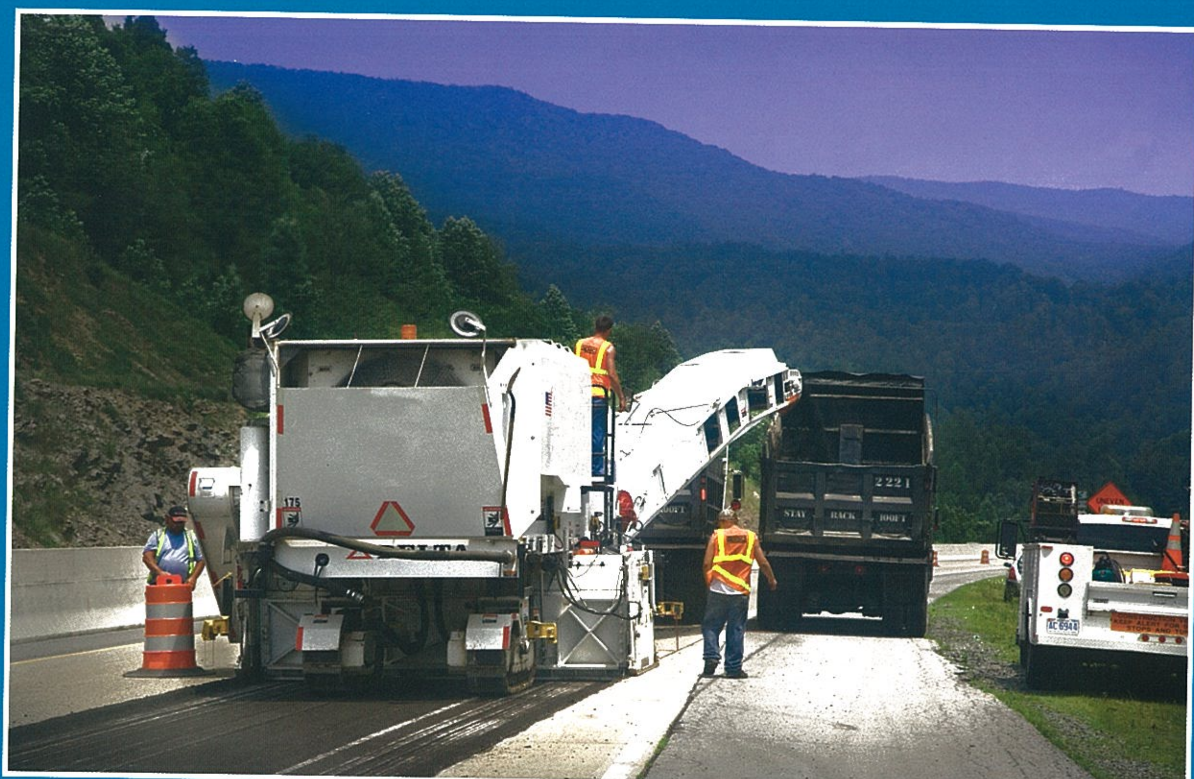
How to Increase RAP Usage and Ensure Pavement Performance



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Why Recycle?

The use of reclaimed asphalt pavement (RAP) in new asphalt mixtures has obvious advantages to the environment, pavement owners, and contractors.

Environmental benefits include a reduction of the carbon footprint of the product and any of its end uses, conservation of natural resources, and conservation of landfill space, making asphalt paving an excellent sustainability practice.

From an economic standpoint, the reuse of materials provides an opportunity to stabilize construction prices, which may fluctuate as the economy and demand for raw materials change.

The technology for using increased amounts of RAP in asphalt mixtures has improved significantly in terms of mix design and material processing and handling.

Finally, the long performance history of RAP mixtures over the last 40 years provides confidence that, appropriately done, RAP mixtures can provide the same or better level of service than virgin asphalt mixtures.

What is the history of asphalt recycling?

The history of modern asphalt pavement recycling dates back to the oil embargo of the 1970s. Asphalt shortages at that time made it necessary to find practical means of extending the materials supply. At about that time, milling machines started being used to remove asphalt pavement surfaces in preparation for overlays. With a ready supply of materials, the industry began to explore ways to reuse the reclaimed pavement.

