1st National Conference on Intermodal Transportation: Problems, Practices, and Policy

Proceedings

of

1st National Conference on Intermodal Transportation: Problems, Practices, and Policies

Held at

Hampton University, Hampton, Virginia

October 11 – 12, 2012

Organized

by

Eastern Seaboard Intermodal Transportation Applications Center (ESITAC)

Hampton University

Hampton, VA 23668, *USA*

Student Center, Hampton University,
Hampton, Virginia 23668 *USA*

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1st National Conference on Intermodal Transportation (NCIT): Problems, Practices, and Policies

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Welcome to 2012 NCIT

On behalf of the Organizing Committee, I would like to welcome you to the 1st National Conference on Intermodal Transportation: Problems, Practices, and Policies hosted by Eastern Seaboard Intermodal Transportation Applications Center (ESITAC), Hampton University, Hampton, Virginia. The Conference includes a wide range of transportation topics. These topics include transportation policy, safety, security, environment, infrastructure, simulation education and workforce development. The conference will include plenary sessions, panel discussions and technical paper presentations. Technical paper abstracts were submitted and were reviewed by the organizing committee.

The Organizing Committee would like to extend special thanks to Mr. Jeff Keever, Senior Deputy Executive Director, Virginia Port Authority and Ms. Molly Ward, Mayor, City of Hampton for agreeing to deliver keynote speeches. We would also like to thanks all the plenary sessions' and panel discussion's speakers. We would also like to thank various session chairs for their time.

This conference would not be possible without the support of ESITAC, a Tier II UTC transportation center funded by the US Department of Transportation. We extend our thanks to co-sponsors: Virginia Department of Transportation, Virginia Port Authority, Parsons Brinckerhoff, National Center for Intermodal Transportation for Economic Competitiveness, Rahall Appalachian Transportation Institute, Virginia Center for Transportation Innovation and Research, and Kentucky Transportation Center. We are also indebted to Hampton University for its support, especially to the Dean of School of Business Dr. Sid H. Credle and Dean of School of Engineering and Technology Dr. Eric Sheppard.

We hope that you have a rewarding and enjoyable time at the conference. Welcome to NCIT 2012.

Kelwyn D'Souza
Member Organizing Committee &
Director, ESITAC

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EASTERN SEABOARD INTERMODAL TRANSPORTATION APPLICATIONS CENTER (ESITAC)

Hampton University has been awarded funding from the Research and Innovative Technology Administration (RITA), U. S. Department of Transportation (DOT) to implement and operate a University Transportation Centers Program. The ESITAC began operating in the Hampton Roads region as a Tier II University Transportation Center (UTC) on December 19, 2006.

The Eastern Seaboard Intermodal Transportation Applications Center (ESITAC) located in Hampton Roads. The Center utilizes resources of the University in partnership with state and city governments, private industries, regional universities, and local transit organizations to conduct research on current transportation problems facing this Region, and provide students with special emphasis on minorities and women, the opportunities to pursue transportation careers. This Region is at the crossroad of air, rail, road, and water modes providing intermodal transportation systems for passengers and freight. The recent growth in all these modes of transportation has added pressure on our highways and environment, resulting in traffic congestion and air pollution. The Center addresses these challenges through a combination of research, education, and technology transfer programs. The goal is to advance U. S. technology and expertise in transportation that will provide safe, secure, efficient, and interconnected transportation systems.

The theme of ESITAC is *to enhance regional intermodal transportation systems by improving safety and efficiency while minimizing environmental impacts*. The theme contributes to the overall goal of the USDOT which seeks to advance U. S. technology and expertise in transportation that will provide safe, secure, efficient, and interconnected transportation systems.

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National Conference on Intermodal Transportation: Problems, Practices and Policies

Conference Program

National Conference on Intermodal Transportation: Problems, Practices and Policies

October 11 – 12, 2012

Student Center

Hampton University, Hampton, VA 23668, U. S. A.

THURSDAY, OCTOBER 11	
8:00 AM	**NCIT Registration and Welcome Table** **(Student Center 1st Floor Foyer)**
8:00 AM – 8:45 AM	**Refreshment** **(Student Center 1st Floor Foyer)**
8:45 AM – 8:50 AM	**(Student Center 1st Floor Ballroom B & C)**
	Introduction : Kelwyn D'Souza, Director, *Eastern Seaboard Intermodal Transportation Applications Center (ESITAC)*, Hampton University.
8:50 AM – 8:55 AM	**(Student Center 1st Floor Ballroom B & C)**
	Welcome-School of Business: Sid Credle, Dean, School of Business, Hampton University.
8:55 AM – 9:10 AM	**(Student Center 1st Floor Ballroom B & C)**
	Welcome-Hampton University: Elnora D. Daniel, Special Assistant to the President for Research, Hampton University.
9:10 AM – 9:40 AM	**(Student Center 1st Floor Ballroom B & C)**
	Inauguration: Jeff Keever, Senior Deputy Executive Director, Virginia Port Authority. *Maintaining Transportation Connections Through Effective Partnerships.*
9:40 AM – 10:00 AM	**(Student Center 1st Floor Ballroom B & C)**
	Guest Speaker: Molly Ward, Mayor, City of Hampton. *Regional Transportation and Local Economics.*

