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IMPROVEMENTS IN DESIGN AND CONSTRUCTION STANDARDS OF SURFACE DRESSINGS FOR NATIONAL ROADS IN SRI LANKA

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THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN HIGHWAY AND TRAFFIC ENGINEERING

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August 2003

To
my husband, Nimal
and
daughter,Samali

ABSTRACT

Surface dressing is a well-established, economical and effective method for maintaining the surface of roads. The object of surface treatment is to seal the existing road surface and to arrest disintegration of the road as well as to provide a comfortable surface to its users. In Sri Lanka most of the periodic maintenance of roads is done by using one of the surface dressings; sand sealing, single bitumen surface treatment (SBST) or double bitumen surface treatment (DBST).

However, premature failures in the form of stripping of aggregate, flushing of the surface, peeling off, patches, cracks and streaking along the surface are some of the problems that predominate in most of the local roads that are surfaced using SBST and DBST. As a result of these failures road maintenance cost increases and also cause inconveniences to the road users. Some attempts have been made over many years to minimize the above-mentioned defects and increase the life of surface dressings. However, economical and significant improvements have not been established.

This research concentrates on developing improved standards for surface dressings that includes selection of material, application rates and necessary quality controlling which should be done in the laboratory and in the construction sites. This study focused on identifying the specific factors that will contribute to the failure of SBST and DBST from the design stage up to the construction stage.

The properties of emulsions used for surface dressings were analysed using samples collected at the manufacturing units and construction sites. It was found that viscosity, of emulsion need to be improved and mix proportions need careful adjustments to achieve better results.

A locally available, less expensive modifier and adhesive promoter were identified to improve the quality of the emulsion used for surface dressings. This modifier can incorporate to emulsion easily without any additional effort even at the construction sites.

A formula to determine the rate of binder that suit the condition of the road surface and to the expected traffic level was derived depending on the percentage of bitumen in emulsion and the size of the aggregates used for different layers are known.

Some new testing equipment that is economical and could be locally produced was devised to monitor the material properties and rate of applications at the construction sites. Field performance study using test sections was also done in order measure the effectiveness of the research findings. Finally an economic evaluation was also carried out to identify the benefits of the improvements proposed.

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CHAPTER 1

1. INTRODUCTION

1.1 Back Ground

In any country adequate transport infrastructure is a necessity for economic and social development. It is imperative that highway authorities to provide a road network to fulfill the demand of the country. Therefore it is the responsibility of any highway sector to provide road network which is more resistive to damage such as less susceptible to deformation for the pavements that will bear higher stress limits and increased tire pressure.

The function of a road is to provide a user-friendly structure, which is strong enough to provide vehicle mobile facility. However, the existing ground is not always strong enough to support the repeated application of loads due to wheel loads. Therefore it is necessary to provide a structure in between the wheels and the existing ground (sub grade). This structure is normally termed as the road pavement. Road pavement is a structure consisting of a series of layers of selected and processed materials whose primary function is to distribute the applied vehicle load to the sub grade. Two types of pavement are generally available; flexible pavements and rigid pavements. Almost all the road pavements in Sri Lanka road network belong to flexible type of road pavements.

Sri Lanka has a well-distributed network of roads nearly 100,000 km of total length, which are being maintained by Road Development Authority, Provincial Councils, Municipal councils, Urban councils, Pradeshiya Sabhas and few other organisations. Of these over 25,000km are classified roads which belong to classes A,B,C D and E. The roads of class A are the trunk roads joining the provincial and district centers. The B class roads are termed the main roads, joining other important towns with provincial and district centers and also between them. Class C roads constitute secondary links and D and E roads are considered as tertiary links. A and B roads which constitute the National highway network amounting to about 11,000km are presently managed by the Road Development Authority

(RDA). Nearly 10% of these are surfaced with Asphalt Concrete. About *50%* of these are surface dressed with Double bituminous surface treatment DBST.

The main structural features of flexible pavement are sub-base, base and surfacing, which are constructed on the sub grade. The thickness of each layer is decided by carrying out a detailed investigation and followed by road pavement design so that the transmitted stresses from the vehicle load are sufficiently reduced so that they will not exceed the supporting capacity of the sub grade.

Surface course or surfacing is the uppermost layer of a flexible pavement and is one of the most important layers since it provides a smooth riding surface for the motorists. Its main function is to provide a safe and comfortable riding surface to traffic. In addition it is expected to protect the layers beneath from the natural elements and if a surface course is used to give an additional strength to the pavement by using even stronger material than the base. The materials in a flexible road pavement can vary from loose mixtures of earth and gravel to thin surface dressing or thicker surface courses using bituminous mixtures, depending on the quality of service that is required of the roadway.

There are several types of surface treatments which are specified in Road industry to rectify the existing road surfacing. The fundamental types are as given below.

1. Sand sealing
2. Single Bituminous Surface treatment (SBST)
3. Double Bituminous Surface Treatment (DBST)

In sand sealing sand is used as the sealer. The SBST the fundamental type which is done by applying a single film of binder, cationic rapid setting 2 bitumen emulsion (CRS-2) at a particular rate and followed by a single layer of aggregate. DBST has two layers of aggregate and two applications of binder, CRS-2, where the second being applied between the layers of aggregate. There are instances where straight run bitumen is used instead of bitumen emulsions.

Surface dressing has a very important maintenance role that is to extend the life of an existing road pavement if the process is undertaken at the right time. Under certain instances surface dressing may retard significantly the structural failure of a structurally inadequate road pavement thus postponing the need for a structural overlay or pavement reconstruction. Therefore these techniques are highly useful especially in developing countries because of its economic feasibility.

1.2 Problem Statement

In most countries SBST and DBST are well-established techniques used as effective maintenance tools in road industry. There are also local roads have been rectified with DBST performing satisfactorily about 15 years. These local roads carry moderate traffic about 10,000vpd per lane.

However from the recent past premature failures could be observed on this type of road surfacing which may require frequent maintenance. The main failure types which could be observed on the local roads in case of DBST and SBST are whipping off aggregate, flushing of the surface, peeling off, cracks, stripping of aggregate and streaking along the road surface. Frequent maintenance of this type of road surfacing is required as a consequent of these failures. For example removing a stone from the road surface will remove another 5 or 6 stones around the 1st stone and hence will lead a pothole soon in future. Negligence will lead extensive patching resulting an additional unnecessary cost which may be economically viable for a developing country.

Steps have been taken by the highway authorities to seal the DBST and SBST surfaces just after the construction in order to avoid aggregate whipping off. This step is not an economically feasible solution being Sri Lanka is developing country.

1.3 Objectives

The objectives of this research program are to investigate the road surface dressings such as SBST & DBST with the following views.

1. Studying the factors which will effect the surface dressing from the design stage up to the construction stage.
2. Studying the quality of the materials, aggregate and the binder that are currently in use.
3. Study the local quality controlling techniques currently used at laboratory and construction sites and also study the design methods used.
4. Identifying the causes for premature failure which are not material related.
5. Suggest improvements required for the quality of the materials, binders and the aggregate used in construction of road treatments when necessary.
6. Studying the compatibility of local aggregate with binder and the precautions to be taken whenever there are problems.
7. Proposing improvements to the current design and construction standards related to surface dressings.

1.4 Out Line of Research

Surface dressing comprises of a thin film of binder sprayed on to the road surface and then covered with a layer of aggregate. This process is applied as single layer or multiple layers.

The thin film of binder acts as a water proofing seal and prevents the entry of water into the road structure. The aggregate protect the film of binder from damage by vehicle tires and oxidation and they form a durable skid resistant wearing surface. There are two types of binders used in construction of surface dressings: CRS-2 and penetration grade bitumen. CRS-2 emulsion is the main type of binder while penetration grade bitumen in hot condition is being rarely used in Sri Lanka.

The research looked into the reasons for premature failures by analyzing the material properties, construction techniques and quality controlling methods adopted from the selection of materials up to the construction stage. All defects in material, machinery, and labour together with the quality assurance were assessed. Consideration was also given to the determination of the quantity of aggregate and binder used.

Few literature was locally available regarding bitumen emulsions but not deeply explained. Research papers were available proposing solutions to the problems encountered with emulsions in certain countries.

The database for CRS-2 analysed in the research showed that CRS-2 emulsion had to be improved in some properties which was very important in surface dressing emulsions.

Therefore a few attempts have been made to improve CRS-2 emulsions. Two local modifiers: modifier-1 and modifier-2 were identified. Modifier-2 was better than modifier-1. And also the modifier-2 is cheap and available in plenty and can be incorporated without any additional effort even at the construction sites depending on the situation. Modifier-1 is also a solution to the problems of adhesion of CRS-2 to the aggregate.

A doping agent was also identified to be used when the emulsion is to be further improved.

In most of the cases there were complaints from the construction sites of the surface dressing for unexpected flow of CRS-2 even across the camber. As a solution an apparatus which can be used to find out the viscosity of CRS-2 at the construction sites were devised.

And also no testing facilities were available in the regional laboratories to check the binder content of the emulsion whenever necessary. It takes time to send the samples of emulsion to Central Laboratory and get tested. During this period the construction was over and there was problems in payment in case of failing emulsions.

Few other test methods such as to find out fuel susceptibility, rate of aggregate applied on to the road surface in case of surface dressing were also devised to be used whenever necessary.

Formula was derived to determine the quantity of bitumen to be used to suit the road section to be rectified. Material properties of aggregate such as loose bulk density, unit weight, least dimension and absorption properties of aggregate were considered in deriving the formula. The factors for traffic simulation, condition of the road surface, rate for embedment of aggregate into the road surface were also considered. Quantity of emulsion could be calculated knowing the percentage of bitumen in the recipe of CRS-2. Voids presents among the aggregate particles at different stages such as just after application, just after rolling and after considerable traffic are as per literature. (1)

Performance study was done to find out the effectiveness of the modifiers and the verification of the formula. In addition emulsion formulated using 60/70 bitumen also tried in the field. (Emulsion formulated using 80/100 bitumen is the current practice.)

Two internal roads in the university of Moratuwa (road to Textile building and road to Civil complex) were selected for the study. 16 nos. of subsections were selected to test at this stage based on the different options on particular sections. Studying the necessity of a steel vibration roller and sand sealing just after construction to cover DBST was also included in these trials.

This part of the research was done with collaboration of Road Construction and Company Ltd. (RC&DC). The cost for this study was around Rs. 400,000 and funded by RC&DC.

Second stage of the performance study was carried out in Uva province on Badulla-Mahiyangana road. Left hand side of 1.2KM road section starting from Badulla end (just passing the heavy slope ground) was selected for the study. This part of the research was funded by Provincial Director, Uva Province. The trial section consists of 12 sub sections and 6 sections were done with CRS-2 which was formulated using 60/70 bitumen. Photos of the sections were also studied for comparison of the sections.

Finally economic feasibility of the proposed improvement is to be analysed. According to the analysis, material and construction cost for the proposed improvement can be cut down more than 1/3 of the cost incurred for the current practice. Further inspection is proposed to be carried out to assess the durability of the sections. Predicting about the duration of the sections by studying only within 1or 2 years may not be reasonable.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to Surface Dressing

Surface dressing is a simple and inexpensive road surface treatment which is highly effective if adequate care is taken in the planning and execution of the work. The process is used throughout the world both for surfacing medium and low traffic roads as a maintenance operation for roads of all kinds. {TRRL road note 3, 1982}.

A surface dressing comprises a thin film of binder which is sprayed on to the road surface and then covered with a layer of stone chipping. The thin film of binder acts as a water proofing seal and prevents the entry of surface water into the road structure. The stone chipping protect the film of binder from damage by vehicle tires and they form a durable skid resistant and dust free wearing surface.

Surface dressing has a very important maintenance role that is to extend the life of an existing road pavement if the process is undertaken at the right time. Under certain instances surface dressing may retard significantly the structural failure of a structurally inadequate road pavement thus postponing the need for a structural overlay or pavement reconstruction.

Surface dressing can be used successfully on all types of roads from the country lane that carries only an occasional vehicle to trunk roads and motorways carrying thousands of vehicles per day. {TRRL road note 39, 1997}

Inappropriate specification of poor materials and inferior bad workmanship can drastically reduce the service life of a surface dressing.

2.2 Functions of a Surface Dressing

In road maintenance surface dressings are applied for three purposes; (TRRL, road note 39 4th edition, 1997)

1. to provide both texture and skid resistance to the surface
2. to seal the road surface against ingress of water
3. to arrest disintegration from impact load.

In addition, it is also used as a surface treatment for other two purposes: (TRRL, road note 39 4th edition, 1997)

1. To provide a more uniform appearance on a patched road
2. To provide distinctive colour to a certain road (if necessary)

2.2.1 Road surface texture and skid resistance

Provision of adequate skid resistance is very important on all roads. However this parameter depends on the surface texture. There are two main types of texture, micro- texture and macro- texture. Micro-texture is the texture of the aggregate particles with amplitude of 0 to 0.2mm. (TRRL road note 39 4th edition, 1997) Hence micro-texture cannot be measured directly. However, this is required for skid resistance at all speeds to provide the grip.

Macro texture is the overall texture of the road with amplitude larger than 0.2mm. (TRRL road note 39 4th edition, 1997)

This can be measured by using

1. The sand patch method (which gives the mean texture depth, BS 598: Part 105)
2. The laser texture meter (Which gives the root mean square)

Macro- texture is very essential at higher speeds in wet weather because it helps to remove water from the tire/road interface. Surface dressing with an aggregate appropriate resistance to polishing under traffic action will provide both micro and macro- texture. It is also possible to re-texture the concrete surfaces by applying a surface dressing. The design of a surface dressing depends on the traffic intensity and the level of skid resistance required at a given site.

2.2.2 Sealing

Surface dressing with appropriate binder contents, can be effectively used to seal hairline cracks and binder-lean surfaces. However, repairs to existing road surfaces such as crack sealing and pothole patching should be done before surface dressing.

Surface dressing neither restore the riding quality of a deformed road nor it directly strengthen the road structure. However, sealing the surface and thereby reduction of the ingress of water will protect the structure from deterioration and hence increasing the lifetime of the road pavement.

2.2.3 Arresting disintegration

If a surface dressing is done at the appropriate time, it will reduce the need for major repairs which are costly. It will improve the durability of the road pavement by protecting it from water penetration and perhaps oxidation as well.

2.3 Types of Surface Dressing

There are several types of surface dressings varying in the number of layers and the binder type. The common types which are recommended by local standards are as given below.

1. Single surface dressing (Single Bituminous Surface Treatment, SBST)
2. Double surface dressing (Double Bituminous Surface Treatment, DBST)

In addition there are a few other types available, which are specified in (TRRL road note-39 4th edition, 1997). They are

1. Inverted double surface dressing
2. Sandwich surface dressing
3. High friction systems
4. Racked in surface dressing

2.3.1 Single surface dressing

This method of sealing is normally adequate to fulfill the functions required of maintenance reseal which aims at water proofing the road surface arresting deterioration and restoring skid resistance. The single surface dressing is sufficient to seal less traffic new road pavements and is done by applying a single film of binder, cationic rapid setting bitumen emulsion-2, CRS-2 applied at a particular rate followed by a single layer of aggregate.

2.3.2 Double surface dressing (DBST)

This type of treatment is particularly suitable for a road surface which is binder-lean. Generally double surface dressing produces a smaller texture depth compared to SBST. In double bituminous surfacing two layers of aggregate and binder are applied with the second emulsion (CRS-2) layer being applied between the two layers of aggregate.

2.3.3 Racked in surface dressing (TRRL road note 39 4th edition)

In this method about ninety (90) percent of the aggregate that would be used in the case of surface dressing is used with a thicker layer of binder followed by a layer of aggregate of smaller size applied to fill the gaps in the matrix. It is the normal practice that a slight excess of the smaller aggregate is used to ensure that each larger size aggregate is locked by the smaller size aggregate.

2.3.4 Inverted double surface dressing (TRRL road note 39 4th edition)

An inverted double surface dressing is a surface dressing with small size aggregate, which is applied to a road which has an uneven surface hardness, possibly due to extensive patching followed later by a second single dressing with larger size aggregate.

The first single dressing is done to produce a more uniform surfacing which can be subsequently surface dressed. This method of dressing is also used on concrete road surfaces, in order to reduce the hardness of the existing surface.

2.3.5 Sandwich surface dressing

In this method a layer of aggregate is used prior to apply a single surface dressing. Sandwich dressing is used in situations where the existing surface is binder rich. And also this method is preferred in hot weather condition on heavily trafficked roads.

2.3.6 High friction systems

This system is preferred at sites where the skid resistance is required to be upgraded, such at junctions at pedestrian crossings, level crossings,- etc. High friction systems are normally used with modified binders as such are expensive compared to other surface dressings.

2.4 Surface Dressing Operations

The main steps of a surface dressing operation are as follows.

1. Identify roads to be dressed
2. Repair damages on the existing road surface
3. Evaluate the road by assessing the traffic, roundabouts, sharp bends, traffic lights, steep hills-etc
4. Design the dressing

5. Decide the materials to be used
6. Contract administration
7. Plan method of implementation
8. Site preparation
9. Traffic control and execution
10. Aftercare
    I. Recording
    II. Inspection of work
    III. Investigation

2.5 Basic Parameters to be Considered in Design of Surface Dressings

Design of a surface dressing is the very important part of the surface dressing in order to determine the quantity of binder, bitumen emulsion and the quantity of the aggregate.

Different parameters must be determined for different aspects of the design.

These aspects are

1. Selection of type of surface dressing
2. Selection of type of component materials
3. Calculation of the rate of spread of binder, which is further subdivided into
    I. Basic design based on information about the site
    Ii. Adjustment when properties of the component materials known and
    III. Local adjustments along the site with changes in conditions

Some parameters are needed for more than one aspect of the design. When considering type of the binder, its rate of spread has to be considered. Therefore the parameters can be grouped into the following classes.

1. Parameters for selecting the type of dressing together with the stage 1 binder, based on information about the site

I. road hardness
II. total traffic and traffic speed
III. road layout
IV. radius of curvature
V. junction or crossing
VI. Parameters for selecting the general surface condition
VII. component materials

2. Parameters for selecting the component materials, basically aggregate and binder listed as:

I. skid resistance requirements
II. seasons and weather conditions
   a) High humidity conditions where bituminous emulsions are to be used
   b) Long term weather forecasts
III. The consequences that would result from a failure usually determined by the class of road to be dressed;
IV. Other local situations

3. Parameters for determining the stage 2 binder spread rate when the properties of component materials known are as follows:

a. Shape of aggregate

The shape of the aggregate important in terms of the amount of binder needed to fill the interstices between the aggregate. For aggregates of nominal size 10mm and above, the flakiness index is used as an indication of shape while for aggregate of 6mm, the proportion passing the 5mm sieve used.

b. Type of aggregate

The majority of the aggregates are of crushed rock type and the rate of the binder spread is based on their use. However, according to TRRL Road Note 39 4th

edition, 1997 gravel also can be used on roads where the traffic and speed are very low.

4. Parameters for determining the rate of spread of binder when local adjustments along the road is to be done

Surface condition, shade, gradient and local traffic are the important factors to be considered.

Local variations in the condition of the existing road is important in determining the rate of binder spread, as such there should be sufficient binder for the initial retention of the aggregate prior to the long-term embedment. Care should be taken not to provide excess of binder so that the road may bleed in the future. Therefore the existing road surface can be categorized visually as very binder rich, binder rich, normal, binder lean and very binder lean. Measurement of the texture depth of the existing surface is a useful tool in order to determine to what extent the surface is open textured, and hence the percentage of binder. Visual assessment is completely subjective and therefore an experienced person must carry it out. (TRRL road note 39 4th edition)

The gradient of the road is also important to determine the strength of the binder adherence to the surface. The binder should be viscous enough so that not to flow downwards on steep grades. Areas of the road which is covered by trees, shadows of buildings and bridges tend to be cooler than the areas which are open to the sun. Therefore, higher rates of binder application must be used where the surface is covered by trees provided that the surface may not bleed in long term.

Further, slightly higher percentage of binder must be provided in areas where traffic is very low and hence the embedment of aggregate is less.

2.6 Voids Consideration in Design of Surface Treatment

When a single sized aggregate is dropped by the spreader on to the road surface the aggregate particles are in an unarranged position. The particles will be oriented to its densest position after it is compacted by the roller and followed by the subsequent traffic leaving about 20 percent voids between the particles. A typical design is to fill 70 percent of the voids to be filled with binder According to TRRL road note39 4^{th} edition, 1997 the residual binder can be reduced to 55 to 60 percent of the voids between the aggregate under average conditions in the case of bitumen emulsion.

There are several theoretical procedures for determining the quantity of cover aggregate. However a simple way of determining the quantity of aggregate is to spread the aggregate to be used in a pan of known area. Placing aggregate in the pan carefully by hand and arranging the aggregate so that it fills the pan in its densest condition anticipated the field after the surface treatment has been subjected to traffic. The volume of aggregate per unit area of the pan will be the rate of aggregate to be used. Then the pan is filled with water just to top of the aggregate. Approximately the two thirds of this volume is taken as the volume of the binder. The rate of application of the binder can be determined from the volume per unit area.

2.7 Selection of Type of Dressing

2.7.1 Sections within a site

The type of dressing can be varied even within a site depending on traffic condition and also on the condition of the road. For instance it is preferred to provide less binder content for a section of high traffic. And also when the road section is highly deteriorated generally more binder is required. In this regard the site can be divided longitudinally or transversely. However the sections shall not be too short for the adjustments of the construction equipment.

2.7.2 Type of dressing for a section

The types of surface dressing available were discussed in a preceding section. The choice of an appropriate surface dressing is dependent upon several factors.

However the use of a modified binder depends on the severity of the traffic stresses at the site which warrants a modified binder.

2.7.3 Rationalization of dressing types for a site

A detailed surface dressing design should be carried out for each identified section. However it is impractical to change the design within a site very often. Therefore, it is required to identify the most suitable dressing type for the entire site by considering the following constraints:

The constraints are

1. The changes should be more towards the robust type.
2. No change should be too extreme
3. The changes may be allowed in the detailed design that section

2.8 Selection of Aggregate

Normally aggregate used for surface dressing should be single sized, cubical in shape, clean and free from dust, strong, durable, and susceptible to polishing under the action of traffic. Samples of the aggregate should be tested for grading, flakiness index, and aggregate crushing value and, when appropriate, the polished stone value and aggregate abrasion value should be checked before commencing the work. The results of these tests should comply with the specifications of the project.

The nominal sizes of the aggregate used for surface dressing are 6,10,14,and 19mm. Flaky aggregates are those with a thickness (smallest dimension) which is less than 0.6 of their nominal size. Therefore, the portion of the flaky particles clearly affects the average thickness of a single layer of the aggregate, and also there is also a tendency to break the aggregate under the traffic as they results planner surfaces, orienting the least dimension vertical.

The aggregate should be laid on the binder immediately after spreading the binder as at this time, the aggregate has yet to become an interlocking mosaic and is held in place solely by the adhesion of the binder film. Adhesion is retarded if the aggregate is dusty or if they remain wet for sometime. However, in tropical countries it gives advantageous to suppress the dustiness of the aggregate by slightly dampening it prior to spreading. (TRRL road note 39 4th edition, 1997)

It dries out quickly in contact with the binder, and good adhesion develops more rapidly than when a coating of dry dust is present to interfere with the development of adhesion between the aggregate and the binder. Affinity of aggregate to water is higher than that to binder. Hence it is possible to loss of aggregate under traffic if heavy rain occurs within a few hours before the completion of the adhesive bonding action. Adhesion develops more rapidly when a coating of dry dust will not interfere with its development between the aggregate and the binder.

2.9 Types of Aggregate

Generally there are a few types of aggregates identified as suitable for surface dressings as explained below.

2.9.1 Uncoated aggregate

The cleanliness of the uncoated aggregate is important in achieving good adhesion to the binder film. Adhesion may develop more slowly in damp conditions because the aggregate needs to dry out before adhesion can occur. Uncoated aggregate usually works well with emulsion binders as well.

2.9.2 Lightly coated aggregate

Lightly coated aggregate has a very thin film of binder, applied at a coating plant. The binder film eliminates surface dust and helps to ensure rapid adhesion to the surface dressing binder. Lightly coated aggregate is used with cutback bitumen and also it improves adhesion with bitumen in cooler condition. However they are of little advantage with bitumen emulsions because the shielding effect of the coating will delay the breaking of the emulsions. However, if an extensive layer of dust is present on the aggregate beneath the binder coating, adhesion of the aggregate could be affected a condition that must be avoided. Care should be taken to avoid contamination of coated aggregate after production especially from wind blown dust.

2.9.3 Heated aggregate

The use of hot aggregate is recommended under certain circumstances. Uncoated or lightly coated should be applied at a temperature within the range 60^0C to 120^0C. Particular care should be taken to ensure that additional dust is not generated during the heating process. Heated aggregate may create problems with bitumen emulsion producing localized breaking of part of the emulsion around the aggregate and delaying the breaking of the remainder.

2.9.4 Size of aggregate

Increased traffic volumes and softer substrates increase aggregate embedment. Therefore selection of size should be done accordingly. Normally bigger size of aggregate is selected for the sites where the traffic density is high and the substrate is soft. Smaller size of aggregate is selected to the sites where the traffic density is low and on hard substrates.

2.9.5 Rate of spread of aggregate

The aggregate quantity depends upon the size, shape and relative density of the selected aggregate. Further the quantity of aggregate applied must be sufficient to cover the film of the binder. However the rate of spread depends upon the type of dressing as well. The required rate of spread can be checked using the tray test or spread box method. (TRRL Road Note -39)

2.10 Binders Used in Surface Dressing

2.10.1 Binder types

The commonly used binder types are as follows:

1 Bitumen emulsion

2 Cutback bitumen

3 Penetration grade bitumen

Of these, bitumen emulsion and cutback bitumen are the preferred binder types. Surface dressing binder types are also classified in terms of their viscosity. According to TRRL road note 39 4th edition, 1997 higher viscosity binders are preferred for roads having high traffic flow. In Sri Lanka about some years back bitumen was used for surface dressings. However with the increase in production of bitumen emulsion hot bitumen as partially replaced and at present almost all the surface dressings are done with CRS-2 and hot bitumen is rarely used.

The rate of spread of binder should not vary more than 10% both longitudinally or transversely (TRRL road note 39 4th edition, 1997). Localized factors which were discussed earlier in this report are also to be considered in determining the rate of flow.

Adhesion promoters can improve the wetting properties and promote the development of adhesion between the aggregate and the binder. Adhesion is particularly important in the case of heavy traffic. However excessive additions of the adhesion promoter can change the viscosity of the binder.

2.10.2 Selection of binder

The correct choice of the binder for surface dressing is critical. The binder must

1. be capable of being sprayed,
2. wet the surface of the road in a continuous film,
3. not run off a cambered road or form pools of the binder local depressions

4. wet and adhere to the aggregate at road temperature
5. be strong enough to resist traffic forces and hold the aggregate
6. sufficiently flexible at he working temperature
7. resist premature weathering and hardening

2.11 Construction Equipment Used in Surface Treatment

2.11.1 Asphalt distributor

This is the most important equipment in surface treatment and it is mainly used to spray the binder uniformly on the surface at a specified rate regardless of changes in grade or direction of movement. The distributor consists of a truck mounted insulated tank with appropriate controls for setting the rate at which asphalt is applied. The tank normally contains some type of oil burning system to maintain asphalt temperature to assure the required application rate. There is a system of spray bars at the back of the tank through which the binder is sprayed onto the surface. Normally the width of the spray bar is between 2m to 8m. The spraying is done under a designated pressure.

A hand spray gun is also attached to most of the distributors in order to provide a manual spraying facility where the machine is inaccessible and position of the spray bar can be changed accordingly and the tanks of capacity varies from 800 to 5500 gallons are available each equipped with full circulation system including the spray bars in order to prevent solidification.

The most common failure associated with this machine is streaking. Alternated, narrow, longitudinal areas of excessive and then insufficient amounts of asphalt characterize streaking. Streaking is caused by one or more of the following conditions: clogged distributor nozzles, improper pump pressure, interference of sprayed asphalt from adjacent nozzles, or improper spray bar height. It is important to check that the nozzles are not damaged. Improper openings may result in distortion of the spray fan. The manufacture's recommendations should be followed when the nozzle size is selected. It is also essential to set the height of the spray bar. If it is too high, wind distortion may be the result and if it is too low, an incorrect overlap may result cause a non-uniform spray on the road.

Best result is achieved with an exact coverage, but triple coverage can sometimes be used with 4-inch nozzle spacing.

2.11.2 Aggregate spreaders

The function of the aggregate spread is to apply a uniform aggregate cover at a specified rate over the freshly sprayed binder film. There are three types of machines available.

1 tailgate spreader
2 mechanical spreader
3 mechanical self-propelled spreader

The spread may vary in width from 3 to 4.5 m, and the flow of aggregate is controlled individually by means of gates that can be opened and closed by the operator. The calibration and adjustment of all types of aggregate spreaders should be made according to manufacture's instructions and operating manuals.

Following additional steps can be used to ensure good result:

1. A tachometer used as an aid in maintaining uniform spreader- speed has proved to be highly successful.

2. Marking off the length that each truckload of aggregate should cover can closely control distribution rates. A quick check can also be done using a spreader box.

2.11.3 Rollers

It is essential that the aggregate be embedded in the binder film to prevent loss through traffic abrasion. Although a slight embedment takes place due to gravity as the aggregate drops from the spreader onto the binder film, the major portion of the embedment takes place due to the rolling process.

Normally pneumatic tired rollers are used on surface treatments. The resilient tires on this type of roller force the aggregate firmly into the binder without crushing the particles. It has been found that steel wheeled roller has a tendency to bridge slight depressions in the pavement, as such causing some of the aggregate to be improperly embedded (TRRL road note 39 4th edition, 1997). Degradation of aggregate can take place on the road surface due to crushing of aggregate under the steel roller.

2.11.4 Auxiliary equipment

2.11.4.1 Power broom

It is essential to apply the surface treatment on a cleaned surface. Therefore, a power broom is used to remove dust and debris from the existing road pavement. Cleaning equipment must be in top operating condition before the job starts.

2.11.4.2 Blowers

It is possible to use blowers for the purpose of cleaning whenever a power broom is not available at the site. Further there should be enough of equipment and material available at the site to ensure the continuous work at the site. Frequent stop and start work will lead variations of the rates of aggregate and binder spreading and hence create variations in riding quality along the road surface.

2.11.4.3 Water bouser

A water bouser is also required to wash the road pavement if clay has been adhered on to the road surface.

2.12 Bitumen Surface Dressing Application Techniques

Successful surface dressing application begins with a thorough inspection of the pavement over which the surface treatment is to be placed.

The normal types of failures, which have been identified, are as follows.

1. potholes
2. raveling
3. badly cracked areas
4. corrugations
5. depressions
6. absorbent areas
7. bleeding asphalt

It is also necessary that good drainage be provided prior to carrying out surface dressings. All the ditches and other drainage facilities should be cleaned so that no water is collected on the road surface.

2.12.1 Sequence of the application procedure

The sequence of operations is almost the same as for all types of surface treatments. The usual procedure is as given below.

1 Improve drainage if necessary.
2 Patch potholes and repair damaged areas in the existing road pavement
3 Clean surface to be treated with an approved method
4 Spray binder at specified rate.
5 Spread aggregate at specified rate immediately behind the binder application.
6 Roll aggregate to seat in the binder film.

If a double or triple surface treatment is required steps 4, 5, 6 should be repeated.

According to TRRL road note 39 4th edition, 1997, care should be taken to permit the previous layer of binder and aggregate to cure prior to application of the next immediate layer.

2.13 Quality Control

Even when the good quality materials are used inferior surface dressings can result. Attempts at shortcuts or construction at bad weather probably would result in poor performance and increased maintenance. For instance, if bitumen emulsion is used in bad weather it may not break properly and the binder will not satisfactorily retain the aggregate.

When rapid setting emulsions are used for surface treatments a simple thumb rule is that the emulsion should break just after the roller pass has been made. This assumes that the roller is applied as quickly as possible behind to the aggregate spreader.

Several precautions must be taken to avoid the segregation of the aggregate into large and small particles. In this regard spray bars should be checked for clogged nozzles.

Further the proper rate of application of aggregate and binder should be checked frequently. Spray bar height should be adjusted properly. It is also very important to clean the spray bars just after using. Visual inspection of all delivered materials for apparent changes in uniformity or quality should be carried out.

2.14 Evaluation of Pavement Surface properties

One of the methods of evaluation of surface properties is the surface texture, macro texture. (Explained in 2.2.1, under the heading road surface texture and skid resistance)

The common surface types are

1 Smooth
2 Fine textured and rounded
3 Fine textured and gritty
4 Coarse textured and rounded
5 Coarse textured and gritty

Parameters associated with macro- texture are height, width, angularity and the bulk density, where as the parameters relevant for micro-texture is harshness and rugosity. On the other hand skid resistance is a function of hysterisis which is a combination of friction produced by damping losses in the tire rubber and adhesion which the shear force developed at the interface between the tire and road surface (TRRL road note 39 4th edition, 1997).

Harsh or gritty pavement surfaces yield larger skid numbers than round, polished or smooth surfaces. According to TRRL road note 39 4th edition, 1997 this is true for both locked-wheel and peak braking. The sharp asperities of the aggregate tend to penetrate the water film and grip the tires to provide better friction on wet pavement. The sharp coarse texture is even more effective for peak braking than it is for locked wheel braking.

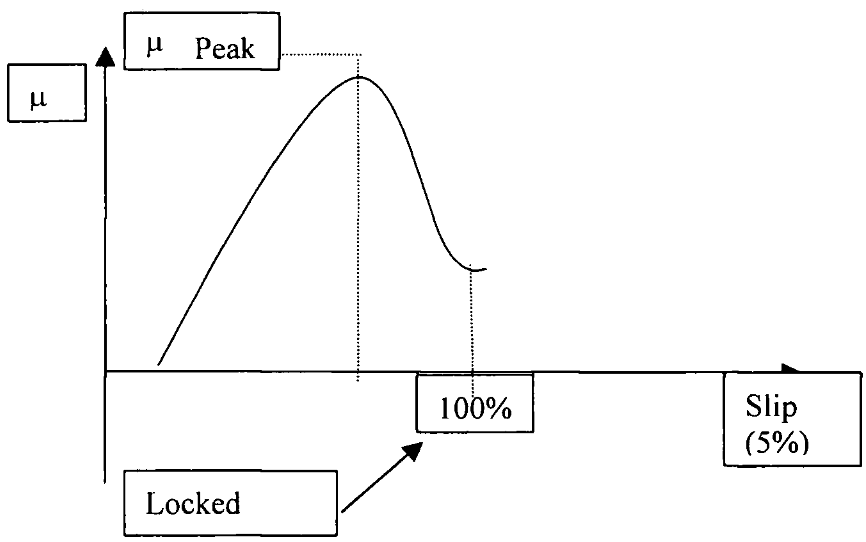


Figure 2; Graphical Representation friction of co efficient (ref: professor M.Gunerathne Personnel Guidance)

The skid resistance-speed gradient can be defined as

$G_{(A-B)} = (SN_A-SN_B)/(B-A)$ {TRRL road note 39 4th edition,1997}

Where A and B are the test speeds at which the skid numbers SN_A & SN_B are measured.

The speed gradient is not as steep for coarse surfaces as for fine textured roadways because the large voids in the coarse surfaces allow more rapid expulsion of water at the tire/road interface and because the coarse texture develops greater hysteretic effects in the tire thereby improving its friction characteristics. Skid resistance therefore decreases more slowly with increasing speed.

Open or coarse textured pavements are therefore excellent for safe, wet weather travel at high speeds. They also reduce objectionable splash and spray, reduce hydroplaning, and diminish headlight glare by dispersing light. Glare is intolerable when the road is smooth wet and reflective. Gritty and fine textured surface usually yield larger skid numbers at lower speeds than that of open graded road surfaces. Therefore this makes them suitable for low speed traffic. It has been found that the mean skid number increases with increasing texture depth irrespective of type of the vehicle. The plot of mean skid number against the mean texture depth lies at a higher elevation at higher speed than at lower speeds. The gradient is also higher when increasing the speed.

2.15 Noise and Wear

Noise increases with speed, depth of the pavement texture and moisture and it is the dominant traffic noise at higher speed. It also increases with load and wear for many tire tread patterns. Tread vibration is a major source of tire road noise. Irregularities of the road surface such as texture, aspirates, and roughness create an oscillation in the tread that emits sound waves.

Pavement surface wears by abrasion, degradation and decomposition as a result of vehicle traffic and environmental changes. The rubber tires interact with the detritus on the roadway to abrade homogeneous exposed rocks, degraded and laminated stones or those with zones of weakness and disintegrate the bonding medium, which in turn releases surface aggregates. The polishing or wear reduces the texture depth of the surface due to decrease in the void space of open graded seal coats. As this action continues on the road surface other foreign materials will clog the void spaces over a period of time and gradually decrease the texture and skid resistance.

Pavements are often resurfaced to improve roughness and skid resistance. Adequate texture should be provided during resurfacing to obtain the best drainage relief and friction characteristics.

Stereo photographic interpretation and the Sand Patch method can be used for measuring surface texture. Texture depth of 1.3mm or greater measured by the Sand Patch method is advocated for high-speed roads. However measurements of this nature do not fully evaluate the characteristics of the texture. Textural requirements should probably be varied with the geometric design of the highway and traffic demands. Deeper texture depth is required in geographic locations where rainfall intensities are greater and vehicle speeds are higher.

CHAPTER 3

BITUMEN EMULSION

3 .1 Back Ground of Bitumen Emulsion

The first road binders were tars which is obtained when natural organic materials such as wood and coal are carbonised or destructively distilled in the absence of air. Coal tar was used for road construction because it was superior. It is very often mentioned that 1854 as the date at which the first paving was laid at "Place Sallinis" in France using fluid tar from a gas plant. Road tarring really became widely as of March 1902. As the years went by, it was possible to more precisely define a true roadwork technique using a tar base. A new generation of a road binder was commenced with the invention of bitumen emulsion in mid of 1922, by the English chemist Hugh Alan Mackay. This could completely modify the surface coating techniques. As of 1923, around 100 tons of emulsions were spread in Metropolitan France and by 1925 the same was introduced and applied abroad. It was in 1951 that cationic emulsion was quickly replaced. 50% of the manufactured tonnage was cationic in 1962 and more than 92% in 1971.

3.2 Components

Bitumen emulsion is a thermodynamically unstable heterogeneous system of which finely ground bitumen particles are dispersed in an acquious medium {Fig3.1}. The base binders used for the manufacture of bitumen emulsions, used in construction and maintenance of roadways are pure or modified bitumens, possibly cutback or fluxed bitumen. There are three basic criteria which the bitumen emulsion can be categorised; (1) the ionic nature (2) The stability when in contact with aggregate or any surface, (3) the percentage of base binder by the total weight.

3.3 Continuous Aqueous Phase.

There are wide varieties of surfactants used in the manufacture of emulsions. However knowing the expected properties of the bitumen emulsions and the inherent technical and economic constraints, it is the great responsibility of the authorised person to select the most appropriate surfactants, emulsifiers among them For instance as the aggregate in Sri Lanka is acidic except the aggregate available in Jaffna cationic type of emulsifiers should be selected.

Cationic soaps are made up of polar molecules whose general formulation may be $R'NH_3^+ Cl^-$ in which R' is the hydrocarbon chain characterising the emulsifiers. The chain is hydrophobic or lipophillic part. In the acquous phase the soap molecules are ionised and produce $R' NH_3^+$ cations and Cl^- anions.

When the emulsion is being manufactured the cations are adsorbed to the bitumen droplets such that the lipophillic part, R' turns inwards and the NH_3^+ group places itself at the bitumen/ water interface. The Cl^- remains in the water.

The bitumen particles are positively charged due to NH_3^+ group cover which is formed around the bitumen droplets. On the one hand, this provides bitumen emulsion stability because of electrostatic repulsion and on the other hand and strong attraction with the negatively charged aggregate surfaces.

Cationic emulsifiers have some advantages. Cationic emulsifiers are less sensitive to weather because they have a chemical break. Cationic emulsifiers can be stabilised without making longer break time controls. More suitable for aggregate and also even with silica aggregate. No precoat is required for a cationic emulsions if aggregate is clean and dust free.

However close attention should be given in storage procedures and it is more critical in handling.

3.4 Stabilisation of the Emulsion

The nature of the hydrophilic portion governs the mechanisms of stabilisation. Emulsifiers with large hydrophilic portions may prevent close approach of the bitumen droplets.

The size and sign of the charge on the droplets can be measured and is expressed as the zeta potential. The zeta potential depends on their concentration and the pH. The higher the zeta potential the faster the particles move and the higher the ionic characteristic the more the setting tendency is evident.

3.5 The Setting (Breaking) Process

Bitumen emulsion must revert to a continuous bitumen film in order to fulfil the performance as the binder in road construction. The speed of setting and curing process depends on the reactivity of the emulsion, the reactivity of the aggregate and the environmental conditions such as temperature and humidity.

The process follows the steps explained below

3.5.1 Breaking

Breaking of emulsions in contact with aggregate will take place in 3 steps. (Explained in detail later in this chapter)

a. Separation

Separation will occur as a consequent of sedimentation or creaming (bitumen particles are moving to top surface.)

b. Flocculation {Fig. 3.2}

Flocculation takes place when bitumen particles move closer into an open or loose network.

c. Coagulation (Coalescence) {Fig 3.2}

Loosely packed bitumen particles will form a compact mass.

3 .5.2 Setting

This is the phenomenon which occurs when an bitumen emulsion is in touch with aggregate. This process starts with breaking of emulsion and leads to water separation.

3 .5.3. Curing

Curing occurs when the base binder contains a volatile solvent. These fractions starts to disappear at the same time as the water evaporates and the final phase is only the base binder remains on the surface.

3.6 Types of Bitumen Emulsion

Bitumen emulsions used in road construction can be categorized based on the polar charge which the bitumen particles carry. These are cationic, anionic and non-ionic. The emulsions which are used in road construction are most probably cationic type of emulsions.

