# Using Reclaimed Asphalt and Polymer Modified Asphalt (PMA) to Maximize Cost Saving over the Pavement Life-Cycle in Qatar

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## ABSTRACT

Low performing asphalt mixes along with poor construction practices reduce the pavement serviceability and lead to early failure under repetitive traffic. Government agencies are sometimes urged to implement maintenance and rehabilitation at earlier stages throughout the pavement lifecycle. As an innovative pavement material solution, Polymer Modified Asphalt (PMA) along with an optimized recycled asphalt (RA) content in the recycled hot-mix asphalt (HMA) provide higher performance for the hot asphalt mixes (HMA) with an upfront saving on the cost of material, and a reduced maintenance cost over the lifecycle of pavement. While the mix performance is driven by various factors, RA characteristics and PMA properties contribute to the performance of HMA. In this study, RA and PMA mixes were produced using an existing target Job Mix Formula (JMF) of a dense graded 19.0 mm Nominal Maximum Aggregate Size (NMAS) and Pen 60/70 neat asphalt binder. Five recycled HMA were produced using respectively RA content ranging from 15 to 35%. PMA was added to every mix at a fixed percentage in order to match mixes using PMB PG 76E-10 (extremely heavy traffic with ESALs > 30 million). The Marshall mix design method was used to verify the properties of the recycled HMA. This paper highlights the benefits of using PMA with RA in Qatar as an ultimate solution that provides durability, values, and reduced maintenance cost over the lifecycle of the pavement.

**Keywords:** Polymer modified asphalt; Reclaimed asphalt; Pavement life-cycle; Cost analysis

## 1 INTRODUCTION

The cost of rehabilitation and maintenance of pavement increases especially when the pavement life is shorter than designed, and when it is impacted by various factors such as unanticipated traffic loads and harsh weather conditions that do not align with the appropriate binder grade selection. Moreover, the cost aspects such as material, construction overhead, and maintenance need to be properly assessed to optimize cost over the pavement lifecycle (Chen et al., 2002). Low performing asphalt mixes along with poor construction practices reduce the pavement serviceability and lead to early failure under repetitive traffic. Poor quality pavement causes governments to implement maintenance and rehabilitation at earlier stage throughout the pavement lifecycle (Cooper, 2011).

## 2 MAIN RESEARCH TOPIC AND WORK METHODOLOGY

Transportation authorities continuously seek innovative solutions and technologies that increase pavement durability and life. Among those innovative products, Polymer Modified Asphalt (PMA) along with an optimized content of reclaimed asphalt (RA) in recycled hot-mix asphalt (HMA) provide a performing and durable pavement with the advantage of an upfront saving on the cost, and they reduce the maintenance cost over the lifecycle of pavement (Bennert et al., 2014). The main objective of this study was to compare the quality characteristics and cost of production of various mixes using PEN 60/70, PMB and CRMB with recycled HMA in the state of Qatar. However, the study aimed to highlight the upfront costs and reduction of maintenance cost over the lifecycle of pavement associated with each mix. The reduction in maintenance was assumed based on the potential need of performing preventive maintenance throughout the pavement life taking into consideration that the typical failures of the roads in Qatar are either fatigue crack or rutting due to pavement densification under repetitive traffic.

## 3 THE RESEARCH APPROACH

The thirteen mixes, summarized in Table 1, were developed using PEN 60/70, PMA, PMB 76E-10 and CRMB binder while considering 15 and 30% RA content in mix (Zaumanis et al., 2014) in addition to using rejuvenator (Mogawer et al., 2016) for mixes with 30% RA. Dense graded asphalt mixtures with a 19-mm Nominal Maximum Aggregate (NMAS) were produced to encompass the various asphalt mixes. Four replicates were collected from each mix, and tested according to Marshall method (Asphalt Institute, 2007) and Qatar Construction Specification (QCS, 2014). The Tensile Strength Ration (TSR) and in-place air void were reported and summarized in Table 3. Moreover, the cost analysis per ton of asphalt mix ex-plant was based on the raw material actual rates as of October 2019 (Figure 1). For the Life cycle assessment, samples were tested in accordance with EN 12697-31 by compaction of cylindrical specimens of bituminous mixtures using a gyratory compactor $N_{max}$= 200 load cycles so that the specimens represented the mixture at the end of its life cycle.

