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Upper Layers

Rut-Resistance in

The total thickness of the new lanes on the 4.57-mile Beltway section is 21.5 inches, including 15.5 inches of HMA and 6 inches of aggregate subbase. A base course of three-inch lifts of 57.5mm-sized mix was placed on the aggregate subbase. Then 1.5 inches of 25mm-sized mix with PG 70-20 was placed on the base course. The new lanes, along with the six existing lanes, were then surfaced with 2 inches of stone matrix asphalt (SMA).

Thick Enough

Good Mixes

‘The reason the pavement works so well is that we used good mixes,’ says Dave Parkhurst, Maryland State Highway Administration (SHA) design engineer for the 4.57-mile Beltway section. ‘We used a 37.5mm-sized mix in a 12-inch thick base course, and we placed it on 6 inches of graded aggregate subbase.’ He says that all heavy-use roads in the Piedmont region around Baltimore require an aggregate subbase. The subbase is compacted to 92 percent maximum density.

Parkhurst says that good aggregate interlock and stone-on-stone contact was an essential ingredient in the mix design. ‘That’s why we wanted to go with the new Superpave mixes—37.5mm and 25mm. At the time of construction we were in transition from old Maryland SHA mixes to the new Superpave mixes. The new mixes gave us good aggregate interlock and stone-on-stone contact.’

Drainage Factor

The SHA installed underdrains at the shoulders on both sides of I-695, as well as underdrains in the median area. The pavement and drainage system now extends from shoulder to shoulder.

We provide a positive drainage system on all of our major roadways,’ says Parkhurst. ‘It’s an inexpensive way to ensure longevity.’

Rutting and Roughness

The three-year-old I-695 pavement shows little or no deformation and has a smooth riding surface. Paul Dorsey, Maryland SHA Pavement Management Engineer, says that there is very little rutting on the 4.57-mile pavement surface. Using an ARAN (automated road surface condition) to measure rutting and smoothness, Dorsey says that data for the year 2000 shows less than 1/10th of an inch of surface deformation. ARAN data also shows that surface smoothness measures in the ‘good’ range. On International Roughness Index (IRI) ratings, the Federal Highway Administration (FHWA) says that 0 to 60 is very good and 60 to 95 is good. Over 95 is ‘fair’. The ARAN shows that the average roughness on the new lanes is between 78 and 84. That is in the good range.

Dorsey adds that an SMA surface measures a little rougher because of its texture. ‘But the ride is smooth,’ he says, ‘and the overall rating of the SMA surface is very good.’

Rut-Resistance in Upper Layers

Perpetual pavement designers agree that rut resistance in the upper layers depends on good aggregate interlock, asphalt binder that is stiff enough to resist deformation, and air voids at a reasonable level—between 4 and 6 percent. The surface mix must also resist thermal cracking.
Traffic projections for this section in the year 2020 exceed 256,000 ADT with 9 percent trucks.

**Thick Enough**

The total thickness of the new lanes on the 4.37-mile Beltway section is 21.5 inches, including 15.5 inches of HMA and 6 inches of aggregate subbase. A base course of three 4-inch lifts of 37.5mm-sized mix was placed on the aggregate subbase. Then 1.5 inches of 25mm-sized mix with PG 70-20 was placed on the base course. The new lanes, along with the six existing lanes, were then surfaced with 2 inches of stone matrix asphalt (SMA).

Thickness was a primary consideration when the SHA designed the roadway. Structural failure for thin asphalt pavements is much higher than for thick asphalt pavements. If the asphalt is too thin, it will exhibit strain from bending, say SHA design engineers. If it is thick enough, it will resist fatigue.

Angela Smith, SHA pavement design engineer for a 2.75-mile section of I-695 currently under construction, says that 12 inches of thickness or more provide structural integrity where sustained and heavy loads are continuous. She cites US 183 in Maryland as an example of thick pavement where sustained and heavy loads are continuous. It is 17 inches thick, she says.

‘A lot of the reason for the good performance of the road,’ says Parkhurst, ‘is the thickness, the SMA surface, the large-size rock in the base and intermediate courses and the good stone-on-stone contact throughout the pavement structure.’

Parkhurst says the Maryland SHA used a 30-year design analysis period for the new lanes. ‘We used 76 million ESALs for the 30-year period design analysis and 28 million ESALs for the period from the 1998 opening to the first overlay, which is scheduled in 12.5 years.’

**Good Mixes**

‘The reason the pavement works so well is that we used good mixes,’ says Dave Parkhurst, Maryland State Highway Administration (SHA) design engineer for the 4.57-mile Beltway section.

‘We used a 37.5mm-sized mix in a 12-inch-thick base course, and we placed it on 6 inches of graded aggregate subbase.’ He says that all heavy-use roads in the Piedmont region around Baltimore require an aggregate subbase. The subbase is compacted to 92 percent maximum density.

