

# **Evaluation of RAP Material from Matterhorn, Nevada**

## **REPORT**

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### RAP Aggregate Properties

The recycled asphalt pavement (RAP) material from Matterhorn, Nevada was wet when it was delivered to the Western Regional Superpave Center (WRSC). The RAP was dried at 140°F until it reached a constant mass. The gradation of the RAP material was evaluated and is shown in Figure 1 along with the Pacific Coast Conference on Asphalt Specifications (PCCAS) control points for CIR. The RAP was extracted using 85% Toluene and 15% Ethanol mixture in accordance with AASHTO T164; then, the asphalt binder was recovered in accordance with ASTM D5404. The RAP material had a high asphalt content of 8.75% by total weight of the RAP material. The properties of extracted aggregate including the gradation and the specific gravities were evaluated. Figure 2 shows the gradation of the extracted RAP aggregate which was found to be different that that measured by Asphalt Pavement And Recycling Technologies, Inc. (APART) for the RAP obtained from the same project. The difference is mainly attributed to the sampling technique used to acquire the material. In the case of RAP for APART, large slabs were cut from the pavement and crushed down to the required size in the laboratory. On the other hand, UNR received milled RAP material directly from the pavement. Table 1 summarizes the gradations of the RAP materials and extracted RAP aggregate. The specific gravities and the absorption of the extracted aggregate were also measured and are summarized in Table 2.

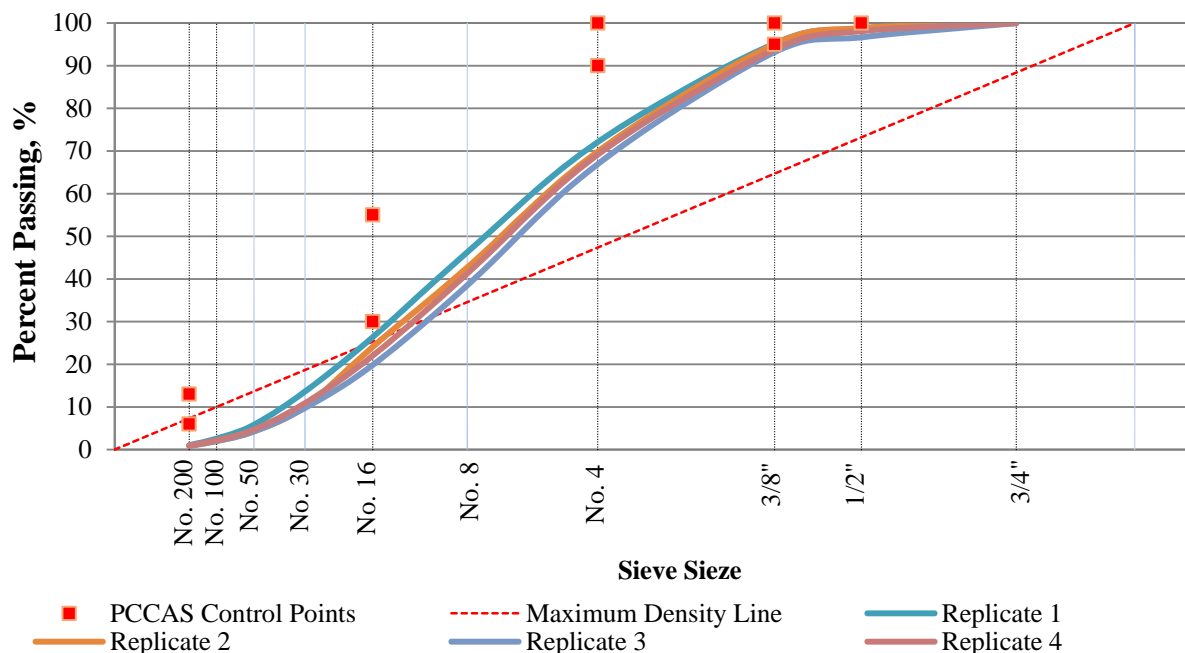
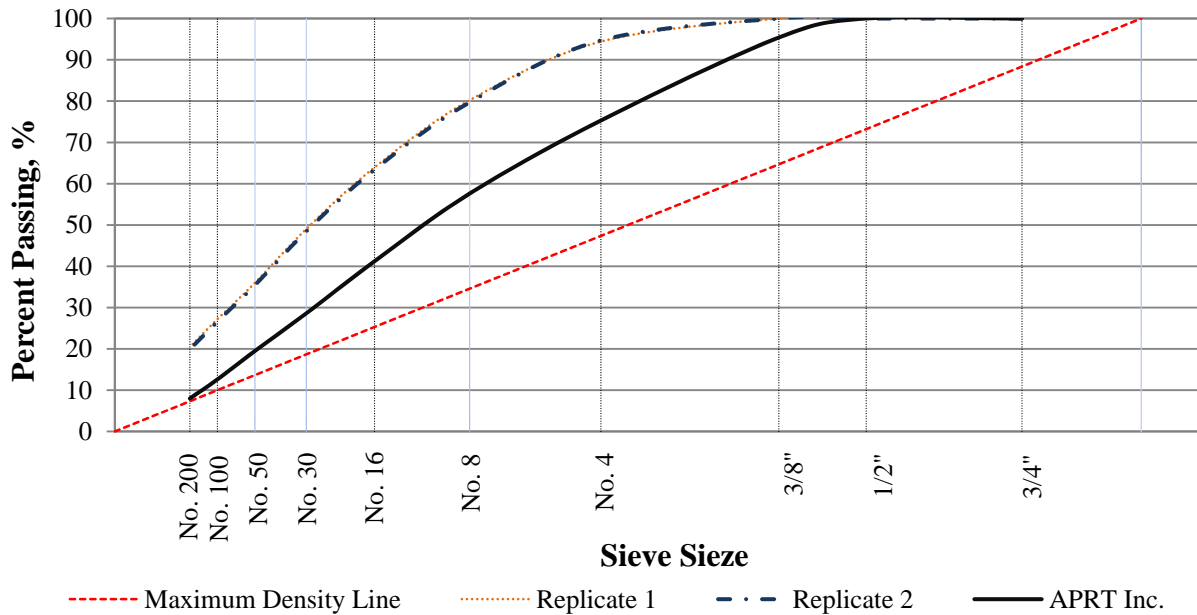


