PROFESSOR E.O.E PEREIRA COMMEMORATION LECTURE 1997

ROAD BUILDING (EMBANKMENTS AND PAVEMENTS) IN SRI LANKA -THE PAST, PRESENT AND FUTURE

by

D P Mallawaratchie

1.0 Introduction

Mrs. E.O.E Pereira and other distinguished guests, Mr. Chairman, fellow engineers, ladies and gentlemen. I consider it a great honour and a privilege to deliver the Professor E.O.E Pereira Commemoration Lecture this year. I thank the Institution of Engineers, Sri Lanka and, in particular, the Civil Engineering Sectional Committee for inviting me to deliver this lecture. I apologize for not providing you with the customary copies of my lecture notes as I had to prepare my lecture at very short notice.

Professor Eustace O. E. Pereira, whose 90th birth anniversary we commemorate on Saturday 13th September 1997, was the father figure of all engineering graduates who passed out from the University of Ceylon for more than two decades from the early nineteen fifties. I take pride to have been a student of Professor Pereira.

Prof. Pereira had his school education at Royal College, Colombo. He won a Science Scholarship to University of Cambridge, England and took its Mechanical Science Tripos Degree in 1931 with a first class, having had the distinction of completing it in two years.

He returned from Europe after his studies in the early nineteen thirties and found himself unemployed during the years of the Great Depression.

After working as a Road Overseer in the Public Works Department (P.WD) for a few months, he secured a job in the designs Office of the Department.

Prof. Pereira worked in the PWD for about 15 years. During this period he also lectured at the Ceylon Technical College. Sir Ivor Jennings, the first Vice Chancellor of the University of Ceylon solicited his help to set up the Engineering Faculty. He was elected the Dean of the Faculty of Engineering, University of Ceylon, when it was set up in 1950, at Thurstan Road, Colombo.

Mainly through his efforts, the Faculty of Engineering shifted to New buildings at Peradeniya in 1964. The post of Dean he held almost uninterruptedly until 1969, when he was appointed Vice-Chancellor of the University of Ceylon, Peradeniya. He retired in 1970.

After his retirement from the University, Prof. Pereira served as the Chairman of the National Science Council and headed various Government Commissions and served as a consultant to many Organizations and Institutions.

I do not wish to go into more details of his illustrious career including his great contribution to engineering in this country.

During my days as an undergraduate at the Colombo and Peradeniya Campuses and subsequently as an Instructor at Peradeniya Campus, I could always remember his simplicity and consideration towards his students. After I had worked for a period of 5 months as an Instructor, of a usual period of 12 months till the next batch of students passes out, I remember a day in February 1966 when I approached him very nervously to get my release from the University to take up my first appointment as an Engineer in the Public Works Department which was the same Government Department he had joined 35 years earlier. I was surprised at his prompt agreement of my release, even when he was finding it difficult to carry on his work as Prof. of Civil Engineering without an adequate number of Instructors.

2.0 The Topic of my Lecture

I have selected a Civil Engineering topic within my field of experience for today's lecture on "Road Building in Sri Lanka - The past, present and future". I will be covering only Embankment and Pavement aspects in my lecture.

At the outset of my lecture I have to state that materials and techniques used in road building are very similar to those of constructing embankments and pavements of Airport Runways, Taxiways and Aprons.

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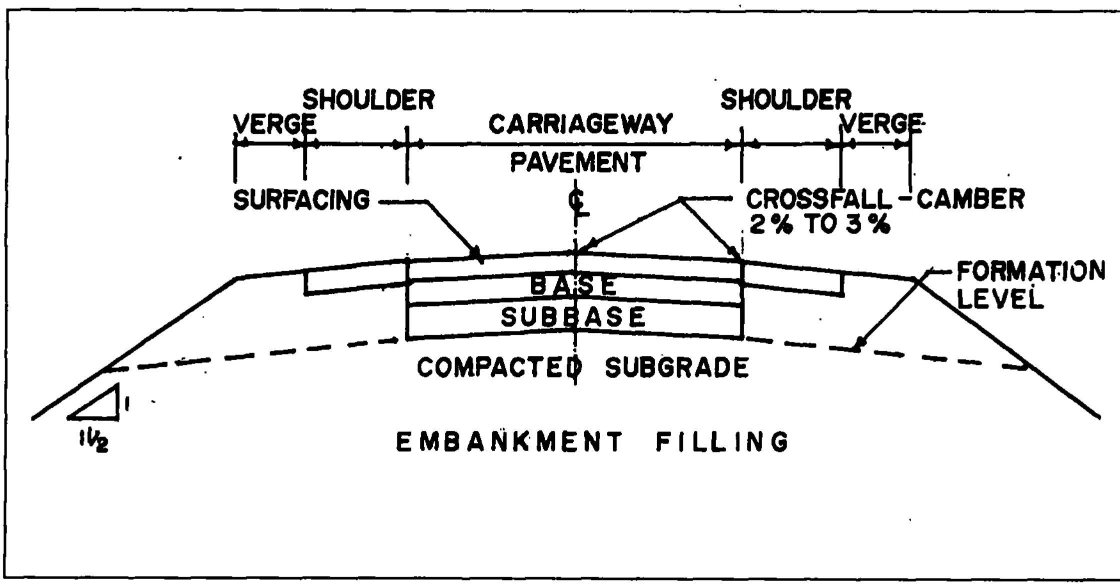

Figure 2.1 Flexible Pavement

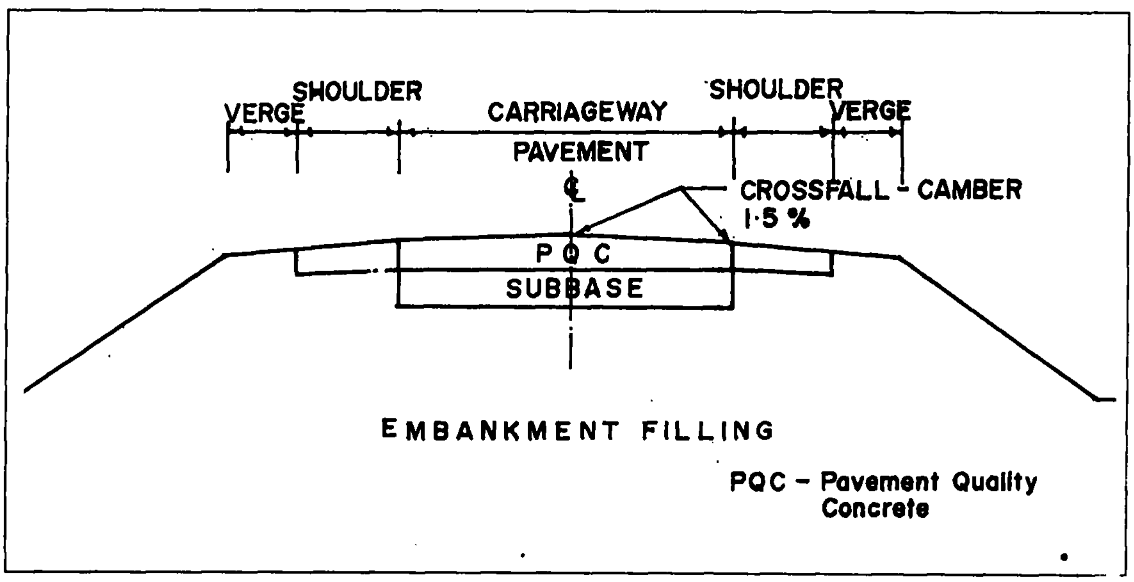

Figure 2.2 Rigid Pavement

I would like to depict the common types of pavement structures, namely flexible and rigid pavements, in Figures 2.1 & 2.2.

Other important aspects of embankments and the three types of subgrades that are obtained for road construction are depicted in Figure 2.3. In this figure, a capping layer is also marked and the definition for this layer, as given under section 2.1 will explain when such a layer is required in road construction. The definitions and terminology used in my lecture are given in the ensuing paragraphs.

