
RURAL ROAD PAVEMENT AND SURFACE CONDITION MONITORING

APPENDIX E

UNSEALED SURFACE LEVEL DETERIORATION

UNSEALED SURFACE LEVEL DETERIORATION

1 Introduction

Level measurement is undertaken in order to measure material loss and deterioration in cross-sectional shape along designated monitoring sections. Greater accuracy than +/- 5mm is not necessary for this rural road activity and hence it is possible to use equipment readily available at PDoT level. Two measurement methods are described, as follows:

1. By measuring"dips" from a level tape.
2. By using standard simple Engineering Level (or theodolite) procedures.

In both cases measurements are taken at pre-determined cross-sections and compared with previous data from the same sections. For the RRT programme the Engineering Level method is currently in use.

2 Survey Layout

For the RRST programme the cross-sections are at 20m to 25m intervals and for a standard rural road 3.5m wide carriageway and each section includes 9 survey points at 0.5m apart (7 on the carriageway and 1 on each shoulder), Figure E1.

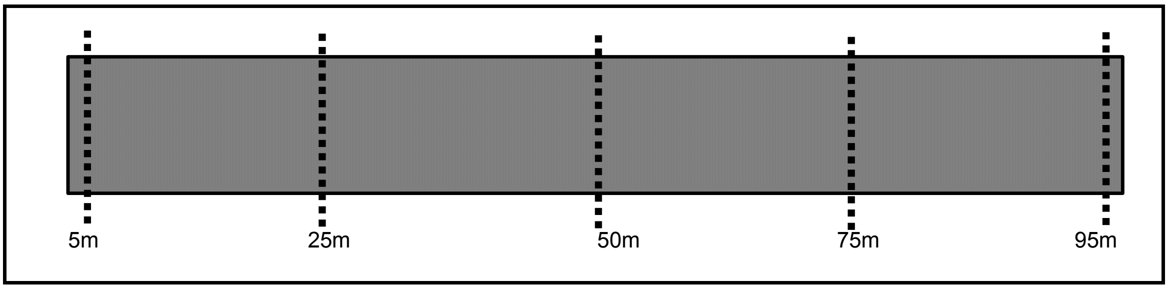


Figure E1: Level Survey Location Arrangement for Unsealed Surfaces

3. Dip Measurement Method

3.1 Description

Fixed peg stations are set out along the monitoring section on either side of the road at the require 20m or 25m intervals. These may either be concrete blocks into which fixed length rods may be inserted or rods permanently fixed into concrete blocks. In either case it is essential that the fixed peg stations are stable, robust and remain undisturbed during the monitoring period.

Once the peg stations have been set out the only equipment required is:

- Standard rod (if not fixed into pegs)
- Nylon string,
- Spirit level.
- 5m tape
- 2m measuring rod
- Standard Field Sheet

3.2 Procedure

For each cross-section location the following procedure should be followed:

1. Set up the nylon string across the section at the fixed rod height.
2. Ensure the string is horizontal of string by checking with spirit level (a light weight spirit level can be hung on the string). Figure E2
3. Using the 5m tape to determine the locations of the dip points along the cross section at 0.5m intervals .Figure E3
4. Use the 2m measuring rod or straight edge perpendicular to the string to measure and record the dips at the 0.5m intervals.

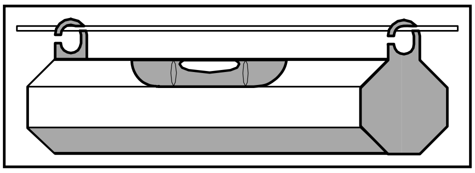


Figure E2: Light Weight Spirit Level

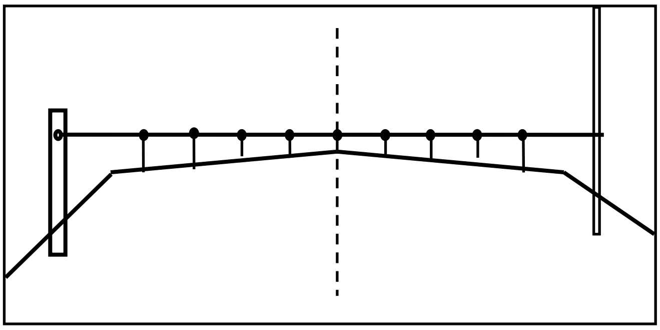


Figure E3: Simple Dip Measurement Method

The relative change in levels of survey points at each cross-section can be calculated by referring to previous dips at the same locations.

