UNIVERSITY OF MORATUWA

DESIGN AND MAINTENANCE OF GRAVEL ROADS FOR SRI LANKA.

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A PROJECT REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF MASTER OF ENGINEERING IN HIGHWAY AND TRAFFIC ENGINEERING

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ABSTRACT

A study has been carried out to gather, review, summarise literature in order to prepare a set of recommendation for design and maintenance of gravel road for Sri Lanka.

Paved roads are all weather while earth roads are not. The cost of construction and maintenance of paved roads are very high compared to earth roads. A need has always been there for all weather gravel roads to bridge the gap between paved roads and earth roads, in order to accommodate low volume of traffic on agricultural and rural roads

In this study, the available literature and practices were studied and revived by the author, who has considerable field experience in this subject, spanning a period of about two decades. It was possible after the study to present suitable recommendations, for most required items in design and maintenance of gravel roads. The surveys carried out reveal that magnitude of traffic and their composition can be accommodated with suitably designed, constructed and maintained gravel roads.

The outcome of the study presents recommendations on selection of sites for gravel roads, essential geometric standards, drainage, selection of material, design procedure for pavement structure, maintenance requirements, items of maintenance and their frequencies, and the cost aspects of construction and maintenance.

The study of cost aspect reveal that the gravel roads require one third of the cost that would require for traditional bitumen surfaced aggregate base (mettaled and tarred) roads. Maintenance of gravel roads could be carried out on self-help basis. This would further help to bridge the gap with respect to cost, between traditional paved roads and earth roads.

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CHAPTER 1

1.0 INTRODUCTION

There are over 90,000 km of roads in Sri Lanka out of which about 11,000 km roads are classified as National roads (A & B class) and are managed by the Road Development Authority. The balance of about 79,000 km are owned and maintained by Provincial Councils (C D & E class roads), Local Government Authorities, (Municipal council, Urban Councils, Pradeshiya Sabhas. Roads in major towns and village areas) and other organizations such as: Irrigation Department (Major irrigation and settlement projects), Mahaweli Authority (Mahaweli Development area roads), Department of Wild life (Roads in wild life sanctuaries), Department of Town and Country planning (Planning scheme roads), Estate Authorities (Tea, Rubber and coconut estate roads) and Department of Land Development (Colonies and settlement schemes).

A broader definition of classified roads in Sri Lanka is as follows, but it is not the only criteria. 'A 'class roads are; roads connecting capital with district centers and 'B' class roads are; roads connecting district center with major town in the district. They are the primary net work of roads in Sri Lanka. 'C, D, E' class roads are; roads branching off from A,B class roads and are usually roads leading to Village centers.

While a portion of these roads are paved, over 60% of these roads; predominantly agricultural and feeder roads are unpaved. They, the unpaved roads are either earth roads or gravel surfaced roads. These roads approximately carry less than 150 vehicles per day (Average Daily Traffic - ADT). In addition, this traffic consists of mostly light traffic, such as bicycles, two wheel farm tractors, light trucks Carts etc. However, this traffic plays a very important role in the economy and social interaction.

It may not be difficult to conclude that this secondary and tertiary road network provides the main, if not the only mean of access, to most of the rural areas of the country. In other words these roads are very vital for the people living in those areas; not only because those facilitate the transportation of their agricultural or other produce to the market place and the transportation of agricultural inputs, building materials, food and other basic needs. Therefore these roads are essential to be provided and maintained, so that the Socio-economic development and well being of the people living in those areas can be ensured.

The options available today for roads, tracks, paths, trails etc are as follows; they are arranged in the following decreasing order of cost per km for both Construction and maintenance and also for inferiority of level of service

1. Concrete paved roads
2. Asphalt concrete paved roads
3. Double bituminous surface treated paved roads
4. Single bituminous surface treated paved roads
5. Bitumen penetration macadam roads
6. Bitumen primed gravelly soil roads.
7. Gravel surfaced roads
8. Earth roads
9. Tracks (Seasonal roads) Single lane, generally unimproved traversable at time by four wheel drive vehicles, pickup, trucks, tracks and animal drawn vehicular traffic.
10. Trails only suitable for two wheeled traffic or pedestrian and animal traffic.
11. Paths which are narrow cleared ways for walking traffic and in some cases for bicycles & motor cycles.

Most of the roads mentioned in the above 79,000 km of roads are on categories 5,6,7, & 8. There are very many kilometers of roads in categories 9,10,11 and there is a severe pressure on politicians, leaders and developers to upgrade them to categories 5,6,7 and 8, usually to category 5.

The standard of functionality between categories 5, 6, & 7 for rural traffic are similar, but the cost of construction and maintenance is very different by many proportions.

The organization that manage roads of categories 5, 6, 7 & 8 generally are Road Development Authority, Provincial Councils, Local Government Authorities. These are done under Decentralized budget, Integrated Rural Development Projects, Kandy Peasantry Commission budget, funds from Non Government Organizations etc., and occasionally by other organizations mentioned in the paragraph one above.

Although there is no specific data as to how many, such road kilometers are constructed per year, from experience of the personal working in the districts, that it is in the order of hundreds of road kilometers per province per year at present.

1.1. BACKGROUND

The break down of ownership of the roads of various categories is Sri Lanka is given in Table 1.1 the extent of rural road is over 70%.

Road Development Authority	11,000 Km
Provincial Councils	14,000 Km
Local government	
Irrigation Department	
Mahaweli Authority	
Wild life department	
Department of town and country planning	
Department of land Development	
Other minor roads	65,000 km
Total:-	90,000 km

Table 1.1 Ownership of roads in Sri Lanka

The traffic on National roads are summarized in Table 1.2, (from survey carried out). This indicates approximately 4.2 % of National roads, carrying traffic less than 150 vehicle per day.

Traffic	Number of roads
ADT Over 1000 VPD	68%
ADT 150 - 1000 VPD	27.8%
ADT Below 150 VPD	4.2 %

Table 1.2 State of Traffic on A & B, Class Roads

A survey carried out on selected gravel roads shows that there are only a very small percentage of roads carrying over 150 vehicles per day but it reveals that there is no road carrying in excess of 200 vehicles per day. The composition of traffic on rural roads is given in Table 1.4. This reveals that 85% of the traffic comprised bicycles, motor cycles, and three wheelers and only 1% were heavy vehicles.

Traffic on Rural roads comprising bicycles, motor bicycles, three wheelers are given below in table 1.3

Traffic Vehicle per day	No. of Roads
Less than 50 VPD	41.7 %
50 - 150 VPD	33.3 %
150 – 200 VPD	25 %

Table 1.3 – Traffic flows on gravel roads.

BICYCLES	MOTOR CYCLES	THREE WHEELERS	TRACTORS	CARS VANS/ JEEPS	LIGHT GOODS VEHICLES	HEAVY GOODS VEHICLES	BUSES
57 %	21 %	6 %	6%	6 %	3 %	0 %	1 %

Table 1.4 Traffic on Rural Roads – Classified Count

Agricultural and feeder roads constructed as gravel roads can easily carry traffic up to about 150 vehicles per day (ADT) and for category of traffic envisaged there on; at a very much lesser investment than paved roads. Well design and constructed gravel roads could be used as a step in stage construction of paved roads, there by making use of much needed funds over a period. Also certain locations such as, sacred places, National wild life parks, Archeological sites, warrants only unpaved roads due to environmental considerations.

Paved roads require large investments. It is worked out that it will be in the order of three times the investment that will be required for gravel roads. The paved roads of category (5) mentioned in this Section require regular maintenance and if not, very expensive reinstatement costs will occur. In addition, it requires various sizes of locally available rock aggregate and sand, and also bitumen, which is a by-product in the manufacture of petroleum products from imported petroleum crudes. Added to that, bitumen could be purchased only in Colombo, and is expensive (one litre of bitumen is Rs.18/=which is costlier than diesel oil Rs.13/= per litre). It is uneconomical to transport small quantities (less than 50 barrels at a time) of bitumen to distant places. Hence, it requires stocking large quantities, tying up scarce funds. (50 barrels of bitumen costs 145,00.00 including transport) Unlike in gravel roads and earth roads, which uses only indigenous materials and labour which is in abundance.

Even a badly dilapidated gravel or earth road could be made motorable at a very much less investment and shorter time than a paved road by grading the surface using a motor grader and compacting the same suitably or using much abundant labour on self help basis.

As stated before some organizations manage earth and gravel roads; though their main function is not the same. Some of them are Engineering Organizations and some are not. These agencies do not use uniform methods neither for construction of gravel roads nor for maintenance of them. This is due to non-availability of standard specifications for the same. Present methods are either rule of thumb or more often those using the experience of the officers responsible.

There is no comprehensive guide for design, construction, and maintenance of gravel roads at present. Hence, its time to review available literature for design, construction and maintenance of gravel roads and identify any area where further studies are required.

1.2 NEED FOR INFORMATION ON GRAVEL ROADS

Currently it is required to collect the available knowledge and dissemination of the knowledge regarding the usefulness and limitations of gravel roads for Sri Lanka. Also it is required to collect and organize the available knowledge scientifically in a usable manner in order to harness the advantage of the use of gravel roads. This will in turn facilitate the use of gravel road for matching needs at a very much less investment requirement for construction and maintenance of the same. In addition, utilization of available resources like gravelly material and labour optimally.

Therefore its required to

(1) Review available literature for design and maintenance methods. At present useful research work has been carried out in the Research & Development Division of the Road Development Authority.

Other than that, there is hardly any literature available for work done in Sri Lanka though there is much experience with the persons involved in such activities. It is noted that, there is literature available on work done, practices and experience elsewhere in the world in organizations such as oversees unit of the Transport Research Laboratory in

United Kingdom, Transport Research Board, U.S.A, CBPT, and funding organizations such as Asian Development Bank, World Bank that have carried out work in tropical countries .This may be usefully adopted for our conditions.

(2) Collect details on current methods used in different Institutions in Sri Lanka constructing gravel roads.

As already mentioned in the introduction, gravel roads are constructed by several organizations in Sri Lanka, such as Provincial Councils, Irrigation Department Mahaweli Authority etc., but there is not much publicized reports or guidelines, practiced by individual organizations. In addition, what is available not readily available for reference.

(3) Develop suitable guidelines for design of gravel roads.

It is required to formulate guidelines on elements required to be considered such as geometric elements of road, drainage, pavement layer thickness etc., This will assist Road Planners, Engineers and other Technical personnel to design and construct gravel roads, even if they have inadequate experience on the same.

(4) Develop suitable guidelines for maintenance of gravel roads.

This will facilitate systematic maintenance of such roads, which will reduce wastage of funds while prolonging the life span of such roads. It will be particularly useful for Engineers and Technical personnel with less experience and experience personnel to better organize their knowledge.

1.3 DISCUSSION

Not all the sites are suitable for gravel roads. For example, gravel roads in high rainfall areas are more in a wet state thereby reducing carrying capacity. Also, gravel roads constructed in built up areas, The dust emanating from the road will become be a problem. Those sites would not be suitable for gravel roads. Therefore identifying suitable locations for gravel road is required.

If gravel roads are aimed as a low cost method of road construction then very high geometric standards will not suit the purpose. On the other hand these roads are expected to be upgraded some day to paved roads, when the traffic increases. Then it is imperative that the required geometric standards such as gradients, horizontal curve radius, platform widths and road reservation should be maintenance even for gravel roads. It is therefore proposed to select those values that meet the entire requirement within the scope of the objectives and recommend the same for use in Sri Lanka.

Drainage is a very important aspect without which road will deteriorate very rapidly increasing cost of maintenance very rapidly. On the other hand, gravel road surface by itself is pervious but of low cost. Adopting high standards or omitting essential drainage features will be of concern. Therefore, suitable standard of drainage is essential and it is proposed to recommend set of guidelines for this purpose..

Quality of any product will depend on materials to be used. Gravel roads are no exception. Apart from that different climatic zones may require different material. In addition functional requirements will determine the quality of such material. The gravel available in Sri Lanka differs from place to place, at least by their texture. Therefore any uniform method of design, construction maintenance requires determining basic properties of material , keeping in mind that these materials will be used in rural roads which will be constructed by using minimum laboratory facilities, engineering knowledge and sophisticated machinery.

The next step would be to determine the thickness of different Layers. Considering the available material and the location of site.

In Sri Lanka already a fair amount of gravel and earth roads are available. Irrespective of weather they are designed and constructed according to certain standard, it is a prime requirement that they are kept intact in a suitable state. It need not be over emphasized that for agencies who are responsible for maintenance of such roads are in fact, unaware of the basics of maintenance in order to procure funds. Therefore, identifying maintenance requirement and ranking them in the order of importance would be advantageous.

The specification for maintenance are not available in any of the curriculums of Engineering courses for technical and supervisor grades such as, medium level T.OO, and Work Supervisors, at least up to now. Therefore, this exercise will be useful in preparing a set of guidelines for maintenance. Therefore this would be useful to disseminate the knowledge and practice of gravel road construction and maintenance

1.4 METHODOLOGY

The methodology proposed to adopt is to analyze the available knowledge by way of literature, experience and observation on existing practices and conditions under each of following headings, which is considered to be covering the whole spectrum of design and maintenance of roads in Sri Lanka. This data could be summarized in the form of a set of tables with the following topics:-

(a) Suitable locations for gravel roads in Sri Lanka viz. selection of sites.
(b) Selection of geometric standards.
(c) Suitable Drainage Standards.
(d) Selection of materials.
(e) Design procedure of pavement structures.
(f) Maintenance requirements.
(g) Guidelines for maintenance.

CHAPTER 2

2.0 LITERATURE REVIEW METHODOLOGY AND SURVEY OUTCOME

2.1 LITERATURE

2.1.1 Low volume Rural roads in Sri Lanka. Senanayake D.D and Mallawaratchie D.P (1989)

The paper presented at the International Seminar on Rural Transportation - New Delhi- by Senanayaka D.D. and Mallawaratchie D.P. on "Low volume Rural Roads in SriLanka "(1989). This is the earliest published referance available on gravel roads in Sri Lanka, other than some scattered technical data available on specifications used by Department of Highways, Department of Irrigation and the Road Development Authority. This publication has useful information on traffic on low volume roads - Earth , gravel and paved roads- that can carry, with regard to sustainable maintenance. The proposed ranges of traffic volumes per day are , earth roads 0-50 Vehicles per day, gravel roads 50 - 150 vehicles per day. This publication also fairly covers the thickness of layers of pavements. There is also useful information on suitable material characteristics , geometric standards such as maximum radius of curves , maximum gradients, carriage way width and platform width. These values were used in the study in comparing the same with other available specifications.

2.1.2 Earth and Gravel Roads in Sri Lanka. Malawaratchie D.P (1993)

The paper presented at the 12th World meeting of the International Road Federation at Madrid, Spain on "Earth and Gravel roads in Sri Lanka" by Mallawaratchie D.P. (1993). This is the latest published work available for reference on gravel roads for Sri Lanka.

This publication could be considered as an improved version of the previous publication on "Low volume rural roads in Sri Lanka" , but most of the values for geometric standards, soil characteristics, thickness of gravel surfacing, intermediate layer thickness, remain unchanged. Soil characteristics also had hardly changed from original recommendations. The salient feature is that there are records of field trials and their performances with respect to soil properties. There have been no records available on the performances of gravel roads prior to this publication. This publication adequately covers construction aspects of gravel roads. The maintenance aspect of gravel roads has been covered only broadly but provide very useful information.

2.1.3 Rural Transportation Services a guide to their planning and implementation - by Beenhacker Henry Scraoeliss and Herbel S. (1987).

This text book provides most useful information on planning aspect of rural roads including motorized rural roads. This also provides useful technical data on road geometry with regard to all modes of rural transport means such as pedestrian, bicycles, carts etc. also material and construction of rural transportation facilities. These technical data are useful in comparing specifications and deciding suitable recommendations on gradients and cross slopes.

2.1.4 Miscellaneous References

The other reference material provide specific information on topics such as geometric designs (Road note 6 - 1988 - Geometric design : Seminar notes - George Perera – 1987) Road maintenance – (Haththotuwegama - 1989 : Road maintenance manual - RDA - 1989) Pavement design - (Highway Engineering - Khanna SK -1987 : Sehgal SB - Text book of soil mechanics -1984).

2.2 PROBLEM STATEMENT

Gravel roads has been known to Sri Lankan road infrastructure providers for over 30 years. During the last 15 years the Road Development Authority has been involved in such design, standardizing this construction and maintenance. It has been found that gravel roads can accommodate traffic volumes up to about 150 vehicles per day and up to 300 vehicles per day with slight improvement to road surface. (Senanayake and Mallawartchie 1989) There is very much scope for gravel roads to accommodate low volume of traffic in rural roads in Sri Lanka
(Chapter 1).

The presently available publications on designing and maintenance of gravel roads of Sri Lanka does not adequately cover the aspects of selection of suitable sites , geometric standards with respect to type of traffic on rural low volume roads in Sri Lanka. It also fiends that there geometric standards do not adequately consider defects encountered on gravel roads such as erosion. It also finds that the available literature is brief and does not provide details such as readily useable standard cross sections considering geometric standards, drainage and pavement design. The presently available literature on maintenance of gravel roads requires to be organized in a manner where cost aspect are taken into account The cost comparison is not readily available, to appraise the usefulness of gravel roads. Hence it is required to collect, review, fill the gaps and organize available knowledge on design and maintenance of gravel roads in Sri Lanka.

2.3 METHODOLOGY OF ANALYSIS

The methodology adopted is to carry out traffic surveys & condition survey on existing gravel roads. Collect and compare available standards with survey results, current local standards and recommend standard practice for gravel road design and maintenance , while filling gaps in guidelines and details such as cross sections etc. Also work out cost comparisons to appraise gravel roads over paved low volume roads in Sri Lanka.

2.4 ROAD CONDITION AND TRAFFIC SURVEY

A road condition survey and traffic surveys has been carried out on 12 gravel roads selected from 6 districts. The outcome of traffic surveys are given below.

1 Classified count - type of traffic on rural roads - Table 1.4
  This reveals the predominant type of vehicles are bicycles , motor cycles and three wheelers.
2 Traffic flows on rural roads - Table 1.3
  This reveals that all of the roads carry less than 200 vehicles per day. Most roads carry less than 50 vehicles per day, other than bicycles, motor cycles and three wheelers whose damaging effect to the road is negligible.

3 (a) Road platform width vs cross erosion - Figure 2.1

Tra.E	FF
1	4.2
1.25	4
2	4.8
3	4.5
5	5.9
5.5	7
6	4.9
6.3	4
6.3	4.9
9	8

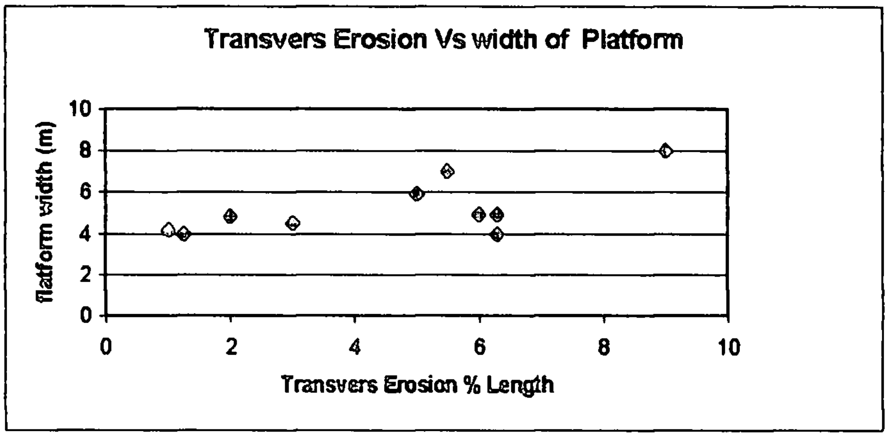


Figure 2.1 Transevers Erosion Vs Platform Width

Tra.E	CW
1	3
1.25	2.4
2	3.5
3	3.8
5	4.3
5.5	3.7
6	3.6
6.3	3.5
6.3	3.2
9	4.5

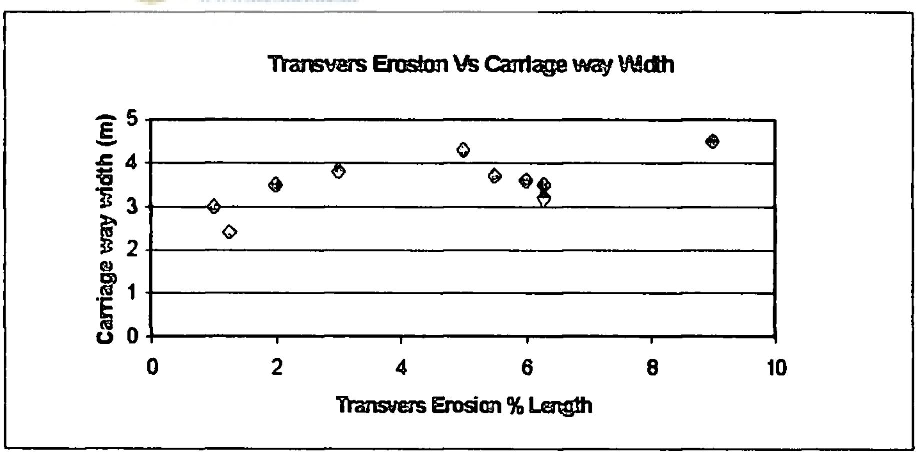


Figure 2.2 Transevers Erosion Vs Carriage way Width

(4) Drains Vs potholes relationship is given Table 2.1

Drain Pot holes	Clear			Not available / Blocked			One side Clear			%
Low < 10 %	81 %	81	78.8%	54.5%	18	17.4 %	80%	04	3.9%	100 %
Medium 10% - 30 %	14 %	14	66.7 %	18.2%	06	28.6%	20%	01	4.7%	100 %
High ➢ 30 %	05%	05	35.7 %	27.3 %	09	64.3%	00%	00	00%	100 %
	100%			100%			100%			

Table 2.1 Drains Vs Pot holes.

This category analysis shows that potholes intensities are low when drains are clear.

(5) Drain Vs. longitudinal erosion relationship is given in - Table 2.2

Drain Longitudinal Erosion	Clear			Not available / Blocked			One side clear			%
Low < 10 %	69.4%	77	76.2%	47.6 %	20	19.8%	57%	04	4.0%	100%
Medium 10% - 30 %	23.4%	26	72.2%	16.7%	07	19.4%	43%	03	8.4%	100%
High ➢ 30 5	7.2%	08	34.8%	35.7%	15	65.2%	00%	00	00%	100%
%	100%			100%			100%			

Table 2.2 Drain Vs longitudinal Erosion.

