# Performance Evaluation of Asphalt Mixtures with Rediset LQ-1200 Additive

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**ABSTRACT**

**One of the primary causes of premature pavement deterioration in Asphalt Concrete (AC) mixtures is the breaking of the adhesive bond between the aggregate and the binder. The purpose of this study is to assess the performance characteristics of AC mixture utilizing the Rediset LQ-1200 additive. In order to achieve this goal, tests such as the Marshall Stability (MS), Marshall Stability Ratio (MSR), Indirect Tensile (IDT), indirect tensile cracking, and Wheel Tracking (WT) were deployed to evaluate the mechanical properties of AC mixtures. The findings demonstrated a considerable improvement in the physical parameters of the AC mixture with the Rediset LQ-1200 additive compared to the base AC mixture. The MS and MSR were improved by about 28% and 13%, respectively, while the AC mixture's resistance to rutting and cracking was efficiently increased.**

***Keywords-asphalt concrete mixture; additive; Marshall stability; rutting resistance; cracking resistance***

## I. INTRODUCTION

Additives are frequently used to improve the physical and mechanical properties of AC mixtures. Therefore, lately, a growing number of researchers focus on the study of additives and their impact [1-9]. The multiple existing types of such additives involve Hydrated Lime (HL), Styrene-Butadiene-Styrene (SBS), Nanomaterial, Crumb Rubber (CR), Kraton SBS, Europrene SOL. HL is treated as an additive, with the basics of its impact on asphalt mixtures addressed in [1]. Based on this study's results, HL modifies the aggregate's surface properties, allowing surface roughness and composition that are more favorable for bitumen adherence to be formed. The use of SBS and Titan7205 polymers to modify the base binder can enhance the aging properties and mechanism of modified binder [2]. According to the derived test results, mixes containing 3% of Titan7205 perform as well as or better than mixes including SBS polymer additives. The possibility of utilizing Kraton SBS and Europrene SOL as polymer additives for Hot Mix Asphalt (HMA) mixtures was investigated to evaluate the properties of the binders. Experiments conducted in the lab demonstrated how the aforementioned chemical additions immediately alter the characteristics of the mixture and the binder by raising their viscosity [3]. In [4], the effectiveness of the AC mixture utilizing the Korean modified asphalt binder was assessed and it was discovered that the latter can greatly enhance the asphalt pavement's resistance to moisture damage as well as its rutting performance. The CR modified asphalt binder was evaluated using the toughness and tenacity test methods. The test results indicated that the CR additive improves the maximum initial strength of base binders [5]. The influence of different percentages of polymer and nanoparticle-modified asphalt binders was investigated through the physical and frequency sweep tests in [6]. By altering the binders' rheological and physical characteristics, the application of polymers and nanomaterials has been proven to be highly significant in the longevity and performance of asphalt pavements. The performance of asphalt mixtures was reviewed in relation to the use of Carbon Nanotubes (CNTs) as a binder modifier [7]. It was discovered that the addition of CNTs to binder greatly ameliorates the resistance to rutting at high temperatures and cracking at intermediate temperatures. According to [8], adding Toughfix to an HMA mixture can augment its tensile strength, rutting resistance, and Marshall stability. Every additive performs better than the basic AC mix, but further investigation might be required to identify additional additives with better capabilities and more affordable costs. Furthermore, the performance of the Rediset LQ-1200 additive utilized in the AC mixture is not well understood or researched.

This study attempted to close the aforementioned knowledge gap by examining the performance characteristics of asphalt mixtures with the Rediset LQ-1200 addition. To this end, the performance characteristics of AC mixes were assessed using the MS, IDT, WT, and indirect tensile cracking tests.

## II. EXPERIMENTAL PROGRAM

### *A. Aggregate Gradation*

In the current study, the dense gradation with nominal maximum aggregate size of 16 mm was employed for the base AC mixture and asphalt mixture utilizing the Rediset LQ-1200 additive, as portrayed in Figure 1.

