

Summary Report of PG64-28TR and PG64-28PM

*A testing summary prepared by Asphalt Institute on plant mixed,
laboratory compacted samples.*

Project: Essex, CA, I-40 19.0mm NAMAS mixture. Compare polymer (PM)
mixture to Tire Rubber (TR) terminal blend mixture

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AASHTO R18

INTRODUCTION

CALTRANS through Granite Construction placed a test section of PG 64-28PM (polymer modified) and PG 64-28TR (tire rubber) on I-40 near Essex, CA in October 2008. Project location is shown in Figure 1. An LTPPBind elevation map is shown Figure 2 indicating higher altitude of this project at about 1950 feet. Each test section was 500 feet in length. Asphalt binder and mixture samples were retained for laboratory testing. Mixture samples were taken at the paving site from the windrow. CALTRANS performed deflection testing, coring, and condition surveys with assistance from the Asphalt Institute. CALTRANS also plans to monitor the pavement sections' performance on an annual basis in accordance with their proposed Work Plan (1).



Figure 1. Map of project location on I-40.

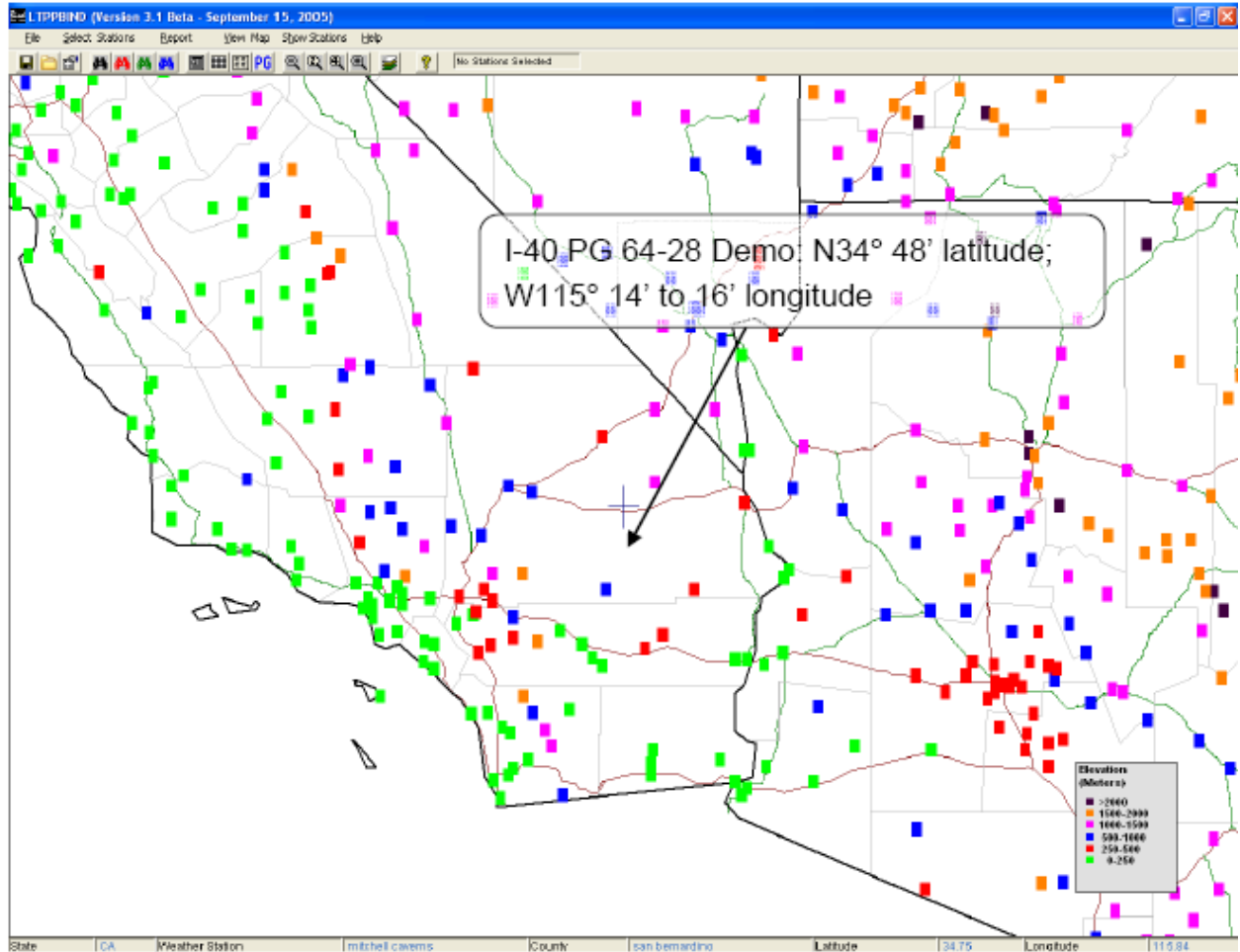


Figure 2. LTPPBIND elevation map.

OBJECTIVE

The overall goal of this study is to determine if the terminal blend tire rubber (PG 64-28TR) is equivalent to the same Performance Grade (PG) using polymer modification (PG 64-28PM) in accordance with the CALTRANS Work Plan. The goal of the abbreviated mixture testing by Asphalt Institute is to compare the potential fatigue and rutting performance by laboratory testing using AASHTO T321/ASTM 4760 and AASHTO T320, Procedure C test methods. While CALTRANS will complete the whole test matrix in Table 6 of the Work Plan, Asphalt Institute tested part of the CALTRANS' matrix to provide a second set of test data for comparison.