This category analysis shows that cross erosion is low when drains are clear.

(6) Wheel path rutting Vs age of the road relationship is given in -Table 2.3

Age Rutting	< 1 Yr.			1 – 5 Yrs.			> 5 Yrs.			%
Low < 10 %	24%	07	18%	58%	14	37%	33%	17	45%	100%
Medium 10% - 30%	45%	13	43%	13%	03	10%	27%	14	47%	100%
High > 30%	31%	09	25%	29%	07	19%	39%	20	56%	100%
%	100%			100%			100%			

Table 2.3 Wheel path rutting Vs age of the road.

This category analysis shows that when age of the road is above 5 years wheel path rutting is highest whether low intensity , medium intensity or high intensity.

(7) The relationship between traffic on rural roads Vs failure types – Figure 2.3, 2.4, 2.5, 2.6. These tables shows that there is no definitive relationship between traffic volume and failure types.

Traffic VPD	Failure pot holes % Length
13	7.1
17	8.9
23	5.6
26	0.05
40	3.2
43	20
63	3.6
65	0.07
106	8
186	21.5
191	8
200	18

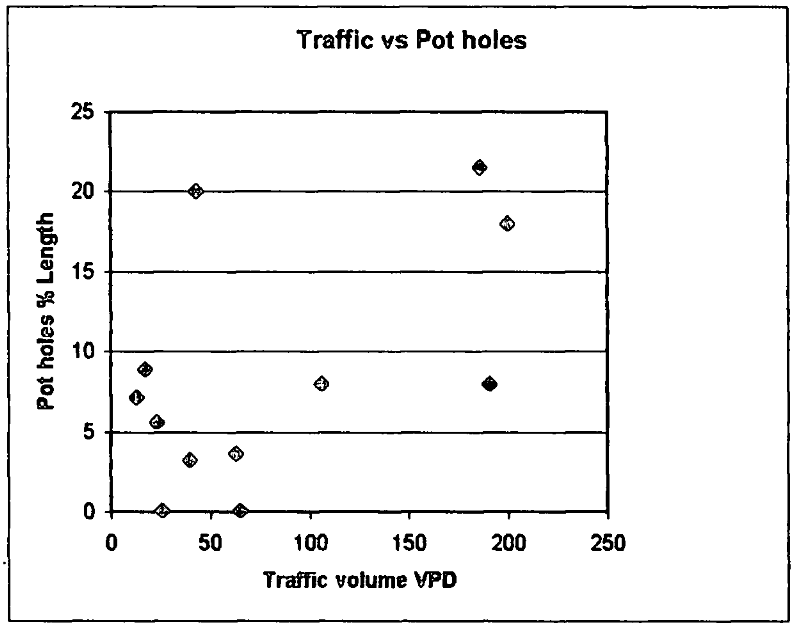


Figure 2.3 Traffic and Pot holes

Traffic VPD	Wheel Path rut % length
13	5
17	11.4
23	8
26	11
40	38
43	42.5
63	25
65	35.1
106	17.8
186	
191	12.8
200	2.3

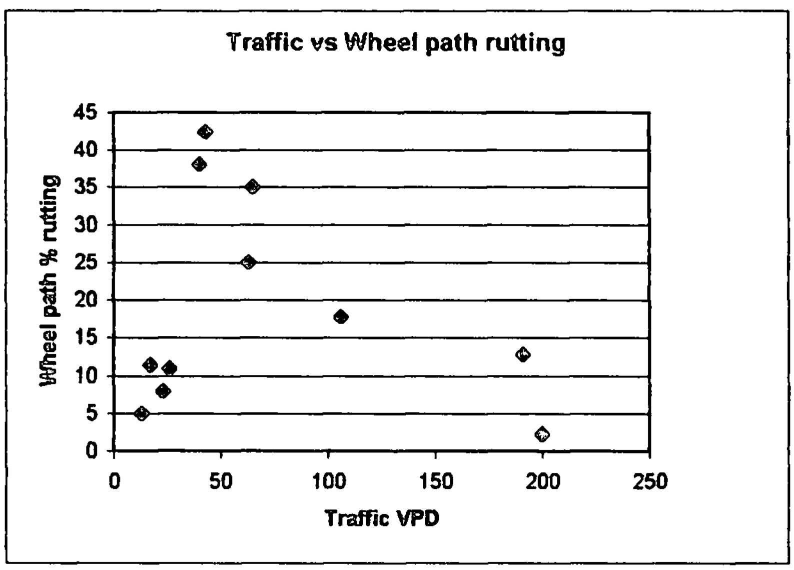


Figure 2.4 Traffic Vs Wheel path rutting

Traffic VPD	Corrugation % Length
13	
17	9.3
23	
26	37
40	42
43	25
63	5.3
65	31
106	12.5
186	1
191	4.1
200	18

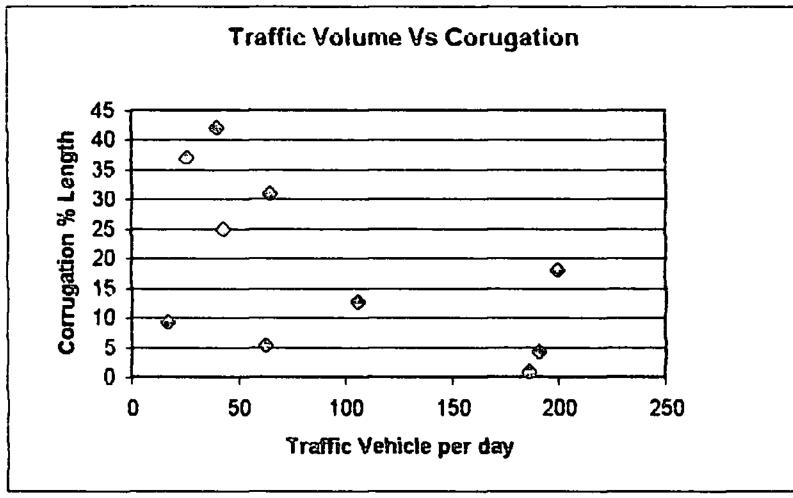


Figure 2.5 Traffic Volume Vs Corrugation

Traffic VPD	Longitudinal Erosion % Length
13	
17	2.9
23	56.4
26	1
40	46
43	33
63	89
65	2.2
106	1.4
186	
191	0.1
200	18.5

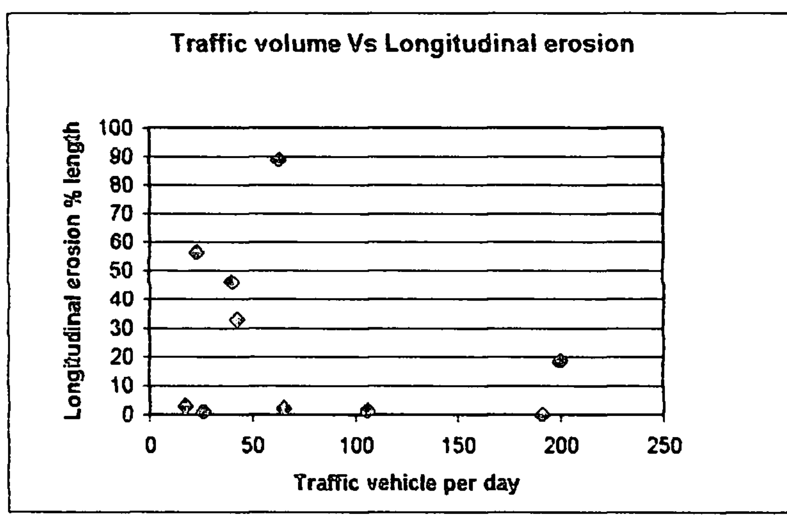


Figure 2.6 Traffic volume Vs Longitudinal erosion

CHAPTER 3

3.0 SUITABLE LOCATIONS FOR GRAVEL ROADS

3.1 INTRODUCTION

Gravel road as a low cost construction has its own limits, to serve the purpose it is built for. For example a gravel road constructed on a mountaineous terrain will be eroded during one or two rainy seasons making maintenance of Carriageway very expensive and not serving the purpose. The road, which is impassable or difficult to be used during and after a rainy season, will be a problem. In addition, the people to whom the road is meant will loose the faith in the technique of gravel road construction. The result is the public will be reluctant to accept this technology, in spite of the benefit over the paved roads irrespective of the technical feasibility. Hence, selection of suitable sites for gravel roads is very important factor before taking a decision to construct a gravel road. What is more important is to identity the sites that are not suitable for gravel roads.

Present day road engineers are fully aware of the fact that road pavements have a specific life span. Beyond which the road pavement will not be functional at a reasonable maintenance cost.

A badly located gravel road will not last the life span expected for it to survive. This in turn will fail to accrue the benefits to be derived from it. A badly located gravel road will reduce its life span due to

(i) Fast deterioration of pavement condition making it difficult to use at reasonable level of service

(ii) Maintenance cost is far too high or equal to a paved road.

(iii) Exhaustion of suitable materials at a reasonable transport distance

Paved roads are sometimes referred to as all weather roads and gravel roads unpaved. But gravel roads are usually classified as all weather roads. Due to the very nature of the gravel roads, the surface is not sealed, in other words, it is porous - (water can penetrate to the subgrade) - and fine particles could be carried away due to rain. Therefore, high rainfall areas may reduce the life span of gravel road drastically. In Sri Lanka, there are different climatic zones. At least three, wet zones where high annual rainfall is received, dry zone where low annual rainfall is received and an intermediate zone. Therefore, it may be possible to exclude some areas as unsuitable for gravel roads even if some other conditions like availability of material, low traffic etc. are complied with. Hence, a comprehensive screening for suitable locations is required to be predetermined.

3.2 UNSUITABLE LOCATIONS

The areas and sites that are unsuitable due to high maintenance costs (economic considerations)
can be categorized as follows:

(a) High longitudinal gradients resulting in washaways.
(b) High traffic volume resulting loss of material and wheel path rutting very frequently.
(c) Heavy rainfall areas resulting, washaway of fine particles or loss of fine particles.
(d) Sites where excessive vehicle speeds resulting loss of material and resulting wheel path rutting corrugations and loss of gravel surface shape.
(e) Areas where gravel is not available at economical haulage.

3.2.1 High longitudinal gradients resulting in washaways

When high gradients are unavoidable in hilly terrain, due to the very fact that facilities are not available for surveying and design for suitable gradients. In addition, due to the small scale of the project, constraints of funding, some agencies tend to resort to convert footpaths into vehicle paths and then to gravel surfaced roads. This is shortsighted policy. When longitudinal gradients are high, water tend to flow along the longitudinal erosion gullies on the road. Larger the water path more and more water collects to this erosion gullies Larger the water path more momentum is gathered, hence more speed of flow resulting in small particles to be carried with the water flow. When more and more particles are lost, eventually longitudinal ditches are formed. This process would continue since water will follow on the same path thereafter. Not only rectification of these defects is difficult, expensive and time consuming and it would get inevitably postponed due to rapidity of occurrence Therefore the road will go from bad to worse within a short duration of time. Hence, mountainous terrains are not suitable for gravel roads due to high gradient resulting it to be uneconomical. Limiting gradients are considered in the following chapters with respect to geometrical designs etc., Due to less frictional characteristic of gravel surfacing, vehicles find them difficult to ascend gravel road with gradients.

3.2.2 High traffic volumes, cause loss of material and wheel path rutting

In gravel surfaced roads fine particles are disintegrated and fly behind vehicles as a cloud of dust, when the traffic volume is high. The speed of loss of material increases with the traffic volume. The other factors are wheel path rutting. This will reduce the life span of the pavement and frequent rehabilitation would be inevitable. This will lead the public to loose faith in gravel roads since repairs are needed more frequently. Due to the fact when vehicles are followed one after the other loss of material is higher than when its not so. Therefore, maintenance is required frequently, which will not be practicable and economical. Hence, places where high traffic volumes are expected construction of gravel surfaced roads is not economical.

3.2.3 High rainfall areas causeing washaways and loss of fine particles

This is complementary to facts stated in previous paragraph. In addition, due to high rainfall, gravel surface will be in wet state frequently than in dry areas. Since gravel roads are unpaved, water will percolate to sub grades and stay there for long time. When even occasionally heavy vehicles are traversed on these roads, damages to the subgrade will be very high. Also it is worth noticing that when heavy loads pass on gravel surfaced roads water will collected on deformed places making the sub grade wet which in turn, is detrimental to the strength of the same.

In this case, intensity of rain, duration of rain and frequency of rain also will matter. Same annual rainfall could be received in many ways theoretically and rain pattern in Sri Lanka could be stimulated to some of those patterns at least approximately. Even at low annual rainfalls, following details are evident.

Intensity of rain	Duration of rain	Frequency	Damage to gravel surface
Low	High	High	High
Low	Low	High	Low
High	High	Low	High
High	Low	Low	Low

Heavy rainfall will washaway fine particle and also gravel particles when they get crushed under the wheel. Due to the absence of fine particles to fill the voids, loss of material will be very high resulting in deterioration of condition of gravel surfacing. Hence, the construction of gravel roads in heavy rainfall areas may not be economical requiring frequent maintenance and rehabilitation. Even in low rainfall areas higher duration are detrimental for gravel roads.

3.2.4 Areas where gravel is not available within economical haulage.

In Sri Lanka in most parts of the country, gravelly soil materials are available, though they are of different colours, origin qualities and properties. All these materials are not equally suitable for gravel surfacing. When all others conditions are conducive for gravel roads, if suitable gravel is not available at a reasonable distance of transport, it may not be able to justify the gravel roads on an economic basis. Therefore locations where roads are to be constructed, should have suitable gravel at a reasonable haul distance.

3.2.5 Due to other considerations

Some locations may be unsuitable for other gravel roads due to reasons other than economic reasons such as:

(a) Environment sensitive to dust as in built up areas and near places such as hospitals.
(b) Where excessive speeds of vehicle would cause safety hazards.
(c) Roads to be constructed by organization not having maintenance facilities.
(d) Areas with poor drainage facilities and flood prone areas such as low lying areas.

- <u>Environments sensitive to dust as in built up areas and near hospitals.</u>

Even if all the conditions warrant gravel roads, dust emanating from the gravel surface may be a problem in built up areas. Where, lack of free space for dust to settle could be a problem. Also closer to institution like hospital where patients are taken care of, and sophisticated equipment which are susceptible for damage due to dust; gravel roads may not be suitable. However, even in these environments roads could be kept as gravel roads until all service lines are completed. In such cases, there should be specific period for completion of these under ground service installation projects in order to pave the road surface to enhance the carrying capacity and to have dust free environment.

- <u>Roads to be constructed by organizations that do not have road maintenance facilities.</u>

Gravel roads needs maintenance like any other roads, but it is not worth if proper maintenance is not carried out on time, in gravel roads deteriorate faster than paved roads, as should be expected due to short life span as well.

- <u>Areas with poor drainage facilities flood prone areas.</u>

As gravel roads are constructed as low cost roads, it will not be practicable to protect subgrade and sub base from water, which enters from many ways. In paved roads vehicle can even use the road pavement at the time its inundated event inundation is shallow. The post flood damage too will be very much higher than paved roads. It is a fact that those gravel roads are not possible to be used just after flooding. Therefore its advisable to avoid areas where poor drainage areas and flooding areas for construction of gravel roads.

3.3 WARRANTS FOR GRAVEL ROADS.

After considering the locations unsuitable for gravel roads, because they are uneconomical or otherwise as discussed in para 3.2. It is required to consider locations more suited for gravel roads.

They are:

(a) Low traffic and low speed roads.

(b) Roads in flat or rolling terrain

(c) Roads in low rainfall areas

(d) Temporary roads such as construction sites.

(e) Access roads in village.

3.3.1 Low traffic low speed roads

Roads carrying low traffic volume such as agriculture and feeder roads. Agriculture vehicles, such as farm tractors, two wheel tractors, bicycles, and light trucks are usually slow in speed except occasional high-speed vehicles. The construction of paved roads is very much expensive than gravel roads and gravel roads could easily carry this vehicular traffic. This will reduce the large initial investment required at least until the growth of traffic over the years, justifies the paving of such roads.

3.3.2 Flat or rolling terrain

According to facts discussed already in the unsuitable locations for gravel, roads flat and rolling terrain are more suited for gravel road.

3.3.3 Low rainfall areas

Also it was discussed that high rainfall areas are not suitable for gravel but it is observed that from gravel roads constructed in dry zone or intermediate zone where annual rainfall is less 1000 mm / year and between 1000 mm/year - 2000 mm/year respectively are satisfactorily behaving.

- <u>Climatic Zones of Sri lanka.</u>

Sri Lanka could be divided into three climatic zones. (Mallawaratchie 1993)

(1) Dry zone	Rainfall < 1000 mm
(2) Intermediate Zone	Rainfall 1000 - 2000 mm
(3) Wet zone	Rainfall greater than 2000 mm

It is clear from Figure 3.1 that two third of the area is under dry and intermediate zone. Therefore, it provides a conducive environment for the construction and maintenance of gravel surfaced roads.

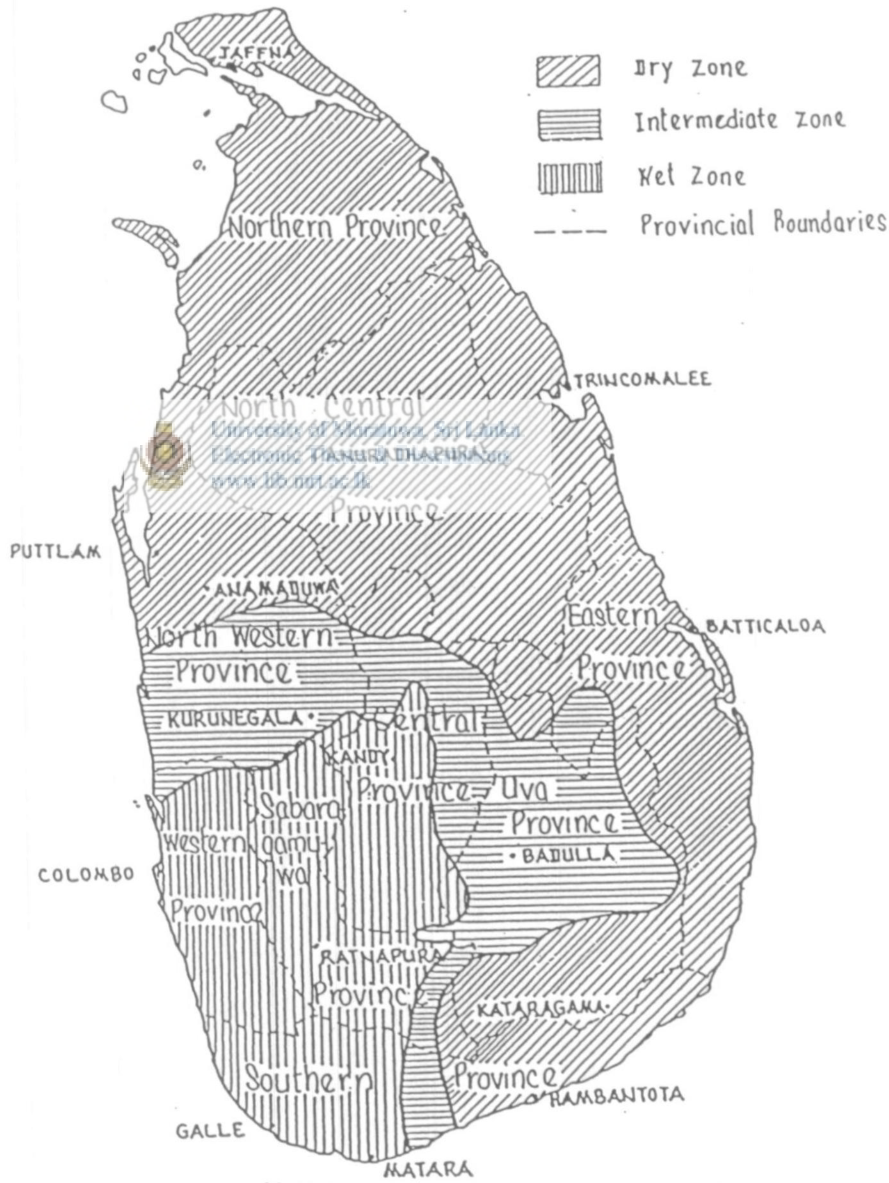


FIGURE 1.1 CLIMATIC ZONCE OF SRI LANKA (Mallawaratchie 1993)

3.3.4 Temporary roads such as in construction sites.

These by nature are required to serve its purpose only for a limited period usually 1-2 years. It will not be economical or logically acceptable to construct paved roads unless for some special reasons it is required to do so. Therefore, a well-constructed gravel road is more appropriate. Readily available maintenance equipment will be supplementary to the concept; such as grading when corrugations, washaways occur, regravelling, also watering daily to prevent dust due to plying of vehicles, preventing loss of fine particles. It is worth mentioning that the gravel road constructed to transport big boulders required for Kirinda fishery harbour from Bogahapelessa aggregate quarry to Kirinda harbour via Yodakandiya used a gravel road of 15 km. (Southern Province). Due to request of villagers on either side of road watering, was done to lay the dust using a water bowser three times a day. This road after some time appeared to be very much in shape since small particles from the road surface was intact due to watering and compaction by tyres of trucks carrying huge boulder weight up to 20 tons.

3.3.5 Access roads to villages

It could be agreed that the only means of access road to rural areas of the country are mostly earth roads. These roads are vital for the people living in those areas not only because these roads facilitate their mobility, but also because they facilitate transportation of agricultural inputs, building materials, food, and their basic requisites back to such village. It is not difficult to perceive that this traffic is less than 150 VPD and a well constructed gravel road would carry them until such the villages are developed after 8-10 years (which is also the life span of well maintained gravel roads before major rehabilitation) and warrants paved roads.

3.3.6 Location where gravel roads warrants by purpose

From the proceeding discussion its easy to derive that following locations warrants gravel roads subjected to limitations discussed. (3.3.1-3.3.5)

(1) Village road such as agricultural and feeder roads.

(2) Roads in new settlements.

(3) Estate roads (Tea , Rubber, Coconut)

(4) Roads in wild life reserves.

(5) Access roads in villages.

(6) Roads in sacred areas

(7) Roads in construction sites.

3.4 QUALIFICATIONS FOR GRAVEL ROADS - MAJOR PARAMETERS

Proceeding discussion enables to screen out the major parameters in deciding whether to construct a gravel road or not.