Friday, October 12	
3:25 PM – 4:45 PM	**Technical Session 5.2** (Student Center 1st Floor Theatre)
	S5.2 Integration of Operations, Maintenance and Planning **Session Chair:** Joseph Curtis, Parsons Brinckerhoff. **S5.2 P1 (Invited Paper):** *Maritime Trade/ Importance of Port Safety Security.* ADM Kevin Cook, United State Coast Guard. **S5.2 P2:** *The Appropriate Material Specification and Manual are Key for Effective Gravel Road Design, Construction and Maintenance Practice.* Richard R. Mwaipungu and Dhiren Allopi, Durban University of Technology, South Africa. **S5.2 P3:** *GIS Web-Based Applications for West Virginia's Outdoor Advertising Program*. Wael Zatar, Marshall University; Hussein Elkhansa, & Bill Light, West Virginia Department of Transportation; and Paulus Wahjudi, Rahall Transportation Institute. **S5.2 P4:** *The 'Gateway to Africa' concept: prospects for a transshipment hub in Limpopo Province.* Dinesh Chaithoo, ARUP (Pty) Ltd, South Africa; Mac Mashiri, Gwarajena TRD, South Africa; and James Chakwizira, University of Venda, South Africa.
4:45 PM	**Conclusion**

THE APPROPRIATE MATERIAL SPECIFICATIONS AND MANUAL ARE KEY FOR EFFECTIVE GRAVEL ROADS DESIGN, CONSTRUCTION AND MAINTENANCE PRACTICE

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ABSTRACT

It is a matter of fact that the gravel road network dominates as the mode of transport infrastructure in most sub Sahara Africa. These roads comprises a huge national asset that requires adherence to appropriate locally formulated Pavements and Materials Design Manual (PMDM) and Standard Specification for Road Works in order for them to give satisfactory performance during they design life. As the length of the engineered gravel road network is steadily growing in Tanzania and elsewhere in sub-Sahara Africa, appropriate Pavements and Materials Design Manual and Standard Specification for Road Works to be employed during design, construction and upkeep of this investment becomes increasingly important for optimal use of locally available gravel materials.

In response to the above call, a number of sub-Sahara Africa countries, Tanzania included, has in place Pavements and Materials Design Manuals (PMDM) and Standard Specifications for Road Works (SSRWs) [1-3], which are being used during the design and construction of new gravel roads and also during maintenance and rehabilitation of existing gravel roads. These PMDM and SSRWs are used in order not only to standardize design practices and quality control during design, construction and maintenance period, but also to be able to predict the performance of gravel roads.

For these PMDM and SSRWs to be effective and dynamic they have to address local condition and after a certain period of time are to be revised so as to capture changes which are constantly occurring in the gravel road construction industry. The intention is this that eventually it should be obligatory to observe the PMDM and SSRWs during design, construction, and maintenance of gravel roads, as they will carry with them the practical experience of over extensive period of time to be questionable.

Although it’s always mentioned that engineering practice and judgment has to be observed during the use of any PMDM and SSRWs and under no circumstances shall the PMDM and SSRWs waive professional judgment in applied engineering. But it has to be acknowledged that PMDM and SSRWs carry with them some authority in arriving at a final decision during the initial stage of design, preparation of tender documents and whenever an inexperienced engineer is supervising part of the project or a new challenge emerges during the execution of road works.

This paper focuses on what is specified in Tanzania PMDM and SSRWs, particular on gravel roads materials, design, construction and maintenance in one part and what is practiced in the country in another part as it influence the performance of gravel wearing course. It also compares these PMDM and SSRWs with those of Developed countries and South Africa. It is expected that by addressing those area the PMDM and SSRWs has fell short will make them an effective tools in gravel roads design, construction and maintenance works.

Key words: Appropriate material specification, Manual, Effective, Gravel Roads, Practical experience.

INTRODUCTION

The importance of standardized and consistent test procedures in road construction in order to establish quality cannot be over emphasized [1-3]. It is obvious that the public accepts and trusts those actions of the engineer built on competence, ethics, integrity and maintenance of standards and by self-regulating through code of conduct , and demonstrating true professional behaviours [4]. All this has to be reflected on their works output.

The paper looks on the extent of practical engineering application of the Tanzania PMDM and SSRWs on Gravel Roads Design, Construction and Maintenance. It has to be noted that Gravel roads in Tanzania constitute about 93% of total road network [5] and although the country have more than 30 years of experience in design, construction and maintenance of gravel roads, the existing PMDM and SSRWs has only few sections set aside for gravel roads.

The paper attempts to look at those sections so as to learn whether they have succeeded in guiding the gravel roads design, construction and maintenance standard. This is done by reflecting on the actual performance of the gravel roads network, particularly in terms of materials characteristics and gravel loss. It has to be understood that gravel loss is one of the parameter which dictate the re-gravelling exercise. In addition to that re-gravelling exercise is the major costing item in management of gravel roads which has environmental impacts as well.