4 Measurement by Level*:*

4.1 Description

This procedure uses standard engineering leveling procedures to obtain road surface heights relative to fixed Temporary Bench Marks (TBMs). The TBMs must be fixed and robust enough to be used for all surveys during the monitoring period; for example, fixed on adjacent bridges or culverts. As a precaution it is recommended that the TBMs also be related to the Absolute Levels.

Required equipment is as follows

- Engineering level (or theodilite)
- Survey staff,
- 30m tape.
- Standard survey book or survey sheet

4.2 Survey procedures

.

1. Locate the level on stable ground between 2 bench marks so that these marks and the survey points on the road surface are observable from the level station.
2. Set up the instrument for horizontal leveling by use of the adjusting screws that support so that the bubble is centered in the spirit level. Check for gross errors by checking levels between TBMs.
3. Set out the cross-section location on the centre line by means of the 30m tape and locate and mark individual leveling points along the cross-section at 0.5m intervals from the centre line.
4. Use a TBM as Back Sight and note the staff levels in the survey book or sheet.
5. Note: on the RRST programme all surveys should be from low to high chainage and cross-section points measured in sequence from left shoulder to right shoulder,
6. Repeat actions 3 to 5 for all cross sections in the monitoring section.
7. Complete the survey by taking leveling readings back to the TBM to check for error.
8. If the level instrument has to be relocated during the survey (for long sections) ensure that the survey is "closed" back onto the bench mark for correlation.
9. The absolute or temporary levels of road surface cross-section points are calculated in a standard leveling procedure on the basis of TBM data.

The changes in road shape and cross-section levels are calculated by reference to previous monitoring surveys. Table E1 presents some typical monitoring results

		26/05/2005			HUE SURVEY					
Base 1 (culvert0		1225								
Base 2 (H12 E)		1180								
					(mm)					
		Sh(L)				CL				Sh(R)
	Section	1	2	3	4	5	6	7	8	9
A	5m	1630	1580	1550	1510	1495	1500	1520	1550	1590
B	25m	1565	1530	1455	1415	1400	1415	1440	1470	1530
C	50m	1550	1500	1475	1450	1440	1445	1460	1485	1540
D	75m	1530	1480	1440	1415	1410	1420	1450	1480	1550
E	95m	1500	1460	1430	1400	1390	1410	1445	1485	1535
	Reduced to culvert									
	A	595	645	675	715	730	725	705	675	635
	B	660	695	770	810	825	810	785	755	695
	C	675	725	750	775	785	780	765	740	685
	D	695	745	785	810	815	805	775	745	675
	E	725	765	795	825	835	815	780	740	690

Table E1: Sample Monitoring Data from Hue Trial Road (RRST-I)

5 Advantages and Disadvantages:

The advantages of the two surface level monitoring procedures are summarised in Table E2

Procedures	Advantages	Disadvantages
1.Dip Measurement	Straightforward and easy site measurement with no need for leveling equipment.	Significant danger of the movement or loss of cross-sectional peg markers over the monitoring period of at least 5 years.
2. Level Measurement	Greater accuracy than method 1. Base measurements more stable than 1 and are recoverable if reacted to absolute levels; less likelihood of losing base control.	Requires leveling equipment and suitably experienced technicians.

Table E2: Advantages and Disadvantages

RRST GUIDELINES
RURAL ROAD PAVEMENT AND SURFACE CONDITION MONITORING

APPENDIX F

MOISTURE CONTENT SAMPLING

MOISTURE CONTENT SAMPLING

1 Introduction

Moisture condition is monitored by sampling and testing materials from gravel and stabilised soil shoulders adjacent to the carriageway. (Plate F1) In some special situations it may be necessary to undertake moisture content profiles within the carriageway. This is not a standard requirement for the RRST monitoring. .

Plate F1: Moisture content sampling site

2 Procedures

Required equipment is

- Crowbar,
- Knife,
- Shovel or shovel-hoe
- Plastic bags and labels

1. Take 2 disturbed soil samples for each 50m of monitored section. More samples should be taken if there is an obvious change in moisture condition (Figure F1).

2. The minimum mass of samples is 100g for stabilised soil and 0.5kg for granular materials.

3. The samples should be typical of the in situ materials of shoulder, with any inclusions be taken out.

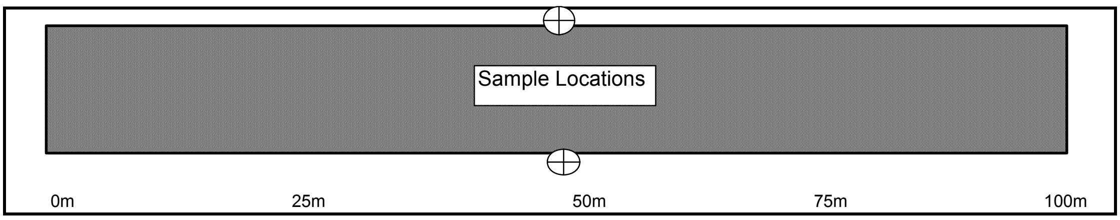


Figure F1: Moisture Content Sample Locations

4. Moisture content samples double sealed in plastic bags and stored in stainless steel box or plastic box with closed cover.