(a) Traffic

(b) Gradients

(c) Rainfall

(d) Economic haul distance

(e) Duration of use or life cycle

3.4.1 Traffic

In consideration of traffic, volume of traffic ADT (Average Daily Traffice) composition of traffic (a count of different classes of vehicle, classification) growth rate will play an important role. According to Mallawaratchchi (1993) maximum number of vehicle per day recommended is

Not to exceed 150 v.p.d. - But traffic volume of up to 300 v.p.d could be accommodated with slight modification like priming and sand sealing on gravel roads.

With respect to classification of vehicles that could be accommodated, there are no specific details to be found, anyhow carts, motor cycles, agricultural vehicles, and bicycles will have not much damaging effect. However, heavy axle loads like large lorries (5 tons and above) Busses (5tons - D type) in small numbers will not cause severe problems.

Growth rate is directly applicable as to when the road is to be converted to metalled and tarred road due to excess of vehicles per day (V.P.D.). {150 - 300 vehicles per day which ever is applicable}. Convention of gravel road to metalled road is not a major problem, but will not require less than 5-year period in most cases after the construction.

ould kept for improvement to geometric standard anticipating that traffic is

Provi apidly by reserving additional land.

Gradients.

This will be dealt in geometric standard but its clear from proceeding discussions that high gradients would cause washaways. Hence, rolling terrain would be suitable locations. Mountainous locations are not suitable.

3.4.3 Rainfall

The proceeding discussion clearly establishes that high rainfall areas are not recommended for gravel and construction. Sri Lanka receives relatively high rainfall, particularly through two monsoons they are from south west in the months of May - June and other from Northeast in months of October to December. There are inter monsoon rains as well. The highest rainfall is in excess of 4000 mm per year. Those are referred to as wet zone. This area is referred to as wet zone. The remaining areas are referred to as intermediate zone, Dry zone. Dry zone normally receive less than 1000 mm of rainfall per year and intermediate zone between 1000mm 2000 mm per year.

From the experience of roads already constructed in these areas, dry zone and intermediate zones are more suitable for gravel roads. Generally, a rainfall less than 1000-mm is more suitable.

It is evident from the figure 3.1 map the larger area of Sri Lanka fall within this category. In addition, dry and intermediate zones cover better half of balance area and hence, there is a large scope for gravel road in such areas.

3.4.4 Economic Haul distance

The suitable gravel quarries are not in abundance in most parts of the country due to lands have already alienated for other purposes. Also, there is an only limited reserve of government lands where suitable gravel is available. Therefore, there are instances where gravel has to be transported for long distances. This haul distance is a comparative one. Since paving with aggregate too needs transportation, which is no exception to gravel with respect to availability and possibility of extracting them.

Therefore, allowable haul distance should be considered in individualistic basis to arrive at cost comparison in the cost/benefit analysis. Generally, less than 50 km is recommended as a limiting distance.

3.4.5 Duration of use or economic life.

This also is to be compared on roads where they will be used for limited period as in construction sites, when cost/benefit analysis are done Economic life of gravel roads are generally 5-8 years. If traffic has not grown beyond limits, the conversion to pave the same could be taken on merit of importance.

3.5 SUMMARY

- Warrants for gravel roads

(1) Low traffic low speed roads.

(2) Roads in flat or rolling terrain

(3) Roads in low rainfall areas

(4) Temporary roads such as construction sites.

(5) Access roads in villages.

- Unsuitable locations for gravel roads.

(1) High longitudinal gradients resulting in wash away.

(2) High traffic volume resulting in loss of material and wheel path rutting very frequently.

(3) Heavy rainfall areas, resulting wash away of fine particles or loss of fine particles.

(4) Areas where gravel by soils are not available at economical haulage.

- Suitable location for the constructions of gravel roads.

(1) Village road such as agricultural and feeder roads.
(2) Roads in new settlements.
(3) Estate roads (Tea , Rubber, Coconut)
(4) Roads in wild life reserves.
(5) Access roads in villages.
(6) Roads in sacred areas.
(7) Roads in construction sites.

- Decisive factors.

(1) Traffic

(2) Gradients

(3) Rainfall

(4) Economic haul distance

(5) Duration of use or life span.

CHAPTER 4

4.0 GEOMETRIC STANDARDS

4.1 INTRODUCTION

There are well-compiled standards for geometric design of road in other countries, though there is no comprehensive design standards of our own. The widely used geometric standards in this country are British standard specifications, ASTM standard specification, and Australian code of practice for paved roads. But as reiterated in Chapters 2 and 3 the attention is on low volume low speed rural roads. There are no specific standards to adopt as it is. On the other hand adopting very high standards would not be appropriate for low volume rural roads, since the amount of investment for such roads is low.

Some components of geometric design for low volume agricultural and feeder roads using speed criteria are inappropriate because they increase the cost without improving the access. Design speed is a concept used to standardize the relationship among the geometric elements of a road. Geometric design includes all the visible dimensions of roads, horizontal and vertical alignments and cross sectional elements. An increase of design speed dictates longer horizontal and vertical curves. Flatter gradients and wider road surfaces. The use of specific design speed on the arterial highway network is essential to provide constant level of service over a specific road segment so a motor vehicle driver unfamiliar with the road is never surprised by a sharp curve or slowed by a steep hill.

Design speeds are reduced, as terrain features become more pronounced. The cost of building a road to a specific design speed increase rapidly as the road goes from flat to rolling to mountainous terrain. The economic requirement that users vehicle operating cost saving should equal or exceed the construction and maintenance costs of a road, therefore prohibits application of the same design speed in different types of terrain and for different traffic volumes. Instead road users pay a penalty in travel time, discomfort and increased vehicle operating costs, so the government can build and maintain the road at a reasonable and a justifiable cost.

The strategy in selecting suitable standards from available literature is predicated on the following factors:

(i) Access is not related to design speed

(ii) Traffic volumes on agricultural and feeder roads are so low that vehicle operating costs are not a major decision parameter in overall project evaluations

(iii) High-speed operation is not desirable on feeder roads with mixed traffic including carts, bicycles, and pedestrians.

(iv) Time lost because of slower speeds over relatively short length of road is insignificant compared to the slow loading and unloading procedures practiced in rural areas and

(v) Feeder roads serve mainly to local traffic whose drivers are familiar with local conditions.

(vi) Traffic volume will increase only as the local transport needs increasing, feeder roads with the above features can be built at reduced costs if the design speed concept is waived (Henry L Beenhaker et.al 1987)

It is also noted that most of the low volume rural roads in the country had evolved out of footpaths and cart tracks and as such, they are original layout and alignment need adjustments. In some hill country roads, the gradients are far too excessive. It is recommended some improvements to these poor geometric standards be affected before gravel surface is done.

The geometric element of a road includes cross sectional elements such as roadway and platform widths, Pavements and shoulder slopes, horizontal and vertical alignment such as minimum radius of curvature, transition curves , super elevation, maximum and minimum grades etc.,

The methodology would be to list out available standards specifications and recommend suitable values on the light of above mentioned strategies.

4.2 ROAD TOP WITDH AND CROSS SLOPE.

4.2.1 Topographical classification:

The RDA (1988) has recommended top width for roadway and platform according to the following classification terrain.

(a) Flat (f) cross slopes 0-14.5% (0-8^0)

This includes level of gently rolling country with few obstacles to overcome having continuously unrestricted horizontal and vertical alignments.

(b) Rolling ® cross slope 14--27% - (8^0 -15^0)

This includes slightly hilly country with moderate rise and fall of slopes in general. Steep slopes may be encountered occasionally. There will be some restrictions in this terrain to horizontal and vertical alignment.

(c) Mountainous (M) cross slope over 27%- [over 15^0]

This includes hilly and mountainous terrain which imposes definite restrictions in the standard of alignment obtainable and involves steep grades and limited sight distances.

This classification of terrain is recommended which fully agreed with facts stated in the introduction.

4.2.2 Road Top width:

This is usually termed flatform width is a combination of carriageway width and two times shoulder width and width of verges (if any)

(a) Recommended carriage and shoulder width by RDA (only portion relevant to AADT less than 1000 is quoted)

Class of road	Design year average annual PCUS	Terrain	Design speed KM/H	Desirable mountain grade	Carraigeway width (m)	Shoulder width (m)
D,E	0 -200	F	50	9	3.7	2.4
		R	40	10	3.7	1.8
		M	30	11	3.0	1.2
C,D	200 -1000	F	50	9	5.6	1.8
		R	40	9	5.6	1.2
		M	30	10	5.6	1.2
A,B	200 -1000	F	70	5	6.2	1.8
		R	50	7	6.2	1.2
		M	40	10	5.6	1.2

Table 4.1 Carraigeway and shoulder width RDA

(b) Department of Irrigation based on their own experience and based on RDA standards for roads in Irrigation and settlement projects recommended as follows: (only potion relevant AADT less than 1000 is quoted)

((REF. Department of Irrigation 1972)

Average Annual daily traffic in PCUS	Roadway ft (m) recommended by Highways Department			Commonly used roadway width ft (m)	Platform ft (m) recommended by Highways Department			Commonly used width ft (m)
	F	R	M		F	R	M	
50 –200	12 (3.7)	12 (3.7)	10 (3.1)	12 (3.7)	24 (7.3)	22 (6.7)	22 (6.7)	16 (4.9)
200 –1000	22 (6.7)	20 (6.1)	18 (5.6)	18 (5.6)	30 (9.1)	28 (8.5)	26 (7.9)	22 (6.7)

Table 4.2 Widths recommended by Irrigation Department

(c) The road width recommended by Senanayaka & Mallawaratchie (1989)
The paper on "Low volume roads in Sri Lanka" by above others have recommended following carriage way and formation widths.

Road type	Terrain	Vehicles per day (VPD)	Carraige way width (m)	Formation Width (m)
Paved	Flat	150 - 300	3.5 - 4.0	6.0 -8.0
	Rolling		3.5 - 4.0	6.0 - 8.0
	Hilly		3.0 - 3.5	5.0 - 6.5
Gravel	Flat	50 - 150	3.0 - 3.5	5.0 - 7.0
	Rolling		3.0 - 3.5	5.0 - 7.0
	Hilly		2.5 - 3.0	4.0 - 6.0
Earth	Flat	0 - 50	3.0 - 3.5	5.0 – 7.0
	Rolling		3.0 - 3.5	5.0 –7.0
	Hilly		2.5 - 3.0	4.0 – 6.0

Table 4.3 Road widths recommended by Senanayake & Mallawaratchie (1989)

(d) Minimum width of surfacing two lanes Rural Highways with adequate shoulder recommended by the World Bank funded projects from their experience on work done in all parts of the world is given below (National Academy of sciences 1978)

Design speed	Average	Daily	traffic	
KM/H	50 - 300	300 -650	650 -1200	Over 1200
45	6.1	6.1	6.1	6.7
65	6.1	6.1	6.1	6.7
80	6.1	6.1	6.1	7.3
100	6.1	6.1	6.7	7.3

Table 4.4 Minimum width of surfacing for two lane Rural Highways recommended for the World Bank funded projects

(e) Minimum of road way

Average annual daily traffic per day	Under 600	600 -1200	1200 -2500	Over 2500
Shoulder width	1.2 -2.4	1.8 -3.0	2.5 -3.0	3.0 -3.5
Pavement Width (Design speed 80 KM/H)	6.1	6.1	6.1	7.3
Total width of roadway	8.5 -10.9	9.7 -12.1	11.1 -12.1	13.3 -14.5

Table 4.5 Minimum width of roadway (National Academy of Sciences USA 1978)

4.2.3 Recommendations:

The road way widths and shoulder widths recommended in Table 4.1 – 4.5 for two lane undivided standard, if we try to accommodate these widths it would definitely excalate the cost of the facility which is hard to come by for a developing country like Sri Lanka. Even the widths recommended for ADT 50- 300 is for two lane undivided standard. It may be good practice to reserve the land for future expansion on the basis of "Total width of road way" proposed in Table 4.5.

The Figure 4.1 gives the comparison of roadway widths. The adaptation of widths proposed by RDA is desirable on the basis of future improvements, but it is observed that wider the road platform more the erosion. Also failure due to percolation of water to subgrade. Widths recommended by Irrigation Department and Mallawarachchi (1993) closely agrees. From the field observation it is found that narrower the road width, lesser transverse erosion and road failure. From the field observation carried out the gravelled width 3.5 m and platform width of 5 m. is satisfactorily behaving. Also it is noted no reduction of these widths necessary for hilly terrain either. Hence following widths are recommended. This carriageway width agrees with lane widths given in Road Note 6 (3m – 3.7m). The total width agrees with the width of precast concrete pipe culverts widely used in Sri Lanka (8'0" long two pipes)

Road Type	Terrain	Carriage way width	Flatform width
Gravel	Flat	3.5m	5 .0m
	Rolling	3.5m	5.0m
	Hilly	3.5m	5.0m

Table 4.6 Recommended Carraigeway and flatform widths

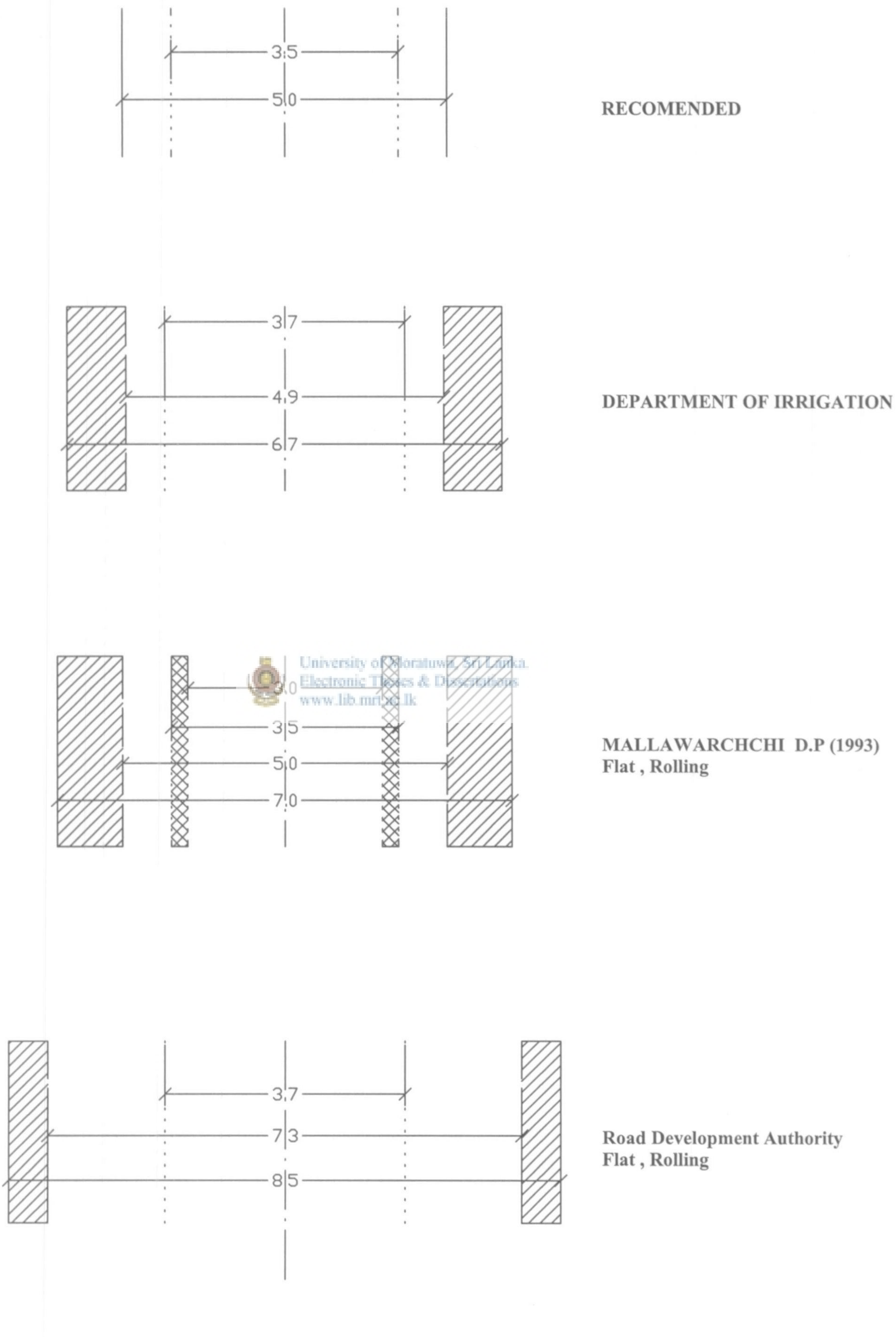


Figure 4.1 Comparrision of Road top widths

4.3 Pavement and shoulder slopes

Pavement and shoulder slope play an important role in drainage. Though higher slopes would facilitate good drainage, too high slopes would result in erosion of gravel surfaces. Usually in rural areas, cross fall is away from the shoulder.

Pavement and shoulder slopes recommended by the Irrigation Department on their Irrigation and settlement projects. { (Irrigation Department (19 88) }

(a) Pavement slopes

For metalled surfaces 1 in 40 - 1 in 46

For gravel surfaces 1 in 25 - 1 in 24

(b) Shoulder slopes ; these slopes should be equal or greater than pavement slope

RDA recommends the following cross-falls; RDA gives required figures to both carriageway and shoulder on gravel or earth roads. (RDA 1987)

Type of surface or pavement	Recommended cross fall	Type of shoulder	Recommended cross fall
Portland cement concrete	0.20 (2%)	Earth & Loam	0.60(6%)
Asphalt pavement surface seals	0.25 (2.5%) 0.30 (3%)	Gravel Bitumen or other all weather surface	0.50 (6%) 0.40(4%)
Unsealed gravel Earth Loam	0.40(4%) 0.50(5%)	Gravel surface	0.4(4%)

Table 4.7 Shoulder and pavement slopes recommended by RDA

The technique of construction gravel roads published by the Ministry of Highways recommends a camber (Cross fall) of 4% away from the pavement. (Ministry of Highways 1986) Road Note 6 – (1988) recommends cross falls of 5% - 6%

4.3.1 Recommendations:

As discussed under drainage the cross slope is to facilitate taking the water falls on to the road surface expeditiously, but too high slopes will erode the surface as shown in Figure 4.3 below, too low the cross slope water will take long time t o to travel to sides. A cross falls higher than paved road (3%) & less than earth road would be suitable.

Hence, a cross fall of 4% is recommended for both carriageway and shoulder. As compared in figure 4.2.

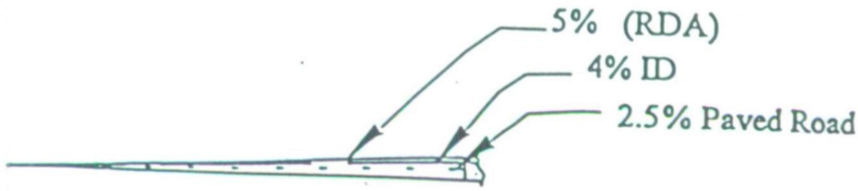


Figure 4.2 Comparison of Cross fall

Figure 4.3 Erosion of shoulder when cross fall exceeds 6%

4.4 Gradients (Vertical alignment)

The rate of rise or fall of a road surface is called the road gradient. This is expressed as percentage (%) or as a ratio of 1 vertical in 'X' horizontal which is the distance measured along the length of road.

The standard maximum gradient for a gravel road need to be considered carefully since it does play an important role in the total cost. For example in a mountainous terrain it may be possible to achieve relatively flat grade with lesser heavy excavation but at expense of many sharp curves or heavy excavation increasing the cost of construction and maintenance.

In situation of that nature, higher gradients may have to be adopted but restricting the length of slope. But these to be considered as localized exceptions.

In some existing hilly roads, no adjustment could be made without excessive changes to horizontal alignments at a high cost. In new construction, this has to be considered seriously.

RDA recommendation on gradients and alignments.

Class of road	Average annual daily traffic in PCUS	Terrain	Design speed Kmph	Desirable maximum grade %
D,E	0 -200	Flat Rolling Mountainous	50 40 30	9 10 11
C,D	200 - 1000	Flat Rolling Mountainous	50 40 30	9 9 10

Table 4.8 Recommended values for gradients and alignments by RDA

Also it states that there are no rigid standards for maximum grades as these vary with class of road, speed, and topography, on high speed roads, grades not over 3% provides for satisfactory level of service. On roads with more modest design speeds, grades up to 6% cause no problems. Gradients over 10% bring problems of very low climbing speed and high down hill speeds. But above are the maximum grades used.

Grades recommended by the Department of Irrigation on their Irrigation and settlement roads are as follows.

Terrain	Ruling gradients	Limiting gradient	Absolute Maximum gradient
Flat	1 in 30 (3.0%)	1 in 15 (6.6 %)	1 in 12 (8.3%)
Rolling	1 in 25 (4.0%)	1in 12 (8.3 %)	1 in 10 (10%)
Mountainous	1 in 20 (5.0%)	1 in 10 (10 %)	1 in 10 (10%)

Table 4.9 Grades recommended by the Department of Irrigation

" Ruling gradient is the desirable gradient, limiting is the maximum allowable gradient, absolute maximum gradient is that permissible for short distance up to 300ft." Also its states that the length of steep grade should be that it reduces the average running speed by 15mph from the level running speed, the critical length recommended for various grades are 1700ft (3%) 518 (m) 1600 ft (4%) 487 (m) 800ft (5%) 243(m), 600ft. (6%) 182(m), 500ft(7%) 152(m) and above.

According to Mallawaratchie & Senanayaka (1989)

Road type	Terrain	Maximum gradient (%)	Maximum length of gradient
Paved	Flat	4	None
	Rolling	7	1600 over 6%
	Hilly	10	500 over 8%
Graveled	Flat	6	None
	Rolling	9	1000 over 7%
	Hilly	12	500 over 9%
Earth	Flat	6	None
	Rolling	9	1000 over 8%
	Hilly	12	500 over 10%

Table 4.10 Grades recommended by Mallawaarachchi and Senanayake (1989)

4.4.1 Recommendations:

The gradients for gravel roads cannot be solely decided by maximum grade and maximum length of grade as given in all the specifications above since:

1 The erosion of gravel roads is critical in higher grades.

2 According to surveys carried out over 75% of vehicle population on rural roads are bicycles,Motor cycles and three wheeles.

The Irrigation Department proposed gradients are moderately low. RDA specifications caution any gradient above 6%. The gradients proposed by Mallawaratchie (1993) seems to be too high in respect of maximum length of gradients.

