Study on the Effect of Warm Mix Additive on the Performance of Hot Mix Plant Asphalt with High Reclaimed Asphalt Pavement

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Abstract:

In this paper, the performance of Recycled hot mixed asphalt with high reclaimed asphalt pavement (RAP) content is studied through a series of laboratory experiments, including Marshall Stability Test, Wheel Track Rutting Test, Low Temperature Cracking Test, and Indirect Tension Strength Test. Based on the results, is was found that the addition of different percentage of RAP, the dynamic stability would increase linearly, however, the low temperature performance would deteriorate reversely. Meanwhile, the addition of warm agent (WA) and reclaiming agent (RA) would significantly improve rutting resistance and durability of recycled asphalt mixture, but the WA and RA has limited influence for the Marshall Stability of high RAP content asphalt mixture. The performance of high RAP content recycled asphalt mixture can meet the AASHTO standard requirements and can elongate the service life of pavements.

KEYWORDS: High Reclaimed Asphalt Pavement Content, Hot recycling, Performance Evaluation, Warm Mix Additive

1. Introduction

High RAP content hot recycled mixture is the hot mix asphalt mixture with more than 25% RAP content. It has been used in asphalt pavement rehabilitation for decades, however, some problems still remain:

(1) Aging of asphalt in recycled mixture. The mixing temperature of hot mix plant recycled mixture is 5-15℃ higher than conventional mixture. To meet the mixing temperature requirement, new aggregate need a higher temperature because of high content of RAP, leading to severe aging of hot recycled mixture in the mixing process.

(2) High energy consumption in producing the mixture. As content of RAP increase, temperature of producing process is raised, and mixing time is prolonged, leading to reducing efficiency of mixing machine and raising production costs.

(3) Increase of noxious gases emission. Rising of mixing temperature and time also result in more emission of "blue smoke" and noxious gases.

(4) The objective of this paper is to analyze the influence of different factors (specifically, RAP contents, RA, warm mix additives) on mixture performance. Marshall Stability, high-temperature rut resistance, low-temperature cracking resistance and splitting fatigue resistance were used in this study in order to provide a reference to pavement design and rehabilitation.

2. Laboratory Experiments

2.1 Mix Design

The asphalt mixture specimens are derived from the combination of the course RAP (CRAP) and fine RAP (FRAP), and the weight ratio of CRAP and FRAP is one to one. For maintaining the gradation consistency throughout the different RAP percentage, we adjusted the sieve passing rate of fresh aggregate and tried to eliminate the deviation of gradation, the gradations of RAP-30%, RAP-40%, and RAP-50% are shown in Figure 1. The asphalt content of CRAP and FRAP is 3.9% and 4.6%, respectively. Therefore, the asphalt content for the RAP, which is combined by CRAP and FRAP, is 4.44%. Then, all the asphalt mixture

specimens with different RAP ratio are made by the asphalt content of 4.4%, and the specimens are designed according to SUP20 of Superpave^{TM} method.

