Improving the sustainability of asphalt pavements

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An increasing number of agencies, companies, organizations, institutes and governing bodies are embracing principles of sustainability in managing their activities and conducting business. Historically, sustainability referred to environmental sustainability and simply meant using natural resources in a way that people in the future could continue to rely on their yields in the long term.

Today, there are slight variations of this definition, but the underlying idea of ensuring that we are using natural resources responsibly, so they can support both present and future generations, resonates with many of us.

What is a sustainable asphalt pavement?

For the pavement community, a sustainable asphalt pavement is one that achieves its specific engineering goals, while on a broader scale, 1. meets basic needs, 2. uses resources effectively and 3. preserves/restores surrounding ecosystems. (U.S Department of Transportation, 2016)

The major challenge facing materials for asphalt pavements with respect to sustainability, is that the production of asphalt is energy and green house gas (GHG) emissions-intensive, which has a negative impact on global warming potential and the environment. So, to improve the sustainability of asphalt pavements, we need to reduce both the energy and emission levels, which means effectively using fewer virgin materials and extending the lives of asphalt mixtures.

Effectively using fewer virgin materials

A popular strategy considered for reducing the environmental impact is to reduce the amount of virgin materials in asphalt mixes by using more recycled materials such as reclaimed asphalt pavement (RAP). Furthermore, the asphalt binder in asphalt materials carries much of the total environmental impact of the mixture because of the impact of petroleum acquisition and refining. RAP replaces both virgin aggregate and, to some degree the asphalt binder, both of which are non-renewable and finite materials. Therefore, the use of RAP in asphalt mixes is a very attractive solution.

While this can be an effective strategy and it intuitively lowers the environmental and economic impact of the material production phase, it is essential to consider the impact on the entire pavement life cycle, which also includes pavement design, construction, use, maintenance and preservation and end of life as depicted in Figure 1. Without this consideration, the use of recycled materials such as RAP may not support our goals and efforts toward a sustainable industry.

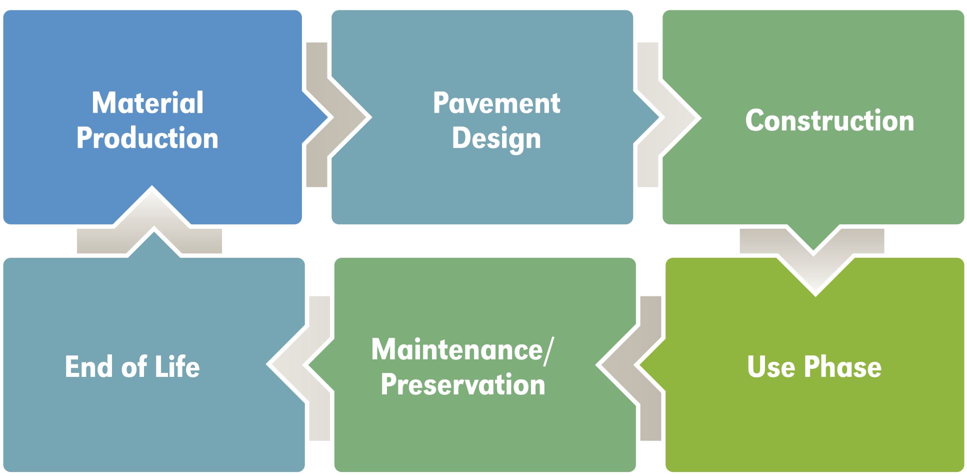


Figure 1: Pavement Life-Cycle Phases

Selection of the final asphalt binder content used in the asphalt mixture should be based on relationships between the binder content and other mixture volumetric and performance properties, aware that if too much binder isn't used there could be resulting rutting and shoving. While on the other end considering the risk of too little binder, which results in early cracking, raveling, water damage, and inadequate compaction, all of which have additional negative impacts that affect the long-term performance of the asphalt mixture.