In addition to being classified by their electrical charge, emulsions are further classified according to how quickly they will revert back to asphalt as such Rapid setting, Medium Setting and Slow Setting emulsions. RS, MS, and SS have been adopted to simplify and standerdise this classification. Rapid setting emulsions set quickly in contact with clean aggregate of low surface area such as aggregate used in surface dressing

Rapid setting emulsions set quickly in contact with clean aggregate of low surface area such as aggregate used in surface dressings (chip seals). Medium setting emulsions set sufficiently less quickly that they can be mixed with aggregate of low surface area such as those used in open graded mixes. Slow setting emulsions will mix with aggregate of high surface area such as dense graded mixes.

High float emulsions are also available. High float emulsions are designated because they pass the float test and have a quality imparted by the addition of certain chemicals that permit a thicker asphalt film on the aggregate particles with a minimum probability of drainage. Therefore this property allows high float emulsions to be used with dusty aggregate with good success.

Finally emulsions are subdivided by a series of numbers that relate to the viscosity of the emulsion and the hardness of the base asphalt cement. The numbers 1 and 2 are used to designate the viscosity of the emulsion. The lower the number, the lower the viscosity and the more fluid the emulsion is. If the number is followed by the letter "h", the emulsion has a harder base asphalt.

3 .7 Emulsion Storage

Emulsion is a cold product which may be stored for up to several months. This has the following main advantages.

1. The emulsion can be manufactured and stored when bitumen is available at the manufacturing plant, without storing bitumen, raw material which will be heated in order to produce emulsion or without maintaining the required temperature.

2. Even though the consumption of emulsion at the construction sites vary due to stopping the construction as a reason of bad weather, machine breakdown or miscellaneous incidents no problem may come across if the binder is the bitumen emulsion as it can be stored up to several months.

3. The construction works can be carried out without any description even at the breaking down of the emulsion manufacturing plant.

4. It is able to run the manufacturing plant smoothly and earn a profit even when there is no or less work.

3.8 Storage Places

Emulsion can be stored at the manufacturing sites as well as a depot which close to the job sites. Care should be taken not to mix different types of emulsion at storing, as mixing will cause breaking of emulsions within the tanks. It is advisable to use tanks of constant horizontal cross section whose filling piping is dipped down to the bottom of the tank. Storing temperature should lie in between 15^0C and 60^0C. It is recommended to mix emulsion every 1-2 week in bulk storage using gentle agitation to prevent setting of bitumen particles.

3.9 Dilution of Emulsion

Dilution can be done for stable emulsions when there is really a need to dilute in the field. However it is not recommended to dilute rapid setting grades of emulsions with water as this may cause them to break. The following steps should be followed if dilution is to be carried out.

1 Compatibility of the emulsion with the water should be checked by testing a small quantity before diluting.

2 Water should be added to emulsion. In any case emulsion should not be added to water.

3 Warm water is preferred (if possible) and water should always to be added slowly.

3 .10 Emulsion Transport

Bitumen emulsion is a non-flammable product, and it is not included in the nomenclature of the dangerous materials. Bitumen emulsion may be transported either from the manufacture plant to the storage depot or from the depot to the job site. Transportation is easier than that for bitumen as it is not necessary to provide a heating system.

3.11 Manufacture of Bitumen Emulsions

Bitumen emulsions are usually made using a colloid mill although other dispersion devices are possible. In the colloid mill energy is applied to the system through which the mixture of hot bitumen and water phase is sent. The rotor as well as the stator are grooved or have teeth in order to create a turbulent flow.

Bitumen emulsions can be produced either in a batch or continuous plant. The batch process involves at least two process steps, water phase preparation and the actual emulsion production. The water phase is prepared in a tank into which heated water, emulsifier and other chemicals are metered and the solution properly mixed. In the emulsion production process the bitumen and the ready-made water phase are dosed to the colloid mill. If solvent is to be added to the bitumen then a batch tank is needed for bitumen as well, or the solvent is dosed in line.

In the in line process the water heating and all material dosage are done continuously using individual dosage pumps for each material. No batch tanks are required. Instead the water phase systems must further be designed to provide sufficient reaction time so that adequate solution takes place before the water phase meets the bitumen. The process consists of automatically controlled flow meters for all material dosage except acid, which should be controlled by the pH in the water phase. In the in line plant the emulsion cooling can be done by heat transfer to the in - going process water during production.

3.12 The Emulsification Process

Emulsification involves the break of the bitumen into droplets. The internal cohesion and viscosity of the bitumen and the surface tension oppose this process, which resist the creation of new interface. Droplets also have a tendency to rejoin or coalescence. To achieve a small particle size in the emulsion, it is necessary not only to apply mechanical energy in the right way in order to create small drops but also to prevent once formed.

The particle size of the resulting emulsion can be related to the mill rotor speed, the gap between rotor and stator, the dwell time in the mill, the concentration and type of emulsifier and the emulsification temperature.

Normally the highest temperature is used to prepare the emulsion in order to reduce the bitumen viscosity. Normally bitumen is heated to 110-160^{0}C until it has the viscosity of 500cSt or less for pumping into the mill. The water phase is also heated to 30-70^{0}C to dissolve the emulsifiers and also to achieve the required emulsification temperature after mixing with the bitumen. In colloid mills, which are not pressurized systems, the temperature is limited to 100^{0}C however in modern pressurized systems it may reach up to 120^{0}C

3.13 Function of the Emulsifier

The interfacial area between the liquid phases is greatly increased in an emulsion. For instance a liter of bitumen emulsion may have an interfacial area of 5000 m^2 .{Technical Emulsion Bulletin, Akzo Nobel}It needs energy to create this interface but this energy can be reduced by the adsorption of emulsifiers. The choice of the emulsifier and its quantity used affects the quality of the emulsion.

Once the droplets are formed they must be stabilised against coalescence both within the colloid mill and afterwards. Coalescence can only occur when the droplets get very close together. Emulsifiers adsorbed at the surface of droplets provide an electric repulsion energy barrier between the droplets, which prevent close approach. Even if this barrier is overcome and the droplets flocculate the film of emulsifiers on the surface of the droplets can prevent coalescence. The flocculation and coalescence can result from settlement, shear and heating of the emulsion. And also this may be initiated due to contamination with chemicals and dust.

Generally more emulsifier is needed to provide good stability and the right performance properties than is necessary to fill the interface, so bitumen emulsion will contain some free emulsifier present in solution. The free emulsifiers in the solutions may form micelles in the water phase and help to prevent coalescence{fig.3.2} during emulsification, storage stability and also will maintain transport stability.

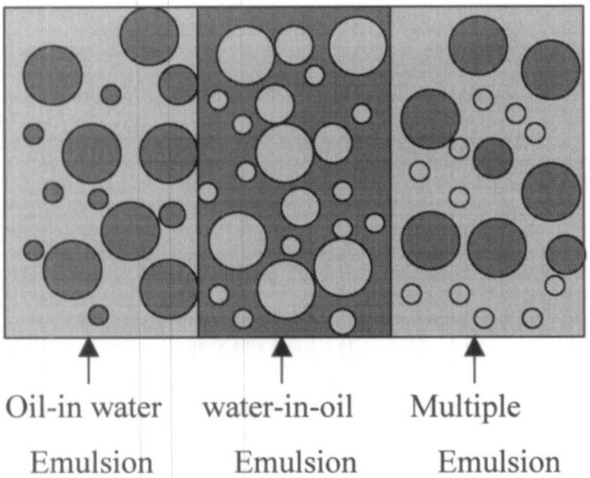


Figure 3.1: Basic types of emulsions

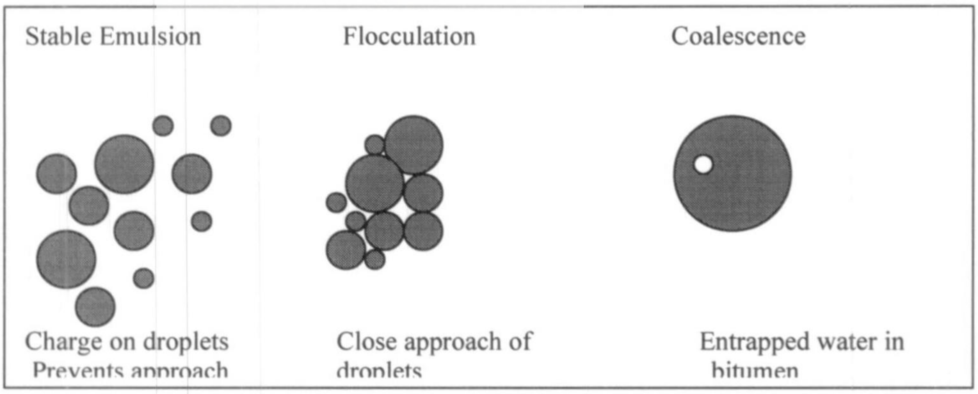


Figure 3.2; Different stages in storage tanks

Concentration at the interface depends on the emulsifier molecule having both lipophillic and hydrophilic portions. The emulsifier molecule is much smaller than a bitumen droplet and is stabilised by thousands of emulsifier molecules

Many cationic emulsifiers are supplied in a water insoluble neutral form and need to be neutralized with an acid like Hydrochloric, Phosperic, Acetic or Sulfuric before the cationic is generated.

3.14 Breaking of Emulsions

Basically all emulsions loose their carrying phase which is the water phase at the time of breaking. Depending on the time taken to break emulsions these are further categorized as rapid setting, medium setting and slow setting type of emulsions {Chapter 3.6}. As most of aggregate available in Sri Lanka is acidic cationic type of emulsions are used. Therefore the study is confined to cationic type of emulsions. Cationic emulsions can break in two ways.

1. By increasing the pH value in contacting the substrate. This can only possible if the substrate can absorb protons, H^+
2. By direct Electro chemical load exchange between substrate and emulsion droplet.

There are five stages, which are identified in breaking of emulsions.

Stage-1

The first stage is the droplets are freely moved and the emulsion is fully intact. At this stage all kinds of mixings, spreading, thinning and applications have to be done. This is the only stage in which the emulsion can be mixed homogeneously and unperforated coating of any substrate is possible

Stage-2

Adsorption of emulsifier on to the aggregate surface is taken place. Free emulsifier adsorbs rapidly; emulsifier may be abstracted from the bitumen water interface much more slowly. Removal of the reservoir of stabilizing emulsifier makes the emulsion liable to coalesce and hence the emulsion droplets start to coalesce. They have approached so much that they form conglomerates. In this stage the droplets are clearly identifiable but not freely movable. Most of the oil phase has separated from the continuous phase and the emulsion seems to be full of lumps or clods and the consistency has increased. In this stage no uniform coating, mixing is possible. This stage is possible when the emulsion droplets approach by creaming or sedimentation. Sometimes stage 2 to stage 1 is possible if little stirring is done.

Normally cationic emulsifiers adsorb much more strongly on siliceous minerals than anionic or nonionic emulsifiers. (Movements of the emulsion droplets to the aggregate surface)

The droplets of bitumen in the emulsion have a small charge and move towards an aggregate surface with the opposite charge. (Electrophoresis) Concentration at the surface brings the particles together leading to flocculation, coalescence and spreading over the surface.

Stage-3

In this stage conglomerates which can be seen in stage 2 have so far coalesced. That no emulsion droplets can be seen any more. However the bigger particles of coalesced bitumen are still coated with water. In this stage the emulsion has a cheesy appearance the substrate or the aggregate surface are fully coated with good adhesion.

Some aggregates like limestone or fillers like lime or cement may actually neutralized the acid in a cationic emulsion causing the pH to rise and the emulsion to be stabilized. In other cases the aggregate may absorb hydrogen ions leading to less marked rise in pH, but still sufficient to destabilize.

Stage –4

At this stage the conglomerates have coalesced so much they are linked and become cohesive and the oily phase has become the continuous phase and after that no separation of the bitumen particles could be observed. However there is a possibility that water may entrap in between the island of the bitumen islands. This is the stage where the good bond between the aggregate or substrate and the bitumen takes place by solidification of bitumen.

Stage-5

As water leaves the system by evaporation, the droplets are concentrated, and therefore the results will be the forming coagulum.This is the stage which a solid, water free oil phase can be achieved. Binders have produced full adhesion and also cohesion so that all mixes are solidified. Mixes and applications are durable and fully serviceable.

3.15 Influence of the Droplet Size

Quantity of the emulsifier required in an emulsion depends on the size of the particles, such that the smaller the particles more emulsifier is needed in stage 1 than when does the particle are coarser. When the emulsifier content is less with small droplets can coalesce perhaps with few water inclusions, so stage 1 and stage 2 will fast and reach stage 4 and stage 5 very soon.Particle size distribution of an emulsion is also another factor to be considered. Normally when the particles are coarser stage 1 is quicker but leaving more water trapped among the particle hence the consequent is an inverted emulsion. In most of the cases setting stops at stage 4 and stage 5. If big droplets and small are mixed fractional breaking takes place; i.e.-big droplet coalesce while small particles are flowing as the emulsion. No particular stage is visible. From this it can be concluded that emulsion having narrow particles is preferred to a boarder distribution.

3.16 Influence of the Viscosity of the Bitumen

When the viscosity of the bitumen becomes lower the quantity of emulsion improves such that the emulsion produces a continuous phase as emulsifier looses its activity. The particle size is also smaller and narrower distribution the stage 5 can be achieved by over jumping intermediate stages. For instance the particle size distribution of bitumen emulsion produced using 80/100-penetration grade bitumen is better than that produced using 60/80 bitumen.

CHAPTER 4

IMPROVEMENTS TO BITUMEN EMULSIONS

4.1 Introduction

With the development of bituminous emulsion in recent past, the bitumen and cutback bitumen used as the binder have partially replaced by bitumen emulsion. Percentage of use of bitumen emulsion has been gradually increased with time and the production units have also been improved for the supply of the demand. At present almost all the surface treatment is done by using bitumen emulsion as the binder in Sri Lanka.

Surface dressing done with bitumen emulsion had been locally modified over many years to provide a fast and economical means of increasing the life of local roads and footways. However it was difficult to achieve consistent in performance. Stripping of aggregate, flushing of the surface, peeling off patches, cracks and streaking along the surface were some common problems and stripping of aggregate was the most predominate out of them when emulsion was used.

As a solution it was suggested by RDA to apply a sand seal over the surface dressing, DBST and SBST in order to overcome the problem of stripping of aggregate. However this option was costly and may not be an appropriate solution.

Therefore a research work was commenced in order to find the reasons for frequent premature failure of surface dressings and propose sustainable solutions to minimize failures. Results of the tests carried out on the samples of Cationic Rapid Setting-2 (CRS-2) emulsion sent by the Plant Manager, Emulsion plant, RC&DC to R&D division of RDA and tested by the staff attached to R&D division of RDA were analysed for the properties of CRS-2. Samples collected by the staff of RDA from the work sites as well as from the Emulsion Plant were also included to this study. This analysis was done to identify the problems related to properties of CRS-2.

Laboratory studies were also carried out to improve the qualities of bitumen emulsion which were most important in construction of surface dressing. The effect of the properties of the bitumen emulsion on surface dressing and techniques adopted to improve bitumen emulsion (when necessary), in order to minimise the failures identified were discussed in this chapter.

4.2 Methodology

Field investigation was carried out on roads where the surface dressing had been completed and at on going construction sites and major common failure types were identified.

Samples of binder were collected from the sites and from the manufacturing plant and tested at R&D division of RDA according to the accepted standards, American society for testing of materials, (ASTM D244, 1991) {ref; Annex-2}

Records of the bitumen emulsions for the years 1999 and 2000 were collected and analysed for the properties. {ref; Annex-3, Test methods of bitumen emulsion}

Laboratory experiments were carried out by changing recipe formulation of bituminous emulsion together with changing the settings such as pressure and temperature of the manufacturing plant.

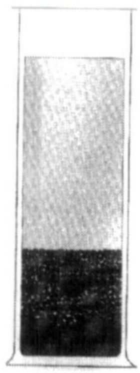
Three organic modifiers and a doping agent were tried to improve the properties of bitumen emulsion further.

4. 3 Analysis of the Data

Special attention was given to the intrinsic properties of bitumen emulsion.

Viscosity is very important in case of surface dressing emulsions as it indicates the flow property of the same. Bitumen emulsions with less viscosity runs off across the road even due to the normal camber. Therefore the required bitumen film or the requiied binder content does not remain on the road surface to hold the aggregate firmly resulting higher rate of stripping of aggregate, with time. The aggregate which are not properly bonded to the road surface will damage the windscreen especially on cars when moving on newly laid roads. And the surface dressing would also become poor in covering and protecting the pavement structure underneath from inclement weather conditions.

Storage stability is another important intrinsic property of bitumen emulsion in storing the same to maintain the homogeneity of emulsion. Failing of storage emulsion varies viscosity from top to bottom inside the storage tank. This will create problems in the performance of the surface dressing as well as damaging the windscreen of the vehicles due to spraying of less viscosity portion. And also there will be a tendency to block the nozzles of spray bar of the sprayer when the presence of coagulated bitumen particles in storing tanks. A complement test, sieve test was also important to get to know the presence of the coagulated particles. Fig.4.1 shows settlement of emulsion in storage tanks.



fig; 4.1 Coagulation of bitumen particles in storage tanks

4.3.1. Storage stability

The analysis of the samples of the bitumen emulsions for storage stability is shown below. The analysis also shows that 62% of the values satisfied the specification limits. 28% of the values were in between 0 and –1 and 10% of the values were above the specification limits. {Fig.4.2} Almost all the samples satisfied the specification limit for the sieve test. Table 4.1 Shows the specification limits for bitumen emulsion.

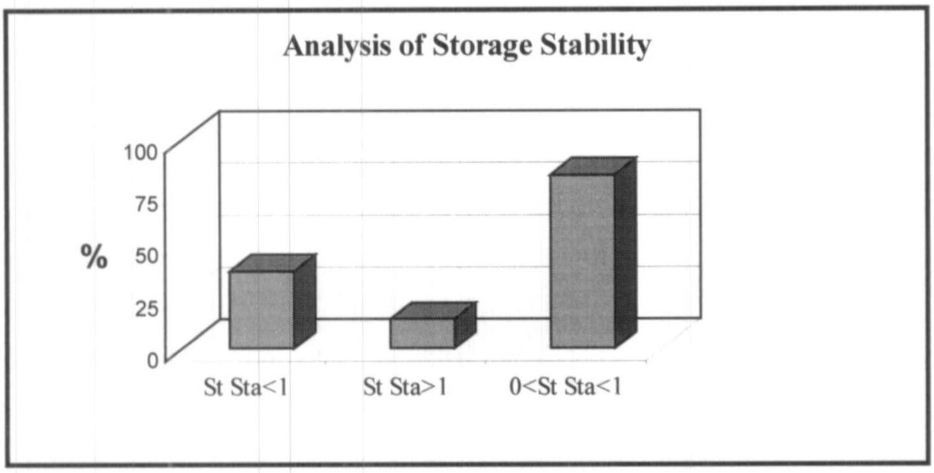


Figure.4.2. Representation of the analysis of the storage stability

St. Sta. Storage stability

4.3.2 Viscosity

The analysis of results for the Saybolt Furol viscosity in seconds is shown in figure 4.3. 74% of the results were below the specification limits. Only 26% of the results satisfied the specification limits. (ASTM 2397,1991) However according to some other specifications the values of viscosity of CRS-2 emulsions should be in between 150 and 300 Saybolt Furol Seconds if it is to be used as surface dressing emulsions.

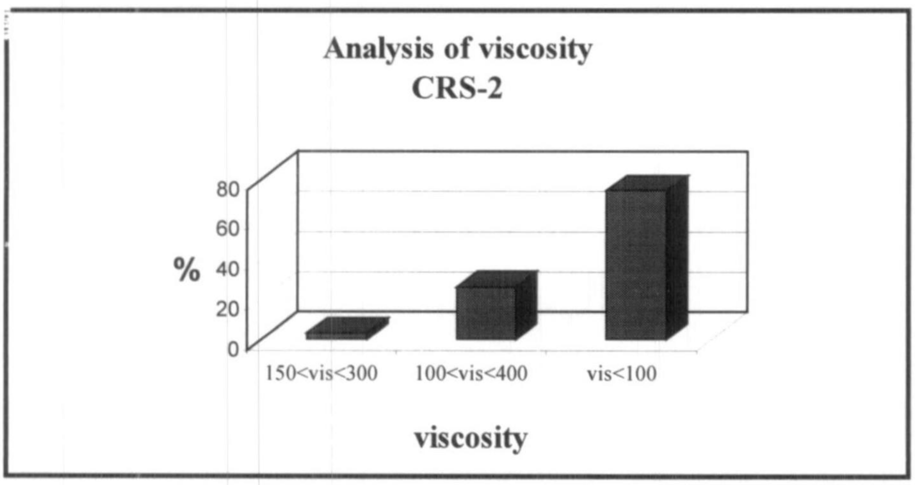


Figure 4.3; Representation of the analysis of viscosity

Table 4.1:Standard specification for CRS emulsions

STANDARD SPECIFICATION FOR CATIONIC EMULSIFIED ASPHALT (ASTM Designation D 2397-85) Requirements for Cationic Emulsified Asphalt				
Type	Rapid - Setting			
Grade	CRS - 1		CRS-2	
	min.	max.	min.	max.
Test on emulsions:				
Viscosity, Saybolt Furol at 77° F(25° C) - s.				
Viscosity, Saybolt Furol at 122° F(50° C) - s.	20	100	100	400
Storage Stability Test 24hr. - %		1		1
Classification Test	passes		passes	
Coating ability and water resistance:				
Coating, dry aggregate				
Coating, after spraying				
Coating, wet aggregate				
Coating , after spraying				
Particle charge test	positive		positive	
Sieve test %		0.10		0.10
Cement mixing test %				
Distillation:				
Oil distillate by volume of emulsion %		3		3
Residue %	60		65	
Tests on residue from distillation test:				
Penetration 77°F(25°C) 100g 5s	100	250	100	250
Ductility 77°F(25°C)cm/min.cm	40		40	
Solubility in trycloroethylene %	97.5		97.5	

When considering both the above-mentioned properties of CRS-2, only 18% satisfy the specification limits.

Therefore the analysis shows that there is an extreme necessity to improve the bitumen emulsion. Therefore as the first step, the research commenced with improving bitumen emulsions used in case of viscosity mainly to avoid runoff as such reasons for less viscosity even for the samples sent from the production unit were investigated {fig.4.4}.

Therefore the research concentrated to the production of bitumen emulsion in order to commence the improvement of bitumen emulsion.

4.3.3 Manufacturing of bitumen emulsion

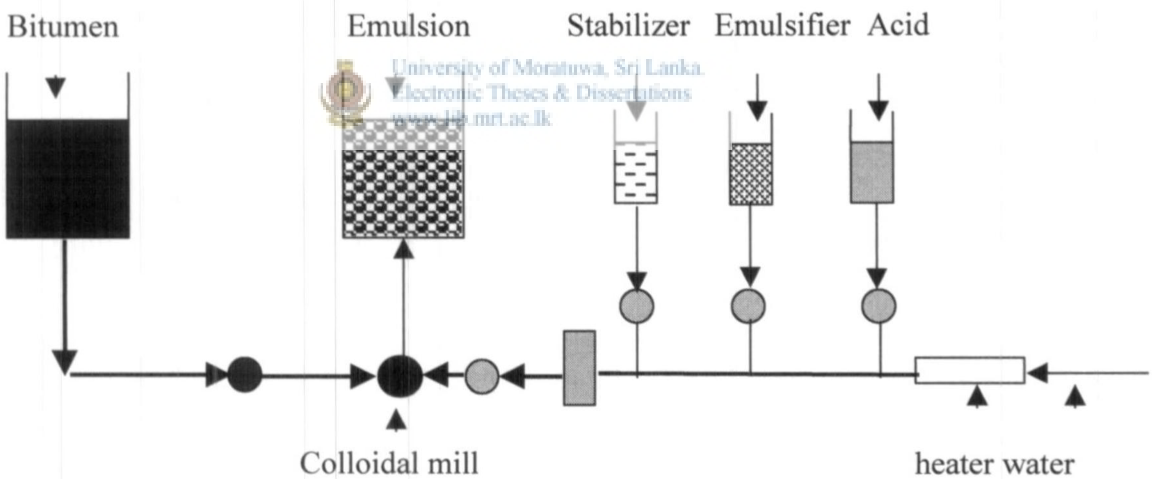


Figure 4.4; A typical in- line emulsion plant

Bitumen is one of the major components of bitumen emulsion. Therefore the research concentrated to the bitumen content set at the production unit. The figure 4.5 shows the variation of the bitumen content of the CRS-2 emulsion produced at the emulsion plant.

4.4 Binder Content of the Samples of Emulsions Analysed

The graphical representation (figure 4.6) of the binder content of the samples was analysed. 76% of the samples had the binder content in between 65 and 66 inclusive of the boundaries by the total weight of emulsion. Only 4% had the binder content less than 65%. 9% of the samples had the binder content equals to 67%. 11% of samples had binder quantity over 67%.

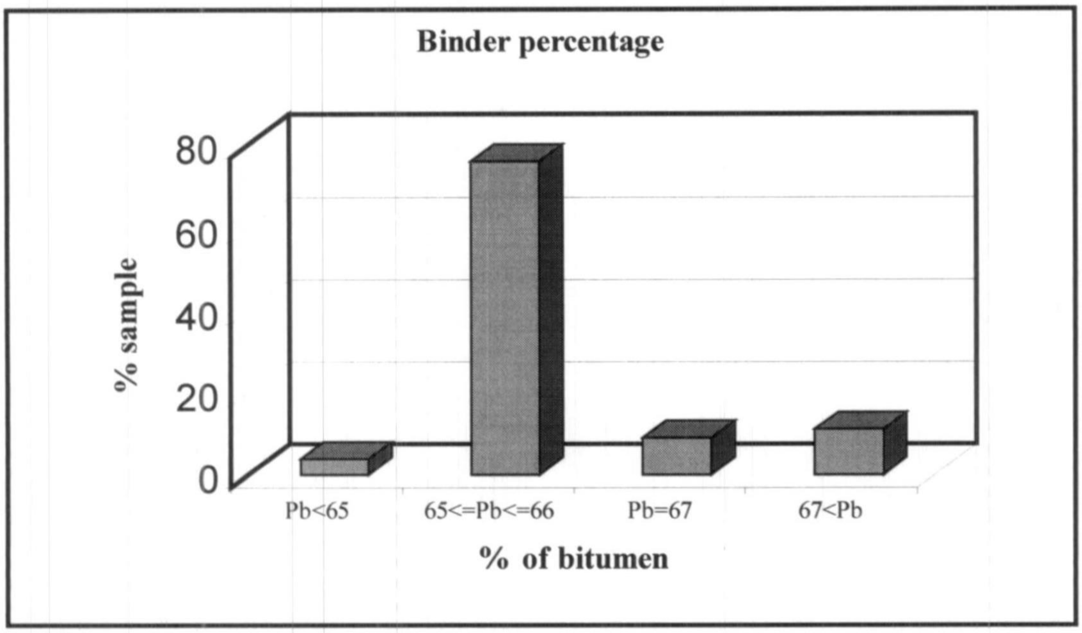


Figure 4.5: Representation of binder content in the emulsion

The variation of the viscosity of emulsion at particular bitumen content was also analysed and presented figure 4.6

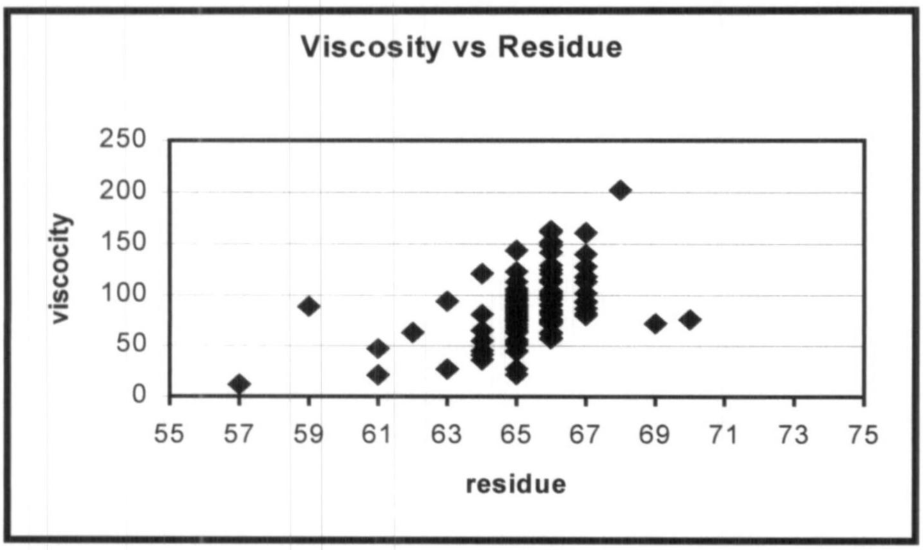


Figure 4.6: Representation of viscosity Vs Residue

It was observed that there was a wide variation of viscosity for a particular binder content while other parameters such as type and quantity of emulsifier, recipe of the emulsion, temperature of soap solution and bitumen, temperature of emulsion at the collection and pressure and mill rpm, mill gap remain the same.

Figure 4.7 shows that average viscosity variation of the CRS-2 emulsion against the binder content. It can be shown that the relationship follows a polynomial equation, $y = 1.7386x^2 - 213.3x + 6597.4$ where

Coefficient of regression, $R^2 = 0.9894$

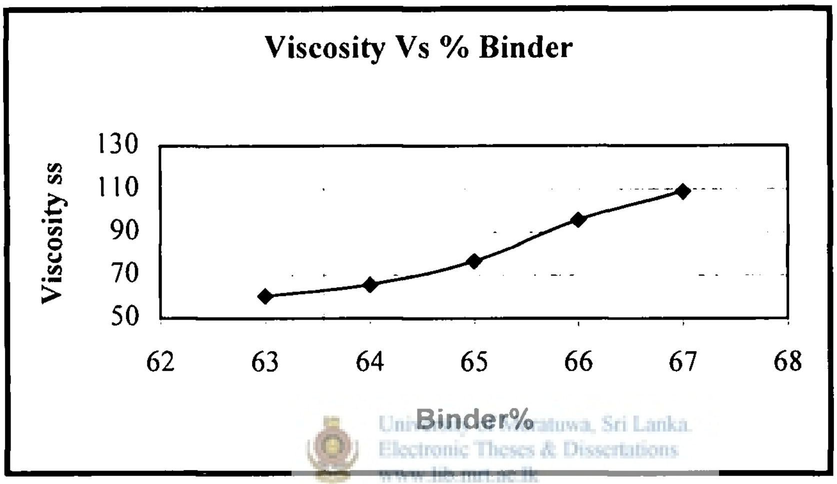


Figure 4.7: Representation of average viscosity Vs binder percentage

Generally viscosity variation with binder content is such that the viscosity varies at low rate at bitumen content and higher rate at higher bitumen content. This relationship was obtained for particular settings, such as temperature of the manufacturing plant and also for a given formulation for emulsions. The temperature at different stages of the manufacturing unit will effect the particle size distribution of the emulsion even the formulation, mill type and gap are remained fixed. In other words when the settings changes the properties of the production will change. Further study shall be proposed to be carried out in this regard and to find out whether there exist a series of curves for the manufacturing plant at different temperatures. The existence of the set of curves will make easier to select the optimum curve which gives the required properties of emulsion. The research

can also be further extended to find out the relationship with the mill type and gap of particular type of mill.
Emulsions with smaller particles having narrow range will provide still better emulsion. (Refer test results on the samples done in the Swedish laboratory)

The analysis also showed that 85% of the samples set at the binder content 65% by the total weight of emulsion, had the viscosity 55-65 SS. 55% of the samples set at the 60% by the total weight of emulsion had the viscosity 65-75 SS. 61% of the samples set at the binder content, 67% had the viscosity 75-80 SS. (Figure 4.7)

4. 5 Effect of Properties of Bitumen on Emulsion

As discussed earlier, the basic purpose of emulsion production is to combine of two immiscible liquids (bitumen and water) to produce a serviceable binder. The viscosity of the bitumen at the milling stage is absolutely critical, as the mill will not satisfactorily produce globules of the desired size range when the binder does not flow properly. In this regard temperature to which bitumen would have to be heated would be very important. This temperature mainly depends on the type of the bitumen used in production of emulsion. Normally the penetration is inversely proportionate to the viscosity of bitumen. It was noted that the penetration of even a particular grade of bitumen which is locally available often changes and hence may affect the properties of emulsion.

Changing of penetration of a particular grade of bitumen was analysed and shown below. (Figure 4.8 & Figure 4.9). The penetration of samples of bitumen labeled as 80/100-penetration grade had penetration value ranging from 70 to 115 (1/10 of mm). Similarly the penetration of bitumen labeled as 60/70-penetration grade had the penetration value ranging from 40 to 90 (1/10 of mm).

The mean and the standard deviation of the penetration values of 80/100 pen. grade bitumen are 84.65 and 20.88 and that for 60/70 pen. grade bitumen are 70.3 and 11.04 respectively. {fig. 4.8 and fig.4.9}

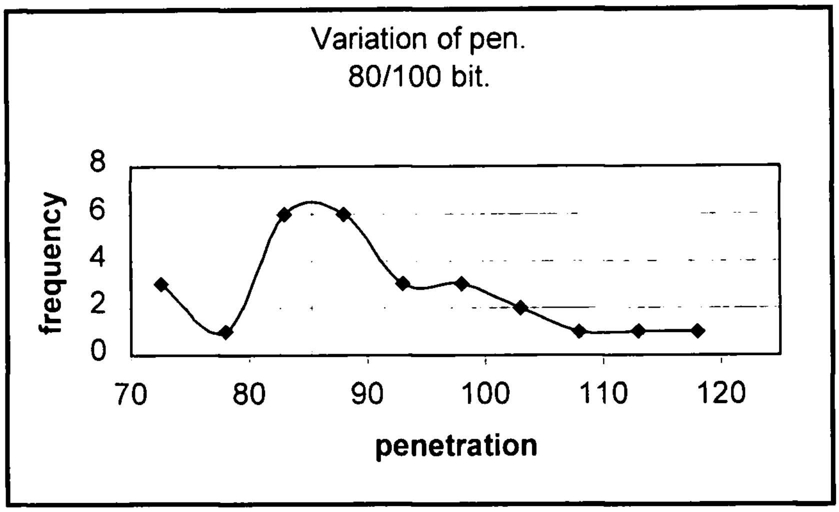


Fig.4.8 Variation of penetration of 80/100 bitumen

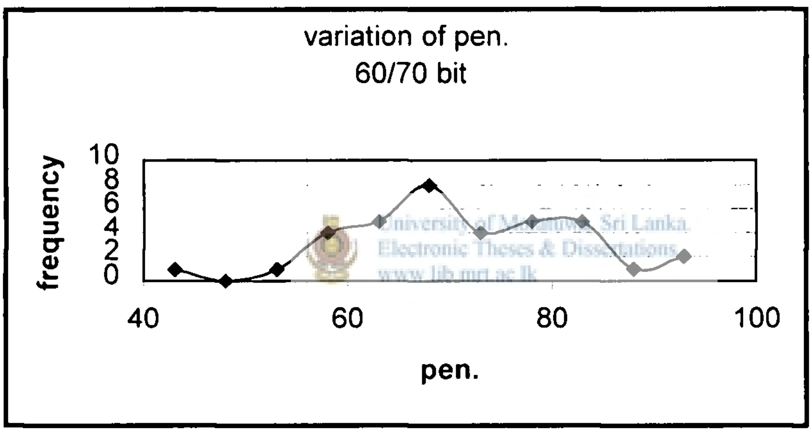


Fig .4.9 Variation of penetration of 60/70 bitumen

It was decided to compare the properties of bitumen emulsion with the corresponding base bitumen data used to produce that bitumen emulsion. This was required because that there was a variation in the properties of same type of emulsion produced using different batches of bitumen.

Therefore the samples of bitumen emulsion were collected with the sample of bitumen used from the production unit RC&DC. These samples were tested at the Central Laboratory of RDA. The summary of the results of the tests are shown below in table 4.2.

The table shows that viscosity of the emulsion increases when the other conditions remained same.

Table 4.2: Effect of penetration of raw bitumen to the properties of emulsion

Pen. Raw Bitumen	Type of emulsion	Viscosity ss	Storage stability	Sieve test	Distillation test		Tests on residue	
					oil %	residue %	pen	Ductility
81	CRS-1	16	0.3	0.00	2.0	64	135	118
	CSS-1	18	0.2	0.00		61	185	127
	CRS-1	15	0.3	0.00	2.0	65	132	116
87	CRS-1	26	0.0	0.00	2.5	65	140	134
	CRS-1	20	0.3	0.00	1.5	60	133	126
90	CRS-1	20	0.0	0.00	2.5	60	105	125
	CRS-1	22	0.1	0.00	1.5	59	97	145
	CRS-1	21	1.0	0.00	1.5	56	123	150
	CRS-1	21	0.0	0.00	2.5	58	105	120
102	CRS-1	30	0.2	0.00	2.0	63	105	95
	CRS-1	28	1.0	0.00	2.0	61	110	132
	CRS-1	25	1.0	0.00	2.0	60	163	94
	CRS-1	24	0.6	0.00	2.5	60	96	140
	CRS-1	29	0.5	0.00	2.5	63	100	122
105	CRS-1	36	1.0	0.00	1.5	64	103	131

The study also revealed that changing the temperature/settings to suit the viscosity of bitumen at the emulsion plant will provide a feasible solution to maintain the range of the desired particle size of bitumen globules and hence better properties of bitumen emulsion. A further study is needed to establish a calibration chart of temperature/settings of the manufacturing unit and the penetration of bitumen, provided that the penetration of bitumen is known. For this the production unit of bitumen emulsion must have the facility to test the penetration of bitumen prior to use.

However there are other parameters which will affect the particle size distribution of emulsion and will be discussed later in this chapter.

Three samples were tested at the Emulsion laboratory, Scan Road at Nacka, Stockhorm (Sweden) for the particle size distribution of bitumen emulsion using the Granulometer HR 850 the results are tabulated below. {table 4.3 & 4.4} The particle size distribution is unable to test in the RDA laboratory. Test reports are attached in the annex-10

CaCl2 is used to improve the stability of bitumen emulsion. The table 4.3 shows that the particle sizes of the three different bitumen emulsion samples done using the Granulometer HR850. The table explains that the mean size of the bitumen globules has become smaller with the presence of CaCl2. And the range of the particle size distribution also has become narrow. This indicates that adding of CaCl2 will improve the particle size of bitumen emulsion. For instance storage stability improves as the range of the particle size distribution becomes narrow and viscosity increases because the mean size of the particles is smaller, compared the non-modified samples. The same table also shows that the modified emulsion with chemical-1 has the best particle size distribution and the least mean size of particles distribution and the least mean size of particles, such that the chemical –1 (Di-Amine OLB) will be a better modifier than to CaCl2.

Table 4.3: Particle size distribution of bitumen emulsion

Item	type	Median size microns	Dia. for 10% microns	Dia. for 90% microns
1	No $cacl_2$	4.54	0.75	16.38
2	With $cacl_2$	3.88	0.75	15.76
3	With chem.1	3.04	0.58	9.58

Note: Dia. - Diameter

The above table shows that the medium size of the particles modified with chemical 1 is 3.04 microns which is the least of the three and the narrowest range of the particle size distribution. This indirectly shows that there is an improvement in emulsion specially in case of viscosity. (Table 4.4)

Table 4.4: Viscosity of the samples

Item	No $cacl_2$	With $cacl_2$	With chem.1
Viscosity ss	12	14	20

The research scheduled to study the factors which effects the properties are as mentioned below.

1. The formulation variables that are dealing with the ingredient nature, (type of emulsifier, type of bitumen)
2. The composition variables that describe the different ingredients proportions.
3. The mechanical aspects of mixing device the energy input and its duration.

1. The research study about the emulsions was initiated by varying the type of emulsifiers. The emulsifiers tested for CRS emulsions were redicote E-965, Asifer N100L and Dinoram SL. These results are shown in table 4.5 & table 4.6.

Table 4.5: Effect of type of emulsifier

Type	Viscosity SS	Storage Stability	Sieve Test %	Residue %	Oil %	Tests on residue	
						pen.	Duct.
Dinoram SL	16	0.4	0.3	62	3.0	110	145
Asifer N100L	21	-0.2	0.0	62	3.0	109	130
Redicote E965.	70	-1.2	0.08	63	2.5	108	89

Formulation of above emulsions were done based on the so-called optimum formulation which were proposed by the manufacturer of the particular emulsifier. The optimum formulations are as shown below

Table 4.6; optimum formulations used as manufacturers guide

Emulsifier	Bitumen	Kerosene	Emul. %	$CaCl_2$	pH	Water %
Dinoram SL	61	2.0	0.16	0.1	2.5	36.74
Asifer N100L	61	-	0.16	0.1	2.0	38.74
Redicote E965	61	1.0	0.25	0.1	2.5	37.65

2. The study was carried out by changing the composition variables as the second step. This step includes the changing of the proportion of an emulsifier, by changing the proportions of solvent, kerosene and the proportion of bitumen. The values are tabulated as below.

The table 4.7 shows that the properties of bitumen emulsion increases with the % of emulsifier. Bitumen emulsions having higher quantity of emulsifier makes stable emulsions. However creaming of emulsions may possible because of high viscosity water media.

Table 4.7; Effect of emulsifier on CSS emulsions

Emul.	% emul.	Vis. SS	St.Sta. %	Sieve Test %	Residue %	Oil %	Tests on residue Pen	Duct.
Redi. 4875	0.8	20.00	0.70	0.00	61.00	2.0	99	68
Redi. 4875	1.0	22.00	0.80	0.00	61.00	2.0	102	120
Redi. 4875	1.2	25.00	0.80	0.00	61.00	2.0	100	101
Em 26	0.7	16.00	0.10	0.00	61.00	2.0	125	55
Em 26	0.9	16.00	0.30	0.02	61.00	2.0	127	89
Em 26	1.0	17.00	0.70	0.01	60.00	2.0	124	96
Em 26	1.2	18.00	0.10	0.00	61.00	2.0	134	90

The table 4.8 shows that the viscosity of bitumen emulsion increases with increasing the kerosene content. This can be explained when the kerosene content increases it is easier to break down bitumen into finer globules than when there is no kerosene. It was also observed that penetration of the residue (base binder) also increases with the kerosene content because bitumen dissolves in kerosene and hence becomes softer. However care should be taken not to increase kerosene much because it takes more time to cure at the field.

