INTRODUCTION
CHAPTER 1

Chapter 1: Introduction

<table>
<thead>
<tr>
<th>S. No</th>
<th>Name of the Sub-Title</th>
<th>Page No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Introduction</td>
<td>3</td>
</tr>
<tr>
<td>1.2</td>
<td>Work background</td>
<td>3</td>
</tr>
<tr>
<td>1.3</td>
<td>Study Objectives</td>
<td>5</td>
</tr>
<tr>
<td>1.4</td>
<td>Research Methodology</td>
<td>5</td>
</tr>
<tr>
<td>1.4.1</td>
<td>General</td>
<td>5</td>
</tr>
<tr>
<td>1.4.2</td>
<td>The Research Stages &amp; Methodology</td>
<td>5</td>
</tr>
<tr>
<td>1.4.2.1</td>
<td>Stage 1: Identification of dosage of PPA required as a modifier through fundamental tests</td>
<td>5</td>
</tr>
<tr>
<td>1.4.2.2</td>
<td>Stage 2: Experiments to assess the high temperature performance grading of unmodified &amp; modified and aged &amp; un-aged binders as well as the polymer modified bitumen (PMB 40) using Dynamic Mechanical Analysis.</td>
<td>7</td>
</tr>
<tr>
<td>1.4.2.3</td>
<td>Stage 3: Experiments to assess the consistency of bituminous binder at mixing temperature using indigenously developed rotational viscometer.</td>
<td>7</td>
</tr>
<tr>
<td>1.4.2.4</td>
<td>Stage 4: Experiments to explore the micro structural properties for unmodified &amp; modified, and aged &amp; un-aged binders through Scanning Electron Microscopic (SEM) Imaging, X-Ray diffraction (XRD) and Thermo Gravimetric and Differential Scanning Calorimetric (TG-DSC) analysis</td>
<td>7</td>
</tr>
<tr>
<td>1.4.2.5</td>
<td>Stage 5: Investigating the efficacy of PPA modification on bitumen for mix applications</td>
<td>8</td>
</tr>
<tr>
<td>1.4.2.6</td>
<td>Stage 6: Analysis and report writing</td>
<td>8</td>
</tr>
<tr>
<td>1.5</td>
<td>Report Organization</td>
<td>8</td>
</tr>
<tr>
<td>1.6</td>
<td>Summary</td>
<td>8</td>
</tr>
</tbody>
</table>
CHAPTER 1
INTRODUCTION

1.1 Introduction

Road Pavement is a layered structure used for vehicular movement. Two types of Pavements are in use viz. Flexible, Rigid and composite. The essential difference between the flexible and the rigid pavements is the way the load gets transferred from the top most layer to the soil subgrade. In flexible pavements, the load transfer happens through grain to grain contact and for rigid pavements, it happens through slab action. However, in a composite pavement, no distinct load transfer mechanism has been observed as this structure comprises a combination of flexible and rigid layers. Often, the choice of pavement type goes in favor of flexible pavements in view of low construction cost, notwithstanding its high life cycle cost. However, the rigid pavements have high initial cost of construction with low life cycle cost as proved in many case studies [1].

In flexible pavements, pre-matured failures are observed often and many factors are attributed to this phenomenon. These include: improper grading and choice of materials, wrong construction practices, inadequate maintenance, excessive vehicular loading and extreme climatic conditions to name a few critical parameters. Construction of flexible pavements involve the use of bitumen, a dark brown organic compound, a petroleum derivative; as the binder matrix which holds aggregate in place. Besides its complex behavior at varying temperature regimes, the material is very costly. Hence, it is very essential to understand the behavior of this binder under varying service conditions before it is being used. In addition, the high cost of the binder makes the pavement engineer to use this in a judicious manner.