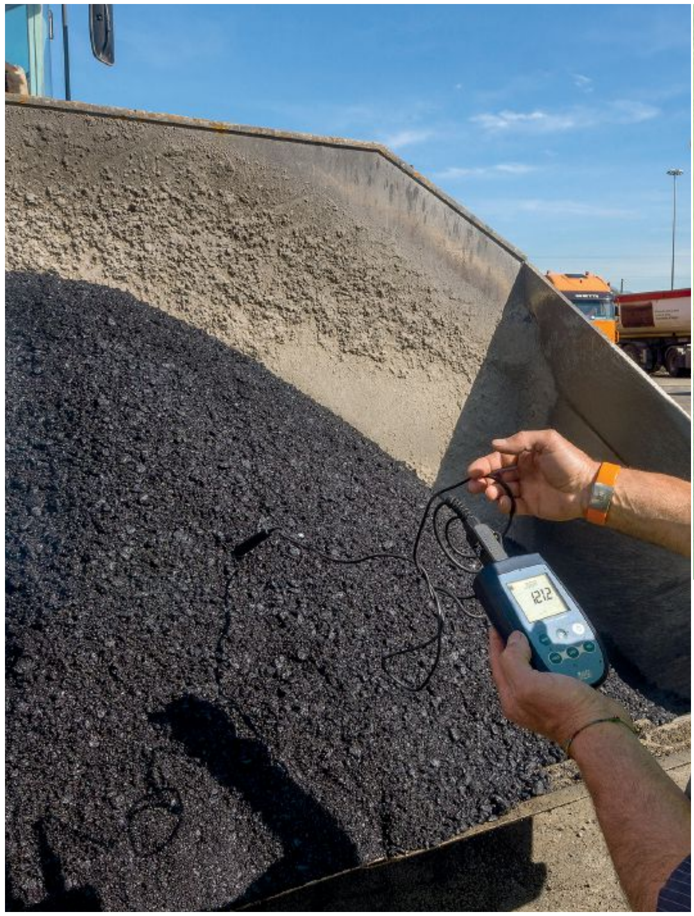
Other effective ways to use RAP in pavements is through central plant recycling (CPR) and in-place recycling process such as full-depth reclamation (FDR). CPR combines virgin aggregates with new asphalt binder and recycling agents along with a certain amount of RAP either through hot (HCPR) or cold central plant recycling (CCPR). FDR is a technique in which the full thickness of the existing asphalt pavement and a predetermined portion of the underlying materials (i.e., base, subbase, and subgrade) are uniformly pulverized and blended to provide a homogenous material. The pulverized material is mixed with additives, or water, and is placed, graded, and compacted to provide an improved base layer before placement of the final surface layers. The reuse and recycling of asphalt pavements result in economic and environmental impacts for both the old and new pavement structures.

Additional strategies for reducing the environmental impact of asphalt mixtures include:

- Reducing transportation distances of all raw materials through the use of more local materials while maintaining target specifications, quality requirements, and expected performance.
- Minimizing the moisture content in aggregate and RAP stockpiles
- Improving the efficiency of plant processes to allow producing asphalt mixtures at the desired quality (to achieve required volumetrics) but with reduced energy consumption

Extending the service life of asphalt pavements

Long service life is one of the primary drivers of pavement sustainability. Asphalt pavements with longer design life offer the opportunity to reduce life-cycle costs, user delays and environmental impacts compared to a standard 20-year pavement design.



Longer-life pavements use more durable materials and/or provide greater structural capacity. Higher structural capacity can be achieved by increasing pavement thickness, by increasing the stiffness and/or strength of critical layers, or both. Because of the increased thickness or increased material stiffness/strengths, or the use of more durable materials, longer life designs may have a higher initial cost and/or greater initial environmental impacts, but the overall life-cycle costs and environmental impacts are often expected to be less.

It's important to note that poor drainage conditions can contribute to early failures and reduced pavement life and therefore can significantly increase the environmental and cost impacts of the original pavement design because of early and more frequent maintenance and rehabilitation activities. It is essential to review drainage needs for all new and rehabilitation projects.

Another way to improve the sustainability of asphalt pavements is to ensure that the design of new pavements and rehabilitation projects includes consideration for future maintenance and rehabilitation that will be required based on the design decisions.

Construction quality

The ability to achieve longer service life is strongly impacted by the quality of the materials utilized, as well as by the quality of construction. In fact, the potential gains in sustainability afforded by the optimization of structural design, the use of highly durable or recycled materials, and the improved efficiencies in the production of materials can be completely negated by poor construction quality and improper construction techniques. (U.S Department of Transportation, 2016)

In many cases, increases in performance can be achieved with small increases in construction quality and associated reductions in overall variability. A careful review of construction specifications could show where increased levels of quality could be achieved that would positively impact performance.

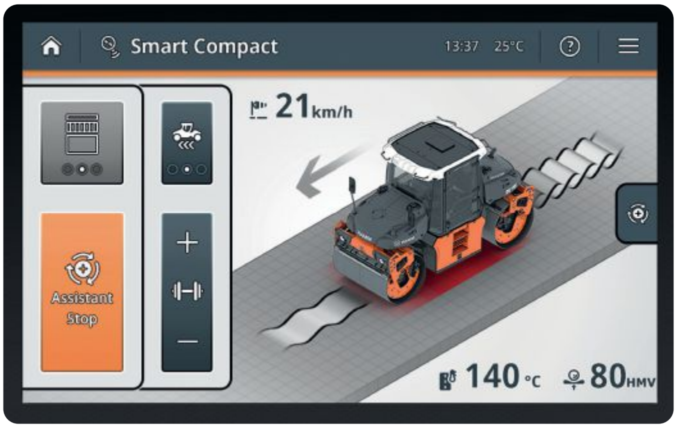
Proper use of technologies such as warm mix asphalt (WMA) and incorporation of automated compaction systems, such as Intelligent Compaction, have been demonstrated to improve compaction practices, affording the opportunity to achieve higher and more consistent densities.