Additional project details such as project construction, pavement condition, sample log and binder testing results are referenced in an earlier report by Robert Humer (2). According to Humer's report, four laboratories (including Asphalt Institute) tested the asphalt binders. All labs reported that the binders met the PG 64-28 requirements. The

only notable difference in the binders was the absolute viscosity which was expected. Rubber and polymer additives usually produce different binder viscosities.

LABORATORY EXPERIMENT

Materials

The mix design from the contractor is listed in Table 1. The average production values of the PG 64-28Pm and PG 64-28TR test sections are shown in Table 2.

TABLE 1. Mix Design from I-40 Test Section as Provided by Hot Mix Contractor

| Sieve | 0.4 | 0 | 0.4 | 1.5 | 1.5 | % Lime | 0.82 | X Val | Caltrans |
|--------------|------|------|------|--------------|-------|-----------|-------|--------------|----------|
| Size | 3/4" | 1/2" | 3/8" | Fill Sand | RxDst | | Total | (L of PG) | O. R. |
| % Used | 42 | 0 | 20 | 8 | 30 | 0 | 100 | | Spec. |
| 37.5mm(1.5") | 100 | | 100 | 100 | 100 | | 100 | | |
| 25mm(1.0") | 100 | | 100 | 100 | 100 | | 100 | 100 | |
| 19mm(3/4") | 83 | | 100 | 100 | 100 | | 93 | 93(88-93) | 89-97 |
| 12.5mm(1/2") | 34 | | 100 | 100 | 100 | | 72 | 74(72-88) | 69-79 |
| 9.5mm(3/8") | 10 | | 99 | 100 | 100 | | 62 | 64(55-70) | 58-70 |
| 4.75mm(#4) | 1 | | 26 | 100 | 100 | | 44 | 46(35-52) | 39-53 |
| 2.36mm(#8) | 1 | | 2 | 81 | 77 | | 30 | 32(22-40) | 27-37 |
| 1.18mm(#16) | | | 1 | 66 | 52 | | 21 | | |
| 600um(#30) | | | | 50 | 36 | | 15 | 16(8-24) | 12-20 |
| 300um(#50) | | | | 33 | 25 | | 10 | 11(5-18) | 7-15 |
| 150um(#100) | | | | 21 | 16 | | 6 | | |
| 75um(#200) | | | | 11.8 | 10 | | 3.9 | 4.2(3-7) | 2.2-6.2 |

