Sustainability in Practice 100

NATIONAL ASPHALT PAVEMENT ASSOCIATION

Sustainable Asphalt Pavements
A Practical Guide

This publication is provided by the Members of the National Asphalt Pavement Association (NAPA), who are the nation's leading asphalt producer/contractor firms and those furnishing equipment and services for the construction of quality asphalt pavements.

NAPA Members are dedicated to providing the highest quality asphalt paving materials and pavements, and to increasing the knowledge of quality asphalt pavement design, construction, maintenance, and rehabilitation. NAPA also strongly supports the development and dissemination of research, engineering and educational information that meets America's needs in transportation, recreational, and environmental pavements.

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Sustainability in Practice 100

Sustainable Asphalt Pavements: A Practical Guide

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9. Abstract

This is a compilation of the four publications in the *Sustainable Asphalt Pavements: A Practical Guide* series published by the National Asphalt Pavement Association. The series focuses on what an asphalt producer or asphalt project can do now to address sustainability within the confines of good business practice. The four publications in this series are meant to work together and are organized as follows:

1. SIP 101: *Sustainability Overview*. A practical definition of sustainability and the elements of and reasons for a business approach to sustainability.
2. SIP 102: *Sustainability Specifics*. Specific sustainability actions that can be taken in corporate/organizational strategy, project delivery, mix design, materials production, construction activities, and pavement design.
3. SIP 103: *Procuring and Evaluating Sustainability*. How sustainability is included in public project procurement, and how sustainability efforts are evaluated within the industry.
4. SIP 104: *How to Develop a Sustainability Program*. Important components of a company sustainability program including goals, best practices, implementation, and reporting.

Accompanying webinars for each publication in the series can be found at www.AsphaltPavement.org/PracticalGuide.

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Upper Left: Michigan Department of Transportation and Rieth-Riley Construction Co. Inc. earned a 2015 Quality in Construction Award, Over 50,000 Tons, for the construction of M-231 near Nunica, Michigan. The project used a 24-foot-wide wedge-lock screed and material transfer device to place the base and leveling courses in a single 24-foot-wide pass, eliminating a cold joint at the center line for a smooth, uniform mat.

Upper Right: Ajax Paving Industries of Florida earned an Operational Excellence Award — Ecological Operations, Existing Plant, in 2015 for its Plant No. 1 in North Venice, Florida.

Lower Right: Granite Construction Alaska Branch earned a Quality in Construction Award in Green Airport Paving for its work in 2015 at Ted Stevens Anchorage International Airport. The project included 25 percent reclaimed asphalt pavement in one of the runway pavement mixtures.

Lower Left: Pennsy Supply in Pennsylvania won a 2014 Operational Excellence Award — Community Involvement for the company's food bank collection program in which operational units competed against each other to collect the most food by weight.

Introduction

Sustainable Asphalt Pavements: A Practical Guide

The asphalt pavement industry has a long history of outstanding environmental performance. With more than 93% of pavements in the U.S. surfaced with asphalt (FHWA, 2018), it is clear that pavement owners know that asphalt is unparalleled as a cost-effective pavement material for everything from tennis courts and parking lots to country roads and interstate highways. You probably also have heard that asphalt pavement is the most consistently recycled material in America, with nearly 100 percent of material from old pavements reclaimed for future use; in fact, more than 80 million tons of reclaimed asphalt pavement (RAP) was put to use in new pavements during 2018 (Williams et al., 2019).

You might also know that emissions from asphalt mix plants are so low that the U.S. Environmental Protection Agency (EPA) delisted the industry as a major source of emissions in 2002 (EPA, 2002), and the rapid adoption of warm-mix technologies over the past decade has enabled even further reductions in emissions while also providing opportunities to improve construction quality.

The asphalt industry has been a leader when it comes to protecting the health and safety of its workers, too. When concerns were raised about the potential health impacts of asphalt fumes, an award-winning partnership between industry, labor, and regulators confronted the challenge head-on to pre-emptively reduce worker exposure through advanced engineering controls and to thoroughly evaluate the potential health impacts of asphalt fumes (Chang et al., 2015). A similar approach was embraced to control the emissions of silica dust during milling operations (Hammond, 2015).