Figure 1: Gradation of RAP material





**Figure 2: The gradation of extracted RAP aggregate**

**Table 1: Gradation of RAP material and extracted RAP aggregate**

Sieve Size	% Passing		
	RAP	Extracted aggregate	
		UNR	APART
3/4"	100.00	100.0	100.0
1/2"	98.08	100.0	100.0
3/8"	94.32	100.0	95.4
#4	69.54	94.5	75.3
#8	42.17	80.0	57.6
#16	23.08	63.7	41.2
#30	11.08	48.7	28.6
#50	4.76	35.7	19.5
#100	2.21	26.9	12.6
#200	0.92	20.2	8.0

**Table 2: RAP aggregate specific gravities and absorption**

Property	Coarse Aggregate	Fine Aggregate	Blend RAP Aggregate
Bulk specific gravity	2.219	2.281	2.278
Apparent specific gravity	2.399	2.474	2.470
Absorption, %	3.39	3.41	3.41

## RAP Binder Grade

The recovered RAP binder was graded as PG82-10 according to Superpave PG grading system (AASHTO M323). The multiple stress creep recovery (MSCR) test also was conducted on RTFO-aged asphalt binder at 82°C. The non-recoverable creep compliance at 3.2 kPa ( $J_{nr3.2}$ ) was 3.039 kPa<sup>-1</sup>. The percent difference between non-recoverable ( $J_{nrdiff}$ ) strains at 1.0 and 3.2 kPa was 14.56%. According to AASHTO TP70, the RAP binder met the maximum allowable  $J_{nr3.2}$  of 4.0 kPa<sup>-1</sup> and the maximum  $J_{nrdiff}$  of 75% for the standard traffic. Hence, the RAP binder was graded as PG82-10S.