| | | |
|--|-------------------|----------------|
| PERCENT CRUSHED PARTICLES (Fine/Coarse) CT205 | 99 | 99 Min. |
| FAA AASHTO A T304 (Rx Dst / Fill Sand): | 46.4 | 45 Min. |
| L A ABRASION (100/500) CT 211: | 4/22 | 10 / 45 Max. |
| Kc / Kf CT 303: | 1.2/1.0 | 1.7 / 1.7 Max. |
| CLEANNES VALUE CT 227 (3/8 & 3/4): | 79.5 | 57 Min. |
| ASPHALT MIXTURE DATA AT OBC | | |
| HVEEM STABILITY CT 366 (3/8 & 3/4): | 49/50 | 37/35 Min. |
| PERCENT AIR VOIDS CT 367: | 5.0 | 5.0% Target |
| VMA: | 13.7 | 13 Min. |
| VFA | 63 | 60-70 |
| SWELL CT 305: | 0.051 | .76mm Max. |
| DUST to ASPHALT: | 1.1 | 0.6-1.2 |
| OPTIMUM BITUMEN CONTENT CT 367 (Dry Wt. Of Agg): | 4.5 | (4.2% to 5.0%) |
| TYPE OF BITUMEN: | PG 64-28PM | |

PLANT LOCATION:
AGGREGATE SOURCE:

I-40, CA
29 Palms, CA (91-36-0055)

TABLE 2. Average Production Values of Hot Mix Asphalt Test Sections

| | PG 64-28PM Section | | PG 64-28TR Section | |
|---------------------------|--------------------|-------|--------------------|-------|
| | Hveem Stability | AC, % | Hveem Stability | AC, % |
| Average | 39 | 4.5 | 40 | 4.5 |
| Standard Deviation | 2.41 | 0.15 | 1.0 | 0.13 |

Field samples from this hot-mix asphalt (HMA) design were collected and sent to Asphalt Institute (AI), Lexington, KY by AI field engineer, Robert Humer. The samples consisted of:

- **PG 64-28TR, 1st lift in lane 2, Post Mile 102.7190 sampled 10/22/2008 (10 boxes)**
- PG 64-28TR 2nd lift in lane #2, Post Mile 102.7190. sampled 10/23/2008 (5 boxes)
- **PG 64-28PM 2nd lift in lane #1, Post Mile 104.7518, sampled 10/28/2008 (10 boxes)**

HMA samples (shown in bold above) from sample dates 10/22/2008 were compared with samples from 10/28/2008 due to the larger material quantity from those dates. Only those comparison samples were tested. All mixtures were pre-heated and broken down into pans. Initial samples of were taken to verify the mixture maximum specific gravity (Gmm) for each sample date.

Sample Preparation, Testing, and Analysis

Preparation

HMA samples were covered with aluminum foil to reduce further mixture aging. As needed, samples were placed in a forced draft oven at 149°C (300°F) until compaction temperature was reached. Next, samples were removed from the oven and placed in a Superpave gyratory compactor (SGC) or linear kneading compactor to prepare samples for repeated shear and fatigue testing. Samples were compacted to a constant height to achieve the desired air voids. The linear kneading compactor, as constructed by Cox and Sons, produces rectangular samples that can be trimmed on all sides for fatigue testing.

Once cooled, samples were cut and tested for mixture bulk gravity (Gmb). The desired density to represent in-place pavement density was set to 93 ± 1.0 percent of

Gmm (or 7 ± 1.0 percent air voids). Any samples not meeting these requirements were not tested.

Superpave repeated shear samples trimmed on each end face. Beams for flexural fatigue trimmed on all faces except the ends.