Table 4.8; Effect of the solvent on the properties of emulsion CRS-1

Solvent %	Viscosity	Storage stability	Sieve Test %	Residue %	Oil %	Test on residue Pen.	Duct.
0.0	21	0.2	0.0	65	1.0	96	115
2.5	43	0.2	0.02	65	2.0	165	80

Formulation tried

Formula-1

Emulsifier Asifer N100L

Quantity 0.16%

$CaCl_2$ 0.1%

pH 2.5

Settings of the emulsion plant were not changed.

Table 4.9: Effect of quantity of bitumen on the properties of emulsion

Bitumen %	Viscosity	Storage stability	Sieve Test %	Residue %	Oil %	Test on residue Pen.	Duct.
60	21	0.0	0.00	61	2.0	133	119
65	30	-0.6	0.00	64	2.0	115	133
68	43	0.4	0.12	67	2.0	163	80

The table 4.9 also shows that the normal behavior of increasing viscosity of emulsions at high bitumen content.

Formula –1 (mentioned above) was used and the settings of the plant were not changed.

3. The study of changing the mill type was not possible because only one laboratory mill was available in the laboratory. Therefore the study confined only to establish the mill rpm at RC&DC emulsion plant which produces emulsions having almost similar qualities as emulsions produced at the laboratory

Emulsion produced using laboratory emulsion plant at 9000rpm, 145^{0}C bitumen temperature and 80^{0}C emulsion was very similar to 5060rpm, 145^{0}C bitumen temperature and 80^{0}C emulsion temperature at RC&DC production unit. The research also extended to study the variation of bitumen emulsion with the mill rpm.

Table 4.10: Effect of mill rpm on the properties of emulsion

Item	mill rpm	water pump rpm	Viscosity SS	Storage Stability	Sieve test	Distillation test	
						oil %	Residue %
1	5000	110	16	0.4	0.05	2.5	62.2
2	5060	109	20	0.1	0.00	2.5	61.5
3	5500	110	18	0.2	0.01	2.5	63.4
4	6000	110	19	0.3	0.00	2.5	62.0
5	6500	110	19	0.2	0.00	2.5	62.0
6	7000	109	21	0.1	0.01	2.5	62.0
7	7000	109	21	0.5	0.02	2.5	64.0
8	9030	110	23	0.3	0.00	2.5	61.4
9	9030	110	24	0.2	0.00	2.5	61.9
10	9040	110	24	0.2	0.00	2.5	61.5
11	9000	110	25	0.1	0.01	2.5	62.0
12	9000	110	24	0.2	0.01	2.5	61.4
13	10,000	109	25	0.2	0.02	2.5	61.5
14	11,000	110	19	0.3	0.0	2.0	61.6

The table 4.10 & figure 4.10 show the variation of the viscosity with mill speed, rpm. The viscosity changes with rpm such that increases with increasing rpm. The study also further investigated that the variation follows a certain polynomial distribution having the following equation. The regression coefficient is .9685 which indicates that a good co-relation between the two variables.

$y = 5E\text{-}07x^2 - 0.0047x + 28.694$

$R^2 = 0.9685$

For particular settings there exists a curve for the variation of viscosity with the mill speed. This may due to the variation of particle size distribution which is one of the main governing factor for viscosity. There is a possibility to have a series of curves in this regard for different settings which has the main advantage of selecting the particular mill speed and the settings to attain the viscosity required.

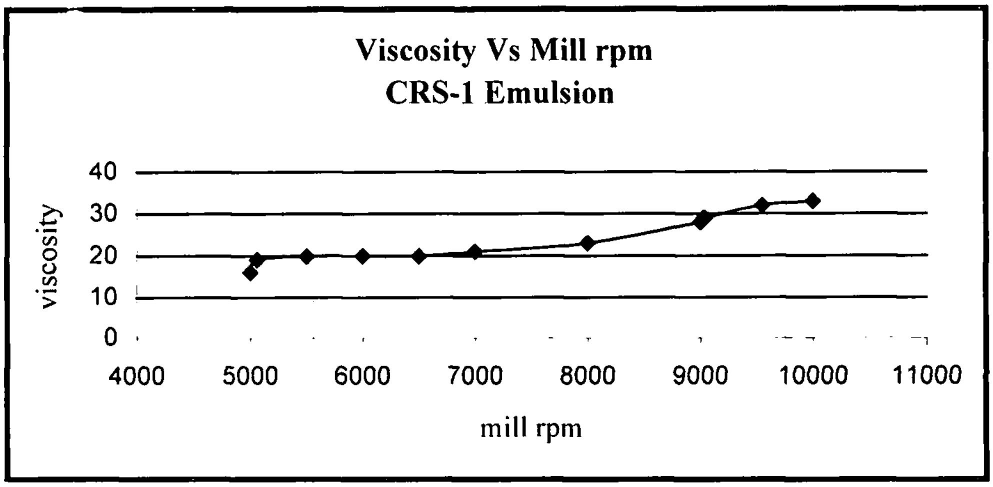


Figure 4.10: variation of viscosity Vs mill rpm

Changing the mill gap is not possible in all the types of production units. However rings of different gauges and the same diameter are available in the laboratory emulsion plant. These rings can be inserted in the gap in order to reduce the mill gap. Mill gap is reduced more if a ring of higher gauge is inserted.

4.6 Conclusions

Properties of bitumen emulsions can be improved by changing the above-mentioned factors. However these prime factors may not be continuously increased or decreased until the required improvement is gained. For instance bitumen content should not be increased above 70% because the result will be an inverted emulsion. Therefore the study intended to research for the modifiers.

CHAPTER 5

INVESTIGATION FOR LOCAL MODIFIERS

5.1 Introduction

Two modifiers and a doping agent were tried out in order to improve bitumen emulsions. These two modifiers are locally available at a less cost and the doping agent is not locally available but a small quantity of the substance can improve emulsion properties considerably. The two modifiers are "modifier-1" and "modifier-2". The doping agent is "doping agent 1".

The main objective of this study is to improve the bitumen emulsion in case of viscosity together with the other properties. For instance one advantage of bitumen emulsion is its storability for several months. In most of the cases the value of storage stability is greater than one indicating that settling of emulsion takes place in the storage tanks which should be improved.

5.2 Local Modifiers

5.2.1 Local modifier-1

Industrial grade of local modifier 1 is suitable for the modification of the emulsion. The industrial grade of modifier 1 is very cheap and available in plenty as a powder. This acts as a thickening agent.

5.2.2 Local modifier-2

Local modifier-2 is a cheap modifier & available in plenty anywhere within the country. It is available in liquid form. Therefore it is easy to incorporate.

5.2.3 Laboratory Research Work with Local Modifier – 1&2

Local modifier-2 is available in liquid form and cheap. The modifier 2 can be incorporated to bitumen emulsion either at the manufacturing plant or at the construction sites. This is compatible with any type of emulsion.

Laboratory investigations were carried out by using both the modifiers to investigate how effective they are with bitumen emulsions.

Figure 5.1 shows the results of the viscosity tests carried out on the samples of emulsions with the presence of modifiers 1&2. The same control sample was used for testing with modifiers.

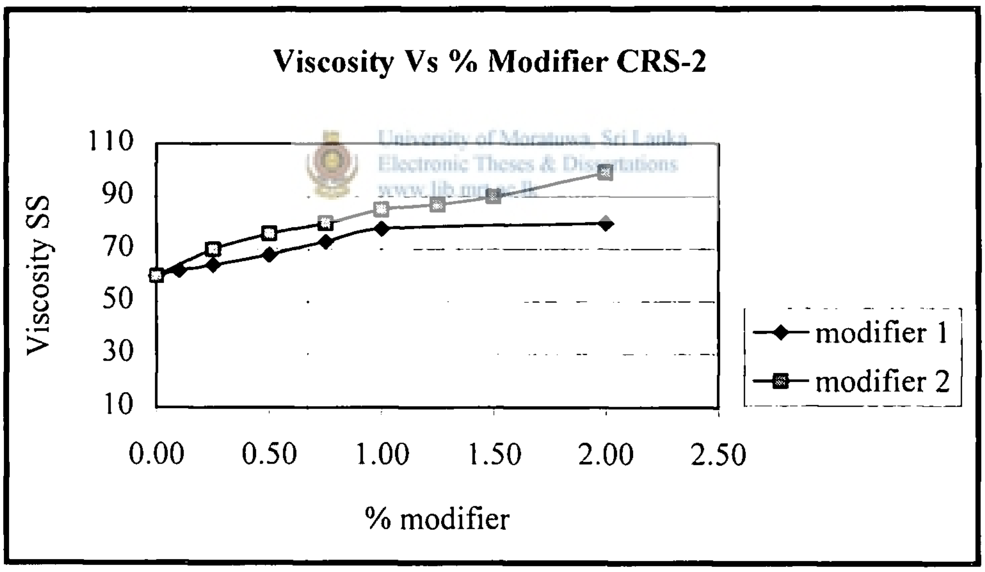


Figure 5.1: Viscosity of modified CRS-2

The figure 5.1 shows that the effectiveness of local modifiers with CRS-2, surface dressing emulsion. According to the above figure viscosity increases with increasing both the modifiers. Viscosity has improved from 60ss to 100 ss with 2.0% of modifier-2 and 80ss with 2.0% of modifier-1.

Therefore according to the test results modifier 2 is superior to modifier 1 as a viscosity enhancer.

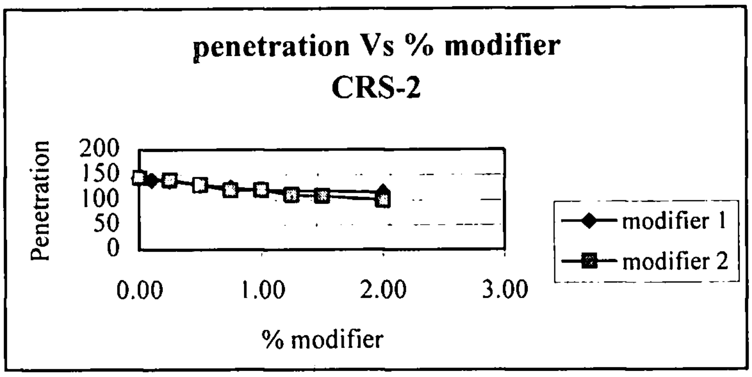


Figure 5.2; Penetration of the residues of modified CRS-2

Figure 5.2 shows that the penetration of the residues of CRS-2 samples tested with the presence of both the modifiers. The test results shows that penetration with modifier-2 is lesser than that with modifier-1 at a particular percent. For instance penetration at 2.0% of modifier-2 is 100 (1/10 mm) and that with modifier 1 is 115 (1/10 mm). Modification of emulsions to have residues of lesser penetration is feasible to a tropical country.

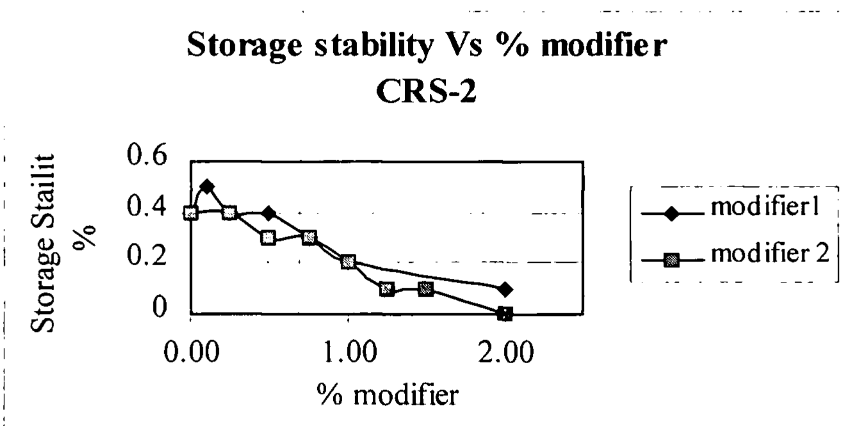


Figure 5.3:Storage Stability of modified CRS-2

Figure 5.3 shows that the storage stability improves with the presence of modifier 2 than with the presence of modifier 1. Reducing storage stability indicates that emulsion modified with modifier 2 is better than emulsion with modifier 1 in storage.

Settlement after 5 days has reduced which indicates the improving in storage stability. (Table 4a-7a of annex 4)

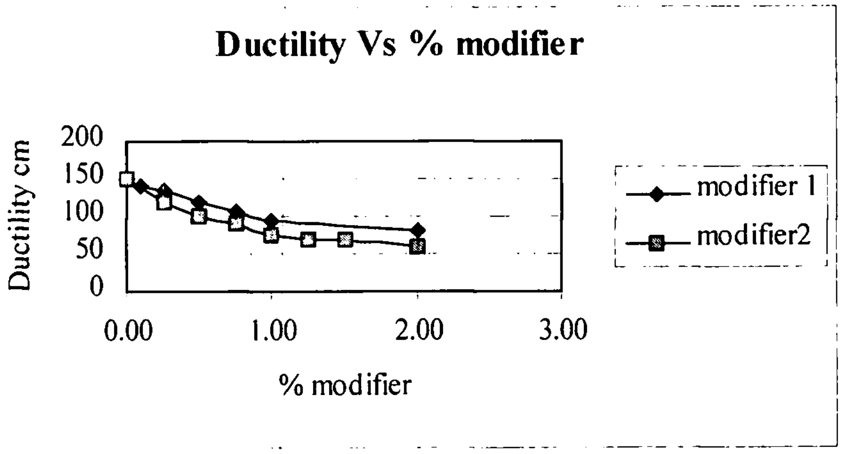


Figure 5.4: Ductility of modified CRS-2

Figure 5.4 shows that the results of the ductility of the modified CRS-2 with modifier 2 are of lesser values than that with modifier 1. The values are above the minimal given in the specification, ASTM 244. However reducing ductility indirectly indicates that improving internal cohesion.

A similar series of tests as with CRS-2 were also carried out with modified CRS-1 and also CSS-1 (shown in annex 4). These results of the tests were also have shown similar patterns to CRS-2.

Therefore it can be concluded by analysing the above-mentioned three series of the tests carried out different samples, modifier 2 is better to use as a viscosity enhancer. Modifier –2 also improves emulsion to suit the local hot condition of the country.

5.4 Method of Incorporation of the Modifier 2

Modifier-2 is miscible with emulsion and also with emulsifiers. Modifier-2 dissolves in water. Therefore modifier 2 can be incorporated into the bitumen emulsion either at the production unit by adding to the soap solution or by adding to water line .It also can be incorporated through a separate tank. This is easily done for the production units where separate tank is available for the incorporation of polymers.

As the modifier-2 is locally available in plenty and can be purchased anywhere within the country at a cheaper rate the incorporation can be done at anywhere in the country. As this is available in liquid form incorporation can be done without taking an additional effort or without using any mechanical device. Circulating system, which is normally available in emulsion tankers, sprayers and bousers can be used for mixing, as the modifier-2 is not that viscous. If the Emulsion available at the construction site, anywhere within the country, is of substandard in quality, insitu improvement will be-possible by adding modifier-2 to the sprayer or bouser containing emulsion which is an advantage in case of eliminating the failures on surface treatment. The flow property of the Emulsion can also be adjusted to suit the site such as hilly terrains. It should be mentioned that Modifier-2 is available in anywhere in the world.

5.3 Doping Agent

A doping agent was also tried to improve the quality of the emulsifier. This material can be used in very small quantities. However the material used for this study is not locally available. It is not expensive as the dosage is very small. This is also an economical option, comparing the additional cost may due for the frequent rectification of the surface surface dressings because of inadequate quality of material. There is also no problem in incorporation of this substance. It can be added to the soap solution in the production line as in the recipe without any additional effort. The Figure 5.5 shows the improvement that can be made to bitumen emulsions.

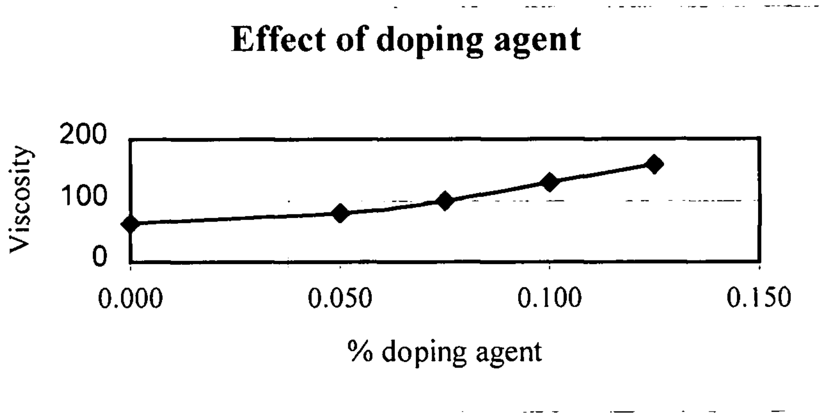


Figure 5.5: effect of doping agent with CRS-2

The figure 5.5 shows that viscosity of the modified sample has increased above 100 ss even with the 0.1% of the doping agent. Table 4.3 will show the improvement of the particle size distribution if the sample is modified with this agent. Adding of this doping agent will reduce the range of the particle size distribution and also the mean size of the particles which always preferred to have for better quality of bitumen emulsions.

CHAPTER 6

ADHESION PROMOTERS

6.1. Introduction

The prime function of a binder used in road surface dressing techniques is essentially to promote the retention of aggregate on the existing road surface. Until such times as the aggregate have been adequately embedded into the surface, it is the adhesive properties of the binder which must prevent their removal from the surface. It should also be acknowledged that a tight mosaic (shoulder to shoulder) coverage of aggregate could greatly assist the binder in its task. Therefore it is understand that one of the principle functions of bituminous binder is to act as an adhesive for bonding the aggregate particles together

Stripping of binder from the mineral aggregate surface especially in the presence of water is no new phenomenon in the field of highway engineering.

In general under suitable weather conditions, well-designed techniques and compatible materials, surface dressings are usually carried out very successfully. However premature failures on road surfaces in the form of raveling and cracking have become a common occurrence in most of the local roads. Frequent maintenance of road surfaces, is required as a consequent of these failures which will incur an additional cost as well as creating inconveniences to the road users for not providing the due comfortability to them. This may attribute to loss of adhesion between the binder and the aggregate surface.

The Research has identified different aggregate having various minerals compositions are frequent in road construction sites where aggregate is used. Spraying temperature of binder is around 50^{0}C even though the binder is bitumen emulsion. The research revealed that there is also stripping problems in surface dressing as a result of presence of the incompatible aggregates in the sites. In this chapter, the research work in this area is discussed.

Water damage is more likely in the presence of water and when the traffic is high it will damage the road very soon. It is possible for water to penetrate a film of bitumen and displace the bitumen from the aggregate. In the same way if the aggregate is wet, it is impossible to disperse the water with bitumen and get adhered to aggregate.

6.1.1 Adhesion

There are two distinct states in adhesion, namely active adhesion and passive adhesion, in active conditions the binder wets the aggregate surface and cannot easily be stripped off the stone by water. In passive condition the aggregate are protected against stripping at a later date due to wet weather damage.

It is worth considering briefly another property associated with the binder/stone combination, namely cohesion. These two stages are also named as wetting (taking hold) and keeping hold (resistance to stripping) In general terms, it can be said that once adhesion has been achieved, then the bond or strength which keeps the composite together is the cohesive strength.

Bitumen is an oily material of low polarity with little chemical affinity for aggregate, where as the aggregate has a high affinity for water, which means bitumen, is easily displaced by water. In practice the adhesion between bitumen and aggregate depends on the source of bitumen and the minerals of the aggregate. Aggregate may be of an acidic type whose surfaces are negatively charged or basic with surfaces which are positively charged. Most of the aggregate available in Sri Lanka are acidic which is more hydrophilic.

6.1.1.1 Active adhesion/Wetting

As the viscosity of bitumen is high and also with poor affinity for the surface of aggregate it is difficult to coat aggregate. Cutting down the viscosity of bitumen and incorporating an adhesion promoter are the two methods of ensuring good wetting.

There are three ways of cutting down viscosity of bitumen. These methods are heating, adding solvents and emulsification. As the affinity of aggregate to bitumen is much lesser than for water, it needs less effort to displace bitumen from the aggregate surface. Poor wetting can be recognized by the presence of uncoated surfaces in mixes and early loss of aggregate from the surface dressing. Even though the aggregate is apparently well coated with bitumen a dust or water layer may prevent the contact and hence establishing the bond. There are two ways to ensure good wetting, modification to binders and modification to the aggregate surface. Aggregate are precoated with bitumen, or with a water solution of adhesion promoters, to make the surface more receptive to the bitumen. Figure 6.1 illustrates the adhesion problem with dusty aggregate and in rainy weather (Figure 6.2)

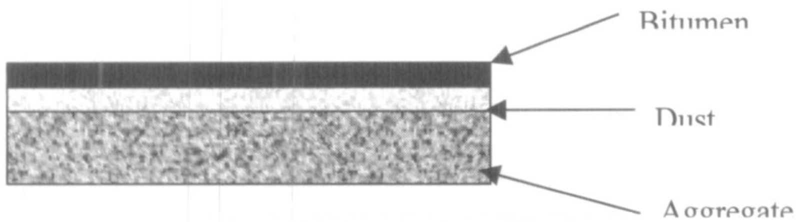


Figure 6.1; Loss of adhesion due to dust layer

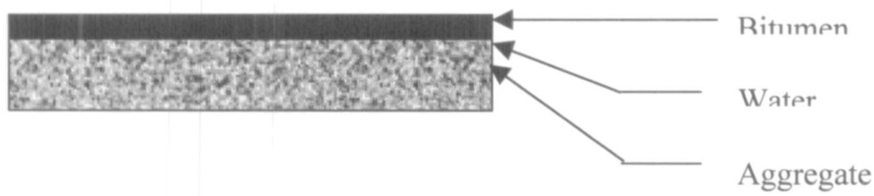


Figure 6.2; Loss of adhesion due to water

6.1.1.2 Stripping

The main reason for stripping is water getting in between the bitumen film and the surface of aggregate. Some of failures due to stripping are listed below.

1. Cracking
2. Deformation
3. A tendency for bleeding

4. Loss of structural strength
5. Raveling
6. Loss of aggregate from surface dressing
7. Pealing off seals from the underline surface
8. Uncoated aggregate surface

Stripping is the retraction of bitumen film from the surface of the aggregate. However it is the detachment of the bitumen film from the aggregate or substrate.

6.2 Function of Adhesion Promoter

Adhesion promoters are used by addition of small quantities of chemicals, which improves the chemical affinity in between bitumen and aggregate.

In most of the cases they are surface-active materials. Head groups on the surface-active materials bind strongly to the acidic aggregate surface, if the electrical charge is positive. The hydrocarbon "tails" of the molecules are compatible with the bitumen. Thus there exist a bridge action in between the bitumen and the surface which resists stripping. (Akzo Nobel. Technical Bulletin, Adhesion Promoters)

Even though the adhesion promoters can be added either to bitumen or to aggregate the accepted norm for administering adhesion agents to a surface dressing system is through their inclusion in the binder.

6.3 The Factors Affecting Bitumen Aggregate Adhesion

The factors which influence the bond between the aggregate and bitumen are numerous. However most of these factors are controllable during construction and production. Properties of the aggregate and bitumen, design properties and external factors will effect on adhesion.

6.4 Objectives of Studying Adhesion

Therefore this study was carried out in two steps; inside the laboratory and field performance having the following objectives

1. Searching for a locally available adhesion promoter/promoters.

2. Improving the adhesive properties of bitumen emulsions with aggregate by incorporating the locally available adhesive promoter.

3. Studying the performance of the road surface treatments that are carried out with the modified bitumen emulsion.

6 .5 Methodology

1. Few different samples of aggregate which are common in construction sites were collected from different quarries.

2. Coating and stripping tests ASTM D1664 and ASTM D3625 were carried out on each of the sample with CRS-2 emulsion, at different temperature, 30^{0}c, 40^{0}c and 50^{0}c.Area coated was estimated at these three temperatures.

3. Few adhesion promoters were added to CRS-2 emulsion in small quantities and repeated the tests as mentioned in step-2.

4. The test was repeated for 19mm as well as 12.5mm aggregate.

Note;

Pink Feldspar, white Feldspar, Hypersthenes, and granite were the aggregate selected for the study.

Effect of water on binder coating with and without the adhesion promoter is shown in figure 6.3.

6.6 Results and Findings

Figure 6.3 shows the graphical representation of percentage coating of coating of aggregate with bitumen emulsion and the temperature for few types of aggregate, with bitumen emulsion and the temperature for few types of aggregate, namely "Pink feldspar", "Hypersthenes", and "Granite". Graphical representation for each aggregate follows the same pattern such that the resistance is less at higher temperatures.

The figure 6.3 also indicates that the resistance to stripping depends on the type (mineralogical composition) of the aggregate. According to figure 6.3 pink feldspar is not good source of aggregate for better resistance to stripping. This was observed at the construction sites as well.

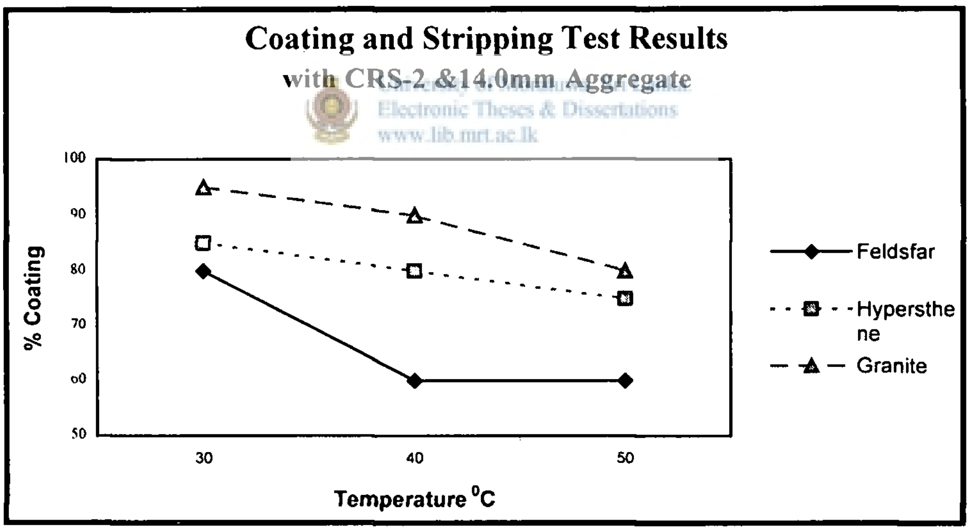


Fig 6. 3; % Coating Vs Temperature for varying minerals of aggregate.

The same test procedure was repeated with 80/100 bitumen to study the variation with binder (figure 6.4). The similar relationship could be observed but at a lesser resistance to stripping than with bitumen emulsion, which may possible due to the opposite polarity of the emulsifier and the aggregate. The strength of the attractive force is a function of the ionic nature of the aggregate.

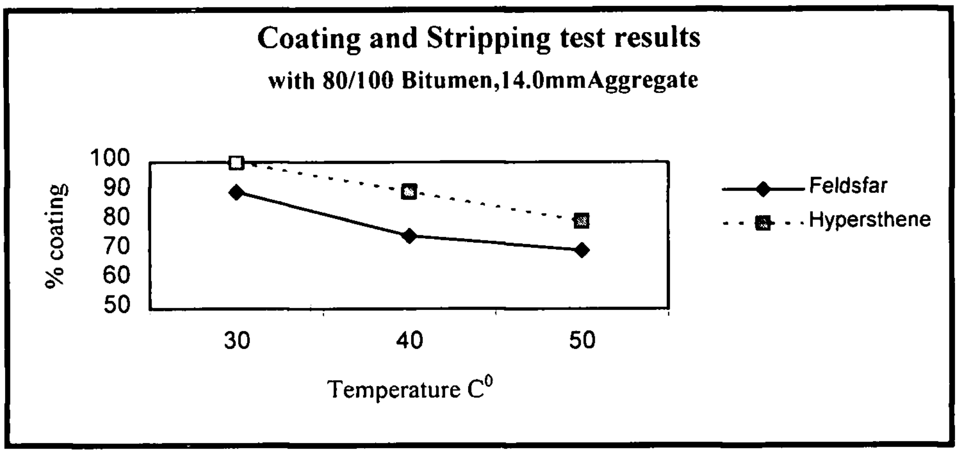


Fig 6.4; % coating Vs temperature for varying minerals of aggregate.

Research also finds that the resistance to stripping will depend on the physical parameters such as size of the aggregate, grain size of the aggregate-etc. Aggregate of larger grain size are weaker in resistance. It was identified that presence of mica which are flaky will result less resistance. Figure 6.5 and figure 6.6 show the representations of the test results.

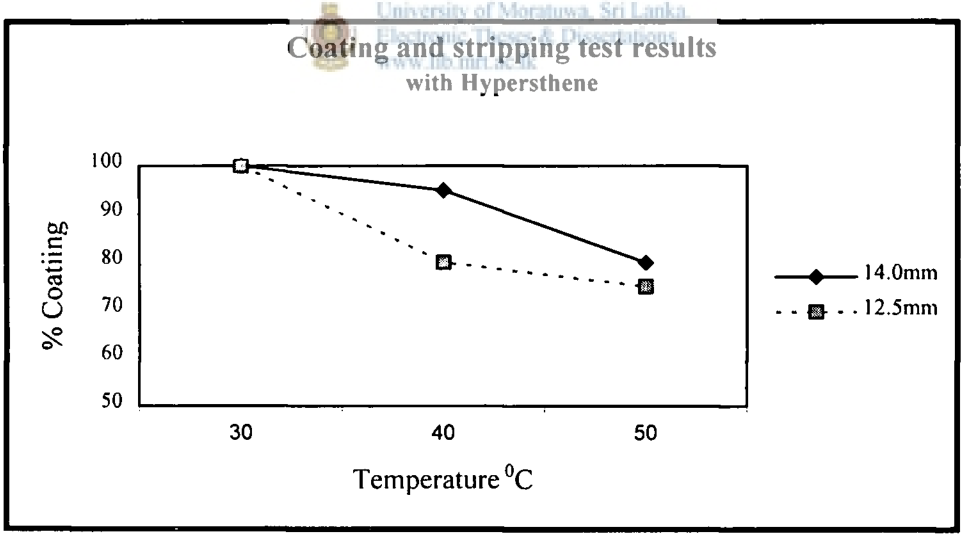


Fig 6.5; % coating Vs Temperature for different sizes of the aggregate

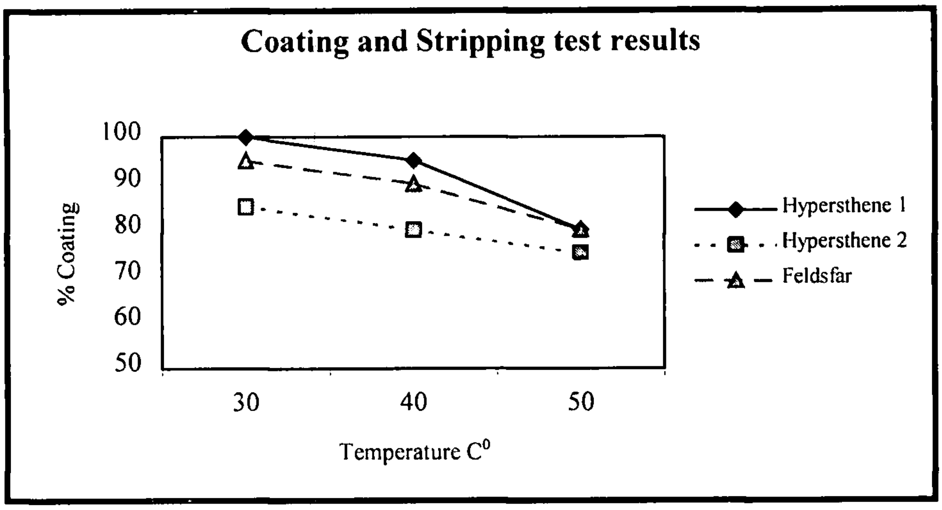


Fig. 6.6; % Coating Vs Temperature for varying grain size of the aggregate

Note; 1- small size grains

2-larger size grains

Another test for resistance to stripping, ASTM D 3625 was also carried out for the same set of aggregate and the test results are presented in figure 6.7. The test results follow the same pattern as with the test ASTM D1664 (declining resistance with increasing temperature).

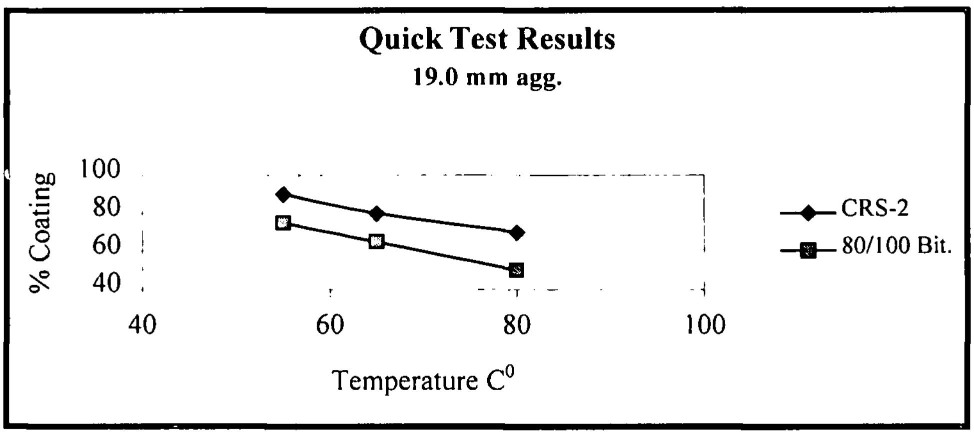


Fig. 6.7: % Coating Vs Temperature for CRS-2 and 80/100 bitumen

Note:

The above two tests are subjective in that they require visual estimation of stripped aggregate after the prescribed conditioning. They generally provide a numerical pass/fail criterion. Even though most of our aggregate passes if the test is done at standard temperature, 25^{0}C but also almost all the aggregate fails at higher temperature, especially around the local working temperature.

Therefore it is necessary to find a method to improve resistance at the working temperature. Therefore the research investigated for adhesion promoters. Few adhesion promoters were incorporated into bitumen emulsion and tested the modified emulsion using the above two testing methods. The results with the best modifier are represented in figure 6.8 & figure 6.9. The emulsion with small quantities of modifiers.

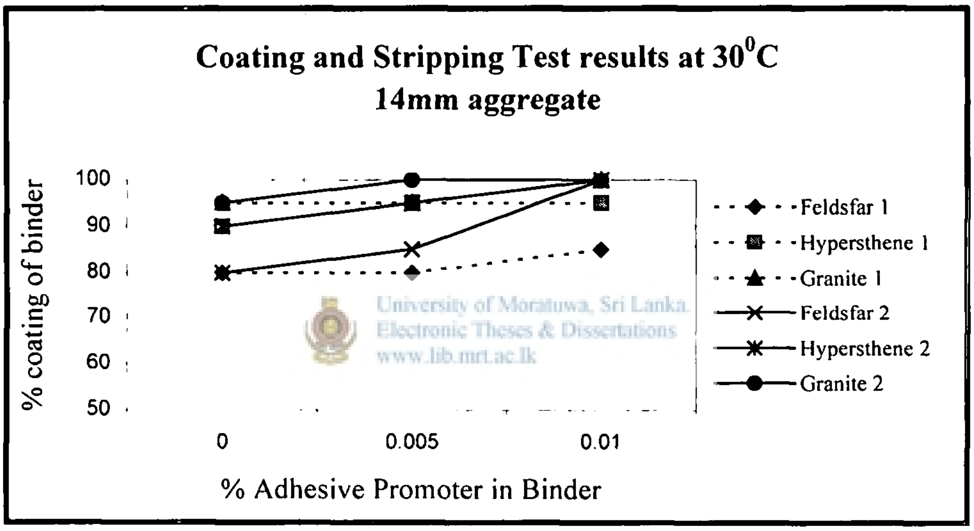


Fig 6.8: % coating "V" % adhesion coating at 30^{0}C

Note;

1 without adhesion promoter

2 with adhesion promoter

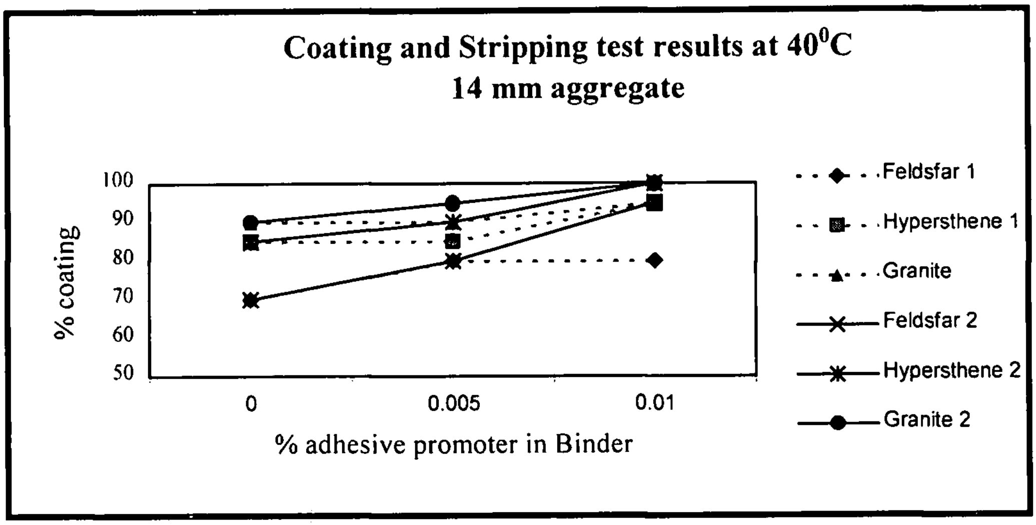


Fig 6.9: % coating "V" % adhesion coating at 40^0C

Note;

1- without adhesion promoter

2- with adhesion promoter

Addition of adhesive agents in small quantities such as 0.5% and 1.0% y weight of emulsion will improve the resistance to stripping of aggregate such that the results satisfied with the specification even at higher temperatures. ($>25^0C$)

In case of feldspar which was of course not a good aggregate for better coating (fig.6.9) might require a more quantity of adhesive agent.

6.7 Observations

1. The following figure 6.10 shows the improvement of the coating with the presence of the liquid modifier.

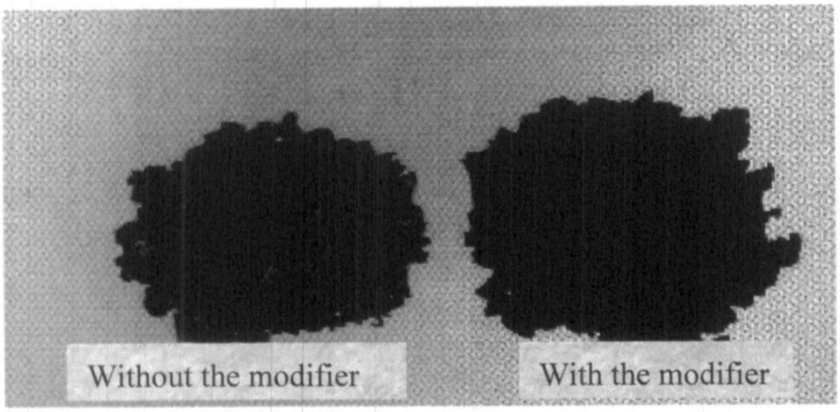


Figure 6.10: Effect of the adhesion promoter

2. The results of ASTM D3625 showed that the adhesion of CRS-2 emulsion is better than that of the bitumen. It was observed that about 50% of the area coated had been stripped under the action of the hot water if the binder was bitumen. The colour of the mix was changed from black to light brown in the case of bitumen. It was also observed that the coating had improved in considerable percentage for the mixes prepared with modified CRS-2.

3. Arising of air bubbles to the top of the water surface carrying bitumen was also observed. These air bubbles were brown in colour and hence could be assumed that they carried bitumen. It was also noted that the amount of the same was higher in the case of bitumen than CRS-2 and much less than the modified CRS-2 with the adhesive promoter-2.

6.8 Method of Incorporation

The incorporation of the adhesion promoter or the antistripping agent could be done at the manufacturing sites as well as at the construction sites.

It can be incorporated to the manufacturing plant by adding the required quantity to he soap solution (mixing with water) or through the latex pump.

It could also be added to the bitumen bowser having circulation facility or barrels of CRS-2. However sufficient mixing should be done to ensure the homogeneity of modified emulsion.

6.9 Discussion

Adhesion of bitumen/bitumen emulsion can be discussed as adhesion in the absence of water and adhesion in the presence of water.

Normally bitumen/bitumen emulsion adhere most of the local types of aggregate if the aggregate is dry and not dusty. However practically there is always a tendency for the layer of dust on the aggregate which will be coated prior to the solid surface because there exists an intermediate layer in between aggregate and the binder. (Figure 6.1). Perhaps viscosity of the binder may also increase in the presence of dust and possibly resulting in inadequate coating of the large aggregate leaving pinholes in the bitumen film. Water can penetrate in between the aggregate surface and the film of the binder and the consequent will be the stripping in rainy weather.

Adhesion problems in the presence of water arise in two ways; firstly due to the aggregate is being wet before mixing and secondly due to the effect of rain at the sites just after the construction. It was observed that there was a difficulty to coat wet aggregate which in turn detaching the layer of binder from the solid surface. Because of this incidence there would be a risk of stripping of aggregate that would take place.

Roads which were inspected after a rain showed that premature deterioration were attributed to most probably due to improper adhesion which might cause stripping of aggregate which in turn a function of the affinity of aggregate to binder and the consequent ability of aggregate to resist the displacing effect of bitumen in the presence of water. Most of the aggregate were of good resistance while some were not. Deterioration of the weaker types of coarse aggregate of variable quality and breakdown of aggregate/binder bond (possible for both and hard aggregate) are some of the reasons for premature failure.

The research was able to invent an adhesion promoter enabling higher resistance to stripping even at higher temperatures. The addition of the adhesion promoter could be done without any additional effort and also available plenty in liquid form.

Normal CRS-2 has better resistance to stripping than bitumen which may be the consequent action of bridging of cationic emulsifiers with the electrical charge of the aggregate.

The air bubbles which was observed rising from the aggregate surface with bitumen might be the air entrapped in the pores of aggregate. (ASTM D 3625). These air bubbles would have come out as a consequent of either due to film rupture which is likely to occur at the sharp edges and corners where the film can be the thinnest or incomplete coating during mixing (presence of pin holes). The study observed this character of the binder is very much less in case of modified binder.

