CHAPTER 1
INTRODUCTION

This chapter emphasize the primary demand of modified bitumen as road pavement in transportation field of India. This chapter also describes the world-wide production of crumb rubber and PET and the economic ways for safe disposal. With that, this also chapter deals with motivation towards the research work behind waste utilization, and the concept of crumb rubber incorporation in bitumen modification for road pavement application. In second section, it outlines the aim of current research work, major objectives or outlines, problem statement, research objective, research methodology and proposed chapters of the thesis in upcoming context with thesis layout.

1.1 BACKGROUND

World over road construction has taken a centre stage owing to the impetus it provides to the economy. India has the second largest road network in the world is about 5.4 million kilometers (km). Indian road transportation infrastructure is apace booming with a challenging development of road networks. There will be a further requirement for road transport network with a high-quality pavement structure for the fast-growing Indian economy. Currently, most of the Indian roads are flexible pavements made up of the bituminous layer. Due to increase in traffic load on road, there is a demand for higher flexible pavements.[1] There is a need to use modified bitumen in road pavement, which are much superior and with enhanced pavement properties as compared to neat bitumen.

Industrialisation and modern civilisation leads to generation of huge amount of waste, i.e. plastic bottles, e-waste, chemicals, municipal waste etc. Automotive & Transportation Sector is increased drastically with economic development, logistics, human mobility and to meet the supply and demand, which generate about 15 million tons of waste tires every year globally. The disposal of waste tires by burning or piling up in landfills causes many environmental problems and effect human health. Crumb rubber granules are recycled rubber from automotive scrap tires and could be eco-friendly disposed of by incorporation in bitumen for road pavement. Crumb rubber application in bitumen modification is most efficient way of waste disposal is considered as a cleaner approach for sustainable future. Waste Polyethylene terephthalate (PET) disposal is another major concern with increased production. Hence, several attempts are mare to reduce the overall cost of highway construction and maintenance of bitumen.

Large volumes of scrap tires and waste plastic are generated may act as cheap materials for bitumen modification. Thus, the major goal of this research is to find an economic, safer and cheaper way of disposal of crumb rubber and waste PET by incorporation in bitumen for road pavement application with improved performance properties. However, crumb rubber and waste plastic modified bitumen have some serious issues regarding their storage stability as crumb rubber

particles settle at the bottom of the container which causes difficulty in transportation of these modified bitumen and therefore restricts their use for bitumen modification. So, another aspect of our research is to increase the storage stability, rheological and mechanical properties of crumb rubber modified bitumen by using certain quality binder using certain chemical modifiers.

Certain modifiers, additives or process that are presently being used in bitumen modifications i.e. anti-stripping chemicals, reactive polymer, thermoplastic & thermoelastic polymer, scrap crumb rubber has been adopted for commercial use to ameliorate the properties of bituminous road pavements to meet severe service conditions, i.e. extreme temperature variation, increase vertical stresses, shear actions etc.

This research work is carried out to utilize waste material for bitumen modification purpose. Bitumen modified with waste material should not only improve bitumen quality but also must make the product cost effective. Therefore, in our research work, we have used waste tires rubbers for bitumen modification which also provide an alternate solution for the disposal of waste rubber keeping the environment free from pollution.

Globally 15 million tons of waste tires are generated annually, out of which India contributes one million tonnes.[2] This huge generation of waste tires contaminates landfill if not used for the appropriate application. The poor disposal of tires may also pose a potential scourge to human health and environmental risks. Maximum countries, in Europe and worldwide, have used waste tires as land filling. Waste tires are an inveterate environmental problem not only in western countries but also in India.

There are several applications of waste tires rubbers viz. pyrolysis, reclaimed rubber production etc. One of the applications of waste tires is in bitumen pavement modification. Because of elastic nature of rubber, bitumen modified with rubber was found to have high elastic property.