The 1970s and 1980s saw several recycling field trials placed with RAP contents up to 80 percent. The plant designs and processes at that time did not allow quality high-RAP-content mixtures to be produced consistently. The mid to late 1980s were also the beginning of widespread use of quality control/quality assurance specifications which focused more on the end result of asphalt mixture production with volumetric controls. These specifications required a great degree of consistency in the produced asphalt mixture. As the 1980s wore on, asphalt prices fell, and most asphalt mix producers and agencies became content with relatively low RAP contents (less than 20 percent).

The 1990s brought in the era of Superpave and stone-matrix asphalt (SMA) mixtures. Because Superpave was new and SMA was a premium surface mix, the amount of RAP was severely reduced or eliminated altogether until mix designers and producers felt more comfortable with the new technologies. The focus on volumetric specifications was maintained through the development of Superpave and SMA. Toward the end of the 1990s, however, interest in increasing RAP usage was rekindled, and a Superpave mix design method for incorporating RAP was developed.

From 2004 through 2008, the industry saw the price of all construction materials increase along with the price of asphalt binder. These trends increased focus on the use of RAP. However, modern asphalt plant design with counterflow and unitized drums, better RAP processing, and better controls have allowed for more RAP to be introduced while maintaining compliance with environmental standards and without compromising mix quality. Screens have been developed to size the RAP to provide mix producers with better control and more flexibility in reusing this resource. Using modern methods of mix design, the industry now understands materials, including RAP, better than ever, and this, combined with statistical procedures for quality control, ensures better uniformity of its RAP-bearing product. The result is an industry which views RAP as being as valuable as virgin aggregate and asphalt, and which is capable of utilizing RAP to its full extent in producing a high-quality mix.

In the end, RAP use helps stabilize the price of asphalt mixtures, since the aggregate and asphalt are already captured and are not subject to the same volatility as other construction materials. Generally speaking, the cost to obtain and process RAP is about four to six times less than that of raw materials. Thus, increasing the amount of RAP in a mix by 10 percent provides appreciable savings, not only to the contractor, but to the customer.

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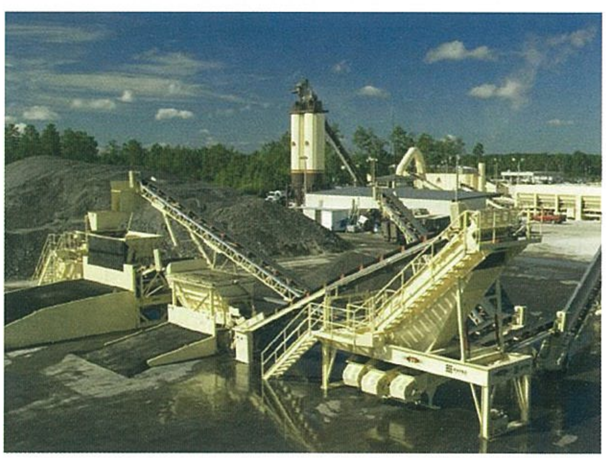
What concerns do engineers have regarding increased RAP use?

Concerns over the use of high-RAP-content mixtures come largely from a few experiences in the 1970s and 1980s when mix production was not controlled as well as it is today. The primary issues that have been raised include:

- Durability
- Consistency of RAP
- Skid resistance in surface mixes
- Stiffness of the RAP binder
- RAP aggregate degradation
- Mix-design practices and volumetric calculations
- Extent of blending between virgin and RAP binder

All of these issues can be handled through proper mix design, material processing, and production. Each of these will be addressed in the following sections.



Are RAP mixtures more prone to poor performance than virgin mixtures?

Raveling and cracking in asphalt mixtures are often attributed to a lack of durability. Durability problems in mixes can be related to many factors, including aggregate characteristics, the volume of effective asphalt binder in a mixture, asphalt binder properties, in-place mix density, and conditions during placement.

Aggregate characteristics leading to distresses are generally associated with stripping, i.e., the inability of the binder to adhere to the aggregate surface. This is more common in virgin, silicon-bearing aggregates such as quartzites and granites, but it can be mitigated through the use of liquid anti-stripping agents or lime. Stripping is not generally an issue with recycled aggregates, as they have already been coated with an asphalt binder. As with any asphalt mixture design, ensuring a sufficient amount of binder to coat the aggregate and testing the mixture for moisture susceptibility according to AASHTO test method T-283 or other approved test method is important.

