Chapter 1
INTRODUCTION

1.1 GENERAL

Road network is vital to the economic development, trade and social integration of a country. It facilitates smooth conveyance of both people and goods. Global competition has made the existence of efficient road transport an absolute imperative. Transport demand in India has been growing rapidly since independence. Easiness in accessibility, flexibility of operations, door-to-door service and reliability has earned road transport an increasingly higher share of both passenger and freight traffic vis-a-vis other transport modes. In recent years this demand has shifted mainly to the advantage of road transport, which carries about 87 percent and 61 per cent of passenger and freight transport respectively (COCSSO, 2011). Road transport has grown, despite significant barriers, to inter-state freight and passenger movement compared to inland waterways, railways and air which do not face rigorous enroute checks/barriers.

According to the Road Network Assessment by National Highway Authority of India, national highways constitute approximately 2% of the total road network of India, but carry nearly 40% of the total traffic. India has 67,000 km of highways connecting all the major cities and state capitals. Most of them are two-lane highways with paved roads. They are widened to four lanes and eight lanes in developed areas and large cities. As per latest reports, 19,064 km of the National Highway system still consists of single-laned roads. The government is currently working to ensure that by December 2014 the entire National Highway network consists of roads with two or more lanes (Balchand, 2010). The total road length in India had increased significantly from 3.99 lakh km as on 1951 to 42.36 lakh km as on 2008. Concomitantly, the surfaced road had increased from 1.57 lakh km to around 20.90 lakh km over the same period (GOI, 2010).
The average annual increase in maintenance expenditure increases with the increase in vehicle registrations. This demands the urgent need for building better, long-lasting, and more efficient roads preventing or minimizing bituminous pavement distresses. The condition of the roads has a direct impact on travel costs, from vehicle operations, to traffic delays and to crash-related expenses. Roads in poor condition cause vehicle wear, tear, and even damage. Also, traffic queuing and delays occur when vehicles slow down to avoid important pavement distresses (e.g., potholes) or when the road surface fails to provide safe maneuvering and/or adequate stopping conditions. Many of the principal distresses in bituminous pavements initiate or increase in severity due to the presence of water. When moisture is present in the pavement, the mechanical properties of the material deteriorate and the serviceability of the pavement gets reduced.

### 1.2 SCENARIO IN KERALA

Kerala can be proud of having developed a good road network compared to other States in India. Transportation infrastructure of Kerala consists of 1.62 lakh km of road, 1148 km of railways, 1087 km of inland waterways, 111 statute miles of airways and 17 ports. Even though it is comparatively better placed than other States as regards to road length, the quality of many of these roads are in poor condition.

Traffic in Kerala has been growing at a rate of 10–11% every year, resulting in high traffic intensity and pressure on the roads. Kerala's road density is nearly four times the national average, reflecting the state's high population density. Inadequate maintenance and the harsh monsoon resulted in potholed roads. The entire state of Kerala is classified as one meteorological subdivision for climatological studies. The state experiences humid and tropical monsoon climate, with seasonal heavy rainfall, followed by hot summer. The month of March is the hottest, with a mean maximum temperature of about 33°C. The total annual rainfall varies from 3600 mm in the northern part of the state to about 1800 mm in the south. The South-West monsoon (June - October) is the principal rainy season, when the state receives about 70% of its annual rainfall. Maximum rainfall is in June and July, accounting individually to about 23% of annual rainfall (Attri and Tyagi, 2010).
Roads in Kerala get damaged mainly on account of torrential rains during the Monsoon season. The annual road maintenance and repairs cannot withstand the severity of rains. The other reasons for the faster deterioration of roads are insufficient pavement strength to accommodate the increase in traffic (10 - 11% every year) and inadequate drainage system. Pavement shows severe distresses (cracks, large potholes, edge breaks and damaged shoulders with high edge drops).

1.3 BITUMINOUS PAVING MIXES USED IN INDIA

Bituminous mixes are used in a flexible pavement to serve the following three important functions such as improved structural strength, facilitating subsurface drainage and providing surface friction especially in wet condition. The bituminous paving mixes as specified in MoRTH specifications (MoRTH, 2001) are commonly used in India. Mixes like bituminous concrete, semi-dense bituminous concrete, premix carpet, mix-seal surfacing etc., are commonly provided as wearing courses.