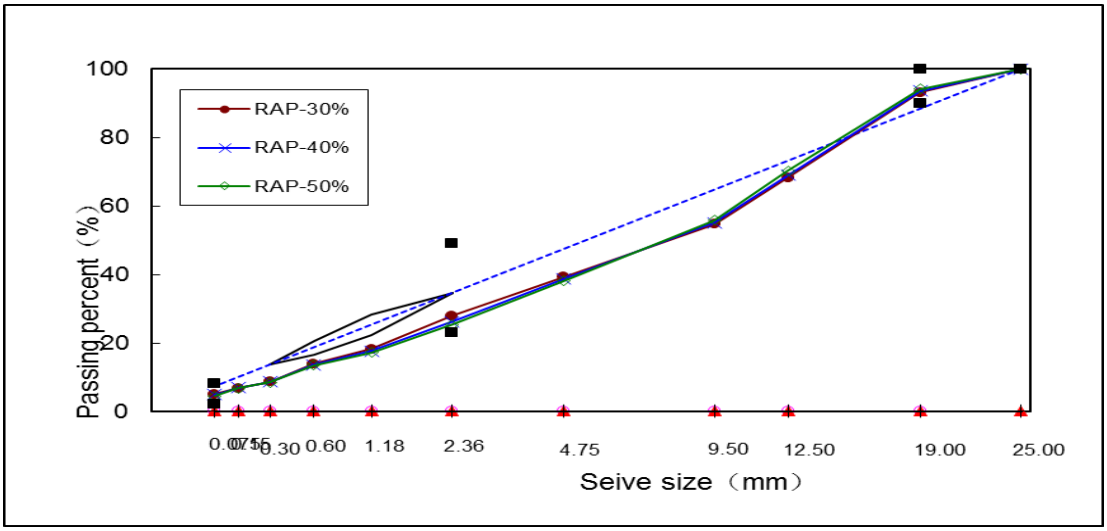

FIGURE 1 Composite Gradation Curves

2.2 Marshall Tests

Figure 2 shows three groups specimens of Marshall Stability test and immersion Marshall Stability (MS) test modified with different RAP, RA and WA ratio, respectively. Retained stability (RS) value for each mixture is 95.7%, 95.0%, 91.0%，88.5%，91.0%，92.0%，93.3%，91.0% and 91.2% respectively. For all mixes, RS values are all greater than 85.0%, which is the value formulated in the criterion.

As can be seen in Figure 2, both MS and RS decrease when the RAP content is increasing. It indicates that RAP has some negative effect on MS. The reason is that the interface between RAP and aged asphalt increase with the increasing RAP contents, and the weak interface increases. Reclaiming agent contents and warm mix additive contents have little effect on MS and immersion Marshall Stability when the mix consists of 50% RAP contents. Thus, mixes with high reclaimed asphalt pavement are not sensitive to reclaiming agent and warm mix additive.

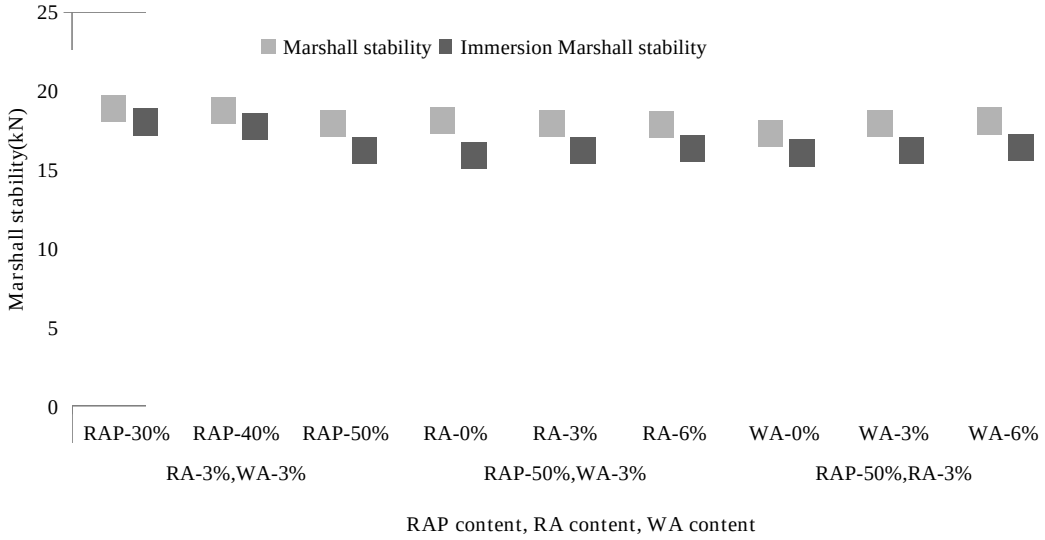

FIGURE 2 Results of Marshall tests

2.3 Wheel Tracking Rutting Tests

Figure 3 shows the results of the high temperature rutting resistance. As addition of reclaiming agent and warm agent are both 3%, dynamic stability (DS) of SUP20 recycled mixture would increase rapidly with the increasing RAP contents. Dynamic stability values for mixes consisting of 30% and 50% RAP are 4682 and 6116 times/mm. The DS value increase 31%. All DS values in the figure are greater than 1000 times/mm the value stipulated in the norm.