5. The samples should be labelled immediately with information, as shown Figure F2. Two labels should be use, one between the two plastic bags and one attached to the outside of the outer plastic bag.

6. The samples should be protected from excessive heat and moisture while stored on site or being transported to the laboratory testing.

7. While the samples are stored in the laboratory they should be maintained with humidity lower than 80% and the temperature being not higher than 20^{o}C.

8. The time taken from sampling to testing should not be longer than 5 days.

Project:	RRST monitoring
Trial road:	My Phuoc Tay
Consultant:	Intech-TRL
Sample No:	SHL-01
Chainage:	Km2+100
Surveyor:	Pham Gia Tuan
Date:	30 June 2006

Figure F2: Typical Sample Label

RRST GUIDELINES
RURAL ROAD PAVEMENT AND SURFACE CONDITION MONITORING

APPENDIX G

TRAFFIC COUNTS

TRAFFIC COUNTS

1 Introduction

The normal RRST traffic surveys are undertaken by means of **standard classified manual traffic counts**. In some circumstances, for example where there is a suspected risk of commercial vehicle overloading on light pavements, it may necessary to undertake more **detailed commercial traffic counts**. These latter counts may be undertaken in conjunction with axle load surveys.

The procedures in this document refer primarily to standard RRST manual traffic counts, although suitable forms are included for use in detailed commercial traffic counts as well.

2 Site Procedures

Manual counts are carried out by observers situated at an observation point at the side of the road, from where they record each vehicle on a survey form according to the vehicle type, Form G1.

For tertiary rural roads a minimum survey period of 3 days is recommended for RRST roads. A 7 day count is recommended where significant variability of traffic is suspected. Traffic should be counted in each direction for a 12 hour period, (6am to 6pm). A survey team should consist of at least two people to allow for a shift system to be adopted.

Periods of *abnormal* traffic flow should be avoided, (i.e. periods when relatively rare short-term events occur such as public holidays). In locations where a large seasonal variation occurs, surveys may be necessary at different times of the year to reduce errors in estimating annual traffic.

For more detailed commercial traffic counts Form G2 should be used.

3 Calculation

Figure G1shows a typical completed RRST form. From completed forms such as these the daily average flow counts for each vehicle type should be calculated and then converted into an equivalent daily traffic using the factors in Table G1 to determine the Average Daily Traffic (ADT).

If traffic is known to pass at night, then a multiplication by 1.2 should be applied to estimate the 24 hour count; if no traffic passes at night, the 24 hour count equals the day count. Table G2 presents a spreadsheet of typical results and from the RRST programmes.

Traffic Counted	ADT Factor
Truck>5t	5
Large Bus	5
Truck <5t	2.5
Small Bus	2
Cong Nong	1
Car	0.8
Animal	0.2
Motorcycle	0.1
Bicycle	0.05
Pedestrian	0.02

Table G1: Correction factors for Traffic Conversion to ADT
(Based on ORN 20, TRL, 2000)

Form G1: Standard RRST Traffic Count Form

FORM: Manual Classified Traffic Count

Province					**SURVEYOR**	
District					**LOCATION**	
Daily 12 hour counts	***DATE***					
Traffic Class						**Daily Average**
MOTORCYCLE						
CAR, 4WD, PICKUP						
CONG NONG & Tractor						
LIGHT TRUCK =< 5 TONS GVW						
TRUCK > 5 TONS GVW						
Mini-bus/Bus						
PEDESTRIAN, WALKER						
ANIMAL/HAND CART						
BICYCLE						
TOTALS						
Rain This Period?						
Daily Survey Period:	6.00 hours to 18.00 hours		*GVW =*	*Gross Vehicle Weight*		