Scope of Paper

The paper will:- 1) study the indicator tests and strength parameters of the gravel materials used as wearing course for engineered gravel roads in the study areas and check the conformity of the results with the SSRWs, 2) look at the design, construction, and maintenance guidelines specified by the PMDM for the engineered gravel roads and compare them with what is actually happening at sites, 3) give highlights on the PMDM treatment of gravel loss and defects associated with gravel loss, and 4) compare the PMDM and SSRWs on gravel roads with those of South Africa and developed countries.

Objectives

The main objectives of this paper are to: - 1) improve the design, construction and maintenance procedure of gravel roads. This improvement will have to be mirrored in the PMDM and SSRWs, 2) tailor PMDM and SSRWs to suit Tanzania current economic and technological status, and 3) improve the performance of gravel roads in terms of reduction in grading and re-gravelling frequency

Problem Statement

The specification governing the gravel materials and gravel roads design, construction and maintenance as depicted in the current Tanzania PMDM and SSRWs are quite loose and do not allow close enough control on gradation. Apart from that these manuals do not address the local and diverse nature of gravel materials. The paper attempt to focuses on those areas which the Tanzania PMDM and SSRWs have fell short.

THE BACKGROUND OF TANZANIA PAVEMENT AND MATERIALS DESIGN MANUAL AND STANDARD SPECIFICATION FOR ROAD WORKS

The Tanzania PMDM, Laboratory Testing Manual (LTM)–1999, and later the SSRWs-2000 [1-3] were prepared as a component under the Institutional Cooperation between the then Ministry of Works (MoW), Central Materials Laboratory (CML) and the Norwegian Public Roads Administration (NPRA). The project was a part of a programme to establish technical standards and guidelines for highway engineering.

The Tanzania PMDM and SSRWs looked on the relevant road design manual and specifications from the east and southern African region. Also it searched other relevant guidelines from countries with similar environments notably Australia. The PMDM and SSRWs were a reflection of the Ministry of Works experience gained in the road sector over the past 30 years that is from 1970 to 2000.

The main purposes of the PMDM and SSRWs were to ensure a standardized policy in the procedures for structural pavement design of new roads and rehabilitation of old pavements.

The PMDM is divided into two main sections, namely design elements and structural design. The design elements considered by the PMDM are environment, cross section, shoulders and drainage, traffic, subgrade, problem soils and pavement materials, while structural design are further divided into pavement design for new roads, pavement rehabilitation, bituminous surfacing and gravel roads being treated last. The SSRWs is divided into seven series, which are: i. general, ii. drainage, iii. earthworks and pavement layers of gravel or crushed stones, iv. bituminous layers and seals, v. ancillary road works, vi. structures, and vii. tolerances, testing and quality control.

The PMDM and SSRWs has been in existence for 13 years now and it is high time they are revisited, and where necessary changes be made. This paper does not attempt to revise the whole PMDM and SSRW, but it looks on how these documents have treated gravel roads wearing course, which constitute a big chunk of road networks in Tanzania and sub-Sahara Africa at large. The paper suggest changes paramount to suit the local condition and are expected to be effective in ensuring good performance of the gravel roads.

GRAVEL ROADS DESIGN

The aim of structural design of gravel roads is to protect the subgrade by provision of appropriate granular layers to achieve a determined level of service - with maintenance - over a chosen design period. A successful gravel road design will meet these requirements at the lowest possible total cost over a design life.

According to the PMDM, the design of gravel roads in Tanzania is limited to roads with a traffic volume up to Annual Average Daily Traffic (AADT) of 300 at the time of construction. The PMDM sets out design standards for fully engineered major gravel roads as well as minor gravel roads and a catalogue format is used in structural design. The manual asserts that flexible approach is required in the design of gravel roads as construction economy is usually of vital importance for successful execution of these projects.

Knowledge about past performance of locally occurring materials for gravel roads is essential. The PMDM point out that one may divert from the given materials standards if necessary to take advantage of available gravel sources provided that past experience has proved they give satisfactory performance. One can also add that an experienced materials engineer might also use new locally available gravel materials, which has the potential of performing well under the prevailing condition. Normal maintenance is assumed to take place throughout the design life of the gravel road. Although in reality the economic situation and the funds availability dictate which road shall be given priority.

The PMDM assumes drained condition for the gravel road throughout its design life, ensured through adequate maintenance of the drainage system. Climatic zone affects the selection of gravel materials types, material requirements for gravel wearing course and earth work, moisture for testing CBR and design of improved subgrade. Climatic zones also affect the formation of natural materials, and its composition. The effect of climatic zones in selection of gravel materials is significant where it affects the performance of the materials in question, and then those materials which perform well under the certain climatic zones will be selected. Other factors, like construction methods and timing of maintenance and its quality also affects the performance of the gravel materials.

Climatic Zones

For the purpose of gravel roads design, Tanzania has been divided into three climatic zones, namely a dry zone in the interior, a large moderate zone and several wet zones, mainly at high altitudes. The climatic zones are demarcated on the basis of the number of months in a year with surplus of rainfall over potential evaporation as presented in Table 1.