Parkhurst says that good aggregate interlock and stone-on-stone contact was an essential ingredient in the mix design. ‘We felt it was a critical part of the design,’ he says. ‘That’s why we wanted to go with the new Superpave mixes—37.5mm and 25mm. At the time of construction we were in transition from old Maryland SHA mixes to the new Superpave mixes. The new mixes gave us good aggregate interlock and stone-on-stone contact.’

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**Rut-Resistance in Upper Layers**

Perpetual pavement designers agree that rut resistance in the upper layers depends on good aggregate interlock, asphalt binder that is stiff enough to resist deformation, and air voids at a reasonable level—between 5 and 6 percent. The surface mix must also resist thermal cracking.
Compaction Principles for Heavy-Duty HMA

By Gary Fitts, P.E., Asphalt Institute District Engineer

While the increasing use of large rock base courses and coarser mixtures to resist rutting in new and reconstructed asphalt pavements, proper compaction of hot mix asphalt (HMA) is more important than ever.

Proper compaction requires confinement, space (mat thickness relative to aggregate size), elevated temperatures and compactive effort.

Confinement

Confinement is necessary to mechanically reduce the volume and increase the density of a mass of material. In HMA construction, confinement is provided by the underlying foundation, adjacent materials or structures, and by the internal friction and cohesion of the mixture. Regardless of whether a harsh or tender mixture is being placed, proper compaction cannot or will not be achieved if the underlying surface is yielding under the paver and rollers or sliding along the interface between old and new material.

Confinement is most difficult to achieve at free, unsupported edges. While much attention has been given to the best method to construct a longitudinal joint, problems with joint density have less to do with how the fresh material is placed and compacted against an existing lane than with poor compaction at the edges of the first pass.

Current research at the Texas Transportation Institute indicates that densities measured on the boi side of paving joints is comparable to that in interior sections of the mat, while the cold (unsupported) edge is considerably lower.

Approaches to compacting unsupported edges include:

- Attaching end gates to the paver to act as slip forms,
- Using small edge rollers immediately behind the paver,
- Using an attachment to a roller or motor grader to literally cut away a small strip of material after compaction has been completed.

Although wasteful, the latter approach is probably the most effective. It has been used frequently on projects that have a joint density requirement, such as those constructed under the Federal Aviation Administration (FAA) P-401 specification.

Space

Space is a word that has not been used often when describing compaction, but it is a term that means having sufficient lift thickness to allow for particle reorientation during compaction of coarse mixtures. In the past, the rule-of-thumb was that lift thickness had to be at least two times the maximum aggregate size. That was appropriate for fine or continuously-graded mixtures, but in mixtures containing a much higher proportion of coarse aggregates, the 2:1 ratio does not allow enough room within the mat for moving the particles during compaction. Additional compaction applied on a mat with a 2:1 ratio only serves to fracture aggregate particles or break the mix apart.

For coarse-graded mixtures and stone matrix asphalts (SMAs), the minimum placement thickness should be at least three times the nominal maximum size rock, which is defined as one size larger than the first size to retain more than 10 percent of the combined aggregates. Table 1 shows the preferred range of compacted lift thickness that should be used for various mixture classifications.

Temperature

For any HMA mixture, compaction must occur within a temperature range in which the asphalt binder is sufficiently fluid. The aggregate particles can be oriented while the binder is in a fluid state. As the HMA

The SMA surface course on the 4.37-mile stretch, together with the PG 76-22 polymer modified asphalt binder used in the mix, meet these requirements.

Traffic Maintenance

During the widening of the 4.37-mile section from six lanes to eight lanes, SHA and the contractor had to keep six lanes open from 6 AM to 7 PM everyday. "One lane was closed at 7 PM and another at 10 PM, says Bob Steffy, SHA traffic engineer. "All construction equipment had to be off the road at 5 AM."

Steffy says there was some vehicle back up when the lanes first closed, but that back up quickly dissolved. He says that Dick Corp. of Pittsburgh did an excellent job of traffic control. Penalties were assessed at $50 per minute if Dick Corp. and the paving contractor did not have their equipment off the site at 5 AM. Steffy says few if any penalties were levied because the contractor was always ahead of the deadlines. Parkhurst says the traffic handling was the best he has ever seen on a major project.

Summary/Conclusion

Although traffic handling and scheduling is critical on major interstate projects such as the I-695 widenings, it is the design and construction of the roadway that ensures it will be a perpetual pavement. The essential ingredients of this design and construction are:

- A base course that supplies an indefinite fatigue life.
- A surface that is custom-designed for specific loads and applications.
- A surface course that is renewable and that can be milled and filled every 12 to 20 years.
- A road that is smooth and reliable and one that is enjoyable to use.

These are the essential ingredients that describe I-695.