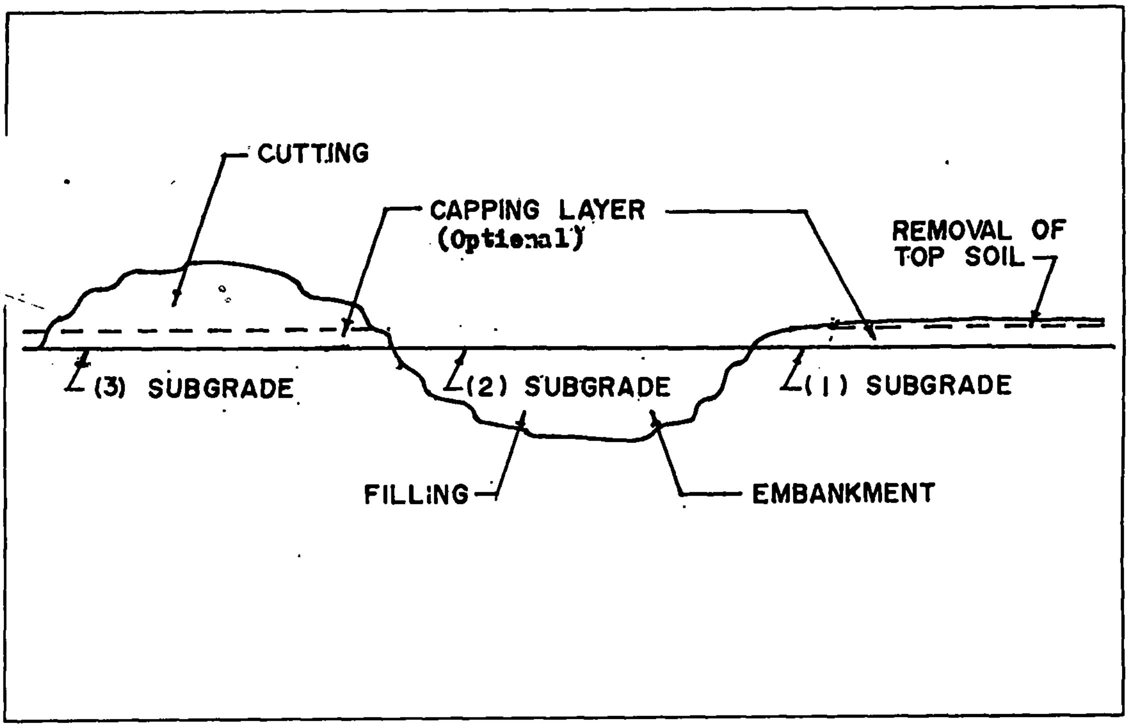

Figure 2.3 Capping Layer and Three Types of Subgrades

Road Cross sections in cutting and filling are given in Figures 2.4 & 2.5

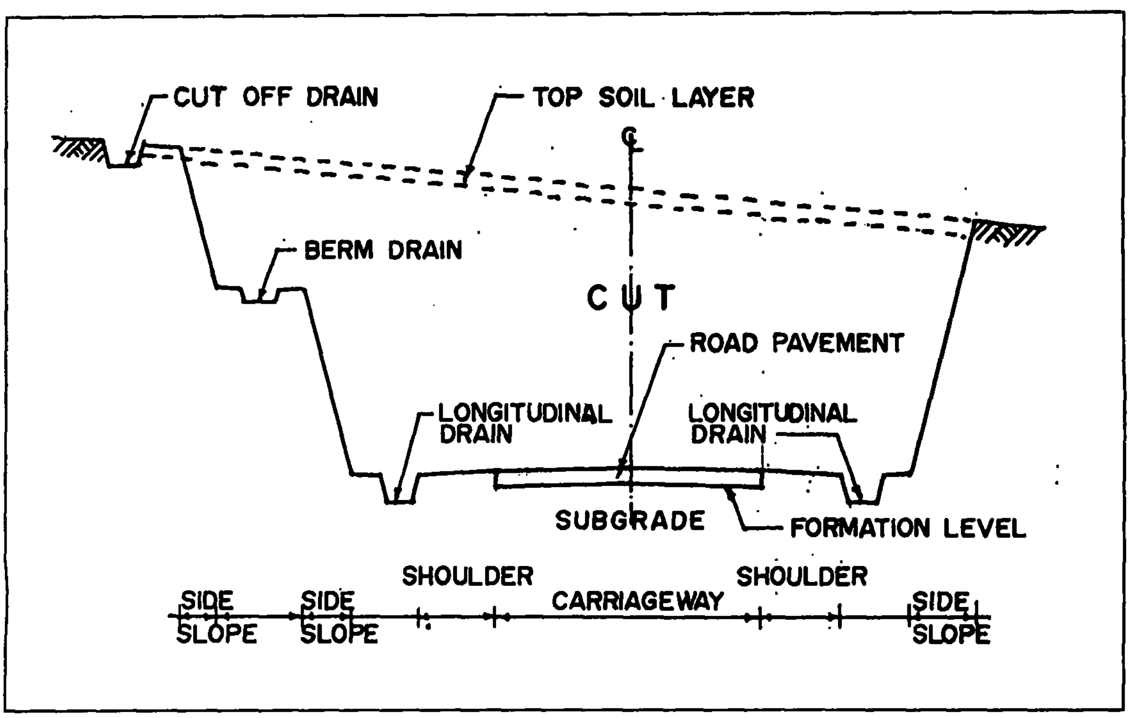

Figure 2.4 Road Cross Section in cutting

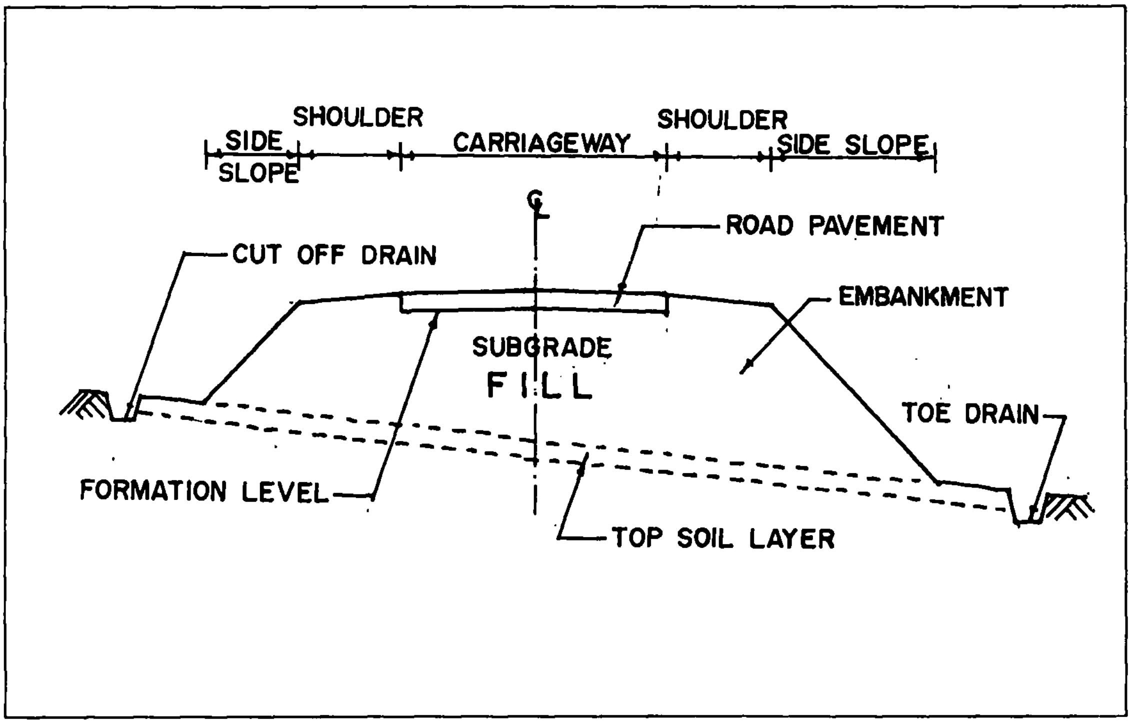

Figure 2.5 Road Cross Section in Filling

2.1 Definitions and Terminology in Alphabetical Order

Reference is made to Figures 2.6 & 2.7.