Crumb rubber is the term commonly applied to recycled rubber derived from automotive scrap tires. Rubber from discarded tire is ground to rubber crumb.

This crumb rubber mixed with bitumen to form CRMB. Utilization of scrap tires in CRMB can not only help in the conservation of natural resources but also enable the creation of high-performing asphalt pavements in comparison with conventional paving grade bitumen. There are two processes (a) wet process (b) dry process shown in Figure 1.1 to produce crumb rubber modified bitumen. Crumb rubber is blended with bitumen binder in wet process, however in dry process, aggregate is premixed with crumb rubber prior to bitumen addition and widely applied for road pavement.

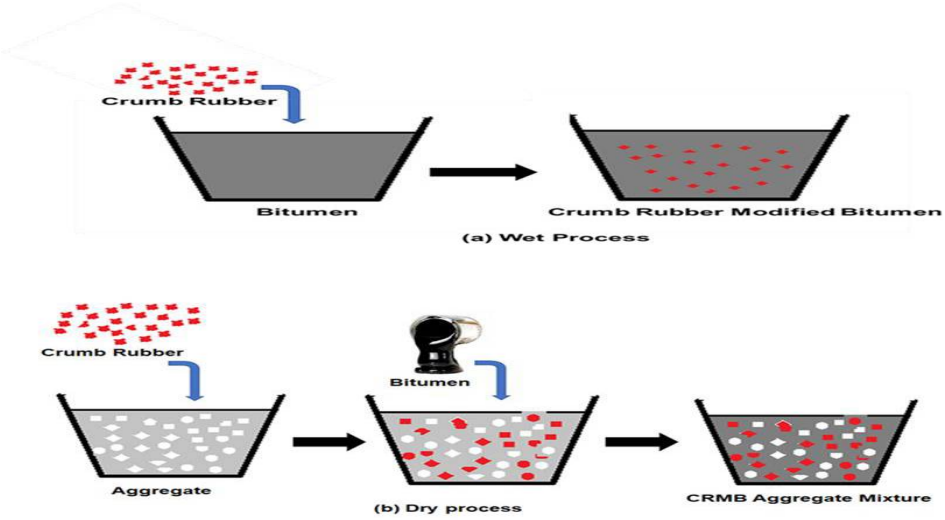

Figure 1.1: Mixing process of crumb rubber in bitumen

Various researchers suggested that crumb rubber modified bitumen obtained through the wet process has lower fatigue, reflective cracking and greater rutting resistance.[3] This improvement is due to the swelling process of rubber particles in bitumen. Bitumen-rubber pavement has lower noise generation, higher skid resistance with lower maintenance costs.[4]

With increased plastic production and consumption, the recycling of waste materials in developing and civilizing countries necessity for environmental protection. Plastics, i.e. Polyethylene terephthalate (PET) is currently used in large amount for making package bottling applications, bags preparation due to high

tensile strength and thin property However, this poses an environmental pollution due to difficulty in degradation of polymeric materials by environmental factors. Landfills takes several years to partially decompose the plastic depending on the quality of the plastic. Figure 1.2 shows that the plastics production was shored up from 1.5 MT in 1950 to ~322 MT in 2015. It was reported that global plastic was enhanced by 3.4% as compared to 2014 with annual growth rate of 8.6% from 1950 to 2015.[5]

