CHAPTER 5
CONCLUSION AND FUTURE SCOPE

5.1 CONCLUSION

In this chapter, a detailed conclusion for the discussed results of the various characteristics studies of the PMB is given. The conclusion mainly focuses on whether the polymer chosen can be used for the modification of bitumen.

Process – both the dry and the wet process can be effectively used for the preparation of PMB. The advantage of using dry process is that it is in situ and can be used easily with available techniques. In dry process, the PMB formed is in situ and its structure is imaginary in nature and also in dry process, with waste plastics modification only is tried. But, in wet process, the formation of PMB is very effective.

- Softening Point- As per the observations on softening point, the PMB shows high value compared with the unmodified bitumen. This observation is concludes that PMB can be used in pavement applications. The increase in softening point will also increase the resistance against rutting- a permanent deformation of flexible pavement (Noor et al 2011). Hence it is concluded that, when PMB shows higher softening point, it indicates lower temperature susceptibility (Mathews &Rao 2006) and it makes the bitumen to be used in higher temperate regions.

- Penetration Point - The results of Penetration values of PMBs suggests that, when the PV decreases, the stiffness of the polymer modified bitumen increases. This results in the increase of the load bearing capacity of the sample. The observations concludes that the
increase in stiffness will make the PMB less temperature susceptibility and less sensitive towards permanent deformations like rutting and raveling

- Penetration index - From the present study it is concluded that the PI values of all the PMBs are above standard value due to the increased and decreased values of SP and PV respectively. Both higher SP and lower PV indicate the increase in the stiffness of the PMB which infers PMB with less temperature susceptible and increased resistance towards permanent deformations.

- Ductility – From the observed ductility values of all PMB except the WP it is concluded that the addition of polymer does not impart noTable changes in the ductile nature of the PMB. Hence it is concluded that the polymers impart elasticity to the bitumen and make it elastic enough for pulling even at high percentages. But in the case of WP modified bitumen there is a different observation, showing poor ductile nature even at 5 % modification. This behavior is due to heterogeneous nature of PMB in which the plastic will start separating from the bitumen layer and form two different phases.

- Stripping Test - Stripping value depends on the binding nature of the bitumen and the aggregate. PMB as a binder shows increased binding (Vasudevan et al 2012). Hence the PMB layer resists the water to penetrate through the aggregate. Thus from the present it is concluded that the PMBs are very resistant against water stripping and in turn reduces the formation of deformations like pot holes and cracks, due to water stagnation.

- Storage stability Test - As per the analysis, the modified bitumen shows a maximum temperature difference of 2. Deg. C only. It is observed for all the PMBs in all percentages. In the present study, all the PMBs except WP PMB show homogeneity up to 7 %. The results also indicate that the storage stability of the bitumen is also high, i.e.
the property of these PMBs is not affected by storage of the bitumen before its use in pavement. This tendency of PMB also confirms that the polymers used in the study are compatible with the bitumen.

- **Marshall Stability Test**: From the results obtained, it is concluded that the MSV of the PMB is more when compared with the MSV of unmodified bitumen. The values also suggest that there is an increase in the MSV of all the PMBs with respect to their increment in the percentage. The maximum value of MSV is obtained for Waste plastics PMB- 2400 Kg at 7%. The value of all the PMBs at 7% is more than 2000 kg which is a very positive result. The normal MSV for a road mix is 1000 kg as per IRC standards. Thus, it is concluded that the addition of polymer to the bitumen increases the MSV.

- **Viscosity studies of PMB**: Concludes that the observed value shows that the polymer mixed with the bitumen plays a major role in changing the viscous nature of the unmodified bitumen. Non-Newtonian behavior is observed in all the PMBs. This behavior is a result of the influence of the polymer in the bitumen constituents. Polymer modification increases the dynamic viscosity of the binder at low temperature regions and decreases the kinematic viscosity at high temperature regions thus the improved viscous properties of the PMB exhibits low thermal stability at the service temperatures and decreased viscosity at high temperatures provides easy processing and application of PMB in pavement. In this part it is concluded that the resistance to permanent deformations of the pavement is reduced due to the improvement in the viscous properties of the modified bitumen.

- **FTIR study of all PMB**: Concludes that the bitumen mainly consists of Saturates, Aromatics Resins, and Asphaltenes. When the bitumen is functioning in the pavements, hydrocarbon groups present in the chain start oxidizing due to the interaction of bitumen with the atmospheric oxygen and moisture. This reaction results in the
decomposition of the continuous chain which reduces the binding nature of bitumen, as a result of oxidation. In the case of PMBs, polymers influence the basic chain of the bitumen by imparting changes as discussed. This can prevent oxidations in the PMB due to the oxidizing stability nature of the polymers. Hence it is concluded that the PMB prepared can perform for a longer period in the pavement by reducing the extent of oxidation of the hydrocarbons present in the bitumen chain.

- TGA all the PMB’s studied here confirms that there is an increase in the thermal stability of the PMB. Most of the PMB show three stages of decomposition. Moreover TG also concludes that the PMBs are safe to use for road construction, since there will be no gaseous evolution up to the road laying temperature 160 °C. The addition of polymers to the bitumen decreases the volatile matter content of the bitumen by increasing the molecular weight and hence on heating the PMB shows stability.

- OFM study on PMB concludes that all the samples show homogeneous dispersion. If phase separation occurs, the PMB cannot perform as a binder and it loses its basic qualities (Visco elasticity). The present study on the PMB shows not only the degree of dispersion but also the optimum percentage of polymer to be used for the modification. Optimum of 5 % of plastics to the weight of bitumen is recommended from the study. Mixture at 5 % also exhibits continuous and homogenous matrix. This behavior of PMB indicates the compatibility of the polymer over bitumen. Hence it is concluded that the morphological change influenced by the polymer in PMB depends on the polymer type, compatibility between polymer and bitumen, the swelling potential of polymer and the polymer content. Moreover the storage stability of PMBs can be very well established by OFM studies.
In a nutshell, the following conclusion is arrived after studying the PMB nature and its performances.

The aim of developing a PMB is to make the binder to perform well at all workable temperature levels with different loading parameters. The present study on PMB shows positive results in their empirical tests like SP, PV and PI. This concludes that the PMB shows less temperature susceptibility and lower deformation due to cracking. The thermal studies concluded that the modified binder shows an increase in the temperature stability and decreased crystalline nature of the PMB which results in decreasing the extent of permanent deformations like rutting, fatigue cracking and low temperature cracking. FTIR study is a quiet interesting study when compared with other studies. IR spectrum obtained show that there is a change in the chemical structure of the bitumen chain and further studies in this area will be much interested in finding the molecular level rearrangements present in the bitumen composition. The viscous study also shows improved results and the resistance to permanent deformations of the pavement is reduced, due to the improvement in the viscous properties of the modified bitumen. The morphological study also supports the conclusion with a clear morphological picture of the bitumen polymer blend and its distribution without any phase separations.

It is evident that the PMB prepared can be very well used for pavement application.

5.2 FUTURE SCOPE

- The characterization methods of the PMB are needed to be normalized since the PMB behaves differently when compared with the unmodified bitumen.
- Laboratory findings need to be carried out to the field of application.
The present study is mainly focuses on the binder nature and discusses less about the mixer properties. Studies on enhancing the adhesion of the binder with the aggregate is need to be studied.