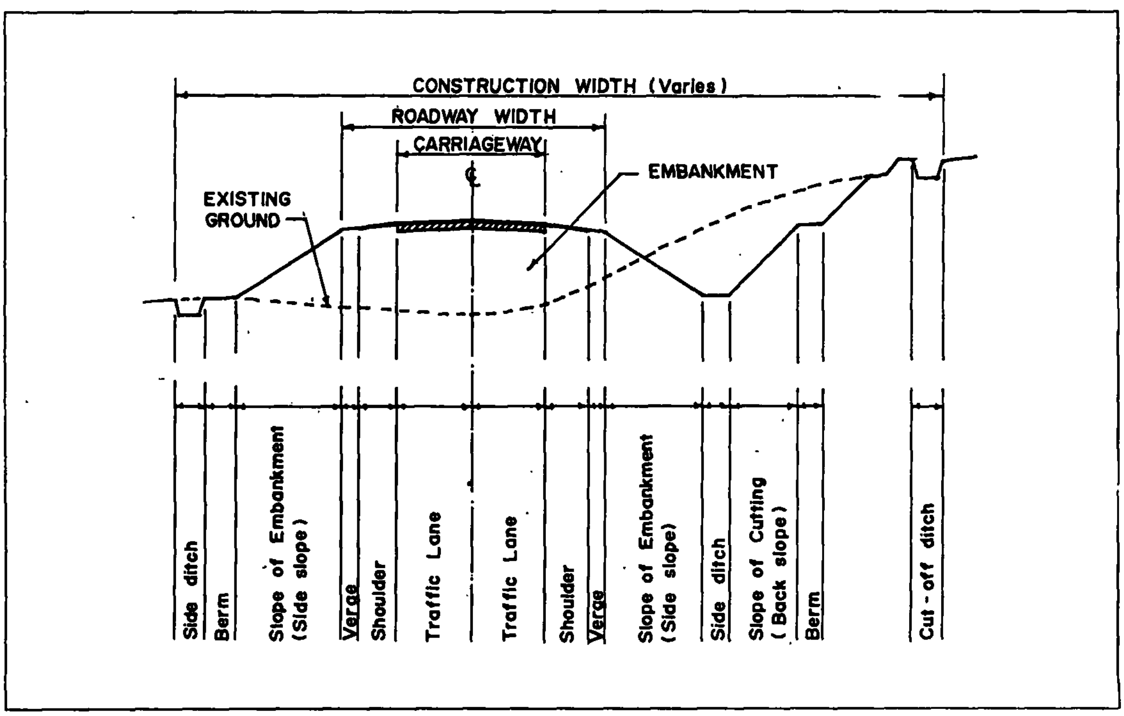

Figure 2.6 Cross - Section Terminology

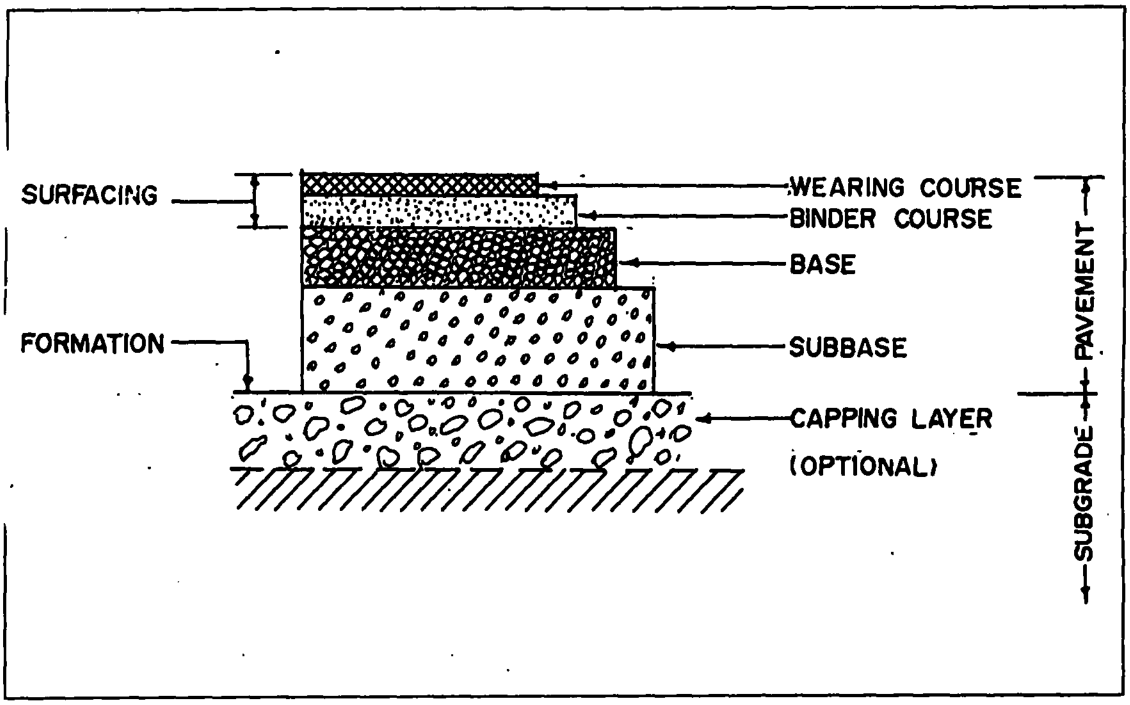

Figure 2.7 Pavement Terminology

Base

The base in a road pavement structure is that component between the top level of the subbase or the subgrade, if the subbase is missing, and the bottom face of the surfacing.

Capping layer (selected or improved subgrade)

The capping layer consists of selected fill material in the lower pavement as a substitute for a part of a thick subbase to reduce cost.

Carriageway

The carriageway is the road pavement surface on which vehicles travel.

Embankment

The embankment is the earth fill above natural ground (after stripping top soil) up to formation level.

Formation

The formation is the shaped surface of the earthworks, or subgrade, before constructing the pavement layers.

Roadway

The roadway is the portion of a highway, including shoulders, for vehicular use.

Shoulder

The shoulder is the paved or unpaved part of the highway next to the outer edge of the pavement. The shoulder provides side support for the pavement and allows vehicles to stop or pass in an emergency.

Standard Compaction and Modified Compaction

The standard compaction and modified compaction are the compaction performed in accordance with the British Standard (Light) Compaction Test and British Standard (Heavy) Compaction Test respectively.

Subbase

The subbase in a road pavement structure is that component between the top level of the subgrade and the bottom face of the road base.

Subgrade

The subgrade is the supporting ground immediately beneath the pavement structure. It could be any one of the following, depending on the cross section of the road way (see Figure 2.3 also):

(1) The natural ground (after stripping top soil) on which the road trace is located when there is no embankment or cutting.

(2) The uppermost layer left in a cut when the road is located in a cutting.

(3) The capping layer.

(4) The uppermost layers of an embankment when the road way is built on an embankment.

Surfacing

The surfacing is the uppermost layer of a road pavement structure. It normally consists of a bituminous surface dressing or a layer of premixed bituminous material. Where premixed materials are laid in two layers, these are known as the wearing course and the binder course (or base course).

3.0 Embankments and Common Components of Pavements and Shoulder for flexible and Rigid Pavements

First of all, I would like to take up embankments and describe the past, present and future aspects for road building in Sri Lanka and then take up such aspects for subgrades, selected borrow and capping layers, shoulders, subbases and lime stabilized subbases and bases that are common to both flexible and rigid pavements. Bases and surfacing for flexible pavements will be covered next, followed by rigid and other pavements

3.1 Embankments

3.1.1 Principles of Embankment Construction

Many years ago, road embankments were constructed by dumping or tipping soil to full height of the embankment or fill. In this procedure the material slides or rolls into place down the face of the progressing fill. Attempts were not made to control moisture content nor to secure compaction.

These embankments would settle for a few years, culminating in depressions and surface irregularities. These effects would cause the failure of pavements constructed on the embankments, if the settlements exceed about 100mm.

Engineers have found out that high class embankments could be constructed by spreading fill material in relatively thin layers and compacting same at a moisture content near the optimum. This improvement occurs largely because a greater dry density is attained, which in turn results in higher strength in the soil mass and thereby decreasing settlement and rutting. Layered construction also produced greater uniformity in the material itself and in its density and moisture contents. This was beneficial since any subsequent settlement or swelling would be relatively uniform. At present, highway engineers agree that proper construction of embankments, requires that the fill material be spread in layers, moistened or aerated close to the optimum moisture content as required by the compacting equipment and compacted.

3.1.2 Selection of Fill Materials for Embankment Construction

1. In the Past, there was no restrictions in the use of materials for embankment construction and invariably soils from the vicinity of road whether good or bad were used. This practice caused the construction of several embankments requiring pavement structures of very high thicknesses resulting in failures when pavements of usual or somewhat higher thicknesses were provided. Good examples of such roads are Chilaw-Puttalam section of Katunayake-Puttalam road and several Mannar roads where poor soils from the sides of the road having 4 day soaked California Bearing Ratios (CBR) of 1 to 4 have been used to construct embankments.

2.1 At present, soils used as embankment materials should be naturally occurring and should not include highly plastic clay, silts, peat or other organic soils or any soil that is contaminated with top soil, vegetable and other deleterious matter.

2.2 The material used for top 500mm of embankment should have a maximum dry density under standard conditions of compaction (MDD-SCC) not less than 1600 Kg/m3 and the material for lower layers of embankment should have a MDD-SCC not less than 1500 kg/m2.

3. In the future, almost all types of materials extending from sandy clay soils to broken rock can be used for embankment construction. The main criterion being the ease with which the material can be economically handled and compacted. The fill material will usually be procured from borrow areas in the vicinity of the road or transported from close by cuttings. Materials of low plasticity characteristics are preferred, as such material will generate less complications during wet weather. With soils of high plasticity, greater care has to be taken during construction to keep the soils from absorbing moisture by maintaining the surfaces shaped and compacted so that rain water is shed quickly. For embankments less than 6m height, the soil used should have a Liquid Limit (LL) not more than 70 and Plasticity Index (PI) not more than 45. If the embankment is higher than 6 metres, it is desirable to use the material having LL less than 50 and PI less than 25 for the lower layers below 6m. At the subgrade level the top 300mm of embankment construction should have a CBR not less than 5. The material used for embankments should also conform to the general requirements as given in section 3.1.2.2.

3.1.3 Degree of compaction

The upper 500mm of soil immediately beneath the subbase or capping layer i.e. the top of the embankment fill or the natural subgrade, should be well compacted. In practice this means that a minimum level of 100 percent of the maximum dry density obtained in the British Standard light compaction test using the 2.5kg rammer or if higher compaction is required 95 percent of the maximum dry density obtained in the BS(Heavy) Compaction Test,4.5kg rammer should be specified. The same density should also be specified for fills behind abutments to bridges and for the backfill behind culverts. For the lower layers of an embankment, a level of 95 percent of the maximum dry density obtained in the BS light compaction test or if higher compaction is required a compaction level of 90 percent of the maximum dry density obtained in the BS(heavy) Compaction Test is suitable. Trials are being carried out to take a suitable decision regarding the two levels of compaction that are given above. Before construction, compaction trials should always be carried out to determine the best method to achieve the specified density with the available compacting equipment.

3.2 Subgrades on Natural Ground or in cutting

3.2.1 Procedures of compaction

Long ago, such compaction was not carried out. Presently and in the future where the height of embankment fill is less than 300mm or where the road is in cutting the original ground or the surface exposed by the cut should be excavated up to a depth of 300mm below the road formation level or to further depths if the density of compaction of the original ground or the exposed surface is less than the density stipulated for top of embankment. The surface exposed by this operation should be compacted either by 6-8 passes of a 8-10 tonne smooth wheeled roller or by an appropriate number of passes of any other roller. The excavated depth should be refilled as for construction of embankments.

3.3 Selected borrow and capping layers

In the past and the present no such layers were used in road construction. In the future such layers will be utilized as given below.

3.3.1 Selection of Materials

A new concept introduced by the Transport Research Laboratory, UK, Road Note 31, Fourth Edition,1993 (RN 31) is the selected subgrade material and capping layer. These materials are generally required to protect weak subgrades with CBR ranging from 1 to 4 for different types of pavement construction and are being used in the lower layers of the pavement, as a substitute for thicker subbase layers. For our work, the capping layer should have a minimum CBR of 8 when compacted to 100 percent MDD at the OMC of BS light compaction or if higher compaction is required 95 percent MDD at the OMC of BS Heavy Compaction. (See section 7.0)

3.4 Shoulders

3.4.1 Different types of shoulders

Long years ago, materials used for embankment whether good or bad were used for shoulders. At present, gravelly soils that are used for gravel surfacings are being used for shoulders.