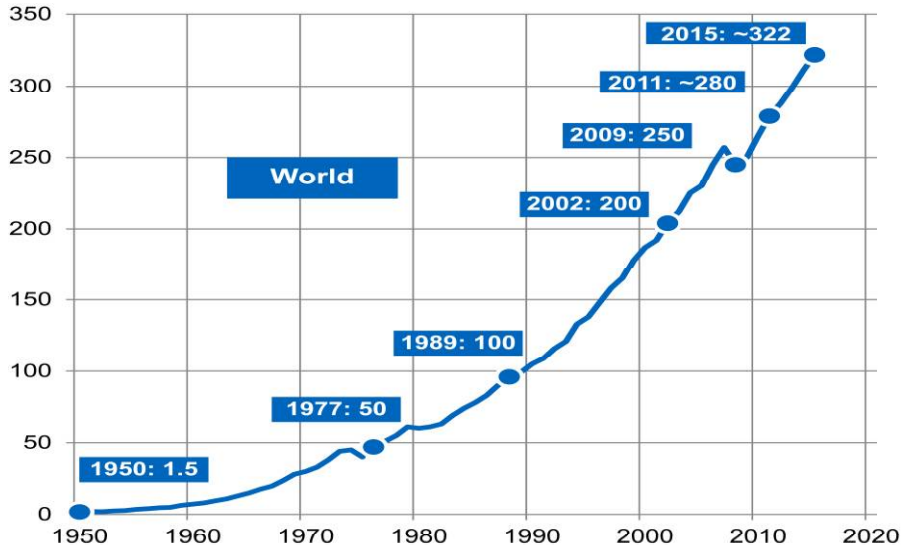

Figure 1.2: Waste plastic production from 1950 to 2015 (Million Tonnes)

Incorporation of these waste PET in crumb rubber bituminous mixture (CRMB) is another environmental friendly approach for waste PET disposal for road construction of flexible pavements (Figure 1.3).

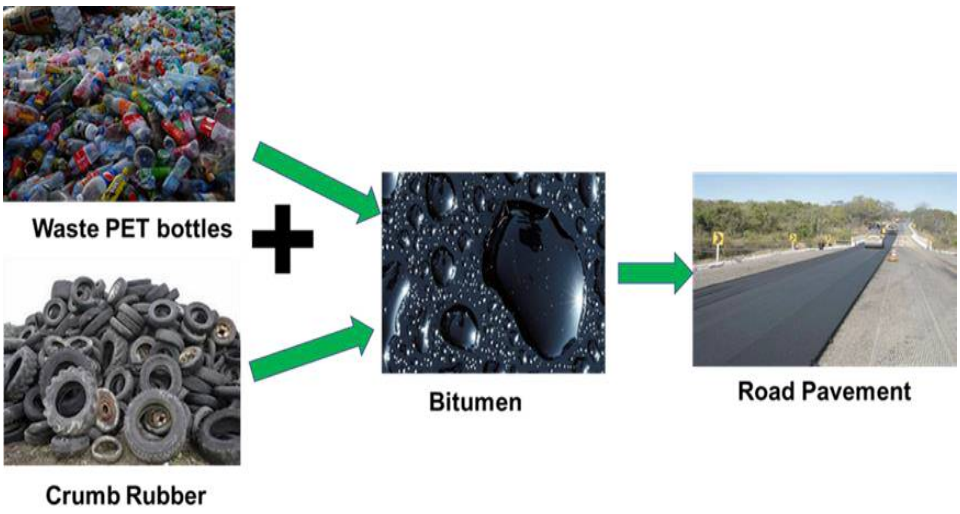

Figure 1.3: Utilization of various wastes in bitumen modification

For instance, Zoorab & Suparma (2000)[6] reported that waste plastics, i.e. low-density polyethylene and polypropylene could be used for bituminous concrete mixtures modification to increase durability and fatigue life. They showed this incorporation have increased the Marshall stability. Similarly, Nkanga et al. (2017)[7] showed that waste polymeric materials in various percentages, i.e. 5%, 10% and 15% could be blended with bituminous mix to increase the strength and performance of bitumen/plastic blends. They reported that bituminous plastic mixture has increased the Marshall Stability from 14.03 to 14.80 kN as compared to the conventional bituminous mix (11.35 kN).