Table 1: Climatic Zones

Climatic zone	Number of months per year with higher rainfall than evaporation
Dry	Less than one month
Moderate	1-3 month
Wet	More than three moths

Figure 1: Map showing climatic zones

GRAVEL MATERIALS

The gravel material used for the construction of wearing course for unsealed roads need to fulfill a number of functions and comply with a number of basic engineering properties [6]. The most important of these are 1) sufficient cohesion to resist raveling and erosion; 2) a particle size distribution that facilitates a tight interlock of the individual material particles, and 3) Sufficient strength to support the applied traffic load without significant plastic deformation. Deficiencies in any of these properties result in poor riding quality and high maintenance requirements as well as increased gravel loss. It is thus essential that the best available material is used for construction of gravel roads [6].

The PMDM emphasize the need of having gravel materials that do not generate excessive dust in dry weather for gravel roads passing through populated areas and materials that do not become slippery in wet weather or erode easily for gravel roads on steep gradients.

According to SSRWs clause 3702, gravel materials shall be obtained from approved sources. The same clause 3702 list the gravel materials type according to its minimum CBR value. Gravel materials are depicted with letter G followed by a minimum value of CBR 1) GW – for gravel wearing course and gravel shoulders, 2) G45 – for subbase (Natural gravel with nominal CBR value of minimum 45), and 3) G25 – for subbase, Low traffic roads (Natural gravel with nominal CBR value of minimum 25).
SSRWs stress that, irrespective of the minimum required quality specified, the highest quality of approved gravel materials for pavement layers available at economic haul distances, complying with the requirements of the specifications and drawings, shall be selected for the individual pavement layers.

Materials Characteristics of Gravel Wearing Course (GW) and Unsealed Shoulder

Materials for unsealed shoulders and gravel wearing course layers of GW materials shall meet the requirements given in Table 2 (SSRWs, Table 3702/1 & PMDM, Table 11.1). The only difference between Table 3702/1 of SSRWs and Table 11.1 of PMDM is in the climatic criteria combination; where PMDM combines moderate and dry climatic zones, and SSRW combines wet and moderated climatic zones.

Table 2: Requirements for Layers of Gravel Wearing Course (GW) materials (SSRWs Table 3702/1)

Materials Properties	Materials Class (GW)
CBR [%] Wet of Moderate Climatic Zones	Minimum 25 after 4 days soaking
CBR [%] Dry Climatic Zones	Minimum 25 at OMC
% Passing the 37.5 mm sieve	Minimum 95%
Shrinkage Product (SP)	Minimum 120, and Maximum 400
Grading Coefficient (GC)	Min 16, Maximum 34

Note: In built up areas the maximum SP value shall be 270 in order to minimize dust problems.

Table 3: Requirements for subbase layers of G25 materials (SSRWs Table 3702/5)

Material properties	Material Class G 25			
	General Requirements		Coral rock, Calcrete or other Pedogenic Materials	
CBR [%] Wet or Moderate Climate zones	Minimum 25 after 4 days soaking			
CBR [%] Dry climatic zones	Minimum 25 at OMC and also Minimum 15 after 4 days soaking			
CBR swell [%]	Maximum 1.0 measured at BS-Heavy Compaction			
Atterberg limits Climatic zones	Wet of Moderate	Dry	Wet	Dry or Moderate
Maximum LL	45	50	45	55
Maximum PI	16	20	18	24
Maximum LS	8	10	9	12
Grading requirement	GM shall be maximum 1.2			

Uses of CBR in Gravel Roads Design

It can be readily noted that the PMDM and SSRWs employ the California Bearing Ratio (CBR) test results as one of its key parameter in assessing the required strength of gravel materials for gravel wearing layer to cover and protect the subgrade against the traffic load. The CBR was the result of extended Proctor compaction test by the California Department of Transportation to determine the load required to penetrate the soil compacted to AASHTO T 99 effort at a standard rate and comparing this with the load required to penetrate a standard material [7]. The test does not represent the strength characteristic of in situ soil with all its variability. The concluding remarks is that CBR tests results should be used with caution, and those test equipments which can directly measure the in-situ characteristics of natural materials like Dynamic Cone Penetrometer (DCP) be employed instead.

Laboratory Testing of Gravel Materials

Prior to preparing the specification for a project, representative samples of soil should be collected and tested in the credited laboratories to determine their properties, including the dry unit weight and the percent of moisture required for maximum compacted density [8].

Significance of Gravel Materials Testing

One of the major controllable aspects that can be used to control the deterioration rate of a gravel roads is in the correct selection of the gravel quality used for the surfacing or regravelling gravel roads [9]. Materials quality affects two things;

- The deterioration of the road after grading,
- The amount of gravel loss over time.

Common defects on gravel roads have a direct relationship to the material quality. It is therefore suggested that [9] the organization maintaining gravel roads complete soil testing of their gravel materials before it is used on their gravel roads network. If it is worth building it is worth testing according to specification [10]. By testing the gravel materials, one can be able to specify and manage the quality. By managing the quality one will be able to save money in the long term. Quality of gravel materials directly affects the rate of deterioration of a road through the rate of gravel loss and time grading or regravelling is required.