In the future the following types of shoulders will be constructed.

1. **Extended base and subbase (After Reference IR)**

   From the drainage point of view, it is ideal to carry the base and subbase materials right across the shoulders to the drainage ditches. This has the further advantage of simplifying the construction.

   However, considering the high cost of base materials, this solution may be envisaged only for shoulder widths of less than 1.5m.

   If the base consists of gravelly soil with clay, the shoulders may be left unsurfaced.

   If the base consists of cohesionless material such as graded crushed stone or non-plastic gravel, the shoulders should be primed and sealed. A sand seal or single or double surface dressing may be necessary, depending on traffic conditions.

2. **Gravel shoulders**

   This is the most common type of shoulder. The material may consist of gravel as given below.

   Gravel shoulders for bitumen surfaced roads should be constructed with materials of wearing course quality for gravel roads, meeting the requirements given in section 601 of the Standard Specifications for Construction and Maintenance of Roads and Bridges.

   However the following material requirements as an amendment to standards could also be tried out and implemented if successful.

   PI : 5 - 15

   CBR : Minimum 30 percent (for traffic loading on carriageway > 2.5 million ESA)

CBR : Minimum 20 percent (for traffic loading on carriageway < 2.5 million ESA)

The CBR shall be determined at 95% of the MDD obtained in the BS Heavy Compaction Test and at OMC, tested after 4 days soaking.

3. **Earth shoulders**

For shoulders of normal gravel roads and the lower levels of shoulders for bitumen surfaced roads, selected soils can be made use of.

4. **Topsoiling and Grassing of earth and gravel shoulders**

It is recommended that the soil should have at least a CBR of 20.

After the final trimming and compaction, the shoulders shall be topped with 20mm of humus or topsoil and lightly rolled. Sprigs or sods of indigenous grass shall then be planted or alternatively seeding may be used.

This type of protection is applicable to such shoulders, in the wet zone.

The shoulder surface should then be about 20mm below the carriageway edge. With the growth of grass the top level of grass should be maintained in such a way to facilitate the free flow of water across the shoulders. The disadvantage of grassing of shoulders is that the surface becomes skiddy making vehicles to skid off the road.

5. **Priming and sand sealing**

After the final trimming and compaction, the gravel shoulders should be primed with cutback or bitumen emulsion as per section 501 of the SSCM and the primed surface shall be blinded with coarse sand. After priming, a sand seal as per section 504 of the SSCM shall be applied to the shoulders. This type of shoulders has been recommended where the traffic on the shoulders is less than 150 vehicles per day and when heavy vehicles do not turn and park on such shoulders. Shoulders can be further improved by carrying out a priming and single surface dressing as per section 505 of the SSCM.

6. **Bitumen surfaced aggregate shoulders of 150mm thickness.**

If emulsion is used as a binder, these shoulders can be conveniently carried out by constructing a dense graded aggregate base of thickness 75mm as per SSCM, cleaning the top of the surface, constructing a blended aggregate base of thickness 75mm, using a blend of 37.5, 19 & 12.5mm single sized aggregate, applying a first coat and second coat as per section 4.3.1.

Alternatively the bottom layer of the base can be constructed as per the top layer as given in the above paragraph and the top layer by blending 37.5 and 19mm single sized aggregate in the proportions given in section 4.3.1 and choking the surface interstices with 12.5mm single sized aggregate applying a first coat and a second coat as per section 4.3.1.

If hot bitumen is used as a binder, then single sized aggregate base as per section 4.1.1 can be constructed. These types of shoulders are recommended for traffic on the shoulders greater than that given in section 3.4.1.5 above.

3.5 Pavement Drainage(After Reference IR)

3.5.1 This subject does not come strictly under those components of pavements common for both flexible and rigid pavements as it is not relevant to rigid pavements. However as it is closely related to shoulders it is dealt with in this section.

In the past and the present, except for a few porous layers within the shoulders and verges from the edges of the carriageway to the edges of the embankment longitudinal at intervals of 3 to 5m, no pavement drainage has been adopted. In the future pavement drainage will be adopted as given below.

3.5.2 Internal Drainage of Pervious pavement layers

When permeable base materials are used, particular attention must be given to the drainage of the base layer. The "trench" type of cross-section, in which the pavement layers are confined between continuous impermeable shoulders, must be avoided. This applies principally to crushed stone bases.

If it is too costly to extend the roadbase and subbase material across the shoulder, drainage channels at 3m to 5m intervals should be cut through the shoulder to a depth of 50mm below subbase level, These channels should be back-filled with material of roadbase quality but which is more permeable than the roadbase itself, and should be given a fall of 1 in 10 to the side ditch. Alternatively a continuous drainage layer of pervious material of 75mm to 100mm thickness can be laid under the shoulder such that the bottom of the drainage layer is at the level of the top of the subbase. The latter is by far the better of the two alternatives.

The main cases to be considered are as follows:

(i) **Pervious base - impervious subbase**

It would be ideal to extend base and subbase across the shoulders. However, except for narrow shoulders, this solution is extremely costly (see pavement cross-section B in Figure 3.1).

In most cases, the drainage of the base should be ensured by a continuous drainage layer, placed under the shoulder at the level of the underside of the base. This drainage layer shall consist of proper filter material (graded crushed stone, sand etc.) and should be at least 75mm thick (see pavement cross-section D in Fig. 3.1).

(ii) **Pervious base - pervious subbase**

Although costly, the only effective solution is to extend the subbase across the shoulders to the drainage ditches (see pavement cross section C and E in Fig. 3.1)

(iii) **Impervious base**

Provided that the shoulders are sufficiently impervious and the joint between base and shoulder is properly sealed, internal drainage should not be necessary. (see pavement cross section A in Fig. 3.1). However, if this cannot be assured then drainage must be considered.

In case (i) and (ii) above, it is essential that the surfaces of the subbase and the drainage layer be given an adequate crossfall to ensure the egress of water under any circumstances. In the case of a superelevated section, the drainage layer should be omitted on the upper side.

Note : Longitudinal pipe-drains may also be used, but their cost is such that they will be justified only along urban sections where the pavement is confined between footpaths.

3.6 Soil Subbases

The subbase is required to be of material having superior engineering properties than embankment material. Material to be accepted for use in subbase construction should have a 4 day soaked CBR value of not less than the values given in Table 3.1 when tested under 100% BS light compaction or if higher compaction is required, 95% BS Heavy compaction. In the latter case, the CBR value is determined at the equilibrium moisture content under field conditions rather than under four day soaked condition especially in high ground sections of road where the subbase will never be under saturated (soaked) condition. For traffic less than 2.5 x 10^6 Equivalent Standard Axles (ESA), this CBR value may be relaxed to 8 for lower layers when the thickness of subbase is more than 150mm (6"). The subbases should have Liquid Limit (LL) and Plasticity Index (PI) not more than 40 and 15 respectively.

Table 3

Subbase CBR Requirement for various Traffic Levels

Traffic(million ESA)	Subbase minimum CBR requirement
0 to 6	Type I (CBR-20) & Type II (CBR-8)
> 6	Type III (CBR-30)

Naturally occurring well graded gravels and clayey sands could be found to satisfy this requirement. In case the haul distance for such material is uneconomical, then economically available material that would give the required CBR after appropriate stabilization could be used. (See section 3.7).

3.7 Soil stabilization for subbases and bases

In the past and present, such work was carried out when the CBR values attained in the laboratory were more than 30 & 80 for subbases. Attempts will be made to obtain the laboratory criteria given in RN 31, and if so the specifications given in that document will be used for such construction.

In Sri Lanka, road Engineers are running out of good quality gravels for subbase materials. A recent survey in Galle, Matara and Hambantota Districts for rehabilitation of Galle-Matara, Matara-Hambantota and Matara-Akuressa roads, Gampaha District and other areas especially in urban areas have shown that there is a dearth of natural materials for the subbases. In the cases of bases suitable crushed or broken rock are not available in most areas due to environmental issues. This may make stabilization of soils mandatory in future, for most areas in Sri Lanka for the construction of subbases and bases.

4.0 Flexible Pavements - Aggregate Bases

4.1 Past

Long years ago, both Telford and Macadam methods of road construction were adopted as given in Figure 4.1 and 4.2. Roads were then constructed, by clearing a pathway, laying and compacting hand broken rubble and aggregate. No compaction of the subgrade was carried out. The development of the local method of single sized aggregate bases ("Metal consolidation") cum bitumen surfacings ("Tarring") together taken as "Metalling and Tarring" is given in the ensuing paragraph.