Recycling, reducing emissions, and safeguarding worker health are just three examples of how the asphalt pavement industry puts the principles of sustainability into practice every day. Despite the economic, social, and environmental benefits of these sustainable practices, many companies do not formally recognize what they are doing as part of an organized sustainability program.

Sustainable Asphalt Pavements: A Practical Guide, for the first time, offers asphalt mixture producers, paving contractors, road owners and specifiers, and civil engineers the information, resources, tools, and guidance needed to understand and leverage the unique attributes of asphalt pavements to recognize, document, and advance sustainability goals that benefit their company, their customers, and the public.

The four sections of the *Practical Guide* are arranged in a logical order and each section stands on its own. The first (SIP 101) outlines what sustainability means in the context of

asphalt pavements and presents the business case for integrating sustainability into an organization's activities, products, and services. The second (SIP 102) is a comprehensive guidebook for sustainable practices available to the industry, owners, and design engineers. The third (SIP 103) provides a much-needed overview of how to integrate sustainability into procurement, while also explaining the role of green rating systems in evaluating the sustainability of asphalt pavements. The fourth (SIP 104) explores how to build a sustainability plan and to report out on its successes. Resources, including webinars discussing each section of the *Practical Guide*, can be found at www.AsphaltPavement.org/PracticalGuide.

— *Joseph Shacat*
Director of Sustainable Pavements,
National Asphalt Pavement Association

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Sustainability in Practice 101

Sustainable Asphalt Pavements: A Practical Guide

Sustainability Overview

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SIP 101: Sustainability Overview

"Sustainability" is a concept that expresses our desire, as humans, for health and happiness within the context of a healthy planet over the long term. In 1987, the United Nations Report of the World Commission on Environment and Development (known as the Brundtland Report) said it like this:

> Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs. (Brundtland Commission, 1987)

This "sustainability" idea has become common over the last decade. It has made its way into corporate culture, religious teachings, investment strategies, and preschool through college curriculums. Importantly, it is possible and completely reasonable to make it part of good business practice in the asphalt pavement industry. Why would you want to do this? Three reasons: (1) a moral obligation to do the right thing for future generations and the planet, (2) sustainability features are (or will be) required parts of projects, and (3) there is a business opportunity to increase revenue and market share, reduce expenses, improve productivity, and reduce risk.

Practical Sustainability

If you want to "do sustainability" it is hard to figure out what that might mean for a business if you are using the United Nations definition that we started with. Perhaps a more practical shorthand definition is helpful:

> **In practice, doing "sustainability" means (1) going above-and-beyond standard practice and/or required national regulatory minimums, or (2) showing innovation in meeting these standards and minimums in support of people and the environment.**

This is not a common definition of "sustainability," but it is a convenient way to think about it, and it is a way that relates well to business practice: going above and beyond and being innovative are long standing contributors to business success. The next section presents a few technical details that can help you understand sustainability and make it a part of a successful business.

Sustainability is about more than just doing the right thing and getting good business performance. It's about looking after our employees, protecting the environment, and engaging our communities — all of which enables us to work safely and effectively and provides us our license to operate.

— James H. Roberts, President & CEO, Granite Construction Inc.

The Technical Details of "Sustainability"

A Longer Definition

We just presented a practical definition, so in the interest of full disclosure here is the longer, more involved definition from the FHWA's Sustainable Pavements Program:

> The "sustainability" of a human-devised system is its ability to (1) exist and function within a larger system without degrading it, and (2) provide for and meet the human needs for which the system was developed. … Thus "sustainable" in the context of pavements refers to system characteristics that encompasses a pavement's ability to (1) achieve the engineering goals for which they were constructed, (2) preserve and (ideally) restore surrounding ecosystems, (3) use financial, human, and environmental resources economically, and (4) meet basic human needs such as health, safety, equity, employment, comfort, and happiness. (Van Dam et al., 2015)

It seems everyone wants to define "sustainability" in a slightly different way, which can be confusing. However, most definitions converge on the idea that "sustainability" is a concept that expresses a desire for human health and happiness within the context of a healthy planet over the long term. They also typically recognize the following:

- **Sustainability can be divided into three main dimensions: human, environmental, and economic**. These represent separate and sometimes competing concerns that are frequently termed the "triple bottom line."
- **Each dimension should be considered, but you need to set priorities**. While all three dimensions should be considered, sometimes you need to make one more important than the others based on the situation. In other words, when you get down to the nuts-and-bolts, you usually have to prioritize these dimensions rather than making them all equal. Consider what the National Park Services does: consider all three, but in some situations you prioritize ecosystems (think limited permits to raft the Grand Canyon) and in others you prioritize humans (think Old Faithful access).

