

We have all heard a lot of discussion recently about the \$12 million WesTrack project, located about 100-km southeast of Reno, Nevada. This accelerated test track facility was constructed under a Federal Highway Administration (FHWA) contract by a group of organizations headed by the Nevada Automotive Test Center. The intent of WesTrack was to look at construction variability, to further develop the asphalt performance-related specifications of the Strategic Highway

same crushed material with some additional local natural sands.

To evaluate gradation changes on performance, another fine mix was also designed and constructed with an additional three percent of dust (minus 0.075 mm) material. All of these mixes had a nominal maximum aggregate size of 19 mm and used an unmodified PG 64-22 binder. Three levels of binder content (optimum, optimum -0.7 percent, optimum +0.7 percent) and three levels of in-place air voids (4, 8, and 12 percent) were scheduled to be evaluated.

follow the initial ruts rather than the guiding cab vehicle. Although the traffic is well controlled and documented for performing an accelerated experiment, there are differences from an actual roadway.



Basis for Mix Design

The mix designs were based on a total traffic of 3 to 10 million ESAL,



A WesTrack Analysis

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Research Program (SHRP) and to validate the Superpave Mix Design method. The pavement was completed in November 1995.

The 2.9-km oval track includes 26 test sections to evaluate the effect of variations in binder content, gradation, and density on the Superpave Mix Design System. Four of these sections were designed by strictly following all of the Superpave recommendations. Two distinct mixes were used on the track. A coarse gradation (plotting below the maximum density line and restricted zone) was made from partially crushed gravel and screenings. A fine gradation (plotting above the maximum density line and restricted zone) was made from the

An automated vehicle guidance system was designed and installed in March 1996, and four heavily loaded driverless triple-trailer trucks began trafficking at 65 kph for up to 21 hours each day. As planned, the track would be subjected to ten million 80 kN (18,000 lb.) equivalent single axle loads (ESAL) in two years. The initial traffic on the track was applied with very little lateral wander, which is unrealistic compared to actual highway conditions. This "wheel tracking" was later modified. Once the initial deformation was established in the wheelpath, however, the following trailers tended to

which is the amount of traffic planned for the 2-year study. Therefore, the track was designed to fail by the end of the 2-year life of the experiment. Unfortunately, the table of compaction levels for the Superpave Gyrotory Compactor (SGC) was established for the total design traffic, intended (but never really foot-noted) to be accumulated over 15 to 20 years. If the WesTrack 5 million ESAL-a-year planned loading is multiplied by a normal pavement design period, the mix should more realistically have been designed for 75 to 100 million ESAL.



This higher design level of ESAL would have increased the design number of gyrations to be used in simulating actual traffic from 96 to 126.

Since the minimum Voids in Mineral Aggregate (VMA) criteria (13 percent) and design level of air voids (four percent) are fixed, the result would have probably been a stronger aggregate blend to meet the same mix criteria for 30 more gyrations. If the same aggregate blend was used, the binder content would have decreased.

In addition, the higher *design traffic* would have changed some of the consensus aggregate requirements. The coarse aggregate angularity would have changed from 85 percent with one crushed face and 80 percent with two crushed faces to 100 percent with two crushed faces. The final numbers documented by John D'Angelo, FHWA, for the Dayton stone used at WesTrack were 86 and 73 percent according to the ASTM D-5821 procedure. The clay content or sand equivalent would have also changed from a minimum of 45 percent to 50 percent.



The Unexpected

By September 1996, approximately one million ESAL had been applied and several test sections were experiencing various degrees of rutting. As expected, the sections placed with the highest binder content were exhibiting the most severe deformation. But, the unexpected also happened! The fine-graded mixes were outperforming the coarse-graded mixes.

We learned from subsequent investigations and testing that the binder content of all of the 26 sections was significantly higher than amount stipulated in the original plan. Consequently, WesTrack has definitely confirmed that binder content is critical to mix performance.

Coarse mixes made from quarried

Another lesson we have already learned or confirmed from size that counts but the quality (angularity, shape, and texture)

(crushed) stone have usually performed very well in the US and in Europe. One of the best success stories has been the design for Stone Matrix Asphalt (SMA), which uses an even steeper S-shaped coarse-graded blend of aggregates. Many feel the reason for the success has been the requirement of 100 percent crushed cubical quarried stone.



Not Size but Quality

Another lesson we have confirmed from WesTrack is that it is not the size that counts but the quality (angularity, shape and texture) of the aggregate particle. Rounded gravels, even when crushed to induce one or two angular faces, are probably not appropriate for severe traffic situations like WesTrack.