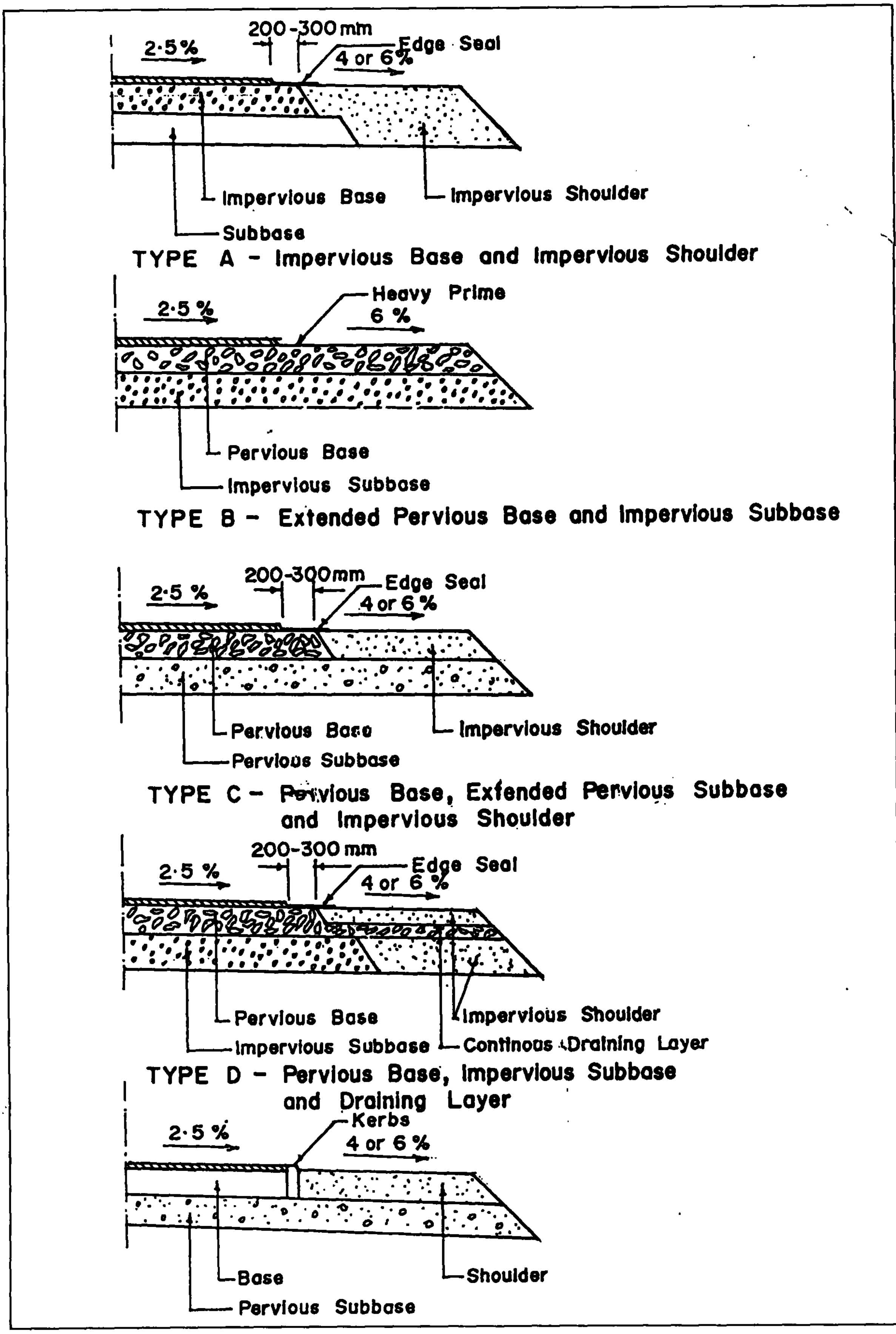

Figure 3.1

Pavement Cross - Sections of Bitumen Roads With Normal Width Shoulders (1.5)

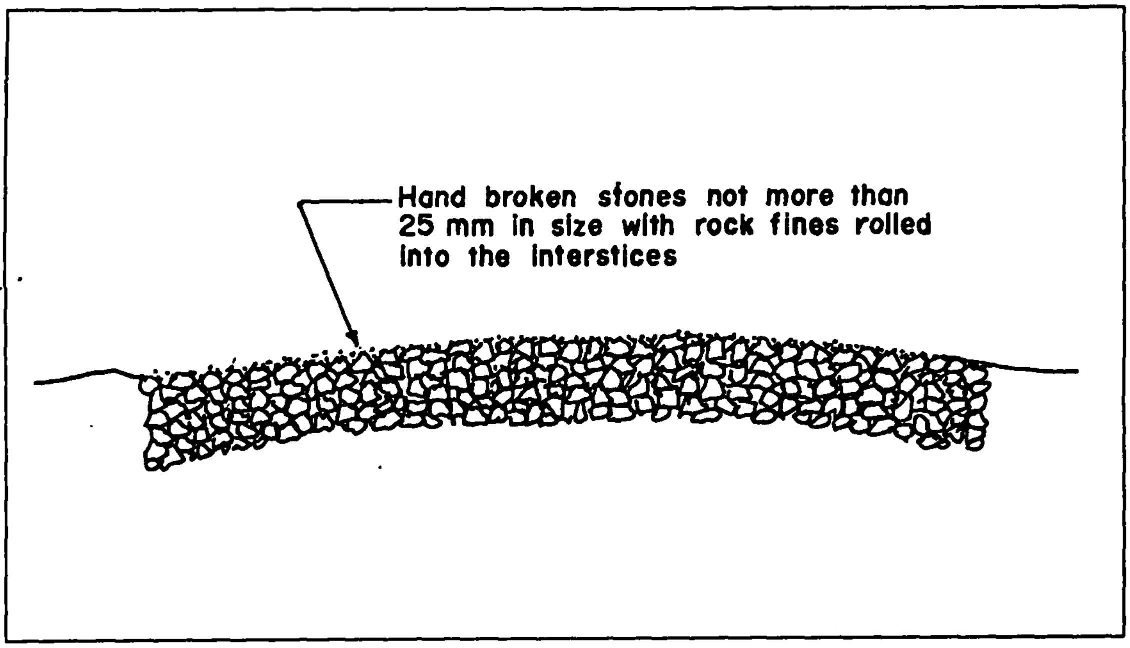

Figure 4.1 Macadam Construction

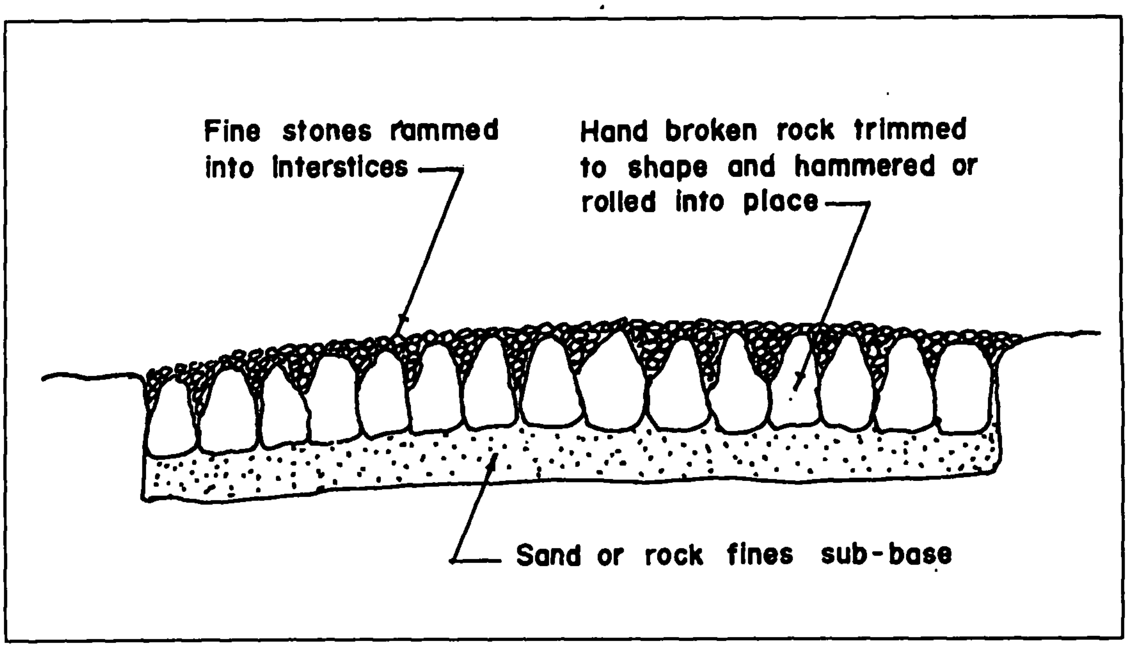

Figure 4.2

Telford Construction Traditional Method of road Pavements Construction

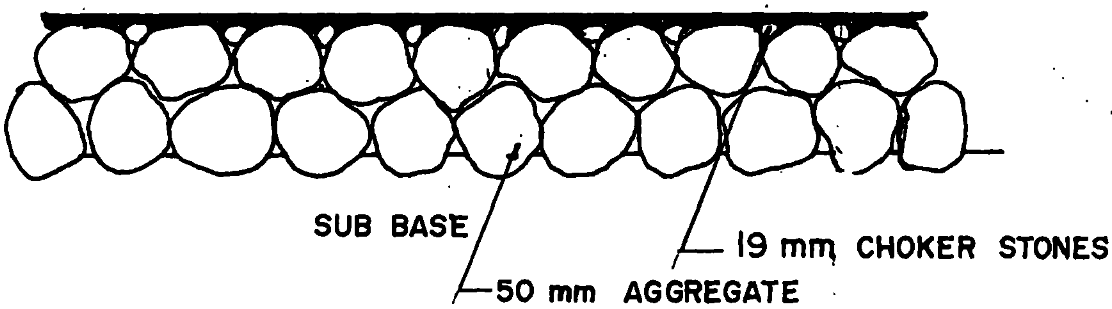

Figure 4.3 Single sized Aggregate Base and Surfacing (Metalling & Tarring) Traditional Method of base cum surfacing in Sri Lanka.