The End Goal: A Sustainable Society

Our goal in pursuit of sustainability is to achieve a sustainable society: where we are all healthy and happy and living on a healthy planet. It is safe to say we have not achieved this yet. Certainly, in some form, our human activities are disrupting and degrading Earth's natural processes, and we fall short of meeting every human's basic needs. In 1989, Dr. Karl-Henrik Robèrt founded The Natural Step and provided a simple framework to define success in our pursuit of sustainability.

> In a sustainable society, nature is not subject to systematically increasing …
>
> 1. … concentrations of substances from the earth's crust (like fossil CO_2 and heavy metals).

2. … concentrations of substances produced by society (like antibiotics and endocrine disruptors).
3. … degradation by physical means (such as deforestation and draining of groundwater tables).

… and in that society …

4. … there are no structural obstacles to people's health, influence, competence, impartiality, and meaning. (The Natural Step, n.d.)

That is a lofty, but worthy, set of goals.

Implications

Given its definition and end goals, there are several characteristics of sustainability that are worth mentioning.

Sometimes it is necessary to take sustainable actions without immediate payback. Examples we have done include investing in warm-mix asphalt foaming equipment well before it was in specifications. Another is investing in preparing product EPDs well before they are required.

— Dan Gallagher, Executive Vice President, Gallagher Asphalt Corp.

Sustainability is a high-level strategy. Based on its definition, sustainability is the highest-level goal of an organization or project. It is not an add-on feature or something you can decide to do at the last minute. A typical starting point is with the business strategy itself (the economic dimension): simply put, a sustainable business strategy is one that allows the business to stay in business over the long term. But that only gets us part of the way there; we still must have happy and healthy people and a healthy planet.

Sustainability elevates the value of human and environmental health, and the long-term. Historically, these ideas have been given lower priorities when compared to first costs. However, evidence suggests there is substantial business value in (1) elevating environmental or social issues above what they used to be, and (2) considering impacts, costs, and benefits over the long term. Thus, while "sustainability" might mean "consider everything," these ideas (human/environmental health, long-term) are emphasized.

There are priorities and trade-offs within sustainability. There is rarely a perfect solution that addresses every part of sustainability. Therefore, an organization sets goals and strategies (for instance, goals for safety, conservation, employee health) that are an expression of (1) which parts of sustainability that organization particularly values, (2) an order of precedence for those values, and (3) a plan to turn those values into action. In other words, consider everything, study the trade-offs, do what makes good sense.

Sustainability depends on the context. Priorities will vary depending upon a business's or project's context. What makes good sense in one context may not in another. Sustainability needs to be customized; it's not a one-size-fits-all solution.

Sustainability implies improvement. We should not be satisfied with negative impacts from the infrastructure we build, operate, and maintain. While reducing the harm caused by infrastructure is an admirable first step, the ultimate goal is for infrastructure to actually improve society and the environment. We should get better, and the goal should not be to just "do less bad," the goal should be to "do good."

Sustainability goes beyond the bare minimum. Regulations and standard practice are the bare minimum. They can be untimely, heavy handed, and impractical, and are generally meant to address problems and laggards. They do not drive innovation. If improvement is the required action, sustainability demands that we do better than the minimum. If an industry can be collectively proactive and go beyond the minimum, sometimes it can avoid cumbersome regulations altogether.

Sustainability constantly evolves. What was once exceptional or innovative ultimately becomes standard practice and regulation. As minimum standards are raised, sustainability actions must improve to stay ahead.

Sustainability must create value. To be a viable approach, sustainability must create value over the long term. If it is only a cost, we will only do it when we can spare the money, time and effort. In short, it will be too low on our list of priorities.