Study showed that chemical properties as well as external properties of the aggregate had effects on adhesion between aggregate and bitumen. In other words the properties such as mineralogy, surface texture, dust, surface area, shape and moisture content and grain size showed considerable variations in resistance to stripping

6.10 Conclusions

Antistripping agent or adhesion promoter can be incorporated successfully into CRS-2 in order to reduce stripping when necessary. Feldspar, ferrous aggregate have less resistance to stripping. Chemical composition as well as external factors affects the resistance to stripping.

6.11 Concluding Remarks for Minimizing Stripping

1. Good drainage system shall be provided to the road pavement structure.

2. Dry aggregate shall be used. If the aggregate is surface dry and no moisture available in between the aggregate particle, stripping is less likely to occur.

3. Aggregate shall be thoroughly cleaned. Scalping shall be done at the crusher plant to remove the clay if available at the quarry.

4. If there is a possibility, aggregate of highly hydrophilic or less resistence to stripping shall be avoided. (Water sensitivity test)

5. Incorporation of an antistripping agent will be a solution when the use of hydrophilic aggregate is unavoidable or there is a mix of different types of aggregate varying the mineralogical composition available in the construction sites.

6. Viscosity of the emulsion shall be maintained so that proper wetting shall take place at the construction sites.

CHAPTER 7

DESIGN OF SURFACE DRESSINGS

7 .1 Introduction

Surface dressing is accepted as an effective and efficient maintenance tool that seals the road pavement against ingress of water and prevents further disintegration of the existing surface. Well-designated quantities or proportions of bitumen and aggregate to suit the pavement is required for better performance. Improper designed surface dressings may attribute additional cost because of frequent damages. Therefore the design procedure shall include selection of sufficient quality materials, asphalt and aggregate with the desired properties for a successful surface treatment project.

7 .2 Binder Considerations

Hot asphalt, cutback asphalt and asphalt emulsions can be used as the binder in construction of surface dressing. In present days the most commonly used binder is the bitumen emulsion of which water evaporates as the binder cures. This will result in a collapse of the asphalt film; effectively reducing the height of the binder as a consequent of evaporation of water.

Many local road engineers reported problems in surface dressings where the binder is asphalt emulsion. One of the main reasons is applying insufficient quantity of asphalt emulsion which may possible the variation of residual binder. This lack of binder will lead excessive chip loss and which may cause to lack of confidence in asphalt emulsions. Therefore it is very important to know the residual binder quantities that are used in the site.

According to the literature the aggregate should be embedded into the residual binder at least 70% of their height. To make this happen practically the aggregate should embed fully in the emulsion (100% filled) and will roughly reduced to two thirds filled after curing since about 1/3 of the binder will evaporate. Failure to allow emulsions to rise this height will result insufficient embedment and loss of cover aggregate as soon as the seal coat is exposed to traffic.

7.3 Cover Aggregate Considerations

When designing the seal coat, there are several factors in regard of aggregate to be considered which will play an important role in determining the quantity of aggregate and binder.

7.3.1 Shape of the particle

The shape of the aggregate will determine how they lock together on the road surface that will effect to the voids among the aggregate. More they lock together, the better the seal coat is able to withstand the load due to traffic specially turning and stopping of vehicles.

7.3.2 Bulk specific gravity of aggregate

The bulk specific gravity of the aggregate also plays an important role in determining the quantity of aggregate. The lower the specific gravity the aggregate will be lighter and hence it will take less weight of aggregate to cover a particular area of a road pavement with a unit weight of lighter aggregate than with a unit weight of heavier aggregate.

7.3.3 Aggregate absorption

The amount of binder applied to the roadway needs to compensate the absorption into existing pavement, absorption into the aggregate and also remain the required binder film on the road surface to hold the aggregate. Failure to investigate the aggregate absorption and adjust accordingly, will lead to excessive aggregate loss due to lack of embedment. Normally aggregate of different sources have different percentages of absorption. For example Limestone has high rate of absorption than granite.

7.3.4 Gradation

The gradation of the cover aggregate is important not only to determine the rate of aggregate but also to determine the rate of bitumen emulsion as it effects to maintain the voids in skeleton of the aggregate. Graded aggregate will leave little room for bitumen which may cause bleeding in consequent. The single size aggregate is the best option for seal coat.

There are advantages of using a single size aggregate. Some of these are as given below.

1. Maximum friction is obtained between vehicle tires and the pavement surface as more chips are in contact with tires.
2. It is easy to check quickly and accurately, even just after rolling and it is easy to avoid bleeding because if one particle is embedded properly all the other particles are also embedded similarly.
3. Better drainage due to clear surface channels between the aggregate particles which may allow for rapid and easy removal of water.

Graded aggregate are not preferred as cover aggregate in seal coat construction. Normally graded aggregate and less binder on larger size aggregate on the road surface may cause bleeding and loss of aggregate with time respectively.

7.3.5 Loose unit weight of the cover aggregate.

The loose unit weight (W) is determined according to ASTM C 29 and is needed to calculate the voids in the aggregate in a loose condition. Loose unit weight depends on the gradation, shape and specific gravity. Aggregate with high dust content will have the highest loose unit weight than the single size aggregate.

The air space between the aggregate particles is the only space available for the binder.

7.4 Parameters to be Considered

7.4.1 Selection of size of aggregate

The guiding principle in any surface dressing work is the size of aggregate used. This is very important to ensure the proper embedment produced by traffic forces in substrates of different degrees of hardness.

Selection of size of the aggregate in a surface dressing depends mainly on the hardness of the existing road surface. Therefore it is essential to carry out a site inspection to assess the hardness category of the existing old road surface so that the correct size of the aggregate for the particular situation may be selected. The hardness of the existing surface is determined by a probe penetrometer. Normally, smaller size of aggregate is selected for a harder surface and larger size aggregate is selected for a softer surface. Special care should be taken when using 20mm aggregate to ensure that no loose aggregate remain on the surface when the road is opened traffic as there is a risk of wind screen damage. Normally surface dressing with larger size aggregate is noisy. However the aggregate greater than 20mm is not recommended to be used in surface dressing in order to reduce noise and to prevent damages to the windscreens of cars.

7 .4.2 Selection of rate of aggregate

The quantity of aggregate is also a very important factor which provides sufficient cover to surface of binder film after rolling. Excess aggregate left on the surface will tend to spoil the dressing and may sometimes damage the windscreens of the vehicles. Therefore careful attention is to be given to select the correct rate of application of aggregate. The physical properties such as dimensions and shape of aggregate will effect on this parameter. Loose bulk density of aggregate will also effect the rate of aggregate as discussed above.

Sufficient voids among aggregate should always there on the road surface allowing binder to work up to the top so as to ensure adequate embedment of aggregate in the binder. For instance when the rate of application of aggregate is high there will be aggregate on the road surface lying incorrectly. As a consequent of this a little or no film of binder is adhered on to the aggregate. No reorientation and the minimum required of the depth of embedment of aggregate in the binder may also not possible.

7.4.3 Selection of rate of binder

Another important factor in construction of surface dressing is the rate of application of binder. This factor depends on several parameters. These are condition of the road surface, traffic on the road pavement, absorptive properties of aggregate, required minimum depth of aggregate and size and rate of application of aggregate. Climatic condition, geometric design and trees and buildings by the side of the road which cover the road sections from sun also influence and determination of rate of binder.

7. 4.3.1 Condition of the road surface

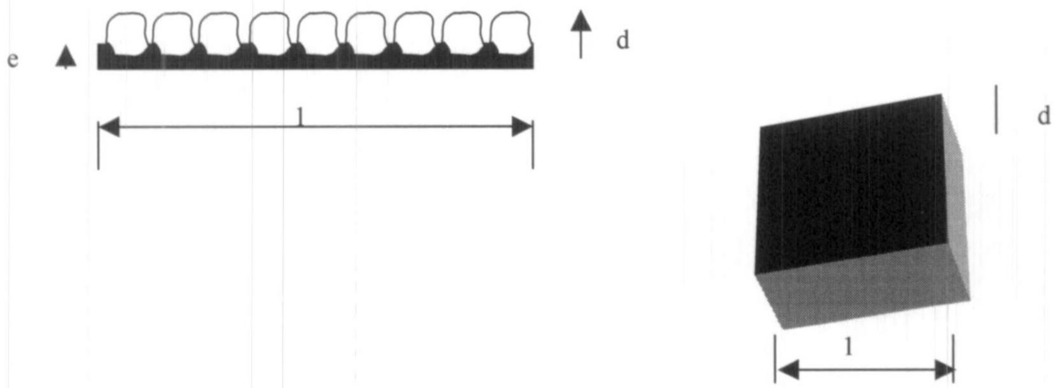
Condition of the road surface is extremely important in determining the percentage of the aggregate as well as the size of the aggregate. Generally porosity, surface texture and degree of weathering are some of the main factors to be considered in assessing the condition of the road surface. For instance when the road surface is rich in bitumen it is preferred to have a less application rate for binder because there is a tendency to bleed after the construction.

7.4.3.2 Traffic volume

The traffic volume on the road surface in terms of the number of vehicles per day, plays an important role in determining the amount of asphalt binder required to sufficiently embed the aggregate because traffic forces the aggregate reorientation and hence aggregate will lay on their flattest side. For instance when there is less traffic or no traffic, the aggregate would be laying in the same orientation as when they were rolled during construction as such the aggregate would lie taller and need more binder to achieve the desired percent of embedment. However with high traffic the aggregate would lie flatter as possible. As a consequent the seal coat will be thinner and hence the road surface may bleed with time if this factor is not taken into account.

7 .5 Determination of Percentage of Emulsion CRS-2

Step-1 Determination of percentage of asphalt



Volume of asphalt = e.d.1.1 –volume of aggregate embedded in bitumen

e = percentage of depth of embedment

d = average mat thickness mm

Volume of aggregate embedded in asphalt is calculated as below.

$$\text{Bulk volume} = \frac{\text{Bulk weight}}{\text{Bulk density}}$$

Bulk volume of the aggregate spread on the road, embedded in asphalt with average depth, ed mm is given by the following equation.

$$\text{Bulk volume} = \frac{\text{e.d.W.1.1}}{\text{Bulk specific gravity. water density}}$$

Therefore volume of asphalt in l/m^2 is calculated as per the equations below.
Density of water is 1000 kg/m^2

$$\text{Volume of asphalt} = e.d.1.1 - \frac{e.d.W.1.1}{\text{Bulk specific gravity.Water density}}$$

$$\text{Volume of bitumen} = e.d\,\{1 - \frac{W}{\text{Bulk specific gravity.water density}}\}$$

Asphalt quantity of the surface dressing is inversely proportionate to the level of traffic as discussed above as the level of embedment increases with increasing traffic as discussed above. Therefore a multiplicative type factor for the traffic should be considered.

$$\text{Volume of bitumen} = e.d\,\{1 - \frac{W}{\text{Bulk specific gravity.water density}}\}.K_1$$

Where

"K_1" stands for the factor for traffic simulation given in table 7.1. The values for "K_1" were initially taken from the asphalt emulsion manual (Asphalt Institute, 1984). These values were changed to suit the local condition of the country. As such three values were selected for the factor "K_1" and have been tried in the field. The appropriate values for the factor "K_1" will be determined by studying the performance of the field trials.

Table 7.1: Correction factor for traffic

Traffic simulation factor				
Average Daily Traffic per Lane				
Under 100	100 to 500	500 to 1000	1000 to 2000	Over 2000
0.6	0.55	0.50	0.45	0.40
0.65	0.60	0.55	0.50	0.45
0.75	0.70	0.65	0.60	0.55

Normally some pores of the aggregate surface absorbs asphalt. If the absorption is considerable there will be less quantity remains on the surface as mentioned above. Therefore a quantity for the absorption of aggregate shall be added.

By co.isidering asphalt absorption to the pores of the aggregate. $K_2=0$ for local aggregate.

$$\text{Volume of bitumen} = e.d \left\{1 - \frac{W}{\text{Bulk specific gravity.water density}}\right\} K_1 + K_2$$

And also the asphalt content varies with the condition of the road surface as discussed above. Normally highly weathered surface absorbs asphalt and vise-versa as such some value should be added or deducted depending on the construction site.

Therefore

$$\text{Volume of bitumen} = e.d \left\{1 - \frac{W}{\text{Bulk specific gravity.water density}}\right\} K_1 + K_2 + K_3$$

Where

"K_3" stands for the factor for the condition of the road surface. It was obtained from the Asphalt Emulsion manual (asphalt Institute, 1984). (Table 7.2)

Table 7.2: Correction due to existing surface condition

Description of existing Surface	Correction factor l/mm^2
Flush asphalt surface	-0.27
Smooth non porous surface	-0.14
Slightly porous slightly oxidised surface	0
Porous oxidised surface	+0.14
Bad porous oxidised surface	+0.27

Table 7 .3: Factor for present embedment

Present Embedment				
Average Daily Traffic per Lane				
Under 100	100 to 500	500 to 1000	1000 to 2000	Over 2000
0.36	0.36	0.34	0.32	0.30

Therefore

Percentage of emulsion is given below.

$$\text{Emulsion\%} = \frac{\text{Asphalt\%}}{\text{residual\%}}$$

% residual or the % of asphalt in emulsion is determined by the "*distillation test*" specified in ASTM D244.

Note:

1.60% to 70% of the voids is to be filled with the binder and at least 20% of voids should be there on the road surface after rolling and subsequent compaction even after considerable traffic. (Asphalt Emulsion Manual, manual series no. 19 3rd edition USA

2.55% to 65% is selected for the percentage filled with binder, as Sri Lanka is a tropical country. (Asphalt Emulsion Manual, manual series no. 19 3rd edition USA

3. Rolling partly reorients the aggregate particles and reduces the voids to about 30 percent Asphalt Emulsion Manual, manual series no. 19 3rd edition USA

7 .6 Determination of Rate of Aggregate

The samples of the aggregate shall be collected from the quarry and tested for following

a) Dry loose unit weight
   The dry loose unit weight shall be determined in accordance with American Society for testing of materials, ASTM C29

b) The bulk specific gravity of the same aggregate shall be determined in accordance with ASTM C 127

A plate or sample tray of which the area is known shall be taken to find out the quantity of aggregate required to cover a particular area of the road surface. Aggregate shall be laid on the plate/sample tray such that it is covered with one stone. However adequate care shall be taken in placing aggregate on the plate so that minimizing errors.

A_g = rate of spread of aggregate determined at the laboratory Kg/mm^2

d = size of the aggregate mm

W = Dry loose bulk density Kg/m^3

$$d = \frac{A_g}{W} 10^3$$

Generally it is better if the aggregate which is to be used in the construction sites is checked for its application rate.

The aggregate available in the Nagoda quarry is used for this experimental study.

7.7 Conclusion

High percentage of whipping of aggregate at the initial period is one of the main problems highlighted on local roads that were treated with DBST. One of the main reasons is higher rate of application of aggregate at the construction sites leaving insufficient space to move and reorient aggregate particles so that they lie as flat as possible. As a result of the excess aggregate laid on the road surface, the voids in between the aggregate will not be sufficient to gain proper interlocking of the aggregate of the second layer. Perhaps proper bonding of the aggregate may also not possible. This makes it easier to pick up the aggregate from the road surface due to the action of tires. If the rate is less there are more voids remaining on the road surface allowing more exposure of the binder to the sun. As a result cracks appears on the road surface because of increasing viscosity of the binder due to age hardening.

Special care should be taken to spread the correct quantity of the binder on the road surface to establish the proper bonding of the aggregate but eliminating flushing of the road surface. Insufficient binder quantity will lead thinner film thickness around the aggregate particles which will expedite the road deterioration due to age hardening when exposed to sun. This condition will become worse when the rate of aggregate is less leaving higher percentage of voids.

The formula developed calculates the optimum usage of binder to be used on the road surface to be treated considering the properties of the aggregate, condition of the road surface and the level of the traffic. The optimum values for the binder which are calculated using the formula 1 for field trials is 1.1 l/m^2 for the first seal and 1.6 l/m^2 for the second seal together with the 9.5 mm and 19.0 mm used for the 1^{st} and 2^{nd} seal at the rates of 10 Kg/m^2 and 18 Kg/m^2 respectively. The optimum values for the binder calculated with formula 2 for field trials are 1.2 l/m^2 and 1.8 l/m^2.

CHAPTER 8

DEVELOPING OF EQUIPMENTS AND TEST METHODS

8.1 A Viscometer to Check the Insitu Viscosity of Bitumen Emulsions at construction sites.

8.1.1 Introduction

Viscosity is an intrinsic parameter which is very important in case of bitumen emulsions & used for surface dressings. This property is very important to retain the binder on the road surface without flowing.

According to the test results of the samples of emulsions collected from the manufacturing plant shows that viscosity shall be modified. It was also observed that the emulsions collected from the construction sites were even worse than collected from manufacturing plant. The emulsions available in the construction site may inferior in certain properties even though the emulsion from the same batch at the manufacturing plant confirms to the specification. One of the main reasons is settling of bitumen emulsions in the storage tanks. Therefore it is necessary to test emulsions available at the construction sites. However the facilities to test the emulsions are not available in the field laboratories. The two reasons are (1) these laboratories run in small scale and (2) higher cost of the equipment. Viscometer and method to verify the binder percentage are two important tests to be provided to the field laboratories because most of the samples sent to central laboratory from the construction sites are deficient in viscosity and the binder content. (Chapter 4,Sections 4.3.1 and 4.3.2)

Normal practice is the samples are collected from the fields and sent for testing while construction is going on. This process may consume time and hence while finishing the testing of the samples construction of that particular section with the same emulsion will be over. Therefore the consequent will be inferior quality of emulsion will be used. For surface dressing if emulsion fails. Therefore aggregate embedment into the binder film will become less due to the excessive flow of emulsion even across the camber. And also the required binder quantity as per design is also not be available on the road surface, because exact binder content is not known.

A simple viscometer which can be used at the construction sites and in the field laboratories was devised and calibrated to Sayolt Furol viscosity. Therefore emulsion can be pre-checked just before the construction. If preferred binder content also can be checked in the field laboratory using the method proposed. This method will be discussed in section 8.2.

Knowing the insitu viscosity of the emulsion, an authorized person can decide weather to use the emulsion, or to modify the emulsion with viscosity modifier. Quantity of the modifier to be added will depend on how viscous the emulsion available at the site is.

This chapter discusses the insitu viscometer and the calibration with the Saybolt Furol viscometer.

8.1.2 Apparatus

The apparatus proposed consist of the following items

1. Separating funnel, 100 ml capacity and 2mm diameter slot
2. Stopwatch
3. Thermometer
4. 1 no of 100ml beaker (not essentially required)
5. 1 no of 250 ml beaker (not essentially required)

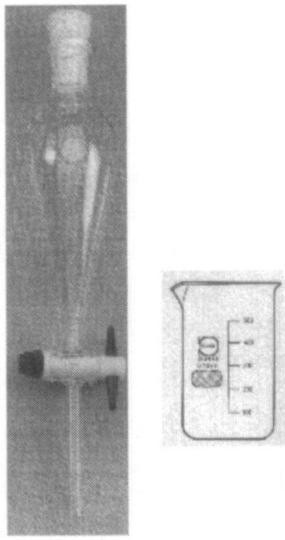


Figure 8. 1: Separating funnel used for the viscometer

8.1.3 Methodology

1. A sample of emulsion which was available at the site was taken from the bouser or sprayer.

2. The separating funnel was filled up to the line indicating the 100 ml volume.

3. Time taken is to be measured to flow 100 ml of emulsion through the slot of 2 mm and measured in seconds and recorded as the insitu viscosity.

4. The temperature of the bitumen emulsion was recorded at the time of testing.

8.1.4 Applicability of the apparatus

This apparatus can be used at any construction site without difficulty. The method of testing is simple as such no any complicated technique is involved in carrying out the test.

8.1.5 Handling the apparatus

This apparatus is portable & easier to be taken to sites. No safety hazards are involved when handling the apparatus. No additional damage to the environment is possible, as there will no heating requirement. All regional laboratories can be equipped with the separating funnel and other accessories necessary because of its less cost.

The accessories such as thermometers, stopwatches, hot plate and beakers are normally available in every regional laboratory. Therefore only the separating funnel would have to be supplied to them.

Separating funnels are made out polyurethane (unbreakable) are also available. If preferred the funnels made out of this material can be purchased.

8.1.6 Cleaning of the apparatus

Cleaning of the apparatus working with the bituminous materials is critical and hence cannot be neglected in case of designing an apparatus.

Cleaning after carrying out the test is also very easy because of its simplicity. The separating funnel can be cleaned by rinsing with water just after completing the test. If the funnel requires to be cleaned further it can be done with simply by rinsing with kerosene which is possible even after being to the laboratory.

8.1.7 Calibration of the equipment with the Saybolt Furol viscometer

1. Viscosities of the few samples at different temperatures were tested using the separating funnel. These temperatures were 40 ^{0}C, 45 ^{0}C, 50 ^{0}C and 55 ^{0}C.

2. Viscosities of the same samples were tested using the Sayolt Furol viscometer at the standard temperature.

3. Graphical representations of insitu viscosities of different samples at above temperatures against Sayolt Furol Viscosities of the same samples at standard temperature were plotted. (Figure 8.2 and table 8.4)

Calibration of the viscosity with insitu viscometer to the Sayolt Furol viscosity is required because the standard specification of RDA is based on ASTM D2397 where the viscosity is given in Saybolt Furol seconds.

It is better if the calibration is done to each separating funnel. However calibrations should be done if the brand changes or diameter of the slot changes.

A further study was carried out to study the pattern of variation of the viscosity with the insitu viscometer. 12 samples of different types of emulsions were taken for the study. (Table 8.1). Graphical representations are shown in annex 5.

The same procedure was followed with the Saybolt Furol viscometer.

The graph of the insitu viscosity against the temperature shows that there exists a peak for the viscosity around the temperature 40 ^{0}C in each graph. All the peaks were in between 40 ^{0}C to 50 ^{0}C however most of the samples show the peaks more towards 40 ^{0}C. It was also observed that the curve also very flat in this range. The regression coefficients of these polynomial curves fitted were in between 0.7 to 1 except for one sample which the value was 0.49.

The same pattern of the representation could also be observed with the Sayolt Furol viscosity and the peak exists around 42 ^{0}C. The viscosities carried out at different temperatures by using the Saybolt Furol Viscometer also follows the polynomial curve having a maximum which was very similar to the above curves. The regression coefficient of this curve was 0.745.

Surface dressing emulsions shall be sprayed at a temperature where the viscosity is high in order to retain the binder film on the surface without flowing. According to this further study of viscosity variation with the temperature it can be said that there exist an optimum range of temperature for spraying of bitumen emulsions. If emulsion is sprayed at a temperature 40 ^{0}C to 50 ^{0}C (more towards 40^{0}C is better) the viscosity may still improve.

8.1.8 Discussion

1. When the emulsion is heated water will evaporate and at the same time bitumen gets soften. Due to evaporation of water viscosity increases. At the same time viscosity decreases because of softening of bitumen due to heating. The resultant of these viscosities will be the viscosity of emulsion. At low temperature (before softening point) softening of bitumen is not that predominate. Therefore viscosity increases to a particular temperature until softening of bitumen predominate and followed by viscosity reduces. (Increase in viscosity of bitumen emulsion due to evaporation of water is lesser compared to reduction of viscosity due to softening of bitumen.)

2. It is also noticed that there is a 6 to 10 ss difference in between the viscosity done with the separating funnel and Sayolt Furol viscosity at a particular temperature. (table 8.2} and 10 to 15 ss difference to the Sayolt Furol viscosity done at the standard temperature. (table 8.2 & 8.3)

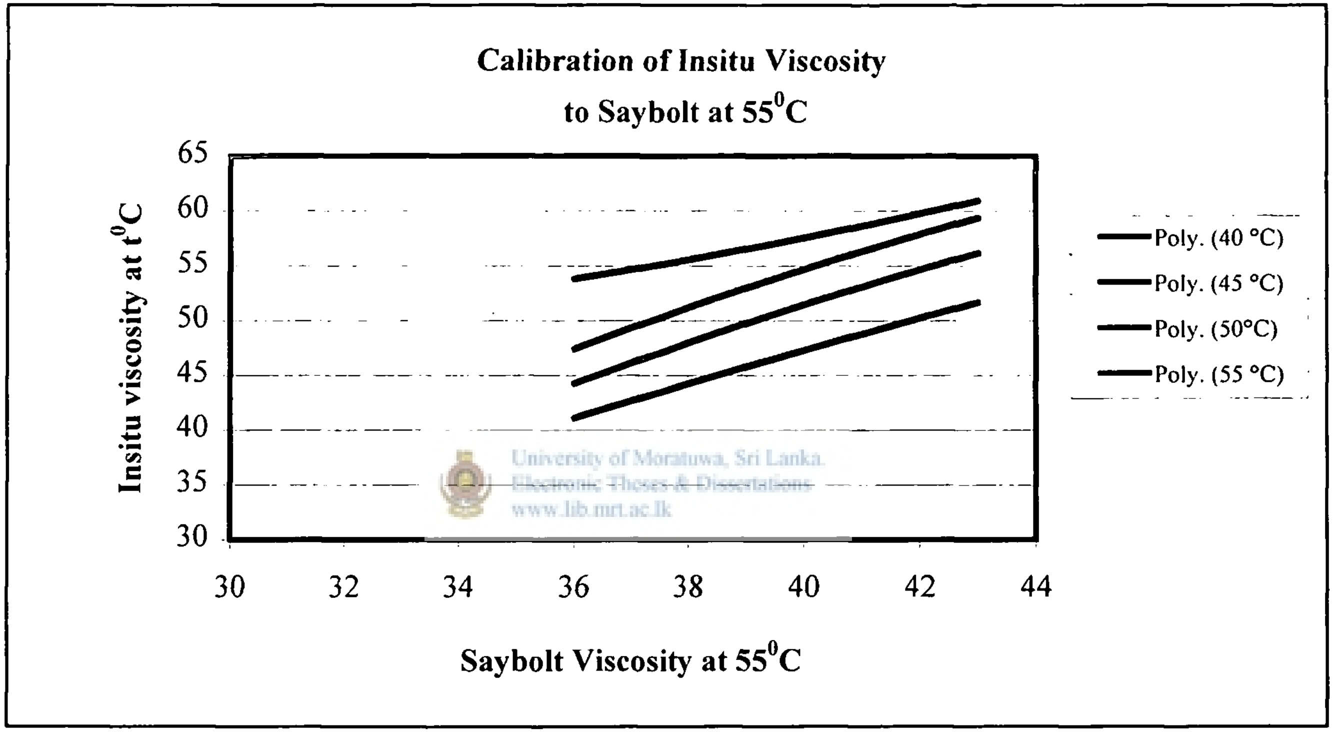


Fig. 8.2: Graphical Representation of Insitu Viscosity Vs Saybolt Furol Viscosity

Table 8.1: Variation of insitu viscosity with temperature for different samples

sample	Type		Sabolt furol	Seperating funnel						
1	CRS-2	Temp ^{0}C	55	28	35	40	42	43	50	53
		Viscosity	51	51	50	55	57	53	43	40
2	CRS-2	Temp ^{0}C	55	28	35	40	45	50	55	60
		Viscosity	37	56	58	52	50	47	45	42
3	CRS-2	Temp ^{0}C	55	28	40	45	50	56	59	62
		Viscosity	36	51	54	53	50	43	40	40
4	CRS-2	Temp ^{0}C	55	30	35	42	45	53	58	64
		Viscosity	31	36	60	63	55	46	43	40
5	CRS-2	Temp ^{0}C	55	30	35	42	46	52	58	63
		Viscosity	30	36	60	61	55	50	46	47
6	CRS-2	Temp ^{0}C	55	28	34	43	47	52	58	65
		Viscosity	34	40	45	47	46	43	40	36
7	CRS-2	Temp ^{0}C	55	30	34	44	50	54	59	62
		Viscosity	38	48	57	54	50	45	35	36
8	CRS-2	Temp ^{0}C	55	30	35	42	45	50	55	61
		Viscosity	45	60	65	60	55	46	42	40
9	CRS-1	Temp ^{0}C	55		35	40	45	50	53	59
		Viscosity	19		21	21	22	21	20	20
10	CRS-1	Temp ^{0}C	55	30	35	39	45	52	59	62
		Viscosity	18	21	21	24	22	20	19	19
11	CSS-1	Temp ^{0}C	25	30	35	40	45	50	54	58
		Viscosity	19	16	17	18	17.5	17	16	17
12	CSS-1	Temp ^{0}C	25	30	34	42	45	49	55	60
		Viscosity	18	16	17	19	18	18	17	16

Table 8.2: Calibration of insitu viscosity at temp. ^{0}t to Saybolt viscosity at standard tempertatu

Temp. ^{0}C	Item	type	viscosity ss					
40	1	insitu	46	52	54	59	55	61
45	2	insitu	45	48	50	55	54	58
50	3	insitu	43	46	46	48	52	55
55	4	insitu	42	40	45	46	49	53
55	5	Saybolt	34	36	37	38	40	43

Table: 8.3 Saybolt Viscosity at different temperatures

Item / Temp ^{0}C	viscosity ss Saybolt Furol					
	1	2	3	4	5	6
40	40	42	44	46	47	48
45	37	40	43	46	43	47
50	32	37	39	43	37	45
55	34	36	37	38	40	43

Table 8.4: Representation of Saybolt

temp. ^{0}C	Item	Type	Values of Viscosity SS					
40	1	Insitu	46	52	54	55	59	61
		Saybolt	40	42	44	47	46	48
45	2	Insitu	45	46	50	54	55	
		Saybolt	37	40	43	43	46	
50	3	Insitu	43	44	46	47	48	50
		Saybolt	32	37	39	37	43	45
55	4	Insitu	42	43	45	45	46	51
		Saybolt	34	36	37	40	38	43

Table: 8.5 Variation of Saybolt Furol Viscosity with temperature
Type: CRS-2

Item	1	2	3	4	5	6	7
Temp. ^{0}C	31.2	33.8	36.8	42.2	45.8	49.6	54.2
Saybolt	57	61	67	63	60	57	54
Insitu	64	68	72	70	65	64	60

8.2 A Method to Determine Residue Percentage in Regional Laboratories

8.2.1.Introduction

The method "residue by distillation" is used in the central laboratory to determine the percentage residue and the oil percentage.

This apparatus is not available in regional laboratories due to the cost. However these laboratories should have facilities to test the percentage residue of bitumen emulsions because most of the problems regarding the quality are reported from the construction sites.

There is another method available in ASTM D244 " Residue by evaporation" which also can be used to determine the percentage residue. Oil distillate is unable to determine by this method.

This method needs only simple glassware such as beakers and glass rods in addition to hotplate and an oven. All these are available in regional laboratories. Therefore it is sustainable to propose this test to carry out in the regional laboratories to determine the percentage residue.

However this test is so far not in practice in these laboratories. Therefore it is suggested to do a comparative study of the two residues obtained by using these two methods.

8.2.2 Methodology

1. 50 numbers of the samples of bitumen emulsions were collected and tested for the % residue using this method. Preliminary evaporation of water was done by careful heating on a hotplate (stirring while heating) followed by oven treatment at 163^0C for 1hr.(quicker path)

2. Residues of the same samples were determined by using the method of "residue by distillation."

3. A comparative study was made by analyzing the two sets of results obtained for different samples.

8.2.3 Procedure for Determination of the Residue using the Method "Residue by Evaporation" (ASTM D244 1987)

1. 50 gm of thoroughly mixed bitumen emulsion was taken into each of three beakers of size 100ml. Each beaker had been previously weighed with a glass rod.

2. Preliminary evaporation of water was done by heating on a hot plate.

3. Then the samples were kept in an oven in which the temperature had been adjusted to 163 ^{0}C (163 ^{0}C +2.8 ^{0}C) for two hours.

4. Finally the beakers were removed from the oven and stirred the residue thoroughly.

5. These samples were again kept in oven for another 1 hour and were allowed to cool to room temperature and were weighed with rods.

Note: Care should be taken to prevent loss of asphalt from beaker through foaming or spattering or both.

8.2.4 Alternative method (ASTM D244 1987)

Preliminary evaporation of water can be done by careful heating on a hotplate (stirring while heating) followed by oven treatment at 163^{0}C for 1hr. This method was done, as it is easier and quicker.

8.2.5 Calculation

% Residue = (A-B)/50 %

Where A = Weight of beaker, rod and residue gm

B= Tare weight of beaker and rod gm

The percentage of residue by evaporate is taken as the average of the three results.

8.2.6. Results and findings

The statistical analysis shows that there is no variation in the results in between these two test methods. The results of the tests are given in annex-6.

8.2.7 Statistical calculation

The residues obtained from both the tests are tabulated in the table 8.6 The difference between the percentage residues lie within +1% and –1% in most of the cases. The statistical analysis done on the samples are shown as below.

N = number of samples =50

Hypothesis: - Assume population mean =0

Standard Deviation of the 50 numbers of samples =0.927802

(For the samples shown in table 3 of appendix 5)

Calculated mean =0.42

(For the samples shown in table 6 of appendix 5)

By carrying out the "Z" test

The value obtained for Z, Z=2.967

Therefore degree of confidence =99.85

Therefore it can be said that with a level of confidence of 99.85% the "residue by evaporation" test could be used to determine the percentage of residue instead of "residue by distillation" test to determine the residue percentage of emulsion.

8.2.8 Discussion

The residue by evaporation test can be used successfully to determine the residue percentage of emulsion not only in the regional laboratories but also in central laboratories. However in the central laboratory distillation test is carried out because to determine both the residue as well as the water content in emulsion. In the regional laboratories residue percentage is the most important parameter to be known.

8.3 Laboratory Test to Determine the Rate of Aggregate at the Site.

8.3.1. Introduction

Rate of aggregate and also rate of binder are that important for the quality of the surface dressing. The rate depends on the shape of aggregate and its loose bulk density. The quantity of aggregate applied such that it must be sufficient to cover the surface of the binder film after rolling. Excess aggregate left on the surface will tend to spoil the dressing, as there is no sufficient space for binder to fill. And also these particles may remove from the surface and hence will damage to windscreens of the vehicles. Therefore it is essential to determine the rate of application of a particular aggregate prior to commence the surface dressing so that the aggregate spreaders can be adjusted accordingly.

A laboratory test has been proposed to determine the rate of aggregate with which the construction will be done.

8.3.2. Methodology

1. Dry loose unit weight of the aggregate was measured according to ASTM C 29.

2. A plate or board of known area was used for this test. Normally a tray of 250mm*250mm outside dimension was used to carry out this test.

3. The aggregate, which was used at the construction site, was spread on the board so that the bottom of the board was covered with a single layer of aggregate.

4. The weight of the aggregate on the board was taken. The weight of the aggregate used was divided by the inner area of the plate. This gave the rate of spread of aggregate and was calculated in kg/m^2.
5. Average depth of the mat was also calculated and this value was again used in the calculation of the rate of binder.

6. 5 numbers of tests were done and average of these five values was taken as the rate of aggregate. (For the accuracy of the test)

8.3.3. Apparatus

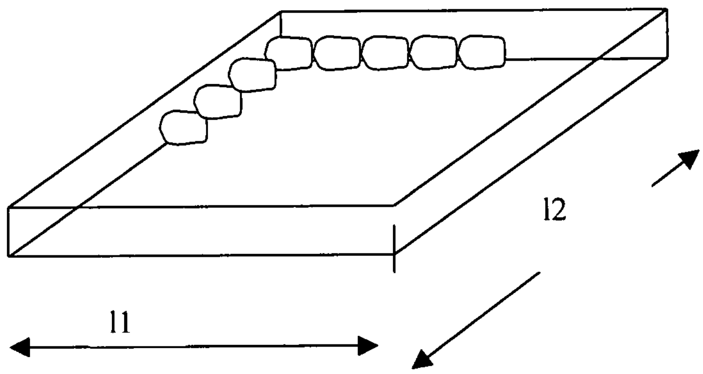


Figure 8.4; Board test

8.3.4. Calculations

Weight of the tray	= w1 kg
Weight of the tray +aggregate	=w2 kg
Therefore weight of the aggregate	=(w2-w1) kg
Area of the board	=A m^2
Rate of spread of aggregate	=(W2-W1)/A kg

8.3.5 Results of the board test

Note: the test was repeated five times and recorded as one item.

The results carried out for 19 mm, 9.5 mm are given in table 8.6

8.3.6 Conclusion

The rate at which the aggregate is spread depends on their size, shape and specific gravity.

Majority values obtained for 19 mm aggregate when it used as the first seal lies in between 15.0 kg/m^2-17 kg/m^2. As local roads are not smooth in most of the cases the values for the rate of aggregate are proposed to higher side than the laboratory value.

Similarly almost all the values (table 2 of annex 6) obtained for 9.5 mm aggregate when it is used as the second seal of 19.0 mm aggregate lies between 9 kg/m^2-11 kg/m^2

When the tolerance is allowed at the construction sites these values are shown in the following table.

Table 8.6 Rate of application of aggregate

Nominal size of aggregate mm	Rate of application kg/m^2
9.5 (second seal)	10±1
19 (First seal)	17±2

CHAPTER 9

PERFORMANCE STUDY ON THE FIELD TRIALS

9.1 Introduction

Field trials were carried out as part of the research with a view to carry out a performance study as well as to study the cost effectiveness of the research findings.

The trials were done on the internal roads of the University of Moratuwa (UOM) and on Badulla Karametiyagara Mahiyanganaya Road, which is a rural high traffic road carries about 10,000 average daily traffic (ADT) per lane in Uva Province.

These trials were carried out to test the effectiveness of the modified binder, adhesion promoters, effect of rolling, and for verification of the formula derived for designing the road surface dressings. Sixteen sections were done on the internal roads of UOM and twelve sections were done on the Badulla site with different parameters in the design.

The study gathered a large amount of condition data from surface seals at different time intervals for all the test sections. The effectiveness of binder as well as the defective modes of the surface dressings are being analysed. Findings regarding the data gathered for the internal roads of UOM during the period from October 2001 to April 2003 and for Badulla from February 2002 to April 2003 are outlined.

9.2 Objectives of the Performance Study

The following main topics were investigated by the seal performance study.

1. The effectiveness and the effect on whole life cost of modified binder, adhesion promoter to reduce the stripping which is one of the main problems on local roads.

2. The effect of different sizes and grades of aggregate on seal performance including minimizing stripping and avoidance of bleeding.
3. The effectiveness of emulsion manufactured using 60/70-penetration grade bitumen as the base binder.
4. Feasibility of applying the steel roller during construction of chip seals.
5. The appropriate resealing frequency of different districts.

9.3 Method of Investigation

Field inspection record sheet outlining the detailed procedures for site inspections and providing large areas of data recording were initially prepared. Using these inspection reports a summary sheet was prepared and provided in annex....

9 .4 Data Collection

The actual data collection involved recording the details of the pavement and temperature, speed limit, age of the road, aggregate size and source. For the bituminous binder the data was collected for binder type. The strength and the condition of the pavement were almost same for one site. Frequent visit to the sites were made for inspections.

9.5 Rating Systems

A numerical coding system for the various rating characteristics was adopted as much as possible to allow for subsequent sorting and analyses of data. A rating of zero was given to the most desirable condition and plus or minus five to the most undesirable conditions. Intermediate conditions were also selected.

9 .6 Analysis of the Data

All data has been entered into a Microsoft XL –worksheet, keeping each site separate. One of the main requirements was to analyse the change the parameters of the trial sections measured with increasing age.

9 .7 Variation of Parameter Charts

These charts provide a simple pictorial view of the data. They show the variation in rating of each parameter at each site.

Trend analysis charts were prepared where relevant for all parameters. The average rating measured for the parameter is plotted against the age.

The charts allow the following to be analysed.

1. Uniformity of the parameters with increasing age.
2. Change of the parameters with age.
3. Variability between sites.

Table 9.1 Mosaic and appearance from initial construction at UOM

Condition	Rating	Designed surface dressing					
		Normal bit. emulsion		Modified bit. emulsion		Bit. Emulsion 60/70 Bit.	
		Roller+	Roller-	Roller+	Roller-	Roller+	Roller-
Lean	5	0	0	0	0	0	0
Loose	3	0	10%	5%	5%	0	0
Normal	0	80%	70%	70%	80%	60%	80%
Tight	-3	10%	15%	15%	10%	30%	20%
Choked	-5	10%	5%	10%	0	10%	0

Note1

Roller +; application of the tandem roller

Roller –; no application of the tandem roller

Bit; bitumen

Table 9.1 shows the approximate area of the conditions of the road surface done according to the proposed designed method. Trial sections were tried according to the present practice and according to the proposed design method.

It was observed in present practice the aggregate spread was tight just after spreading of the aggregate by the spreader. Due to manual spreading this condition became worse. Applying a steel roller after the pneumatic roller is also in normal practice.

Conditions were still worse with the application of the tandem roller. Aggregate were crushed under the steel roller and patches of choked crushed aggregate could be observed throughout the section. Trial sections done according to the designed method were seemed to be normal except in few locations. However the uniform appearance of the surface was changed due to crushing aggregate under the steel roller.

Table; 9.2 Mosaic and Appearance from initial construction, Badulla

Condition	Rating	Designed surface dressing					
		Normal Bit. Emulsion		Modified Bit. Emulsion		Bit. Emulsion 60/70 Bit.	
		Roller+	Roller-	Roller+	Roller-	Roller+	Roller-
Lean	5	0	0	0	0	0	0
Loose	3	0	0	0	10%	0	10%
Normal	0	80%	90%	80%	85%	75%	75%
Tight	-3	10%	10%	20%	5%	15%	15%
Choked	-5	10%	0	0	0	10%	0

Table 9.2 shows the appearance of the aggregate spread done on Badulla Mahiyangana road. The same observation as the roads in UOM premises could be made on these trial sections.

However the mosaic appearance of the aggregate spread could not be observed as the control section had been surface dressed just before the research sections were started.