Repeated Shear Testing

Superpave repeated shear at constant height for rutting determination testing was performed in accordance with AASHTO T320, Procedure C. The highest test temperature in the Work Plan suggested by CALTRANS was 60°C (140°F). The temperature was chosen for this partial testing matrix for the most severe condition.

After samples were glued, they were conditioned at the test temperature for 2 hours. Samples were then tested in shear using the standard loading for 10,000 cycles. Results are shown in Table 3, Figure 3 and Figure 4. Table 3 shows a detailed data summary with standard deviations. Figure 3 shows the progressive deformation over the number of cycles with R_2 of 0.99 for the three data points per mix. Figure 4 is the summary of the data set at 5,000 and 10,000 loading cycles.

The average of the two samples per mixture shows that the PG 64-28 TR mix exhibited more rutting resistance (lower permanent shear strain) at 2.27 percent shear strain as compared to the PG 64-28PM mixture at 3.16 percent shear strain. It should also be noted that all samples are extremely rut resistant at 5,000 and 10,000 cycles of loading. This is further demonstrated using a predictive rutting analysis developed by Jorge Sousa(3). Using his analysis method, both the TR and PM mixtures have predicted rutting resistance at 60°C of greater than 2 billion Equivalent Single Axle Loads (ESALs).

While there is a large difference in the predicted ESALs to failure, it is a prediction only and is derived from the extrapolation of data to 5 percent permanent strain. Since neither mix reached 5 percent strain and the predictions are in the range of billions of ESALs, the prediction of ESALs to failure should only be used as reference to understand that both mixtures are extremely rut resistant.

TABLE 3. Superpave Repeated Shear at Constant Height for Rutting Determination

| Specimen ID | *Gmm | Air Voids (6.5 to 7.5 Spec.), % | γ_{perm} (strain) @ | | | Average ESALs to 12.5mm Rut Depth by Extrapolation |
|---------------------------------|-------|---------------------------------------|-------------------------------|-----------------|------------------|---|
| | | | 100 cycles | 5,000 cycles | 10,000 cycles | |
| PM-1, sampled 10- 28-2008 | 2.485 | 6.8 | 1.18% | 2.95% | 3.41% | na |
| PM-2, sampled 10- | | 6.7 | 0.71% | 2.54% | 2.91% | na |

| | | | | | |
|---------------------------|------------|--------------|--------------|--------------|----------------------|
| AVERAGE | 6.8 | 0.95% | 2.74% | 3.16% | 2,391,949,245 |
| STANDARD DEVIATION | 0.1 | 0.33% | 0.29% | 0.35% | na |

| Specimen ID | *Gmm | Air Voids (6.5 to 7.5 Spec.), % | γ_{perm} (strain) @ | | | Average ESALs to 12.5mm Rut Depth by Extrapolation |
|---------------------------|-------|---------------------------------|----------------------------|--------------|---------------|--|
| | | | 100 cycles | 5,000 cycles | 10,000 cycles | |
| TR-1, sampled 10-22-2008 | 2.482 | 6.9 | 0.51% | 1.57% | 1.87% | na |
| TR-2, sampled 10-22-2008 | | 6.9 | 0.86% | 2.29% | 2.67% | na |
| AVERAGE | | 6.9 | 0.69% | 1.93% | 2.27% | 154,123,057,870 |
| STANDARD DEVIATION | | 0.0 | 0.25% | 0.51% | 0.56% | na |