1.2 Work Background

Typically, bitumen is found to be a non-crystalline viscous; visco-elastic liquid at room temperature [1], possessing excellent adhesive and water-proofing qualities. It is classified as a visco-elastic material since it is neither purely viscous nor elastic. It essentially consists of hydrocarbons with about 80% carbon and 15% hydrogen, the remainder being oxygen, sulfur, nitrogen and traces of various metals. Several grading systems have been proposed to characterize this complex material. In India
empirical method of grading system is being followed. Until 2006, penetration grading system was in use and later viscosity grading system \[2\] is implemented. The Viscosity Grading (VG) system is empirical due to the fact that it depicts the flow behavior and measures the consistency at a temperature of $60^\circ$ \[2\] and does not takes into account the behavior at other temperatures. Mechanistic methods of grading are being implemented in developed countries which attempt to address deformation behavior in response to loads over a wider range of temperatures.

The bitumen is obtained by fractional distillation of crude oil \[1\]. The bitumen should be soft enough at low temperatures to withstand stripping, stiff enough to resist rutting at high temperatures and should have resistance to fatigue cracking at medium temperatures. Bitumen obtained from refineries rarely possesses all these properties in parallel and therefore different paving grades came into existence. Modification was suggested by researchers through acids, polymers and minerals to enhance binder performance to cater to wider climatic conditions.

There is also a need to establish the viability of the proposed modification through the experimental observations for the performance of bituminous mixes to be used in the construction of flexible pavements.

In the light of the discussion made in the previous paragraphs, this research addresses the issues related to enhancement of binder properties for use in wider climatic conditions using acid modification, assessment of performance grading for unmodified, modified, aged & modified and aged binders; the grading system, which is considered to be far superior to the present grading system in India, the testing of consistency of modified binders at mixing temperature to ensure the workability of bituminous mixes during the construction, for the possible changes in the fractions of bitumen for straight run, aged, modified and aged modified bitumen using micro structural & imaging studies, the changes in the thermal properties of these binders using thermo gravimetric analysis and differential scanning calorimetry and finally the applicability of the proposed modification in bituminous mixes.
1.3 Study Objectives

The main aim of this research work is to verify the efficacy of Poly Phosphoric Acid (PPA) as a bitumen modifier through the necessary experimental investigations. To achieve this aim, the following objectives have been set.

1. To investigate the pre and post short term ageing performance of VG30 bitumen, modified with optimum dosage of PPA, vis a vis un modified VG 30 as well as SBS PMB 40 bituminous binders using suitable laboratory investigations.
2. To investigate the consistency of the modified & unmodified binders under aged and fresh states at mixing temperature using indigenously developed rotational viscometer.
3. To carry out micro structural investigations on fresh and aged binders, modified with PPA to examine the changes at micro level for in-depth understanding of the modification.
4. To investigate the Bituminous Concrete and Dense Bituminous Macadem mixes prepared with optimized aggregate gradations and modified binders using suitable laboratory investigations.

1.4 Research Methodology

1.4.1 General

In order to fulfill the stated objectives of present research activity, the details of the experimental studies and study methodology are presented in this section.

1.4.2 The Research Stages & Methodology

The current research has been carried out in five stages to fulfill the set objectives. Details regarding all the stages are depicted in Fig 1.1 for ready reference.

1.4.2.1 Stage 1: Identification of dosage of PPA required as a modifier through fundamental tests

In this stage, it is proposed to optimize the PPA dosage for unmodified VG 30 bitumen collected directly from industry. The optimization process is being proposed by subjecting the VG 30 as well as PPA modified VG 30 with different proportions of
Investigations

Binders

Bitumen Sample collection (VG 30 & PMB 40)

Preparation of PPA modified sample

Fundamental Tests

Identification of optimum dosage of PPA

Experiments on consistency measurement using indigenously developed rotational viscometer

Dynamic Mechanical Analysis

Fractionation Tests

Short term aging tests

Tests on bituminous mixes

Vacuum filtration and simple distillation

SHRP Rutting Parameter

Asphaltenes

BC and DBM Layers (Grade 2)

Development of software for JMF

Marshall’s Test
Indirect tensile strength tests
Resilient Modulus tests
Aggregate stripping tests

SEM

XRD

TG-DSC

Report Writing

LEGEND

Colour

Stage

1
2
3
4
5
6

2,3 & 4

Fig 1.1 Flow chart showing the sequence and connectivity of investigations
PPA with respect to fundamental properties namely penetration, ductility and softening point tests.