## Change of RAP Aggregate Absorption with Aging Time

The loose RAP material was aged in a forced-draft oven at 275°F for different period of time. The theoretical maximum specific gravity ( $G_{mm}$ ) of the RAP material at different aging periods was measured in accordance with AASHTO T209. The asphalt binder absorption and the effective binder content of the RAP material were computed from the  $G_{mm}$  measurements (Equations 1-3). Figure 3 shows the calculated RAP binder absorption and the effective binder content for different aging periods. The effective binder content for the RAP material reduces with time (by about 0.5%) while the absorption increases from 4.0 to 4.6% after 120 hours of oven aging. It should be noted, a discrepancy was observed in the cacluated RAP binder absorption which was found to be higher than the measured RAP aggregate absorption. This finding may be attributed to: (1) an over-estimated RAP binder content (RAP material had a very fine aggregate gradation); and/or, (2) a minimal amount of extracted material (i.e., less than the minimum of 1,500 grams as recomemended by the AASHTO T85) for specific gravity and absorption testing of coarse RAP aggregate.

$$G_{se} = \frac{100 - P_b}{\frac{100 - P_b}{G_{mm}} - \frac{P_b}{G_b}} \quad [1]$$

$$P_{ba} = 100 \left( \frac{G_{se} - G_{sb}}{G_{se} G_{sb}} \right) G_b \quad [2]$$

$$P_{be} = P_b - \frac{P_{ba}}{100} P_s \quad [3]$$

where;

$G_{mm}$ - Theoretical maximum specific gravity

$G_{se}$ - Effective specific gravity of aggregate

$P_b$ - Asphalt binder content by total weight of mix

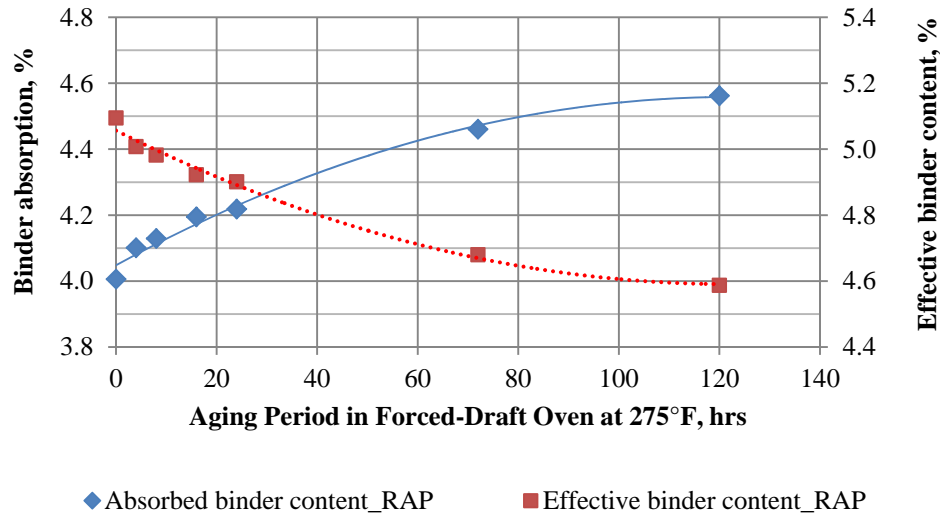
$G_b$ - Bulk specific gravity of asphalt binder

$G_{sb}$ - Bulk specific gravity of aggregate

$P_{ba}$ - Percent of absorbed asphalt binder by weight of aggregate

$P_{be}$ - Effective binder content by total weight of mix

$P_s$ - Percentage of aggregate in the mix



**Figure 3: Variation of RAP binder absorption and effective binder content with time**

### Properties of Cold-in-Place Recycled (CIR) Mixtures

The RAP material was used in the laboratory to produce two CIR mixtures:

- 1- RAP with 4% PASS R emulsion, 2% water, and 1.0% hydrated lime.
- 2- RAP with 4% PASS R emulsion, 2% water, and 0.5% cement.

The CIR mixtures were aged in a forced-draft oven at 275°F for different periods of time in order to evaluate the influence of additives (i.e., hydrated lime and cement) on the RAP binder absorption and effective binder content. The test results are shown in Figure 4. The theoretical maximum specific gravities of the CIR mixtures with lime were lower than the CIR mixtures with cement. The change in RAP binder absorption with time shows that the CIR mixture with lime significantly reduced the absorption of RAP material by approximately 2.7% after 5 days of aging while CIR mixture with cement reduced it only by 0.6%. Accordingly, the change in effective binder content with time shows that the CIR mixture with lime significantly increased the effective binder content by approximately 4.8% after 5 days of aging while CIR mixture with cement increased it by only 3.0%. This observation may be attributed to the amount of filler material (lime and cement) added to the mixture. The higher percentage (1%) of lime compared to 0.5% of cement filled more surface voids and reduced the binder absorption, thus resulted in higher effective binder content for CIR mixtures with lime.