9. 8 Bleeding During Service Period UOM

Table 9.3 Bleeding during services, UOM

Condition	Rating	Designed surface dressing					
		Normal Bit. Emulsion		Modified Bit. Emulsion		60/70 Bit. Emulsion	
		Roller+	Roller-	Roller+	Roller-	Roller+	Roller-
X>1	5	0	0	0	0	0	0
2/3<X<1	3	15%	5%	20%	15%	20%	10%
X =2/3	0	75%	85%	70%	75%	65%	80%
1/2<X<2/3	-3	10%	10%	10%	5%	15%	5%
X<1/2	-5	0	0	0	5%	0	5%

X indicates the height of the bitumen film in contact with the aggregate particle

No appearance of flushing the road surface could be observed during the period of nearly two years. However more aggregate whipped off from the places where the aggregate was crushed under the steel roller. These patches have the tendency to bleed with time due to the removal of aggregate as well as reduction in the height of the aggregate due to crushing.

Table; 9.4 Bleeding during services, Badulla

Condition	Rating	Designed surface dressing					
		Normal Bit. Emulsion		Modified Bit. Emulsion		60/70 Bit. Emulsion	
		Roller+	Roller-	Roller+	Roller-	Roller+	Roller-
X>1	5	0	10%	35%	25%	5%	5%
2/3<X<1	3	40%	20%	30%	40%	30%	25%
X =2/3	0	60%	70%	20%	35%	65%	70%
1/2<X<2/3	-3	0	0	15%	0	0	0
X<1/2	-5	0	0	0	0	0	0

Table 9.4 shows the area of the road surface where the colour of the road surface is darker. The rectification of the existing road surface was done by coldmix.in most of the places. These cold mix has emulsion percentage around 6.5% to 7.0% by weight of the aggregate which may be towards higher side of binder.

The almost all the places rectified with cold mix were darker than the places where the rectification done with blended aggregate.

9.9 Stripping of Aggregate During Services

Table; 9 5 Rate of Stripping, UOM

Condition %	Rating	Designed surface dressing					
		Normal Bit. Emulsion		Modified Bit. Emulsion		60/70 Bit. Emulsion	
		Roller+	Roller-	Roller+	Roller-	Roller+	Roller-
Y<10	5	10%	10%	15%	15%	5%	15%
10<Y<20	3	70%	75%	80%	80%	85%	75%
20<Y<30	0	20%	15%	5%	5%	10%*	10%*
30<Y<50	-3	0	0	0	0	0	0
Y>50	-5	0	0	0	0	0	0

* More aggregate were spread due to a mechanical problem of the spreader. The rate of removal of that area was high.

Y; Rate of stripping of aggregate.

Whipped off aggregate which was at the side of the road was collected after two weeks and the rates of whipping off were calculated. The approximate areas which the sections belong to different categories are shown in table 9.5. The least quantity of the aggregate whipped off could be observed from the section done with the modified CRS-2 of which the base binder was 60/70-penetration grade bitumen. However the sections done with modified CRS-2 had considerably less quantity of whipped off aggregate. These values were marginally above 10%. More whipped off aggregate could be observed from the patches crushed under the steel roller.

Table; 9 6 Rate of Stripping, Badulla

Condition %	Rating	Designed surface dressing					
		Normal Bit. Emulsion		Modified Bit. Emulsion		60/70 Bit. Emulsion	
		Roller+	Roller-	Roller+	Roller-	Roller+	Roller-
Y<10	5	20%	5%	15%	15%	15%	20%
10<Y<20	3	70%	80%	80%	80%	85%	80%
20<Y<30	0	10%	15%	5%	5%	0	0
30<Y<50	-3	0	0	0	0	0	0
Y>50	-5	0	0	0	0	0	0

The research assistant attached to provincial director calculated the rate of whipping of aggregate from the road sections under research. According to the data the least quantity was observed from the sections done with modified CRS-2 which the base binder is 60/70-penetration grade bitumen. Table 9.6 shows the summary of the area which belongs to different category of whipping off aggregate. However rate of whipping off is less on the road sections where the tandem roller was applied than the sections where the tandem roller was not applied as a consequent of embedment of aggregate into the cold mix used for the rectification. The control section had been done with the immediate application of the sand seal hence whipping off was not possible.

9.10 Binder Spray Rates

Binder spray rates are often low compared to the designed values in case of present practice. However the binder rates depend on the geometry of the road such as steep bends, grades, traffic and condition of the road surface etc. Normally the rates of binder in case of surface dressings used in general practice are 1.1 l/m^2 for the first coat and 1.4 l/m^2 for the second coat. For the sections done according to the proposed design method are 1.1 l/m^2 and 1.2 l/m^2 for the first coat and 1.6 l/m^2 and 1.8 l/m^2 for the second coat. The specimen calculation is shown in 9.17.

The results of the rate tests carried out for CRS-2 are given in annex 8.

9.11 Binder Level

It is expected that the binder level at a site would not normally be time dependent unless continuous binder absorption will be a problem. Excessive embedment will be a problem for pavements with softer pavement material or for the pavement which have been bleeding for some years. It is assumed that the sections selected for the study are free from these problems.

9.12 Binder Ductility

Binder ductility was measured by using a non standard test. Stones were removed with a spatula of standard size. A tail could be observed where it touches to the substrate and the length of the tail gives an indication how ductile the binder at the time of the removal. Sometimes this tail takes a form of a string which indicates that the binder is more ductile as well as of more adhesive at the time of removal.

Binder ductility was measured as the length of the tail measured in mm. Low or no ductility is considered if the length is less than 5mm. If the length is in between 5 and 20mm it is considered as the minimal ductility, medium ductility is when the length is 26 to 100mm and extreme ductility is considered if it is greater than 150mm.

Extreme care was given to carry out at the same temperature. Stones from few sections on the internal roads of UOM were removed and observed. The length of the tail was about 10mm in many cases and 20 mm on Badulla –Mahiyangana road.

9.13 Condition of the Aggregate

Condition of the aggregate was assessed by visual examination and also by comparing photos.

A rating of 5 is given severe breakdown of particles. A rating of 3 is given for breaking down of particles. If there is no breaking down or polished aggregate particles the condition is satisfactory and 0 is considered. If some polished aggregate are visible the rating given is –3 and –5 is given for severe condition of polished aggregate.

Breaking down of aggregate was observed under the steel roller only. No further breaking down could be observed under the action of traffic.

9.14 Condition of Seal

Table 9.8; Condition of the Seal

Description	Surface Texture Depth	Scale
Bleeding (b)	< 0.7	5
Smooth (s)	0.7-1.1	3
Matt (m)	1.2-1.6	0
Hungry (h)	1.7-2.4	-3
Very Hungry (VH)	>2.4	-5

Surface texture depth was measured in few locations on road trials done on the internal roads of UOM premises.

Table; 9.9 Surface texture measurement.

Texture	1month	3months	6months	Year	15 months
No modifier	2.2	2.0	2.1	1.9	2.0
Modified	2.0	1.9	1.8	1.6	1.6

9.15 Cracking

Study of cracking was carried out by visual assessment or by photo study.

Level of cracking is defined as
Level of cracking/100m = length of cracking * 100

The cracks types were categorized as meandering, transverse, longitudinal, diagonal, and slippage and a rating of 1,2,3,4and 5 was assigned to them respectively. However no cracks could be observed on the research sections of both sites.

9.16 Crack Widths

This study was done by visually assessing the crack width or by studying the photos. Crack width gauges were also supposed to be used when necessary. However there were no cracks appeared neither on the internal roads of UOM premises nor on Badulla Mahiyanganaya road.

9.17 Specimen Calculations

First seal

$$\text{Volume of asphalt} = e.d\left\{1 - \frac{W}{\text{Bulk specific gravity}}\right\} K_1 + K_2 + K_3$$

(Refer: the equation given in chapter 7, Design of Surface Dressing)

Formula 1

Traffic category 1000-2000 vpd
e = 0.32
k1 = 0.60
k2 = 0
k3 = 0
d = 10.8 mm

$$\text{Volume of asphalt} = 0.32 * 10.8 * \{1 - \frac{1405}{2.65 * 1000}\} * 0.60 + 0 + 0$$

$$= 0.975 \text{ ltr/m}^2$$

Therefore

$$\% \text{ \% Emulsion } = \frac{0.975}{0.65}$$

$$=1.5 \text{ l/m}^2$$

Second Seal

$$\text{volume of asphalt } = 0.32 * 8.4 * \{1 - \frac{1410}{2.65 * 1000}\} * 0.60 + 0 + 0$$

$$= 0.755$$

% Emulsion = 1.2 l/m^2

Therefore total quantity of emulsion = (1.5+1.2) l/m^2

= 2.7 l/m^2

For the first seal

% Emulsion $= \frac{40}{100} * 2.7 \text{ l/m}^2$

$=1.1 \text{ l/m}^2$

$=1.2 \text{ l/m}^2$ (allowing for wastage)

For the second seal

% Emulsion $= \frac{60}{100} 2.7 \text{ l/m}^2$

$= 1.7\ l/m^2$

$= 1.8\ l/m^2$ (allowing for wastage)

Similarly

Formula2

Traffic category 1000-2000 vpd

First seal

$$\text{Volume of asphalt} = 0.32 * 10.8 * \{1 - \frac{1405}{2.65 * 1000}\} * 0.55 + 0 + 0$$

$= 0.893\ l/m^2$

e = 0.32

K1 = 0.55

K2 = 0

K3 = 0

d = 10.8mm

$$\%\ \text{Emulsion} = \frac{\%\text{asphalt}}{\%\text{residue}}$$

Therefore

$= 1.37\ l/m^2$

$$\%\ \text{Emulsion} = \frac{0.893}{0.65}$$

$= 1.4\ l/m^2$

Second seal

$$\text{Volume of asphalt} = 0.32 * 8.4 * \{1 - \frac{1405}{2.65 * 1000}\} * 0.55 + 0 + 0$$

$= 0.694\ l/m^2$

$$\%\ \text{Emulsion} = \frac{0.694}{0.65}$$

$= 1.06\ l/m^2$

$= 1.1\ l/m^2$

Therefore total quantity of emulsion $= (1.4+1.1)\ r/m^2$

$= 2.5\ l/m^2$

For the first seal

% Emulsion $= \frac{40}{100} 2.5\ l/m^2$

$=1.0\ l/m^2$

$=1.1\ l/m^2$ (allowing for wastage)

For the second seal

% Emulsion $= \frac{60}{100} 2.5\ l/m^2$

$= 1.5\ l/m^2$

$= 1.6\ l/m^2$ (allowing for wastage)

9.18 Performance of the Sections Done at Badulla- Mahiyanganya road

Basically there are 6 sections. Each section has two sub sections, a and b depending on the application of the steel roller (tandem roller). Other than that all the construction techniques as well as the materials are same for all the sections.

Table; 9.10 Summary of the parameters, Section 1,2,3

Description		Sub section					
		1a	1b	2a	2b	3a	3b
1st seal	CRS-2 %	1.1	1.1	1.2	1.2	1.2*	1.2*
	Agg. %	18	18	18	18	18	18
2nd seal	CRS-2 %	1.6	1.6	1.8	1.8	1.8*	1.8*
	Agg. %	11	11	11	11	11	11
Whipping of agg.		11.04	9.46	8.16	8.26	7.02	8.02
Bitumen type		80/100					

* Modified binder

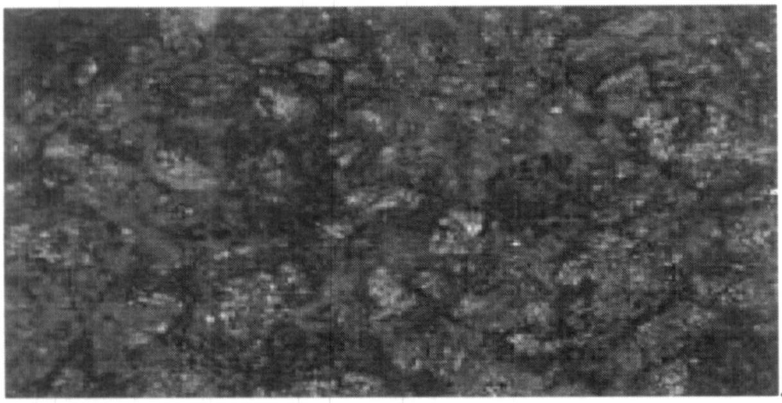
9.18.1 Section 1

9.18.1.1 Condition of the road section

The full width of the road had been rectified with blended aggregate. The rectified road surface was appeared to be normal. Deformations where binder could stagnate were not observed. And also there was no excess binder. Therefore factor for the condition of the road surface was considered as zero (refer table; 7.2). Both the subsections were flat and straight

The aggregate whipped off was collected after ten days where during mean time heavy rain was received. These values are tabulated in table; 9.10.
Frequent observations of these two sections were able to conclude that the performance of the same was very good in all the respects that tried to evaluate the performance of the sections.

However there was a localized area around 2 m^2 on section 1b on the culvert 2/4, where the rectification had been done with cold mix.



Fig; 9.1 Condition of the road surface after 1 year

9.18.2 Section 2

Rate of binder and the rate of aggregate used in the construction of 1st seal and the 2nd seal are given in table 9.10. Rate of whipping off aggregate is also given in table 9.10.

9.18.2.1 Conditions of the road sections

The entire road section had been rectified with blended aggregate for the full width.

The appearance was so normal; there were no deformations where binder could collect as well as there were no any signs to conclude the surface was rich in bitumen. The road section was approximately flat and straight and it was seemed that there were no such drainage problems. The shoulders were also clear such that no any dumps on them.

The aggregate whipped off was collected after 4 days where heavy rain was received during the mean time. These values are tabulated in table 9.10.

Crushed aggregate could be observed on the road surface and at the side of the road in case of the section 2a where steel roller was engaged.

The performance of the section 2a was better compared to section 1a and 1b. A patch of about 10-20m long and 0.5m wide of rich bitumen could be observed somewhere close to middle where the rectification had been done with cold mix. There were so many slight deformations within section 2b where binder could collect. These low elevation spots have flushed while the high spots were not flushed. These high spots were of lean appearance, less binder (x<2/3). The rectification had also been done with premix at this area of the section 2b.

Figure 9.2; Schematic diagram of a bad section, Section 2b

9.18.3 Section 3

This section was done by using the modified CRS-2 with 1% of viscosity enhancer. The base binder was 80/100 bitumen. The rate of application of CRS-2 and the rate of application of aggregate are shown in table 9.10.

The road section was flat and straight. There were many numbers of locations of small areas which had been rectified with cold mix in both the subsections.
There were lots of minor deformations in which binder can collect through the road section.

Whenever designing the quantity of the binder for the road section the condition of the rectified surface should be considered and the adjustment should be done accordingly to suit to the site. However it was in practicable to adjust the sprayer bar and nozzles and even the speed of the sprayer for such small areas which had been rectified with cold mixes. Almost all these locations looked like flushed.

The aggregate stripped off to the side of the road surface was collected after few days during which heavy rain was received to the construction sites and these values were recorded in table 9.10. It should also mention that the construction was also done in a cloudy weather.

Crushed aggregate were not that much as in the case of the other sections, 1 and 2 where most of the part was done with blended aggregate. It could also be observed that the section with the steel roller was worse than the section without the same. Higher embedment of aggregate could be observed and binder collected to the spots of low elevation was apparently with high binder content. Humps which were at higher elevation were of lean appearance.

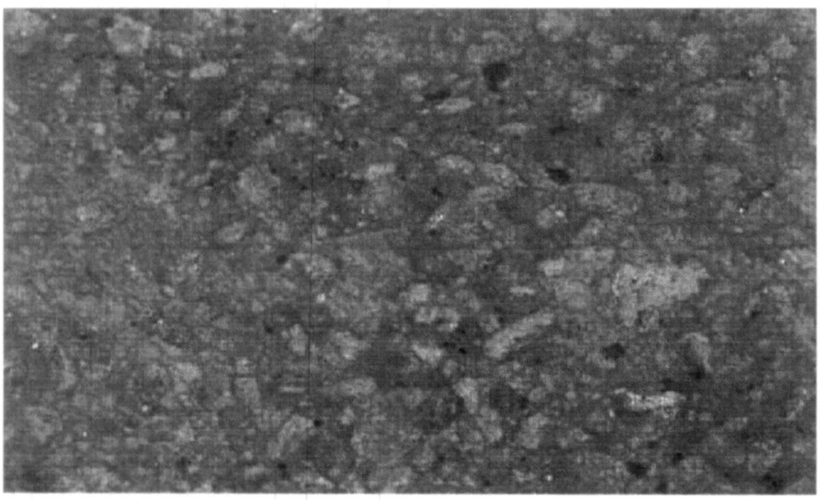


Figure 9.3: Condition of the road surface after 1 year

9.18.4. Comparative study of the sections 1, 2 and 3

Sections 1 and 2 performed very well. Section 2 performed better than the section 1 except the location done with cold mix. Stripping of aggregate was determined for all the three sections. Whipping off aggregate of section 2 was lesser than that with section 1 where the formula 2 was used for the design. However the least rate of whipping off was observed from the section 3 where modified binder was used.

It was difficult to compare these sections because of the non-uniformity of rectification work done to the substrate and due to the undulations of the existing road surface.

Generally sections which were rectified with cold mix were seemed to be flushed compared to the sections done with blended aggregate.

The recipe of the cold mix used at that time contained approximately 7.0% of CSS-1 emulsions and the quantity of water 5.0% -5.5% by the weight of aggregate. There are excess binder in the cold mix.. There fore the excess of binder may work to the top and the surface may bleed with the local tropical condition of Sri Lanka. It was clearly visible that the locations underneath which were rectified with cold mix has worked up to the top of the road surface.

As the run off is less when the viscosity increases more bitumen will retain on the road surface in case of modified CRS-2 than in case of normal CRS-2. Visually the section 3 was dark in colour than in section 2 where there was no cold mix. Therefore it can be suggested to use the formula 1 which gives the lesser quantity of CRS-2. However it is difficult to propose to change or reduce the CRS-2 content by studying the performance of road sections during short period.

9.11: Summary of the construction parameters

Description		4a	4b	5a	25b	6a	6b
1st seal	CRS-2 %	1.1	1.1	1.2	1.2	1.2*	1.2*
	Agg. %*	18	18	18	18	18	18
2nd seal	CRS-2 %	1.6	1.6	1.8	1.8	1.8*	1.8*
	Agg. %	11	11	11	11	11	11
Whipping of agg.%		9.8	10.7	8.33	11.33	6.4	7.64
Bitumen type		60/70					

9 .18.5 Section 4

This section also comprises of two sub sections,4a and 4b depending on the application of the steel roller. The base binder is 60/70 bitumen and CRS-2 emulsions with 65% by total weight was used as in the previous sections

Formula 1 where k1= 0.55, k2 = 0, k3 =0 and e=0.32 was used. The percentage of emulsion and the percentage of aggregate for the first seal were 1.1 l/m^2 and 18 kg/ m^2 and for the second seal 1.6 l/m^2 and 11 kg/ m^2 respectively. Both the sub sections flat and located on a slight bend. R 580.

Most of the rectification work, specially on and close the culverts was done with cold mix.

The aggregate stripped off to aside of the road was collected after few days. These values were 11.04% for the section 4a and 9.46% for the section 4b.

However there was a localized area around 2 m^2 on section 1b on the culvert 2/4, where the rectification had been done with premix.

The aggregate and binder used in section 4 is shown in table 9.11.The rate of whipping off also as shown in that same table. Formula 1 was used for the calculation of rates of CRS-2. Both the sub sections flat and situated on a slight bend. R 580

9.18.5.1 Condition of the road section

The aggregate stripped off to aside of the road was collected after few days. These values were shown in table 9.11.

Most of the rectification work, especially on and close the culverts was done with cold mix. An isolated spot of high rate of whipping off could be observed just at the cross road

There was a localized area around 2 m^2 on section 4b on the culvert 2/4, where the rectification had been done with premix. Except this location the section 4b is performing better than section 4a. However part of the subsection 4b, close to the starting point of upgrade was rich with bitumen as a consequent of flow CRS 2 from the upgrade.

This research section was situated in inner side of the curve. It could be observed that flow of CRS-2 towards the research section has taken place (along the super elevation) at the time of the construction of the right hand side of the road.

9.18.6 Section 5

The aggregate and binder used in section 5 is shown in table 12.The rate of whipping off also as shown in that same table. Formula 2 was used for the calculation of rates of CRS-2. both the subsections are situated on a slope and on the inner side of a curve.

9.18.6.1 Condition of the road surface

No cold mix has been used for the rectification work. Dark appearance of the section 5 was less compared to sections 4 and 3. However few local patches ere noticed at the middle of the section. This has happened due to flowing of CRS-2 at the time of construction of the other side of the road.

9.18.7 Section 6

The aggregate and binder used in section 6 is shown in table 12. The rate of whipping off also as shown in that same table. Formula 2 was used for the calculation of rates of CRS-2. Both the sub sections are situated on a sharp bend, R 50 and on a steep slope. CRS-2 modified with 1% of the viscosity enhancer was used.

<u>9 .18.7.1 Condition of the road surface</u>

No cold mix was used for the rectification work.

The both sections were performing well except the section in front of the school.

9. 18.8 Comparison of section 4,5,6

Section 5 and section 6 perform better than the section 4. One of the main reason cold mix was not used for the rectification work. Another reason was flowing of CRS-2 at the time of construction of other sites. Stagnating of CRS-2 in small undulations will appear on the road surface with time as patches.

From table 11 the least whipping off was observed from the road section 6 where the modified CRS-2 produced with 60/70 bitumen as the base binder.

9 .19 Field Work University of Moratuwa, UOM

The internal roads to the "Civil Complex" and "Textile building" were selected for the research work and carried out with the collaboration of Road Construction and Development Company limited

The descriptions of the 15 numbers of sub sections are given in sheets 1 to 5 of the field sheet in annex 7. The map which shows the details of the subsections is also shown in the same annex.

9.19.1 Section 1 & 2

These two sections were situated on the left hand side of the road towards textile building. Normally vehicles park on the road section 1.

Section 1 performed in good condition. Sand seal was not applied on DBST as in the present practice. The aggregate stripped off from the road surface was collected and it was found that the value was 9.8%in case of section 2.

9.19.2 Section 3

Section 3 was very similar to section 2 except that the section was situated on a shaded area. It was noted that slight damages could be observed on the road surface. Rate of whipped off aggregate was 11.2%. Apparently more stones were stripped from the road section than road section 2.

9.19.3 Section 4

There is less traffic on section 4 and no parked vehicles are also available. Rate of whipping off aggregate was comparatively high. The calculated value is 18.2%. This was done according to the present practice.

9.19.4 Section 5

This section was done with DBST according to the standard specification of RDA. It was clearly observed that the rate of aggregate was too high (choked condition) Considerable amount of aggregate particles laying on the top of the aggregate of the first layer was also observed. And also some of these aggregate particles carried no or little binder. This amount of aggregate particles cannot be neglected because these aggregates will be removed under the action of traffic in the case of second seal.

The amount of aggregate whipped off was no or less binder 23.2% which was considerably high.

9.19.5 Section 6

This section was done according to the proposed method.

Formula 2 was selected to calculate the rate of aggregate.

9.19.6 Specimen Calculation for the Rate of Binder

First seal

$$\text{Volume of asphalt} = e.d\left\{1 - \frac{W}{\text{Bulk specific gravity}}\right\} K_1 + K_2 + K_3$$

(Refer: the equation given in chapter 7, Design of Surface Dressing)

Formula 2

Traffic category <100vpd

e = 0.36
k1 = 0.65
k2 = 0
k3 = 0
d = 10.8 mm

$$\text{Volume of asphalt} = 0.36 * 10.2 * \{1 - \frac{1405}{2.65 * 1000}\} * 0.65 + 0 + 0$$

$$= 1.12 \text{ l/m}^2$$

Therefore

$$\% \% \text{ Emulsion} = \frac{1.121}{0.66}$$

$$= 1.725 \text{ l/m}^2$$

Second Seal

$$\text{volume of asphalt} = 0.36 * 9.2 * \{1 - \frac{1420}{2.65 * 1000}\} * 0.65 + 0 + 0$$

$$= 0.999 \text{ l/m}^2$$

$$\% \text{ Emulsion} = 1.514 \text{ l/m}^2$$

Therefore total quantity of emulsion $= (1.7+1.5)\ l/m^2$

$= 3.2\ l/m^2$

For the first seal

% Emulsion $= \frac{40}{100} * 3.2\ l/m^2$

$=1.28\ l/m^2$

$=1.3\ l/m^2$

For the second seal

% Emulsion $= \frac{60}{100} 3.2\ l/m^2$

$= 1.92\ l/m^2$

$= 1.9\ l/m^2$

Similarly

Formula 1

Traffic category 500-1000 vpd

First seal

$$\text{Volume of asphalt} = 0.36 * 10.2 * \{1 - \frac{1405}{2.65 * 1000}\} * 0.65 + 0 + 0$$

= 1.121 l/m2

e = 0.36
K1 = 0.65
K2 = 0
K3 = 0
d =10.2mm

$$\% \text{ Emulsion} = \frac{\%\text{asphalt}}{\%\text{residue}}$$

Therefore

$$\% \text{ Emulsion} = \frac{1.12}{0.66}$$

$= 1.69\ l/m^2$

Second seal

$$\text{Volume of asphalt} = 0.36 * 9.2 * \{1 - \frac{1420}{2.65 * 1000}\} * 0.65 + 0 + 0$$

$= 0.999\ l/m^2$

% Emulsion $= 1.514\ l/m^2$

Therefore total quantity of emulsion $= (1.7+1.5)\ l/m^2$

$= 3.2\ l/m^2$

For the first seal

% Emulsion $= \frac{40}{100} * 3.2\ l/m^2$

$= 1.28\ l/m^2$

$= 1.3\ l/m^2$

For the second seal

% Emulsion $= \frac{60}{100} 3.2\ l/m^2$

$= 1.92\ l/m^2$

$= 1.9\ l/m^2$

9 .19.7 Section 6,7,8,

These sections were on the right hand side of the road towards the textile building. Section 6 was sand sealed as per the current practice.

Sections 7,8 were not sand sealed as per the current practice. When the sections 7,8 and 9 were compared performance of the section 7 was the best out of these three sections. Rate of stripping of the section 7 was 8.3%. Formula 2 was used to calculate the quantity of CRS-2 for the rectification 6 & 7 while formula 2 was used for section 8. Specimen calculation was shown in section 9.19.6.

9.19.8 Section 9

Formula 1 was used for the calculation of rates of binder for this section. When section 9 was compared with section 5 (current practice) it was observed that there were more voids among the aggregate. The aggregate particles oriented such a way that the least dimension remained vertical. Area of the aggregate particles in contact with the binder was also more than that of the section 5 where the standard specification was followed. This section was also not sand sealed.

9.19.9 Section 11

Section was done with the CRS-2 emulsion produced using 60/70 bitumen as the binder. No sand sealing was done to cover the DBST as per current practice. This section was situated on a bend. Rates of binder and aggregate of DBST was done according to standard specification. Tandem roller was applied. It was observed that the aggregate were crushed under the tires of the tandem roller. Patches of crushed stones could be observed.

9 .19.10 Formulation of emulsion with 60/70 bitumen

Settings such as temperature and pressure of the manufacturing plant were adjusted to attain the required fluidity of 60/70 bitumen at the mill in order to obtain proper size of globules of bitumen to be in emulsion. Formula used for 80/100 bitumen was slightly modified by increasing the quantity of the solvent. And also temperature of bitumen was also increased. These two steps were taken to make the 60/70 bitumen softer at the time of breaking bitumen into globules.

9 .19.11 Conclusion

Steel-wheeled roller crushed aggregate remaining crushed patches of aggregate on the road surface.

Less voids were there in the surface dressings which were in current practice. Manual spreading of aggregate after the spreader would become the situation even worse.

No reorientation to the least dimension of aggregate particle vertical was observed. Choked appearance of the aggregate spread could be observed. There was no possibility to reorient the aggregate particles to the least dimension vertical as there was no space.

Whipping off aggregate was less for the sections done with modified CRS-2.

More voids present in aggregate spread for the rates proposed by the design,

9.20 Summary of the performance of the research trials

CRS-2 with 1% of modifier appears to be better during the period of inspection. Formula 1 which results lesser quantity for bitumen emulsion can be used for the calculation of CRS-2 percentage. Thicker binder film will retain on the road surface than the normal CRS-2, as the viscosity of the modified binder is higher.

Using a steel roller for the compaction is not required in case of construction of surface dressing. Steel roller will crush the aggregate. Reorientation under the action of the pneumatic tired roller is sufficient.

Rate of whipping off is lesser with modified CRS-2 compared to non-modified CRS-2. However modified CRS-2 with the 60/70-penetration grade bitumen shows the least removal of aggregate from the road surface.

CHAPTER 10

COST EFFECTIVENESS OF THE RESEARCH FINDINGS

10.1 Introduction

No research would worth if the findings are not economically feasible. Therefore it was tried to analyse the cost per square meter of the proposed construction.

The proposed methods of construction are mentioned below.

1. To be used CRS-2 with higher viscosity, i.e. above 100Sayolt Furol Seconds.
2. To be used design quantities of the materials to suit the road section. Therefore no excess or insufficient quantity of binder and aggregate will be used.
3. Not to be used the tandem roller in construction of DBST.
4. No sand sealing is required just after the construction of DBST.

10.2 Cost Analysis

Table 10.1; Cost comparison of DBST (Ref. HSR, 2003)

Cost Rs	Present practice	Proposed practice	Reference table
Equipment	43.50	39.20	10.4 &10.5
CRS-2 (DBST)	44.50	47.25	Ref HSR
Sand sealing	29.15	-	10.6
CRS-2 (sand seal)	19.35	-	10.7
Total cost	135.50	84.45	

The table 10.1 shows that cost for DBST according to the current practice is 135.50 Rs/m^2. Cost for DBST according to the proposed method will be 84.45 Rs/m^2 (table 10.1). Therefore the cost saving will be 51.05 Rs/m^2. There will be about 1/3 of cost saving from the total cost for construction and for CRS-2 if the construction is done according to the proposed methods.

Table 10.2: Quantity of aggregate

Size mm	Present method kg/m^2	Proposed method kg/m^2
19	22	18
12.5	12	10

In addition consumption of aggregate is also less in proposed method compared to the present practice. It was observed that there were excessive aggregate laid on the road surface. Therefore according to the table 10.1 and table 10.2 there is a cost saving in case of construction cost as well as material cost if the proposed method will be followed.

Hence it can be concluded that the cost of construction of a surface dressing done according to the designed method is economically feasible.

Research also tried to find out whether there was a possibility to replace at least a part of the emulsifier. Few laboratory samples were carried out in this regard.

Table 10.3; Effect of the additive on the emulsifier.

Item	% Emulsifier	% Additive	% Residue	Viscosity ss	Storage Stability	Sieve test	Pen.* 1/mm
1	1.3	0.0	60	18	0.16	0.0	85
2	1.2	0.1	60	23	0.12	0.0	84
3	1.1	0.2	60	21	0.10	0.0	84
4	0.98	0.32	60	19	0.10	0.0	82

* Pen:- Penetration

Table 10.3 shows the properties of bitumen emulsion by replacing a part of the emulsifier with modifier –2. The study was carried out with the emulsion whose emulsifier was Em 26. UP to 1/4 th of the emulsifier, Em 26 could be replaced with modifier 2 without reducing the properties of the normal sample (without the modifier).

Therefore it was also able to say that a portion of the emulsifier could be replaced with the modifier-2. The percentage of the emulsifier that could be replaced depends on the type of the emulsifier used. Therefore a few trials would be carried out to find out the quantity of the replaced emulsifier with the available ones at the manufacturing plant.

It also can be said that the cost of CRS-2 can be reduced because that there is a tendency to replace the emulsifier by using the proposed modifier. (Table 10.3) Therefore a further study would be carried out in this regard.

10.3 Conclusion

It can be concluded that surface dressings that are carried out according to the designed method and using the modifier is economically feasible.

Table 10.4: Double Bituminous Surface Treatment with (CRS-2) using Plant and aggregate paid seperately
{Rate includes transport cost of aggregate up to 16km}

Item	Description of item	Qty.	Unit	Rate	Amount
1	Mecanical Broom with tractor	0.75	day	5,091.68	3,818.76
2	Emulsion Sprayer Self Prop.(4000 ltr.)	1.00	day	9,241.44	9,241.44
3	Chip Spreader (Self Prop.)	1.00	day	8,918.32	8,918.32
4	Wheel Loader (1,7 Cu.m.)	0.75	day	10,149.04	7,611.78
5	Roller smooth wheel (7 ton vibrating roller)	8.00	Hrs.	760.77	6,086.16
6	Pneumatic roller (1 ton)	1.00	day	13,581.12	13,581.12
7	Tipper (02 Nos. (Assuming 10km average tansport 6 trips each tipper)	864.00	Cu.m	8.53	7,369.92
8	Lab. (SK/A)	2.00	day	374.00	748.00
9	Labour (S/SK)	12.00	day	270.00	3,240.00
	Cost for 1394 Sq.m.				60,615.50
	Cost per Sq.m.				43.48
	Say				**43.50**

Table 10.5: Double Bituminous Surface Treatment with (CRS-2) using Plant (Binder and aggregate paid separately)
{Rate includes transport cost of aggregate up to 16km} No tandem roller

Item	Description of item	Qty.	Unit	Rate	Amount
1	Mecanical Broom with tractor	0.75	day	5,091.68	3,818.76
2	Emulsion Sprayer Self Prop.(4000 ltr..)	1.00	day	9,241.44	9,241.44
3	Chip Spreader (Self Prop.)	1.00	day	8,918.32	8,918.32
4	Wheel Loader (1,7 Cu.m.)	0.75	day	10,149.04	7,611.78
5	Pneumatic roller (1 ton)	1.00	day	13,581.92	13,581.92
6	Tipper (02 Nos. (Transport 6 trips each tipper) 16km ave.	864.00	Cu.m	8.53	7,369.92
7	Lab. (SK/A)	2.00	day	374.00	748.00
8	Labour (S/SK)	12.00	day	270.00	3,240.00
	Cost for 1394 Sq.m.				54,530.14
	Cost per Sq.m.				39.12
	Say				**39.20**

Table10.6: Application of emulsion, blinding and rolling for 2000 sq.m. (using plant)

Item	Description of item	Qty.	Unit	Rate	Amount
1	Applying emulsion CRS-2	2000.00	Sq.m.	19.35	38,700.00
2	Sand/chip spreader	0.50	day	8,918.32	4,459.16
3	Sand for blinding	16.00	cu.m.	530.00	8,480.00
4	Pneumatic roller	2.00	hrs.	1,697.74	3,395.48
5	Tractor and Trailor (0.75 Cubes)	1.00	day	1,585.76	1,585.76
6	Labour (SK/A)	1.00	day	374.00	374.00
7	labour (US/K)	5.00	day	248.00	1,240.00
	Cost for 2000 Sq.m.				58,234.40
	Cost per 1 Sq.m.				29.14
	Say				**29.15**

Table 10.7: Application of asphalt emulsion for surface treatment using CRS-2 (using plant)

Item	Description of item	Qty.	Unit	Rate	Amount
1	CRS-2 at site	4546.00	ltr.	16.05	72,963.30
2	Mech broom with tractor	0.63	day	5,091.68	3,207.76
3	Bitumen distibutor 4000/ltr.	1.00	day	9,241.44	9,241.44
4	Labour (SK.A)	1.00	day	374.00	374.00
5	(SK/B)	2.00	day	338.00	676.00
6	(UK/S)	6.00	day	248.00	1,488.00
	Cost for 4546 Sq.m.				87,950.50
	Rate per 1 ltr.				19.34
	Say				**19.35**

CHAPTER 11

SUMMARY OF THE RESEARCH FINDINGS

11.1 Introduction

A correctly done surface dressing such as SBST and DBST can be used as an effective and efficient method in road maintenance to improve the riding quality of the road surface as well as to increase the lifetime of a road pavement. A road pavement done with DBST performed well even with considerably high traffic road which was also situated at a busy town.

The research revealed improvements should be made to enhance the quality of the materials especially CRS-2. Improving the miscibility of the aggregate and CRS-2 should also be checked in order to minimize stripping. Proper design of a surface dressing to suit the road section is utmost important in order to decide the rate of application of CRS-2 and the aggregate as well as the size of the aggregate. And also the research identified that proper quality control measures should be adopted at the construction sites to identify that the materials are superior in quality and to check weather the correct rates are applied.

These precautions are

1. The present CRS-2 could be improved (if necessary) by adding the local modifier –2. Incorporation could be easily done even at the construction sites. The modifier-2 is available in plenty everywhere within the country and also it is very cheap.

2. The insitu viscometer can be used in construction sites to check the insitu viscosity of bitumen emulsion at the construction sites. The residue percentage of emulsion can also be checked at the field laboratories itself without sending the samples to the Central laboratory. This modifier also acts as an adhesion promoter eliminating the problems of easy detaching the

binder film possible with some types of aggregate depending on the mineralogical compositions

3. Emulsion laboratories can be maintained in the regional laboratories in small scale with the equipments devised in the research.

4. The design of surface dressing is very important in case of surface dressing. The rate of aggregate and the rate of the binder can be designed by using the formulae developed in this study. The required voids shall be there on the road surface after the construction of the surface dressing. This is necessary because to make easy reorientation of the aggregate.

5. The surface dressing done with the local modifier performed well during period of the investigations. However further inspection would be required in future, as the field-monitoring period was short. The sections were still better if 60/70 bitumen was used. However formulation and settings were different from the bitumen emulsion prepared using 80/100 bitumen.

6. The few polynomials were observed for the viscosity and the settings (temperature) of the manufacturing plant which further research would be carried out.

7. The viscosity of the raw bitumen is also very much important to maintain the required fluidity at the time of breaking into small globules at the manufacturing unit. However the variation of the penetration which is inversely proportionate to viscosity was considerable to maintain a calibration chart at the manufacturing unit so that required settings would be selected depending on the penetration of the bitumen received to the manufacturing unit.

REFERENCES

1. Akzo Nobel. "Adhesion Promoters." Technical Bulletin, Sweden

2. Akzo Noel. "Bitumen Emulsion" Technical Bulletin, Sweden

3. Asphalt Institute, Asphalt Emulsion manual, Manual Series no.19, Asphalt Institute building, Maryland. March 1984.

4. Asphalt Institute. Cause and prevention of stripping in asphalt pavements, educational series No.10 2nd edition. Asphalt Institute building, Maryland.

5. Australian Asphalt Pavement Association Advisory notes 2-17, Level 2, 5 Wellington street, KEW, Victoria.

6. Bitumen and Bituminous Binders. http://www.civil.wits.ac.za/civn207/Textdoubleseal.htm,2002

7. BP Bitumen " a brief overview of Bitumen Emulsions".

8. BP Bitumen "Production". 2002.

9. BP Bitumen, "Where to use of bitumen emulsion."2002.

10. BP Bitumen, "Emulsion Breaking." 2002.

11. BP Bitumen, "Safe Handling." March 2002

12. Cenck, P.D., Jamleson, N.J. and Towler, J.I. The Influence of Texture Depth on skidding resistance. Transit New Zealand: New Zealand.

13. Chandrawat, M.P.S. et al. "Effect of bitumen emulsion on setting, strength, soundness and moisture resistance of oxychloride cement". Indian academy of science, June 2001, pp313-316.

14. Christopher, Thierry. "Road Vehicle Interaction Comparison of two surfacings in terms of rolling resistance, vibrational comfort and noise". France.

15. Colloidal Dynamic Pty Ltd., Australia & Colloidal Dynamics Inc. USA. " The size and charge of Concentrated Bitumen Emulsions." Concentrated Bitumen Emulsions, 2000.

16. Daluwatte, V.R. Life cycle cost analysis for road pavement.

17. Dave Anderson Jack, Youth Cheff, and Mike Zupanick. "Asphalt Binders" TRB A2D01: Committee on characteristics of bituminous materials.

18. David W.Janiseh and Franks Gaillard. Minnesota seal coat handbook, Minnesota Department of Transportation. Office of Research Series, Ireland, 1998.

19. Davis, Lita. "Quality Control and Quality Assurance on Chip Seal Projects."

20. Denis, Rabiot and Jean-Louis, Jariel. "Polymer- modified bitumen emulsions for surface dressings." Second World Congress on Emulsion, France , 1997

21. Detailed surfacing selection http://www.civil.wits.ac.za/civn207/Textdoubleseal.htm,2002

22. Douglas, D. Granserg. Seal Coat Inspectors Field Guide. Department of Science, University of Oklahoma, Oklahoma, August 2000.

23. Dr. Per Redulius. Etal. A laboratory method for determinating the retaining force of chippings in surface dressings. United Kingdom, 1992

24. Dr. Starrd Kohnservedas "LTTB Data Analysis: Factors affecting pavement smoothness." Research Results Digest, Transportation research board NCHRP Project 20, Washington 2002

25. Durand Graziella and Paivier, Jean – Eric. "Emulsifiers affect rapid setting emulsions and their phases. (International Symposium on Asphalt Emulsion Technology Washington, 1999

26. Federal Highway Administration. "Durable Asphalt Emulsion seal coats." Volume III User's manual, Officers of Research & Development, Washington, October 1989.

27. Fernando, Leal Calderon. "Phase behaviour and stability of asphalt emulsion." A paper presented at the second world congress on emulsion, France 1997.

28. Gorelysheva, Lydia. "Bitumen Emulsions for Road Applications." Second World Congress on Emulsion, Congress Proceedings Volume 3, France, 1997.

29. James, Alan. "Solving emulsion Viscosity problems by the choice of emulsifier", Mexico: 24th AEMA meeting, 1997.

30. John de Pont et al. "Validating whole life pavement performance model."

31. John, Epps and Peter, Seebaly. "Performance of seal coat test sections." University of Nevada, College of Engineering, Presented at the second world congress on emulsion in France.

32. Jones, C.R. Rehabilitating roads with bituminous surfacings, R 6023. Berkshire: TRL Limited, 1999.

33. Kalpitzke, John. "Performance study in Western Queens land." Asphalt Review Volume 2 0, No3, July 2001.

34. Koach Pavement Solutions for chip seals.

35. Leveque, Jean. Bitumen Emulsions. France: Montreuil Offset, March 1991

36. Logaraj, Sundaram et al. "Emulsification a solution to Asphaltene Handling Problems." AEMA 2^{nd} joint conference, Florida, USA, 2000.

37. Manager, Engineering and Specifications Division, AAS200. "Seal coats and Bituminous surface treatments." Engineering brief # 39, P609.

38. Mc Laughtin J.L. "Variation the Enemy of Quality." 19^{th} Annual Meeting of the Asphalt Emulsion Manufacturers Association, 1992, pp67-163.