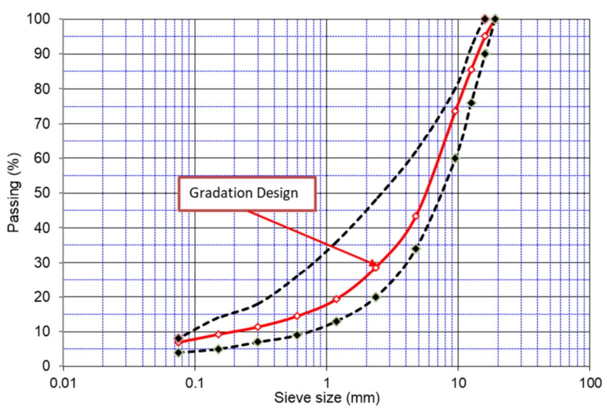


Fig. 1. Aggregate gradation used for this study.

### *B. Rediset LQ-1200 Additive*

The Rediset LQ-1200 (Figure 2) was deployed as an additive at 0.3% by weight of binder. The specific additive's properties are illustrated in Table I.

TABLE I. PROPERTIES OF REDISET LQ-1200 ADDITIVE

| Additive property | Value |
|---|---|
| Appearance at 25°C | Liquid |
| Color | Yelow |
| Flash point, °C | 230 |
| Pour point, °C | <-20 |
| Density, g/cc at 40°C | 0.962 |
| Viscosity, mPa.s (cP) at 40°C | 135 |


Fig. 2. The Rediset LQ-1200 additive.

### *C. Asphalt Binder*

In this paper, a 60/70 bitumen was used as the base asphalt binder. The physical properties of binder with and without the additive are displayed in Table II.

TABLE II. PHYSICAL PROPERTIES OF BINDER

| No. | Test name | Physical properties | |
|---|---|---|---|
| | | 60/70 | 60/70+0.3% Rediset LQ-1200 additive |
| 1 | Penetration at 25°C, 0.1 mm (1/10mm) | 63 | 63 |
| 2 | Penetration Index (PI) | -0.94 | -0.92 |
| 3 | Softening point (Ring and Ball method) (°C) | 48.6 | 48.7 |
| 4 | Kinematic viscosity at 60 °C (Pa.s) | 256 | 261 |
| 5 | Ductility at 25°C – 5 cm/min (cm) | >100 | >100 |
| 6 | Paraphin content (%) | 1.36 | 1.35 |
| 7 | Flash point (°C) | 335 | 325 |
| 8 | Solubitlity in trichloethhylene wax content (%) | 99.31 | 99.5 |
| 9 | Specific gravity at 25°C (g/cm$^3$) | 1.03 | 1.02 |
| | TFOT (Thin film oven test) | | |
| 1 | Change of mass (%) | 0.24 | 0.25 |
| 2 | Retained penetration at 25 °C (% original) | 76.4 | 77 |
| 3 | Ductility at 25°C (cm) | > 50 | > 50 |
| 4 | Coated aggregate using boiling water | Level 2 | Level 3 |

*D. Mix Design*

The typical dosage of Rediset LQ-1200 ranges from 0.3% to 0.8% by weight of binder. In this study, the samples of AC mixture were prepared by adding 0.3% Rediset LQ-1200 by weight of binder to initially evaluate the performance characteristics of the mixture using the Marshall mix concept, as shown in Figure 3. To identify the ideal bitumen content, the compacted samples were tested at various binder contents. The optimum binder content value of the AC mixture was found to be 4.8% by mass of the total mixture for the AC mixtures with and without additive based on the target air void of 4.0%±0.5%.

Fig. 3. The Marshall specimens.

*E. Mixture Tests*

As per ASTM D6927-06 [9], the MS test measures the resistance of compacted cylindrical samples of asphalt mixes to plastic deformation while each sample is loaded at a constant speed rate of 50 mm/min. The maximum load the sample can support at the standard test temperature of 60 °C is known as the MS of the AC mixture. In the meantime, the deformation that the compacted sample experiences during loading up to the maximum value is known as the flow value. In the present study, tests were carried out to assess the moisture damage resistance of AC mixes using the MSR. Six specimens of each combination with target air voids of roughly 4.0±0.5% were made after two groups were established. The first group of specimens was placed in the chamber at 60 °C for 40 min in order to assess their MS under dry conditions (Figure 4). The second group was conditioned for 24 h in a water bath at 60 °C. The MSR was then computed utilizing (1):

$$MSR=\frac{MS_{wet}}{MS_{dry}}\times 100 \quad (1)$$

where MSR = Marshall Stability Ratio, $MS_{dry}$ = Marshall Stability value of the dry samples at 60 °C for 40 min, and $MS_{wet}$ = Marshall Stability value of the conditioned sample after 24 h at 60 °C.