The mixing process of crumb rubber modified bitumen (CRMB) is very sensitive, and depends on external factors i.e. the mixing duration, mixing temperature, and internal factors like the type of bitumen, crumb rubber, quantity, particle size etc. The advantages of crumb rubber modified bitumen are lower temperature susceptibility, better age resistance properties, higher fatigue life and higher resistance to deformation at high temperature of bitumen mixes. With that it

has a better adhesion property between aggregate & binder, which meliorate the performance properties in heavy traffic and extreme climatic conditions.

1.2 PROBLEM STATEMENT

Neat bitumen faces rutting, fatigue cracking in road pavement. The performance properties of neat bitumen are effected by environmental factors, i.e. temperature, water, climate conditions, traffic load etc.

With increased socioeconomic development, waste generation and their disposal is major concern today. For instance, crumb rubber could be used in bitumen modification.

However, it is found that crumb rubber modified bitumen have some serious issues regarding their storage stability and low performance properties. With that the CRMB faces a problem of phase separation during storage and transportation due to weak interaction between crumb rubber particles and bitumen binders, which limits therefore restricts their use for bitumen modification (Figure 1.4).

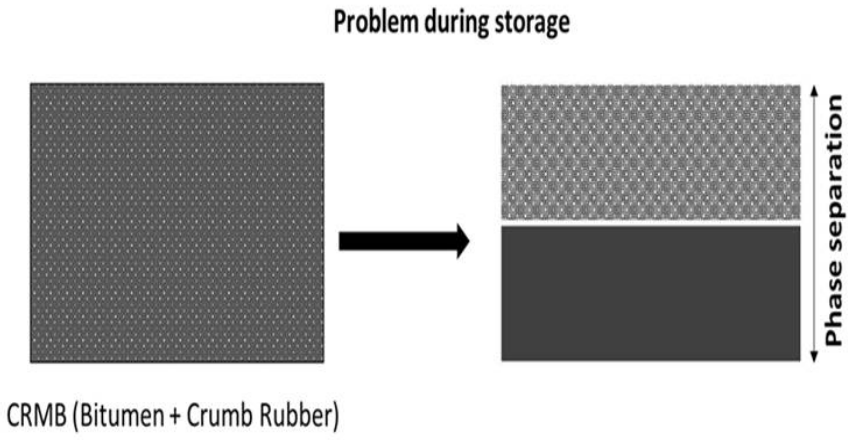

Figure 1.4: Phase separation during storage of CRMB

The mechanism of phase separation is due to the differences in the physical properties of material constituents in the blends due to presence of non-dissolved CR particles in bitumen. Therefore, the swollen crumb rubber particles get settle

down speedily due to a higher density than the bitumen phase and sometimes, migration of crumb rubber particles to the top of the storage container. This type of different mechanisms creates an unstable condition in a rubberized bitumen blend with different properties. [8, 9, 10,11] Therefore, these waste crumb rubber and waste plastic material can contribute to a sustainable development of road paving industry due to their performance and environmental advantages to enhance the storage stability of CRMB by adding some additives or modifiers.

1.3 RESEARCH OBJECTIVES

The research objective of this thesis is to produce cost effective storage stable crumb rubber modified bitumen using waste materials. Another objective is to develop an economic product from waste keeping the environment free from pollution. This will also provide an alternate approach for the disposal of waste rubber materials.

The main aim of this research is to develop storage stable crumb rubber modified bitumen by using the following novel additives.

- Use of long chain amine compounds to form a storage stable crumb rubber modified bitumen.
- To study the synergic effect of a polyamine with fatty acid in the modification of crumb rubber modified bitumen.
- Use of synthesized waste PET derivative along with a bifunctional compound for anchoring the crumb rubber modified bitumen.

1.4 RESEARCH METHODOLOGY

General research methodology for whole research work is divided into five tasks given below. Research is initiated with introduction of area of research followed be the complete literature survey followed by experimental plan. Finally, the outcomes of the overall research conducted were published in the form of publications and

patents writing and with their economic and social importance. Flow chart of research methodology is shown in Figure 1.5.