It is only after completing linear shrinkage and grading tests on gravel materials then one will be able to use Figure 2, which measure and predict the performance of gravel materials to be used for wearing course.

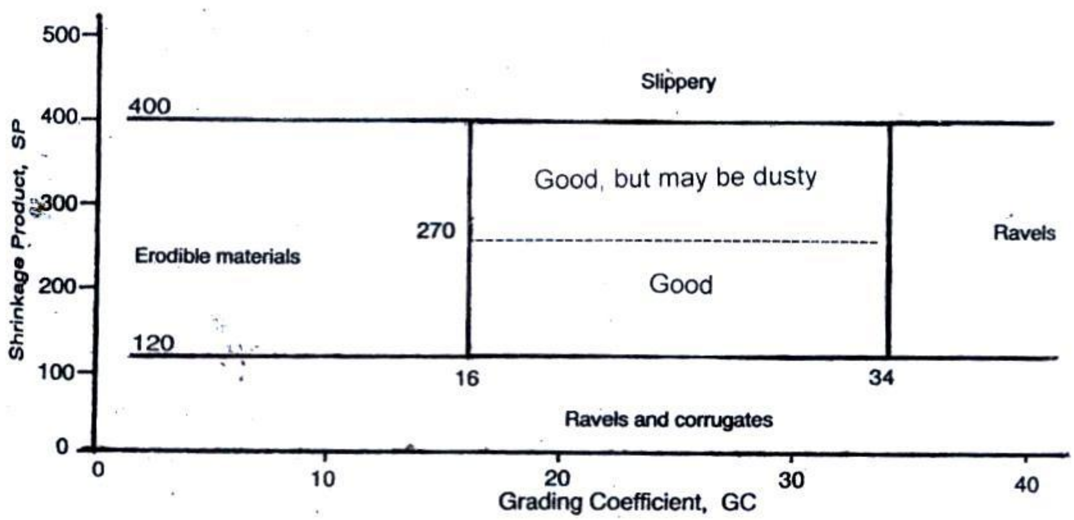


Figure 2: Performance Specification for gravel wearing course (Source: PMDM, Figure 11.1)

The Indicator Tests and Strength Parameters of the Gravel Materials

According to Tanzania PMDM and SSRWs all gravel materials indicator tests and strength parameters shall be measured according to the Central Materials Laboratory (CML) test methods 1.2, 1.3, and 1.4. These methods follow British Standard (BS) procedures and utilize BS equipment. Both documents stress that other laboratory test procedures and equipment do not give comparable results and shall not be used unless proper correlation to CML/BS has been carried out to the satisfaction of the Engineer. The same documents further points out that all grading parameters must be normalize for 100% passing 37.5 mm sieve. One might ask the similarity of British natural materials, which normally govern the sieve sizes to be used during grading exercise, to Tanzania's natural materials.

South Dakota Specification for gravel wearing course specify a minimum of 8% passing the 0.075 mm sieve and a maximum liquid limit of 35 and plasticity index range of 4 to 9 [11]. Example of gradation requirements and plasticity for two types of materials is given in Table 4.

Table 4: Gradation and Plasticity Requirements for Base Course and Gravel Surfacing Materials

Requirement	Aggregate for Base Course	Gravel Surfacing
Sieve	Percent Passing	Percent Passing
25 mm	100	-
19 mm	80-100	100
12.5 mm	68-91	-
4.75 mm	46-70	50-78
2.35 mm	34-54	37-67
0.425 mm	13-35	13-35
0.075 mm	3-12	4-15
Plasticity Index	0-6	4-12

Table 5: Typical specification limits for the liquid limit and plasticity index for gravel materials [13]

Use	Liquid Limit (maximum)	Plasticity Index	
		Min	Max
Base course sealed roads	25	6	8-10*
Combined base and surface course unsealed roads	35	10	12*
Sub base top 150 mm	40	10	12*
Sub base below 150 mm	40	20	20

* May be used in drier areas

Source: Road Construction Authority [RCA](1983) Note 811-04 (Notes on Standard Specification for Road Works)

Table 6: Suggested grading of gravel wearing course

Sieve Size (mm)	Percentage passing by mass						
	Maximum size of particle (mm)						
	TRL (PIARC et, al, 2002)			CSRA (South Africa)			
	37.5	19.0	9.5	37.5	26.5	19.0	13.2
37.5	100	100	100	100	100	100	100
26.5	-	-	-	85-100	100	100	100
19.0	80-100	100	100	70-100	80-100	100	100
13.2	-	-	-	60-85	60-85	75-100	100
9.5	55-80	80-100	100	-	-	-	-
4.75	40-60	60-85	80-100	40-60	45-65	50-75	60-100
2.36	30-50	45-70	50-80	-	-	-	-
2.00	-	-	-	25-45	30-50	35-55	45-70
0.425	15-30	25-45	25-45	15-40	15-40	18-45	25-50
0.075	5-15	10-25	10-25	7-30	7-30	7-30	7-30

The principal requirements for quality of gravel relate to grading of particle size and plasticity of the fine material binding the gravel together. The larger material must also be strong enough not to break down under the effects of traffic and weather. Material may be used 'as-dug' or may be blended from different sources to achieve the desirable specification. In dry climates a fairly high proportion of clay particles is desirable to bind the surface. In wet climates a lower clay proportion is desirable to avoid slippery surfaces and excessive rutting.