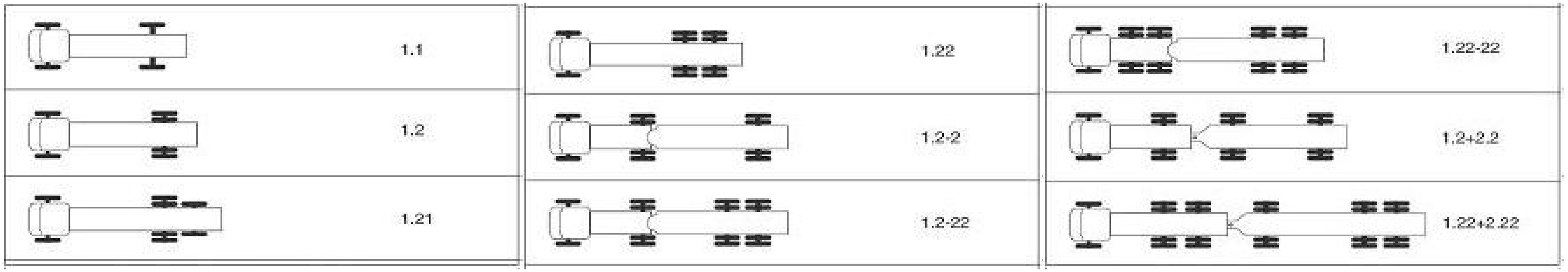
Form G2:
Commercial Vehicle Observation Survey Form

Observer/Surveyor: . . . . Location: . . . . Date: . . . .

No	Vehicle type	Truck/bus axle configuration	Make/of truck	Estimated "rated" gross vehicle weight	Actual loading status	Estimated body size (m3)	Description of payload	Vehicle Direction
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								

Notes:

1. This Survey form is intended to be used for observations of commercial trucks and buses **WITHOUT** stopping traffic or interfering with their natural flow. Some familiarization by the Observer will be required before the surveys commence to allow him/her to quickly and accurately assess the data to be recorded.
2. Traffic type: Information to be inserted in this box i.e. truck or bus.
3. Truck/bus axle configuration: insert number code i.e 1.2 etc. - see chart below



4. Make/Manufacturer of truck: if known.
5. Estimated "rated" gross vehicle weight: i.e. what the plating notice on the vehicle states
6. Actual loading status: Whether Empty/Part Full/Full Load.
7. Estimated body size: in cubic metres
8. Description of payload: stone/aggregates/earth/logs/timber/agricultural crops/building materials/other/unknown etc.
9. Vehicle Direction: coding for each direction, for example: 1 – Tien Phong → Quang Hien, 2 – Quang Hien → Tien Phong.

If the Observer is unsure about any entry, he/she should enter the data within brackets. It is appreciated that in some circumstances it will not be possible to record the data accurately and these incidences should be identified to assist with the survey analysis.

FORM: Manual Classified Traffic Count

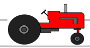
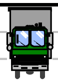
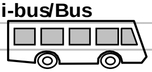
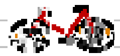
Province	Tien Giang				**SURVEYOR**	Nguyen Minh Nhat
District	Cay Lay				**LOCATION**	Mr Can's house
Daily 12 hour counts	***DATE (2003)***					
Traffic Class	**Tuesday 2nd December**	**Wednesday 3rd December**	**Thursday 4th December**	**Friday 5th December**	**Saturday 6th December**	**Daily Average**
MOTORCYCLE 	**730**	**671**	**711**	**867**	**743**	**744**
CAR, 4WD, PICKUP 			**4**		**2**	**1**
CONG NONG & **Tractor** 						**0**
LIGHT TRUCK =< 5 TONS GVW 	**2**	**4**	**4**	**4**		**3**
TRUCK > 5 TONS GVW 						**0**
Mini-bus/Bus 						**0**
PEDESTRIAN, WALKER	**111**	**119**	**124**	**172**	**107**	**127**
ANIMAL/HAND CART 						**0**
BICYCLE 	**620**	**686**	**667**	**847**	**613**	**687**
TOTALS	**1,463**	**1,480**	**1,510**	**1,890**	**1,465**	**1,562**
Rain This Period?	No Rain	No Rain	No Rain	No Rain	No Rain	
Daily Survey Period:	6.00 hours to 18.00 hours		*GVW =*	*Gross Vehicle Weight*		

Figure G1: Sample Data from RRST I

Traffic Item	Daily Average Counted	ADT Factor	ADT (12hrs)
Truck>5t	0	5	0
Large Bus	0	5	0
Truck <5t	3	2.5	8
Small Bus	0	2	0
Cong Nong	0	1	0
Car	1	0.8	1
Animal	0	0.2	0
Motorcycle	743	0.1	74
Bicycle	613	0.05	34
Pedestrian	107	0.02	2
		Total	**119**
		ADT (24 hrs)	**143**

Table G2: Calculated ADT for Data in Figure G1