The IDT test was performed at a constant displacement rate of 50 mm/min under 25°C according to ASTM D6931-07 [10] (Figure 5).

The peak compressive load was measured to calculate the indirect tensile strength of all the specimens using (2):

$$\sigma_{IDT}=\frac{2000P_{max}}{\pi tD} \quad (2)$$

where $\sigma_{IDT}$ = Indirect Tensile strength (kPa), $P_{max}$ = peak load (N), t = specimen thickness (mm), and D= specimen diameter (mm).

Fig. 4. The conditioned samples.


Fig. 5. The IDT test.

The WT tester, (Figure 6), developed by Hamburg Wheel Tracker and made in Germany was implemented in accordance with EN 12697-22 [11]. Steel wheels were engaged for experiments in water. The wheel diameter and width were 203 mm and 50 mm, respectively. The wheel load of 0.7MPa was applied to the 320 mm × 260 mm × 50 mm slab specimens, submerged in water. The wheel tracking tests were conducted at the temperature of 50 $^{o}$C to evaluate the permanent deformation characteristics of asphalt mixtures.

The indirect tensile cracking test was conducted to measure the asphalt mixture cracking resistance at a temperature of 25 °C following ASTM D8225-19-16 [12], as demonstrated in Figure 7.


Fig. 6. The wheel tracking test.

Fig. 7. The indirect tensile cracking test.

This test considers both crack initiation and propagation in asphalt mixtures. The specimens were readily obtained from Superpave gyratory compactor compacted cylinders with a diameter of 150 mm and 62 mm thickness. The target air void for the test specimens is 7.0%. The load applied is such that a constant load-line displacement rate of 50.0 mm/min is maintained for the duration of the test.

Both load (P) and displacement are measured during the test and are used to calculate the $CT_{Index}$. The $CT_{Index}$ of the AC mixture is computed from the failure energy, the post-peak slope of the load-displacement curve, and deformation tolerance at 75% of the peak load, as can be seen in [8]. Based on the above, (3) is established:

$$CT_{Index} = \frac{t}{62} \times \frac{G_f}{|m_{75}|} \times \left(\frac{l_{75}}{D}\right) \quad (3)$$

where $CT_{Index}$ = Cracking Tolerance index, $G_f$ = failure energy (Joules/m$^2$), $|m_{75}|$ = absolute value of the post-peak slope $m_{75}$ (N/m), $l_{75}$ = displacement at 75% of the peak load after the peak (mm), D = specimen diameter (mm), and t = specimen thickness (mm).

## III. RESULTS AND DISCUSSION

### A. *Marshall Stability Test*

Table III indicates that the MS of the AC mixture with Rediset additive is 11.32 kN, which is 28% greater than the MS of the original AC mixture (8.84 kN). In addition, the AC mixture with 0.3% additive would increase the Marshall quotient by approximately 30% compared to the control mixture. Moreover, after adding Rediset LQ-1200, the MSR of the AC mixture was increased by 13% compared to the original AC mixture. Hence, the AC mixture with Rediset LQ-1200 can improve the moisture damage resistance.

TABLE III. RESULTS OF MARSHALL STABILITY TEST

| AC mixture type | Air void (%) | Marshall Stability (MS) (KN) | Flow (mm) | Marshall quotient (KN/mm) | MS Ratio (MSR) (%) |
|---|---|---|---|---|---|
| AC16 | 4.6 | 8.84 | 3.83 | 2.3 | 81.17 |
| AC 16 + 0.3% Rediset | 4.5 | 11.32 | 3.74 | 3.0 | 91.43 |

### B. *IDT Test*

The IDT test was performed to calculate the IDT strength of the mixes at an intermediate temperature of 25 °C. Asphalt mixtures' crack initiation behavior was assessed by deploying the IDT strength. Both strength and ductility are necessary for a material to have effective initial crack resistance. The IDT strength was calculated through (2). The IDT strength test results at 25°C are shown in Figure 8. In comparison to the original AC mixture (672 kPa), the maximum tensile strength of the AC mixture with the Rediset LQ-1200 additive is 52% greater, at 1023 kPa. These findings disclosed that in comparison to the original mixture, applying the Rediset LQ-1200 additive improved the adhesive qualities of the AC mixture.