4.1.1 The Development of the local method of single sized aggregate bases ("Metal Consolidation") cum bitumen surfacings(See Figure 4.3)

Macadam roads developed originally in England and France are named after J L Macadam (1756-1836), a famous Scottish road builder and engineer. The term "Macadam" later designated a road surface or base in which clean, broken, 50mm single sized crushed stones were mechanically locked by rolling and bonded by stone screenings which were worked into the voids and "bound" with water. This method was known as "Water Bound Macadam", in order to distinguish it from its adaptation "Penetration Macadam" for which bituminous materials were used. The latter originated in the first decade of the twentieth century and consisted of a compacted layer of coarse stone aggregate to which a bituminous binder is applied in order to bind the stones together, followed by the compaction of a layer of keystone. Full grouting of bitumen for a 75mm(3") thick layer of penetration macadam requires about 9 l/m2 (18 gallons/ Square (100 sq/ft.). Certain countries like India use semigrouting which requires about 6.8 l/m2 (13.6 gallons/Square) to reduce the coverage of bitumen. The coverage of bitumen has been further reduced in local method called "metalling & tarring" (see figure 4.3) that is now termed as single sized aggregate base cum surfacing to 1.75-2.0 l/m2 (3.5-4.0 gallons/Square). This reduction in coverage of bitumen was obtained by choking the surface interstices present in the coarse aggregate with 19mm(3/4") aggregate before applying bitumen.

4.2 Present

Presently bases that are used in road construction are given in the Standard Specifications for Construction and Maintenance of roads and bridges (SSCM) and are as follows:-

1. Single sized aggregate bases cum surfacings
2. Water bound/dry bound bases and surfacing
3. Dense aggregate bases and surfacings
4. Penetration Macadam bases and surfacing
5. Open and Dense Graded Bitumen Bound Bases and surfacing

4.3 Future

In the future the presently constructed bases will continued to be used, along with the new bases as given below.

4.3.1 Blended Aggregate Base and Surfacing

The development of the traditional single sized bases is described in section 4.1.1. In the case of the binder

Table 4.1

Recommended Grading Band of "Blended Aggregate"

Sieve sizes mm	Percentage by mass of total aggregate test sieve
50.0	100
·37.5	90 - 100
25.0	35 - 70
19.0	23 - 45
12.5	08 - 21
09.5	0 - 6
04.75	0 - 1

application of the first coat for such bases is carried out using bituminous emulsions, it is found that due to lower viscosity of emulsion when compared to penetration grade bitumen, the emulsion tended to penetrate through the surface leaving only a small amount of binder at the surface for binding, causing failures of the base cum surfacing when similar quantities of binder as that for penetration grade bitumen, were applied. This was solved by obtaining and using a more closely graded base material called blended aggregate by blending 7 parts of 37.5mm, 2.15 parts of 19mm and 1.20 part of 12.5mm by volume of aggregate with a grading band as given in Table 4.1. The first coat is applied at a rate of 3 to 4 l/m2. A second coat in the case of new construction and a subsequent coat in the case of existing surfacings are normally applied by using CRS-1 at the rate of 1 l/m2 and blinded with coarse sand.

4.3.2 New Methods

In addition to the presently constructed bases, the following will be tried out and if found successful, will be introduced in the field.

1. Natural gravelly soils and weathered rock as suggested by French Republic, 1984 "Guide to Pavement Design in Tropical Countries" (CEBTP) and RN 31. This has been tried out successfully at the Free Trade Zone at Koggala where a crushed weathered rock was used.

2. Gravel/soil mechanical stabilization as suggested by CEBTP

3. Bitumen Bound Base where additional Kenyan Gradings are suggested as given in Table 4.2 and the specifications are given below.

3.1 Alternative grading options.

Table 4.2

Additional Gradings for bitumen Bound bases

Sieve Size(mm)	Percentage by mass of total aggregate passing test sieve	
	3A	3B
25.0	-	100
20.0	100	80 - 100
12.7	70 - 100	60 - 80
9.5	55 - 80	50 - 65
6.35	40 - 60	40 - 55
4.75	35 - 50	35 - 45
2.36	25 - 35	25 - 35
0.075	3 - 6	3 - 6
Binder(%)	4.4 - 5.4	4.2 - 5.2

3.2 Mix Design

Optimum bitumen contents should be selected in accordance with the Marshall test (ASTM D 1559), so as to obtain a bituminous mixture meeting the following requirements:

Stability = 5.5 kN (minimum)

Flow = 2-5 mm

Voids in total mix = 3-7%

3.3 Compaction

The field density of the compacted bituminous mix tested on cores, should not be less than 95% of the laboratory compacted specimens cast of the same bituminous mix, in accordance with ASTM D 1559.

Rolled Asphalt Bases as given in RN 31.

Suitable specifications for gap graded Rolled Asphalt Bases are given in Table 4.3

5.0 Flexible Pavements - Surfacings

5.1 Past

1st coat and 2nd/subsequent coat for single sized aggregate bases, a few short sections of surface dressings, prime coats, tack coats and asphaltic concrete surfacings were the only surfacings or surface treatments that were used in the past.

5.2 Present

During the past 12 years to date, prime coats, tack coat, hot bitumen applications, sand seals, single and double surface dressings, asphaltic concrete surfacings and a few short lengths of Cold mix surfacing have been constructed.

5.3 Future

In the future it is intended to carry out the following surfacings.

1. Manually and later on, machine applied slurry seals
2. Single surface dressing followed by slurry seals which are called cape seals.
3. Asphaltic concrete wearing courses and base courses (binder courses) as given below.
4. Bitumen Macadam for wearing courses and base courses (binder courses) the gradings and suggested Marshall criteria for dense graded bitumen macadams are given below.
5. Rolled Asphalt surfacings
6. Flexible Wearing Courses
7. Cold mix surfacings using graded 37.5mm aggregate
8. Bitumen Bound Bases as surfacings

Table 4.3

Suitable Specifications for rolled Asphal Bases

Mix	No.1	No.2
Test sieve(mm)	Percentage by mass of total aggregate passing test sieve	
50	-	100
37.5	100	90 - 100
28	90 - 100	70 - 100
20	50 - 80	45 - 75
14	30 - 60	30 - 65
2.36	30 - 44	30 - 44
0.6	10 - 44	10 - 44
0.212	3 - 25	3 - 25
0.075	3 - 7	3 - 7
Bitumen content (Percent by mass of total max.)	5.7 + 0.6	
Layer thickness (mm)	60 - 120	75-150
Filler binder ratio Bitumen	0.6-1.2	
Grade (Pen)	40/50 OR 60/70	

5.3.1 Asphaltic Concrete surfacings

5.3.1.1 Combined grading of aggregate and binder content

The specifications for combined aggregate and binder content are as given in Table 5.1

5.3.1.2 Mix Characteristics

The mix characteristics designed by Marshall design procedure are as given in Table 5.2.

Table 5.1

Grading Bands of binder Course & Wearing Courses for Asphaltic Concrete Surfacings

Sieve Size mm	/um	Type 1	Type 2	Type 3	Type 4	Binder Course
		Wearing Course				
		Percentage by mass of total aggregate passing test sieve				
37.5		-	-	100	-	-
25		100	-	97-100	100	100
19		90-100	100	87- 97	94-97	88-100
12.5	-	-	80-100	69-87	72-87	-
9.5		65- 93	73- 93	57- 80	57-77	54- 80
4.75		45- 73	52- 69	37- 65	38-63	34- 56
2.36		35- 58	32- 50	25- 52	27-48	21- 38
1.18		26- 48	25- 43	18- 40	20-40	15- 33
	600	18- 38	19- 35	12- 30	15-35	10- 26
	300	13- 26	14- 27	05- 19	10-25	06- 20
	150	08- 20	9- 18	03- 13	07-17	03- 13
	75	04- 12	5- 10	02- 08	05-09	01- 07
Percentage binder content by total weight of mix		4.5-6.5	4.5-6.5	4.5-6.5	4.5-6.5	3.5-5.5

Note: The sieve sizes used herein are of ASTM designation. However, equivalent BS sizes as given in Table 107-1 of section 107 of the SSCM, may be used.

Table 5.2

Wearing Courses and Binder Courses (After TRL, UK Road note 31 (1993))

Total Traffic (10^6 ESA)	< 1.5	1.5-10.0	>10.0	Severe sites(1)
Minimum stability (KN at 60°C)	3.5	6.0	7.0	9.0
Minimum flow(mm)	2	2	2	2
Compaction level (Number of blows)	2x50	2x75	2x75	2x75
Air voids(percent)				
(i) Wearing course	3-6(3)	3-6(3)	3-6(3)	3-6(2)(3)
(ii) Binder course	3-7	3-7	3-7	3-7(2)

Notes:

1. Slow moving heavy traffic, etc.
2. The refusal density must be satisfactory (Refer to Appendix D of TRL, UK Road Note 31 (1993)).
3. In view of the problems of durability attempts should be made to keep the upper limits of air voids to 5.0 percent.

5.3.2 Bitumen Macadam for Wearing Courses and Base Courses (Binder courses) (AFTER RN 31)

Suitable specifications and suggested Marshall criteria for dense graded bitumen macadams (see TRL, UK Road Note 31 (1993)) are given in Table 5.3 & 5.4 respectively.