The allowable gradients could also be given by way of average gradient for a unit length (km) and maximum gradient. Considering the riding ability of bicycles (Beenhacker Hentry 1987) and erosion, average gradient of 5% per km grades (limiting) adapted by Irrigation Department is desirable. The absolute maximum gradients in par with gradient proposed by Mallawaratchie (1989). It is also desirable that these maximum grades are used at curves in order to remedy all negative effects such as:

1 Erosion due to super elevation in curves.

2 Erosion due to higher gradient.

3 Ravelling of gravel at bends due to side thrust in cornering.

4 Safety hazards due to low side friction of gravel roads at bends.

The remedy would be to provide traditional metalling and tarring at bends where gradients exceeding 6% have to be provided. The advantages are that, since low radius of curves are adapted, low speeds are inevitable. This gives more traction hence easy to negotiate high gradients, for motor vehicles. Cyclist can get down at these places on climbs. since length of curves are not long .

Hence, subject to average gradients of 5% per km following maximum gradients and desirable gradients are recommended.

Road Type	Terrain	Maximum gradient	Desirable gradient
Gravel	Flat Rolling Hilly	6% 9% 10%	3% 4% 5%

Table 4.11 Recommended gradients

The minimum gradient of 3% to be provided in order to facilitate drainage.

4.5 HORIZONTAL ALIGNMENTS

The horizontal alignment of roads is usually of straight and curves, more practically combination of straight, circular curves connected by transition curves. The horizontal alignment should be confirming to topography and terrain conditions. The aim should be to establish the easiest, shortest and most economical line of connection between the obligatory points, which will have minimum cost of construction and maintenance. In addition, sufficient length should be provided between curves. The observed problems at curves on gravel roads are; that skidding due to low coefficient of friction and wash aways due to super-elevation (single slope) .

(a) R.D.A. Specifications

The recommendation on radius of curvature by RDA is given below. This is primarily based on speed and should be noted that its dependent on coefficient of side fiction . It is unlikely that these coefficients can be measured but the Engineer can select the values based on type of material he is going to use. The abstract quoted only for speed upto 60km/h.

Though it is not recommended to make the design based on speed for low volume, low cost road, the reasons for including this feature of curves is because of the possibility of stage construction later. Also its considered where possible , provision of designed curves are advantages. If it could be recommended to check the washaways at curves due to super elevation without having to trade off the cost heavily.

The specification laid down by RDA is as follows:

Design speed (km/h)	Coefficient of side friction for gravel surface (f)
30	0.14
40	0.13
50	0.12
60	-

Table 4.12 Coefficient of side friction for gravel surfaced roads by RDA

Minimum radius of Horizontal curves having adverse cross fall not exceeding 3% (0.30)

Design speed km/h	Minimum Radius (m)
30	145
40	200
50	400
60	600

Table 4.13 Minimum Radius of Curves

e+ f- Value lies between 0,3 and 0.5

(b) The Department of Irrigation specification

"The maximum values recommended for super elevation (e) is 10% which may be increased to 12% in mountainous terrain to reduce the curve radius for economic reasons.

The recommended values of Lateral friction (f) at impending skid are between 0.25 to 0.16 for corresponding speed ranges of 20 mph (30 km/h) - 50-mph (80 km/h)" gives following

Speed in mph (Km/h)	**Lateral Friction (ft)**	**Minimum Radius**	**In ft (m)**
		E=10%	**E= 12%**
20 (30)	0.25	80 (25)	70 (20)
30 (50)	0.20	200 (60)	200 (60)
40 (60)	0.18	400 (120)	350 (105)
50 (80)	0.16	650 (200)	800 (180)

Table 4.14 Radius of curves recommended by the Dept of Irrigation for roads in Irrigation and settlement projects

(c) Radius of curves recommended by Mallawaratchie (1993)

The radius of curvature proposed by Mallawaratchie (1993) for rural roads gives the speeds and combines with the gradients. This is same as radius of curvature recommended by Mallawarachi and Senanayake (1989)

Road type	Terrain	Design speed	Minimum curve radius (m)
Earth	Flat	35-50	35-75
	Rolling	25-40	30-35
	Hilly	20-35	25-35
Gravel	Flat	40-60	50-110
	Rolling	30-50	32-75
	Hilly	20-35	25-35

Table 4.15 Radius of curves Recommended by Mallawaratchie (1993)

4.5.1 Recommendations:

From the three specifications available the curve radius recommended, by the RDA are the largest. They tend to increase the cost as discussed in general. The values recommended by the Dept. of Irrigation are on the lower side. But for very high super elevation (10%, 12%).The radius recommended by Mallawaratchie (1993) are closely satisfying with the values given by the Department of Irrigation for lower speeds and slightly higher in higher speeds while it combines with the terrain factors as well But it is proposed to adopt minimum radius of curvature limiting super elevation to 6% since erosion in gravel observed to be critical about this slope. Using the formula

$R= v^2/127(e+f)$

R - Radius of curvature (m)

V- Speed km/h

e- Super elevation

f- Coefficient of side friction (function of speed)

Assuming values for V, e, and f, R could be calculated, and following are the results and recommended minimum radius of curvature proposed to be adapted for gravel roads.

Road Type	Terrain	Design speed Km/h	Minimum curve radius (Metres)
Gravel	Flat Rolling Hilly	40 - 50 30 -40 20 - 35	60 - 110 m 35 - 60 15 - 50

Table 4.16 The recommended radius of curves

CHAPTER 5

5.0 DRAINAGE

5.1 CONSIDERATIONS

In the case of any road irrespective of whether it is graveled or paved, drainage is the most important aspect, for almost all failures are caused by the decrease in strength of subgrade and pavement structure by water getting in to it. The reason for this is roads are founded on soils subgrades and material used in the pavements structure decrease in strength with the absorption of water. In order to ensure stability of a road it is necessary that the soil foundation be kept in relatively dry condition. The following quote explains the importance of keeping water away from the subgrade. "The road can never be rendered thus perfectly secure until the following principles be fully understood, admitted and acted upon, Namely, that whilst it is preserved in dry state it will carry any weight without sinking, that if water passes through a road and fill native soil the road whatever may be its thickness loses support and goes to pieces". (Macadam-1836), The characteristics of soil is such that when water content exceeds the optimum moisture content as evaluated by the standard compactions test, its strength start decreasing rapidly. Roads commences to deteriorate when they are exposed to all the elements in nature such as rain, sun, wind, and also vehicular traffic. When water enters the foundation, it takes some time to drain off even with good drainage facilities. Hence damages to the pavement occur when vehicular traffic traverse the roads whilst the foundations are wet. As illustrated in the figure 5.1

There are six following ways of moisture entering the road subgrade.

i . Seepage of water into the subgrade from higher ground adjacent to the road.
ii. By rise or fall in the level of water table.
iii. Percolation of water through the surface of the road.
iv. Transfer of moisture via shoulders and verges as differences in moisture content.
v. Transfer of moisture from lower soil layers (capilary action)
vi. Transfer of water vapour through the soil (advection)

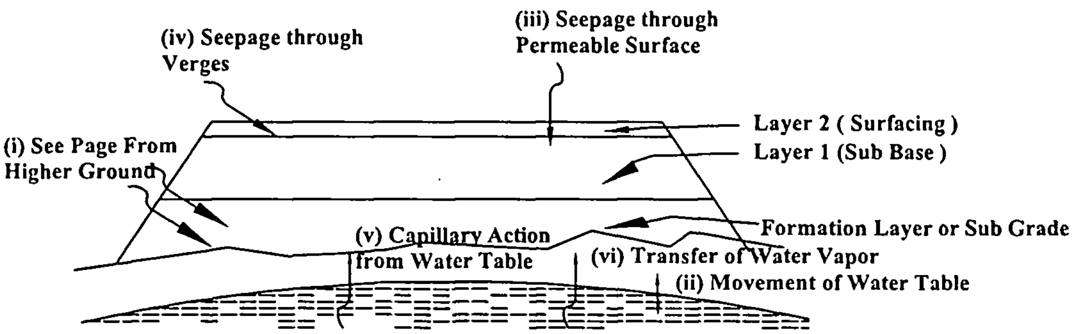


Figure 5.1 Ways of Water Entering the Road Pavement

The phenomenon given in i, ii, v, & vi are common to any highway construction and will not be dealt in detail except for few suggestions. Drainage in general could be divided into ;

- Sub soil drainage.
- Sub base drainage.
- Provision of drainage ways (cross drainage).

Item i, ii,iv,v,vi, in section 5.1 is sub soil drainage will be dealt as a measure of low cost method adaptable to gravel road construction.

5.2 PERCOLATION OF WATER

Unlike in the paved roads, gravel roads are more susceptible to percolation of water through the surface. To overcome this, the flow property of water need to be considered. Water will flow along the easiest path it can flow. The quantity (Q) of water percolate to the road sub base, is a function of height of water - Head (H), permeability of soil in surfacing layer – (P) and duration of stagnation – time (T)

Hence

Q – F (H,P,T)

When (II) increases (Q) increases

When (P) increases (Q) increases

When (T) increases (Q) increases

Therefore it is imperative that to prevent or minimize flow of water into the sub grade. The following measures have to be taken :-

i. Prevent heading up of water

ii. Using less permeable material as much as possible to make a less permeable surface.

iii. Making provision to take off water as quickly as possible from the road surface.

5.2.1 Preventing heading up of water

Heading up of water occur due to:

(a) Inadequate cross falls

(b) Formation of rut and potholes

(c) Blocked side drains & culverts

(d) Raised verges

(e) Poor construction at change of grades

Therefore, construction & maintenance should aim to prevent the above.

5.2.2 Permeability of Material

Using soils with suitable characteristics it is possible to delay the percolation of water through the road surface. Clayey materials have very low coefficient of permeability. Whereas materials with gravelly soils without fines have very high coefficient of permeability. Though clay soils have favourable characteristics with regard to permeability, to prevent percolation of water; these soils produce dust during dry weather, become slippery during rain and also crack when they dry. These properties are not favourable, while loss of fine materials by way of dust causes to wear off the surface.

The granular materials with out fines are more permeable and have characteristics opposite to clayey materials. Hence, suitable mixes of both materials would be desirable. That is to get soils which have a gradation that give highest compactibility and less dusty when dry. Some clays would facilitate cementation of gravelly soils particles. These aspects have to be considered in the selection of suitable materials. Well graded soils with a little clay could be compacted to achieve high density without ravelling of gravelly soil particles

5.2.3 Provision of drainage paths

The water falling on to the road surface due to rain is expected to be taken to either sides of the road by providing suitable crossfalls and through shoulder and verges to the side drains. The ease of flow of water to the sides will depend on the amount of crossfalls, width of the road and the texture of the surface. It should also be considered that wider the carriageway and platforms; the time taken by water to flow out of the surfacing is more; thereby giving time to percolate. Hence, constructing gravel roads for wider widths are not recommended when considering the drainage. This has been considered in chapter 4 on geometric standards as well.

Apart from the materials of the surfacing, consideration of cross section of the roads have a role to play for quick disposal of water. Making appreciable camber and longitudinal gradients, draining of water from the surface is achievable. It has also to be noted that too much camber and longitudinal grades will cause erosion. Therefore upper bounds are required.

Suitable cross-sections for a gravel road considering the drainage and aspects of construction are discussed in chapter 4 in section 4.1.2 . is given below.

Typical cross-sections of gravel roads in cut and in fill are given in figures 5.2 and 5.3 respectivelly.

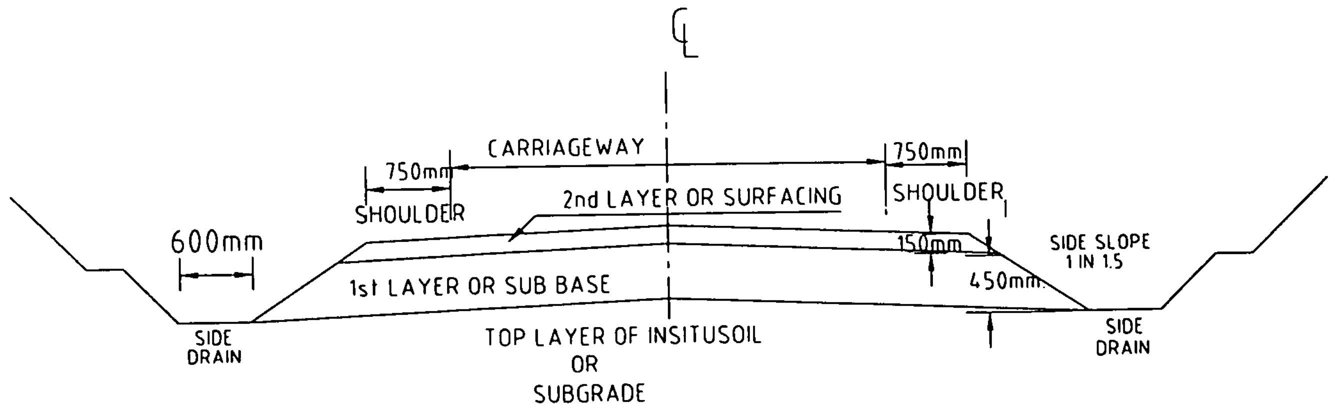


Figure 5.2 Cross section of a gravel road in a cut

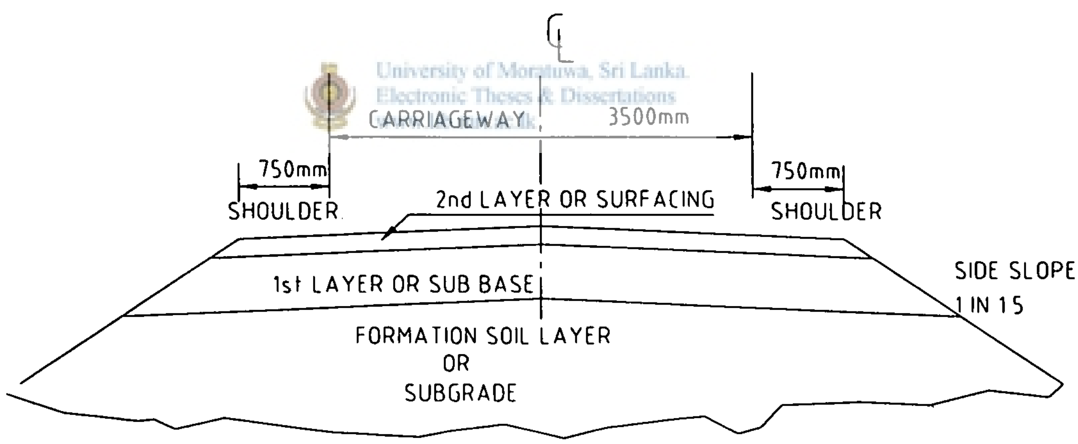


Figure 5.3 Cross section of a gravel road in a fill

5.2.4 Protection of embankment slopes from erosion:

Both side slopes of embankment should be provided with suitable turfing in order to avoid erosion. Erosion of sides leads to progressive failure of road structure while eroded material fill side drains and thereby making them fail to function. . Side slope of one and half horizontal to one vertical (1 ½ : 1) is recommended

5.2.5 Provision of side drains

Provisions of side drains of adequate width are of prime important to take off surface water away from road surface and water flowing from adjacent ground. Table 2.1, 2.2 indicate that road failure are minimum when drains are clear. In addition, provision of cross drainage structures such as culverts along with leadaway drains and bridges at necessary places too is important. A suggested dimension of a side drain is given below figure 5.4. The gradients of side drains should not be less than 3% in order to ensure flow of water. If slopes are too low, water will stagnate.

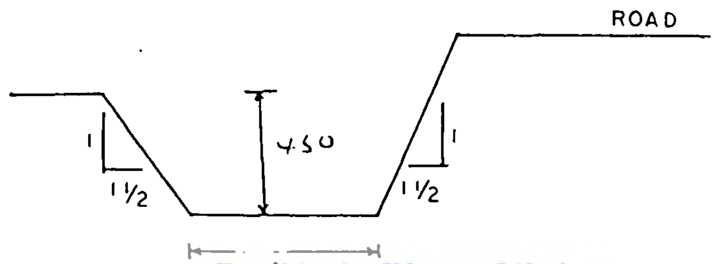


Figure 5.4 Typical cross section of a side drain

5.3 RECOMMENDATIONS

(1) If gravel roads are required in wet zone or high rainfall areas it is recommended to use higher percentage (%) of crossfalls (4% - 5%)

(2) Limiting the gradients will assist to prevent erosion of gravel surfaces. The limiting gradient considering drainage is about 6 %,(Overseas Road Note 6 1988). in places where they are unavoidable such sections are recommended to be paved. In higher rainfall areas even sections with gradients above 4 % may be paved in order to prevent longitudinal erosion.

(3) Limiting the formation width will reduce the length of water path on its way to sides from the center of the road. Adopting lower formation widths and higher cross falls for shoulder than for carriageway facilitate easy drainage. Figure 2.1 and 2.2 shows that when platform width increases cross erosion also increases. A

cross fall of 1% - 2% higher than that for carriageway for high rainfall areas and about 4 % for low rainfall areas are recommended.

(4) Prevention of water percolating from gravel surface is not practically possible. But use of more pervious sandwich layer facilitate easy drainage of percolated water. Hence prevent percolation of water to sub grade. Therefore it is recommended to use at least small sandwhich layer of pervious material in the sub base in high rainfall areas.

(5) More plastic (clayey) materials for road shoulders are recommended to prevent percolation of water through shoulders since shoulders can be provided with more clayey soils than the carriageway.

(6) Regular maintenance may facilitate maintaining a rut free surface, which in turn prevent pooling of water.

(7) If the grass shoulders are not trimmed regularly during rainy season, they will hinder flow of water from carriageway. It is recommended to trim the grass regularly to keep the level of shoulders lower than the carriage way for ease of flow of water.

(8) If both traffic and rainfall are higher than acceptable limits, priming and sand sealing of the gravel surface is recommended to keep the maintenance level within acceptable limits. For priming emulsion CSS – 1 applied @ 1.0 lt/Sqm., and sand sealing applied at the rate of 1sqm CRS-! Emulsion are recommened.

(9) Construction should be done in layers and maximum possible compaction level should be achieved. For this, strictest quality control should be enforced during construction.

CHAPTER 6

6.0 SELECTION OF MATERIAL

6.1 CONSIDERATIONS

There are three layers in structure of a gravel road, They are

(a) Subgrade

(b) Sub base

(c) Surfacing

All of these layers are constructed with naturally occurring soils, unless otherwise a special reason is there to stabilize any one of those layers in any given section of road. There is hardly any control /choice over the material in Subgrade after finalizing the road trace. Subgrade is the naturally occurring layer of soil where road structure is founded. However, traces over highly plastic soils, highly compressible soils and organic soils should be avoided. The material to be used in layer (1), sub base & layer (2) surfacing could be selected subjected to constraints of

(1) Availability in significant quantities

(2) Availability in economic transport distance

(3) Suitability for different layers

If material which satisfy both requirements, for the first layer (sub base) and second layer (surfacing) available, Then the total thickness of construction could be reduced. This will reduce the total cost of construction

6.2 AVALABILITY OF SUITABLE SOILS FOR GRAVEL ROADS

6.2.1 Soils in Sri Lanka has been broadly categorized as (Cooray – 1984)

(a) Reddish brown soils of dry and intermediate zone.

(b) Reddish brown and red yellow soils of the wet and intermediate zones.

(c) Red yellow soils of dry and intermediate zones.

(d) Alluvial and coastal soils and swampy soils.

Soils except the swampy soil consists of clayey sands with silt, silty sands with clays, sandy clays, clays, clayey sand, sandy clays, gravely -sand –clayey sands, silty sands and the five types of gravely soils given later in this chapter. These soils have standard densities ranging from

1.40 -2.22 x 10kg/m3 and their four-day soaked CBR values under standard compaction have generally been found to vary from two to sixty percent. (Mallawaratchic 1993)

Swampy soils are generally peaty soils and extending up to 6.0 meters and their organic contents and moisture contents vary up to 60 percent and 400 percent respectively.(Mallawarachi 1993)

All soils except for marshy soils, clays, silts and silty clays are suitable for the construction of earth and gravel roads. These suitable low cost materials are abundantly available in hillocks and the ground surface and are scattered throughout the island. These materials can be quarried from those places except in built up areas which are used for cultivation.

The predominant types of gravely soils present in Sri Lanka are

(1) Lcteritic gravelly soils
(2) Basal ferruginous gravelly soils
(3) Quertizitic gravelly soils
(4) Noduler Iron stone gravelly soils
(5) Mixture of iron stones and quertzitic gravelly soils. (Mallawaratchie 1993)

An important point is that most of the gravel quarries; the gravel is available in relatively thin layers. Usually 0.75 m - 1.5 m. This is particularly so with lateric gravels. Therefore, obtaining gravel from quarries needs care. It is usually obtained as dug in most locations. Therefore, care should be taken while harvesting, to harvest only suitable material without mixing different layers. Also it is worth noting that construction is done in following sequence.

(1) Subgrade, (Embankment)
(2) Sub-base - Layer 1
(3) Surfacing – Layer 2

But material suitable for surfacing naturally occur in upper most layers, and material suitable for sub base and embankment in lower layers. Therefore, while quarrying it should be clearly noted to pile different material at the quarry separately and then used in proper sequence. Most people realize only later that after using good gravelly soils in to lower layers that they are short of good material for surfacing.

6.2.2 Availability of gravelly soils and their locations

- Lateric gravely soils

The best aged category of these soils are found in the south -west of Sri Lanka within a belt extending 10 -11 km in-land from the coast and up to about 30 m above mean sea level (MSL). These gravely soils are usually blackish brown in colour.

- Basel ferruginous gravely soils

This gravel usually Grey in color, is partly mottled in shapes of red and brown colour. It is formed out of coarse sand grains; fragments of cherk and pellets of iron stone partly cemented together with ferruginous, material. A little clay is also present. These gravelly soils are present within a broad belt extending from Negombo - Mannar (Figure 6.1) and in scattered locations from there.

- Quartzitic gravelly soils

It is a coarse quartzitic gravelly soil that occupies the edges of small river terraces in several scattered locations in the Chilaw (Figure 6.1) and inland.

It is seen in many parts of the island but particularly in the dry zone. The most abundant type of these soils is found on top of the crystallize rocks. Where as it has formed from the disintegration of rock material lying above these rocks. It can be found in many locations in the northern half of the island (especially in between Puttlam)

- Mixture of ironstone and quertzitic gravelly soils

They are generally available through out the island but not in large extents.