The volume of effective binder in any asphalt mixture is critical to aggregate coating and mixture cohesion. Most mix-design procedures cover this aspect by specifying the aggregate gradation, the voids in mineral aggregate (VMA), the asphalt content, and the volume of voids filled with asphalt. The aggregate gradation in a RAP mixture is just as important as in a virgin mixture, and gradation standards need to be maintained to make sure that there are not excess fines that increase the surface area for coating. The RAP binder is a portion of the effective binder in that it coats the RAP aggregate and interacts with the new binder in coating the new aggregate. The amount of new binder needs to be sufficient to coat the virgin aggregate and blend with the RAP binder to provide the needed cohesion. The gradation and volumetric standards that apply to virgin mixtures should be applied to RAP mixtures, although the mix-design calculations for RAP mixtures differ in some respects, as will be explained later.

Over the years, material selection practices, mixture volumetric formulations, and construction practices have evolved to greatly improve the durability of asphalt mixtures. The advent of the Superpave system of mix design, SMA, quality control/quality assurance programs, and infrared temperature monitoring in the field are just some of the advances that have occurred in the last 20 years. Furthermore, new mix-production technologies in the form of warm-mix asphalt (WMA) are being developed. With warm mix, reducing the mixing and placement temperatures of the material may help minimize asphalt hardening during the construction process while maintaining the ability to achieve density and smoothness. Several field projects of WMA have included RAP contents up to 50 percent.

With proper mix-design, material processing, and production practices, a high-RAP-content asphalt mix can provide the same long-lasting durability as a virgin asphalt mixture.

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If RAP is used in surface mixtures, could it negatively affect the skid resistance of the pavement?

One of the most important characteristics of an asphalt pavement surface is skid resistance, especially in wet weather. The friction of a pavement surface is defined by its macrotexture (the bumps in the surface from the aggregate particles) and its microtexture (the roughness of the individual aggregate particles). Macrotexture tends to be more important for maintaining friction at high speeds, while microtexture is more important at low speeds. Macrotexture is largely a function of the maximum aggregate size and gradation, and microtexture can be achieved through the use of angular, hard, durable aggregate in the pavement surface. Asphalt mixture factors that can lead to low skid resistance include the tendency of the aggregate to polish, flushing of the binder, and rutting in the surface layer. Aggregate polishing is a function of the aggregate hardness and mineralogy, and it can be a problem in areas where hard aggregates are scarce and must be imported. Flushing tends to occur when too much binder or low air voids are present in the production of the asphalt mix, and rutting usually happens due to poorly designed mixes.

There are strategies that can be used in regions where soft aggregates are of concern. The first strategy is to specify the hardness of the virgin aggregate and allow up to 20 percent RAP in surface mixtures. If the aggregate in the RAP is soft, it will wear down, but the 80 percent virgin hard aggregate will remain intact and provide the needed micro- and macro-texture. The second strategy is to specify the use of only sand-sized RAP in the surface, allowing the hard virgin aggregate to provide the texture characteristics important to skid resistance. Finally, in regions where hard aggregates have

traditionally been used in surface mixes, separate RAP stockpiles for surface millings can be used to ensure that the RAP possesses sufficient resistance to polishing. In all cases, it is important to test the aggregate being counted on to provide skid resistance to ensure that it meets local polishing or hardness requirements.

Flushing and rutting are not normally associated with RAP mixtures. These are functions of proper material selection, mix design, and quality control. Since the advent of the Superpave system, rutting has largely been eliminated due to the load bearing of the aggregate structure combined with harder binders and quality control/quality assurance programs. Other research shows that excessive levels of rutting are far less likely to occur in RAP-bearing mixtures than in virgin mixtures. The National Center for Asphalt Technology's test track has shown in a number of test sections that rutting is drastically reduced with mixtures that include RAP.

As the majority of asphalt mixture tonnage produced in the U.S. is used in surface layers, RAP should also be used to the fullest extent possible in resurfacing projects. Using the right combination of material selection, mix design, and quality control practices will ensure both the skid resistance and rutting resistance needed to ensure safety.

How can I be sure that the old RAP binder and the new virgin binder blend together properly?