1.4.2.2 Stage 2: Experiments to assess the high temperature performance grading of unmodified & modified and aged & un-aged binders as well as the polymer modified bitumen (PMB 40) using Dynamic Mechanical Analysis.

In this stage, for the identified optimum PPA dosages, it is proposed to establish the resulting high temperature Superpave performance grade for VG 30 bitumen. In addition, it is also proposed to establish the high temperature Superpave PG grade for PMB 40 bitumen. It was proposed to compare high temperature performance of both PPA modified VG 30 grade and PMB 40 grade for further usage.

Continuing with these investigations, it is proposed to investigate the high temperature performance of unmodified aged VG 30 bitumen, PPA modified & aged bitumen to assess the comparative performance of modified and unmodified bitumen when they are subjected to artificial RTFOT aging.

1.4.2.3 Stage 3: Experiments to assess the consistency of bituminous binder at mixing temperature using indigenously developed rotational viscometer.

In this stage, it is proposed to design, fabricate and calibrate a rotational viscometer indigenously. Further, it is proposed to test, unmodified, PPA modified VG 30 bitumen samples before and after aging. Similarly, PMB 40 samples will also be subjected to viscosity testing process with the equipment developed.

1.4.2.4 Stage 4: Experiments to explore the micro structural properties for unmodified & modified, and aged & un-aged binders through Scanning Electron Microscopic (SEM) Imaging, X-Ray diffraction (XRD) and Thermo Gravimetric and Differential Scanning Calorimetric (TG-DSC) analysis

In this stage, it is proposed to investigate for the possible micro structural changes for the following combinations of bitumen and modified bitumen.

- Unmodified VG 30 bitumen
- VG 30 bitumen modified with optimum PPA content
• Short term aged unmodified VG 30 bitumen
• Short term aged VG 30 bitumen modified with optimum PPA content

These investigations are carried out using
• Scanning Electron Microscopy (SEM) (Morphology of asphaltenes)
• X-Ray diffraction Technique (XRD) (Micro structure of asphaltenes)
• Thermo gravimetric and differential scanning calorimetry (TG-DSC) (understanding thermal transitions for bitumen samples and asphaltenes)

1.4.2.5 Stage 5: Investigating the efficacy of PPA modification on bitumen for mix applications

In this stage, it is proposed to investigate the strength properties of MoRTH Grade 2 Bituminous concrete and MoRTH grade 2 Dense Bituminous Macadam using Marshall’s stability testing protocol under static loading condition and Resilient Modulus testing protocol under dynamic loading.

Since it is not practically feasible to prepare the aggregate blends in the field, as done in the usual laboratory experimentation, field practice is to design a Job Mix Formula (JMF) which is usually worked out based up on the sieve analysis followed by some analytical techniques suggested by Bailey’s Method and Rothfusch’s methods etc.

It is with this background that the development of software to quickly give feasible JMF blends for any given situation has been proposed to be developed.

1.4.2.6 Stage 6: Analysis and report writing

The data collected as discussed in the above stages will be subjected to the necessary analysis. Thesis writing is also planned during this stage.

1.5 Report Organization

Background of the current research work, objectives and research methodology are presented in Chapter 1. The review of literature on bitumen, its characterization and acid modified bitumen were discussed in the Chapter 2. The experimental investigations pertaining to the method of modification of bitumen with PPA, short term aging simulation tests using Rolling Thin Film Oven Test (RTFOT),
fundamental tests on straight run, modified, aged & aged modified binders, experimental investigations using Dynamic Shear Rheometer (DSR) for assessing performance grade for high temperature regime, micro structural investigations using X-Ray diffraction techniques (XRD) & scanning electron microscopic imaging (SEM), thermal analysis using thermo gravimetric analysis and differential scanning Calorimetry (TG-DSC) and performance of bituminous mixes for a binder & wearing courses prepared with PPA modified bitumen using Marshall Stability Test & Resilient Modulus test are presented Chapter 3. The results and discussions based on experimental observations have been presented in the Chapter 4. The summary of the research work, conclusions, contributions made and scope for further study were discussed in the Chapter 5.

1.6 Summary
The introduction, study background, study objectives and research methodology have been presented in this Chapter. The detail literature survey is presented in the next Chapter.