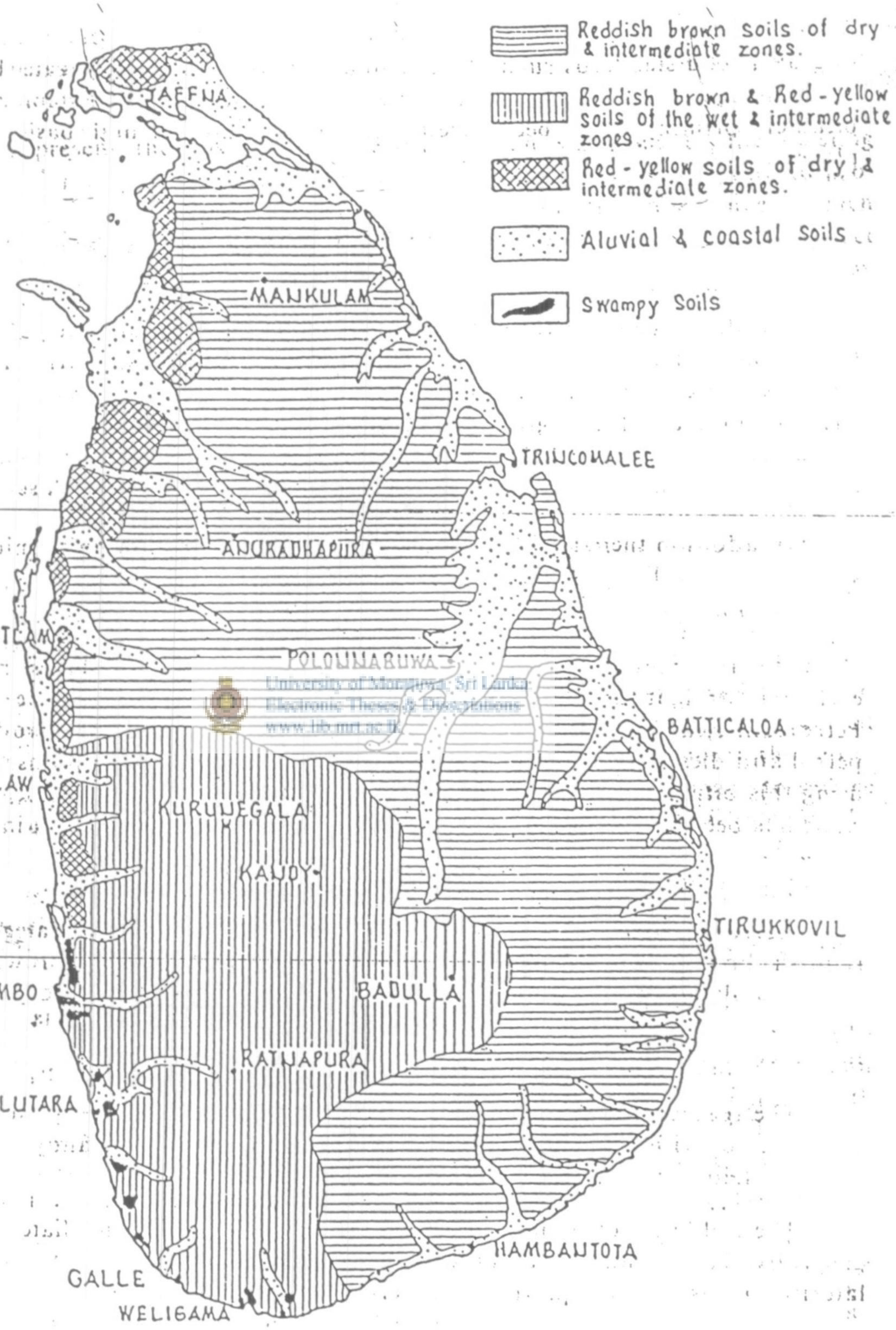


Figure 6.0.1 Available soil types and their distribution in Sri Lanka

6.3 SUITABILITY OR SELECTION OF MATERIAL

6.3.1 General characteristics

Material for different layers of construction require specified properties of material such as gradation, plastic limits, liquid limit, California bearing ratio. However, most of the superior quality material could be used even for lower layers of road embankment. Though not recommended to be used due to inappropriate use of precious material will deplete sooner than desirable. The material used for lower levels of the road embankment such as, sub-base, embankment, would hardly differ from a paved road, Emphasis should be given to consider material for surfacing. However, consideration is necessary on subgrade material in determining the thickness of surfacing layer thickness.

The material suitable for surfacing should be compacted to a high density in order to prevent

(a) Ravelling under wheels of traffic

(b) Prevent or minimize percolation of rainwater

(c) Loss of material by way of dust in dry weather and

(d) Too much of dust which is environmentally hazardous.

(e) Erosion.

In order to satisfy the above condition, the gravelly material should have following engineering properties.

The gravelly material be well graded, high density, low plasticity, characterics. Also gravelly material should be hard enough to withstand repeated traffic loads preventing crushing of particles. Due to crushing of particles it produce a sandy layer of soil on surface and dusty when vehicles speed up, Therefore gravelly material should possess low Los Angeles Abrasion Values (LAAV) & low Aggregate Impact Values (AIV)

When large particles are present in gravelly soil used for surfacing will result very rough riding surface. Also it is not possible to be bladed with a grader to restore an even profile. The presence of course material results in the formation of corrugations during dry season and increases the difficulty in removing those corrugation. Hence there should be a limit on largest size of particles, & quantity present. This will be looked after by controlling the grading of the material.

It was outlined in Chapter (5.0) on drainage that, the surfacing material should have a small but adequate proportion of clay material in order to cement (bind) coarse particles and reduce permeability and erodability of surface. This could be judged by grading, plasticity index, and liquid limit. Also, these values should be taken according to climate conditions.

As surfacing layer take the load of vehicles directly in order to transfer to the other layers, measure of load bearing capacity is necessary. This will be determined by CBR value or unconfined compressive strength; Popularly used index is the California Bearing Ratio (CBR) as explained in section 7.4.2

6.3.1.1 Plasticity Characteristics

The plasticity characteristics of soils for gravel surfacing recommended by AASHTO, TRRL and RDA is given below

AASHTO	
LLMax %	PL %
35	4 – 9

Table 6.1 Plasticity Characteristics Recommended by AASHTO

Climate	LLMax %	PI %	Linear shrinkage %
Moist tropical and wet tropical *	35	4 - 9	2 – 5
Seasonal wet tropical **	45	6 - 20	3 10
Arid and semi arid ***	55	15 - 30	8 - 15

Table 6.2 Plasticity characteristics Recommended by TRRL UK

Note : * this conditions are equivalent to wet and intermediate zone.

** this conditions are equivalent to dry zone.

*** this conditions does not apply to conditions in Sri Lanka.

Local RDA		
Climate	LLMax %	PI %
Wet zone and intermediatezone	40	4 15
Dry zone	50	6 – 25

Table 6.3 Plasticity characteristics Recommended by RDA

Comparing above recommended values by plotting them liquid limit Vs plasticity index shows that :The Local specification encompasses wide range of soils, also research has been carried out by R & D division of RDA of its applicability to Sri Lankan condition by Mallawaratchie (1993). Sometimes available soils with plasticity indices higher than those values given in RDA specification have been used and have behaved satisfactorily as gravel surfacings for several years. Therefore LL, PI could be increa to 55 & 30 respectively.

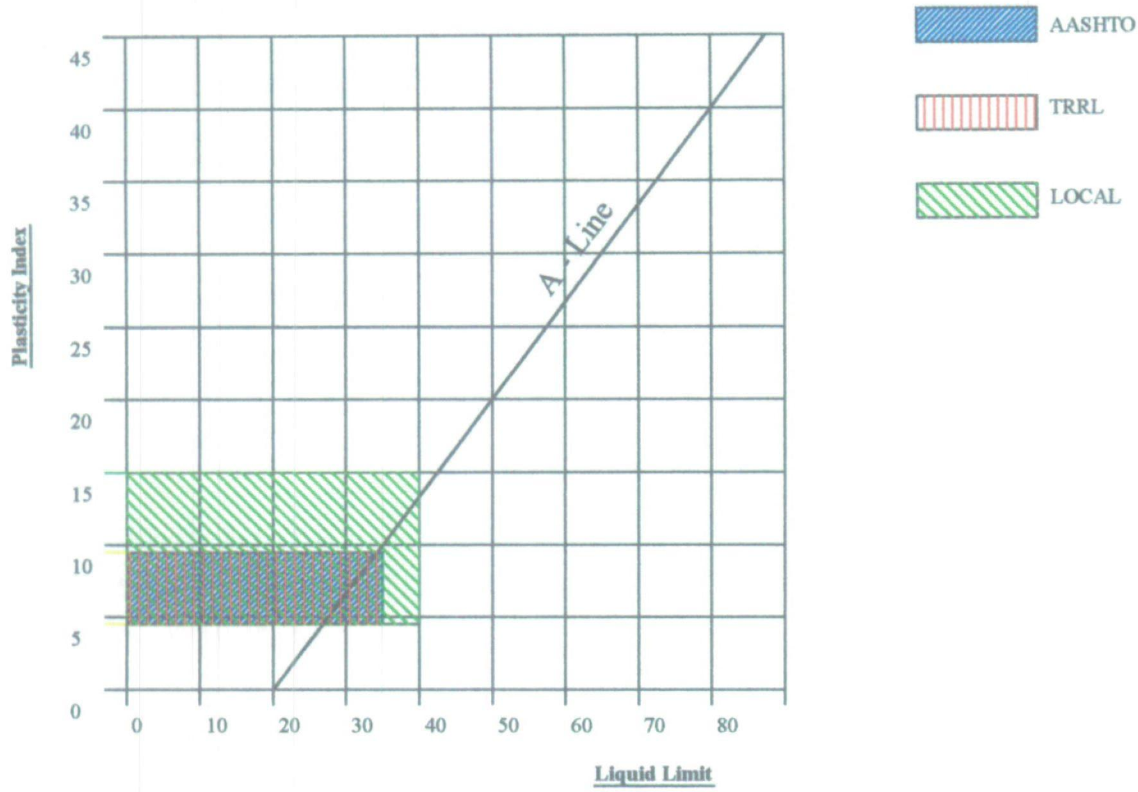


Figure 6.1 Comparision of Plasticity Characteristics for wet and Intermediate Zone

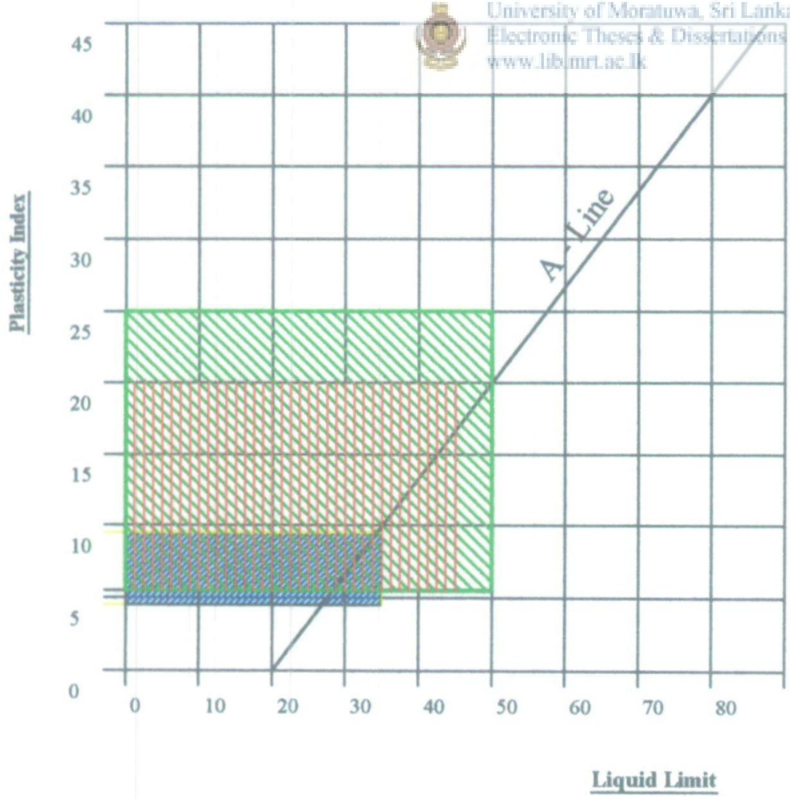


Figure 6.2 Comparision of Plasticity Characteristics for Dry Zone

6.3.1.2 Gradation of soil for gravel surfacing

The Gradation of soils recommended by AASTHO, (four Gradations C,D,E,F) TRRL & RDA specification for gravel surfacing are given below.

US Sieve size	Percentage passing Nominal maximum size			
	Nominal Maximum sizes 25.4mm			
25.4mm	100	100	100	100
9.5mm	50-85	60-100	-	-
4.75mm	35-65	50-65	55-100	70-100
2mm	25-65	40-70	40-100	55-100
425μm	15-35	25-45	20-50	30-70
75μm	5-15	5-20	6-20	

Table 6.4 The Recommended Gradations for gravel Surfacing by AASHTO C,D,E,F)

BS sieve	Percentage Passing		
	Nominal maximum size 37.5 mm	Nominal maximum size 25.4mm	Nominal maximum size 9.5 mm
37.5	100	-	
19	80-100	100	
9.5	55-80	80-100	100
4.75	40-60	60-85	80-100
2.36	30-50	45-70	50-80
425μm	15-30	25-45	25-45
75μm	5-15	10-25	10-25

Table 6.5 The Recommended Gradations for gravel Surfacing by TRRL

Us sieve size	Percentage passing Nominal maximum size 37.5 mm
37,5 mm	100
19 mm	75-10
4.75 mm	40-100
1.36 mm	30-80
600 μm	18-50
75 μm	5-25

Table 6.6 The Recommended Gradations by Local RDA

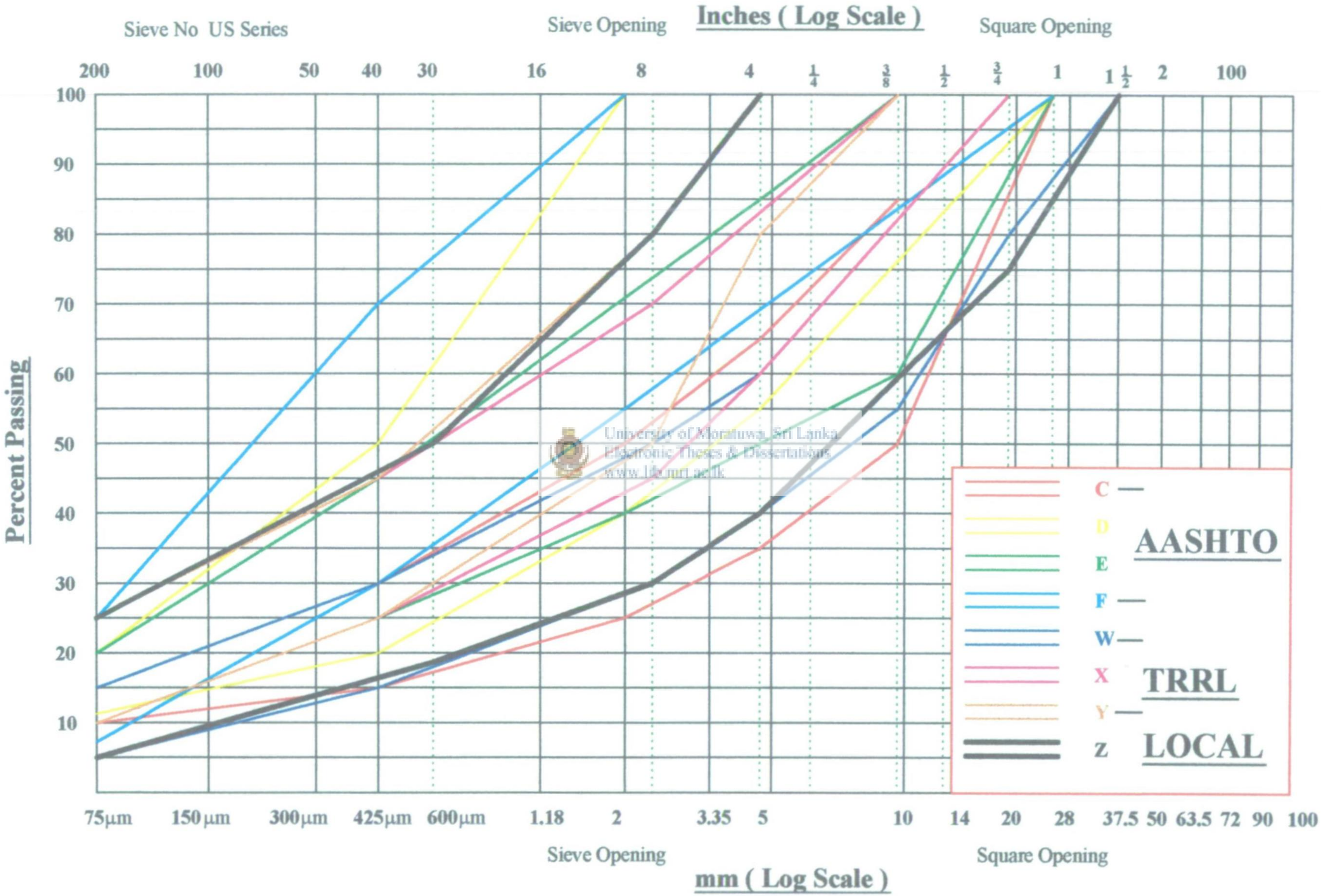


Figure 6.3 Comparision of Particle size distribution - Gravel for surfacing

Recommendation

When those gradation curves are plotted, local gradation encompasses all grading bands except fine grain soil grading of AASHTO (F), figure 6.4 . RDA gradation band covers a wide spectrum and also it is tested for local condition,(Mallawaratchie – 1993). It is also noted that grading band left side of this grading band is with smaller size of particles – which is silty clay type. This type of soil is found to be unsuitable for surfacing by experience. Since the local grading band given in table 6.6 has been tested for local conditions and found satisfactory (Mallawaratchie 1993) it is recommended which also exclude the fine particle portion of other grading bands.

6.3.1.3. Hardness of material

There is no specification for this aspect on any of the specifications for gravel surfaced road but it is considered an important property Therefore adaptation of values recommended for aggregates used for penetration macadam construction by RDA is recommended but this should be researched into for its adaptability.

Those values recommended for hardness of aggregate used for penetration Macadam construction

Los Angelese Abrasion Value (max)	40 % (50)
Aggregate Impact Value (max)	35 % (40)

Table 6.7 Hardness of aggregate particles (RDA 1989)

exceptional Circumstance Values indicated in bracket could be used.

6.3.1.4 Strengths of soils.

There are many ways for deciding strengths of soils, but for the purpose of road construction the strengths of soils are assessed by California bearing ratio. Pavement designs are mostly based on the CBR values of soils and are particularly so in low volume low cost roads.

The value of CBR suggested by Senanayake and Mallawaratchie 1989 is CBR>= 20 percent. This is compatible with the specification adopted for sub base of paved roads. The RDA specifications give the same value. The experimental roads constructed using these specifications have been behaving well. {Mallawaratchie (1993).} Hence the use of material having CBR.>= 20 is recommended for gravel surfacings.

6.3.2 Classification of soils for selecting suitable soils for use in road pavement.

Since gravel roads are mostly constructed in villages in rural areas there is a need for exploration of availability of suitable materials. This could be done by visual classification of available soils in this area and few simple tests in the laboratory such as gradation, PI & LL. Those could be carried out by middle level technical officer. In order to do this for selection of materials based on experience such as

1.) AASHTO and TRRL gradation curves

2.) Local RDA specification LL & PI conditions would be suitable or

a soil classification chart along with testing suitability proposed by Sehgal 1984 is produced in figure 6.2

Division and sub division (1)	(2)	Letter (3)	Name (4)	Drainage character–ristics (5)	Unit dry weight (6)	For road ways: Embankment	Base course	Wearing course
Coarse gained soils	Gravel and gravelly soils	GW	Gravel or sandy Gravel well graded.	Excellent	125 – 140	V.Good	Very good	Good
		GP	Gravel or sandy Gravel poorly graded	Excellent	120 – 130	Good	Good	U/Suit.
		GU	Gravel or sandy gravel uniformly graded.	Excellent	115 – 125	Poor	Poor	Poor
		GM	Silty gravel or soilty sandt gravel	Fair to poor	130 – 145	Poor	Poor	Poor
		GS	Clayey gravel or clayey sandy gravel	Poor to pract–ically impervians	120 – 140	Fail	Fair	Good
	Sand & Sandy soils	SW	Sand or gravelly sand well graded	Excellent	110 – 130	Good	Good	Fair
		SP	Sand or gravelly Sand poor graded	Excellent	105 – 120	Poor	Poor	U/Suit.
		SM	Silty sand or silty gravelly sand	Excellent	120 – 135	Poor	Poor	U/Suit.
		SC	Clayey sand or clayey gravelly sand	Poor to practi–cally impervions	105 – 130	Fair	Fair	Fair
	Low compressive LL<50	ML	Silts ,Sand slits gravelly silts or diatomaceous soils	Fair to poor	100 – 125	Poor	Poor	U/Suit.
		CL	leon clays.sandy clays or gravelly clays	Practically impervions	100 – 125	Fair	Fair	Fair
Gine gained soils	High compressive LL> 50	MH	Poor clays or diatomaceous soils	Fair to poor	80 – 100	Very Poor	Very Poor	U/subit.
		CH	Fat clay	Practically impervions	90 – 110	Very Poor	Very Poor	U/subit.

This uses unified classification of soil

Table 6.8 Classification of soil for selecting suitable soils for use in road pavements. (Sehgal 1984)

CHAPTER - 7

7.0 DESIGN PROCEDURE OF PAVEMENT STRUCTURE

7.1 INTERODUCTION

A road pavement is expected to support the wheel loads imposed on it from traffic, Distribute them to the sub grade, where sub grade itself can safely bear it. and accommodate changes in the environment.

As described in chapter 1.0, the scale of pavement or the options available, according to pavement surface is about eleven. It is known that design of pavement is done for the first 4 types but its known definitely that for category 1 & 2 design of pavement done due to the fact that they are very expensive and expected to carry large volume of traffic and heavy loads. For earth roads - paths (types 8- 11) no pavement design is done. The boundary of change of attitude and use of technology starts from gravel surface road (7) towards type (1) concrete paved roads, unless special conditions exist. Usually agricultural and feeder roads when constructed, carry very little traffic and start growing over the years, until the increase traffic (ADT) justifies a paved road for various economic reasons discussed elsewhere.