The blending of old RAP binder and virgin binder is necessary to provide the cohesion needed in the mixture to preclude premature cracking and raveling. The blending can be thought of in terms of the solubility of the RAP binder in the virgin binder. In other words, if the two asphalts mix well with one another, the dispersion of RAP binder in the virgin occurs so that the needed mix strength develops. Solubility depends on how close the two substances are in molecular weight, the chemical compatibility, the proportion of new asphalt in the blend, and the temperature at which they are mixed. Blending theory says that materials which have molecular weights close to one another generally mix better than those that do not. RAP binder and virgin binder which originate in the same general area usually pose no problems in the two products being compatible, but there are notable exceptions, and historical records should always be consulted. The temperature at blending needs to be sufficient for the aged binder to be mobilized, and this can occur at temperatures well below the standard hot-mix temperatures of 280 to 320°F with the right materials and well-controlled construction processes.

In the past, recommendations have been made to characterize the blending of RAP and virgin binders according to a blending chart. In this approach, the binder was extracted and recovered from the RAP in a long and involved process, then it was mixed with the virgin binder at different concentrations, and viscosity or dynamic shear modulus was determined through testing. The amount of RAP was controlled by the viscosity of the combined RAP and virgin binder achieving the level of viscosity for a desired virgin binder grade. This approach is very time-consuming and makes assumptions, such as complete blending, that were difficult to verify in the final produced mixture.

There are alternate procedures that would be more practical. First, most aged asphalts in a given region have reached a level of maximum stiffness. For instance, in the Southeast and mid-Atlantic regions, researchers have found that asphalt in RAP usually has a high-temperature grade of between 88 and 94. Knowing this, it is possible to estimate the effects of stiffness by assuming a RAP asphalt grade of 92 at 100 percent RAP, then using the high-temperature grade of the virgin asphalt at 0 percent RAP and drawing a straight line between the two points. If the asphalt content of the RAP is known and the virgin and RAP binders are compatible, then the concentration of RAP needed to obtain a specific binder grade can be determined. In cold regions, it is important to check the low-temperature grade as well as the high-temperature grade to avoid premature low-temperature cracking.

Another approach is to test the asphalt mixture resulting from blending the RAP with virgin materials. This has been done using the new Asphalt Mixture Performance Test in dynamic modulus. It has been found that the dynamic modulus will indicate whether blending has occurred. A substantially lower dynamic modulus is indicative of a lack of blending between the RAP and virgin binders.

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Processing RAP changes its aggregate gradation. Won’t that limit the amount of RAP that can be used?

In the past, the amount of fines generated in producing RAP severely limited the amount of RAP that could be introduced into an asphalt mixture. These fine particles are generated from the milling or processing operations used in reclaiming the material. In general, milling results in a higher production of fine materials, but with modern methods of material processing and handling, fines no longer pose the problems they did in the past. These improvements in processing include dust removal systems in plants and the sizing of RAP materials so that consistency is maintained in the mix gradation.

It is recommended that specified mix gradations be maintained, regardless of whether a mix uses all virgin materials or contains RAP. This is because screening can be used to separate the RAP into two or three separate sizes and allow for greater control of the final mix gradation. The finest size will contain sand-sized particles and smaller, and it will have the highest asphalt content. This size is ideal for use in fine aggregate gradations, and will be particularly useful in thin overlay applications. Larger RAP sizes can be used in larger nominal maximum aggregate size asphalt mixtures. The separation of RAP into different sizes allows much greater flexibility and can lead to greater amounts of RAP being used.

As with any aggregate stockpile, greater separation will increase control and reduce the amount of variability in the final product. If only one RAP stockpile is used, it is much more difficult to control the resulting gradation at higher RAP contents, and adjustments for the variability will have to be made in the virgin aggregate. Using two or three stockpiles with a number of RAP cold feed bins will result in much tighter gradation control to meet end product criteria.

How do mix design practices change for mixtures containing RAP? How can I account for the aggregate properties in the RAP?

The specifications for aggregate gradation and mixture volumetrics should be consistent between virgin mixtures and RAP-containing mixtures. However, the calculation of certain parameters needs to change. For instance, the bulk specific gravity of the aggregate is used in the calculation of the voids in mineral aggregate of the asphalt mixture. It is not practical to determine the bulk specific gravity of RAP aggregate because it would require extracting the asphalt from the RAP and this frequently changes the aggregate bulk specific gravity. If the bulk specific gravity of the RAP aggregate is known from original construction records, then that value can be used. If it is not known, which is usually the case, the bulk specific gravity of the RAP aggregate can be estimated from the maximum specific gravity of the RAP. This procedure is outlined in National Cooperative Highway Research Program Report 452 by McDaniel and Anderson.