Table 7: TRL preferred plasticity characteristics for gravel surfacing

Climate	Liquid Limit not to	Plasticity Index range	Linear Shrinkage (%)

	exceed (%)*	(%)*	
Moist tropical & wet tropical	35	4-9	2-5
Seasonal wet tropical	45	6-20	3-10
Arid/semi-arid	55	15-30	8-15

*Higher limits may be acceptable for some laterites and concretionary gravels that have a structure that is not easily broken down by traffic. Lower limits may be appropriate for some other gravels that are easily broken down by traffic. Any variation form these limits should be based on carefully collated local experience.

The Tables 5, 6&7 show some of the established specification in use. In general the appropriate materials specification has to be able to quantify the required amount of fine materials which will be sufficient enough to hold down coarse particles for the duration of the gravel road life cycle before onslaught of periodic maintenance.

Materials Testing Frequency

According to PMDM the minimum materials testing frequency for gravel roads are 2 per kilometre. These tests are indicator testing, namely Atterberg limits and grading, and the minimum CBR strength testing frequency is 1 per 2 kilometre. The PMDM gives no justification for giving this low frequency and long coverage distance for CBR strength testing, although it stipulates that the frequency are minimum averages and the frequency shall vary according to site conditions. Although the PMDM could have got more credit if it had specified these site conditions, particularly for Tanzania condition. It should be mentioned that to find a homogeneous natural materials covering the distance of 2 km is impractical. To be practical the distance should be determined locally after soil exploration exercise.

Oversize Gravel Materials

Adherence to the limits on oversize particles in the gravel material is of particular importance during the maintenance of the gravel wearing course by grading. According to Tables 2, 6 & 8 the maximum size of individual particles in the gravel wearing course should be 37.5 mm, although Table 4 gives 19 mm as the maximum size.

The PMDM outline the methods of preventing excessive oversize particles in the gravel wearing course which include:- 1) removal at source by screening, 2) use of special compaction equipment such as grid rollers, and 3) removal of large stones during processing on the road. The manual recommend combination of 2 & 3 as cost effective method than method 1.

While SSRWs (Clause 3503: Breaking down oversize material) specify that materials from cutting and borrow pits shall be broken down in the cutting or borrow pits, alternatively in the road, to the maximum size specified for the respective layer where it will be used. The SSRWs leave out the methodology of reducing the large size particles to the required size to the contractors. It is only when the methodology employed by contractors is not effective according to the opinion of Engineer; then the Engineer will request the use of appropriate equipments or plants available.

According to studies conducted in Australia [12], the maximum particle size for gravel wearing course should not exceed about 20 mm because larger particles will cause problems when the surface is graded during construction or maintenance operations. The maximum size of particles for lower layers may exceed 20 mm, and coarser gravels may be used, since the lower layers are not subject to maintenance by grading and some unevenness in their surface is not of any practical significance [12].

Excessive oversize material in gravel wearing course affects the riding quality of in service and makes effective shaping of the surface difficult at the time of maintenance. Currently in Tanzania it seems there is no enforcement in place to ensure that this requirement is being met. It is common to find boulders on the gravel surface or materials of uniforms sizes less than 37.5, depending on the borrow pit used.
These types of gravel road surfaces, where oversize materials have been employed, need a unique performance predicting models, which will be improved gradually as the economic and quality of construction and maintenance technique improves, making these models local and dynamic.

Specification for Gravel Wearing Course Materials

Specification for gravel wearing course materials given in PMDM Table 11.1 and SSRW Table 3702/1 in terms of

CBR, grading and Atterberg limits are similar and to some extent inferior to those for sub base materials (SSRWs Table 3702/4). These kinds of specification do not advance the performance gravel roads wearing course and often require high maintenance inputs. The appropriate specification can only be obtained through performance study of the locally available gravel materials. This has been demonstrated in a number of developed countries including South Africa.

For example the South African specifications for gravel wearing course materials have been derived from a large performance-related study of 110 sections of unsealed road in southern Africa [14]. These specifications use standard South African test methods, and are summarized in Table 8 and illustrated in Figure 2.

Table 8: South African Unsealed road materials specification

Maximum size (mm)	37.5
Oversize Index (Io)*	< 5%
Shrinkage product (Sp)**	100 – 365
Grading coefficient (Gc)***	16 – 34
CBR (at 95% AASHTO T180)	> 15%
Tetron Impact Value	20 - 65

(Io)* **-** Per cent retained on 37.5 mm sieve but less than 75 mm
(Sp)** - Linear Shrinkage x Per cent passing 0.425 mm sieve
(Gc)*** **-** (Percent passing 26.5 mm sieve – Percent passing 2.0 mm sieve) x (Percent passing 4.75 mm sieve)/ 100

The major advantage of the South African specification is the ability to identify potential problems associated with materials not meeting specifications [6]. This allows the road agencies staff to make judgment regarding the consequences of using material outside the specifications and to assess whether these can be accommodated in terms of local traffic climate or maintenance capacity.