At the time of upgrading to paved roads, there are two options. Assuming there was no pavement design consideration at the time of first construction and then assess the strength of existing gravel pavement and build a new pavement on it as designed. Various factors such as traffic existing at the time should be considered. Other option is if there was a design consideration at the beginning, to improve upon it for new demand. In stage construction, the option two is followed.

- Advantages of Stage Construction

Due to extreme scarecity of financial and other resources in the country, road construction should generally be done adopting the stage construction policy. A new road for example with the bearest minimum specifications such as gravel surfacing over a particularly designed sub base, thickness.

As traffic grows, additional layers in the form bitumen bound bases and superiors surfacings are added on. Initial outlay should be minimum and additional outlays are in keeping with the growth of traffic. Therefore at no stage the investment made in advance is more than actual requirement and also not discarded at later stages but made best use of by incorporating an improved facility as far as possible. Hence:-

(a) The overall economy up to the time of upgrading arising from maintenance, vehicle operating costs, due to engineering consideration at the time of construction of the road facility.

(b) The concept of stage construction pre considers the improvement necessary at a latter time hence over haul is not necessary. Therefore the use of existing facility economically leading to progressive investment complementary it leads to benefits to the country.

(c) The level of services available to users from the beginning is much higher than that of stage construction is not mooted at the beginning.

(d) Best use of scarce resources such as quality soil, and overall environmental conservation. Otherwise, necessity to discard old material. Land use may also have changed from the time of construction of first facility to the time of upgrading.

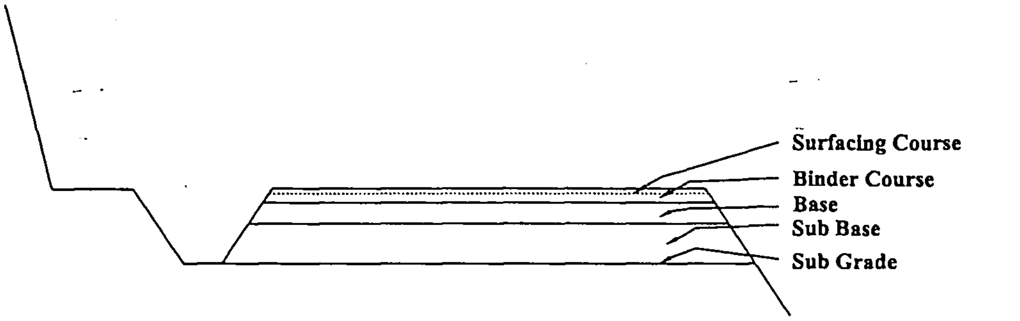
(e) The reduction of investment at the time of upgrading will accommodate more and more upgradement projects than very large costs involved for over haul if stage construction is not considered at the time of construction of the first facility.

Due to the above reasons, some consideration of pavement design is recommended though it is not practiced presently in Sri Lanka. (Non availability of knowhow, non availability of design codes to suit local conditions, the extent of new construction is widespread and no experienced engineering personnel available to design the pavement etc. may be the reasons for not having such. Specification.

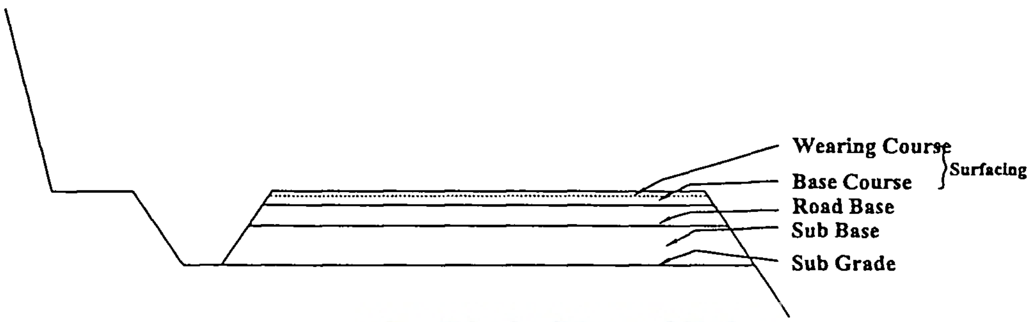
Therefore, some design methodology is necessary for pavement structure, in these exercises of design and maintenance of gravel roads for Sri Lanka. However the traffic survey carried out shows that the composition of traffic on agricultural and rural roads carries insignificantly small number of commercial vehicles.

7.2 PAVEMENT COURSES.

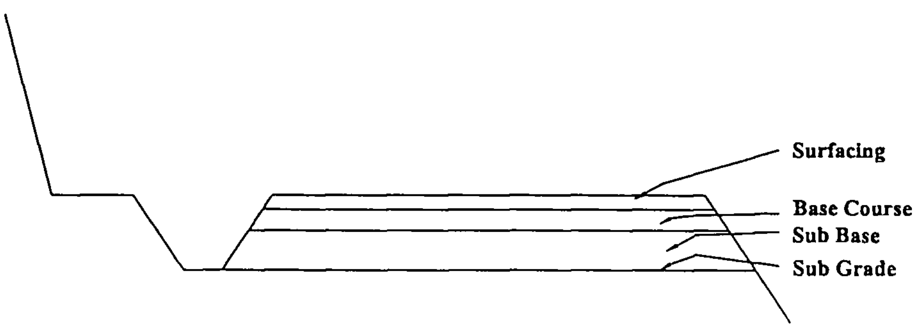
The final product after going through all the stage construction procedures will have sub grade, sub base and surfacing. In this too we mostly used references from the other countries specially USA, UK. Though there are no radical differences in pavement structure except for different terms that are being used. The simplest classification practices are as given figure 7.1 The recommended payment layer classification is given in figure 7.2 as already used in figure 5.2 and 5.3 the recommended cross section for gravel roads.



(a) **American Practice**

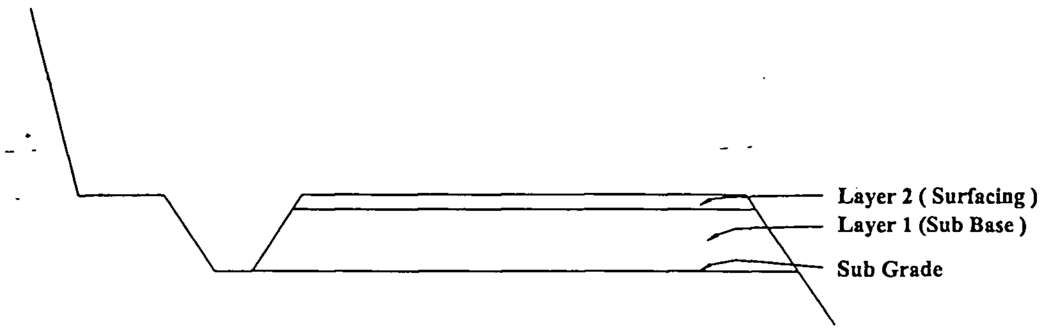


(b) **British Practice**

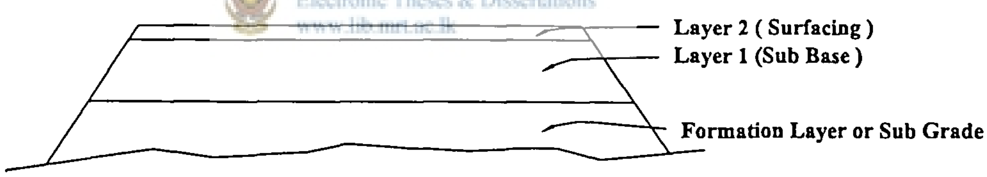


(c) **Sri Lankan Practice**

Figure 7.1 Different terms used for pavement layers



(d) **Cross Section in Cut**



(d) **Cross Section in Fill**

Figure 7.2 Recommended Terms for Gravel Roads

The sub grade is compacted natural earth immediately below the pavement layers. The top of the sub grade known as the formation level.

The top most layer is the surfacing, the base, which comes immediately below is the medium through which the stresses imposed are distributed evenly. Additional help in distributing the load is provided by the sub base layer.

- The function of the sub base layer

(1) To provide additional help to the base and surface courses in distributing loads.

(2) To prevent intrusion of fine grained roadbed soil into base courses.

- The functions of the base course and surfacing

(1) To act as the structural supports of the pavement and thus distribute the loads.

(2) If it constructed directly over the sub grade, to prevent intrusion of sub-grade soil to the pavement.

(3) To resist abrasive forces of traffic.

(4) To reduce the amount of surface water penetrating the pavement.

(5) To provide a skid resistance surface.

(6) To provide a smooth and uniform riding surface

7.3 FACTORS EFFECTING DESIGN OF PAVEMENT

The design of pavement are governed by many factors, among them the relevant for Sri Lankan gravel roads are

(a) Traffic Factors

1. Wheel load: Wheel load causes stresses, and strains in pavement layers and subgrade. The tyre pressure determines the area of contact.
2. Repetition of wheel loads.

(b). Climatic factor:

i. Rainfall

(c) Road Geometry:

1. Curvature - Pavements on curves are subjected to extra stresses due to cornering (Horizontal) pavements at junctions are typical examples.

2. Vertical profile of Pavement on grades are subjected to extra forces due to accelerating deceleration and braking.

(d) Soil and drainage:

(1) Soil Type: Gradation and density of soil.

(2) Drainage The drainage of pavement, subsurface and from adjoining land effect soil strength and hence the pavement design.

7.3.1 **Traffic factors:**

The entire load carried by a vehicle is shared among the axles and through axle by tyres. The heavier vehicles are normally carried on larger number of axles and wheels, thereby reducing or maintaining the individual loads.

The standard axle loads adopted in design vary from country to country. Some of the standard axle loads used are:

U.K.	10.17 Tons
U.S.A.	8.2. - 10.9 Tons
AASHTO	9.1 Tons
Belgium	13.0 Tons
EEC C	11.0 Tons
India	8.16 Tons

The value used in Sri Lanka is '8.16 tons

For analytical methods of design of pavements the axle load, the contact area, and tyres pressures are required. Also spacing of multi axles is important since its effect on, stress induced. Tandem axles are common on modern road transport vehicles.

The analytical methods of design used generally on superior pavement designs where small difference in pavement thickness until to make a big difference in costs. Assessing the number of a repetition of loads of traffic, which consists of a mixture of axle loads of varying magnitudes. Required to be done to assess the damaging effect some vehicles are heavier and some are not.

The standard method to overcome this problem is to express traffic in terms of equivalent number of standard axles. The damaging power is found to be governed by fourth power rule. If

F Vehicle damaging factor

L Axle Load

Ls Standard axlc load

Then F – $(L/Ls)^{4.5}$

Ls used in Road Note 31 ' (1993) is 8.16 tons ('18,000 lbs.) Hence following table is derived.by Liddle which is given in road note 31(1993).

Equivalent factor = $(\text{axle load} - \text{kg} / 8160)^{4.5}$

Wheel load Single & dual (10^3 kg)	Axle load (10^3 kg)	Equivalence Factor
1.5	3.0	0.01
2.0	4.0	0.04
2.5	5.0	0.11
3.0	6.0	0.25
3.5	7.0	0.50
4.0	8.0	0.91
4.5	9.0	1.55
5.0	10.0	2.50
5.5	11.0	3.83
6.0	13.0	8.13
7.0	14.0	11.33
8.0	16.0	20.7
8.5	17.0	27.0
9.0	18.0	35.2
9.5	19.0	44.9
10.0	20.0	50.5

Table No. 7.1 Equivalence factors for different axle loads
(Road Note '31 1993

The requirement is to find out the cumulative number of standard axles that will be used during the design life. (Repetition of wheel loads) Hence some more steps are necessary.

(a) Dcsign lifc

(b) Initial traffic '(In terms of vehicles per day

(c) Annual growth rate of traffic

(d) Traffic used by design lane.

The current Indian standard uses a standard design axle load of '8.16 tons (18,000 lb) which is similar to Road Note 31 standard. Also the current Indian practice (*reference guidelines for the design of flexible pavement IRC - '37 - 1984

Indian Road Congress (1984) provides details to value of vehicle damaging factor with respect to terrain condition, initial traffic (commercial vehicle per day)Rural commercial vehicles Lorries , cars used in Sri Lanka are similar to that of India, and also in the absence of any other reference to similar information (on the basis of terrain and unsurfaced category for Vehicle damaging factor – VDF). It is recommended to use the following standard given by IRC "

Initial traffic (commercial Veh/day)	Terrain	Vehicle Damaging Factor		
		Unsurfaced	Thin Bituminous Surfacing	Thick Bituminous Surfacing
Less than 150	Hilly Rolling Plain	0.5 1.5 2.0	0.75 1.75 2.25	
'150 - 1500	Hilly Rolling Plain		1.0 2.0 2.5	1.25 2.25 2.35

Table 7.2 Vehicle Damaging factor for unsurfaced low volume roads

* - Only required range is abstracted '(up to ' 1500 VPD)

The VDF (vehicle damaging factor) is the multiplier for converting the number of commercial vehicles to the number of standards axle loads (8.16 tons) of repetitions.

The formula that could be used to obtain cumulative number of standard axles in design life is as follows:

Ns - Cumulative number of standard axles to be catered for in design

A - Initial traffic in terms of vehicle per day duly modified to account for lanc distribution.

r Annual growth rate of traffic

n Design life in years.

V DF Vehicle damaging factor

$$N_S = 365 \times A \times VDF\,[(1 + r)^n - 1]/r$$

The rate of growth of traffic is determined from trends or on the basis of growth of other sectors of the economy and - GNP - agricultural out put etc.

7.3.2 The Climate factors and road geometry.

This is looked after in the selection of site selection that is dry zone and intermediate zone, it's the past experience that other than factors described in Chapters 2 there is no need to allow additional of thickness of pavement for climatic factors.

7.3.3. Soil Drainage

The soil type effects the drainage of pavement, hence the thickness of pavement. In unsurfaced road for deciding the soil strength 4-day soaked CBR (soil strength) take this aspect into consideration. As most severe condition. But considering drainage from adjoining lands a minimum height of pavement is recommended. According to current practices this should not be less than 450 mm from the subgrade. This is compatible with thickness of sub-base proposed by Senanayaka and Mallawaratchie (1989) for very poor sub-grade conditions.

7.4. PAVEMENT DESIGN

The actual design of pavement thickness could be categorized in general to

(a) Theoretical - analytical methods

(b) Empirical methods - using soil strength tests

(c) Empirical mcthods - without using soil strcngth tcsts.

The theoretical method, also known as the "analytical " "rational" or "Structural design" approach is not recommended for low cost low volume roads since such a detail analysis will not result in economic gains or even to construction to accurate dimensions. (Rather it will be rounded off to possible general thickness) The use of an emperical method is recommended.

7.4.1 Emperical method - without soil strength

The empirical methods are based on accumulated experience on the performance of pavements on different types of subgrades.

In group index method for evaluation the subgrade some simple soil classifications tests are carried out and California bearing ratio method (CBR) the sub grade strength is evaluated on the basis of CBR value and pavement thickness required on the specific subgrade is obtained. Though there are other methods available in textbooks. These two methods are still widely used and give reasonably acceptable pavement thickness, which has stood by test of time.

- Group Index method :- (Khanna –1987)

In this no elaborate soil strengths tests are carried out, in Group index method of soil classification, soils are thus assigned arbitrary numerical numbers known as group Index (G.I) and Group Index is a Junction of percentage material passing 200 mesh sieve (0.074mm) liquid limit and plasticity Index of soil and is given by the equation.

$$G.I = 0.2\,a + 0.005\,a.c. + 0.01\,bd$$

Here a = That portion of material passing 0.074 mm sieve, greater than 35 and not Exceeding 75 percent. (Expressed as a whole number from 0 to 40)

b = That portion of material passing 0.074 mm sieve greater than 15 and not - Exceeding 35 percent (expressed as a whole number 0 - 40)

c = That value of liquid limit in excess of 40 and less than 60 (expressed as a whole number from 0 - 20

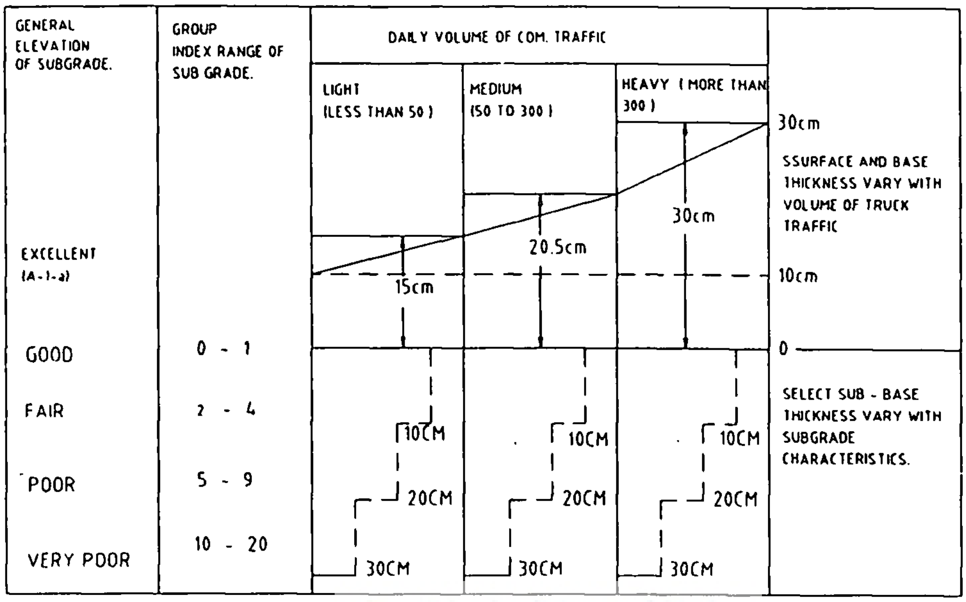
d = That value of plasticity Index exceeding 10 and not more than 30 (expressed as a whole number from 0 to 20)

According to the formula, the minimum possible value of group index is zero and maximum possible value is 20. The higher the value of Group Index, poorer is the soil as subgrade material and for constant value of traffic volume, the greater would Be the thickness requirement of the pavement.

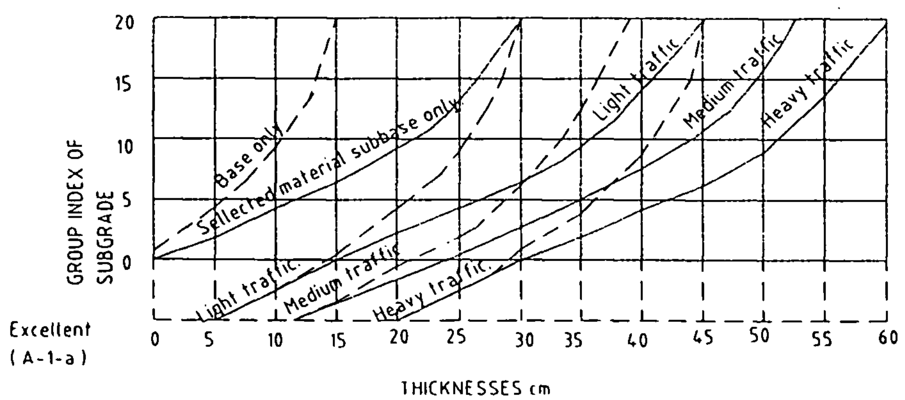
To design the pavement thickness by this method, first the G.I. value of the soil is found. The anticipated traffic is estimated and is designated as light medium, heavy as follows:

Traffic Volume (Commercial Vehicle)	Number of vehicle per day
Light	Less than 50
Medium	50 - 300
Heavy	Over 300

Then appropriate design curves are selected and from figure 7.3 b total thickness of pavement is found. Corresponding to GI value of soil.



(a)



(b)

———— Combined thickness of surface, base and sub-base

– – – – – Thickness of surface and base

Figure 7.3: design Chart by Group Index Value

7.4.2 Empirical method - using soil strength

- California bearing Ratio method :- (Khanna –1987)

The basis of the design charts is that a material with a given CBR requires a certain thickness of pavement layer as a cover. A high load needs a thicker pavement layer as a cover to protect the subgrade. Design curves co-relating the CBR value of sub grade with total pavement thickness cover has been developed by California State Highway Department (for wheel loads 3175 kg and 5443kg)

TRRL, UK has based on the same lines has developed a set of curves based on volume of traffic as A, B;C,E,F,G. But for our purpose design curves A,B,C, would suffix. These curves have been taken by India as given in figure 7.4.

Curve	No. of Commercial vehicles per day exceeding 3 tons		
A	0	to	15
B	15	to	45
C	45	to	150
D	150	to	450
E	450	to	1500
F	1500	to	4500
G	above 4500		

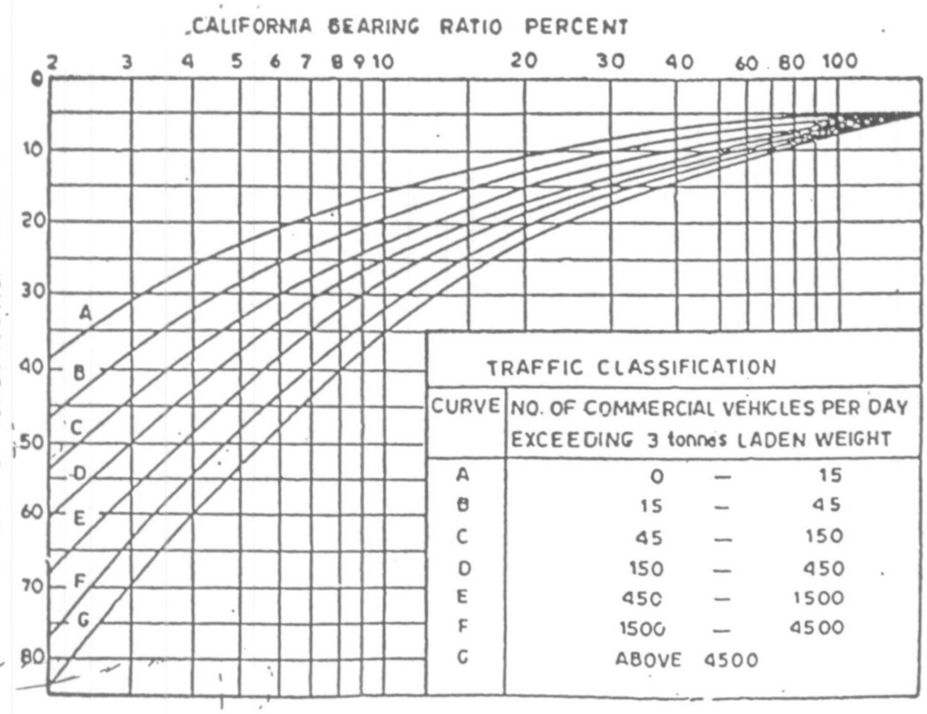


Figure 7.4 C.B.R. Design Chart (Recommended by IRC) (Sehgal 1984)

In order to obtain pavement thickness, first soaked CBR value of the soil subgrade is evaluated. Then appropriate design curve is chosen by taking anticipated traffic into consideration as given in Figure 7.4.