What can I do to encourage greater levels of RAP use?

Although the technology for recycling asphalt mixtures has been around since the 1970s, innovations that have occurred since then have refined our understanding of mix design, material handling, mix production, construction, and performance of RAP mixtures. The improved technology has resulted in opportunities to allow more RAP to be used in asphalt mixtures. The asphalt binder and aggregate in RAP are high-quality materials that are as valuable as the natural resources they replace. The use of RAP in asphalt mixtures provides an excellent means to provide some stability in construction material prices. RAP mixtures can provide high-performance pavements and are known for their rutting resistance.

In order to use more RAP in asphalt mixtures, it is vital that quality standards be maintained through specifications. RAP mixtures should be able to meet all requirements of virgin asphalt mixtures. Adjustments in mixture design procedures should allow for the means to maximize RAP usage. Innovations in materials handling and mixture production which allow for high-RAP-content mixtures of high quality should be encouraged so that producers have the greatest flexibility in providing the most economical high-quality materials. The references listed below will provide greater detail on these subjects.

> *“RAP mixtures can provide high-performance pavements and are known for their rutting resistance.”*

RAP Bibliography

Brown, D. September 2000. RAP Turns in Good Performances. *Recycling Practices for HMA*. Special Report No. 187. National Asphalt Pavement Association. Lanham, Md. pp. 7-9.

Chen, D. and J. Daleiden. 2005. *Roadway Pavement Preservation*. Circular No. E-C078. Transportation Research Board. Washington, DC. pp. 70-84.

Epps, J.A. 1978. *Recycling Materials for Highways*. NCHRP Synthesis No. 54. Transportation Research Board. Washington, DC.

Epps, J.A., D.N. Little, and R.J. Holmgreen. September 1980. *Guidelines for Recycling Pavement Materials*. NCHRP Report No. 224. Transportation Research Board. Washington, DC.

Federal Highway Administration. 1996. *Pavement Recycling Executive Summary and Report*. Report No. FHWA SA 95-060. Washington, DC.

Kandhal, Prithvi and Kee Foo. 1996. *Designing Recycled Hot Mix Asphalt Mixtures using Superpave Technology*. NCAT technical report number 96-5. National Center for Asphalt Technology. Auburn University, Al.

Kennedy, Tom, Weng Tam, and Mansour Solaimanian. 1998a. "Optimizing Use of Reclaimed Aspahlt Pavement with the Superpave System", *Journal of AAPT*, Volume 67. Association of Asphalt Paving Technologists. White Bear Lake, Minn. pp. 311- 333.

Kennedy, T.W., W.O. Tam, M. Solaimanian. June 1998b. *Effect of Reclaimed Asphalt on Binder Properties Using the Superpave System*. Research Report No. 1250-1. South Central Superpave Center. University of Texas. Austin, Tex.

McDaniel, R. and Anderson R.M. 2001. *Recommended Use of Reclaimed Asphalt Pavement in the Superpave Mix Design Method: Technicians Manual*. NCHRP Report 452. Transportation Research Board. Washington, DC.

McDaniel, R.S. and A. Shah. 2003. "Use of Reclaimed Asphalt Pavement (RAP) Under Superpave Specifications." *Journal of AAPT*. Association of Asphalt Paving Technologists. White Bear Lake, Minn. pp. 226-252.

National Asphalt Pavement Association. 2007. *Recycling Hot-Mix Asphalt Pavements*. Information Series 123. Lanham, Md.

National Center for Asphalt Technology. 2009. www.MoreRAP.us. Auburn, University.

Newcomb, D.E., E.R. Brown, and J.A. Epps. 2007. *Designing HMA Mixtures with High RAP Content – A Practical Guide*. Quality Improvement Series 124. National Asphalt Pavement Association. Lanham, MD.

Soleymani, H. R., M. Anderson, R. McDaniel, and M. Abdelrahman. 1999. "Investigation of the Black Rock Issue for Recycled Asphalt Mixtures," *Journal of AAPT*. Volume 69. Association of Asphalt Paving Technologists. White Bear Lake, Minn. pp. 366-390.

Zofka, A., M. O. Marasteanu, T.R. Clyne, X. Li, O. Hoffman. June 2004. *Development of Simple Asphalt Test for Determination of RAP Blending Charts*. Report No. MN/RC 2004-44. Minnesota Department of Transportation. St. Paul, Minn.

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