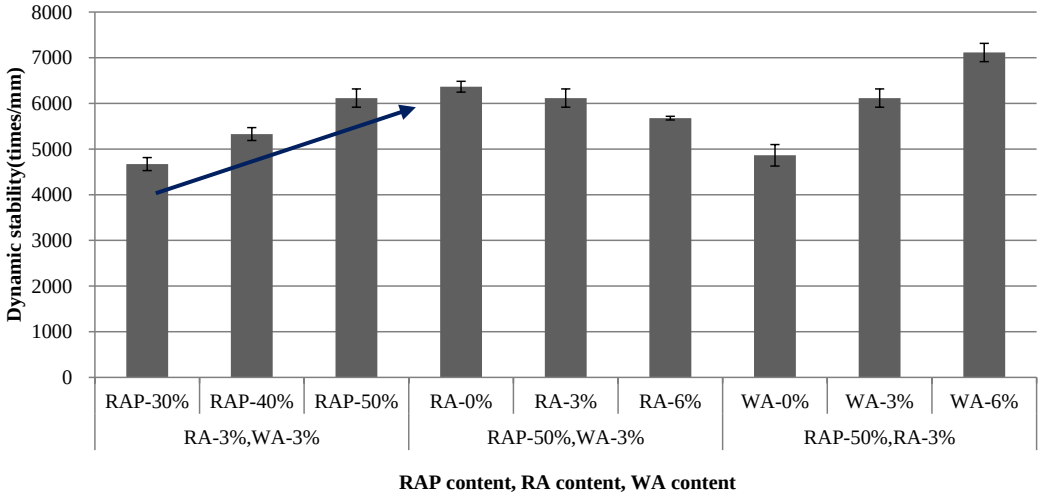

Figure 3 Results of High Temperature Rutting Resistance Tests

A probable reason is that asphalt mixtures (especially the asphalt) get aged under the action of load and environment factors. The light oil volatilization and increased asphaltenes make the asphalt viscosity increase. The viscosity of asphalt mortar increases with the increasing RAP contents, and that help improve the rutting resistance of the mixtures. Furthermore, there is a linear relationship between DS and RAP contents according to linear fitting, and the correlation coefficient has reached 0.99.

This paper further investigated the effect of warm mix additive and reclaiming agent on the high temperature performance of hot mix plant asphalt with high reclaimed asphalt pavement (RAP=50%). As can be seen from Figure 3, the DS values decrease with the increasing reclaiming agent contents when RAP content is 50% and warm mix content is 3%. The slight reduction in rutting resistance performance may be caused by that RAP has been softened and reclaimed by reclaiming agent. The DS values are greater than 1000 times/mm, the value stipulated in the norm.

The study also shows that warm mix addition can help improve the rutting resistance performance of recycled mixtures. The DS value of the recycled mixture contains 6% warm mix addition increased by 46% compared with mixtures without warm mix addition. So, considered from dynamic stability it would be better to add some warm mix addition in the mixtures in the actual engineering.

2.4 Low Temperature Cracking Test

The test results of Low temperature cracking tests are shown in Figure 4. It appears that if ignore other factors, low-temperature performance would decrease in general with the increase of RAP contents. When RAP content is 40% or 50%, failure strain approaches 2000 $\mu\varepsilon$, nearly the critical value in the technical standards. That is mainly caused by the decrease in asphalt ductility after mixing new asphalt and old asphalt together, and the decrease is in positive correlation with RAP content. As a result, the low-temperature performance of recycled mixtures decreases with increasing RAP content.

This paper did some further investigation in the effect of warm mix addition and reclaiming agent on low-temperature performance. Figure 4 shows that reclaiming agent and warm mix addition can help improve

low-temperature performance of recycled mixture. It may be caused by that reclaiming agent help improve the performance of asphalt and increase the proportion of asphalt mixture with good low-temperature performance. Thus, the low-temperature performance of recycled mixture gets improved. The warm mix addition help reduce viscosity of RAP and mixture, and help asphalt coat aggregate better. It also improves low-temperature performance of the recycled mixture.