By mid-April 1997, the track had passed the one-year milestone. During that period, the accumulated traffic exceeded 2.7 million ESAL, less than the 5 million planned. It is still much greater than a normal pavement designed for a total of 3 to 10 million ESAL. Several of the sections had rutted more than 25 mm and severe fatigue cracking had occurred in several other sections. The ten most distressed sections,

mostly the coarse-graded mix, were rehabilitated with a *new* Superpave mix design, which would duplicate the coarse-graded mixes in the original construction, except that a different aggregate *source* was used.

The new mixture was also coarse-

graded below the maximum density line and the restricted zone, using the same PG 64-22 binder. However, this time it was made from 100 percent quarried material. The mix met the same aggregate properties for 3 to 10 million ESAL and volumetric requirements of the same 96 design gyrations as the original design. Sections were replaced with the same variation of low, medium and high binder content and constructed to low, medium and high in-place air voids to continue the original experiment. Quality control testing, from behind the paver, indicated that the required volumetrics, gradations and binder contents were achieved. Therefore, the only intended change from the original mix was the coarse aggregate shape, to learn if that was the solution for the premature failure.



Premature Rutting

Within five days after resuming traffic in July, this new mixture rutted from 12 to 37 mm. The mixes containing the higher binder contents and air voids deformed to a greater degree, as expected. However, no one foresaw this type of immediate failure; it gave new meaning to the term "premature rutting". Without

knowing all of the facts, many people started wondering about the Superpave mix design method. A team of eight independent experts was assembled by FHWA to investigate the cause of this failure and recommend steps that could be taken to improve

WesTrack is that it is not the (structure) of the aggregate particle.

the performance of coarse-graded mixtures at WesTrack. The team met on August 18-20, 1997, to talk with the WesTrack researchers and the paving contractor. They evaluated all of the factors (structure, construction, environment,

traffic and mix properties) that could have affected the mix performance.

They again found that the traffic was more channelized than normal roads would experience. The three main points that were determined to be potential contributors to the rutting were:

- The design number of gyrations, N_{design} , was too low for the accelerated rate of traffic application.
- A stiffer binder should have been selected for such a high traffic loading.
- The design level of VMA was 15.3 percent, well above the minimum of 13.

Their consensus of opinion was that the major cause of the early rutting in the reconstructed

sections with coarse-graded mixes was high binder content and low binder stiffness.

To review, when the design level of VMA is much higher than necessary and the design level of air voids is fixed at four percent, the effective binder content makes up the difference (Figure 1). The total binder content used was 5.7 percent. Unfortunately, there is no maximum VMA requirement in Superpave.

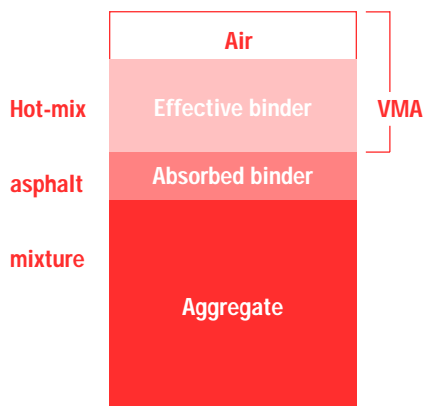


Figure 1. Component diagram of hot-mix asphalt mixture.

The upper Voids Filled with Asphalt (VFA) requirement is intended to avoid this problem. However, the 75 percent maximum VFA requirement was apparently not adequately restrictive in this case. Most mix designers would not have used such a high VMA mix because it

would be cost prohibitive (too much binder). It seems that WesTrack has taught us another valuable lesson. There needs to be some improved restriction either on high VMA, high VFA, or high effective binder content, rather than relying on the experience of the mix designer.



“Wet Side” Values

When the VMA values for this WesTrack mix are plotted against the binder content, it can be seen that the point chosen for the 5.7 percent design binder content lies on the right hand side of the typical U-shaped VMA curve (Figure 2). As

noted in the Asphalt Institute MS-2, *Mix Design Methods for Asphalt Concrete and Other Hot-Mix Types*, these values on the “wet” side of the curve should be avoided for these mixes have a tendency to bleed and/or exhibit plastic flow when placed in the field. This kind of guidance may be appropriate for Superpave as well as Marshall mix design.