39. Nicholls, J.C. Design Guide for Road Surface Dressing, TRL road note 39, 4^{th} edition, revised. United Kingdom: Transport Research Laboratory

40. Nicholls, J.C. Laboratory Tests on High Friction Surfaces for Highways. United Kingdom: Transport Research Laboratory, 1997

41. Pavement Work Tips from No.2 to No.31 Austroads, Australian Asphalt Pavement Association, 1997 to 2001.

42. Rossi Sylvia. "Stability of Bitumen in water emulsions under static and dynamic conditions" A paper presented at the second world congress on emulsion, France 1995.

43. Shukla, Rama Shankar. " Design of Surface Dressing Using Bitumen Emulsion." A paper presented at the second world congress on emulsion, France, 1997.

44. Simple Design Double seal
http://www.civil.wits.ac.za/civn207/Textdoubleseal.htm,2002

45. Summer C.J. " Surface dressing sprayer, Depot spray bar test." The Idiots Guide to Highways Maintenance, 2000/2002.

46. Summers C.J. "Surface dressing Guide, design of surface dressing using aggregate chipping and bitumen." The Idiots Guide to Highways Maintenance, 2000/2002.

47. Summers C.J. "Surface dressing, list of items associated with surface dressing" The idiots guide to Highways Maintenance, 2000/2002.

48. Summers C.J."Thin surfacing bituminous mixtures." The Idiots Guide to Highways Maintenance, 2000/2002.

49. Towler, J.I. and Ball, F.A.. "Permeabilities of Chip seals in New Zealand." Transit New Zealand Head Office, 2000.

50. Transport and Road Research Laboratory Overseas Unit. A guide to surface dressing in tropical and sub tropical countries, Overseas Road note 3. United Kingdom: Department of Environment, 1982

51. Transport and Road Research Laboratory. Recommendations for road surface dressing, Road Note 39 2nd Edition. Department of Environment. London: H.M. Stationery Office, 1981.

52. Walther, Glet. "A five stages Model for the Bitumen Emulsion Setting and its importance for Formulation and Application of such emulsion." A paper presented at the second world congress on emulsion, France, 1997.

53. Wood house, A.R. "Enhancing the Performance of a chip Sealing Ireland." Dept. of Civil Engineering, University of Ulster.

54. Yan, Nianxi and Nandakumar, K. "Stabilization of Diluted Bitumen-in Water Emulsions with clays." NSERC, Industrial Research chair in oil sands, University of Alberta, Alberta.

APPENDIX-1

GLOSSARY OF TERMS

GLOSSARY OF TERMS

Introduction

Throughout the attached thesis and the cited references, numerous terms are used which would not normally familiar among the highway engineers and still others. The following glossary of terms is intended to explain the meanings accepted by the author in theses terms.

Adhesion agent

A cationic surface-active agent high secures thorough, irreversible water resistant between bitumen and aggregate.

Binder

The mixture of bitumen, fluxes etc, used for road sealing or the manufacture of asphaltic materials

Bitumen Emulsion

A dispersion of finely ground bitumen particles in water-achieved by the use of suitable emulsifying agents.

Bitumen

Viscous petroleum derived liquid or solid, consisting essentially of hydrocarbons or their derivatives, which is soluble in tricholoroethelene. It is substantially non-volatile and softens gradually when when heated. It is lack or brown in colour and possesses water and water proofing and adhesive properties. Bitumen is obtained y refinery process from petroleum and is also found as a natural deposit in some parts of the world as a component of naturally deposit in some parts of the world as a component of naturally occurring asphalt.

Coagulation

Formation of a compact mass entailing the separation of a coagulum.

Cut Back Bitumen

Bitumen, the viscosity of which has been reduced by the addition of suitable diluents, such as Kerosene, to render it more fluid for ease of application.

Extrinsic Properties

These are the properties of bitumen emulsions relating to its behavior in various fields of use

Fatting up

Term used to describe a road surface over rich in bitumen

Flocculation

This is the closing up of the dispersed phase globules into an open or loose network

Hot Mix

High quality thoroughly controlled hot mixture of bitumen and well-graded high quality aggregate and can thoroughly be compacted into a uniform dense mass

Intrinsic properties

The properties of bitumen emulsion which are not dependent on the mineral products (type of aggregate) with which they are used.

Penetration Grade Bitumen

These are usually produced by fractional distillation of petroleum followed in some cases by an oxidation process. British standards grades are normally designated y a number representing the mid point of the penetration range and the suffix "pen".

Polymer

A naturally occurring or synthetic compound that has large molecules made up of many relatively simple repeated units.

Pre-coated Aggregate

Aggregate which have been pre-coated with light film of penetration grade bitumen prior to use in surface dressing.

Setting

This is the phenomenon that occurs when an emulsion is in contact with aggregate. This process starts with breaking which in its final stage leads to water separation.

Softening Point

The temperature in ^{0}C at which bitumen attains a particular degree of softening with reference to test conditions prescribed in BS 2000:Part58: 1993.

Stripping

Process where by water displaces binder from the aggregate surface.

Surface Dressing

Technique in which a binder an aggregate chippings are applied to the road surface in one or more layers. Surface dressing provides an aggregate mosaic embedded in bitumen as a surface coating on top of an existing road.

Tack Coat

An application of low viscosity bitumen or bitumen emulsion to an absorbent surface. It penetrates into the base and fills the voids, hardens the top and helps it stick to the overlying bituminous course.

Viscosity

A measure of the resistance of a fluid to flow. Various scales of measurement are used. Kinematic viscosity was used for bitumen and Sayolt Furol viscosity s used in case of bitumen emulsion.

Whipping off Aggregate

Removal of aggregate from the newly laid surface dressings.

APPENDIX-2

PAST RECORDS OF CRS-2 EMULSION

Table1: Results of the samples of cationic rapid setting -2 emulsion

Sent by: Plant manager,Emulsion plant, Angulana

Tested by R&D division, RDA, Rathmalana

Item	entificati mark	ate receive	viscosity	storage stability	Sieve test %	istillatio oil %	Test Residue%	enetratio	Ductility	Solubility
1	P2404	14-Jul-00	102	0.4	0.00	2.5	67	111	112	
2	P2421	21-Jul-00	99	1.4	0.00	2.0	66	110	150	
3	P2431	04-Aug-00	75	0.8	0.00	2.5	65	112	114	
4	CRS-2	20-Jul-00	89	-0.8	0.00	2.0	59	111	48	99.2
5	CRS-2	26-Jun-00	106	0.6	0.00	2.5	65	120	150	
6	P2374	13-Jun-00	75	0.4	0.00	2.5	66	123	150	
7	P2371	13-Jun-00	63	0.8	0.00	2.5	62	120	150	
8	P2364	06-Jun-00	93	0.4	0.00	2.0	67	130	150	
9	P2352	26-May-00	44	0.2	0.00	2.5	65	121	150	
10	P2351	26-May-00	94	0.2	0.01	2.0	65	106	140	
11	P2343	11-May-00	115	0.0	0.00	2.0	66	116	145	
12	P2325	28-Apr-00	161	0.2	0.00	2.5	67	120	130	
13	P2321	28-Apr-00	97	0.0	0.00	2.5	65	112	94	
14	P2311	20-Apr-00	74	0.4	0.00	2.0	66	129	135	
15	P2301	04-Apr-00	65	0.0	0.00	2.5	65	131	90	
16	CRS-2-1	23-Mar-00	57	0.0	0.00	2.5	66	130	109	100
17	CRS-2-2	23-Mar-00	73	0.0	0.04	2.5	66	122	125	100
18	CRS-2-3	23-Mar-00	52	0.2	0.01	3.0	65	121	128	100

Table 2: Results of the samples of cationic rapid setting -2 emulsion

Sent by: Plant manager,Emuision plant, Angulana

Tested by R&D division, RDA, Rathmalana

Item	entificati mark	ate receive	viscosity	storage stability	Sieve test %	istillatio oil %	Test Residue%	enetratio	Ductility	Solubility
20	P2275	10-Mar-00	72	0.0	0.00	2.0	66	147	90	99.6
21	P2268	10-Mar-00	78	0.0	0.00	3.0	65	143	120	99.9
22	P2256	28-Feb-00	74	0.2	0.00	2.5	65	116	140	
23	P2231	01-Feb-00	45	0.2	0.00	2.3	65	145	150	
24	P2242	17-Feb-00	76	0.4	0.04	2.5	66	137	146	
25	P2245	17-Feb-00	79	0.2	0.00	2.5	65	150	144	
26	P2014	14-Jan-00	163	0.4	0.40	2.5	66	144	146	
27	P2219	14-Jan-00	123	0.6	0.13	2.5	65	114	140	
28	P2197	06-Jan-00	94	0.2	0.13	2.3	63	126	116	
29	P2204	06-Jan-00	101	1.4	0.16	2.5	65	155	116	
30	P2208	06-Jan-00	99	1.0	0.01	2.5	65	135	138	
31	P2176	09-Dec-99	78	0.8	0.00	2.5	65	146	74	99.7
32	P2150	24-Nov-99	149	0.2	0.46	0.5	66	165	113	88
33	P2154	24-Nov-99	90	0.3	0.00	2.0	66	115	120	
34	P2159	24-Nov-99	113	2.4	0.00	2.5	65	130	129	
35	P2131	02-Nov-99	81	0	0.13	2.0	65	115	130	
36	P2134	09-Nov-99	121	0.7	0.05	2.5	66	120	135	

Table 3: Results of the samples of cationic rapid setting -2 emulsion
Sent by: Plant manager,Emulsion plant, Angulana
Tested by R&D division, RDA, Rathmalana

Item	entificati mark	ate receive	viscosity	storage stability	Sieve test %	istillatio oil %	Test Residue%	enetratio	Ductility	Solubility
37	P2137	09-Nov-99	102	-0.4	0.03	2.0	66	127	150	
38	P2140	09-Nov-99	85	0.2	0.00	1.5	66	110	145	
39	P2096	08-Oct-00	100	0.0	0.00	2.5	66	98	98	
40	P2078	29-Sep-99	129	0.8	0.00	2.0	66	105	120	
41	P2085	29-Sep-99	47	0.2	0.00	2.0	61	100	120	
42	P2055	17-Sep-99	100	-0.9	0.04	1.4	66	115	123	
43	P2047	10-Sep-99	115	-0.4	0.00	2.0	66	108	103	99.7
44	CRS-2	02-Sep-99	22	-3.2	0.00	1.5	65	121	98	99.3
45	P2010	09-Aug-99	113	-0.6	0.00	2.0	65	127	75	99.2
46	P2004	30-Jul-99	99	2.0	0.21	1.5	66	135	136	99.6
47	P1968	06-Jul-99	71	0.6	0.14	2.0	65	120	129	
48	P1978	19-Jul-99	63	1.0	0.03	2.0	66	126	40	
49	P1959	25-Jun-99	96	-0.6	0.00	1.5	65	130	150	
50	P1952	18-Jun-99	115	0.8	0.00	2.0	66	125	152	
51	P1929	27-May-99	57	0.4	0.00	1.5	66	125	140	
52	P1923	21-May-99	202	-1.6	0.00	2.0	68	130	148	
53	P1917	21-May-99	118	-1.6	0.00	2.0	67	128	152	
54	P1905	11-May-99	81	1.6	0.00	1.5	66	126	120	

Table 4: Results of the samples of cationic rapid setting -2 emulsion

Sent by: Plant manager,Emulsion plant, Angulana

Tested by R&D division, RDA, Rathmalana

Item	entificati mark	ate receive	viscosity	storage stability	Sieve test %	istillatio oil %	Test Residue%	enetratio	Ductility	Solubility
55	P1889	11-May-99	56	0.8	0.00	2.0	65	122	125	
56	P1885	27-Apr-99	142	0.0	0.00	2.0	66	98	122	
57	P1872	08-Apr-99	90	-1.2	0.00	2.0	65	107	65	
58	RS-2 NO	08-Apr-99	75	-0.2	0.00	2.5	65	102	130	
59	P1856	26-Mar-99	71	-1.6	0.00	3.0	65	124	140	
60	P1832	19-Mar-99	58	1.0	0.00	2.0	66	129	157	
61	P1528	19-Mar-99	36	0.0	0.00	1.5	64	104	96	
62	CRS-2	29-Mar-99	82	-1.0	0.11	2.0	67	140	135	100
63	P1791	10-Mar-99	21	1.0	0.00	2.5	61	105	135	
64	CRS-2	10-Mar-99	65	0.2	0.00	1.5	64	121	145	
65	P1788	24-Feb-99	76	1.0	0.00	1.5	70	83	105	99.9
66	P1781	24-Feb-99	68	-0.6	0.00	2.5	65	115	125	
67	P1775	24-Feb-99	64	1.4	0.00	2.0	65	113	97	
68	P1776	12-Feb-99	56	-2.4	0.00	2.0	65	120	114	
69	P1750	03-Feb-99	96	1.0	0.01	2.0	66	119	129	
70	P1744	03-Feb-99	80	-1.4	0.00	2.0	67	110	158	
71	P1682	11-Jan-99	76	0.2	0.00	2.0	65	113	140	
72	CRS-2	22-Jan-99	41	0.0	0.14	1.0	64	105	92	100
73	P1586	10-Dec-98	27	-1.2	0.00	2.0	65	115	125	

Table5: Results of the samples of cationic rapid setting -2 emulsion
Sent by: Plant manager,Emulsion plant, Angulana
Tested by R&D division, RDA, Rathmalana

Item	entificati mark	ate receive	viscosity	storage stability	Sieve test %	istillatio oil %	Test Residue%	enetratio	Ductility	Solubility
74	P1414	20-Nov-99	113	0.2	0.00	2.0	67	127	125	
75	CRS-2	11-Dec-99	12	1.0	0.00	1.0	57	55	98	99.9
76	CRS-2	06-Nov-99	140	-1.8	0.00	1.5	67	127	95	
77	P1454	06-Nov-99	104	0.4	0.00	2.0	66	120	113	
78	CRS-2	23-Oct-99	54	0.0	0.19	2.5	65	120	115	
79	CRS-2	23-Oct-99	85	-0.2	0.00	2.0	65	136	105	99.7
80	CRS-2	05-Oct-99	97	-0.2	0.00	2.0	65	126	100	99.6
81	CRS-2	25-Sep-99	144	-0.8	0.00	2.0	65	140	135	99.8
82	CRS-2	11-Sep-99	83	-1.2	0.00	2.0	65	129	119	99.2
83	CRS-2	05-Sep-99	95	-0.6	0.00	2.0	65	113	120	99.5
84	CRS-2	27-Aug-99	100	2.0	0.00	2.0	66	128	150	99.8
85	CRS-2	17-Aug-99	91	1.4	0.05	2.0	66	118	150	99.8
86	CRS-2	23-Jul-99	75	1.4	0.10	2.0	65	100	140	99.5
87	P1002	15-Jul-99	125	0.2	0.14	2.5	66	112	146	99.9
88	P959	08-Jul-99	87	0.0	0.02	2.0	65	108	144	99,9
89	P925	26-Jun-99	113	-1.2	0.00	1.5	66	115	110	99.8
90	P884	19-Jun-99	73	0.4	0.00	2.0	66	110	115	
91	P860	11-Jun-99	62	0.0	0.00	2.0	66	115	93	
92	P815	27-May-99	72	-2.0	0.00	2.0	69	116	135	

Table 6: Results of the samples of cationic rapid setting -2 emulsion

Sent by: Plant manager,Emulsion plant, Angulana

Tested by R&D division, RDA, Rathmalana

Item	entificati mark	ate receive	viscosity	storage stability	Sieve test %	istillatio oil %	Test Residue%	enetratio	Ductility	Solubility
93	P782	22-May-99	73	-4.6	0.00	2.0	66	130	133	
94	P721	04-May-99	91	0.0	0.08	2.0	65	121	115	
95	P682	24-Apr-99	128	0.0	0.00	2.0	67	125	100	
96	P651	09-Apr-99	44	0.4	0.00	2.0	65	128	127	
97	P603	31-Mar-99	94	0.4	0.00	1.5	67	135	65	
98	P535	16-Mar-99	56	0.2	0.00	21.0	65	134	90	
99	P586	20-Mar-99	72	0.4	0.06	2.0	66	108	105	
100	P463	13-Feb-99	104	0.1	0.00	1.5	65	122	110	
101	P399	23-Jan-99	76	-5.4	0.00	2.0	65	112	143	
102	P390	23-Jan-99	68	-1.2	0.00	2.0	65	120	135	
103	CRS-2	12-Jun-99	51	-0.2	0.00	2.0	65	134	125	
104	CRS-2	30-May-99	83	-0.2	0.00	2.0	66	102	126	
105	CRS-2	03-Apr-99	87	-0.2	0.40	2.5	67	162	110	
106	P1044	27-Jul-98	152	1.0	0.00	2.0	66	112	128	
107	CRS-2	24-Jun-98	72	1.5	0.12	1.5	69	75	105	
108	CRS-2	26-Jun-98	113	-1.2	0.00	1.5	66	115	110	
109	CRS-2	08-Jul-98	87	0.0	0.02	2.0	65	108	144	
110	P884	19-Jun-98	73	0.4	0.00	2.0	66	118	115	

Table 7 : Results of the samples of cationic rapid setting -2 emulsion
Sent by: Plant manager,Emulsion plant, Angulana
Tested by R&D division, RDA, Rathmalana

Item	entificati mark	ate receive	viscosity	storage stability	Sieve test %	istillatio oil %	Test Residue%	enetratio	Ductility	Solubility
111	P860	11-Jun-98	62	0.0	0.00	2.0	66	115	93	
112	P815	29-May-98	72	-2.0	0.00	2.0	69	116	135	
113	P721	04-May-98	91	0.0	0.08	2.0	65	121	115	99.8
114	P782	22-May-98	73	-4.6	0.00	2.0	66	130	133	
115	P651	09-Apr-98	44	0.4	0.00	2.0	65	126	127	
116	P682	24-Apr-98	128	0.0	0.00	2.0	67	125	100	
117	P603	31-Mar-98	94	0.4	0.00	1.5	67	135	65	99.9
118	P519	05-Mar-98	89	1.4	0.02	2.0	65	132	115	
119	P535	06-Mar-98	56	1.0	0.20	2.0	65	134	90	
120	P586	20-Mar-98	72	0.4	0.06	2.0	66	108	105	
121	P390	23-Jan-98	68	1.2	0.00	2.0	65	120	135	
122	P399	23-Jan-98	76	-3.4	0.00	2.0	65	112	143	99.7
123	P463	13-Feb-98	104	0.1	0.00	1.5	65	122	110	
124	P476	24-Feb-98	83	2.4	0.04	3.5	65	112	120	
125	P380	16-Jan-98	89	0.0	0.00	2.0	65	130	160	
126	P300	29-Dec-97	81	-1.0	0.00	2.0	64	111	105	
127	P323	29-Dec-97	55	0.8	0.00	2.0	64	134	125	

Table 8 : Results of the samples of cationic rapid setting -2 emulsion
Sent by: Plant manager,Emulsion plant, Angulana
Tested by R&D division, RDA, Rathmalana

Item	entificati mark	ate receive	viscosity	storage stability	Sieve test %	istillatio oil %	Test Residue%	enetratio	Ductility	Solubility
128	P338	05-Jan-98	79	0.6	0.00	2.0	65	120	115	
129	P276	12-Dec-97	45	0.2	0.00	1.5	64	110	120	
130	P399	22-Dec-97	81	-1.0	0.00	2.0	64	111	130	
131	P221	27-Nov-97	71	0.0	0.00	2.0	65	120	105	
132	P175	17-Oct-97	121	0.7	0.00	3.0	64	119	135	
133	P102	21-Nov-97	162	0.0	0.00	1.5	66	128	126	
134	P073	09-Oct-97	63	1.4	0.00	2.5	65	143	140	

APPENDIX 3

TESTING OF BITUMEN EMULSION

TESTING OF CATIONIC BITUMEN EMULSIONS.

Viscosity Test

Viscosity is defined as the resistance to flow of a fluid. Viscosity of bitumen emulsion is determined using Saybolt Furol viscometer.

The viscosity of emulsion should be such that it should be low enough to be sprayed through the jet of the spray bar of the sprayer or to coat the aggregate in simple mixing and high enough to retain on the road surface in order to hold the aggregate.

In this test the emulsion is allowed to flow through a standard orifice at standard temperature. The time taken to flow 60cc of emulsion through the orifice is taken as the viscosity in Saybolt Furol seconds.(figure 1 annex)

Distillation Test

The proportions of bitumen, solvents and water present in an emulsion can be determined by the distillation test.

The test is useful to find out the variations (if any) in the products from the recipe of the emulsion which the emulsion is formulated.

Additional tests are carried out on the base residue to examine the properties of the base asphalt which was used when manufacturing emulsion. (Figure 2 annex)

Settlement Test

One advantage of bitumen emulsion is its storability for some time. Due to contaminants or any other deficiencies in formulation there is a possibility to settle emulsion. Therefore during storage the bitumen droplets have a tendency to settle giving lower bitumen content in the upper part of the tank.

In the test, emulsion is left in a cylinder for a certain period of time in room temperature without disturbing. The degree of setting is expressed as the difference in bitumen content between a sample from the top of the cylinder and one from the bottom. The test is usually carried out for 24 hrs. or 5 days.(figure 3)

Sieve Test

This test measures the percentage of bitumen present in the form of large globules.

In the sieve test a sample of bitumen emulsion is poured through 850μm sieve. This sieve and the retained bitumen are then rinsed with distilled water. The amount of bitumen retained on the sieve is determined. The specification limits the value. Figure 4 annex

Due to less stability of bitumen emulsion in storage the dispersed phase is collected at the lower part of the storage tank or sometimes in the upper portion of the tank. (Creaming). As a result of this, the flocculated particles may present I in the storage tanks. Negligence at this stage will lead these particles to coalesce. (Combine the particles into compacted mass)

Large particles may clog the nozzles of spraying, equipment and they will not provide a thin and uniform coating of aggregate.

Cement Mixing Test.

This test is applicable only to slow setting emulsions. This test is done to determine the rate at which the bitumen emulsion breaks. This test indicates that ho stale the bitumen emulsions

A sample of emulsion is mixed with finely ground cement and the mixture is washed over a fine-grained sieve till the washing runs clear. Specifications limit the amount of material that may be retained on the sieve. Figure 6 in annex

Demulsibility Test

This test is applicable only to rapid setting emulsions. This gives an indication of the rate at which the bitumen particles will break when spread in thin films.

Sample of emulsion is mixed with a solution of Dioctile Sodium Sulfosuccinate if specified concentration and is poured over a sieve. This chemical causes bitumen particles to coalesce.

A high degree of demulsibility is required of this type of emulsified asphalt. Specification prescribes the minimum amount of asphalt to be retained on the sieve.

Particle Charge Test

This test is done to determine whether the emulsion is cationic or anionic.

Two electrodes are immersed into a sample of emulsion which is connecting to a battery and afterwards the electrodes are inspected. In cationic emulsions bitumen particles will migrate to the cathode while in anionic emulsions bitumen particles will migrate to the anode.

Evaporation Test

This test is also done to determine the percentage of bitumen and water I the emulsion. A sample of emulsion is heated to 163^0c in an oven within three hours.

The residue obtained by this method yields lower penetration and a lower ductility than that derived from the distillation test.

Tests On Residue From Distillation Test

The most common tests prescribed in specifications are the penetration test, ductility test and the solubility test to determine the properties of the base bitumen after emulsification and coalescence.

1.Penetration test

This test is done to determine the hardness of base bitumen.

The test measures the depth of penetration in units of 0.1mm of a standard needle under a load of 100gm during 5sec.when the residue temperature is at 25^0c.

2.Ductility Test

The ductility test measures the ability of the bitumen to remain coherent under large strains in tension.

The test measures the distance in cm a standard briquette of bitumen will stretch before breaking at a temperature of 25^0c.

3.Solubility test

This test on bitumen is done to determine its purity.

Pure bitumen is completely soluble in solvents like Carbon Disulphide and Carbon tetrachloride. Hence any impurity in bitumen in the form of inert minerals, carbon salts etc can be quantitatively analysed by dissolving the sample of bitumen in any of the two solvents.

The portions of the bitumen that is soluble in specified solvents represent the adhesive constituents. Solubility is determined by dissolving in the solvent and separating the soluble and insoluble portions by filtering.

Figure 1;Saybolt furol Viscometer

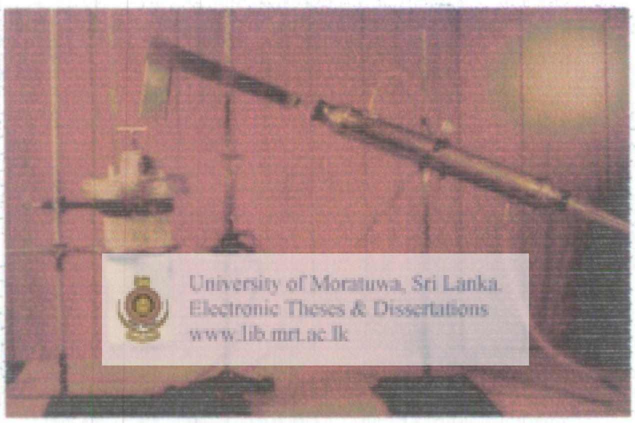


Figure 2; Distillation test

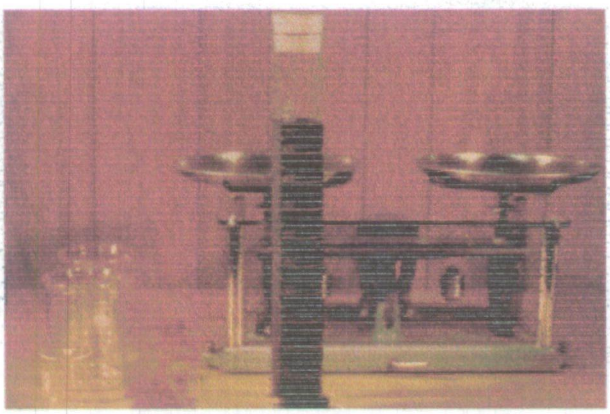


Figure 3; Settlement test

APPENDIX 4

LABORATORY EXPERIMENTS

ON IMPROVING BITUMEN EMULSIONS

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Table 1a; Effect of mill rpm on the viscosity

Item	mill rpm	ater pum rpm	Viscosity	Storage Stability	Sieve test	istillatio oil %	test Residue %
1	5000	110	16	0.4	0.05	2.5	62.2
2	5060	109	20	0.1	0.00	2.5	61.5
3	5500	110	18	0.2	0.01	2.5	63.4
4	6000	110	19	0.3	0.00	2.5	62.0
5	6500	110	19	0.2	0.00	2.5	62.0
6	7000	109	21	0.1	0.01	2.5	62.0
7	7000	109	21	0.5	0.02	2.5	64.0
8	9030	110	23	0.3	0.00	2.5	61.4
9	9030	110	24	0.2	0.00	2.5	61.9
10	9040	110	24	0.2	0.00	2.5	61.5
11	9000	110	25	0.1	0.01	2.5	62.0
12	9000	110	24	0.2	0.01	2.5	61.4
13	10,000	109	25	0.2	0.02	2.5	61.5
14	11,000	110	19	0.3	0.0	2.0	61.6

Table 1b; Recepi of emulsion tested

Item	% by weight
Bitumen	61.00
Solvent	2.50
Emulsifie	0.12
HCL	0.10
water	37.38
total	100

Type of emulsion is CRS-1

Table 1c; parameters set fixed at the production unit

Item	Temp. C^0
Bitumen	145
water pha	45
Emulsion	88

mill rpm 9000 rev

Table 2a Effect of chemical 1 on CRS-1 Emulsion

Item	Chem. 1	viscosity	storage stability	Sieve test %	Oil Distillation Oil %	Residue %	Penetrati	Ductility	Sieve test after 5 days
1	0.00	0.0	0.1	0.00	2.0	63.5	100	120	0.01
2	0.10	100.0	-0.1	0.00	2.5	63.5	99	120	0.00
3	0.10	89.0	-1.0	0.00	2.0	63.4	110	116	0.00
4	0.05	59.0	0.1	0.00	2.0	63.4	110	120	0.00
5	0.05	62.0	0.2	0.00	2.0	63.0	105	125	0.00

Table 2b; Recepe of emulsion

Item	% by weight
Bitumen	62.00
Kerosene	2.50
Emulsifie	0.14
HCL	0.10
Chem. 1	*
Water	*
Total	100

Chemical 1:- Doping agent

Table 3a; Laboratory trials with chemical-1 for CSS-1

Item	Chem.1	viscosity	Storage stability	Sieve test %	Oil Distillation		Penetratio	Ductility	Sieve test %
					Oil %	Residue %			
1	0.05	21.5	0.1	0.01	2.0	63.4	132	127	0.10
2	0.10	22.0	0.8	0.00	2.2	64.0	130	125	0.00
3	0.10	22.0	0.2	0.00	2.0	63.0	123	150	0.00
4	0.05	22.0	0.5	0.10	2.0	63.0	114	150	0.02

Table 3b; Recepe of emulsion

Item	% by weight
Bitumen	62.00
Kerosene	2.50
Emulsifier	1.20
Chem.1	*
Water	**
Total	100.00

Table 4a; Testing of local modifier with CRS-1

Item	Quantity	viscosity	Storage	ettlemen	Sieve test		Distillation test		Tests on residue	
	%	SS	Stability	5 days	850 mm	150 mm	esidue	oil %	enetratio	Ductility
1	0.00	15	0.6	7.0	1.50	0.00	61	2.5	98	115
2	0.50	17	0.5	2.0	0.50	0.00	60	2.5	95	100
3	0.75	20	0.3	1.0	0.10	0.00	61	2.5	95	95
4	1.00	24	0.3	0.9	0.00	0.00	61	2.5	93	90
5	1.25	27	0.2	0.5	0.00	0.00	60	2.5	90	85
6	1.50	27	0.1	0.3	0.00	0.00	60	2.5	87	80
7	1.75	28	0.1	0.1	0.00	0.00	60	2.5	80	75
8	2.00	32	0.1	0.0	0.00	0.00	60	2.5	77	72

Table 4b; Recepe of emulsion

Item	% by weight
Bitumen	60
kerosene	2.5
Emul.	0.12
chem 2	*
water	**
total	100

Table 5a; Physical blends done with chemical-2

Item	Quantity %	viscosity	Storage Stability	Settleme 5 days	Sieve test		Distillation test		Tests on residue		Breaking Index
					850 mm	150 mm	Residue	oil %	Penetrati	Ductility	
1	0.0	19.0	0.3	0.70	0.00	0.00	60	2.00	84	90	133
2	1.0	24.0	0.1	0.1	0.00	0.00	59	2.00	78	89	152
3	2.0	30.0	0.1	0.4	0.00	0.00	59	2.00	70	87	153
4	2.5	32.0	0.1	0.7	0.00	0.00	60	2.00	70	89	157
5	3.0	37.0	0.1	0.3	0.00	0.00	61	2.00	68	90	157
6	4.0	55.0	0.1	-0.1	0.00	0.00	61	2.00	68	85	160

Table 5b; Recepi of Emulsion
Type; CSS-1

Item	% by weight
Bitumen	60
kerosene	2.5
$CaCl_2$	0.1
Emul.	1.2
chem 2	*
water	**
total	100

Table 6a; Testing of local modifier with CRS-1

Item	Quantity	viscosity	Storage	ettlemen	Sieve test		Distillation test		Tests on residue	
	%	SS	Stability	5 days	850 mm	150 mm	esidue	oil %	enetratio	Ductility
1	0.00	15	0.6	7.0	1.50	0.00	61	2.5	98	95
2	0.50	17	0.5	2.0	0.50	0.00	60	2.5	95	100
3	0.75	20	0.3	1.0	0.10	0.00	61	2.5	95	100
4	1.00	24	0.3	0.9	0.00	0.00	61	2.5	93	115
5	1.25	27	0.2	0.5	0.00	0.00	60	2.5	90	98
6	1.50	27	0.1	0.3	0.00	0.00	60	2.5	87	99
7	1.75	28	0.1	0.1	0.00	0.00	60	2.5	80	105
8	2.00	32	0.1	0.0	0.00	0.00	60	2.5	77	110

Table 6b; Recepe of emulsion

Item	% by weight
Bitumen	60
kerosene	2.5
Emul.	0.12
chem 2	*
water	**
total	100

Table 7a; Testing of local modifier with CRS-2

Item	Quantity %	viscosity	Storage Stability	Settleme 5 days	Sieve test		Distillation test		Tests on residue	
					850 mm	150 mm	esidue	oil %	Penetrati	Ductility
1	0.00	17	0.9	7.0	0.12	0.13	60	2.0	130	130
2	0.10	28	0.7	5.2	0.00	0.10	61	2.5	116	74
3	0.25	44	0.5	5.0	0.02	0.00	61	2.0	106	63
4	0.50	57	0.5	4.0	0.06	0.00	61	2.0	100	46
5	0.75	73	0.3	2.0	0.05	0.00	61	3.0	99	44
6	1.00	101	0.1	0.1	0.01	0.00	61	1.5	90	40

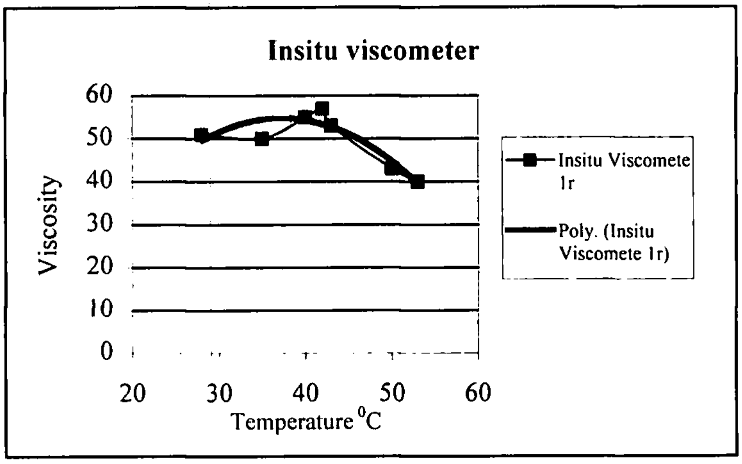
Table 7b; Recepe of emulsion

Item	% by weight
Bitumen	66
kerosene	2.5
Emul.	0.14
chem 2	*
water	**
total	100

APPENDIX 5

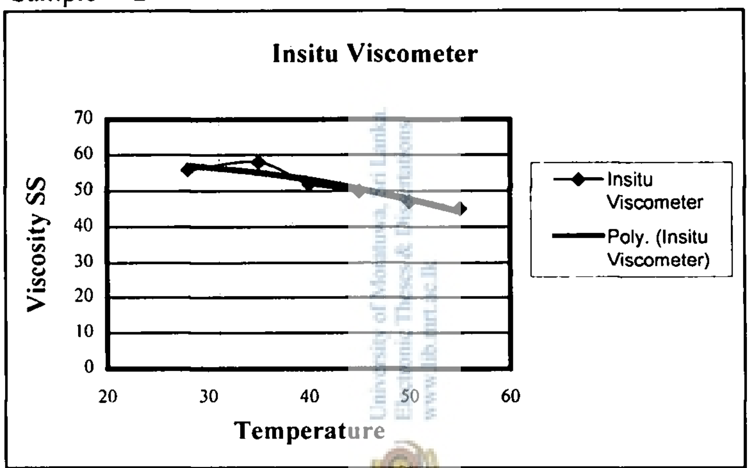
LABORATORY EXPERIMENTS ON INSITU VISCOMETER

Sample 1
Type CRS-2
Emulsion plant RC&DC



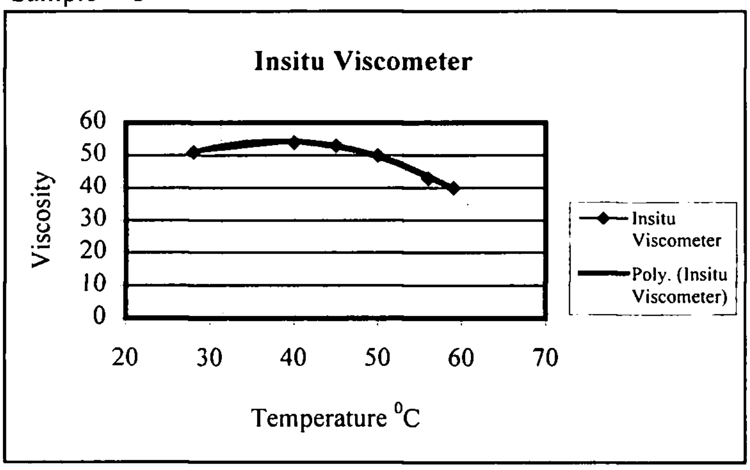
$y = -0.0614x^2 + 4.5733x - 30.378$ $R^2 = 0.8321$

Sample 2



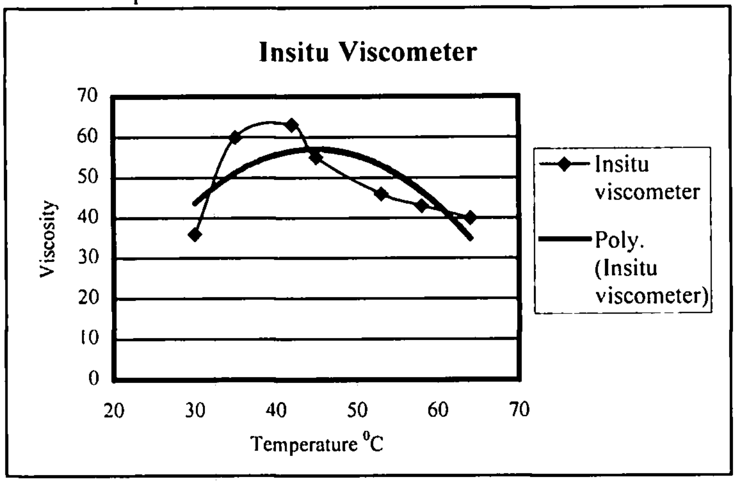
$y = -0.0099x^2 + 0.344x + 55.212$ $R^2 = 0.9039$

Sample 3



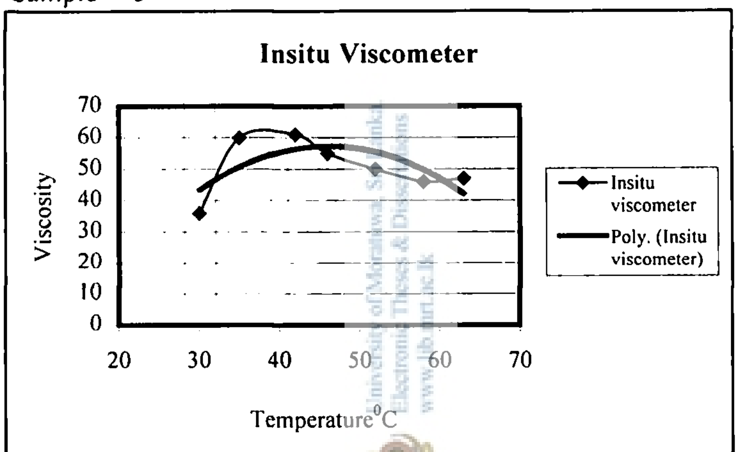
$y = -0.0337x^2 + 2.5709x + 5.4121$ $R^2 = 0.9955$

Sample 4
Type CRS-2
Emulsion plant RC&DC



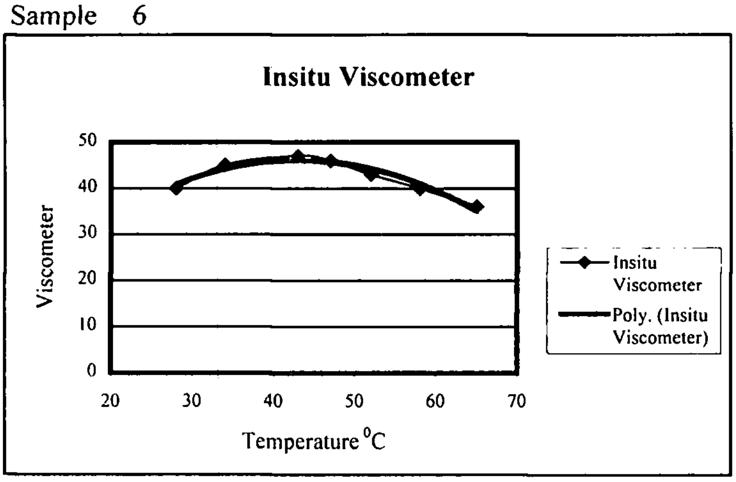
$y = -0.1015x^2 + 8.8619x - 133.45$ $R^2 = 0.7128$

