Performance Evaluation of Asphalt Mixtures Containing Reclaimed Asphalt Pavement (RAP) Modified with Waste Polybutadiene Rubber

Daryoosh Daryaee[1*], Mostafa Vamegh[2]

[1]Dept. of Civil Eng., Faculty of Civil Engineering and Architecture, Malayer University, Malayer, Iran
[2] Department of Civil and Environmental Engineering, Shiraz University of Technology, Shiraz. Iran

ABSTRACT

In this research, the effect of waste polybutadiene rubber (PBR) has been investigated in the performance evaluation of asphalt mixtures containing RAP. Different percentages of RAP, including 20, 30, and 50%, were selected to prepare the asphalt mixture. To prepare polymer-modified bitumen, bitumen 60/70 was mixed with 5% by weight of waste PBR polymer and then added to asphalt mixtures containing different percentages of RAP. In this study, four-point bending beam, modified Lottman and Hamburg Wheel-Track tests were performed to evaluate the fatigue behavior, moisture susceptibility, and the rutting resistance of asphalt mixtures containing RAP, respectively. The results showed that the presence of utilized waste polymer significantly improved the fatigue behavior of asphalt mixtures containing 20 and 30% RAP compared to the control mixture. Also, the use of this polymer can be used in asphalt mixtures with a RAP percentage of less than 50% (about 40%) without any concern about reducing the fatigue resistance of asphalt. Furthermore, the results showed that by using waste PBR in asphalt mixtures containing RAP, the resistance of the mixtures against moisture susceptibility has increased significantly compared to the control mixture. The results of the Hamburg Wheel-track test also showed that the combination of RAP materials and used waste polymer could reduce the rut depth by 70% in comparison with the control mixture.

KEYWORDS

WASTE POLYBUTADIENE RUBBER, RAP MATERIAL, FATIGUE, MOISTURE SUSCEPTIBILITY, RUTTING RESISTANCE

* Corresponding Author: Email: D.daryae@malayeru.ac.ir

1. Introduction

Reclaimed Asphalt Pavement (RAP) are materials, produced by grinding asphalt pavements and stored and collected in deposit places[1]. One of the problems of adding RAP materials to hot mix asphalt (HMA) is reducing its resistance to fatigue cracking[2]. This is because, with the addition of RAP materials, the asphalt mixture becomes harder and becomes more brittle at intermediate temperatures due to the loads caused by the fatigue phenomenon[3]. Various strategies have been introduced to increase the fatigue resistance of asphalt mixtures containing RAP, such as the use of rejuvenators, bitumen with high penetration degree, polymers, etc. [1, 4-7]. Today, due to the large amount of polymer waste, their use in the modification of asphalt binder used in pavement has been proposed as a task among researchers[8]. Mansourkhaki et al. investigated the effect of PBR polymer on the chemical and rheological properties of bitumen specimens containing recycled bitumen from RAP and found that there are good statistical correlations between the chemical and rheological properties of these specimens[9].

According to previous research, it can be pointed out that in these studies, the combined effect of rejuvenator and waste PBR waste polymer on bitumen containing recycled bitumen and asphalt mixtures containing RAP was investigated. Also, many researches have focused on the effect of waste polymers only on HMA asphalt mixture. Therefore, this research tried to investigate the effect of waste polymer alone on asphalt mixtures containing RAP. This research aimed to determine whether this waste polymer can have a positive effect on the intermediate temperature behavior or the fatigue life without having a negative effect on other functional parameters such as moisture sensitivity and rutting resistance.

One of the characteristics of this research is that the PBR polymer waste can be placed as an environmentally friendly option next to the use of small asphalt materials, which itself is a recycled material. Considering that little research has been done on the effect of waste PBR on asphalt mixtures containing different percentages of RAP, in this research the effect of this residue on the performance characteristics of asphalt mixtures containing different percentages of RAP (0, 20, 30, and 50%) takes place.