Task 1: Literature Review

This describes a brief literature review on CRMB and bitumen-crumb rubber interaction with improvement of storage stability of CRMB using different modifiers or additives.

Task 2: Chemical analysis of crumb rubber and bitumen

A laboratory study has been carried out to investigate the chemical analysis of crumb rubber by following test methods.

- Ash content (ASTM D5667)
- Moisture content (ASTM D5668)
- Particle size passing through 600 microns (ASTM D5644)
- Toluene insoluble etc.

The SARA (Saturates, Aromatics, Resin, and Asphaltene) analysis of bitumen has also been carried out to evaluate the bitumen composition.

Task 3: Synthesis of polymeric additives for the modification of CRMB

We have synthesized several benzamide derivatives using waste polyethylene terephthalate (PET). The synthesized PET derivatives additives have been physically blended with a bifunctional compound in bitumen. Comparative study on the performance of additized blend of CRMB with conventional CRMB has also been carried out as per BIS / ASTM / IRC/AASHTO specifications.

Task 4: Rheological properties of CRMB binder

The rheological properties i.e. high-temperature stiffness modulus, low-temperature stiffness, high-temperature rutting resistance and fatigue resistance to permanent deformation of the binder have been carried out by following test methods.

- DSR (Dynamic Shear Rheometer) as per AASHTO T315
- BBR (Bending Beam Rheometer) as per AASHTO T313
- MSCR (Multiple Stress Creep Recovery) as per AASHTO TP70

Task 5: Performance studies of CRMB mix

The performance studies such as marshal strength, rutting and fatigue life of CRMB mix has been carried out by the following test methods.

- Marshal Stability Test for the preparation of Marshall specimen and testing the Marshall Stability with flow value as per ASTM method D6926 & D6927.
- Rutting Test (Wheel Tracking) on bitumen mixes as per EN 12697-22.