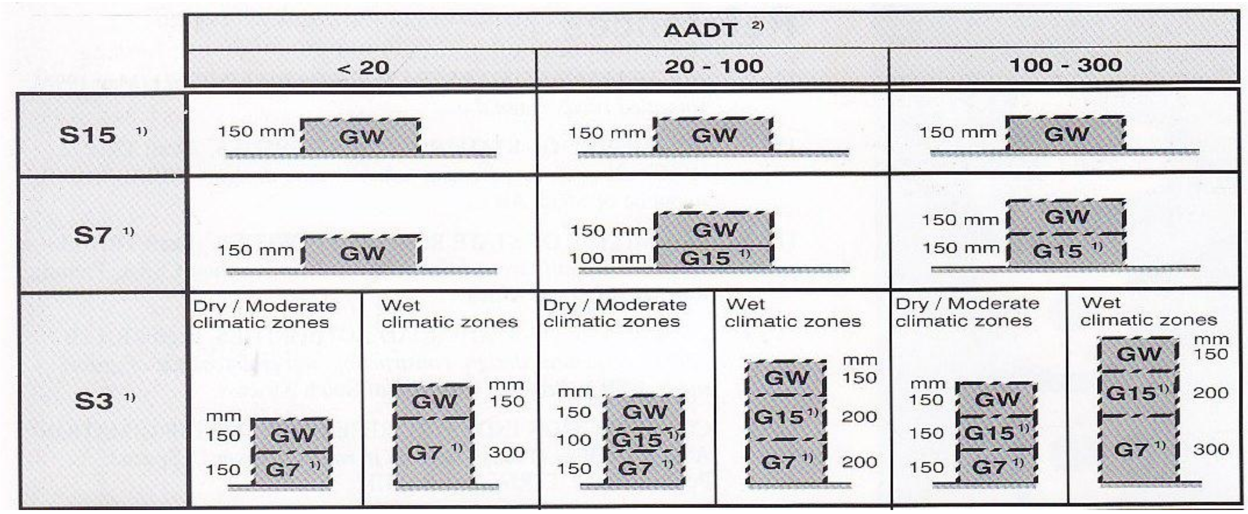
Although the South African specification is being applied in a number of countries however, local calibration may be necessary, not only to cater for regional differences in materials and climate, but also to take the differing test methods into account, e.g. South African versus British and United States Standards [6]. It should be noted that any specification which do not originate from the local areas do not take into account local influences on the performance of gravel materials, influences which are difficult to calibrate. Even for those parameters which can be calibrated, the effort can be translated into formulating local specification.

GRAVEL ROADS CONSTRUCTION

The following items have to be noted during the construction of gravel roads surface prior to placing any layer, namely [13] :- 1) the formation should be properly shaped and compacted beforehand, 2) drainage system must be adequate and functioning properly, 3) quality control mechanisms of gravel materials under experienced supervisors have to be in place, 4) methods to control layer thickness have to be established beforehand, 5) Oversize particles should be removed by hand or broken down with sledgehammers, 6) gravel material should be laid at moisture content suitable for compaction, 7) compaction should be done by appropriate roller to improve durability of the gravel surface, and 8) finished compacted cross fall (3-7%) should be checked with a camber board between the setting out pegs. Briefly put, the gravel road construction has to be formalized.

The above detailed gravel road construction method cannot be noted in Tanzania's SSRWs. The SSRWs (Clause 3703) have just outlined three general construction methods, which are applicable to any pavements construction, which are 1) Underlying layer has to be compacted and finished in accordance with specification, 2) underlying layer shall be inspected and proof rolled to establish whether there is any damage, wet spots or other defects, and 3) any such defects in 2 shall be rectified before the next layer is placed.

According to PMDM, surfacing layer and improved subgrade for major gravel roads shall be constructed in line with Figure 3 design catalogue.



Key: 1) Classification of subgrade classes S3, S7, and S15, and requirement for G7 and G15 materials as provided by PMDM pp 5.6-5.7; 2) Maximum 50% heavy vehicles are assumed.

Figure 3: Wearing course and improved subgrade – major gravel road (Source: PMDM Figure 11.2)

From the gravel roads design catalogue provided it can be noted that the GW compacted thickness is uniform (150 mm) regardless of climatic zones and traffic volume. The changes of compacted thickness of underlying layers varies only on the improved subgrade layer where it compacted thickness is controlled by the CBR of the subgrade, traffic, and climatic zones. This thickness of gravel wearing course is provided regardless of type of gravel materials used, and the annual rate of gravel loss, which is not yet scientifically established for Tanzania condition.

