CHAPTER V
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In this study, a cradle-to-gate life cycle assessment (LCA) technique based on ISO 14040 series is performed to evaluate hot-mixed asphalt (HMA) and warm-mixed asphalt (WMA) in terms of energy and environmental impact. The main focus is to compare WMA (conventional asphalt with additive "Sasobit") and conventional hot-mixed asphalt production and pavement in order to identify benefits in both energy aspect and greenhouse gases (GHG) reduction. The system boundary includes provision of asphalt, raw materials auqisition, asphalt production, paving, and all transportations based on functional units of 1 ton of asphalt product and 1 km x 7 m x 0.05 m road pavement. For HMA, relevant data are collected at actual production sites of Thaiwat Engineering Co., Ltd (Bangbuatong), including pavement. However, for WMA, since we cannot gain acceptance the actual warm-mixed asphalt data from Thaiwat Engineering Co., Ltd (Sriracha) at the time of this study, both production and pavement data for LCA analysis are estimated from HMA based on similar research study in the literature. The results of HMA and WMA are compared together based on functional units and also with those of other studies. The following points can be summarized as the conclusions of this study: the global warming potential (GWP), represented by GHG emissions, comes mostly from raw material and asphalt production with little contribution from transportation and pavement process. The results show that WMA provides considerable environmental benefits compared to HMA in both energy and GHG reduction aspects. This is mainly contributed to the decrease in mixing temperature from 160 to 140°C and also pavement temperature. Consequently, the results showed that WMA had better performance in both GWP and energy aspects, but the benefits were not significant (<5%). More environmental benefits can be expected if the mixing temperature is further decreased. In comparison to other studies, the energy and environmental performance of HMA and WMA in Thailand is not as good as those observed in other countries, which is speculated to be due to lower efficiency in the asphalt production and high uncertainty of the

data obtained from actual production plant. Finally, the end of life phase has shown to be important in improving the life cycle performance of asphalt. It is obvious that recycling process helps reduce both energy input and GWP impact such that the more recycle leads to the better environment performance of asphalt.

5.2 Recommendations

Although the life cycle environmental impact assessment was successfully conducted for two types of asphalt (HMA and WMA), several recommendations could be offered as follows:

5.2.1 Suggestions for Improvement of Inventory Data

In hot-mixed asphalt, we want more complete data. The data of raw-material usage is collected only 3 months but it's not consistent. So the good data should be kept up for long term due to continuous and constant of data.

In addition, in warm-mixed asphalt, because we cannot gain acceptance the actual warm-mixed asphalt data from asphalt industry at the time of this study so we use basis of calculation from literature; it may be not good enough for real case. In order to get good results should seek information from the company.

Finally, as the inventory data from Miliutenko *et al.* (2012) was used as the secondary data for the end of life of asphalt. It has several assumptions and estimations were made in order for the research team to be able to have enough data to assess the environmental impact as planned. This could be improved if more complete and transparent data were achieved.

5.2.2 Suggestions for Improvement of Environmental Performance

From the results, it can be seen that GWP impact mainly comes from the production of asphalt which covers the raw-material and production. We have shown that utilization of recycling asphalt help to reduce GWP significantly. Developing recycling asphalt system is interesting choice to reduce GWP and can be more reduced energy input. For the new generation, the process for recycling asphalt should be percent of recycling to decrease GWP of the process.

According from Zaumanis, 2010, WMA is expected to perform as well as or even better than HMA and can approach to 75% recycling which is more than HMA recycling. Nevertheless, Long-term ageing still needs to be studied in greater depth since this may be the area where there are the greatest differences between HMA and WMA. Moreover, I think the future work should collect more data for absolute performance of production.