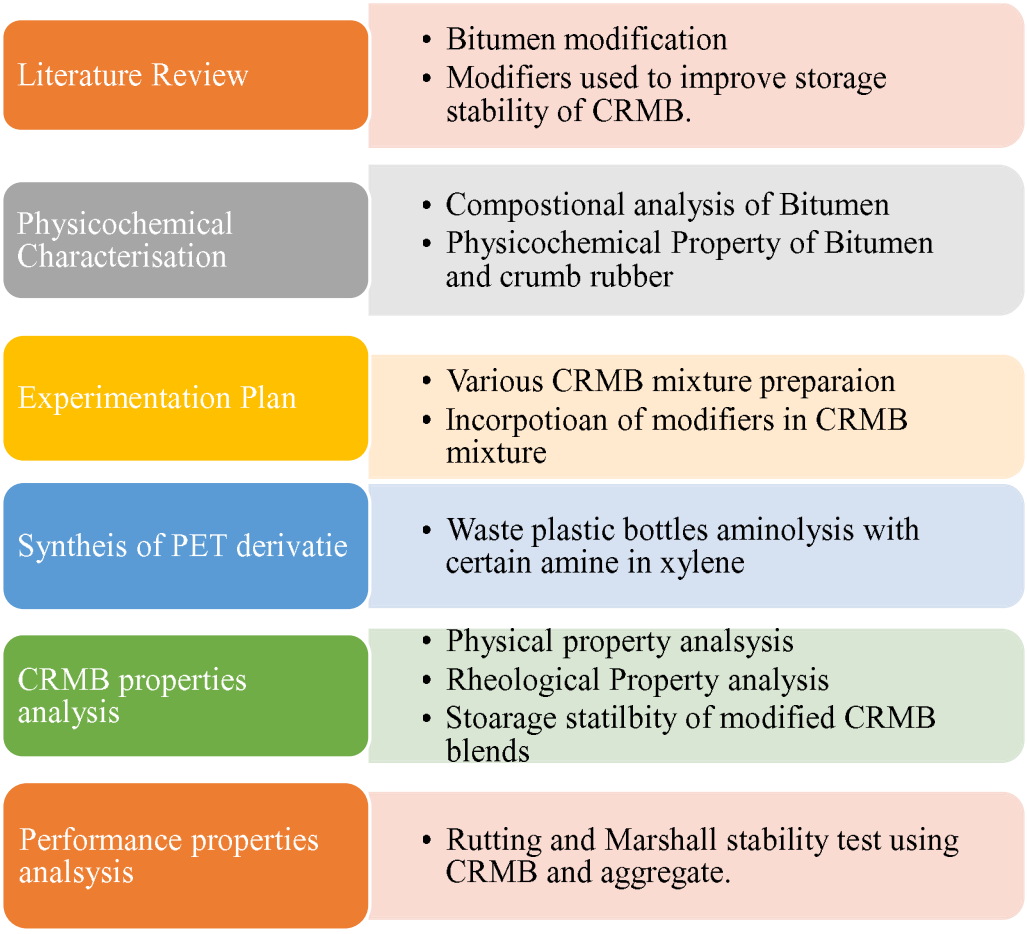

Figure 1.5: Flow Chart of research methodology used

1.5 THESIS LAYOUT

The thesis is subjected to seven chapters to achieve the goal as described above in research methodology. The whole work conducted within the thesis is subdivided into three main parts; (1) Thesis background, (2) Experimental, (3) Conclusion. An overview of the thesis chapters with a brief description is presented below. Conclusion. The thesis layout is shown in Figure 1.6.

Chapter One Introduces the research work behind waste utilization, and the concept of crumb rubber incorporation in bitumen modification for road pavement application. In addition, it described the aim, objectives or outlines, problem statement, research objective, research methodology with thesis layout.

Chapter Two deals with the brief literature of last ten years that motivated and explains the need for bitumen modification using crumb rubber, waste PET, polymers, additives incorporation. It provides a detailed literature of modified bitumen used for road pavement, physical and chemical properties, and different techniques to increase the storage stability of CRMB using different additives.

Chapter three describes various materials and test methods adopted in the research work. This chapter also describes the experimental step up and conditions used for modification of bitumen using crumb rubber and certain additives.

Chapter four, in this chapter we have emphasised to increase the storage stability of CRMB by using long chain amine. i.e. Dodecylamine (DDA), Hexadecylamine (HDA)and Octadecylamine (ODA) to improve the storage stable crumb rubber modified bitumen. The study was further enhanced with physical properties measurement in term of penetration, softening point (SP), elastic recovery (ER), viscosity and rheological properties i.e. DSR, BBR, MSCR tests of modified bitumen.

Chapter five showed another approach to increase the storage stability of CRMB using polyamine and fatty acid. The main objective of this work was to show the synergic effect of diethylenetriamine (DETA) and stearic acid using seven different combination, i.e. 1:0, 0:1, 1:1, 1:2, 1:3, 2:1 and 3:1 on improved CRMB properties. The study was further enhanced with physical properties measurement in term of penetration, softening point, elastic recovery, viscosity of modified bitumen. The rheological properties like DSR, BBR, MSCR tests and field related performance properties i.e. Marshall Stability, Wheel Tracking tests has also been carried out.

Chapter six explains the experimental study on modification of CRMB by using waste PET derivatives along with the bifunctional compound, i.e. sebacic acid to form storage stable crumb rubber modified bitumen synergic effect of synthesized PET derivatives and on the storage stability of CRMB has been studied. This chapter also described the physical, rheological and field related performance properties of prepared CRMB blends to show the impact on storage stability.

Chapter Seven Briefly outlines conclusions and recommendation with future challenges of the investigation.