MAINTENANCE OF EXISTING GRAVEL ROADS

The maintenance of existing gravel roads, which is briefly described in clause 3705 of SSRWs, covers only one page. The method as described below cannot by any case be detailed enough to address the distress mostly found on gravel roads.

a) **General** :
Maintenance of existing gravel roads surfaces shall be classified as one or more of the following operations, namely i) shaping , ii) ripping and processing , and iii) regravelling.

b) **Shaping**
Shaping existing gravel roads comprises the following operation carried out to the satisfaction of the Engineer. i) Bringing loose material back to the road from the slopes and ditches if instructed by the engineer. ii) Shaping by motor grade, or equivalent equipment approved by the Engineer.
The exercise is not followed by compaction; this operation is the most used one in maintaining the gravel roads. Without adding the requirement of compaction, it left the brought back material at the mercy of traffic compaction, which at most is not uniform and contribute to loosening the material again and sent them back where their come from.

c) **Ripping and processing**
Ripping and processing existing gravel roads comprises the following operations: i) Ripping of the existing road to a depth of minimum 100 mm or as required by the engineer. ii) Bringing loose material back to the road from the slopes and ditches if instructed by the Engineer, iii) Mixing, breaking of lumps removal of oversize particles and watering as required to make a homogeneous material having suitable moisture content at or around the OMC of BS-Heavy density, and iv) Shaping and finishing to the correct grade and cross-fall and compaction to the requirements in clause 3704.

d) **Regravelling**
Regravelling comprises the following operation i) addition of gravel wearing course material to an existing gravel road, ii) processing as per specification clause 3703 and 3704, iii) Shaping and finishing to the correct grade and cross fall and compaction to the requirements in clause 3704

There is the need to establish a comprehensive manual that addresses most issues that deals with gravel roads design, construction and maintenance, as it is been practiced in developed countries.

Gravel Road Surface Compaction Specification and Control

There are two types of compaction specification employed by SSRWs, namely 1) method specification, and 2) compaction density control. The method of specification and control depends on the nature of the site. In a small areas one can specify the method of operation that is the maximum thickness of soil to be compacted in each layer, the weight and type of roller, and the number of passes to be made over each layer. In important works, the method of operation is usually decided only after full-scale trials have been made with the actual soil and the actual plant to be used in the final construction. Where the site is more dispersed and the soils more varied it may be better to specify the results to be achieved, rather than to lay down the method to be used to achieve them.

As per SSRWs clause 3704, the minimum required compacted density for pavement layers made of natural gravel shall be as given in Table 8 (SSRWs Table 3704/1). In the Table 9, gravel wearing course is equated with subbase layer.

Table 9: Compaction requirements for pavement layers made of natural gravel

Layer and typical material specified	Minimum dry density: Nominal value
Base course layers G80 or G60 or better materials	98% of BS Heavy
Subbase course layers G45 or G25 or better materials	95% of BS Heavy
Gravel wearing course or unsealed shoulders (G 25)	

It is very contradicting to equate the level of gravel wearing course compaction with that of subbase class G25, which have different function. In such kind of specification you cannot expect the gravel surfaced roads to perform any better.

GRAVEL LOSS AND DEFECTS ASSOCIATED WITH GRAVEL LOSS

The PMDM has noted the importance of gravel loss in designing gravel roads. The manual suggests that – the gravel wearing course needs to be regularly shaped and the gravel wearing course materials needs to be replaced periodically throughout the service life of the road at a rate depending on the gravel loss. The manual suggest that an annual loss of 10 to 30 mm of gravel wearing course material at an AADT of 100 is common, without specifying the climatic condition, road alignment, the gravel materials types and its characteristics.

Material is lost from the gravel road surface due to the action of rain, traffic wear, and dry season dust (fine material) loss [13]. Typically loss rates are 1 – 5 cm of thickness per year. The rate of loss partly depends on the rainfall and traffic characteristics. Alignment gradient, surface crossfall, road width, material quality, compaction and maintenance practices can be expected to influence rates of gravel loss significantly. Gravel loss is very specific to material and location, and there is some variation between the results of trials and relationships derived in different regions and conditions. There is no substitute for local experience and research, which should enable more accurate predictions and specification of gravel loss to be developed [13].

Dust

Dust causes the natural soil fines (binder) in the wearing course material to be lost and the material properties slowly deteriorate. The effect of this is that the wearing course properties slowly to move down both the vertical and horizontal scale in Figure 2, resulting in a good material becoming increasingly prone to corrugation and erosion [6]. To control dust researcher in Western Bay, New Zealand conducted trials with a variety of clay bound gravel materials, and compared dust generation, wearing rates and application and construction practicability issues. These were ranked and prioritized according to their effectiveness in resisting dust emissions, which then led to a material specification that was appropriate to local condition [15].

RECOMMENDATION AND CONCLUSION

- The unsealed road network performance can be significantly improved by providing engineered gravel roads and optimizing the material selection.

- The cost of providing and operating all-weather gravel roads should be scaled down by using appropriate specifications in design, construction, and maintenance procedure, based on performance study tailored to suit the local condition.
- Professional civil engineering bodies should be the custodian of gravel roads materials specification, design, construction, and maintenance manuals through the guardian of the Ministry responsible in the Government.
- It should be noted in advance that the design of gravel wearing course thickness should vary with the anticipated rate of gravel loss peculiar to the type of gravel materials used.
- The adequate compaction, in terms on number of passes and type of roller, on all layers incorporated in the gravel roads structure have to be ascertained through trial sections.

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