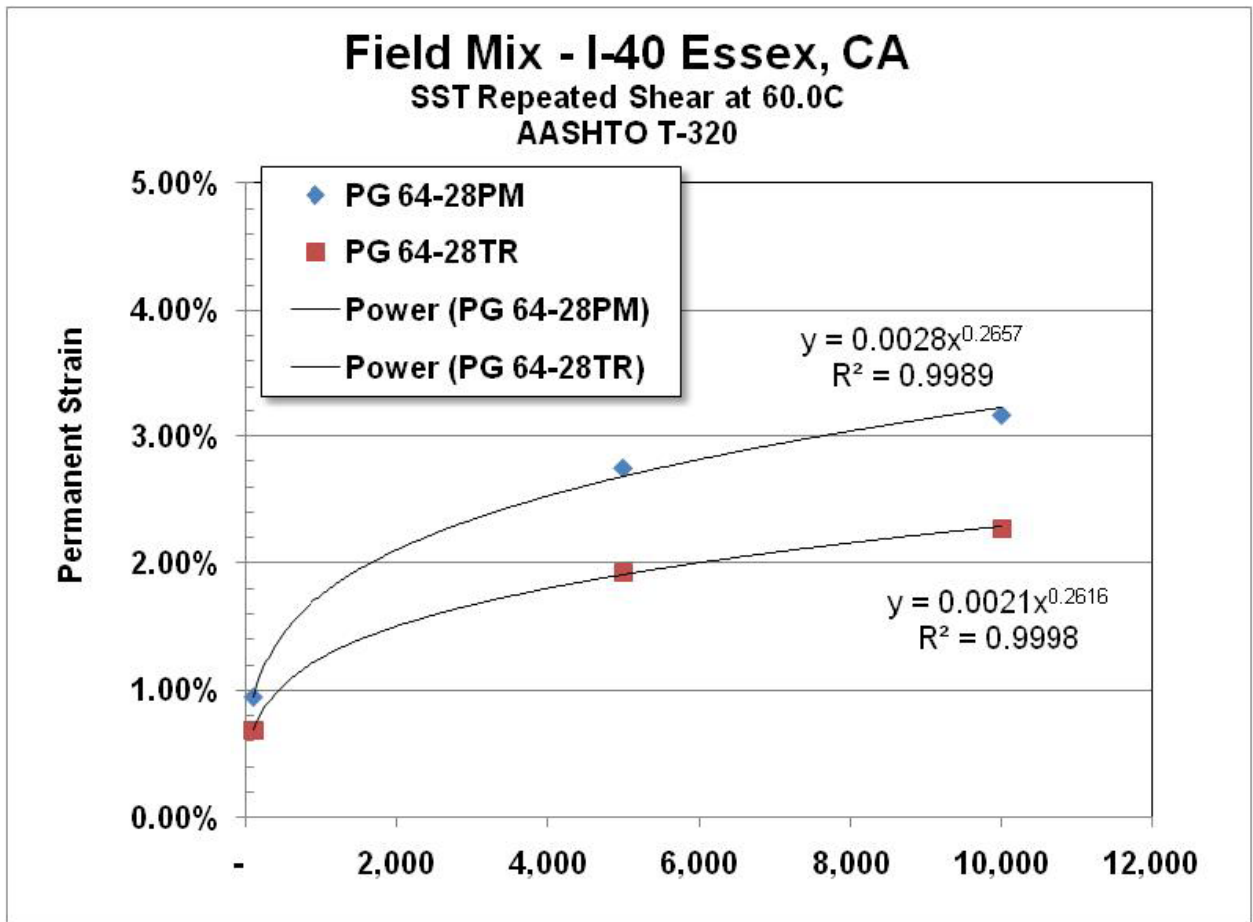


Figure 3. Superpave repeated shear at constant height for rutting determination

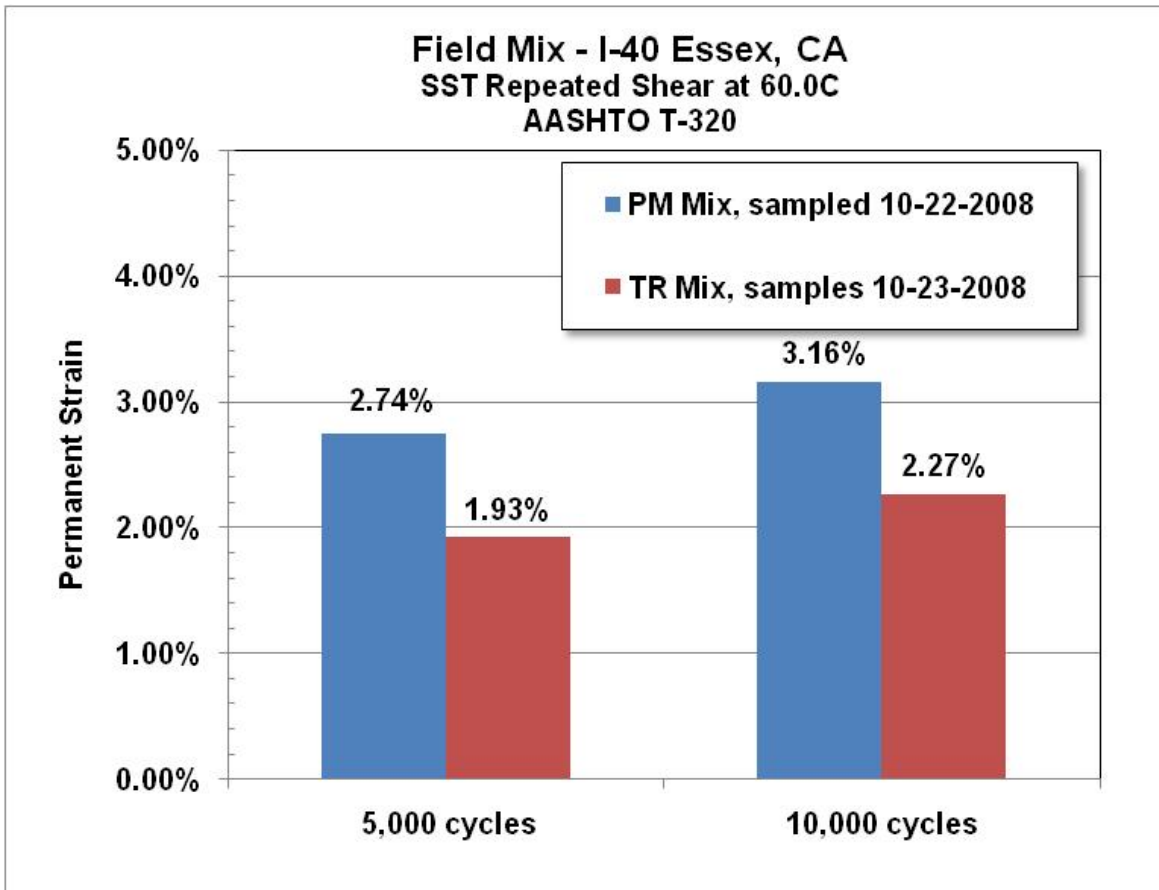


Figure 4. Summary for Superpave repeated shear at constant height for rutting determination.

Flexural Fatigue Testing

The flexural fatigue test was performed using the newer standard, ASTM D4760-08. This newer standard was introduced to improve the loading and analysis procedures. The main difference in this newer procedure is the allowance of a newer numerical method (cycles x normalized modulus) to determine a more accurate cycles to failure (N_f). The standard 50 percent of initial stiffness analysis is also provided in Table 4 for a reference comparison. The newer analysis allows for a more accurate prediction of failure and results in better fatigue curves, usually with lower R^2 as compared to the older analysis that assumes all failures at 50 percent of initial stiffness. While there is no precision and bias available for this test, one can expect sample results to vary by 20 percent.

All testing was performed at 20°C (68°F) and three strains (500, 600, and 800 microstrain). The Work Plan suggested 400 and 600 microstrain test conditions. At 400

microstrain, some samples would not fail within a timely manner, so 500 microstrain was used. In addition to the Work Plan, Asphalt Institute also tested at 800 microstrain so that a curve could be established for each mixture for a total of three data points (1 per strain) at 800, 600, and 500 microstrain. While desirable to test replicates at each strain, this is just an abbreviated study to perform simple material comparison.