Even though the observed reduction in asphalt binder absorption promise the good performance of CIR mixture with lime, further evaluation is needed to assess the influence of aging on the mixture mechanical properties before a final conclusion can be made.

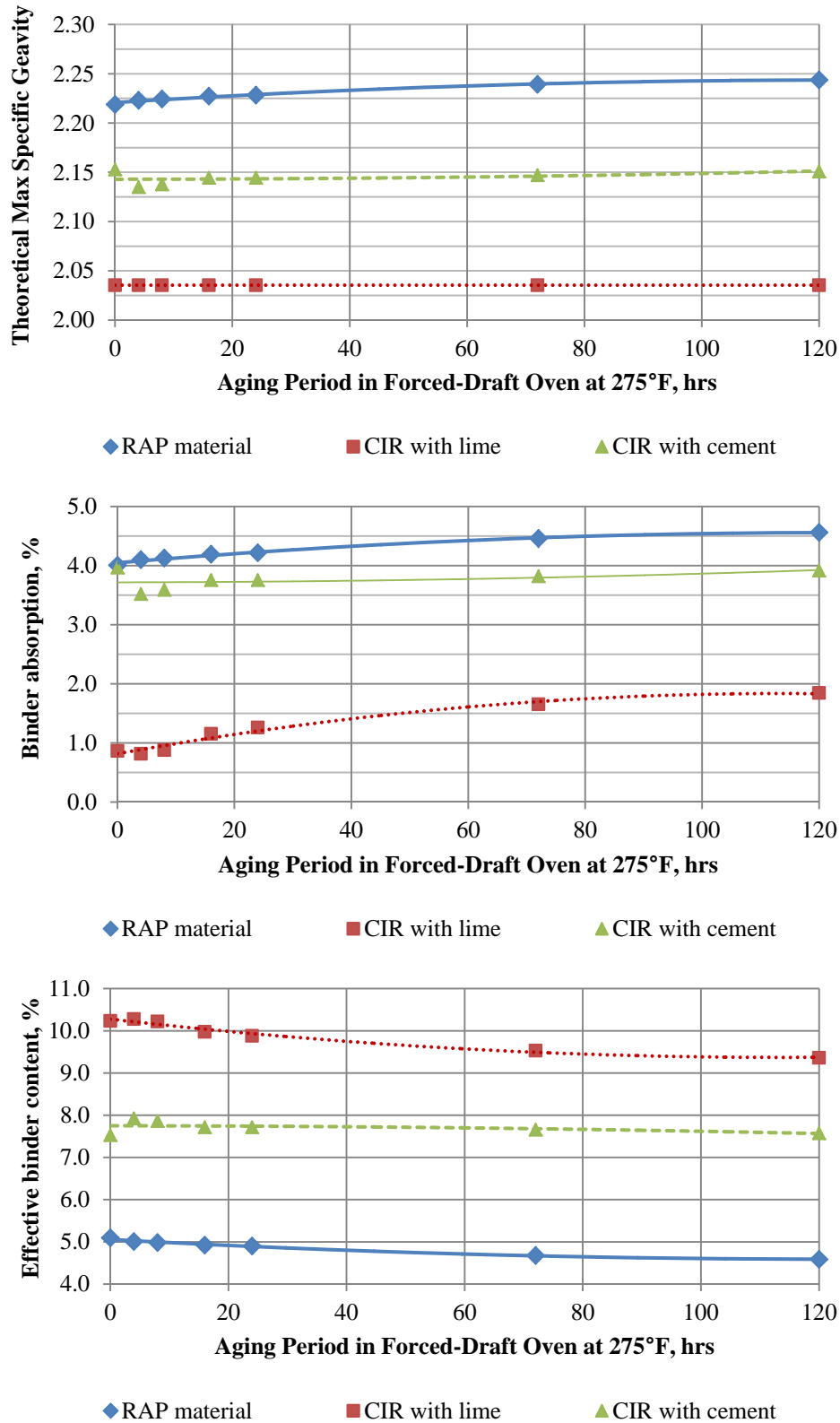


Figure 4: Theoretical maximum specific gravity, Binder absorption, and effective binder content of RAP material and CIR mixtures



The CIR mixtures were also evaluated for moisture susceptibility using AASHTO T283 test method. The following summarizes the steps completed.