Sample 5



$y = -0.0535x^2 + 4.9399x - 56.723$ $R^2 = 0.4903$

Sample 6

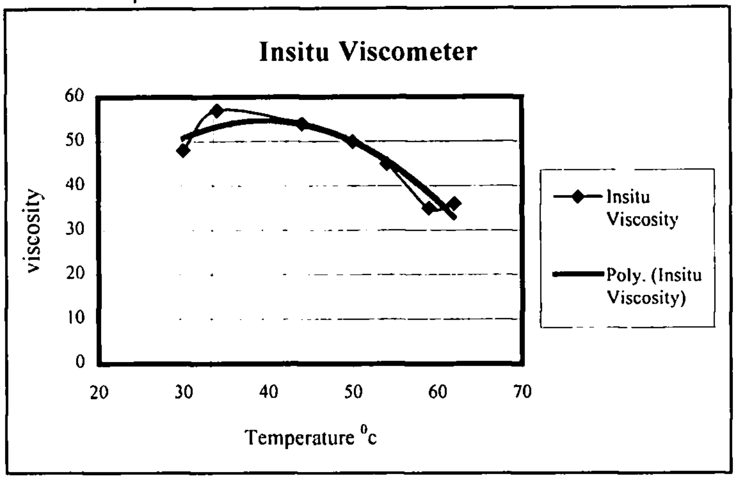


$y = -0.0228x^2 + 1.9639x + 3.7053$ $R^2 = 0.9389$

Sample 7

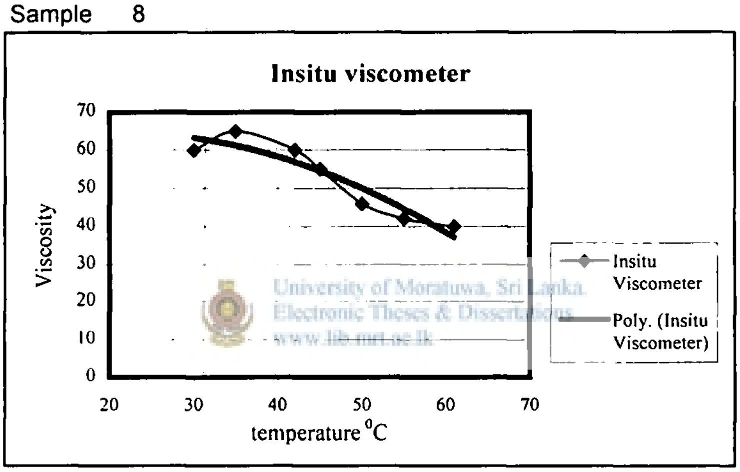
Type CRS-2

Emulsion plant RC&DC



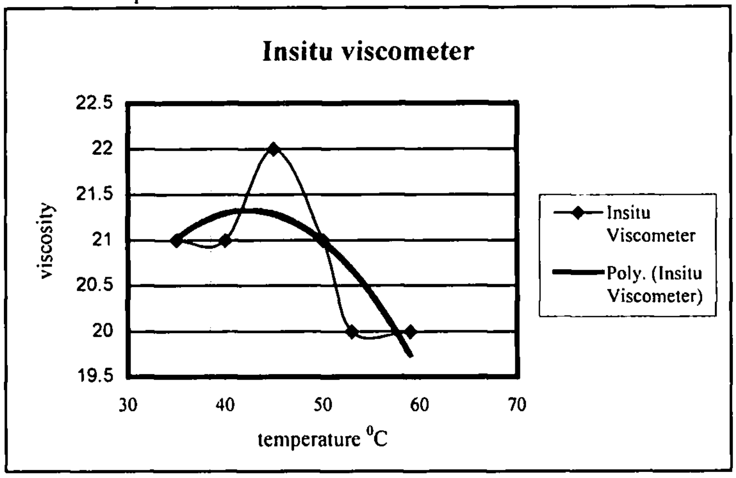
$y = -0.0435x^2 + 3.4412x - 13.389$ $R^2 = 0.9014$

Sample 8



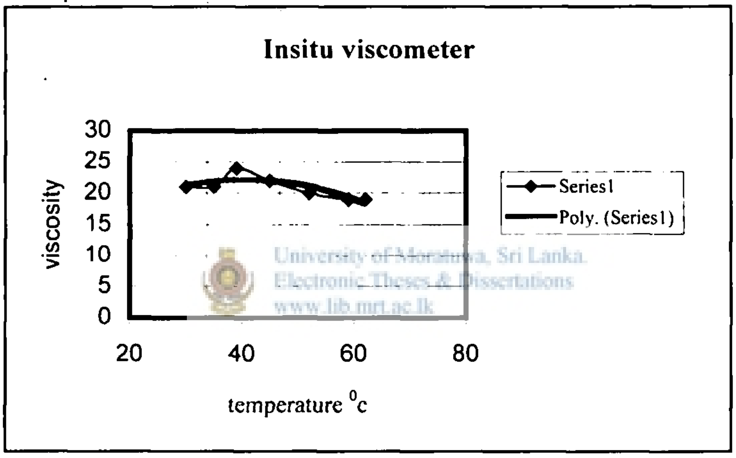
$y = -0.0162x^2 + 0.6338x + 58.902$ $R^2 = 0.8862$

Sample 9
Type CRS-1
Emulsion plant RC&DC



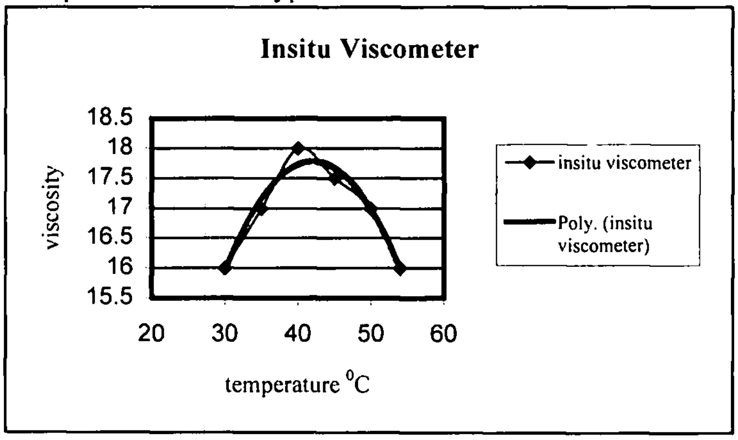
$y = -0.0057x^2 + 0.4868x + 11.018$ $R^2 = 0.6036$

Sample 10



$y = -0.0083x^2 + 0.6774x + 8.404$ $R^2 = 0.6804$

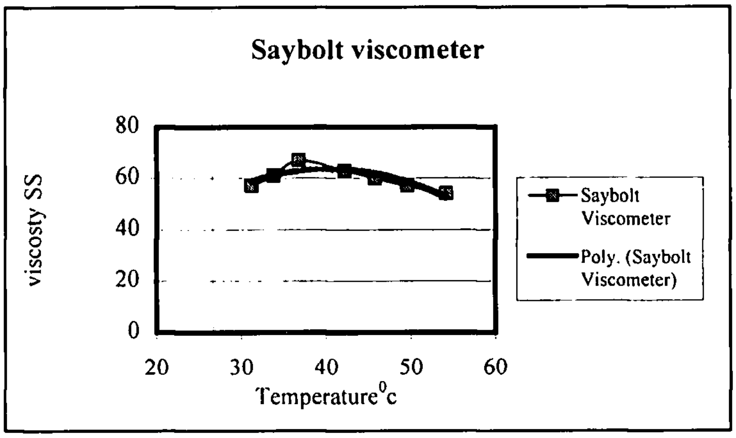
Sample 11 Type CSS-1



$y = -0.0126x^2 + 1.0563x - 4.4128$ $R^2 = 0.9595$

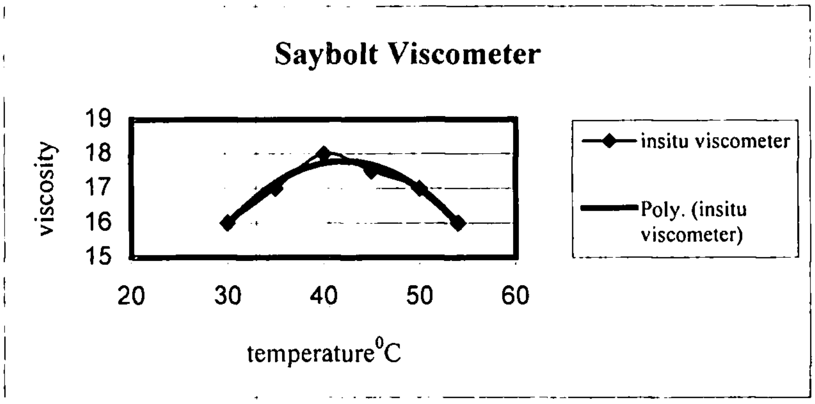
Sample tested using the Saybolt furol viscometer

Sample a
Type CRS-2
Emulsion plant RC&DC



$y = -0.0571x^2 + 4.5981x - 29.02$ $R^2 = 0.745$

Sample 11
Type CSS-1
Emulsion plant RC&DC



y = -0.0126x2 + 1.0563x - 4.4128
R2 = 0.9595

Conversion Charts of Insitu Viscosity to Saybolt Viscosity at t^0C

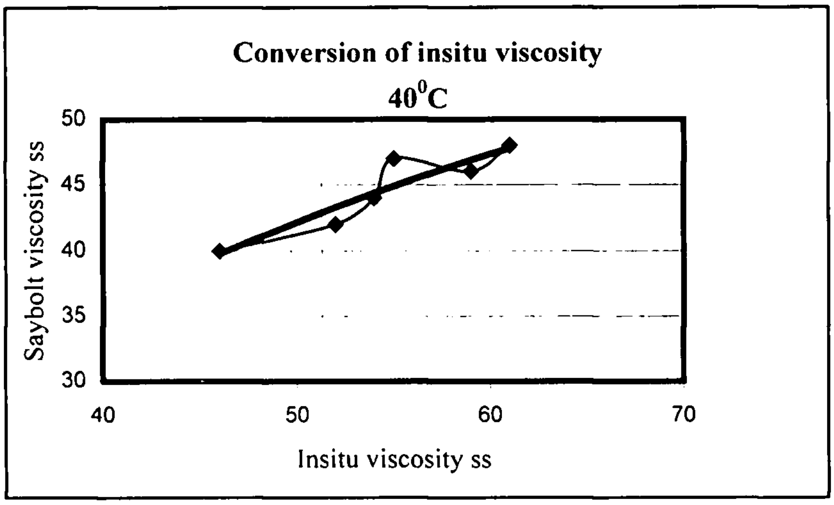


Figure 1 Conversion at 40^0C

$y = -0.0058x2 + 1.1583x - 1.1699$

$R2 = 0.8507$

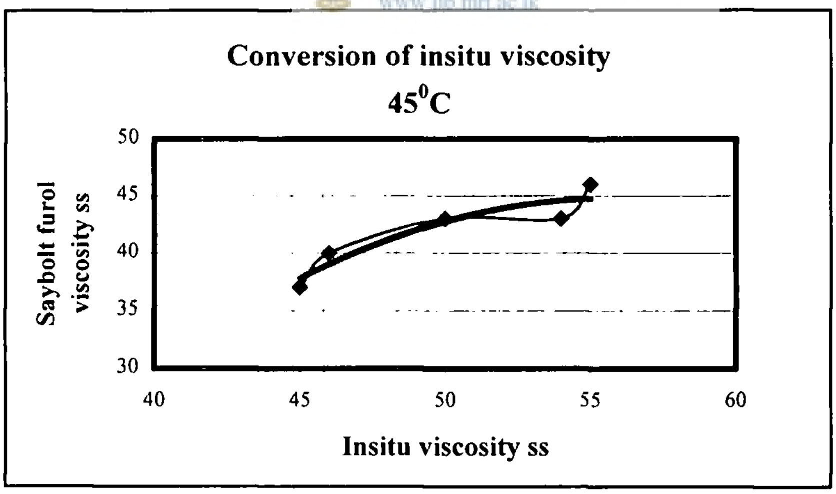


Figure 2 Conversion at 45^0C

$y = -0.059x2 + 6.5916x - 139.4$

$R2 = 0.8776$

ctd'

Conversion Charts of Insitu Viscosity to Saybolt Viscosity at t^0C

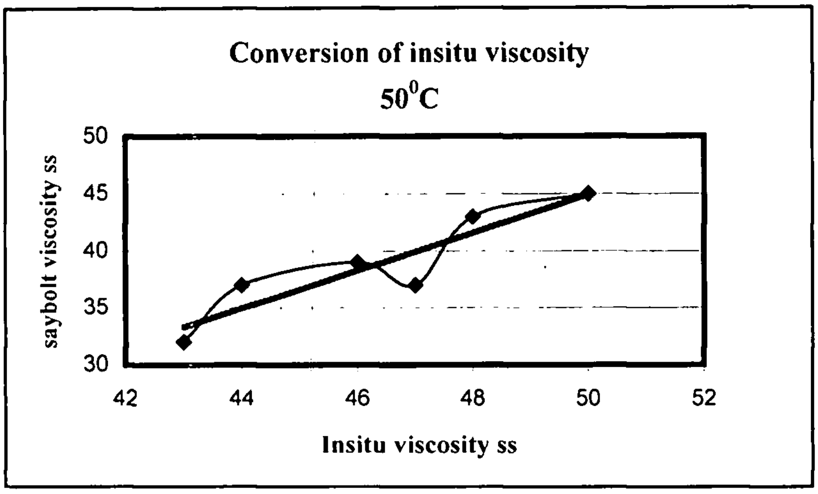


Figure 3 Conversion at 50^0C

y = 0.0026x2 + 1.4221x - 32.574
R2 = 0.844

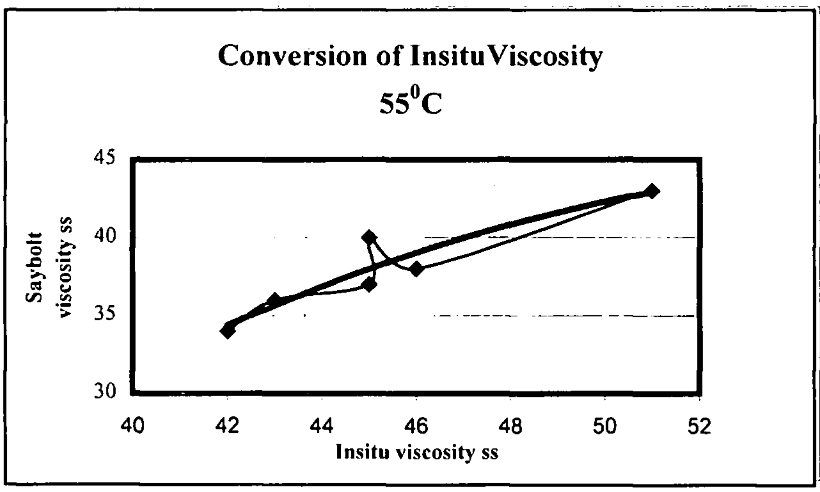


Figure 4 Conversion at 55^0C

y = -0.0429x2 + 4.9383x - 97.329
R2 = 0.8734

Conversion Charts of Saybolt Viscosity at t^0C to at 55^0C ctd'

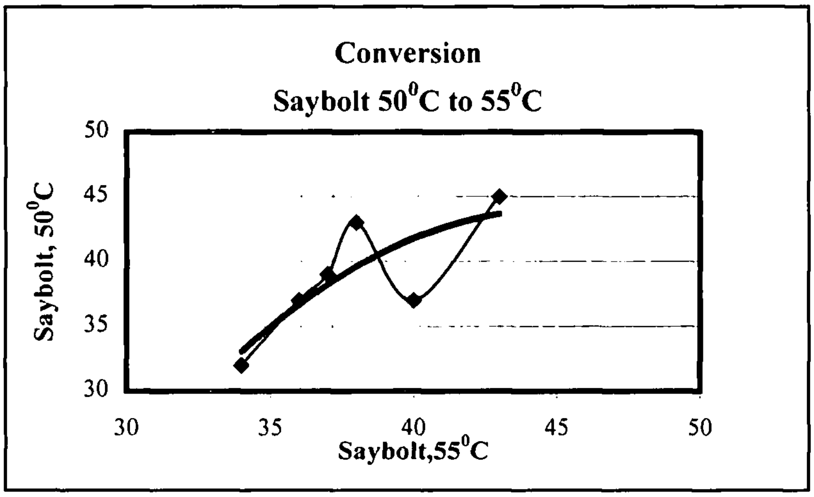


Fig.5: Conversion of viscosity

y = -0.0923x2 + 8.2871x - 142
R2 = 0.6515

APPENDIX 6

LABORATORY EXPERIMENTS

ON BOARD TEST & RESIDUE BY EVAPORATION

RESULTS OF THE BOARD TEST (PLATE TEST)

Table 1; rate of spread of 19mm aggregate as first seal

item	wt tray kg	Area tray m^2	wt tray+ 9mm ag	wt of 19 agg kg	rate kg/m^2
1	0.884	0.235*0.2	1.770	0.886	15.54
2	0.888	0.235*0.2	1.746	0.858	15.90
3	0.884	0.235*0.2	1.762	0.878	15.07
4	0.888	0.235*0.2	1.770	0.832	15.67
5	0.884	0.235*0.2	1.750	0.866	16.33
6	0.888	0.235*0.2	1.790	0.902	15.46
7	0.884	0.235*0.2	1.732	0.848	16.64
8	0.888	0.235*0.2	1.807	0.919	15.80
9	0.888	0.235*0.2	1.780	0.935	15.15
10	0.884	0.235*0.2	1.798	0.920	15.89
11	0.884	0.235*0.2	1.755	0.859	16.22
12	0.888	0.235*0.2	1.810	0.889	16.50
13	0.884	0.235*0.2	1.789	0.880	16.46
14	0.884	0.235*0.2	1.803	0.887	16.58
15	0.888	0.235*0.2	1.741	0.900	15.23
16	0.888	.235*0.23	1.831	0.951	17.22
17	0.884	.235*0.23	1.822	0.938	16.99
18	0.884	.235*0.23	1.809	0.925	16.74
19	0.888	.235*0.23	1.745	0.857	15.52
20	0.884	.235*0.23	1.735	0.851	15.61
21	0.888	.235*0.23	1.782	0.894	16.19
22	0.884	.235*0.23	1.798	0.914	16.55
23	0.884	.235*0.23	1.745	0.861	15.59
24	0.888	.235*0.23	1.829	0.941	17.03
25	0.884	.235*0.23	1.789	0.905	16.39
26	0.884	.235*0.23	1.823	0.939	17.00
27	0.884	0.235*0.2	1.772	0.888	16.08
28	0.888	0.235*0.2	1.748	0.860	15.57
29	0.884	0.235*0.2	1.765	0.881	15.95
30	0.888	0.235*0.2	1.775	0.887	16.06

Table 2; rate of spread of 9.5mm agg. as second seal with 19 mm agg.

Item	Wt of tra kg	Area tray m^2	Wt tray + 9mm ag Kg	Wt tray+ 9+9.5 m agg Kg	Wt of .5mm ag kg	Rate of 9.5mm kg/m^2
1	0.884	.235*0.23	1.770	2.267	0.497	9.00
2	0.888	.235*0.23	1.746	2.305	0.559	10.12
3	0.884	.235*0.23	1.762	2.345	0.583	10.56
4	0.888	.235*0.23	1.770	2.378	0.608	11.00
5	0.884	.235*0.23	1.750	2.286	0.536	9.71
6	0.888	.235*0.23	1.790	2.321	0.531	9.62
7	0.884	.235*0.23	1.732	2.236	0.504	9.13
8	0.888	.235*0.23	1.807	2.354	0.547	9.91
9	0.888	.235*0.23	1.780	2.398	0.618	11.19
10	0.884	.235*0.23	1.798	2.311	0.513	9.29
11	0.884	.235*0.23	1.755	2.254	0.499	9.04
12	0.888	.235*0.23	1.810	2.412	0.602	10.90
13	0.884	.235*0.23	1.789	2.287	0.498	9.02
14	0.884	.235*0.23	1.803	2.409	0.606	10.97
15	0.888	.235*0.23	1.741	2.242	0.501	9.07
16	0.88	.235*0.23	1.831	2.342	0.511	9.25
17	0.884	.235*0.23	1.822	2.381	0.559	10.12
18	0.884	.235*0.23	1.809	2.292	0.483	8.75
19	0.888	.235*0.23	1.745	2.331	0.586	10.61
20	0.884	.235*0.23	1.735	2.246	0.511	9.26
21	0.888	.235*0.23	1.782	2.355	0.573	10.38
22	0.884	.235*0.23	1.798	2.441	0.643	11.64
23	0.884	.235*0.23	1.745	2.334	0.589	10.66
24	0.888	.235*0.23	1.829	2.365	0.536	9.71
25	0.884	.235*0.23	1.789	2.421	0.632	11.44
26	0.884	.235*0.23	1.823	2.278	0.455	8.23
27	0.884	0.235*0.2	1.772	2.241	0.469	8.49
28	0.888	0.235*0.2	1.748	2.234	0.486	8.80
29	0.884	0.235*0.2	1.765	2.344	0.579	10.48
30	0.888	0.235*0.2	1.775	2.349	0.574	10.34

Table 3; Residue by evaporation test

Item	Type of Emulsion	% Residue Distillation	% Residue Evaporation	Difference
1	CRS-1	61	61	0
2	CRS-1	60	59	-1
3	CRS-1	59	59	0
4	CRS-1	64	65	1
5	CRS-1	59	59	0
6	CRS-1	58	58	0
7	CRS-1	48	51	3
8	CRS-1	58	59	1
9	CRS-1	54	54	0
10	CRS-1	60	60	0
11	CRS-1	54	55	1
12	CRS-1	59	60	1
13	CRS-1	60	60	0
14	CRS-1	61	63	2
15	CRS-1	54	55	1
16	CRS-1	62	63	1
17	CRS-1	59	58	-1
18	CRS-1	58	60	2
19	CRS-1	58	57	-1
20	CRS-1	58	58	0
21	CRS-1	63	64	1
22	CRS-1	61	61	0
23	CRS-1	57	57	0
24	CRS-1	60	59	-1
25	CRS-2	64	65	1

ctd'

Table 3; Residue by evaporation test

Item	Type of Emulsion	% Residue Distillation	% Residue Evaporation	Difference
27	CRS-2	58	58	0
28	CRS-2	62	62	0
29	CRS-2	67	66	-1
30	CRS-2	65	66	1
31	CRS-2	67	67	0
32	CRS-2	65	66	1
33	CRS-2	67	67	0
34	CRS-2	65	66	1
35	CRS-2	67	67	0
36	CRS-2	66	66	0
37	CRS-2	67	66	-1
38	CSS-1	60	61	1
39	CSS-1	60	61	1
40	CSS-1	61	64	3
41	CSS-1	62	62	0
42	CSS-1	57	58	1
43	CSS-1	61	62	1
44	CSS-1	62	63	1
45	CSS-1	59	60	1
46	CSS-1	58	59	1
47	CSS-1	60	60	0
48	CSS-1	61	61	0
49	CSS-1	59	59	0
50	CSS-1	59	59	0

APPENDIX 7

FIELD WORK ON

UNIVERSITY OF MORATUWA

FIELD WORK CARRIED OUT ON THE INTERNAL ROADS OF UNIVERSITY OF MORATUWA

Sheet no 1

Item	General Description	Road to Textile Engineering Building			
		1	2	3	4
1	Date of spraying	28/08/01	28/08/01	28/08/01	28/08/01
2	Air temperature at construction C^o	30	30	30	30
3	Road temperature at construction C^o	45	45	40	40
4	Nominal chip size 1st seal	19.0	19.0	19.0	19.0
	2nd seal	12.5	12.5	12.5	12.5
5	Specification used (Note 1)	a	a	a	a
6	Design guide line used (Note 2)	c**	c**	c**	c**
7	Traffic Category (Note 3)	b	a	a	a
8	Type of existing surface before spraying	d	d	d	d
	prior to surface dressing (Note 4)				
9	Date of surface preparation if applicable	None	None	None	None
	(Note 5)				
10	Condition of road surface at the period	b,d	b,d	b,d	b,d
	of construction (Note 6)				
11	Rate of spread of aggregate 1st seal	20.88	20.88	20.88	19.57
	2nd seal	13.37	13.37	13.37	12.8
12	Surface condition of chips (Note 7)	d,e	d,e	d,e	d,e
13	Binder type and grade (Note 8)	b+	b+	b+	b+
14	Rate of spread of binder 1st seal l/m^2	1.13*	1.13	1.13	1.28
	2nd seal l/m^2	1.24	1.24	1.24	1.32
15	Type of traffic control and aftercare				
	afforded to dressing (Note 9)	b	b	b	b
16	When did rain first occur after dressing				
	(Note 10)	c	c	c	c
17	Type of failure if applicable (Note 11)	none	none	none	none
18	When did failures become apparent(Note 12)	none	none	none	none

ctd'

Sheet no 2

Item	General Description	Road to Textile Engineering Building			
		5	6	7	8
1	Date of spraying	27/08/01	28/08/01	28/08/01	29/08/01
2	Air temperature at construction °C	30	30	30	30
3	Road temperature at construction °C	50	48	48	48
4	Nominal chip size 1st seal, mm	19.0	19.0	19.0	19.0
	2nd seal, mm	12.5	12.5	12.5	12.5
5	Specification used (Note 1)	d	d	d	d
6	Design guide line used (Note 2)	c**	c**	c	c
7	Traffic Category (Note 3)	a	a	a	a
8	Type of existing surface before spraying	d	d	d	d
	prior to surface dressing (Note 4)				
9	Date of surface preparation if applicable	None	None	None	None
	(Note 5)				
10	Condition of road surface at the period	b,d	b,d	b,d	b,d
	of construction (Note 6)				
11	Rate of spread of aggregate 1st seal, l/m^2	19.57	18.47	18.47	21.03
	2nd seal, l/m^2	12.8	9.72	9.72	12.53
12	Surface condition of chips (Note 7)	d,e	d,e	d,e	d,e
13	Binder type and grade (Note 8)	b	b+	b+	b
14	Rate of spread of binder 1st seal l/m^2	1.28*	1.13	1.13	1.15
	2nd seal l/m^2	1.32	1.3	1.3	1.35
15	Type of traffic control and aftercare				
	afforded to dressing (Note 9)	b	b	b	b
16	When did rain first occur after dressing				
	(Note 10)	c	c	c	c
17	Type of failure if applicable (Note 11)	none	none	none	none
18	When did failures become apparent(Note 12)	none	none	none	none

ctd'

Sheet no 3

Item	General Description	Road to Textile Engineering Building			
		9			
1	Date of spraying	29/08/01			
2	Air temperature at construction °C	30			
3	Road temperature at construction °C	45			
4	Nominal chip size 1st seal,mm	19.0			
	2nd seal,mm	12.5			
5	Specification used (Note 1)	d			
6	Design guide line used (Note 2)	c**			
7	Traffic Category (Note 3)	a			
8	Type of existing surface before spraying	d			
	prior to surface dressing (Note 4)				
9	Date of surface preparation if applicable	None			
	(Note 5)				
10	Condition of road surface at the period	b,d			
	of construction (Note 6)				
11	Rate of spread of aggregate 1st seal l/m^2	17.42			
	2nd seal l/m^2	9.32			
12	Surface condition of chips (Note 7)	d,e			
13	Binder type and grade (Note 8)	b			
14	Rate of spread of binder 1st seal l/m^2	1.17*			
	2nd seal l/m^2	1			
15	Type of traffic control and aftercare				
	afforded to dressing (Note 9)	b			
16	When did rain first occur after dressing				
	(Note 10)	c			
17	Type of failure if applicable (Note 11)	none			
18	When did failures become apparent(Note 12)	none			

ctd'

sheet no 4

Item	General Description	Road to Civil Engineering Complex			
		10	11	12	13
1	Date of spraying	30/08/01	31/08/01	31/08/01	03/09/01
2	Air temperature at construction °C	30	30	30	30
3	Road temperature at construction °C	42	40	40	38
4	Nominal chip size 1st seal mm	19.0	19.0	19.0	19.0
	2nd seal mm	12.5	12.5	12.5	12.5
5	Specification used (Note 1)	d	a	a	a
6	Design guide line used (Note 2)	c**	c**	c**	c
7	Traffic Category (Note 3)	b	b	b	b
8	Type of existing surface before spraying				
	prior to surface dressing (Note 4)	d	d	d	d
9	Date of surface preparation if applicable				
	(Note 5)	a	a	a	a
10	Condition of road surface at the period	b,d	b,d	b,d	b,d
	of construction (Note 6)				
11	Rate of spread of aggregate 1st seal kg/m^2	17.0	21.5	21.5	21.5
	2nd seal Kg/m^2	11.0	14.5	14.5	14.5
12	Surface condition of chips (Note 7)	d,e	d,e	d,e	d,e
13	Binder type and grade (Note 8)	b	a	a	a
14	Rate of spread of binder 1st seal l/m^2	1.4*	1.1	1.1*	1.1*
	2nd seal l/m^2	1.2	1.2	1.2	1.2
15	Type of traffic control and aftercare				
	afforded to dressing (Note 9)	d	d	d	d
16	When did rain first occur after dressing				
	(Note 10)	c	c	c	c
17	Type of failure if applicable (Note 11)	none	none	none	none
18	When did failures become apparent(Note 12)	none	none	none	none

ctd'

Sheet no 5

Item	General Description	Road to Civil Engineering Complex			
		14	15	16	
1	Date of spraying	03/09/01	03/09/01	03/09/01	
2	Air temperature at construction °C	30	30	30	
3	Road temperature at construction °C	42	42	42	
4	Nominal chip size 1st seal mm	19.0	19.0	19.0	
	2nd seal mm	12.5	12.5	12.5	
5	Specification used (Note 1)	d	d	d	
6	Design guide line used (Note 2)	c**	c	c	
7	Traffic Category (Note 3)	a	a	a	
8	Type of existing surface before spraying				
	prior to surface dressing (Note 4)	d	d	d	
9	Date of surface preparation if applicable	a	a	a	
	(Note 5)				
10	Condition of road surface at the period	b,d	b,d	b,d	
	of construction (Note 6)				
11	Rate of spread of aggregate 1st seal Kg/m^2	17.0	17.0	17.0	
	2nd seal Kg/m^2	11.0	11.0	11.0	
12	Surface condition of chips (Note 7)	d,e	d,e	d,e	
13	Binder type and grade (Note 8)	b	b	b	
14	Rate of spread of binder 1st seal l/m^2	1.3	1.3	1.3*	
	2nd seal l/m^2	1.1	1.1	1.1	
15	Type of traffic control and aftercare				
	afforded to dressing (Note 9)	d	d	d	
16	When did rain first occur after dressing				
	(Note 10)	c	c	c	
17	Type of failure if applicable (Note 11)	none	none	none	
18	When did failures become apparent(Note 12)	none	none	none	

Note 1

a. SSCM
b. Road Note 31
c. Asphalt emulsion manual
d. Formula developed
e. Other
** tandem roller is applied
* sand sealing is applied

Note 2

a. Road Note 3
b. Road Note 39
c. Other

Note 3

a. Under 100
b. 100-500
c. 500-1000
d. 1000-2000
e. 0ver 2000

Note 4

a. Aggregate base course
b. Surface dressing
c. Asphalt
d. Other

Note 5

a. Previous day
b. 0 to 1 week before surface dressing
c. 1 week to 1 month before surface dressing
d. 1 to 3 months before surface dressing
e. 3 to 6 months before surface dressing

Note 6

a. Wet
b. Normal
c. Cold
d. Warm, dry
e. Porous (lean)

Note 7

a. Dry
b. Wet
c. Damp
d. Dusty
e. Clean
f. Flaky

Note 8

a. Bitumen emulsion (Viscosity greater than 100)
b. Bitumen emulsion (Viscosity less than 100)
c. Emulsion prepared with 60/70 bitumen

If an adhesion agent or emulsion modifier is added please insert +

Note 9

a. Barriers
b. Slow boards
c. Other
d. None

Note 10

a. less than 24 hours
b. 1 day to 1 week
c. 1 week to 2 weeks
d. more than 2 weeks
e. during construction

Note 11

a. Less than 1 day after construction
b. Less than 1 week after construction
c. Within 1month
d. 1 month to 3 months
e. 3 months to 6 months
f. 6 months to 1 year

Note 12

a Over loss of chips
b. Chips crushing
c. Chips over embedded
d. Tires picking up chips while construction
e. Poor chip adhesion
f. Longitudinal strips
g. Transverse patches
h. Surface fatting
i. Failure under trees
j. Dressing uneven
k. Dressing polishes

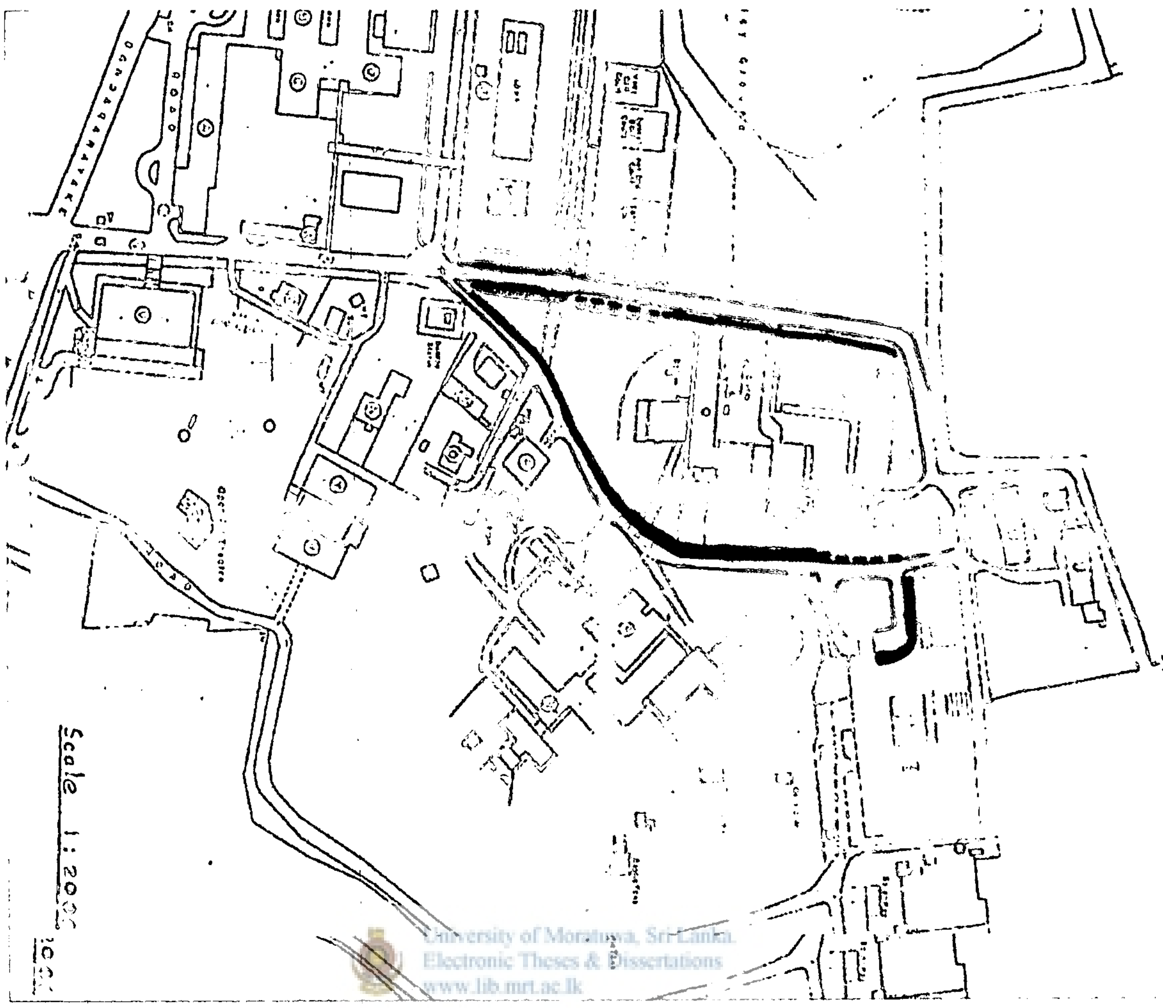
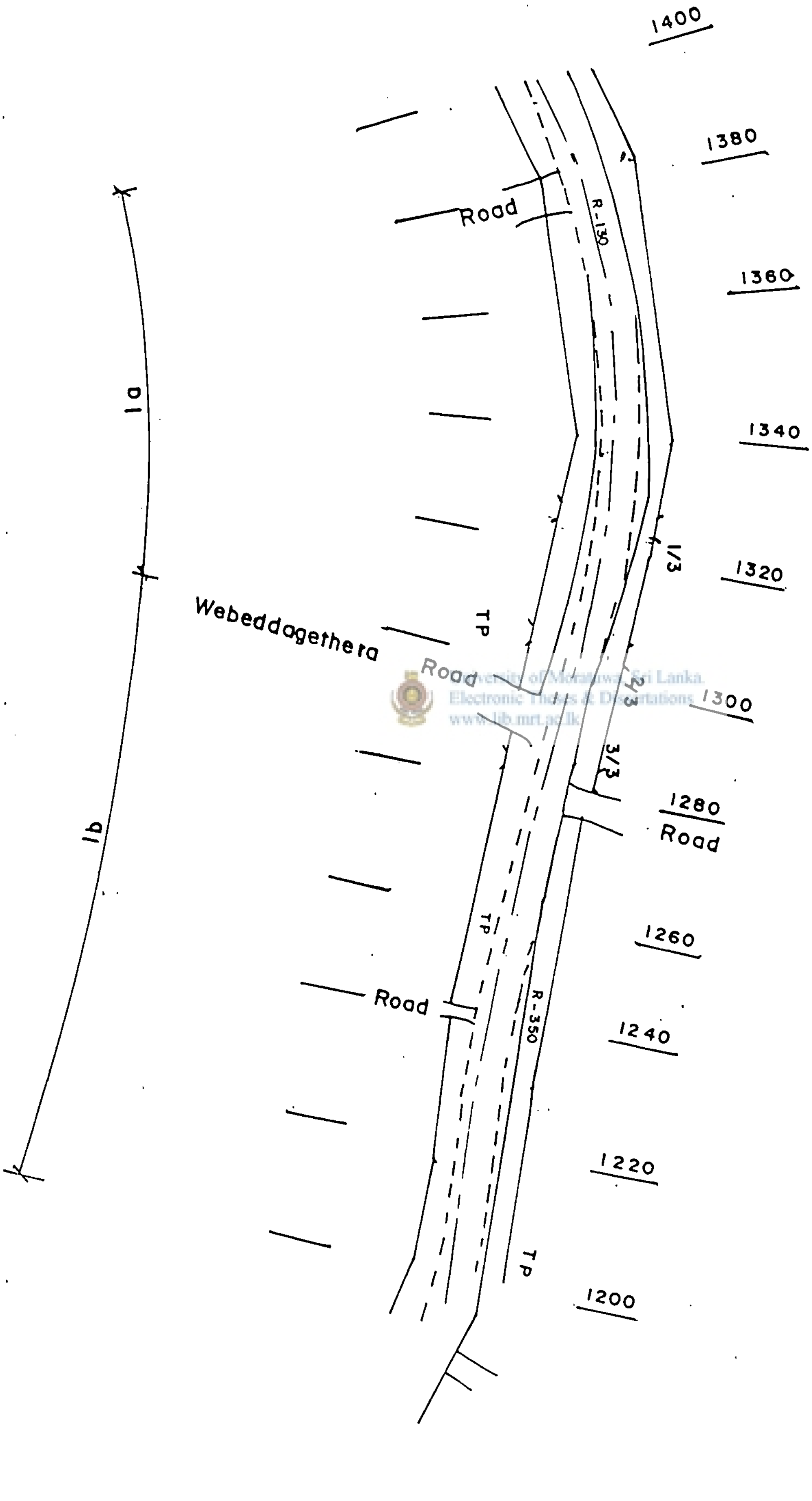


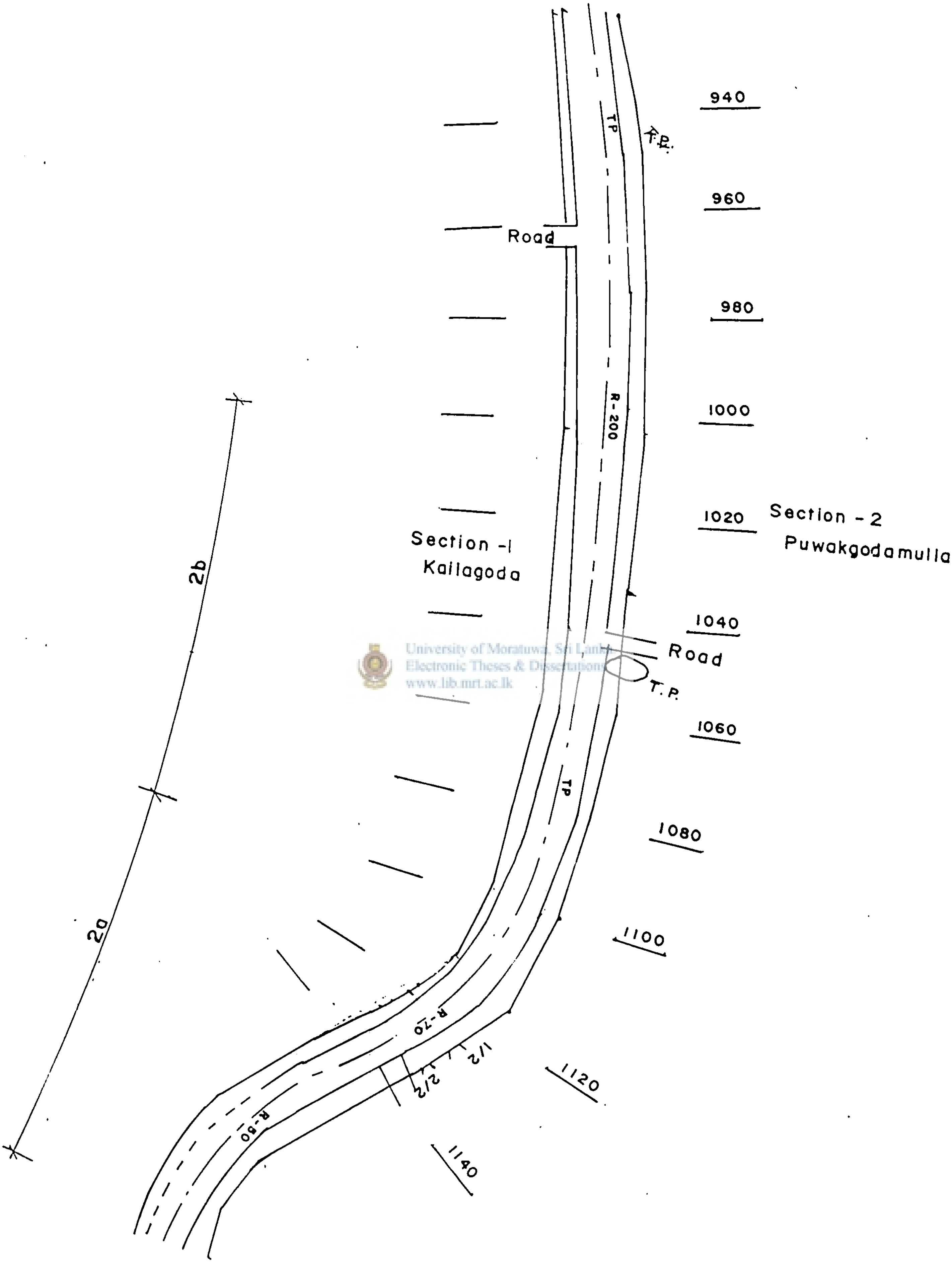
Fig: 1: Layout of the research fieldwork at University of Moratuwa

- Section done with 60/70 bitumen
- Present method of DBST
- Section done using adhesion promoter
- Section done using proposed formula
- Sections done without sand sealing