Table - 5.3

Bitumen Macadam Surfacings

Mix Designation	WC3	WC4	BC2
	Wearing Course		Base course
BS test sieve(mm)	Percentage by mass of total aggregate passing test sieve		
28	-	-	100
20	100	-	95 - 100
14	95 - 100	100	65 - 85
10	70 - 90	95 - 100	52 - 72
6.3	45 - 65	55 - 75	39 - 55
3.35	30 - 45	30 - 45	32 - 46
1.18	15 - 30	15 - 30	-
0.3	-	-	7 - 21
0.075	3 - 7	3 - 7	2 - 8
Bitumen Grade(pen)(1)	80/100 or 60/70	80/100 or 60/70	80/100 or 60/70
Bitumen content percent by mass of total mix)	5.3 + 0.5	5.5 + 0.5	5.0 + 0.6
Thickness (mm) (2)	40 - 55	30 - 40	50 - 80

Notes: 1. 60/70 grade bitumen is preferred

2. In practice the upper limit has been exceeded by 20 percent with no adverse effect.

Table 5.4

Suggested Marshall Criteria for close Graded Bitumen macadams (After RN 31)

Design traffic (10^6 ESA)	< 1.5	1.5 - 10	>10	Severe sites
Minimum stability (kN at 60°C)	3.5	6.0	7.0	9.0
Flow (mm)	2 - 4	2 - 4	2 - 4	2 - 4
Compaction level (number of blows)	2 x 50	2 x 75	To refusal	To refusal

5.3.3 Hot rolled asphalt for wearing course and base course (binder course)(AFTER RN 31)

These construction techniques are not used in Sri Lanka. However, the TRL has recommended Rolled Asphalt surfacings, the specifications of which are given below in Table 5.5 for wearing courses.

Table 5.5

Specifications for rolled asphalt surfacings (After RN 31)

Mix	No.1(1,2)	No.2(1,2)
Test Sieve (mm)	Percentage by mass of total aggregate passing test sieve	
28	-	-
20	100	100
14	90 - 100	90 - 100
10	50 - 85	50 - 85
2.36	50 - 62	50 - 62
0.6	35 - 62	20 - 40
0.212	10 - 40	10 - 25
0.075	6 - 10	6 - 10
Type of fines	Natural sand	Crushed rock
Bitumen Grade (pen)	40/50 or 60/70	60/70
Thickness(mm)	50	50
Bitumen Content (percent by total mass of total mix)	Minimum target value 6.3+0.5(3)	

Notes:

1. The preferred target for Coarse aggregate is 50 percent
2. For mix No.1 a maximum of 12 percent should be retained between the 0.6mm and 2.36mm sieves
3. With 50 percent Coarse aggregate (See BS 594)

5.3.4 Flexible Wearing Courses

The specifications for flexible wearing courses are given below in Table 5.6.

Table - 5.6

Gradings for flexible wearing courses (Kenya)

Mix	No.01	No.02
Sieve size (mm)	Percentage by mass of total aggregate passing test sieve	
20	100	
14	90 - 100	100
10	70 - 95	90 - 100
6.3	55 - 85	62 - 90
4	46 - 75	50 - 80
2	35 - 60	35 - 65
1	25 - 45	25 - 50
0.425	14 - 32	14 - 33
0.300	11 - 27	11 - 27
0.150	6 - 17	6 - 17
0.075	3 - 8	3 - 8

RN 31 states that it is important that the thin bituminous surfacings of 50mm thick should be flexible, mainly for those constructed on granular road bases. As this is the case in Sri Lanka, attempts should be made to introduce such surfacings which are designed to give good durability rather than high stability as in the case of AC surfacings. This can be obtained by producing bitumen macadam or rolled asphalt surfacings, with the sand and bitumen contents at the higher end of the specified ranges.

In localities where it is difficult to obtain river sand and the only alternative is to use AC surfacings, additional stiffening of the bitumen through ageing and embrittlements must be prevented by applying a surface dressing.

At least 40% by weight of the total aggregate mix should consist of rounded sand, whereas the remaining fraction should consist of crushed stone.

The binder for this particular bituminous mix should be 80-100 penetration grade bitumen, at the minimum rate of 4%.

The bituminous mix should meet the following Marshall requirements.

Marshall stability (kN)	4.0 - 7.0
Flow value (mm)	2 - 5
Voids in total mix (%)	3 - 8

The required field density of compaction should be at least 96% of the Laboratory design Marshall density.

This construction technique has been recommended for traffic loadings less than 10 million ESA.

5.3.5 Particular construction techniques

A. Anti reflective cracking measures

The main problem of the construction of an overlay is to prevent or to delay as much as possible the propagation of cracks from the existing surface to the bituminous overlay. This process is called anti-reflective cracking measures. The results of the latest research work in Europe and those of AASHTO carried out in the USA in 1991 were discussed in a Conference held in Belgium in 1993. The conclusion of the different authors were found to be contradictory. However with the latest research work, the most promising solutions to control the reflective cracking in the rehabilitation of cracked pavements were found to be:-

1. Conventional surface dressing with or without geotextile.
2. Increase of overlay thickness
3. Modified bitumen in overlay
4. Stress absorbing membrane interlayer (Sami) or geotextile or granular overlay with minimum thickness of 150mm with bituminous surfacing

B. Anti rutting measures

The problem of rutting due to secondary compaction under severe conditions with high tropical temperatures, very heavy axle loads, channelized traffic, stopping or slow moving heavy traffic has been discussed in detail in Appendix D of the RN 31. The anti rutting measures described in RN 31 gives the technique of compaction at refusal density by using a more permeable Asphaltic Concrete (AC) binder course covered by a seal of a surface dressing, in place of an AC wearing course.

However the above method of compacting to refusal has been found to be practically difficult, and an alternative method of using bituminous mixes with modified bitumen has been found to be satisfactory in Malaysia and at present is being tried out in Tanzania.

In the future the following methods will be used in the anti rutting measures as given below.

1. Marshall refusal density as per RN 31
2. Modified bitumen as per Public Works Institute, Malaysia.

6.0 Rigid and Other Pavements

6.1 Pavement Quality Concrete

Pavement quality concrete can be laid by one of two methods.The two methods are namely vibrated and roller compacted. The conventional methods that is vibrated method have been used in Sri Lanka for bus bays etc. With the construction of several field trials, a method has been developed to construct roller compacted concrete pavings. A section of two kilometers has been constructed successfully at Manampitiya Causeway in Polonnaruwa District. In the future it is intended to construct several sections of roller compacted concrete for causeways and low lying areas which are regularly inundated by floods.

6.2 Concrete block paving

A section of length 150m on Borupana Road, Ratmalana has been constructed by using concrete blocks, having a compressible strength of over 49MN/m2, cast at the Ports Authority factory, with the quality control work being carried out by the staff of the R&D division, RDA. The thickness of the sand layer above the prepared existing surface was kept at 50 to 75mm whilst the edge restraints were constructed by the use of kerb stones as shown in figure 6.1.

In the future it is intended to construct many pedestrian crossings of Colombo-Galle Road from Galle Face to Cross junction, Moratuwa by using concrete block paving.

6.3 Cement Incorporated Cold Mix

6.3.1 Cement incorporated cold mixes have been tried out successfully at few sections of several roads.

In Japan this material has been developed to a great extent through a subcommittee that has been estab-

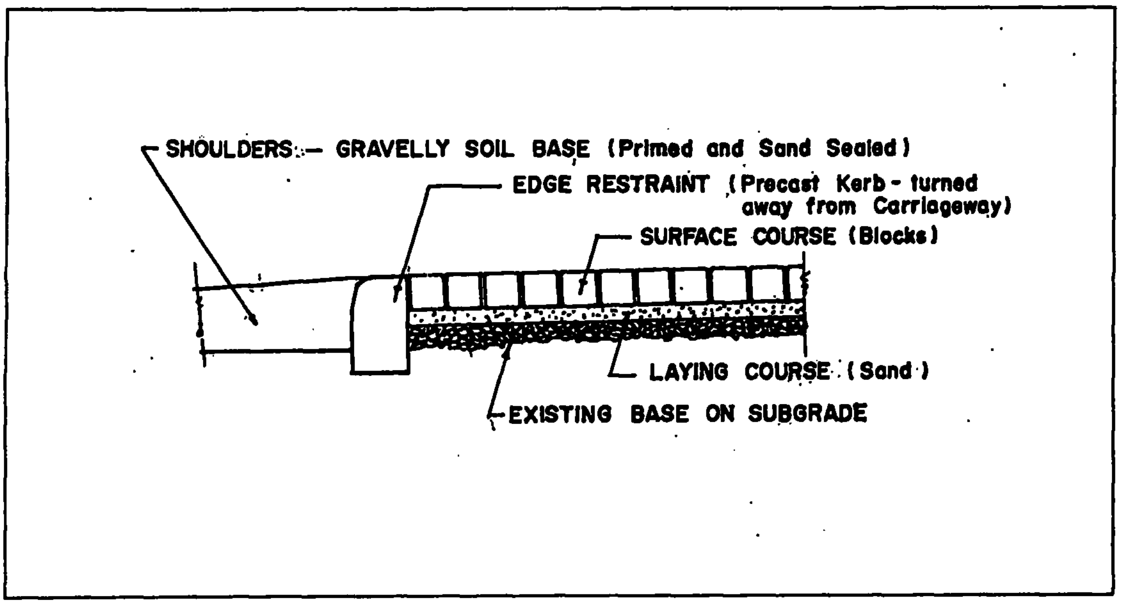

Figure 6.1 Concrete Block Paving

lished since 1982 in the Japan Asphalt Emulsion Association. As authors of paper including Professor S.F. Brown of Nottingham University, UK state that the cementing effect of cement makes this material stronger than hot mixed hot laid asphaltic concrete, even with the addition of a low quantity of Ordinary Portland Cement(OPC) as 2 percent by weight of aggregate (See figure 6.2).