Unlike most developed countries, overloading is a major concern in India. The axle loads in India are quite heavy and further the speed is low with many stop/start condition which leads to the rutting of currently used bituminous mixes in India. Several studies have shown that permanent deformation (rutting) within flexible pavement is usually confined to the top 100 to 150 mm of the pavement. This means that both the binder and wearing course mixes should be designed to be resistant to rutting. That is why in cases of heavy traffic loads and high tyre pressures, it is considered prudent to use Stone Matrix Asphalt (SMA) mix which is the apt specification as per international practice (Kandhal, 2002). The load is carried directly by the coarse aggregate skeleton due to stone-on-stone contact. This will result in a long-lasting pavement with minimum maintenance which is going to be the future concern in India. The advantages of such specifications lie not only in long life but also in the reduced cost of travel with better serviceability. Recently, the Indian Roads Congress (IRC) has adopted a tentative SMA specification, (IRC SP 79:2008) which could be used under such circumstances.

1.4 SMA FOR KERALA HIGHWAYS

Stone matrix Asphalt is the right choice to provide a strong surfacing that can handle the climate and the heavy traffic of a typical Kerala Highway. Roads in Kerala
have to withstand almost six months of heavy rain and will be in a damaged condition for the major part of every year. This results in an improper communication facility. Without proper and effective communication facility like roads, economic growth will not be achieved. Increased life of Stone Matrix Asphalt pavements will justify the additional cost involved during initial construction (Kevin and Trenton, 2007). Apart from that, the huge expenses incurred for the periodic maintenance of roads can be eliminated (Normally the repair work during the rainy season will have only one or two week’s life).

1.5 SCOPE OF STUDY

In Kerala highways, major distress is due to the rain induced damages. It is a well established fact in developed countries that the water induced damages are expected to be less in a gap graded mix like Stone Matrix Asphalt than traditional mixes. But application of SMA in India is very limited due to lack of proper specifications. This necessitates the need for thorough experimental and field investigations in various aspects of SMA, in context of India.

Presently, synthetic fibres or polymers are used as stabilizing additives in SMA. Replacement of expensive imported synthetic fibres and polymer additives with renewable/waste material in SMA is an environmental necessity. Here, a study on the impact of natural fibre / waste material as additives in Stone Matrix asphalt and their role in the volumetric, mechanical and drain down characteristics of the mixture is proposed. Emphasis is also given to assess the effect of water immersion on the performance of SMA mixtures with different additives. The rutting characteristics of the mix are intended to study indirectly by analyzing the stability and strength characteristics of the mixtures.

1.6 RESARCH OBJECTIVES

Considering the importance of the problem discussed, this research mainly focuses on the following objectives.

- The main objective of this study is to propose a durable surface course with Stone Matrix Asphalt by exploring the utilization of various additives such as
natural fibres and waste plastics which are abundantly available and to provide an eco friendly surface for Kerala highways.

- To evaluate the role of additives
  - On the mechanical and volumetric characteristics of SMA mixtures.
  - On the moisture susceptibility of SMA mixtures.
  - In the drain down sensitivity of SMA mixtures.
- To study the effect of additives in SMA and to arrive at the optimum additive content of the mixtures.
- To propose the best natural fibre additive from the fibre stabilized SMA mixtures.
- To investigate the suitability of waste plastics to replace the expensive polymer additives in SMA.
- To suggest the best additive from all the SMA mixtures investigated.

1.7 METHODOLOGY

An extensive literature review on bituminous mixtures is to be carried out. Based on that a systematic experimental investigation has to be planned to study the volumetric, stability, strength and drain down characteristics of the mix. A statistical analysis is also intended to establish the results mathematically.

- Literature Review

  Literature review has to be conducted to identify the existing situation of roads in India, issues in maintenance and other problems related with durability. Secondary data can be collected from Government documents and reports published by the research institutions. Thorough literature study has to be carried out to analyze various researches on bituminous mixtures (Dense graded, Open graded and Gap graded mixtures) with and without additives.

- Experimental Research

  Based on the literature review, experimental research programme has to be formulated. As a preliminary investigation, procurement of various ingredients of
SMA and the evaluation of its properties has to be carried out. Marshall tests are proposed for the mix design of SMA (with and without additives). Indirect tensile strength test, compressive strength test and triaxial test are proposed for assessing the strength characteristics of SMA mixtures. The effects of additives against moisture induced damages on SMA mixtures can be studied by determining the retained stability, tensile strength ratio and index of retained strength of various mixtures. Drain down test is proposed on different SMA mixtures to assess the binder drain down. A comparative study on different characteristics (volumetric, mechanical and drain down) of various stabilized mixtures with varying additive contents and types has to be carried out for optimization. The ideal mix has to be proposed from the various SMA mixtures with optimum additive content.