Thus the total thickness of flexible pavement needed to cover the sub grade of known CBR value is obtained. In case there is a material superior than the soil sub grade, such that it may be used as sub base course. Then the thickness of construction over this material could be obtained from the design chart knowing the CBR value of the sub base. The thickness of the sub base is the total thickness minus the thickness over the sub base.

The CBR method of pavement design by cumulative standard Axle load is also available. There it is based on the concept of cumulative standard Axle loads rather than the total number of all commercial vehicles.

The Indian road congress recommend this method be used in roads with design traffic more than 1500 commercial vehicles per day. It is recommended to check the pavement thickness obtained as per charts, before with this cumulative standard Axle method curves in order to compare required improvement at stage constructions criteria. This is for macadam road mostly.

7.5 BASE OR SURFACE LAYER

The current practice uses gravel surface thickness of 75mm, 100mm & 150mm depending on the type of traffic is to be used. The observation in the field testifies this to be satisfactory. It also proposed by Seenayaka & Mallawarachi (1989) following guides for deciding the gravel thickness and it is in accordance with current practice in Sri Lanka.

VPD	0 50	50 -150	150 - 300
Cumulative No. of std. Axles x 10^6	0-025	0.025 – 0.05	0.05 – 0.10
Type of road	Earth	Gravel	Paved
Type of paving	Suitable soil topping	Gravel surfacing with or without an intermediate layer of soil (see note 2)	Traditional aggregate base and bitumen application with or without sub-base (see note 3)
Thickness of paving (mm)	100 - 300	100 - 150	75 (Nominal) or 150 (Nominal)

Table No. 7.3 Thickness of surfacing layer

The thickness of this layer could be considered in total thickness obtain with reference to 7.3.3, 7.3.4 & adjustment made to sub base (layer 1) thickness.

CHAPTER 8

8.0 MAINTENANCE GRAVEL ROADS

8.1 MAINTENANCE REQUIREMENTS

8.1.1 General

Roads when constructed and put to use, starts deterioration irrespective of how well it is designed and constructed. It is required to carry out maintenance in order to prolong the useful life of the road pavement while preserving conditions of the road at the time it was put to use, as much practically as possible. If proper maintenance is neglected, road pavement will deteriorate progressively leading to rehabilitation and reconstruction prematurely.

There are various elements effecting deterioration of road condition such as

(a) Traffic

(b) Weather (dry weather or rainy weather)

(c) Floods

(d) Winds

(e) Man made causes such as digging, dragging

Except for (a) all others can be considers environmental conditions In order to describe the "Maintenance requirements " objectively, cross sectional feature vise would be more appropriate, since it would emphasize relative weightage of maintenance elements as well.

The cross sectional elements that have to be considered.

(1) Carriageway

(2) Shoulder

(3) Verges (between shoulder and drain)

(4) Drains

(5) Road reservation (beyond drain up to the end of land reserved for the road)

(6) Embankment slopes

(7) Cut slopes

(8) Foot walks

(9) Center medians

The following group of elements of cross sections are considered.

- Carriageway or the roads surface where traffic is actually carried.
- Road shoulder, the element of road adjacent to the road carriageway on either side.
- Embankment and cut slope
- Road rcscrvation, foot walks
- Side drains & Verges

Looking from a different angle, maintenance activities could be divided classified as urgent, routine, and periodic according to the frequency of execution. Sometimes it is easier to be perceived when maintenance activities are described accordingly. Hence, it will bc dcscribcd in both ways, that is clcmcnt of cross scction visc and according to frequency of execution..

8.1.2 Description of maintenance activities

8.1.2.1. Road Surface

The major differences of maintenance activities of a paved road and a gravel road would be maintenance of road surface or the carriageway where traffic is actually carried. Incidentally, the most important element is also the carriageway, which is committed to maintain in the best possible manner, in order to: -

(a) Prolong the life span of the road and postpone the day when renewal rehabilitation (regravlling) is required.

(b) Lowcr thc vchiclc opcrating costs sincc a road in bad shapc would incrcasc thc road user costs.

(c) Provide driver comfort and prevent accidents. Deformed road surface irritates the driver also lowers the operating speeds much below the normal.

(d) Prevent ingress of water to road structure by maintaining the shape of the cross section since any irregular shape aids standing of water. The road structure, base, sub grade deteriorates due to ingress of water.

From long term point of view the last of the four objective (d) would be the most important, since the collapse of road structure beneath, making all the maintenance efforts exerted on the surface, is of very little consequence.

8.1.2.2 Excerted Traffic

Due to traffic, there is a tendency to take off fine particles as dust, also rutting of the wheel path (figure 8.1). Also corrugations are formed where excessive speeds are encountered (around 60 km/h.) That deformation has to be attended timely.

Figure 8.1 Wheel path rutting

8.1.2.3 Environmental condition

Due to environmental conditions such as weather, floods and wind, loss of gravelly soil material occur. During dry weather fine particles are lost as clouds of dust and during wet weather fine particles are carried away with water. The rain drops when falling at a speed on the gravel surface disintegrate the matrix of fine particle bondage and carry fine particles with the flow; wind and floods too carry the gravel particles causing progressive denudation of surfacing. The most prominent would be erosion due to rain and floods which will form ditches and small water paths that would develop into erosion gullies with time, if not corrected in time. Figure 8.2

Figure 8.2 Erosion of carriageway and formation of gullies

8.1.2.4 Man made reasons

Due to man made reasons – such as trenching for service lines (water and telecom) is very common. Also dragging of timber and firewood is also common on rural roads. Piling of material on roads obstruct drainage (Figure 8.3). Trenching if not reinstated properly will erode and form water paths. This will not only clog drains with eroded material, but will be dangerous to traffic as there would be deep erosions gullies.

Figure 8.3 Stagnation of water due to the gravel piling

8.1.3 Road Shoulder

The road shoulder play an important role both in relation to the stability of the road and in relation to accommodate traffic maneuver, when maintained properly.

The shoulders on gravel road either constructed purposely or reserved, space, adjacent to carriageway are usually constructed of inferior material when compacted to road surface itself. Proper maintenance of the shoulders greatly contributes to the stability of road surface and the pavement structure below them.

8.1.3.1 Traffic

The shoulders have to accommodate the wheels of vehicles traffic in their passing and overtaking maneuvers since recommended widths of carriageway widths are also fairly narrow. Therefore there is a tendency to impregment of wheel path which will contribute to subsequent failure in addition to denudation of road shoulder though not to the extent of road surface. During maintenance, this has to be catered for.

8.1.3.2 Environmental conditions

Due to environment conditions, rains and floods, shoulders tend to erode since shoulders are less harder than the carriageway and also when water reaches the shoulders, it comes in the forms of (small) streamlets causing particles to be carried off with it. This progressively leads to erosion if not attended to early to erase them.

8.1.3.3 Man made causes

Due to man made cause such as trenches, shoulders are damaged more often than carriageway. They have to be rectified properly, otherwise erosion is eminent. The clearing of drains & depositing on shoulder is a cause since it prevents water flowing easily to the drain. It is also customary to place heaps of material such as soil, sand, bricks, logs etc., obstructing water paths, hence damage to the shoulder in adjacent areas due to water paths.

The most common feature of all is occurrence of erosions both longitudinally and transversely on shoulders either due to man made reasons or otherwise. They are required to be corrected before they get enlarged with time.

8.1.4 Embankment and slopes.

The stability of the road embankment slopes and cut slopes is an important consideration, in relation to stability of roads. This is particularly so its mountainous terrain where collapse of slopes during the rainy season is a common occurrence.

The two types of slopes - Natural slopes

-Man made slopes

Cut slopes, fill slopes, Embankment slopes

The embankment and cut slopes are mostly effected by the environment. However, traffic is of little consequence.

8.1.4.2 Environmental condition

Due to environment conditions such as rain, floods, erosion of fill slopes, embankment slopes may be encountered, and these need to be attended promptly. During rain and floods, cut slopes may fail, blocking side drains or carriageway itself. Therefore, removal of those earth slips is a maintenance requirement.

8.1.4.3 Man made causes

Due to man made causes such as removal of material from embankment slopes adjacent to paddy field is very common farmers scrape the embankments during every cultivation season reducing the embankment progressively. This should be identified and prevented.

Figure 8.4 Erosion of embankment slope

8.1.5 Road Reservation, footwalks

Road reservation allows space for future expansion and act as a barrier between road and the habitation. Gravel roads provided at sacred places allow a footwalks for ease of pedestrians. Since barefooted pilgrims find it difficult to walk along the gravel surface, maintenance and up keep of them is particularly important for the purpose for which have they have constructed them.

8.1.5.1 Traffic

Due to traffic and environment factors gravel particles pushed to the side, fill the gap between footwalk and road surface near the kerbs. It is required to clean loose material in order to keep drainage paths open and to prevent vehicles climbing onto the foot walks and thereby damaging them.

8.1.5.2 Man made causes

In Sri Lanka it is very common to observe encroachment of road reservation for construction of dwellings and for shops by people living adjacent to the road. It is also very common to observe vendors on foot walks where foot walks are provided at places of worship. Footwalks are required to be kept away from encroachers and vendors. Identifying them as a maintenance activity is important.

8.1.6 Side drains and verges

Side drains are required to carry away the water discharging on to them to suitable discharge channels and subsequently streams and rivers. They intercept surface water flowing from adjoining lands, towards the road. The gradient of the drains is usually the same as that of the road. This may result in erosion in hilly trerrain, and silting in flat terrain. This is a common occurrence in our earth drains and should be taken very seriously in maintenance works.

Maintaining a drainage system in an efficient manner is a very important item of maintenance. The number one factor of road failure is due to water entering the structure of the road as stated in chapter 5.

Verges are the strips of platform between shoulders and side drains. Usually these 300 mm wide strip protects the shoulder from erosion and also the collapse of the side drains. Verges are usually turfed and required to be trimmed regularly to keep them lower, or of same level as the shoulders to facilitate flow of water. Maintenance requirements of side drains verges usually arise due to environmental reasons than due to man made causes.

Figure 8.5 Siltation of drains.

8.1.6.1 Man made causes

Due to environmental reasons siltation and erosion of drains occur (Figure 8.5) . Siltation is very common in gravel roads than in paved roads hence this item requires priority over the other maintenance activities. Trimming of grass an verges to keep them in level with shoulders is needed more frequently, especially during rainy season.

8.2 MAINTENANCE ACTIVITIES ACCORDING TO CHRONOLOGY OF PERFORMANCE.

Maintenance of road "elements" could be classified into three categories according to time at which they need to be performed.

(a) Routine maintenance

(b) Periodic maintenance

(c) Emergency maintenance

The knowledge of this will be useful to organize works such as labour, machinery and material according to a pre arranged program with the required funds. Even if maintenance personnel are aware of all the maintenance activities on a gravel road, if the timing is not adjusted properly, it may lead to waste of funds. If some activities are performed more frequently than necessary, it may not produce results to the proper value of funds at the end, but only will be a luxury, such as, weeding monthly or quarterly when the dry weather prevails.

8.2.1 Routine maintenance

Routine maintenance consists of items of maintenance performed either quarterly monthly, quarterly or more regularly during a month. It is a regular process provided it is performed within limits of funds, equipment and personnel. Most of following activities are required to be carried out regularly.

(a) General up keep of sides involving weeding, clearing rubbish and small slips, obstruction in drains-Every 6 months or more regularly during the rainy season,

(b) Correction of shoulders and verges to line and level by trimming high spots, filling up low spots – trimming grass where necessary performed - every year or as required at site.

(c) Cutting /cleaning of earthen drains, clearing inlets, outlets and passage of culverts. This may need to be performed during every rainy season or possibly once a year in most parts of the country.

(d) Correction of carriageway, areas of depressions (similar to that of potholes on paved roads). Transverse washaways, corrugations, correction of wheel path rutting. This may be required to be performed every 3 - 4 years for a large scale correction like regarding (during periodic maintenance as given under 8.2.2) but leveling up depression should be done before the rainy period and if possible after rainy period.

(e) Patching of small potholes on primed gravel surfaced roads- monthly or regularly.

8.2.2 Periodic maintenance

Periodic maintenance is needed to be carried out at certain intervals in order to replace worm out surface, reshaping of surfacing and regravlling. Also in primed gravel roads, sand sealing on yearly basis. Sometimes some of these activities are refered to as preventive maintenance. - Most of these activities need to be carried out yearly or 2 - 3 yearly basis depending on the volume of traffic.

8.2.3 Emergency maintenance

This type of maintenance arises without prior warning such as floods, cyclones, earth slips collapse of embankment slopes, and falling of trees across the road. Also activities like trenching across and along side the road also gives rise to sudden maintenance requirement.

This type of maintenance needs to be attended almost immediately to prevent aggravation of damage.

8.2.4. Maintenance activities

In order to prolong the useful life of the road pavement as well as roadside and provide the services expected of a gravel road the following maintenance activities are identified. The intervals, at which they have to be performed, the probable unit cost are also useful for carrying out maintenance activities.

8.2.4.1 Maintenance of carriageway

(1) Patching depressions, low pockets and potholes (Figure 8.6)
(2) Correcting, wheel path rutting, corrugations, washaways on carriageway
(3) Periodic maintenance of grading and regravelling.

Figure 8.6 Depressions

8.2.4.2 Maintenance of drains

(4) Clearing & desilting drains

(5) Clearing inlets, outlets of culverts and waterways.

(6) Clearing choked culverts , causeways

8.2.4.3 General Upkeep & Maintenance of Roadsides

(7) Weeding, general up keep of roadsides, road shoulders, verges & embankments

(8) White washing guardrails, guardstones parapets of culverts, bridges, and kilo meter posts.

8.2.4.4 Method of Carrying out maintenance activities

- Patching depressions, low pockets and potholes

The sides of potholes and depressions are cut vertically, loose materials are removed and on the exposed surfaces water is sprinkled sufficiently to lay the dust.

The holes are filled with suitable gravelly soils material in layers of 100mm loose thickness and compact. Repeat this until the pothole is filed slightly proud of the adjoining surfaces.

- Correcting wheel path rutting, corrugations, wash aways on carriageway

This could be done by grading, dragging or regravelling depending on the extent of rutting and corrugations. If regular maintenance is carried out dragging is most suitable. Dragging can be done by a simplest drag such as timber Logs. A set of tyres for sandy surfaces but less effective on hard surfaces, more improvised devices are made of crap metal or wood with metal cutting edges with additional weight added if required. These could be pulled by animals, small tractors or by lorries. However dragging cannot remove corrugation once they are fully formed, dragging cannot replace the camber or lost material. If these problems are extensive heavy grading is needed. Addition of new gravel may be necessary to compensate for the reduction of gravel surfacing due to scraping.

- Periodic maintenance regravelling

The regravelling is done after grading the surface to firm regular base. The edges may be " boxed " to provide lateral support for new gravel surface. The camber of the graded surface should be checked with a camber board to ensure that it falls within 4-6 percent. The graded surface should be wetted then regravelling material is spread using a grader or manually. Water should be sprinkled to bring the gravel to optimum moisture content while mixing when gravel is evenly spread to proper camber and grade, it should be compacted with a 8-10 ton roller, generally with six to eight passes, which is considered to then be sufficient.

- Clearing and desilting drains

The soil deposited on drains should be cleaned and carted away to dumping ground. The miner slips that blocks the drain should also be removed. These soils could be used to fill up low spots if they are of good quality. The weeds and debris should be removed in single operation in order to allow free passage of water. The cleared material should be deposited outside the road where it will not be get washed bock to fill the drains again.

- Clearing inlets, outlets of culverts and water ways

The inlets and out lets of culverts should be cleared of deposited soil and debris. The cleared material should be deposited well away from the inlet and outlet to prevent it getting washed back to the drain.

- Clearing choked culverts, causeways

The culverts inlets and the passages are sometimes filled completely with soil. This should be cleared using mamotties, concrete pans and long iron rods. Firstly either side of the culvert is excavated so that a labour or can reach the inlet and the outlet. If the opening is sufficient so that a labour or can creep, then the clearing operation could be continued until the opening is completely cleaned. If not, a small clearing is made with a long iron rod. Thereafter a long rope is passed through it. One side of the rope is tied to a concrete pan so that it can stand straight using a additional rope, one end is again tied to the backside of the concrete pan, then two labourers can pull the concrete pan to and from the passage taking blocked material from each pull, till the whole passage is cleared.

- General upkeep

This operation generally include removal of debris and rubbish, control and eradication of weeds and shrub jungle, clearing of scupper drains. The weeds and shrub jungle is removed by cutting and uprooting those along with any other rubbish that is collected and either burnt in place or carted away from the shoulders and verges; usually grassed areas of verges and sideslopes are normally re moved with hand tools such as garden shears.

- White washing guard rails, Guard stones parapet of culverts bridges and kilo meters Posts

The guard stones, guard rails, parapets of culverts and hand rails of bridges, which are made of concrete or masonry should be wire brushed and cleaned, then two coats of hydrated lime with some sticking agent like glue or pearlgum should be applied with a brush and allowed to be dried. A 2-3 inch tar skirting is painted with cut back bitumen or bitumen emulsion to allow for contrasting colours and also to reduce the effect of discoloration due to split mud.

Steel and iron railings should be painted with white enamel paint after cleaning the surface thoroughly. Kilo meters post could be painted with either enamel paint or emulsion white paint, to last longer, the numbers should be painted with enamel painting the specified colour code.

8.3 FREQUENCY OF PERFORMANCE

8.3.1 Patching

This item is required to be carried out very regularly may be once a month in the rainy season but during dry season, it may be carried out at the end of the dry season provided it is carried out at the end of rainy season. In most part of Sri Lanka, dry zone and intermediate zone this items may be required to be carried out 3-4 times per year for very good performance and the minimum should be twice a year.

8.3.2 Correcting wheel path rutting

This item too could be carried out along with item 8.3.1 but experience has shown that items like correction of corrugations are required only once in a year or once in two year depending on the traffic volume and speed.

8.3.3 Periodic maintenance of re gravelling

This item need to be carried out once in 5 - 8 years depending on the traffic

8.3.4 Clearing and desilting drains

This item needs to be carried out frequently during the first few rainy seasons after construction later on it could be carried out once before and once after the rainy session.

8.3.5 Clearing inlets of culverts and waterways as same as 8.3.4

8.3.6 General up keep

This item may be carried out once a year if maintenance funds are available. However twice a year is desirable.

8.3.7 White washing of culvert headwalls, guardstones ect.

This item too is usually required once a year. If maintenance funds are not enough, this is usually neglected.

8.4 SUMMARY

The summary of maintenance activities and the frequencies at which these activities are desirable to be carried out are given in Table 8.1

Serial No.	Maintenance activity	Required Frequency of Carrying out the activity during a year.
	Carriage way	
1.	Patching depression, Low pockets	3 – 4 Times
2.	Correcting wheel path rutting , corrugation , Wash aways on carriage way	Once a year.
3.	Periodic maintenance regravelling	Once in 5 – 8 year.
	Drains	
4. 5.	Clearing and desilting drains Clearing inlets, outlets of culverts and Water ways	Twice a year. Twice a year.
6.	Clearing choked culverts, causeways	When required
	Roads sides General upkeep	
7.	Weeding , general upkeep of roads sides Road, shoulder, verges, embankment	Twice a year
8.	White washing , guard rails, guard stones Parapet of culverts, Bridges and km posts	Once a year

Table 8.1 Maintenance activities and Frequencies of performance

CHAPTER 9

9.0 COST OF CONSTRUCTION AND MAINTENANCE.

There are common elements in gravel roads and paved roads. The comparison is required to appraise the cost of construction and maintenance of gravel roads over paved roads. The major differences being the surfacings the comparison is made with regard to cost of construction and maintenance of road surfacing of gravel roads and paved roads.

The following Table 9.1 summarizes the costs involved in construction of road pavements (surfacings). These costs are based on Highway schedule of Rate.

Road Type	Cost per square meter. Rs
1. Traditional metal paved (37.5mm 2 layer)	226.00
2. Paved with blended aggregate/ over 100mm Aggregate base course	403.00
3. Gravel 150mm	110.00
4. Gravel 100mm	75.00
5. Gravel 75mm	58.00

Table 9.1 Cost of construction of paved roads and gravel roads

The costs involved in maintenance of road is given in Table 9.2 below. These cost are based on Highway schedule of Rates.

Road type	Activity	Cost per km/year	
		Routing	Periodic
Paved	General upkeep	Rs.10,800.00	
	Carriage way	Rs.16,905.40	Rs.49,667.00
Gravel	General upkeep	Rs.10,800.00	
	Carriage way	Rs.12,500.00	Rs.22,720.00

Table 9.2 Cost of Maintenance of Paved and Gravel roads.

The detail BOQQ are given in the appendix I – X The assumptions are that general upkeep and other maintenance items of gravel roads could be carried out by force account or people participation hence no G.S.T. is assumed where as maintenance of carriage way of paved roads needs premix which have to be purchased and skill labour are required. Hence it is assumed to be carried out by a contractor therefore G.S.T. is allowed. Periodic maintenance sand sealing is assumed to be carried out every three years. The Periodic maintenance regavelling is assumed to be carried out once in five years.

9-1 COMPARISON OF COSTS.

The cost of construction of paved roads are compared to that of a gravel road and summarized in the Table 9.3

Construction Comparison	Ratio
1. Gravel road 150 mm gravel surfacing Vs Traditional "metalled and tarred" road	1 : 2
2. . Gravel road 100 mm gravel surfacing Vs Traditional "metalled and tarred" road	1 : 3
3. . Gravel road 75 mm gravel surfacing Vs Traditional "metalled and tarred" road	1 : 4
4. Gravel road 150 mm gravel surfacing Vs Paved road with blended aggregate over 100 mm aggregate base	1 : 3.7
5. Gravel road 100 mm gravel surfacing Vs Paved road with blended aggregate over 100 mm aggregate base	1 : 5.4
6. Gravel road 75 mm gravel surfacing Vs Paved road with blended aggregate over 100 mm aggregate base	1 : 7

Table 9.3 Comparison of construction costs of a paved road and a gravel road.