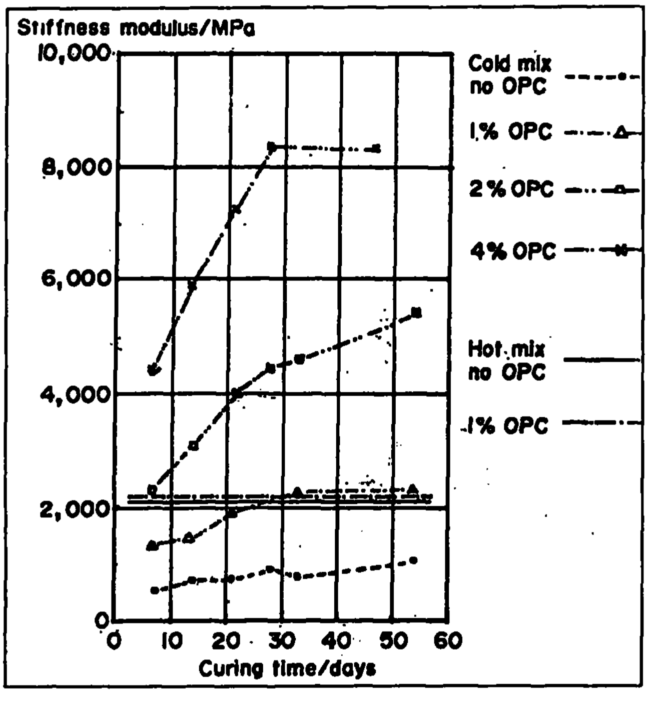

Figure 6.2 Stifness Modulus Vs Time for mixes with different Cement Contents

6.3.2 Preparation of cement incorporated cold mixes

The following trials were carried out successfully at a few sites. A few more trials with more variations of mixes were to be carried out before these mixes can be used for routine work.

6.3.2.1 Using single sized aggregate(1:1:2:4)

The materials by volume to be used for this mix are:

(a) One part of Bituminous Emulsion CSS-1
(b) One part of Portland Cement
(c) Two parts of river sand
(d) Four parts of 19mm single sized aggregate
(e) Water

Mixing Procedure

(a) The single sized aggregate was coated with sufficient amount of emulsion. In case where the aggregate is too dry, moistening of aggregate with water prior to coating with emulsion could be required.

(b) The cement together with sand was mixed and then mixed with the coated coarse aggregates together. In order to avoid the segregation of sand from cement, a small quantity of water could be added to cement sand mix. The balance emulsion could be added to the cement sand and coated coarse aggregate mix, while mixing. Also sufficient water could be added in order to improve the workability.

The time of mixing for above materials to produce a cold mix should not exceed 4 minutes.

6.3.2.2 Using Graded Aggregate (1:1:6)

The materials by volume to be used for the mix are:

(a) One part of Bituminous Emulsion CSS-1

(b) One part of Portland Cement

(c) Six parts of graded aggregate conforming to bands given in Table 6.1 (with and without cement for 19mm nominal maximum size for the preparation of cold mix surfacing). The aggregate should be obtained as a blend of coarse and fine aggregate.

(d) Water

Mixing Procedure

A similar procedure to that given under 6.3.2.1 could be adopted.

6.3.2.3 Construction procedures

(a) The pot holes were patched.

(b) The existing surface was cleaned.

(c) A tack coat was applied on the existing surface using bituminous emulsion at a rate of 0.3 l/m2.

(d) The mixed material was laid to the required thickness and compacted using plate vibrators and small double drum vibrating rollers of weight 650kg, initially without vibration and then with vibration.

It should be noted that the mixing, laying and compacting the above cement incorporated cold mix should be accomplished within a time period of 1 hour.

6.4 Preparation of lab samples for various types of emulsions using a laboratory colloidal mill and their field.

If lab trials using emulsions with different recipes are successful, field trials will be carried out and then these techniques/materials will be introduced to the field. For instance the emulsion used in the manufacture of cold mix in mid 1994 was found to be not coating coarse aggregate of the dense graded aggregate. It was solved successfully by changing the recipe of the emulsion by using a small percentage of an organic oil. Further work that is being carried out are the manufacture of:-

4.1 Sulphuric acid based Cationic Rapid Setting Emulsions

4.2 Rubberized Anionic emulsions

4.3 Rubberized Cationic emulsions

6.5 Geosynthetics

In road work, geosynthetics can be used in the following ways in the future:

1. To provide effective soil improvement for earthworks over water sensitive soils, such as peat, organic clay, soft silty clay, mud and marine sediments
2. To improve the subgrade strength on highways,where the roads are constructed over insitu soils of low bearing capacity
3. To provide separation to pavement layers
4. To assist dispersion of pore water pressures and enhances drainage beneath the road formation

Table 6.1

Aggregate Grading bands for 19mm cold mix prior to adding cement and with cement

Sieve Size(mm)	Percentage by weight of total aggregate passing test sieve	
	Without cement	With cement
25	100	100
19	85 - 100	85 - 100
9.5	55 - 90	55 - 90
4.75	35 - 70	35 - 70
2.36	26 - 55	26 - 55
0.6	8 - 25	8 - 25
0.3	6 - 24	6 - 24
0.075	0 - 02	0 - 15

5. To retard the transmission of reflective cracking and prevent ingress of water
6. To control surface erosion

Presently, Geosynthetics are being used in methods as given in 6.5.1, 6.5.4 and 6.5.5.

6.6 Modified Bitumen

Properties of modifiers for bituminous binders have been reviewed, and extensive laboratory and field experiments have shown that natural rubber in the form of centrifuged latex is an excellent Elastomer to modify bitumen for road making under severe conditions of climate and traffic. Laboratory and model trials to incorporate latex to bitumen have been carried out successfully without foaming. At present trials, using prototype scale cylindrical tank to prepare 7000 l of rubberized bitumen at a time, are being carried out. As centrifuged rubber can be obtained even during wet weather which was one of the disadvantages of using field latex, it is expected that this project will come through in about a years time.

6.7 Cold Recycling of bituminous Pavements in Colombo area

There are a few roads in Colombo area where cold recycling of pavements could be carried out. This is a method where materials in existing road pavements could be recycled. However amount of available work does not warrant the purchase of cold recycling machines. Hiring of a closest machine from India may make this project get off the ground.

6.8 Waste Products of coal ash used for thermal power project

These waste products such as fly ash and bottom ash have been successfully used for fills, subbases and lime fly ash stabilization in many countries having thermal power plants. India our closest neighbouring country has had many decades of experience in the use of these waste products and Sri Lanka would benefit greatly in collaborating with India in the use of such materials.

7.0 Compaction Requirements for Embankments, subbases and other components of road pavements

Table 7.1 gives the requirements for embankments, subgrades, subbases and other components of road pavements from 1977 to date.

From this table it could be seen that the first organization to use the bases of modified densities for compaction in tropical countries was CEBTP in 1984. When scrutinizing Indian Road Congress Specifications (IRC) - 1988 and SSCM -1989, it can be seen that SSCM in 1989 has directly followed IRC - 1988. As RN31 - 1993 has followed Modified compaction, IRC - 1995 appears to have followed similar degrees of compaction. From this table it could be seen that Sri Lanka also will have to follow the trends in tropical countries as those taken by Indian Road Congress in 1995. That is to use modified compaction as the reference and to utilize the degrees of compaction specified by IRC in 1995.

8.0 Other Techniques/Materials to be used in Sri Lanka in the future

8.1 Devising New Specifications due to Environment Restrictions

1. Reuse of materials in existing road pavements.
2. Use of presently discarded substandard materials
3. Use of non traditional or non organic waste materials

8.2 Bitumen Emulsions

1. Current methods as given in paper "Use of bitumen emulsions in road works in Sri Lanka". Indian Highways - April 1997 - Indian Road Congress.
2. Blended aggregate bases cum surfacing as per section 4.3.1

8.3 Sri Lankan method of priming and surface dressing on gravelly soil bases or gravel roads

During the past decade many research projects of priming and surface dressing on gravelly soil bases or gravel roads have been carried out by the RDA. The R&D division has promoted the following low cost types of roads based on different types of average daily traffic.

Types of Roads	Average daily traffic not more than
(a) Gravelly soil bases or gravel roads that are primed and sand sealed	500
(b) Gravelly soil bases that are primed and single surface dressed and sand sealed	750
(c) Gravelly soil bases that are primed and double surface dressed and sand sealed	1000

Table 7.1 - Compaction requirements given in various documents

Document	Embankment Construction		Subgrade	Subbase		Base-Dense Graded aggregate/ wet mix macadam	Shoul- ders soil
	Top	Bottom		Soil or granular	Stabilized soil		
1. RN 31-1977	95%L*	95% L	95% L	100% L	100% L	-	-
2. IRC - 1981	100%L	95% L	100% L	100% L	100% L	-	-
3. CEBTP-1984	-	-	95% H **	95% H	95% H	98% H	-
4. IRC - 1988	100%L	95% L	100% L	100% L	100% L	100% L	100% L
5 SSCM - 1989	100%L	95% L	100% L	100% L	100% L	100% L	100% L
6. RN 31-1993	95% H	90-93%H	95% H	95% H	97% H	98% H	-
7. IRC - 1995	95% H	95% H	97% H	98% H	98% H	98% H	97% H

* L = ASTM Standard or BS light (2.5 kg Rammer) Compaction
** H = ASTM Modified or BS Heavy (4.5 kg Rammer) Compaction

In this type of construction, no expensive aggregate bases have been constructed and in their places gravelly soil bases having four day soaked CBR of not less than 20 liquid limit not more than 50 and Plasticity Index not less 25 have been used. Examples of type (a) and type (b) are (a) 40km of Buttala-Sella-Kataragama and 80km of Bangadeniya-Anamaduwa-Uswewa-Galgamuwa roads; and (b) Approaches to Halwathura bridge across Kalu Ganga in the Kalutara District, respectively.

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