2. Materials and methodology

The type of aggregates selected in this research was limestone aggregates that were prepared from the Asbcheran mine located in Rodehen City, Iran. The RAP materials were collected from one of Tehran's highways. The bitumen was extracted from the RAP materials in accordance with the ASTM D2172 method and then recovered using the rotatory evaporator (ASTM D5404).

Considering that the gradation curve of RAP materials was not within the allowable range of standard gradation, the gradation of RAP materials was modified by adding 4% filler. In this research, bitumen with a penetration degree of 60-70 was selected as control bitumen. The bitumen used was obtained from the Tehran Refinery. PBR waste was prepared from polybutadiene rubber wastes (PBR1220) obtained from the Arak Petrochemical Factory.

To prepare waste polymer modified bitumen (WPMB), control bitumen (70/60 bitumen) with 5% by weight of PBR waste in a high shear speed mixer (6000 rpm) was mixed for 60 min at 160 °C. In this research, four types of asphalt mixture designs were evaluated:

- The first mixture: control asphalt mixture without RAP (unmodified),
- the second mixture: asphalt mixture with 20% RAP and 80% new materials (20%RAP+WPMB)
- the third mixture: asphalt mixture containing 30% RAP and 70% new materials (30%RAP+WPMB)
- the fourth mixture: asphalt mixture containing 50% RAP and 50% new materials (50%RAP+WPMB)

In this research, from each mixing design, three cylindrical samples were used for the Hamburg Wheel Track test and six samples were used for the Indirect Tensile Test (ITS) using a Superpio rotary compactor. To perform the four-point beam fatigue test, using a Prism Shear Box Compactor, samples with dimensions of 150x160x450 mm with a void percentage of 4% were prepared.

3. Discussion and Results

The results of average fatigue life (Nf_{50}) were obtained for different asphalt mixtures with different percentages of RAP at three strain levels of 500, 700, and 800 microstrains and are compared with each other in Figure 1. As seen in Figure 1, by comparing the fatigue life of 30% RAP + WPBR and 50% RAP + WPBR mixtures with 30% RAP and 50% RAP respectively, it can be concluded that the addition of waste polymer in asphalt mixtures containing 30% RAP has been able to increase the fatigue life in strain levels of 500 and 700 microstrains by 85% and 38%, respectively, and in asphalt mixtures containing 50% of RAP, it has been able to increase the fatigue life in strain levels of 500 and 700 microstrains by 50% and 68%, respectively, compared to mixtures containing RAP without polymer.

Figure 2 shows the TSR value of all asphalt mixtures. As can be seen in the figure, with the increase in the percentage of RAP, the amount of TSR has increased. Therefore, the combination of bitumen modified with WPBR along with RAP materials has a positive effect on reducing the moisture susceptibility of asphalt mixtures compared to the control mixture. In Figure 2, by comparing the results of TSR in asphalt mixtures containing 30% and 50% RAP, in two cases without waste polymer and with PBR waste polymer, the effect of PBR additive in improving moisture susceptibility can be clearly seen.

Figure 3 shows the average rut depth of asphalt mixtures containing different percentages of RAP mixed with polymer bitumen compared to the control mixture. Based on the obtained results, with the increase of RAP percentage, the rut depth of the asphalt mixture has decreased. Therefore, the combination of RAP materials and bitumen modified with WPBR has had a positive performance in increasing the rutting resistance, so that with the addition of 50% RAP, the rut depth of the mixture has decreased by 70% compared to the rut depth of the control mixture.