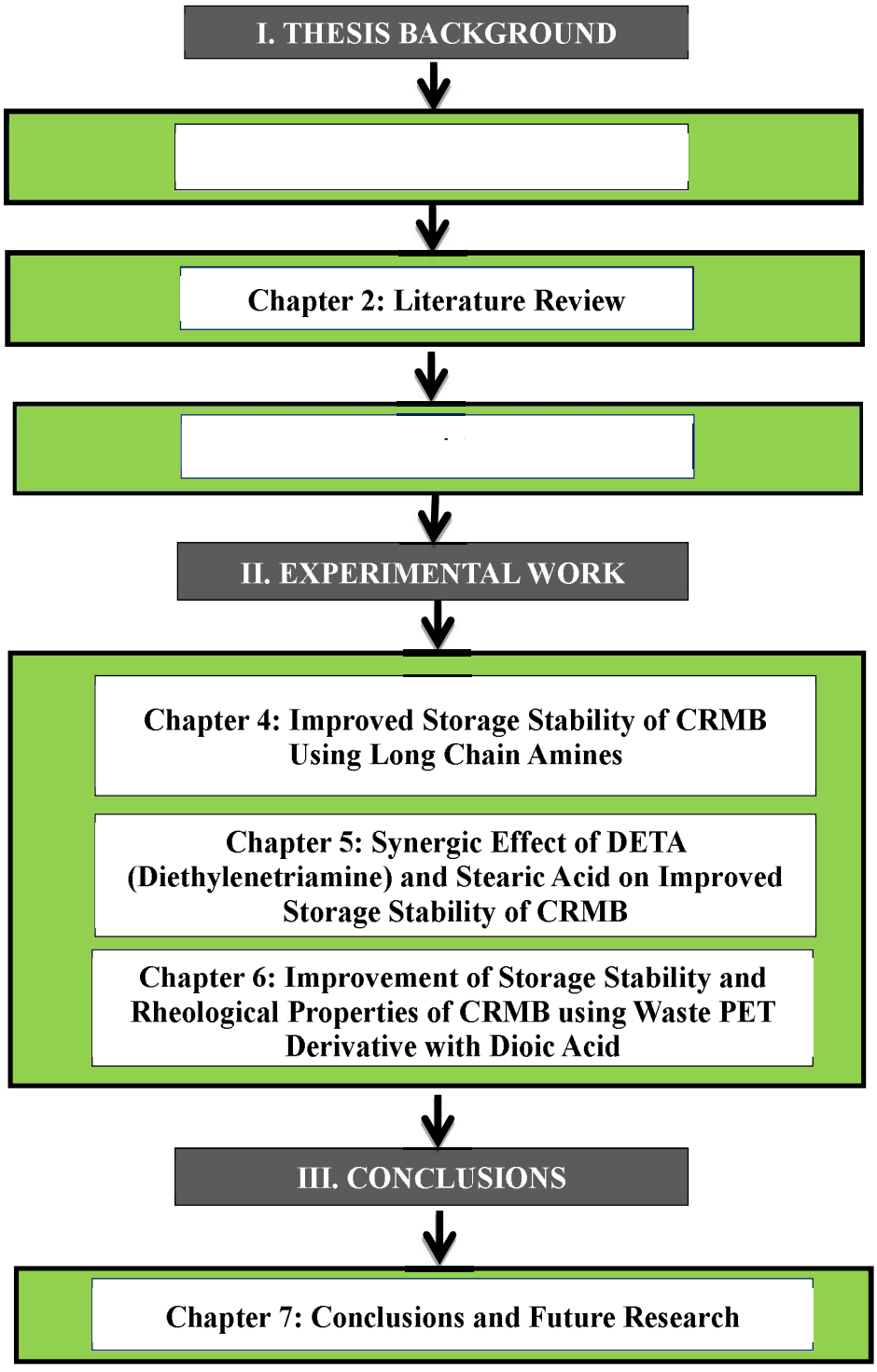

Figure 1.6: Thesis Layout