All fatigue data is shown in Table 4 and Figure 5. As can be seen from the results, the TR mixture lasted about 19 times longer than the PM mixture at 600 microstrain and about 4 times longer at 500 microstrain. While more beams should be tested to improve the accuracy of this fracture test, the R^2 of 0.85 for the Pg 64-28TR mixture and 0.96 for the PG 64-28PM mixture indicate an excellent data fit for these samples. The same trend was also found using the standard 50 percent of initial stiffness analysis, also in Table 4.

A more flexible (less brittle) mixture like the TR mixture should improve pavement life by cracking less in this comparison. This should be further reviewed since the flexural modulus at 50 cycles was also slightly different for the two mixtures. If the TR mixture cracks less than the PM mixture, whether top down or bottom up, there should be a cost savings with the TR mixture over time since less maintenance may be needed.

Table 4. Fatigue Life Using a Repeated Flexural Fatigue Test.

| Test Description | Gmm | Sample Description | Air Voids, % | Actual Avg Strain, $\mu\epsilon$ | Cycles to Failure, Nf | | Flexural Modulus, MPa |
|----------------------------------|-------|--------------------|--------------|----------------------------------|-----------------------|--------------------------|-----------------------|
| | | | | | Cycles*M odulus | 50% of Initial Stiffness | @50cycles, MPa |
| I-40 PM Mix (sampled 10-28-2008) | 2.485 | 5822-A | 7.4 | 800 | 9,540 | na | 3,707 |
| | | 5600-A | 6.4 | 600 | 28,767 | 69,805 | 4,944 |
| | | 5822-1 | 6.2 | 500 | 125,852 | 173,975 | 4,045 |
| I-40 TR Mix (sampled 10-22-2008) | 2.482 | 5600-A | 6.7 | 800 | 109,836 | 130,020 | 3,014 |
| | | 5600-B | 7.0 | 600 | 544,319 | 762,309 | 2,690 |
| | | 5870-A | 6.9 | 500 | 544,072 | 852,452 | 3,062 |