- **Statistical Analysis**

  Statistical Analysis can be employed for verifying the precision of the results of various experimental programmes proposed in this research. SPSS package is proposed for this study as an ideal tool for the selection of best SMA mix from the optimized mixes and for the comparison of various SMA mixtures. In order to test the significant difference in the various properties at various levels of additive contents, ANOVA has to be carried out and if significant interaction is found, Tukey’s Homogeneous Groups comparison should be applied to perform more detailed analysis. The optimum additive contents of every mix with respect to different parameters like stability, bulk specific gravity, tensile strength, compressive strength, cohesion, shear strength and drain down characteristics are to be identified. The significance of differences in mean values of parameters at various levels of additive contents are to be tested by ANOVA. Then a comparison of different additive stabilized mixtures at these optimum contents are to be carried out so as to arrive at the best fibre additive from the fibre stabilized mixtures by ANOVA and also the best additive among the waste plastics and polypropylene stabilized mixtures by paired t-test. A pair wise comparison is also to be made between the best among these stabilized mixtures by t-test for independent samples.
1.8 ORGANISATION OF THE THESIS

This thesis consists of ten chapters. The contents of various chapters are briefly described below.

Chapter 1 illustrates a brief description of the transport infrastructure of India and Kerala with special emphasis on the problems of Kerala highways. An outline of the bituminous paving mixes used in India and the associated problems are mentioned. Scope of the study, research objectives and methodology for the present study is also discussed.

Chapter 2 critically reviews the literature on previous studies in the field of bituminous mixtures. The classification of bituminous mixtures with special reference to SMA, its history, composition, advantages and disadvantages are discussed. A comprehensive summary of the literature associated with SMA and other bituminous mixtures with different additives like fibres, polymers and waste materials is also presented.

Chapter 3 on Material characterisation gives an overview of the materials used for the study and its properties.

Chapter 4 presents the details of the laboratory work conducted for the mix, design of the different SMA mixtures and their analysis are presented. Marshall method of mix design and the test procedure are discussed. Results of all stabilized mixtures are analyzed separately and discussed. Influence of additive content on optimum bitumen content of the SMA mixture is also discussed.

Chapter 5 explains the investigations on the indirect tensile strength of different SMA mixtures with different additive types and contents. The tensile strength ratio of various mixtures is determined to arrive at the water induced damages. Detailed descriptions of the test results of different mixtures within themselves and with control mixture are also presented in this chapter.

Chapter 6 deals with the description of the compressive strength test and the strength values of different SMA mixtures with different additive types and contents. The indices of retained strength values of different SMA mixtures and the effect of
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water on the strength are also discussed. A comparison of the test results of various mixtures within themselves and with control mixture is also discussed.

Chapter 7 narrates the application of triaxial test to pavement design, principles of triaxial testing, specimen fabrication, test conditions and test procedure. A detailed discussion of the triaxial test results is also included in this chapter.

Chapter 8 discusses the drain down sensitivity of the various SMA mixtures and the stabilizing capacities of different additives used for the present study. A comparison of these SMA mixtures with the control mixture is also presented.

Chapter 9 presents the statistical analysis of the experimental programme. It has been done by using SPSS package Ver.16. By using this statistical tool, the optimum additive contents of every mix with respect to different parameters stability, bulk specific gravity, tensile strength, compressive strength, cohesion, shear strength and drain down characteristics are identified using descriptive values. The significance of differences in mean values of parameters at various levels of additive contents are tested by ANOVA. Then a comparison of different additive stabilized mixtures at these optimum contents are carried out so as to arrive at the best fibre additive from the fibre stabilized mixtures by ANOVA and also the best additive among the waste plastics and polypropylene stabilized mixtures by paired t-test. A pair wise comparison is also made between the best among these stabilized mixtures by t-test for independent samples. A comparison between waste plastics stabilized and coir fibre stabilized SMA carried out by Levene’s test for Equality of variances is also presented.

Chapter 10 presents the conclusions derived from this research. This chapter highlights the influence of additives on the characteristics of SMA and supports the selection of ideal stabilized SMA mix from the mixtures investigated. Scope for further research is also presented in this chapter.