Table 1: Details of HMA Mixes

| Mix Detail | Description and Application | Comment |
|---|---|---|
| TQ (PEN 60/70) | Highway and Local road, medium to high traffic | Currently Applied |
| $TQ_r$ (PEN 60/70) +15% RA | Local road, low to medium traffic + 15% RA | Currently Applied |
| $TQ_{rmax}$ (PEN 60/70) + 30% RA | Local road, low to medium traffic + 30% RA + Rejuvenator | Not applied |
| PMA (9%) | Highway, medium to high traffic with PMA | Not applied |
| $PMA_r$ (5%) + 15% RA | Local road, low to medium traffic + 15% RA with PMA | Recommended |
| $PMA_{rmax}$ (5%) + 30% RA | Local road, low to medium traffic + 30% RA with PMA | Recommended |
| $PMA_{rmax}$ (9%) + 30% RA | Highway, high traffic + 30% RA with PMA+ Rejuvenator | Recommended |
| PMB (PG 76E-10) | Highway, medium to high traffic | Currently applied |
| $PMB_r$ (PG 76E-10) + 15% RA | Local road, low to medium traffic + 15% RA | Not applied |
| $PMB_{rmax}$ (PG 76E-10) + 30% RA | Highway, high traffic + 30% RA+ Rejuvenator | Not applied |
| CRMB (PG 76E-10) | Local roads, medium to high traffic | Currently Applied |
| $CRMB_r$ (PG 76E-10) | Local road, low to medium traffic + 15% RA | Currently Applied |
| $CRMB_{rmax}$ (PG 76E-10) | Highway, high traffic + 30% RA+ Rejuvenator | Not applied |

## 4 RESULTS AND DISCUSSION

Through trends analysis, $PMA_{rmax}$ (5%) mix had shown the most performing mix providing the most economical rate per ton compared to the mixes using PMB and CRMB. With $PMA_{rmax}$ (5%): the saving is 8.3% saving on cost, 16.9% on aggregates, and 16.6% saving on bitumen. $PMA_{rmax}$ (5%) and 30% RA is recommended for local road projects as it provides upfront saving and reduction of cost on the future maintenance considering the projected traffic and a minimum 10 years life of pavement. At $N_{max}$=200, comparison of results in Table 2 comprised only mixes with 30% RA using respectively PEN 60/70, PMB PG 76E-10 and PMA (at 9%).

Table 2: Volumetric Characteristic of PMB and PMA Mixes

| Parameter | PEN 60/70 Mix $TQ_{rmax}$ (PEN 60/70) + 30% RA | PMB PG 76E-10 Mix $PMB_{rmax}$ (PG 76E-10) + 30% RA | PMA Mix $PMA_{rmax}$ (at 9%) + 30% RA |
|---|---|---|---|
| Mix Density, $G_{mb}$ | 2.674 | 2.623 | 2.602 |
| Air Void, $V_a$, % | 1.6 | 2,7 | 3,4 |