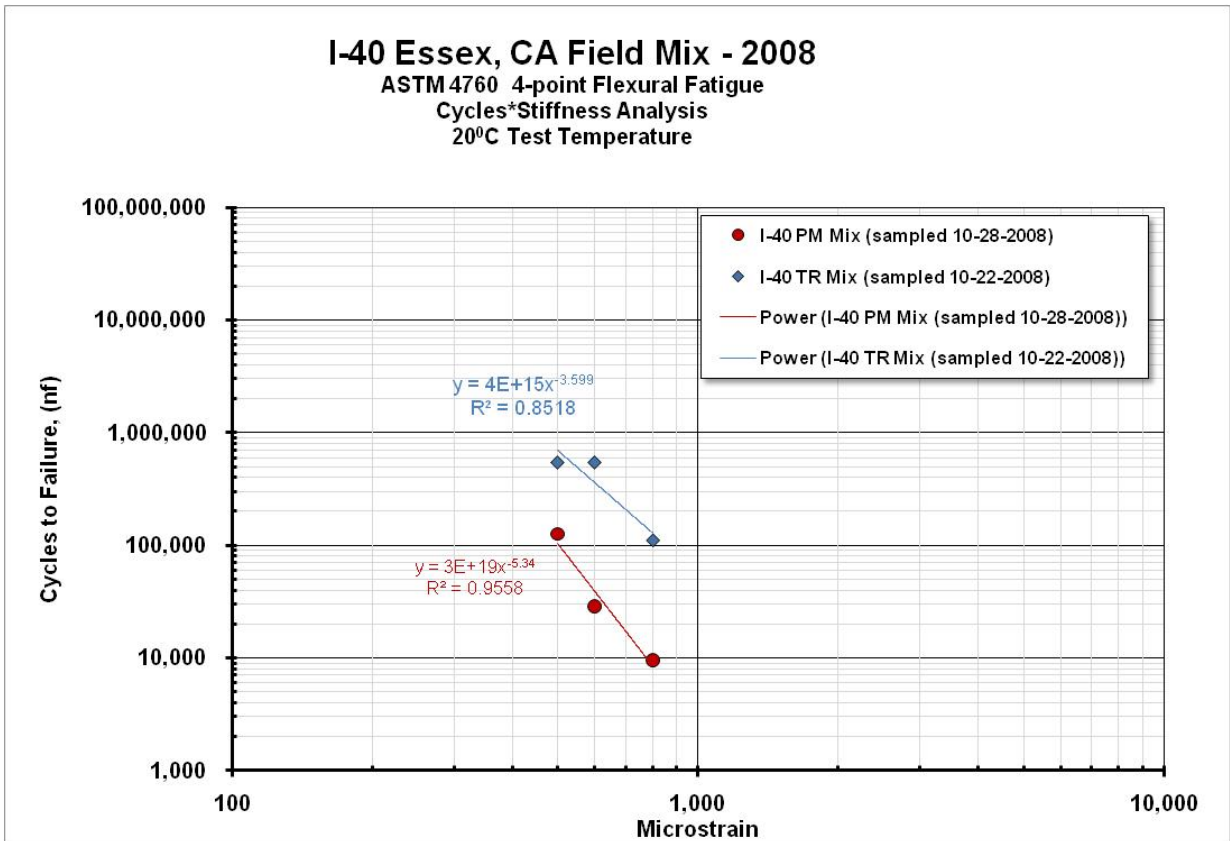


Figure 5. Fatigue life using a repeated flexural fatigue test.

CONCLUSION

Field hot mix Asphalt samples were collected from the demonstration project paving site to compare the PG 64-28 TR to the PG 64-28PM mixture. The overall goal of this study is to determine if the terminal blend tire rubber (PG 64-28TR) is equivalent to the same Performance Grade (PG) using polymer modification (PG 64-28PM) in accordance with the CALTRANS Work Plan. The goal of the abbreviated mixture testing by Asphalt Institute is to compare the potential fatigue and rutting performance by laboratory performance testing.

Loose mix samples were sent to the Asphalt Institute where they were reheated and compacted for further testing. The Superpave repeated shear at constant height test was used for rutting determination and the 4-point flexural fatigue test for fatigue testing in accordance with the proposed CALTRANS Work Plan.

The TR mixture showed a slight improvement in rutting resistance as compared to the PM mixture. The TR mixture exhibited 2.27 percent shear strain as compared to the PM mixture at 3.16 percent shear strain. Overall, both mixtures were very rut resistant and should be able to handle more than 2 billion ESAL's.

The TR mixture outperformed the PM mixture in flexural fatigue by 4 to 18 times, depending on the test strain. This indicates that the TR mixture should crack less over time as compared to the PM mixture. If the TR mixture cracks less than the PM mixture, whether top down or bottom up, there should be a cost savings with the TR mixture over time since less maintenance may be needed.

Overall, the PG 64-28 TR mixture appears to be a good alternative to the PG 64-28 PM mixture. It is possible that CALTRANS could even see an improvement in cracking performance with the TR mixture based on this abbreviated study.

REFERENCES

- ¹ CALTRANS. *Evaluation of Type C Mix with PG 64-28 TR binder* (Work Plan). August 20, 2008.
- ² Humer, Robert. *Testing the Equivalency of Pg 64-28TR and PG 64-28PM Binders*. Unpublished report prepared for Paramount Petroleum, April 7, 2009.
- ³ JB Sousa, Proceedings of the Association of Asphalt Paving Technologists (AAPT) vol. 63, p315. 1994.