The comparison of maintenance costs is summarized in Table 9.4 below

Maintenance Activity	Ratio
1. Maintenance of road side general upkeep of . Gravel road Vs paved road	1
2. Maintenance of carraigeway routine maintenance . Gravel road Vs paved road	1: 1.4
3. Periodic maintenance Gravel road Vs paved road	1:2.2
4. Routine maintenance and periodic maintenance of Gravel road Vs. Routine maintenance and periodic maintenance of Paved road.	1:1.7

Table 9.4 - Comparison of maintenance costs of paved and gravel road.

9.2 Summary

The comparison of costs reveal that cost of construction of a paved road require approximately 3 times investment that is required for a gravel road. The cost of maintenance of a paved road is nearly twice that of a gravel road. In addition a paved road needs stocking of much needed Bitumen which is expensive and also only available in Colombo. Due to the cost of transport for which at least 50 barrels should be transported at a time, this requires approximately Rs. 145,000.00 per batch which is a considerable sum for organizations like a Pradeshia Sabha who owns and maintain rural roads.

CHAPTER 10

10.0 SUMMARY OF RECOMMENDATIONS

10.1 GENERAL

Results of traffic surveys carried out reveals that gravel roads in Sri Lanka is carrying much less traffic (Chapter – 2 .0) than those given in the literature. Eighty four percent of traffic consists of bicycles, motor cycles and three wheelers which is very important to sustain the communication, social interaction and health & education in rural population. Out of the balance, sixteen percent of vehicles population, nine percent are Tractors and Light Goods vehicles which sustain the economy of rural population (Chapter 1.0)

The extent of rural roads in Sri Lanka is approximately 75,000 km (Chapter 1.0) which is over 70 % of total road net work of roads in Sri Lanka. Two third of the land area of Sril Lanka is under dry and intermediate climatic zone. (Chapter 3.0), and are mostly flat to rolling terrain. Gravelly soils have been concentrated available in most parts of the dry and the intermediate zones in Sri Lanka (Chapter 6.0)

The cost of construction of gravel road required one third the cost of construction of a paved road. The road maintenance cost is half that of paved road. (Chapter 9.0). Most of the maintenance activities require labour and locally available equipment such as tractors, drag etc. (Chapter 8.0) This allows maintenance of these gravel roads on self help basis if proper guidance is provided.

The gravel roads are next to paved road in hierarchy of roads types but one level above earth roads. Gravel roads are all weather roads, Earth roads are not. Both Gravel and earth roads are considered as unpaved roads (Chapter 1.0)

There are lot of scope for gravel roads such as for (Chapter 3.0)

1. Village roads - Agriculture and feeder roads
2. Roads in new settlement
3. Estate roads (Tea, Rubber, Coconut)
4. Roads in wild life reserves

5. Access roads in villages
6. Roads in sacred areas
7. Roads in construction sites.

The decisive factors in deciding gravel roads are (Chapter 3,0)

1. Traffic
2. Gradient
3. . Rainfall
4. Economic haul distance
5. Duration of use on life cycle.

Gravel roads could be used as the first stage of stage construction of paved roads. This helps to spread much needed investment over a time period of 5 – 8 years when increase in traffic justifies the large investment in converting gravel roads to paved roads.

According to surveys carried out, the geometry of the gravel road such as carriage way and platform width, play an important role in carriageway erosion (Chapter 2.0) The increases width of platform and carriage way effect the cost of construction too. Drainage is directly related to causes of failures such as pot holes (Chapter2.0 – Table 2.2)

10.2 ROAD GEOMETRY

10.2.1 Platform width and carriageway width.

Minimum width in standardized highway is a function of design speed; the higher the design speed wider the traffic lane to allow time for the small corrections in vehicle direction that are necessary to keep a vehicle in its own travel lane. Research has shown that as lane widths are reduced on low volume rural roads no related increase in accidents occurs.This allow narrow lanes for cost effective means of reducing motorable access infrastructure investments, on the other hand the survey carried out shows that when width of carriage way and platform width increases cross erosion increases which will excalate the cost of maintenance.

Single lane motorable infrastructure is quite sufficient for traffic volumes of the order of 150 vehicles per day. While any wider places along the road way can provide sufficient passing width. Also formal passing bays can be provided. Distance between passing bays vary from 100 m – 400 m when not considered by sight distances. The sharp curve that prevent the application of the above sight distance may be widened to 6.0 m, which is also the recommended width for passing bays.

The recommended width of road platform and carriageway widths are given table 4.1.3 is carriage way width of 3.5 m and platform width of 5.0 m.

10.2.2 Vertical gradient

The maximum slopes as defined in road design standards, is usually related to the length and gradient a truck can climb without its speed being reduced by more than 25 kph (15 mph) Maximum slope for motorable access relates to the slopes and length that is negotiable at any speed by the specific truck. Provided that the low volume of traffic and composition of traffic such as bicycles (57%) (Chapter 1, Table 1.4) the slopes must allow them to climb. The recommended average maximum gradient 5% for gravel roads (Chapter 4 table 4.11) and a maximum gradients of 6% for flat terrain, 9% for rolling terrain and 10% for hilly terrain. These closely agree with the maximum sustained grade of 4% and maximum grade of 8% for bicycles. It is recommended to provide these maximum grades at curves in order to take the advantage of slow speeds and remedy the other adverse effect like cross erosion prevalent at super elevations (para 4.4)

10.2.3. Pavement and shoulder slopes

In earth and gravel roads cross slopes of less than 5% tend to retain water in surface irregularities. Those puddles are caused by poor quality control during construction or irregularities introduced by passing traffic. Cross slopes greater than 5% increases the risk of erosion combined with width of carriageway and platform width. Cross slopes of 4% are recommended for gravel roads 94.2.1)

When gradient on road exceeds 4% the cross slopes are no longer very effective, water tends to travel along the slope, but combined with cross slope and gradient water travel on diagonal path bisecting cross slopes and longitudinal gradient. At these instances, due to longer water path, water flow gain speed and quantity causing erosion. Hence should intercepter drains or water bars using logs anchored across the path at a 45^0 angle is recommended.

10.2.4. Radius of curvature – Horizontal alignment

Maximum degree of curvature, or minimum curve radius, has two definitions in highway design. One is the maximum degree of curvature that the specific vehicle can negotiate at a given speed, width and super elevation. The second is the minimum turning radius for specific motor vehicles. However, the minimum negotiable radius for access is any curve that is wide enough so that the specific vehicles in question can pass around it, even if vehicle must go forward, back up and go forward again until it completes the turn

The methodology adopted is the maximum super elevation at which erosion is critical is (6%) and to obtain desirable minimum radius of curvature on this basis. The recommended radius are given in table 4.16. They are ranging from 60 m 110 m for flat terrain, 30 – 60 m for rolling terrain and 15 – 50 m for hilly terrain.

10.3 DRAINAGE

Since gravelly roads are unpaved, rain water percolate to the sub grade which will in turn weaken the same. In order to reduce the percolation of water, the cross section of the road should be maintained in a proper shape. The rainfall on to the road surface is designed to travel to the sides by the cross fall slopes. A cross fall of 4% is recommended for high rain fall areas and lower for lower rainfall areas. When cross fall exceed 5% it tends to erode the surface farming erosion gravellies. Limiting formation and carriage way width reduce the tendency for erosion (Chapter 2 figure 2). Side slopes of in 1 ½ with the slopes turfed to prevent erosion are recommended. Typical cross sections are given in Figure 5.2 and 5.3 for cut and fill embankment respectively.

Selection of clayey materials for shoulders and carriage way will reduce percolation of water. The proper densification by compaction of embankment, and surface material also reduces the percolation of water to the sub grade.

10.4 MATERIAL

The granular material used for gravel surfacing require to withstand ravelling under wheels of traffic, preventing or minimizing percolation of water, loss of material due to wash aways and formational of dust during the dry season.

The size of granular material used for surfacing should not be lager than 37.5 mm to provide good riding surface which can easily be bladed by using a grader to restore an even profile. The presence of coarse material provides corrugation formation during dry season and increase the difficulty in removing such corrugations.

Gravelly soils with small amount of fines which are non plastic is not suitable due to the fact that they are highly permeable, ravel under the wheels of the traffic and erode forming erosion gullies. Gravelly soils having liquid limit not greater than 40 and plasticity index between 4 – 15 are found to behave well. (6.3.1.1) These limits could be increased to 50 and 6 – 25 in dry zone. There is even scope for increasing the upper limits to 55 and 30 respectively.

The extent to which the gravel could be compacted could be measured by gradation. Compaction improve the physical properties of soils, and increase density squeezing the air out of it. In general compaction makes soil tighter, dense, and stronger and keep it drier, minimize settlement. Well graded granular soil having sufficient fines to bind particles together would be the best. A grading band having maximum particle size between 19mm 37.5 mm and having fine particle (Passing 75 μm)between 5 – 25 % are recommended in Table (6.6)

Gravelly soils strength can be measured in many ways. Most empirical methods of pavement designs use CBR value to express, the strength of soils. Soils of CBR value greater than 20 has been recommended for gravel surfacing (6.3.1.4) stronger soil prevent failure of pavement structure due to heavy loads – given that suitably thick layer is constructed .

Visual classification of soils , saves soils exploration process considerably including deciding suitability. A suitable soil classification chart is produced in table 6.7

10.5 DESIGN OF PAVEMENT STRUCTURE

Design of pavement structure envisaged determining thickness of different layers (Layer 1/ Formation layer) Designing of layer thickness at the initial stage saves lot of waste at the time of improving the facility to paved status when traffic increases.

Empirical methods in determining pavement layer thickness are good enough due to the low accuracy of thickness of layers required and due to low cost of construction.

The popularly used CBR method of design pavement is recommended (Chapter 7.4.2) When projected traffic at the end of life cycle 5 – 8 years is determined and CBR value of sub grade is found depth of construction is determined from design chart 7.4.

However considering the drainage, considerable improvement in the structure capabilities of road surface can be achieved, specially in flat terrain or poorly drain basins by elevating the road surface approximately 450 mm above the existing terrain. This prevent capillary rise in those materials such as fine sands and silts. The gravel surfacing thickness presently adapted are 100 mm for very low traffic, 125 mm for medium traffic and 150 mm for heavy traffic up to and about 150 V.P.D. which could be considered is satisfactory.

10.6 MAINTENANCE

Maintenance is required to keep the road in serviceable condition during its service life. Constantly roads are exposed to all elements of nature such as rain, floods, and also traffic. Roads also deteriorate due to man made reasons such as trenching for services. All the exposed component of the road require maintenance; carriageway, shoulders, verges, drains, embankment slopes and cut slopes.

Carriageway require maintenance more frequently than other components of pavements. Carriageway depressions, potholes, wheel path rutting formation of corrugations and longitudinal and transverse erosion have to be corrected by maintenance measures.

Just sufficient maintenance will undoubtedly save money. Therefore, number of times that certain maintenance activities are to be to performed is important. This is given in Table 8.1.

Correcting surface profile by dragging or grading once a year will assist to keep the proper slope in the carriageway. A drag turned out locally such as set of tyres, or a drag made with timber with metal cutting edges drawn by a tractor could be used.

Pot holes patching 3 – 4 times a year provide good riding surface while it reduce water entering the sub grade and prevent further the damage.

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APPENDIX I - X

Appendix - I

Bill of Quantities - (B.O.Q)

Paved Road with single sizeds aggregate base using two spread of 37.5mm sigle sizes aggregate for 1 km Length

Width of carriage way	= 3.66 m
Width of Shoulder	= 2/1.25m
Width of Road Sides /reservation	= 2/2.0m
Highway schedule of rates (HSR)	= 1999 (RDA - 1999)

ITEM	DESCRIPTION	UNIT	QTY	RATE Rs.	AMOUNT Rs.
1.	Trimming, levelling & compaction of original sub grade. (R1-129M)	m^2	Item	Allow	25,000.00
2.	Supplying 37.5mm aggregate	m^3	366.00	980.00	358,680.00
3.	T' port of aggregate distance 35 kms.	m^3	366	318.50	116,571.00
4.	Excavation of approved soil for shoulder constrution. (EW1-013)	m^3	128	119.00	15,232.00
5.	T' port of soil distance 10km (R1-003M, R1-004 M)	m^3	128.00	126.20	16,153.60
6.	Approved soil spread & rolled. (R1-123M)	m^3	128.00	83.25	10,656.00
7.	Bitumen surfacing 1 st coat using 1.0 Ltr/m2 including blinding with sand @ 125/sqm/m3	m^3	3,600.00	29.45	106,020.00
8.	Bitumen surfacing 2nd coat using 0.75 Ltr/m2 including blinding with sand @ 125/sqm/m3 (R1-307M)	m^2	3,600.00	24.35	87,660.00
					735,972.60
				12.5 % GST	91,996.58
					827,969.18
				Total:-	**827,970.00**

* For sake of comparition only surfacing considered,

Appendix - II

Bill of Quantities (B.O.Q)

Paved road with dense graded aggregate base 100mm and paved with Blended Aggregate 75 mm for 1 km. Length { 37.5 mm "19.5 mm" " 12.5mm" Blended 7:2:1 }

Width of carriage way	= 3.66 m
Width of Shoulder	= 2/1.25 m
Width of Road Sides /reservation	= 2/2.0 m
Highway schedule Rates (HSR)	= 1999 (RDA - 1999)

ITEM	DESCRIPTION	UNIT	QTY	RATE Rs.	AMOUNT Rs.
(1).	Trimming, Levelling & compaction of original sub grade.	m^2	Item	Allow	25,000.00
(2).	Supplying aggregate base cours including spreading and compaction.	m^3	366.00	1,094.00	400,404.00
(3).	Supplying blended Aggregate	m^3	275.00	1,109.00	304,975.00
(4).	Spreading and compaction blended Aggregate.	m^3	275.00	241.75	66,481.25
(5).	Transpot of above aggregate 35km avarage	m^3	641.00	318.50	204,158.50
(6).	Emulsion (CRS-1) surface treatment firatcoat using 3.5Ltr/Sq.m including blinding with sand	m^2	3,660.00	66.55	243,573.00
(7).	Emulsion (CRS-1) surface treatment subciquantcoat using 0.75Ltr/sq.m including blinding with sand	m^2	3,660.00	18.35	67,161.00
					1,311,752.75
				12.5 % G.S.T.	163,969.09
					1,475,721.84
				Total:-	**1,475,700.00**

For sake of comparition only surface cum base considered

Appendix - III

Bill of Quantities (B.O.Q)

Construction of Gravel Surfacing (150mm) for 1 km Length

Width of carriage way = 3.66m
Width of Shoulder = 2/1.25 m
Width of Road Sides /reservation = 2/2.0 m
Highway schedule Rates (HSR = 1999 (RDA - 1999)

ITEM	DESCRIPTION	UNIT	QTY	RATE Rs.	AMOUNT Rs.
01.	Trimming, levelling & compaction of original sub grade. (R1-129M)	m^3	Item	allow	25,000.00
02.	Approved soil excavation for based & shoulder construction including loading & piling (R1 - 121M)	m^3	1,150.20	119.00	136,873.80
03.	T'port of approved gravel soil distance 10 km. (R1-003M, R1-004M)	m^3	1,150.20	126.20	145,155.24
04.	Approved gravel soil spread & rolled including hire charges. fuel & watering (R1 - 123M)	m^3	1,150.20	83.25	95,754.15
					402,783.19
				Total:-	**402,800.00**

For sake of comparition only surfacing considered,

Appendix - IV

Bill of Quantities (B.O.Q)
Construction of a gravel Road (100mm) for 1 km length

Width of carriage way	=	3.66m
Width of Shoulder	=	2/1.25m
Width of Road Sides /reservation	=	2/2.0m
Highway schedule of Rates (HSR)	=	1999 (RDA - 1999)

ITEM	DESCRIPTION	UNIT	QTY	RATE Rs.	AMOUNT Rs.
01.	Trimming, levelling & compaction of original sub grade. (R1-129M)		Item	allow	25,000.00
02.	Approved gravel soil excavation for based & shoulder construction (EW1 - 013)	m^3	767.00	119.00	91,273.00
03.	T'port of above soil distance 10 km. (R1-003M, 004)	m^3	767.00	126.20	96,795.40
4.	Approved gravel soil spread & rolled including hire charges. (R1 - 123M)	m^3	767.00	83.25	63,852.75
				Total:-	276,921.15 **276,900.00**

For sake of comparition only surfacing considered .

Appendix - V

Bill of Quantities (B.O.Q)
Construction of gravel surfaced road (75mm) for 1 km. Length

Width of carriage way	=	3.66m
Width of Shoulder	=	2/1.25 m
Width of Road Sides /reservation	=	2/2.0 m
Highway schedule of Rates (HSR)	=	1999 (RDA - 1999)

ITEM	DESCRIPTION	UNIT	QTY	RATE Rs.	AMOUNT Rs.
01.	Trimming, levelling & compaction of original sub grade.		Item	allow	25,000.00
02.	Approved gravel soil excavation for based & shoulder construction including loading & piling (EW1 - 013)	m^3	575.10	119.00	68,436.90
03.	T'port of approved soil distance 10 km.	m^3	575.10	126.20	72,577.62
04.	Approved gravel soil spread & rolled including hire charges. fuel & watering (R1 - 123M)	m^3	575.10	83.25	47,877.07
					213,891.59
					213,800.00

For sake of comparision only surfacing considered

Appendix - VI

Bill of Quantities (B.O.Q)
Sand Sealing of Paved Road for 1km Length

Width of carriage way = 3.66m

Length of Road Sides/reservation = 2/750.0 m

Highway schedule of Rates (HSR) = 1999 (RDA - 1999)

ITEM	DESCRIPTION	UNIT	QTY	RATE Rs.	AMOUNT Rs.
(1). (I)	Supplying and stock piling premix. Bo - 366	M.T	10	1,987.00	19,870.00
(ii).	Transport of premix from distance (100km)	MT/km.	1000	6.30	6,300.00
(2).	Rectification Road with permix.	M.T	10	425.30	4,253.00
(3).	Sand sealing using emulsion CRS-1, at the Rate, 1 Ltr/Sq.M including	Sq.m	3660	26.40	96,624.00
(4).	Trans port of Sand (20km)	km.m3	29.28	182.00	5,328.96
					132,375.96
				12.5 % GST	16,547.00
					148,922.96
				Total:-	149,000.00

Appendix - VII

Bill of Quantities (B.O.Q)
Periodic Maintenance regravelling for 1km Length

Width of carriage way	= 3.66M
Width of Shoulder	= 2/1.25M
Highway schedule of Rates (HSR)	= 1999 (RDA - 1999)

Item	Description of Item	Unit	Qty.per Time	Rate	Amount
(1).	Grading road platform compacting for regravelly	m^3	Allow	sum	25,000.00
(2).	Approved gravely soil excavation for based and shoulder construction including loading and pilling.	m^3	270.00	119.00	32,130.00
(3).	Transport of gravel distance. 10 km	m^3	270.00	126.20	34,074.00
(4).	Approved gravel spread and compaction.	m^3	270.00	83.25	22,477.50
					113,681.50
				12.5 GST	14,210.19
					127,891.69
				Total :-	**127,900.00**

Appendix - VIII

Bill of Quantities

Maintenance Of Carriage way Paved Road - km/year

Width of carriage way	=	3.66 m
Width of Shoulder	=	2/1.25m
Highway schedule of Rates (HSR)	=	1999 (RDA - 1999)

No.	Description of Item	No of Times per Year	Unit	Qty.per Time	Rate	Amount
1.	Supplying of premix (Asphalt concrete) (R0 - 366)	4	M.Ton	0.75	1,987.00	5,961.00
2.	Transport of premix from distance (100km) (R1 - 005 MC)	4	M.Ton/km	75.00	6.30	1,890.00
3.	Patching Road with permix after preparing surface with emulsion (CSS - 1) at 0.75 Ltr/Sq.m.as tack coat including stamping with machine. (R1 - 955M)	4	M.Ton	0.75	1,192.00	3,576.00
4.	Allow for load Transport a Elf lorry	4	day	1.00	900.00	3,600.00
						15,027.00
					12.5 GST	1,878.38
						16,905.38
						16,905.40

Appendix - IX

Bill of Quantities (B.O.Q)

<u>Estimate for maintenance of carriage way</u>

<u>Gravel road km/year</u>

Width of carriage way	= 3.66 m
Width of Shoulder	= 2/1.25m
Highway schedule of Rates (HSR)	= 1999 (RDA - 1999)

Item	Description of Item	No of Times per Year	Unit	Qty.per Time	Rate Rs.	Amount Rs.
(1) I.)	Approved gravel, soil Excavation.	4	m^3	5.00	119.00	2,380.00
ii.)	Transport of gravel Allow 10km.	4	m^3	5.00	126.20	2,524.00
(2).	Cutting, trimming of clearing pot holes including wetting surface	4	Allow	2 days Labour	175.00	1,400.00
(3).	Filling pot holes with Approved Soil & compact	4	m^3	5.00	83.25	1,665.00
(4).	Allow Local transpot of gravel	4	Allow		900.00	3,600.00
(5).	Draging of gravel surface	1	Allow		900.00	900.00
						12,469.00
					Total:-	**12,500.00**

Appendix - X

Bill of Quantities (B.O.Q)
General upkeep of road Sides - 1km/year

Width of carriage way = 3.66m
Width of Shoulder = 2/1.25m
Width of Road Sides /reservatic = 2/2.0m
No. of culverts = 6 Nos
Guard Stones = 20 Nos
Highway schedule of Rates (HSR) = 1999(RDA - 1999)

Item	Description of Item	No of Times per Year	Unit	Qty.per Time	Rate	Amount
1.	Weeding general upkeep of road shoulder, verges, embankment	2	m^2	1,600.00	2.00	6,400.00
2.	Clearing desilting existing side drains, and Transport excavaled Materials up to 100m	2	m	750.00	2.00	3,000.00
3. (I).	Clearing desilting culverts.	1	No.	1.00	44.55	44.55
(2).	Clearing inlet and outlet of culverts.	2	No.	5.00	40.10	401.00
4.	White washing parapets of culverts, Bridges and k.m. post	1		Allow	Sum	1,000.00
						10,845.55
					Total:-	**10,800.00**