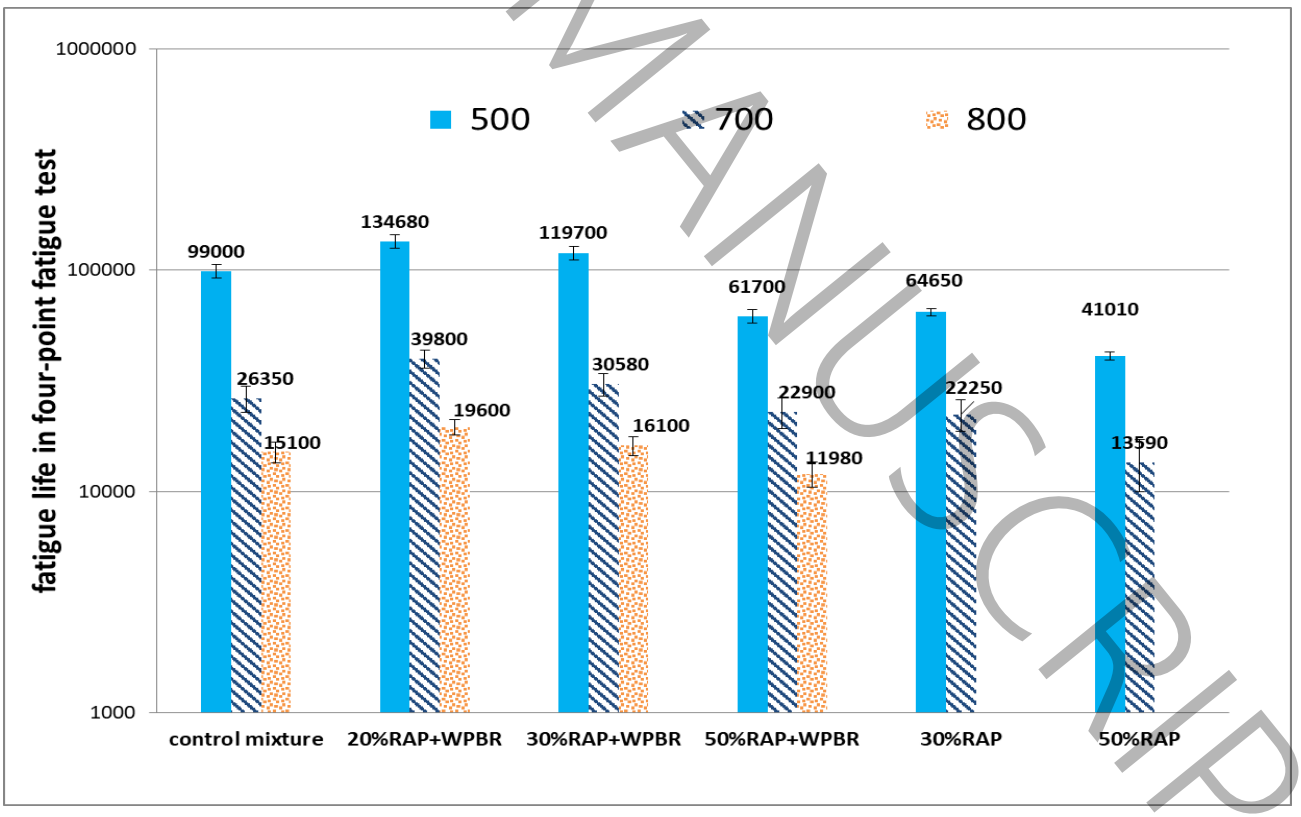

Figure 1. Results of fatigue life of all mixtures

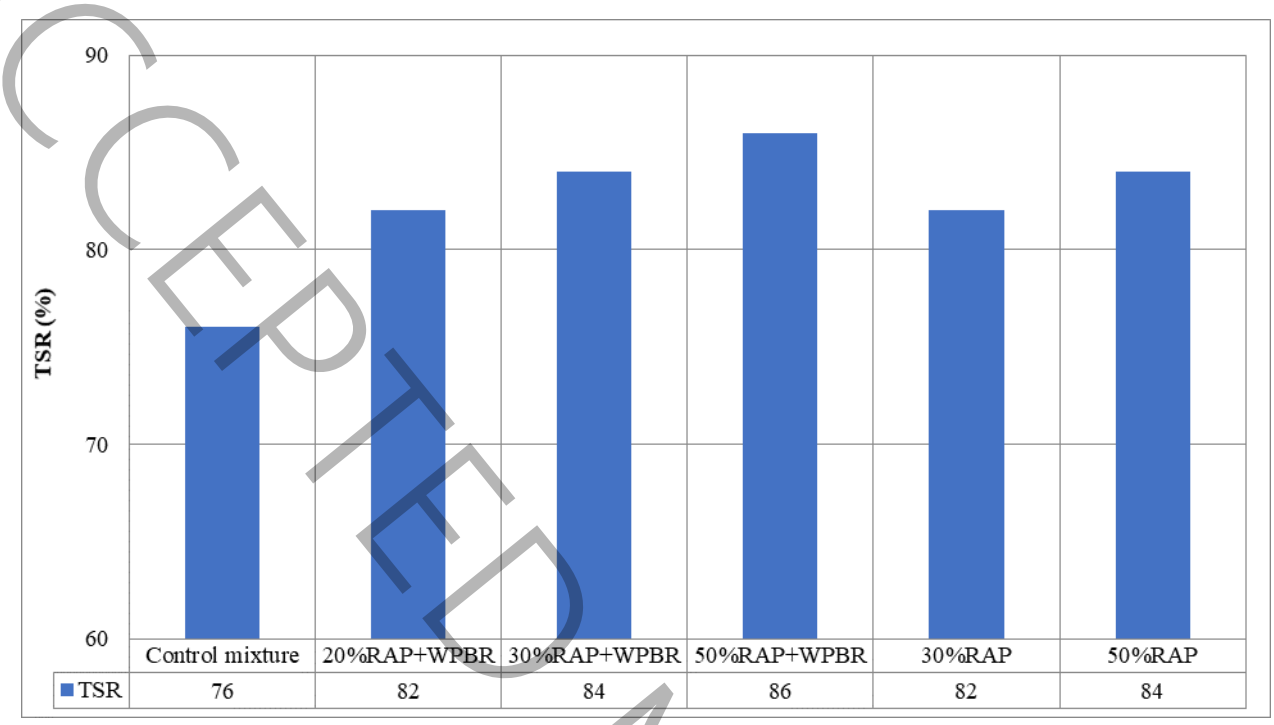

Figure 2: TSR value of all mixtures

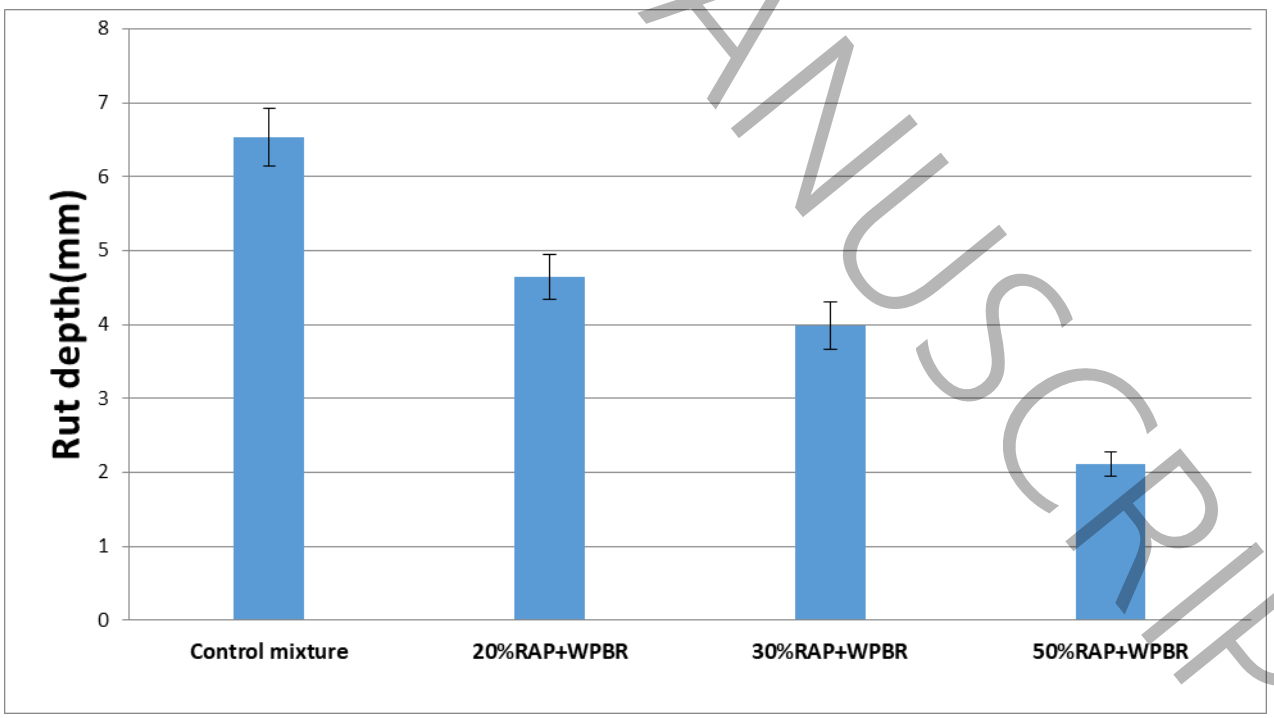

Figure 3: Results of rut depth

4. Conclusions

The main results obtained from this study are:

- The presence of PBR waste polymer improved the fatigue performance of asphalt mixtures containing more than 30% (approximately 40%) compared to the control mixture without RAP.

- By comparing the test results of modified Latman and bending beam fatigue tests in asphalt mixtures containing 30% and 50% RAP, in two cases without waste polymer and with PBR waste polymer, it was found that the addition of PBR waste polymer to asphalt mixtures containing RAP increases fatigue and moisture resistance of asphalt mixtures up to 50% RAP.

- The obtained results of the rut depth in asphalt mixtures showed that the use of bitumen modified with the waste polymer along with RAP materials still had a decreasing effect on the rut depth (improving rutting resistance) of the mixtures.