- Measure the bulk specific gravity and percent air voids of the compacted samples. (*Parafilm method (ASTM D1188) was used to measure bulk specific gravities*)
- Keep dry set of samples (3 samples) at 77°F and moisture condition the rest (3 samples).
- For the moisture conditioning, saturate the samples to 70-80% of the air voids.
- Freeze the saturated samples at -18°C for a minimum of 16 hrs.
- Thaw the frozen samples in 60°C bath for 24 hrs follow by 2 hrs of cooling in 77°F bath.
- Measure the indirect tensile strength of the moisture-conditioned and dry samples at 77°F.
- Calculated the tensile strength ratio (TSR) of the CIR mix.

Figure 6 shows the measured tensile strengths and percent air voids of the mixtures. The target air void of the samples was 10±1%. The tensile strengths of both CIR mixtures were similar and the TSR values were more than 80%. Both mixtures showed good resistance to moisture damage. Further, the CIR mixture with lime was compacted to 85-95 gyrations while the CIR mixture with cement was compacted to 180-190 gyrations to achieve the target air void of TSR samples. This observation indicates that the CIR mixture with lime exhibited better compactability when compared to CIR mixture with cement.

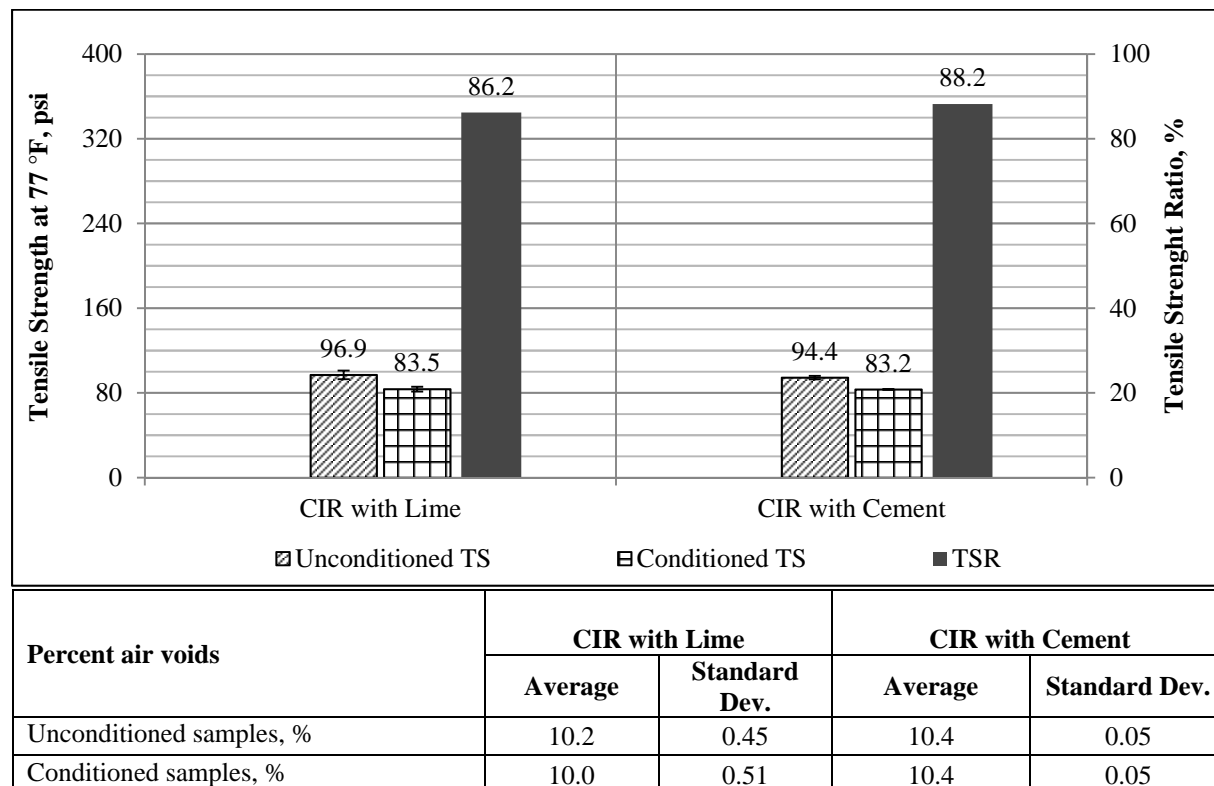
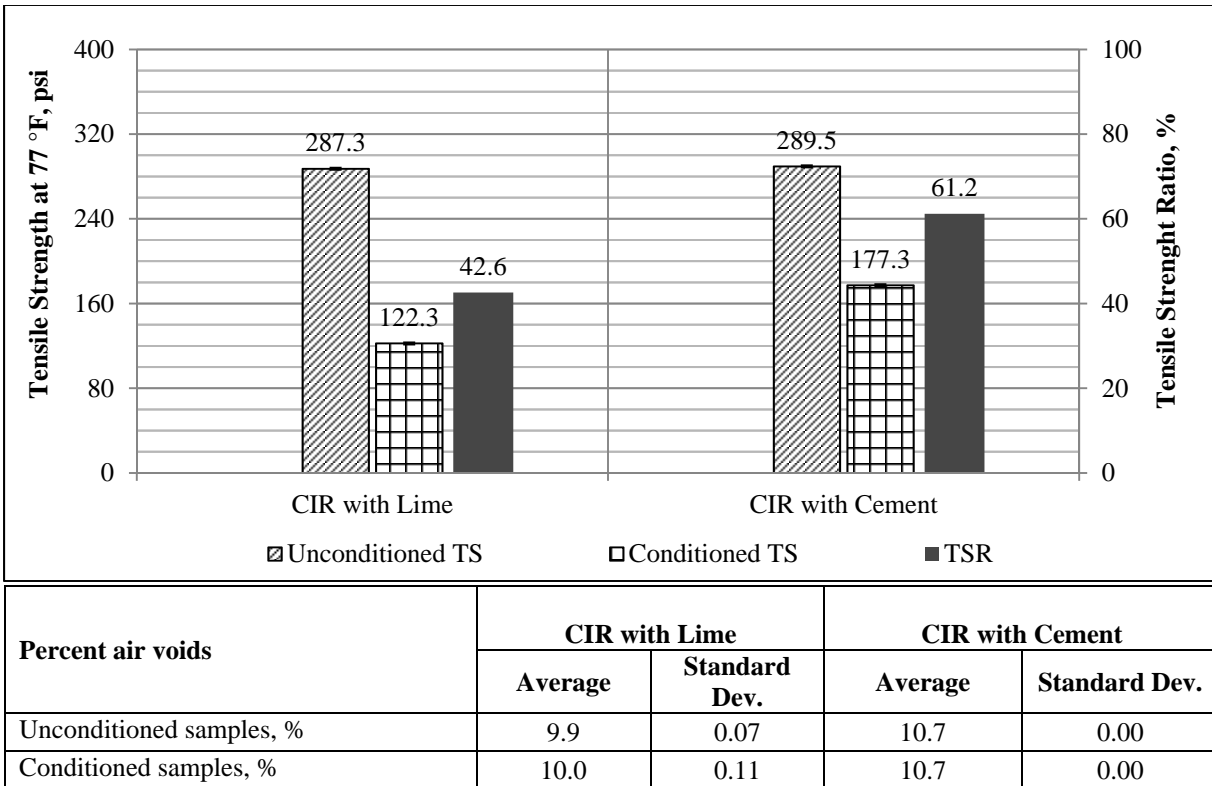


Figure 6: Resistance of CIR mixtures to moisture damage

The influence of aging on the mixtures' resistance to moisture damage was also evaluated. The compacted CIR samples were long-term aged in a forced draft oven for 5 days at 185°F (85°C) in accordance with AASHTO R30 to simulate the long-term aging properties of the mixtures in the field. The air voids for the aged specimens were kept within a range of 10±1%. **Figure 7** shows the measured tensile strengths and percent air voids of the long-term aged mixtures. While the unconditioned tensile strength values for both mixtures were similar, the CIR with cement exhibited a higher moisture-conditioned tensile strength value when compared to the CIR with lime mixture; hence a higher tensile strength ratio (61.2% versus 42.6%).



**Figure 7: Resistance of the long-term aged CIR mixtures to moisture damage**