Addressing Sustainability as a Business

Organizations choose to embrace sustainability for reasons ranging from responsibility (for example, a moral obligation to humanity, or a duty to the planet) to a required project feature (for example, a request for quotation (RFQ) that asks for sustainability qualifications), to business opportunity (increase revenue and/or reduce costs or risks). Ideally, they can do them all: improve human and environmental health, meet project requirements, and realize business opportunities.

Sustainability as Charity

Perhaps the most noble approach is to be more sustainable for the greater good of society; the "it's the right thing to do" argument. Much good has come from this approach, and it should be part of any organization or project. In general, this "greater good" reason, by itself, implies that impacts on humanity or the environment are the driving reason, while business impacts (good or bad) are not considered. Simply put, sustainability is charitable giving.

Sustainability as a Project Requirement

Owner agencies can and do ask for sustainability in asphalt pavement projects. This project sustainability can take several forms:

- **An evaluated "sustainability" or "environment" component on a best-value project**. Often, the pure sustainability portion, if present, of an RFQ is weighted somewhat lightly, or is rather open-ended.

- **Sustainability features required by specifications**. Examples include permeable pavement, minimum recycled content, safety/environmental training, stakeholder engagement, production quality control, and maximum working hours. Specified items are, obviously, mandatory, and are accounted for in contract price.
- **Sustainability features allowed by specification**. Examples include use of RAP and WMA. Generally, these are allowed by the owner and done only if they offer a business advantage to the contractor.

Motivation for the owner agency to ask for or allow sustainability features can be internal or external:

- **Internal: based on an owner's strategies and policies**. These often come from the public and are expressed in comprehensive plans or strategic plans. For instance, the City of Bothell, Washington, has a comprehensive plan (*Imagine Bothell…*) that states its sustainability vision in the introduction. This vision was used as motivation to pursue (and achieve) a Greenroads certification on its $15.2 million SR 522 Bothell Crossroads project in 2015.
- **External: based on requests/demands from stakeholders**. These often come from public or private organization requests. For example, the Washington State DOT included noise reduction features on its $1.34 billion SR 520 Floating Bridge and Landings project that went beyond regulatory requirements so that key stakeholders would support the project.

Sustainability as a Business Opportunity

Is sustainability really a business opportunity, or is it just charity? Well, a lot of writers think it is good business practice: a search for "business sustainability" on Amazon.com returns over 8,000 books. But beyond writers, actual businesses, including the best known in the world, address sustainability in a serious and direct way. Did you know:

- Microsoft achieved carbon neutrality in 2012. They claim their internal carbon fee — to hold business units accountable for emissions — saves them more than $10 million per year. In 2013, they published a free "playbook" to help other businesses do the same.
- Starbucks is committed to hiring 25,000 veterans and military spouses (by 2025), as well as 10,000 refugees (by 2022).
- In 2016 the Ford Rouge Center (factory complex in Dearborn, Michigan) achieved landfill-free status. They do not send *any* waste to landfill from there.
- Walmart's goal is to operate with 100% renewable energy. Their 2025 goal (18% reduction from 2015 levels) is approved by the Science Based Targets initiative and is in alignment with the Paris Climate Agreement.
- In 2016 and 2017 Apple issued $2.5 billion in green bonds to further its goal of operating with 100% renewable energy.

Certainly, these are large, global companies. But advocacy for sustainable business practices applies to all business sizes. Fremont Brewing, a local Seattle craft brewery, claims “activism through beer.” For instance, they use a zero-waste production that gives their spent grain (about 10,000 lbs/day) to a farmer for livestock feed. Bob Willard, in his 2012 book, *The New Sustainability Advantage*, identifies the basic business opportunities for sustainability:

1. **Increased revenue and market share**. For instance, Turner construction, the largest green building builder in the U.S., has long stated, “Building green is good for us, good for our clients, and the right thing to do.” According to *ENR*, their 2017 green contracting revenue was $5.5 billion (47% of their total revenue).
2. **Reduced expenses (energy, waste, materials, water, hiring/attrition)**. For instance, Astec Industries (Brock & Richmond, 2007) points out the expense reduction associated with the recovered virgin aggregate and liquid asphalt in RAP, which they show as over $5.00/ton in 2007 costs at 20% RAP.
3. **Increased employee productivity**. For instance, Pavia Systems and University of Washington research shows using Headlight®, a cloud-based mobile inspection platform, can improve inspector productivity by 25%.
4. **Reduced risks (strategic, operational, compliance, financial)**. For instance, Granite Construction uses its Granite Management System (GMS) to manage and reduce compliance, safety, and quality risks. Systems like these have helped Granite to be recognized by the Ethisphere Institute as one of the *World’s Most Ethical Companies* in 2018 for the ninth consecutive year.

Insights on the Business Case for Sustainability

While advocacy is important, evidence is more compelling. Remember Fremont Brewing? They get multiple wins from their sustainability decisions. For instance, they package most of their beer in cans because (1) cans contain more recycled content than bottles, (2) cans weigh less than bottles so transportation costs are less, (3) cans preserve beer better than bottles, and (4) cans cost less than bottles. Looking at business in general, evidence suggests (1) sustainability is more profitable, and (2) to reap the benefits, a business must be committed to sustainability.

Businesses that address sustainability tend to be more successful and more profitable. For example, three authors from the Harvard Business School (Eccles, Ioannou, & Serafeim) in a 2011 paper describe “Low Sustainability” firms as ones that address social and environmental issues primarily by adhering to regulation, while they describe “High Sustainability” firms as ones that pay attention to social and environmental issues beyond regulatory requirements. What they found was that “high sustainability” firms outperformed “low sustainability” ones in terms of both stock market and accounting measures, *but only in the long term* (see Figure 1). Sustainability is an advantage, but businesses and investors must be patient and in it for the long term.