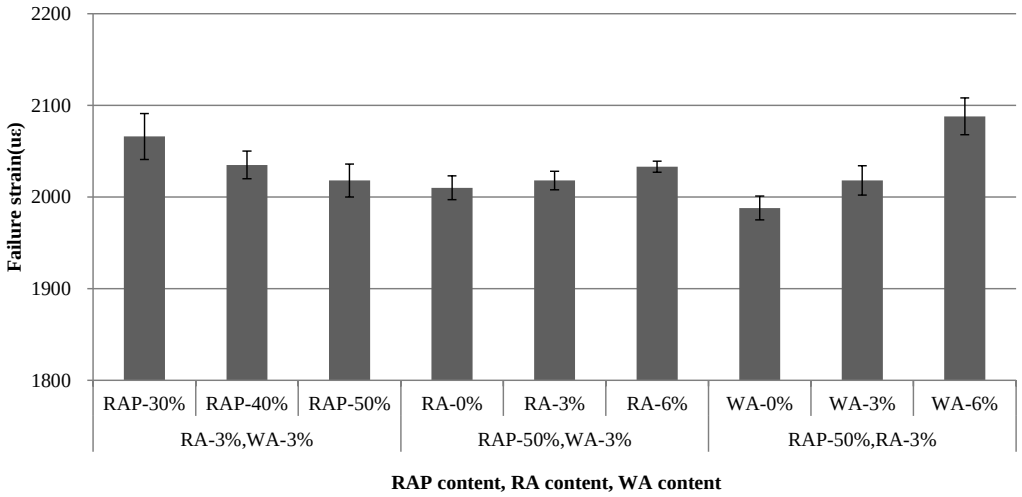

Figure 4 Results of Low Temperature Cracking Tests

2.5 Indirect Tension Fatigue Tests

Figure 5 shows the fatigue life of different samples when the stress ratio is 0.6, 0.4 and 0.2. The figure shows that the samples share the same changing trends under different stress ratios. They all increase exponentially. The fitting formula shows that the correlation coefficient reaches 0.96. Thus, the fatigue performance of a sample under different stress ratios can be estimated according to indirect tensile fatigue tests.

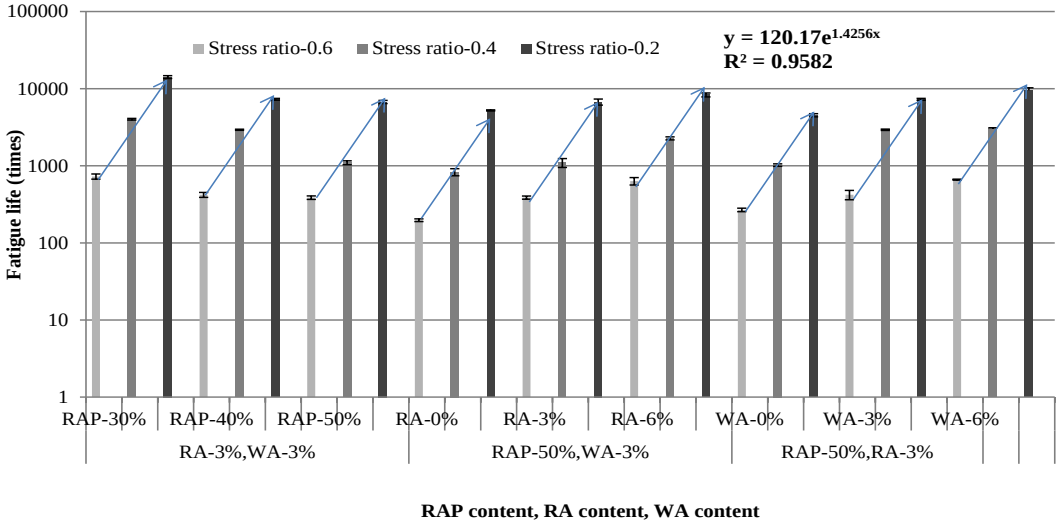

Figure 5 Fatigue Life under Different Stress Ratios

Figure 6 shows the indirect tension strength of recycled mixture. As can be seen from the figure, the tensile strength shows a linearly increasing trend with the increasing RAP contents. This paper investigated the fatigue life of mixtures with different RAP contents under different stress ratios. Figure 7(a)-7(c) shows that

under different stress ratios, the fatigue life of the mixtures decrease exponentially with the increasing RAP contents. The fatigue life reaches the minimum value when RAP content is 50%.