Better compaction through warm mix asphalt

Chemically modified WMA mixes have been shown to provide better and more consistent compaction than conventional hot mix asphalt (HMA). The WMA additives enhance the lubricating properties of the asphalt binder and allow the mixes to remain workable even at lower temperatures. WMA also remains workable for a longer period than HMA because it does not lose heat as quickly to the environment since there is not as big a difference between the WMA temperature and the ambient temperature.

New Brunswick Department of Transportation and Infrastructure (NBDTI) compared core compaction results for HMA, and chemically modified WMA projects completed between 2017 and 2019 with PG 58-28 and PG 58-34 asphalt binders. The core compaction density results for the HMA projects ranged from 92.5% to 93.0% of maximum theoretical density and the WMA project ranged from 93.5% to 94.5%. Other researchers in Canada have found that tighter butt joints can be formed when using WMA compared to conventional hot mix (Hughes et al., 2009).

The reuse and recycling of asphalt pavements result in economic and environmental impacts for both the old and new pavement structures.



Better compaction through Intelligent Compaction

Intelligent Compaction (IC) is an innovation in both the area of compaction control and in the way that the results of compaction can be tested and used. IC consists of a vibratory roller that is equipped with various hardware and software tools that work together to improve the pavement material compaction process through consistency and uniformity, and provide data that can be processed, viewed, and analyzed by contractors/owners for enhanced evaluation of compaction-related parameters.

IC offers a way to improve the compaction process and makes it more effective and efficient. It also provides us with innovative tools that can be used during the Quality Control (QC) and Quality Assurance (QA) process and may ultimately give us an alternative to the normal method of checking density with cores or nuclear gauges.

Better longitudinal joints

Longitudinal joints continue to be the weakest link on our asphalt mats and are often the first place for pavement distress initiation and propagation. Better attention and inspection of construction practices will improve the performance of longitudinal joints. Additionally, the use of specialty products such as joint sealers or Void-reducing asphalt membrane (VRAM) can achieve lower air void contents (higher densities) at the longitudinal joints. VRAM is a highly polymer-modified asphalt membrane, that consists of asphalt binder, an elastomeric polymer, and a wax modifier. The composition is applied at the longitudinal joints before the asphalt mixture is placed and it migrates upward into the asphalt mix layer to fill 50% to 70% of the air voids with the help of the heat from the mix and the compaction process.

VRAM has been used for the construction of longitudinal joints in Illinois, Ohio, Iowa, Indiana, Michigan and Missouri. Research sponsored by the Minnesota Department of Transportation found that laboratory specimens containing VRAM showed good performance in terms of having the highest joint bond energy, fracture energy, and work of fracture and good surface bond energy compared to the specimens without VRAM. The use of VRAM also reduces permeability and air void content, which reduces the intrusion of water into the pavement. (Williams et al., 2020) Proper application of these technologies will have a positive impact on asphalt pavement service life.

Additional considerations for reducing the environmental impact of the construction phase are in fuel consumption during material transport and construction operations which can have a significant effect on the overall sustainability of a paving project. This can be minimized by reducing hauling distances, using on-site recycling, selecting appropriate equipment types and sizes for the job, implementing limitations on idling, using alternative fuels, retrofitting construction equipment with improved emissions control equipment or using hybrid equipment.

Traffic delays, congestion, and noise emissions generated during construction can also have a significant impact on the overall environmental impact of a paving project. These can be minimized by utilizing construction analysis programs for pavements to analyze the effects of pavement design, construction logistics, and traffic operation options on construction-related traffic delays and construction window policies.

Pavement preservation

Pavement preservation inherently improves pavement sustainability. It often employs low-cost, low-environmental-impact treatments to prolong the life of the pavement by delaying major rehabilitation activities. This conserves energy and virgin materials while reducing GHG emissions over the life cycle. Furthermore, well-maintained pavements provide smoother, safer, and quieter riding surfaces over a significant portion of their lives, resulting in higher vehicle fuel efficiencies, reduced crash rates, and lower noise impacts on surrounding communities, which positively contributes to their overall sustainability.

References:

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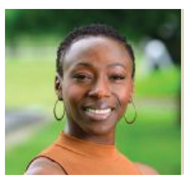

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