5. References

[1] W.S. Mogawer, A.J. Austerman, R. Kluttz, S. Puchalski, Using polymer modification and rejuvenators to improve the performance of high reclaimed asphalt pavement mixtures, Transportation research record, 2575(1) (2016) 10-18.
[2] A. Behroozikhah, S.H. Morafa, S. Aflaki, Investigation of fatigue cracks on RAP mixtures containing Sasobit and crumb rubber based on fracture energy, Construction and Building Materials, 141 (2017) 526-532.
[3] M. Zaumanis, R.B. Mallick, L. Poulikakos, R. Frank, Influence of six rejuvenators on the performance properties of Reclaimed Asphalt Pavement (RAP) binder and 100% recycled asphalt mixtures, Construction and Building Materials, 71 (2014) 538-550.
[4] B.H. Dinh, D.-W. Park, T.H.M. Le, Effect of rejuvenators on the crack healing performance of recycled asphalt pavement by induction heating, Construction, and building materials, 164 (2018) 246-254.
[5] J. Li, F. Ni, Y. Huang, L. Gao, New additive for use in hot in-place recycling to improve performance of reclaimed asphalt pavement mix, Transportation Research Record, 2445(1) (2014) 39-46.
[6] H. Nabizadeh, H.F. Haghshenas, Y.-R. Kim, F.T.S. Aragão, Effects of rejuvenators on high-RAP mixtures based on laboratory tests of asphalt concrete (AC) mixtures and fine aggregate matrix (FAM) mixtures, Construction and Building Materials, 152 (2017) 65-73.
[7] H. Zhu, G. Xu, M. Gong, J. Yang, Recycling long-term-aged asphalts using bio-binder/plasticizer-based rejuvenator, Construction and building materials, 147 (2017) 117-129.
[8] D. Daryaee, M. Habibpour, S. Gulzar, B.S. Underwood, Combined effect of waste polymer and rejuvenator on performance properties of reclaimed asphalt binder, Construction and Building Materials, 268 (2021) 121059.
[9] A. Mansourkhaki, M. Ameri, D. Daryaee, Application of different modifiers for improvement of chemical characterization and physical-rheological parameters of reclaimed asphalt binder, Construction and Building Materials, 203 (2019) 83-94.