Regarding binder selection, toward the end of SHRP, adjustment factors were suggested for the high temperature Performance Grade of the binder in heavy traffic situations. If the

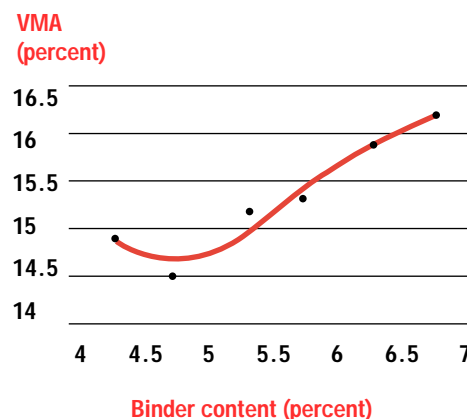


Figure 2. Plot of VMA with binder content from WesTrack mix design.

design traffic is expected to be between 10 and 30 million ESAL, then the engineer may *consider* selecting a binder that is one high temperature grade higher than the selection based on climate alone. If the design traffic is expected to exceed 30 million ESAL, then the binder *should* be adjusted one high temperature grade. Again, the special circumstances of WesTrack have put the total 2-year traffic below the need for the suggested binder grade adjustments; however, in a normal 15 to 20 year design, the binder grade

would have been adjusted up one grade to PG 70-22. From our perspective, much of the WesTrack controversy could have been avoided if the *total* design traffic categories used in Superpave had instead been designated by an *annual* amount of design traffic, which would prevent the need to even consider the pavement design life.



Forensic Team Recommendations

Some of the WesTrack forensic team proposed recommendations, in their final report, *Performance of Coarse Graded Mixes at WesTrack – Premature Rutting – Analysis conducted by Independent Team, August 1997*, appear to be an overreaction. They are recommending:

- 1 When designing for 3 million ESAL or greater with coarse-graded mixes, increase one high temperature binder grade. When designing for greater than 10 million ESAL, consider increasing two high temperature binder grades.
- 2 If the design VMA is more than two percent greater than the minimum, consider reducing the VMA by

changing the gradation or increasing the amount of mineral filler.

3 Check the performance of the mix by performing some type of strength or performance test with which you have comparable historical data.

4 If the binder content is reduced, take care not to instigate early durability problems.

Recommendation 1 would not be necessary if the original intent of the design traffic levels (15 to 20 years) had been adequately described. The additional shifting of binder high temperature grades at relatively low traffic levels appears to be an overly conservative approach that is, in our opinion, not well justified. Taking this approach assumes the asphalt binder is the main factor responsible for resisting permanent deformation.

Recommendation 2 is one way to resolve the high VMA condition. Most mix designers do not need to be guided away from using too much binder in a mix because it increases the cost of the mix.

Recommendation 3 provides an extra level of confidence to the Superpave volumetric mix design process, provided the designer has a true correlation between mix performance and the test result for the local area. This would not be the case for Marshall Stability and Flow and many of the loaded wheel test devices have provided conflicting indi-

cations. It should be noted that many of these devices failed to indicate a problem with the original WesTrack mix design.

Recommendation 4 is always good practice.

One final recommendation of the team was to consider placement of additional test sections at WesTrack to validate the recommendations in their report. This is an excellent suggestion. This, after all, was the whole concept of a test track. Pavement sections were constructed with different variations to learn how the performance is affected. It is significantly less expensive to discover the minor problems and do the fine-tuning with Superpave here rather than on the Interstate Highway System.

Finally, for those who are ready to discount the entire Superpave design system because of WesTrack's experience, consider the fact that over 200 Superpave projects have been built since 1992 by various States. The general experience with this design method has been very positive. In fact, on warranty projects, many contractors prefer to use this method. It would be tragic to hinder all of the progress realized with the recent implementation of Superpave, based on a single test project using a questionable mix design and an inappropriate approach to traffic.▲

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more appropriate for finish rolling.

This pick-up problem is more of a cosmetic issue than a structural deficiency. Therefore, agencies should continue to consider pneumatic rollers as an option for base or intermediate courses to help obtain proper density because of their beneficial kneading, sealing and non-bridging action.

Sticky Truckbeds

96 Superpave or not, modified binders may exhibit a tendency to stick to the flat bed of the dump truck, even more than conventional asphalts. This problem can be reduced by using proper mixing temperature and maintaining the elevated temperature of the mix in the truck by using tarps to prevent heat

loss. A release agent should be applied in a uniform thin spray coating after the truck has been properly emptied and cleaned.

Most agencies and asphalt contractors realize that many of the problems experienced on Superpave projects are not new. The purpose of this review is to expose and record the various Superpave experiences in order to build a better pavement in the future.▲