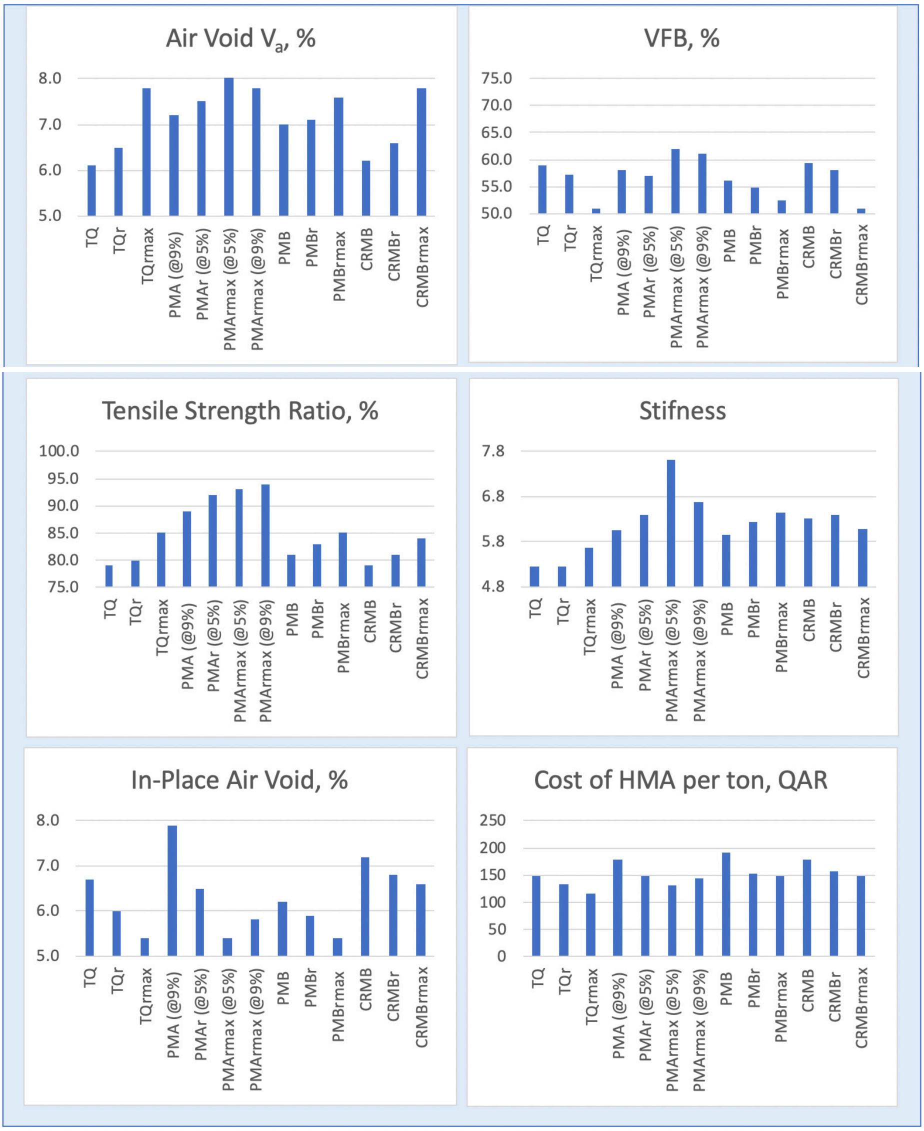


Figure 1: Summary of Selected Parameters

Table 3: Summary of Test Results

| Mix Designation | Marshall Properties | | | | | | | In-Place Air Void (cores) | Cost of HMA per ton |
|---|---|---|---|---|---|---|---|---|---|
| | $V_a$ | VMA | VFB | Stability | Flow | Stiffness | TSR | Void | QAR |
| | % | % | % | kN | mm | | % | % | 149.45 |
| TQ | 6.1 | 14.9 | 59.0 | 14.0 | 2.7 | 5.2 | 79.0 | 6.7 | 149.45 |
| $TQ_r$ | 6.5 | 15.1 | 57.1 | 14.1 | 2.7 | 5.2 | 80.0 | 6.0 | 132.64 |
| $TQ_{rmax}$ | 7.8 | 15.9 | 50.9 | 14.0 | 2.5 | 5.6 | 85.0 | 5.4 | 115.48 |
| PMA (9%) | 7.2 | 16.6 | 58.0 | 17.6 | 2.8 | 6.0 | 89.0 | 7.9 | 179.45 |
| $PMA_r$ (5%) | 7.5 | 16.2 | 57.0 | 17.1 | 2.7 | 6.3 | 92.0 | 6.5 | 148.96 |
| $PMA_{rmax}$ (5%) | 8.2 | 15.9 | 62.0 | 18.9 | 2.5 | 7.6 | 93.0 | 5.4 | 131.62 |
| $PMA_{rmax}$ (9%) | 7.8 | 16.7 | 61.0 | 19.2 | 2.9 | 6.6 | 94.0 | 5.8 | 143.56 |
| PMB | 7.0 | 15.0 | 56.0 | 17.9 | 3.0 | 5.9 | 81.0 | 6.2 | 191.07 |
| $PMB_r$ | 7.1 | 15.7 | 54.8 | 17.3 | 2.8 | 6.2 | 83.0 | 5.9 | 152.09 |
| $PMB_{rmax}$ | 7.6 | 16.0 | 52.5 | 17.9 | 2.8 | 6.4 | 85.0 | 5.4 | 147.47 |
| CRMB | 6.2 | 15.2 | 59.4 | 17.7 | 2.8 | 6.3 | 79.0 | 7.2 | 177.98 |
| $CRMB_r$ | 6.6 | 15.7 | 58.0 | 16.5 | 2.6 | 6.3 | 81.0 | 6.8 | 156.55 |
| $CRMB_{rmax}$ | 7.8 | 15.9 | 50.9 | 17.5 | 2.9 | 6.0 | 84.0 | 6.6 | 149.16 |

## 5 CONCLUSION

PMA is an innovative technology that maximizes cost saving, extends pavement serviceability, and improves production time and quality of asphalt against the currently available solutions within an economic and ecological perspective (Li et al., 2014). Moreover, PMA enables HMA producers to create mixes with high performance, as well as exhibiting resistance to fatigue and rutting (Becker et al., 2002). Compared to PMB and CRMB mixes, PMA offers equal and higher performance characteristics with the advantages of a considerable cost saving over the lifecycle of pavement assumed based on the in-place air void closer to the end life of the pavement. This indicates that early failure such as rutting is less likely to happen due the lower densification rate under traffic compared to the same mixes using PMB or PEN 60/70 binders.

Combined with RA, PMA offers a great value engineering solution where sustainability, upfront saving, and throughout pavement lifecycle saving are clearly demonstrated and measured. Moreover, PMA allows the reduction in asphalt thickness without reduction in performance of lifecycle of pavement, in addition to the reduction in pollutant emissions such as $CO_2$, $SO_2$, $NO_x$ and $PM_{10}$ due to less production and working hours of plant and machinery.

## 6 RECOMMENDATION

In this study, various laboratory and field tests were conducted to evaluate the effect of PMA solution compared to other traditional and alternative HMA mixes. It was found that PMA with 30% RA in recycled HMA provides an economic solution that can sustain a low maintenance over the lifecycle. However, further investigation to have a reliable performance prediction is needed besides testing the mixtures performance characteristics such as permanent deformation, rut depth, fatigue, modulus and sensitivity to moisture using Superpave method.

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