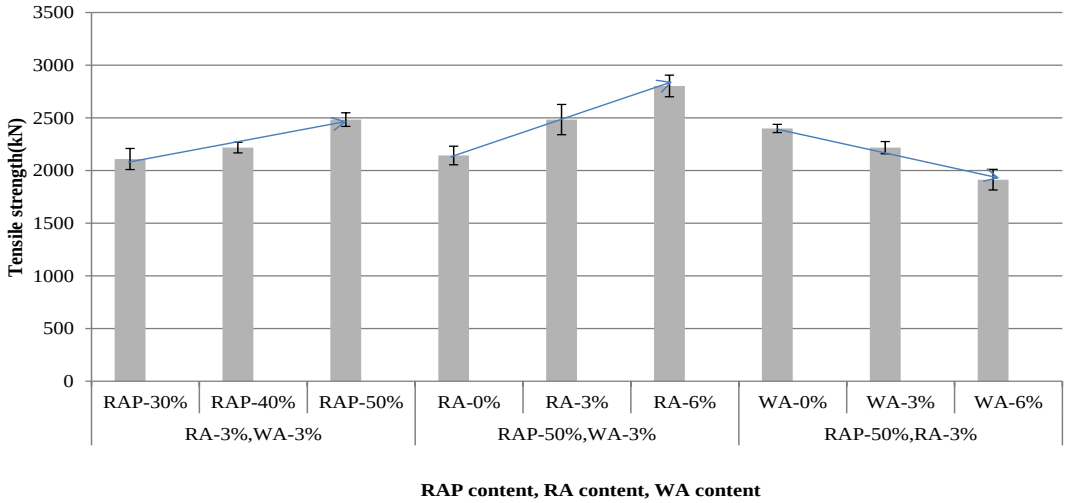

Figure 6 Results of Indirect Tension Tests

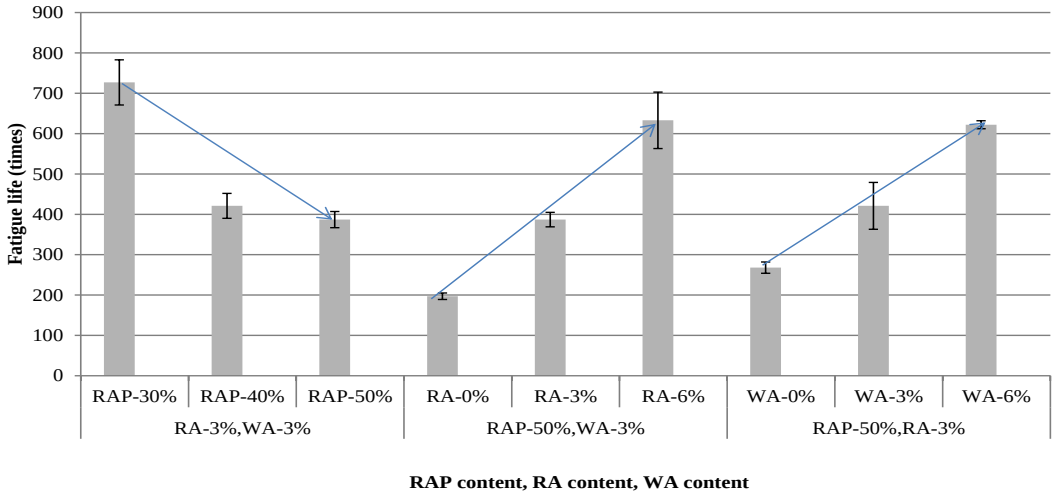

Figure 7(a) Fatigue Test Results at Stress Ratio=0.6

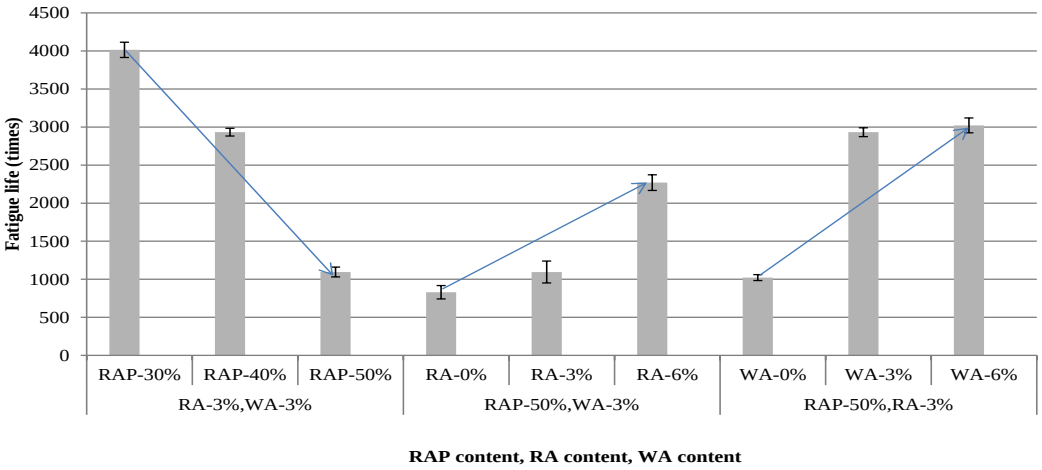

Figure 7(b) Fatigue Test Results at Stress Ratio=0.4

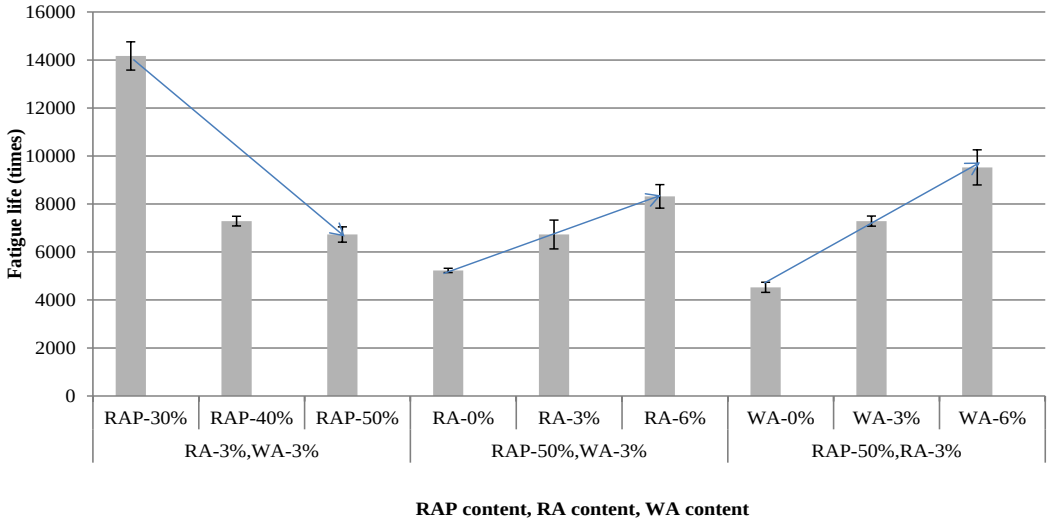

Figure 7(c) Fatigue Test Results at Stress Ratio=0.2

The indirect tension strength increases gradually with the increasing reclaiming agent contents, and there is a good linear relation between them. The indirect tension strength decreases with the increasing warm mix addition contents. Under different stress ratios, fatigue life increases rapidly with the increasing warm mix addition contents. So the addition of warm agent could improve the fatigue life of hot mix plant asphalt with high reclaimed pavement significantly.

In summary, according to the analysis of the indirect tension fatigue life of hot mix plant asphalt, increase of RAP contents has a negative effect on the fatigue life, while reclaiming agent and warm mix addition can help improve the fatigue life. As a result, this paper suggest that reclaiming agent and warm mix addition are needed when hot mix plant asphalt with high reclaimed asphalt pavement is used in engineering, to ensure the construction convenience and to improve the fatigue life.

3. Conclusions

This paper studied the pavement performance of hot mix plant asphalt with different RAP contents, and further investigated the effect of reclaiming agent and warm mix addition contents on the performance of hot mix plant asphalt with high reclaimed asphalt pavement. The main conclusions are drawn as followings:

(1)Fatigue life shows a linear increasing trend with the increasing reclaiming agent and warm mix addition contents, it indicates that reclaiming agent and warm mix addition can improve the durability of hot mix plant asphalt with high reclaimed asphalt pavement effectively.

(2)The fatigue life of hot mix plant asphalt shares the same exponentially increasing trends under different stress ratios, fatigue life under different stress ratios can be estimated according to this law.

(3)All the pavement performance of hot mix plant asphalt with high reclaimed asphalt pavement can meet the criterion requirements. Thus, it can be widely applied in asphalt pavement construction. It is one of the most efficiency methods to use reclaimed asphalt pavement and to realize the green construction of pavement.

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