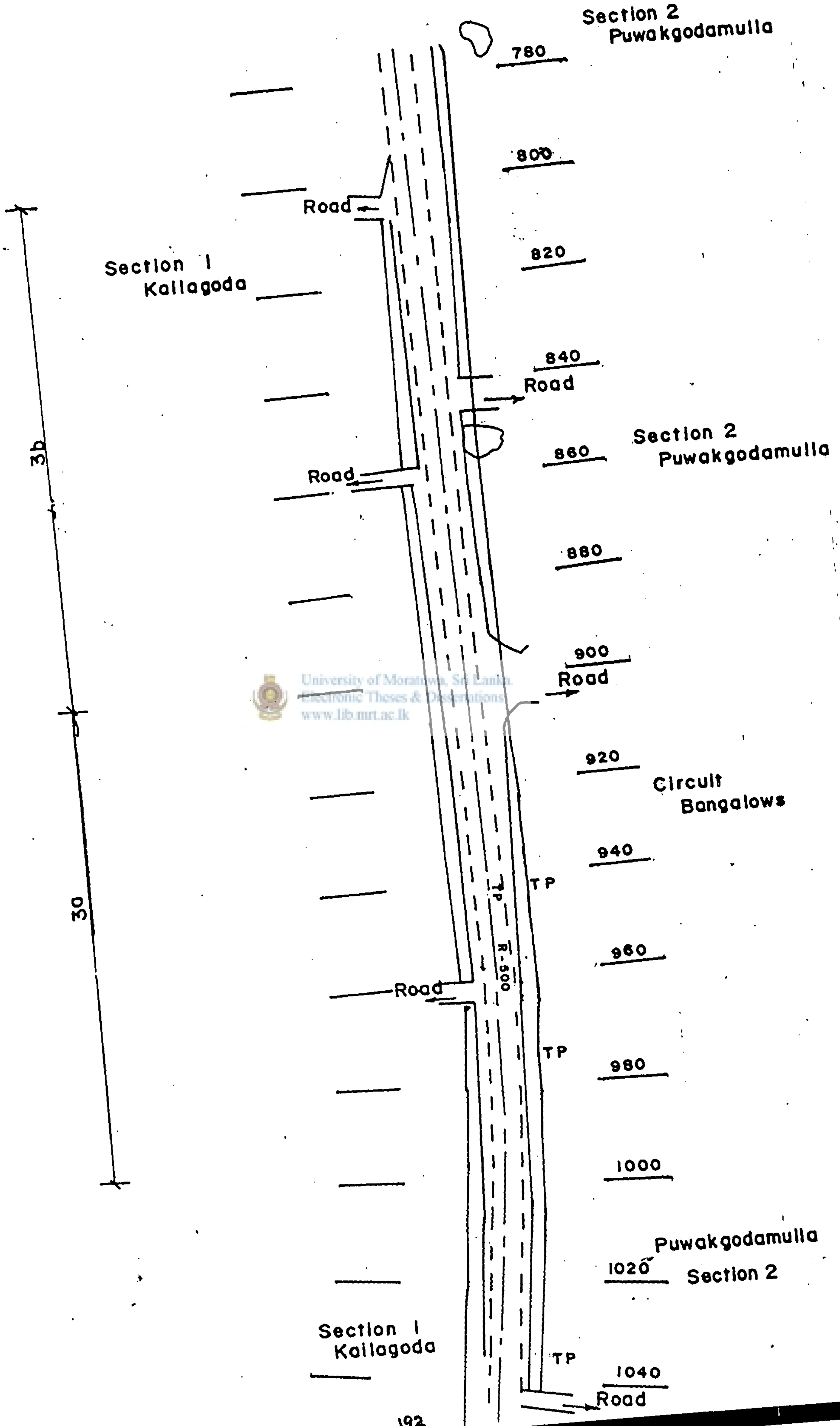


RESEARCH SECTION I

RESEARCH SECTION 2



RESEARCH SECTION 3



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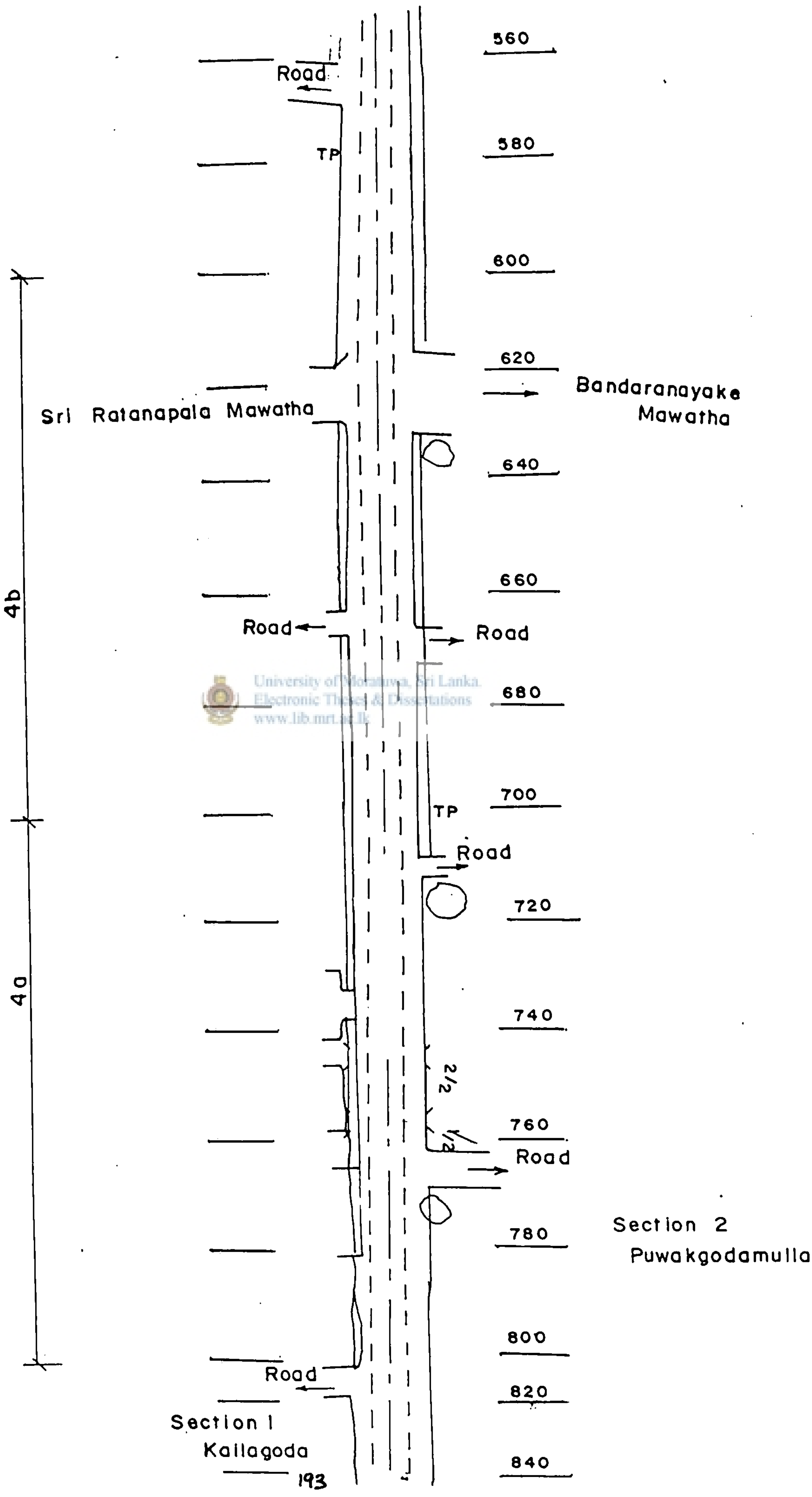

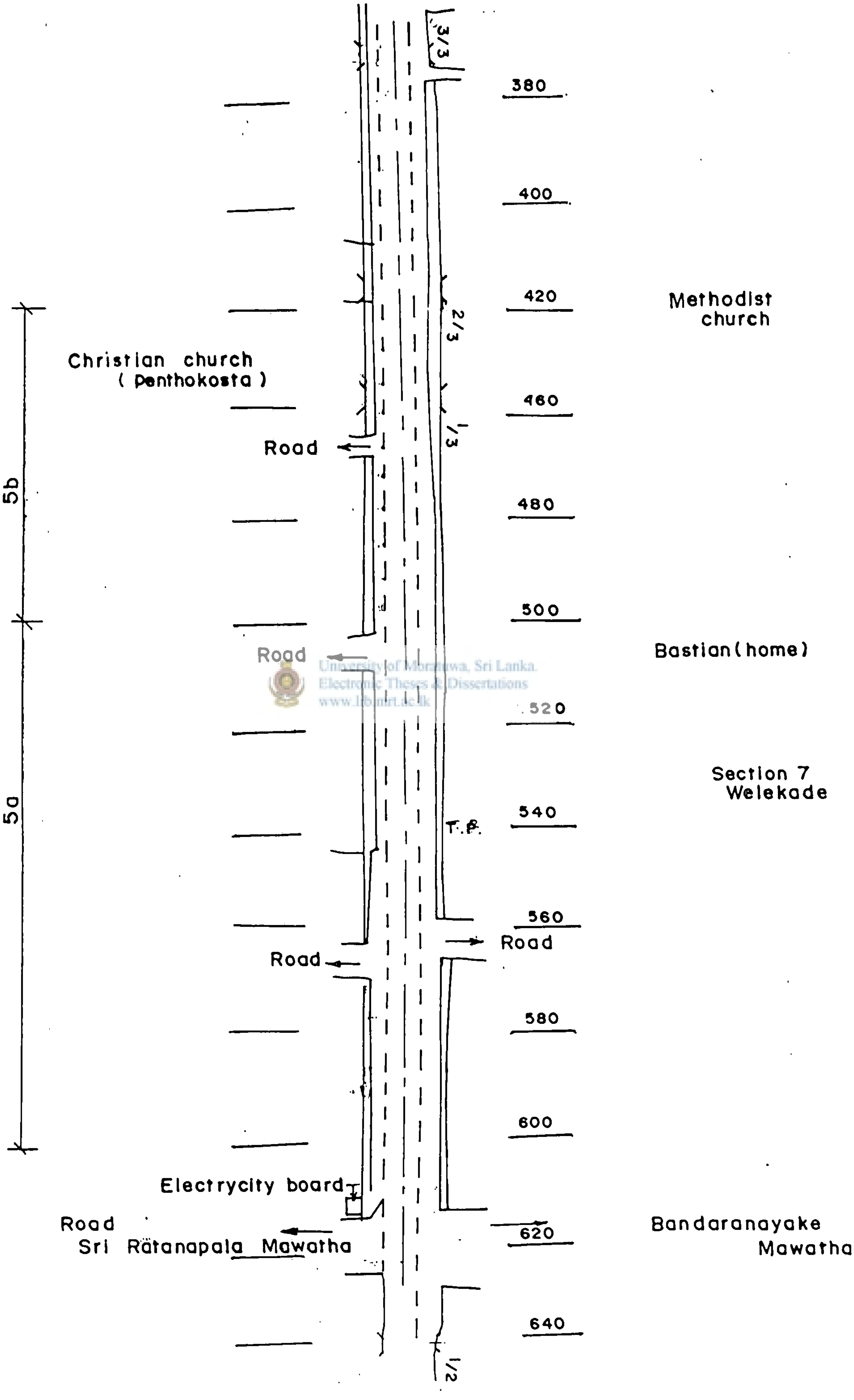

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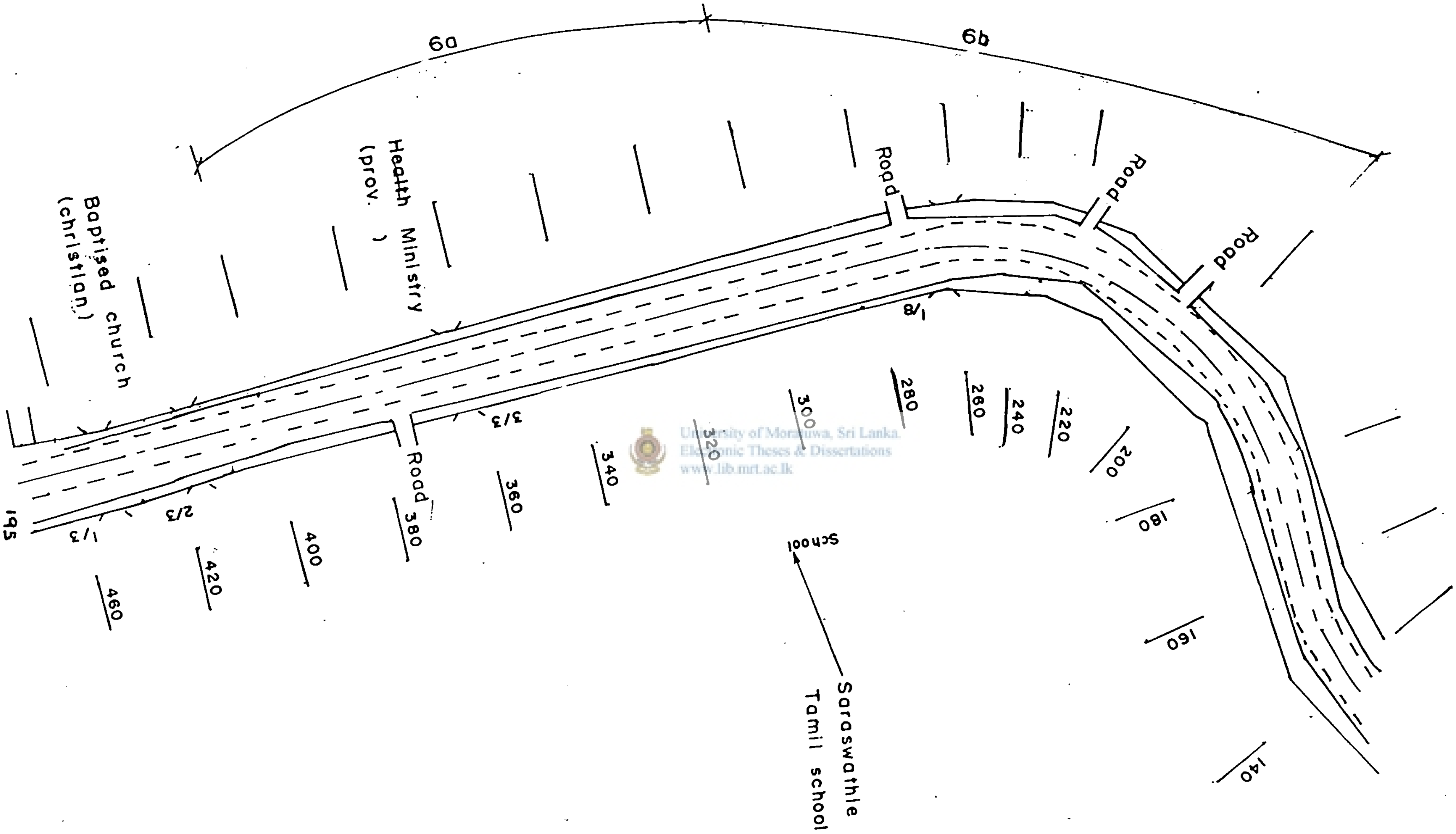


RESEARCH SECTION 6

APPENDIX 8

FIELD WORK ON

BADULLA MAHIYANGANAYA ROAD

FIELD WORK
BADULLA KARAMETIYARA MAHIYANGANAYA ROAD

sheet 1

Item	Section	1a	1b	2a	2b	3a	3b
1st seal	date	26/02/02	26/02/02	03/04/02	03/04/02	03/05/02	03/05/02
	binder% l/m^2	1.11	1.11	1.22	1.22	1.17	1.22
	%aggKg/m^2	17.68	17.74	18.00	18.08	18.20	18.22
	agg.size mm	19.0	19.0	19.0	19.0	19.0	19.0
	binder% l/m^2	1.61	1.67	1.78	1.83	1.78	1.83
2nd seal	%aggKg/m^2	11.48	11.44	10.92	10.94	11.52	11.48
	agg.size mm	9.5	9.5	9.5	9.5	9.5	9.5
General	tandom	yes	no	yes	no	yes	no
	binder type	80/100	80/100	80/100	80/100	80/100	80/100
	app.temp ^0C	60	60	65	65	65	61
	jeometry	0	0	0	0	0	0
	agg.type	1	1	1	1	1	1
	base type	2	2	2	2	2	2
	sub grade	0	0	0	0	0	0
	modifier	no	no	no	no	yes	yes
	% whip off	11.04	9.46	8.16	8.26	7.02	8.62
	date observe	08/03/02	08/03/02	08/03/02	08/03/02	08/03/02	08/03/02
	weather	hot	hot	hot	hot	cloudy	cloudy
	sub. Weather	heavy rai	heavy rai	heavy rai	heavy rain	heavy rai	heavy rain

sub. Weather; subsequent weather after construction

FIELD WORK
BADULLA KARAMETIYARA MAHIYANGANAYA ROAD

ctd'

sheet 2

Item	Section	4a	4b	5a	5b	6a	6b
1st seal	date	03/08/02	03/08/02	03/11/02	03/11/02	03/12/02	03/12/02
	binder% l	1.06	1.1	1.22	1.22	1.22	1.17
	%aggKg/	18.00	18.10	18.40	18.21	18.40	18.40
	agg.size	19.0	19.0	19.0	19.0	19.0	19.0
2nd seal	binder% l	1.61	1.56	1.78	1.78	1.78	1.83
	%aggKg/	11.40	11.40	11.40	11.60	11.40	11.40
	agg.size	9.5	9.5	9.5	9.5	9.5	9.5
General	tandom	yes	no	yes	no	yes	no
	binder ty	60/80	60/80	60/80	60/80	60/80	60/80
	app.temp	65	65	65	65	65	65
	jeometry	2	2	2	2	3	4
	agg.type	1	1	1	1	1	1
	base type	2	2	2	2	2	2
	sub grade	0	0	0	0	0	0
	modifier	no	no	no	no	no	no
	% whip o	9.8	10.7	8.33	11.13	6.4	7.64
	date obse	11/03/02	11/03/02	12/03/02	12/03/02	15/03/02	15/03/02
	weather	cloudy	cloudy	cloudy	cloudy	normal	normal
	sub weat	normal	normal	normal	normal	normal	normal

sub. Weather: Subsequent weath after construction

Table 1; Temperature measurements on road surface

Road: William Gopallawa Mawatha, Kandy
Month: October
Year: 2000

Item	Chainage Km	time	Ambient Temp: ^{0}C	Surface Temp ^{0}C	Remarks
1	2+300	08:10	26	32	
		09:10	26	32	
		10:30	28	38	
		11:30	27	34	
		13:00	29	40	maximum
		14:00	29	39	
		15:30	26	29	
		16:30	26	29	
2	2+350	08:20	26	32	
		09:20	26	33	
		10:40	28	38	
		11:40	27	37	
		13:10	29	40	maximum
		14:10	29	39	
		15:40	26	38	
		16:40	26	38	
3	2+450	08:30	26	32	
		09:30	27	33	
		10:50	28	36	
		11:50	27	37	
		13:20	29	40	maximum
		14:20	26	38	
		15:50	26	38	
		16:50	26	30	
4	2+500	08:40	26	32	
		09:40	27	34	
		11:00	27	36	
		12:00	27	37	
		13:30	29	42	maximum
		14:20	28	40	
		16:00	26	38	
		17:00	26	30	
5	2+550	08:50	26	32	
		09:50	28	34	
		11:10	27	34	
		12:10	27	37	
		13:40	29	42	maximum
		14:50	29	39	
		16:10	22	36	
		17:10	26	30	
6	2+600	09:00	26	32	
		10:00	28	34	
		11:20	26	36	
		12:20	28	38	
		14:50	29	40	maximum
		16:10	28	36	
		17:10	26	30	

APPENDIX 9

TEMPERATURE MEASUREMENTS

Table2; Temperature measurements on road surface

Road: Colombo Kandy Road
Section: Kiribathgoda to Nittambuwa
Month: July
Year: 2000
Weather: Dry

Item	Chainage	Time	Ambient Temp °C	Surface Temp °C	Remarks
1	28+300	08:00	28	35	
		09:40	31	36	
		10:00	32	41	
		11:40	34	45	
		11:50	34	46	
		13:45	35	51	maximum
		14:00	35	51	
		15:05	35	51	
		15:15	35	50	
		16:35	35	49	
2	28+400	08:15	29	35	
		09:30	31	38	
		10:10	33	43	
		11:20	34	45	
		12:10	34	48	
		13:30	34	49	
		14:10	35	54	maximum
		14:55	35	51	
		15:00	35	51	
		15:20	35	50	
		16:30	35	49	
3	28+500	08:30	29	36	
		09:20	31	37	
		10:40	33	44	
		11:10	34	44	
		12:20	34	48	
		13:20	35	48	
		14:20	35	57	maximum
		14:50	35	52	
		15:30	35	50	
		16:10	35	49	
4	28+600	08:40	29	36	
		09:10	30	37	
		10:30	33	45	
		11:00	33	44	
		12:40	35	48	
		13:10	34	48	
		14:30	35	53	maximum
		15:35	34	49	
		16:10	35	49	

Table2; Temperature measurements on road surface con'd

Road: Colombo Kandy Road
Section: Kiribathgoda to Nittambuwa
Month: July
Year: 2000
Weather: Dry

Item	Chainage	Time	Ambient Temp ^0C	Surface Temp ^0C	Remarks
5	28+700	08:50	30	36	
		09:00	30	37	
		10:40	33	45	
		11:50	33	45	
		12:50	34	47	
		13:00	34	48	
		14:35	35	52	maximum
		14:45	35	52	
		15:40	35	49	
		16:00	35	49	

Table 3; Temperature measurements on road surface
Road: CGHW road
Section: Galle to Matara
Month: August
Year: 2000

Item	chainage	Time	Ambient Temperature ^0C	Surface Temperature ^0C	Remarks
1	142+000	08:35	31	34	
		10:25	32	36	
		11:50	33	38	
		13:15	33	48	
		14:15	33	54	maximum
		15:20	34	45	
		16:00	33	42	
		17:15	32	40	
2	143+000	07:45	30	32	
		09:30	32	40	
		11:00	33	48	
		12:05	33	50	
		14:30	33	51	maximum
		15:45	32	45	
		17:05	31	42	
3	142+900	07:50	30	34	
		09:35	34	41	
		11:05	33	48	
		12:00	33	48	
		14:35	33	49	maximum
		15:50	32	46	
		17:05	31	42	
		17:15	31	42	
4	142+800	07:55	30	34	
		09:40	33	40	
		11:10	33	46	
		11:55	33	48	
		14:40	33	48	maximum
		15:55	32	47	
		17:10	32	40	
5	142+700	08:00	30	35	
		09:45	33	42	
		11:15	33	46	
		13:50	33	52	maximum
		14:45	33	47	
		16:35	32	44	
		17:50	31	40	
6	142+600	08:05	30	34	
		09:50	33	40	
		11:20	33	43	
		13:45	33	51	maximum
		14:50	33	47	
		16:30	31	45	
		17:45	31	45	

Table 3; Temperature measurements on road surface cont'd

Ro ad: CGHW road
Section: Galle to Matara
Month: August
Year: 2000

Item	chainage	Time	Ambient Temperature ^0C	Surface Temperature ^0C	Remarks
6	142+500	08:10	31	36	
		08:55	32	41	
		10:00	33	43	
		10:45	34	45	
		11:25	33	45	
		13:40	33	45	
		14:55	33	48	maximum
		16:25	32	41	
		16:55	32	41	
		17:40	31	39	
		18:05	31	38	
7	142+400	08:15	31	38	
		08:50	32	40	
		10:05	33	43	
		10:40	34	45	
		11:30	33	46	
		12:05	33	48	
		13:35	33	49	
		14:05	33	49	maximum
		15:00	33	48	
		15:35	33	48	
		16:20	32	42	
		17:35	31	42	
		18:00	31	43	
8	142+300	08:20	31	34	
		08:45	32	38	
		10:10	33	43	
		10:35	33	43	
		11:35	33	37	
		12:00	32	43	
		13:30	33	48	
		14:00	33	50	maximum
		15:05	33	47	
		15:30	33	44	
		16:15	32	48	
		16:45	32	43	
		17:35	31	40	
		18:00	31	43	

Table 3; Temperature measurements on road surface cont'd

Road: CGHW road
Section: Galle to Matara
Month: August
Year: 2000

Item	chainage	Time	Ambient Temperature ^0C	Surface Temperature ^0C	Remarks
9	142+200	08:25	32	38	
		08:40	31	37	
		10:15	32	43	
		10:30	33	37	
		11:40	33	45	
		13:25	33	47	
		13:55	33	48	
		17:10	33	53	maximum
		17:35	33	48	
		16:10	32	43	
		16:40	32	40	
		17:25	31	40	
		17:50	31	38	
10	142+100	08:30	32	39	
		10:20	32	45	
		11:45	33	47	
		13:20	33	46	
		14:30	33	54	maximum
		15:15	33	49	
		16:25	32	47	
		17:20	31	45	
11	142+000	08:35	31	34	
		10:25	32	36	
		11:50	33	38	
		13:15	33	48	
		14:35	33	55	maximum
		15:20	33	45	
		16:00	33	42	
		17:15	32	40	

Table 4; Temperature measurements on road surface

Road: Colombo- Horana Road
Section: From Vilasitha Nivasa
Year: 2000
Month: September

Item	Chainage Km	Time	ambient temperature ^0C	Surface temperature^0C	Remarks
1	8+500	08:30	30	35	
		10:05	32	40	
		10:30	32	39	
		11:15	33	42	
		12:30	33	45	
		14:20	34	46	
		14:45	34	47	maximum
		16:10	32	41	
		17:45	33	45	
		17:50	32	41	
2	8+550	09:56	32	39	
		11:05	33	41	
		13:55	33	46	
		14:10	34	45	
		14:35	34	48	
		16:20	33	49	maxiimum
		17:35	32	45	
3	8+600	08:38	30	39	
		09:48	32	42	
		10:38	32	43	
		10:55	33	42	
		11:05	33	44	
		12:40	33	45	
		13:05	34	47	
		14:10	34	45	
		14:38	34	48	maximum
		15:45	32	46	
		15:55	33	46	
		16:15	32	46	
		17:25	32	47	
		17:55	32	41	
4	8+650	08:46	31	39	
		09:40	32	40	
		10:00	33	40	
		10:46	32	41	
		12:48	33	48	
		14:45	34	51	maximum
		15:40	32	48	
		16:25	33	48	
		17:18	35	40	
		18:00	32	41	

Table 4; Temperature measurements on road surface ctd'

Road: Colombo- Horana Road
Section: From Vilasitha Nivasa
Year: 2000
Month: September

Item	Chainage Km	Time	ambient temperature ^0C	Surface temperature^0C	Remarks
5	8+700	08:54	31	40	
		09:31	32	38	
		10:35	33	43	
		10:55	32	43	
		12:55	33	46	
		13:45	34	46	
		14:53	34	48	maximum
		15:30	33	43	
		16:32	33	40	
		17:12	32	41	
		18:05	32	41	
6	8+750	09:23	32	39	
		10:28	33	43	
		13:35	34	46	
		15:23	34	47	
		17:05	32	49	maximum
		18:00	35	48	
7	8+800	09:02	31	39	
		09:15	32	39	
		10:05	32	42	
		10:20	33	43	
		13:05	33	46	
		13:28	34	46	
		15:00	34	47	maximum
		15:15	34	45	
		16:40	32	43	
		16:55	32	41	
		18:10	32	41	
8	8+850	09:10	31	40	
		10:13	32	42	
		13:15	33	44	
		15:08	34	48	maximum
		16:08	32	46	
		18:14	32	41	

APPENDIX 10

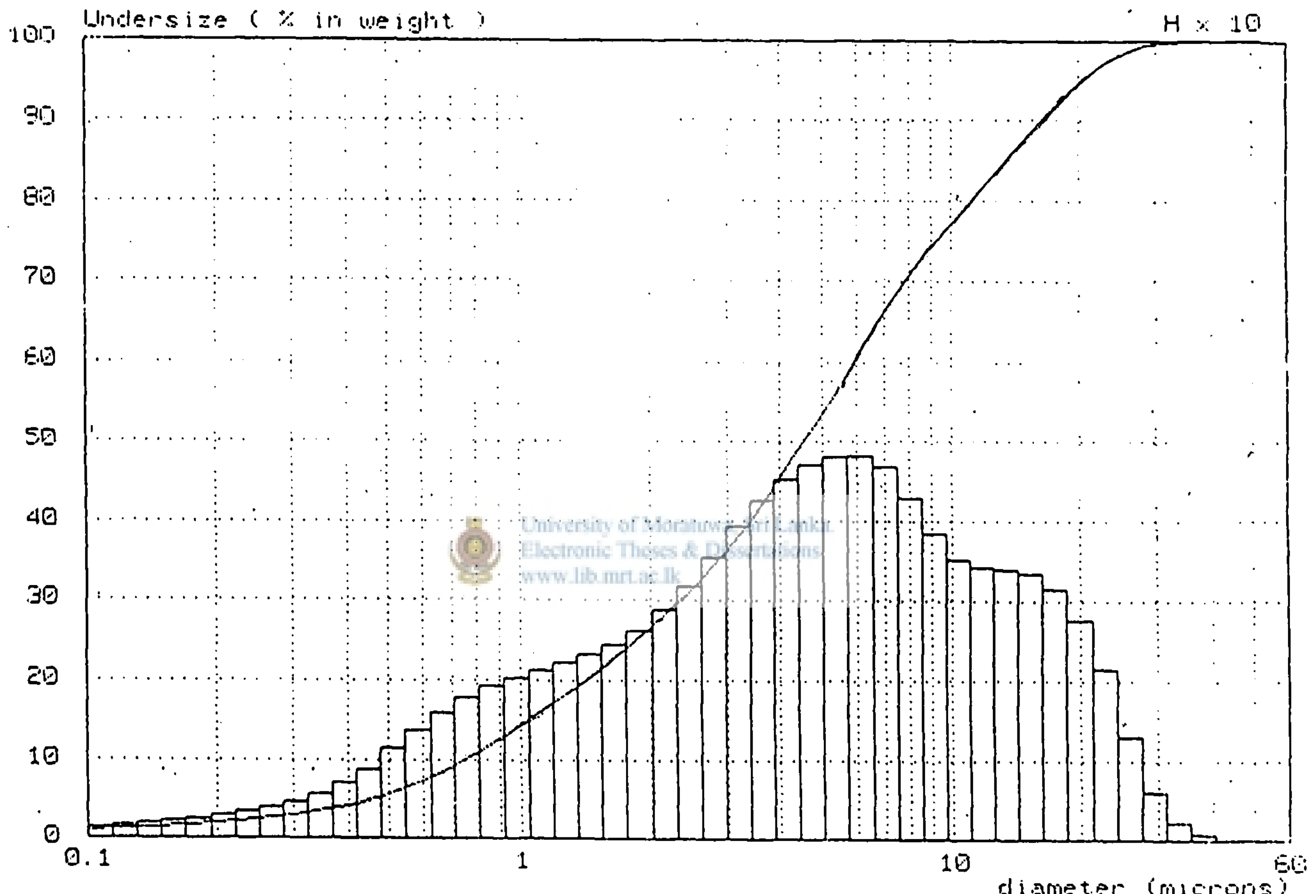
PARTICLE SIZE DISTRIBUTION

OF
BITUMEN EMULSION

Cilas - Alcatel Granulometer HR 850 128

Sample : 1647,no calciumclaride Result number 1

Suspension fluid :
Dispersing agent :
Ultrasonic mixer time : 0 s
Comments :



Median size. : 4.54 microns
Diameter for 10 % : 0.75 microns and 90 % : 16.38 microns

200 < Concentration < 400 : 260

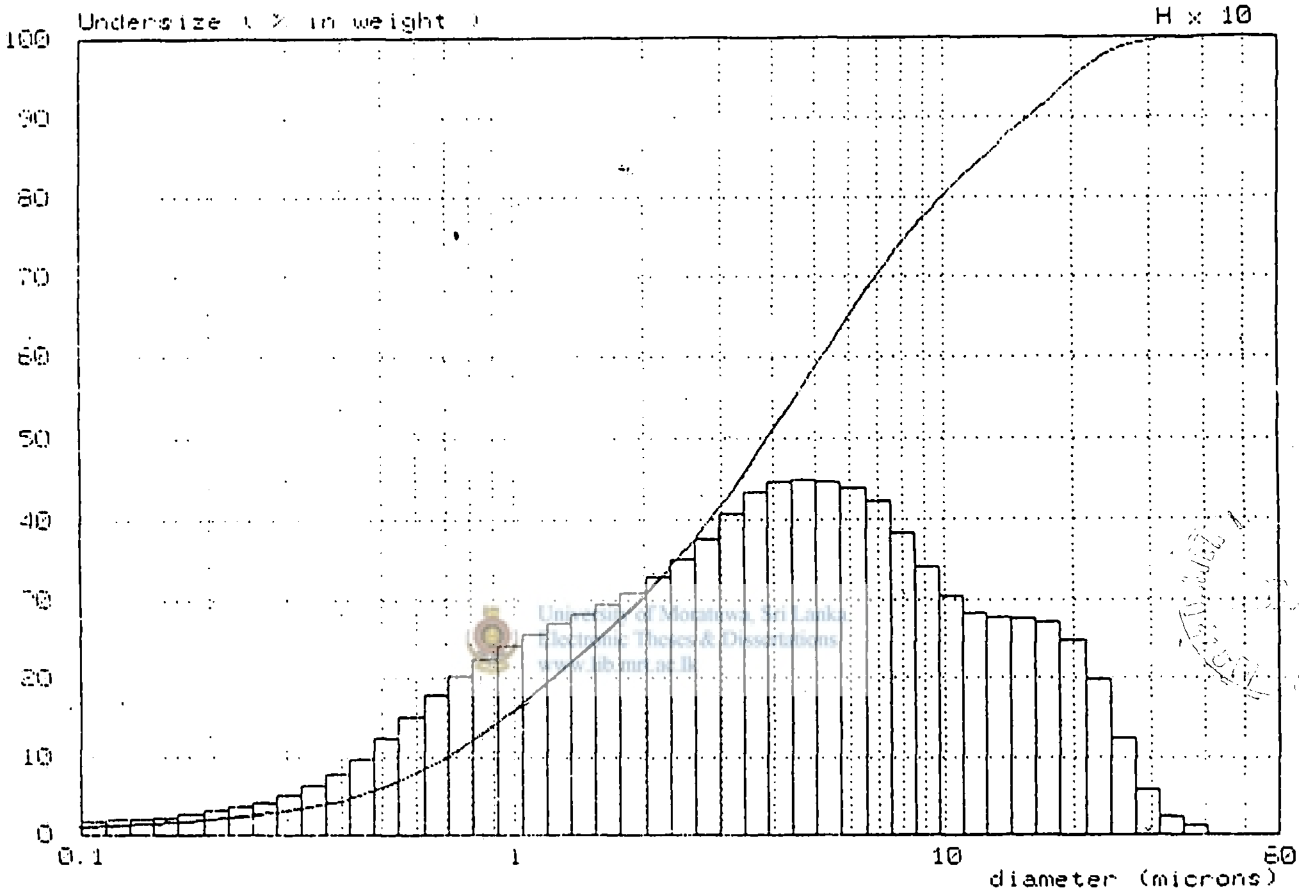
D	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
%	0.8	1.8	2.9	4.0	5.4	7.2	9.1	10.9	12.6	14.2
D	1.1	1.2	1.3	1.4	1.6	1.8	2.0	2.2	2.5	2.8
%	15.7	17.2	18.5	19.8	22.2	24.4	26.5	28.5	31.5	34.4
D	3.1	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	8.0
%	37.2	41.0	45.5	49.7	53.5	57.0	60.2	63.2	66.0	70.7
D	9.0	10.0	11.0	12.0	13.0	14.0	16.0	18.0	20.0	22.0
%	74.3	77.2	79.7	81.9	84.0	85.9	89.4	92.3	94.7	96.6
D	24.0	26.0	28.0	32.0	36.0	40.0	45.0	50.0	56.0	60.0
%	98.0	98.9	99.5	99.8	99.9	100.0	100.0	100.0	100.0	100.0

Measurement performed by : KARL HILLGREN
company : SCANROAD at : NACKA

Cilas - Alcatel　　　Granulometer HR 850　128

Sample : 1648,calciumcloride　　　Result number 2

Suspension fluid :
Dispersing agent :
Ultrasonic mixer time : 0 s
Comments :



Median size : 3.88 microns
Diameter for 10 % : 0.70 microns and 90 % : 15.76 microns

200 < Concentration < 400 : 235

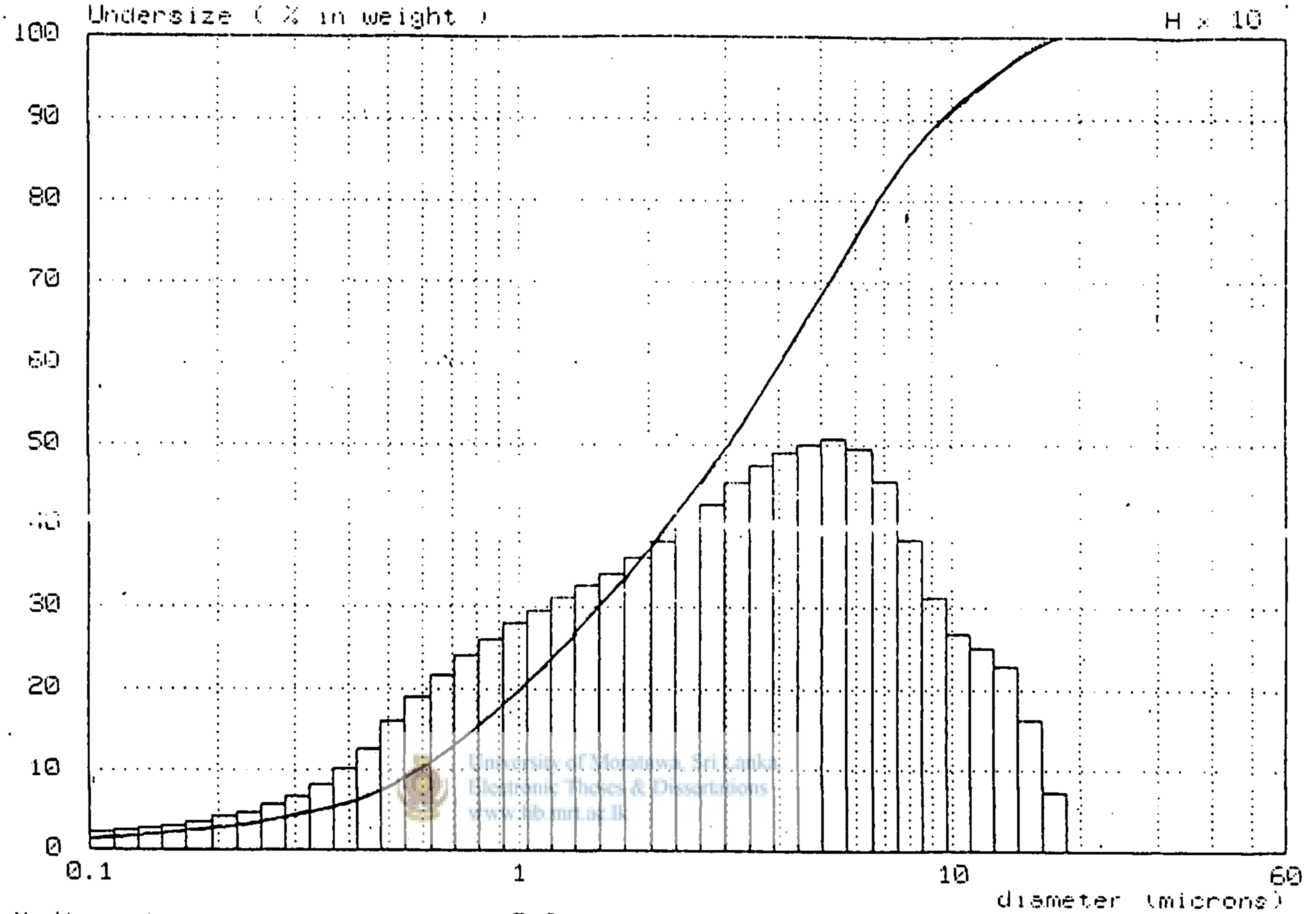
D	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
%	0.8	1.9	3.1	4.3	5.9	7.9	10.0	12.0	14.0	15.9
D	1.1	1.2	1.3	1.4	1.6	1.8	2.0	2.2	2.5	2.8
%	17.8	19.5	21.1	22.7	25.6	28.3	30.8	33.1	36.5	39.6
D	3.1	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	8.0
%	42.7	46.5	51.1	55.2	58.8	62.0	65.0	67.7	70.2	74.4
D	9.0	10.0	11.0	12.0	13.0	14.0	16.0	18.0	20.0	22.0
%	77.7	80.2	82.4	84.2	85.9	87.5	90.3	92.8	95.0	96.7
D	24.0	26.0	28.0	32.0	36.0	40.0	45.0	50.0	56.0	60.0
%	98.0	98.9	99.4	99.7	99.9	100.0	100.0	100.0	100.0	100.0

Measurement performed by : KARL HILLGREN
company : SCANROAD　at : NACKA

Cilas - Alcatel   Granulometer HR 850 128

Sample : 1654 3 days   Result number 1

Suspension fluid :
Dispersing agent :
Ultrasonic mixer Time : 0 s
Comments :



Median size : 3.04 microns
Diameter for 10 % : 0.58 microns   and 90 % : 9.58 microns

200 < Concentration < 400 : 388

D	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
%	1.2	2.6	4.1	5.7	7.8	10.4	12.9	15.3	17.7	19.9
D	1.1	1.2	1.3	1.4	1.6	1.8	2.0	2.2	2.5	2.8
%	22.0	24.0	25.9	27.7	31.1	34.2	37.1	39.8	43.7	47.3
D	3.1	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	8.0
%	50.6	54.9	59.8	64.3	68.3	72.1	75.5	78.6	81.3	85.7
D	9.0	10.0	11.0	12.0	13.0	14.0	16.0	18.0	20.0	22.0
%	88.7	90.9	92.7	94.4	96.0	97.4	99.4	100.0	100.0	100.0
D	24.0	26.0	28.0	32.0	36.0	40.0	45.0	50.0	56.0	60.0
%	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Measurement performed by : KARL HILLGREN
company : SCANROAD   at : NACKA