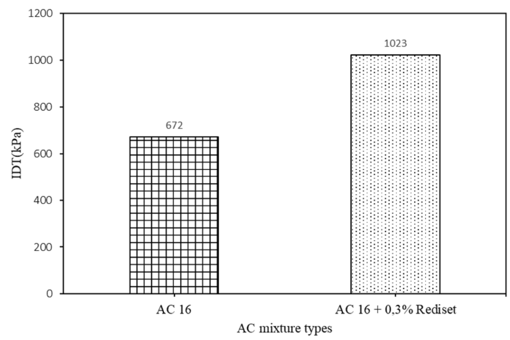


Fig. 8. Comparison of IDT strength.

### C. *Wheel Tracking Test*

The WT test for the AC mixture was carried out in order to evaluate the rut resistance of the mixture with Rediset additive. In Figure 9, the rut depth of the base AC mixture and the AC mixture with the Rediset additive at 20,000 loading cycles are displayed. The rut depths of the AC mixture utilizing the Rediset additive is 7.73 mm, 37% less than that of the original AC mixture (12.27 mm). This occurs due to the fact that Rediset additive employment can strengthen the AC mixture's adhesive bond between the aggregate and the binder. Therefore, the addition of 0.3% Resiset additive to the AC mixture can improve significantly its rutting resistance.

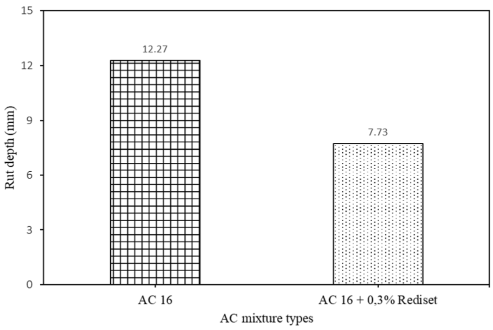


Fig. 9. Rut depth of AC mixtures at 20,000 loading cycles.

## D. Indirect Tensile Cracking Test

The $CT_{Index}$ values for base AC mixture and AC mixture using Rediset additive, according to (3), are presented in Figure 10. It can be observed that the $CT_{Index}$ of the AC mixture utilizing Rediset additive was 24% higher than that of the base AC mixture. Hence, it can be concluded that the use of 0.3% rediset LQ-1200 additive in asphalt mixtures is beneficial in terms of both crack initiation and propagation at intermediate temperature.

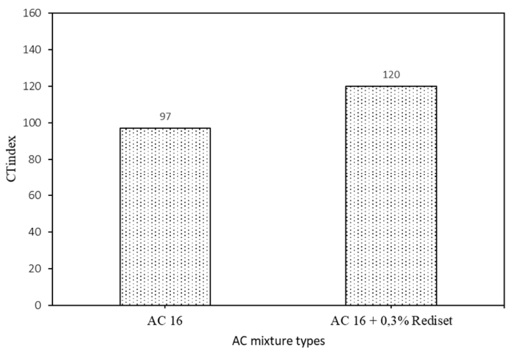


Fig. 10. $CT_{Index}$ values of AC mixture at 25 °C.

## IV. CONCLUSIONS

The current study was mainly focused on evaluating the performance characteristics of AC mixture with 0.3% Rediset additive. Based on the results obtained from experimental testing, the following conclusions are made:

- The application of 0.3% Rediset additive can greatly improve the MS, Marshall quotient, and MSR of the AC mixes. In detail, when 0.3% Rediset LQ-1200 was added in the asphalt mixture, the MS, Marshall quotient, and MSR were 28%, 30% and 13% higher than the control AC mixture's.
- Based on the IDT test, the use of 0.3% Rediset additive in the AC mixture is beneficial in terms of crack initiation. The IDT strength improved by about 52%.
- The results obtained by WT test revealed that the rut depth of the AC mixture utilizing the Rediset additive is 37% less than that of the original AC mixture.
- In order to evaluate the crack initiation and propagation of AC mixtures with Rediset additive, the results indicated that the latter can improve significantly its performance in terms of initial and propagate cracking under intermediate temperature conditions.
- Further studies are recommended to investigate the effect of the AC mixture on rutting and cracking performance asphalt mixtures under actual field conditions. The economic aspects of utilizing this additive will be considered in future work.

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