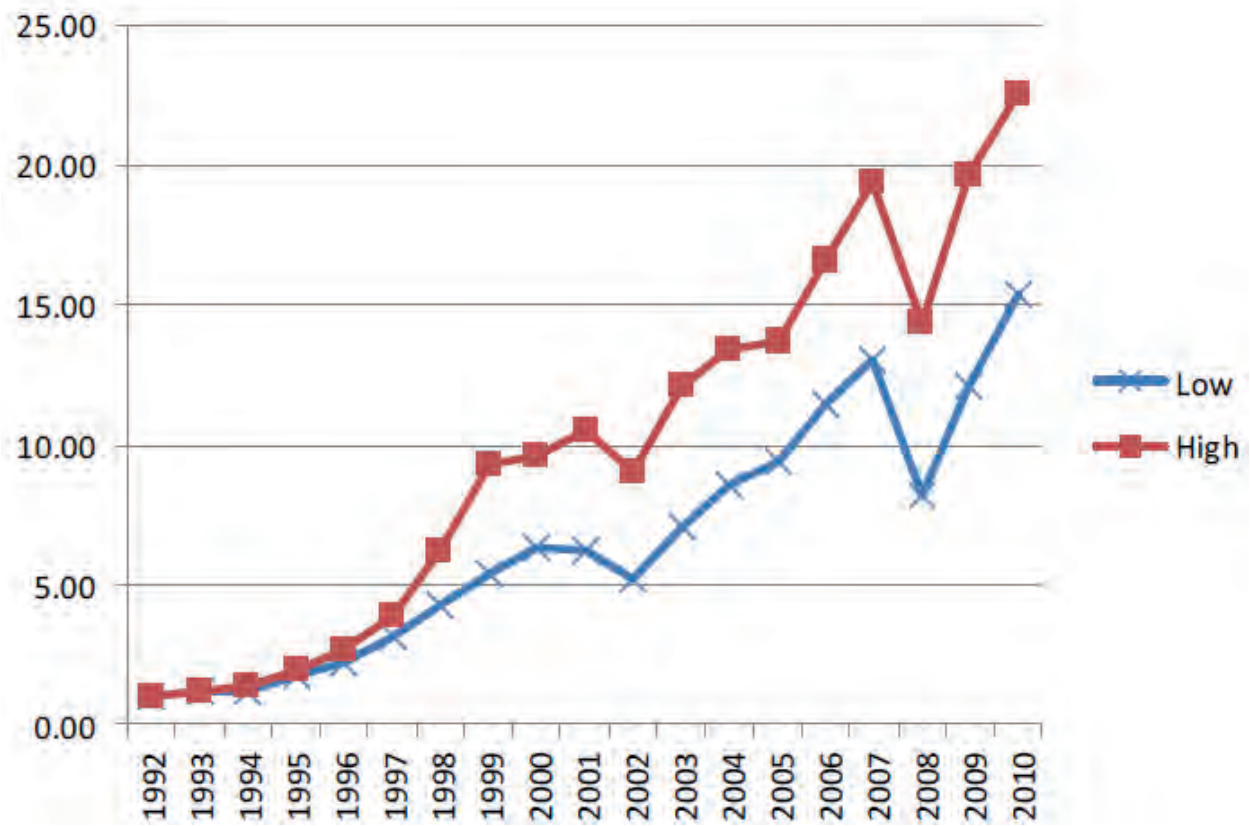

Figure 1. Evolution of $1 invested in the stock market in value-weighted portfolios (from Eccles, Ioannou & Serafeim, 2011).

Organizational culture is critical for sustainability commitment. Certain aspects of an organization's culture make a difference in an organization's commitment to sustainability. An Australian study (Pennington, 2014) found these to be: connectedness, proactive, environmental/social integrity, innovation and creativity, collaboration with stakeholders, and transparency and openness/trust. In other words, commitment to sustainability is rooted in an organization's culture: their collective values, beliefs, and principles. It is not enough to advertise a commitment to sustainability through procedures and marketing.

Summary

"Sustainability" refers to the idea of meeting human needs while maintaining a healthy planet over the long term. A simple way to translate this idea to your business and/or project actions is that "sustainability" asks you to (1) go above-and-beyond the standard/minimum, or (2) show innovation in meeting standards/minimums. This means sustainability implies improvement, constantly evolves, and its specifics depend on the situation. For a business, sustainability efforts must create value, otherwise we will only do it in the best of times: when we have the money, time, and effort to give.

In the asphalt industry, one may encounter sustainability as charity (doing it for the “greater good” regardless of the bottom line), a project requirement asked for by an owner (asked for in a contract, or required/allowed by specification), or a business opportunity.

As charity, sustainability is essentially a donation. It may be support for a particular non-profit organization, volunteer work, or community involvement. Most view this type of work as rewarding, fulfilling, and an essential component of a business that is a good member of the community.

As a project requirement, sustainability may be asked for by the owner on a specific project. This is often through RFQ language and/or specifications. In these cases, it is beneficial to be current and credentialed with sustainability rating systems, or other third-party standards to lend credibility to your claimed expertise.

As a business opportunity, sustainability can (1) increase revenue and market share, (2) reduce expenses, (3) increase employee productivity, and (4) reduce risks. Addressing sustainability also helps a business align itself with the long-term interests of its stakeholders. There are many examples of the best-known companies in the world dedicating substantial resources to sustainability efforts. There are also many examples of how it can and is being done in the asphalt industry. There is also some pretty compelling evidence that businesses that address sustainability tend to be more successful and profitable over the long term.

In sum, these are compelling arguments for a business or project to address sustainability. But there is a catch in realizing the benefits: you must mean it. It is not enough to advertise a commitment to sustainability if the business or project culture does not embrace it at every level.

In recent years the industry has recognized and made improvements in environmental, safety and business performance by learning more about sustainable concepts. The next step for the industry is to plan a path to a net zero footprint with reasonable expectations in terms of timing. Not long ago I would have thought it may be 50–100 years in the future, but today I believe it will be much sooner because of rapid advancements in technology.

— **Craig Parker**, Executive VP
Silver Star Construction Co., Inc.

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Sustainability in Practice 102

Sustainable Asphalt Pavements: A Practical Guide

Sustainability Specifics

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SIP 102: Sustainability Specifics

"Sustainability" refers to the idea of meeting human needs while maintaining a healthy planet over the long term. A simple way to think of this is to: (1) go above and beyond the standard/minimum or (2) show innovation in meeting standards/minimums. If you believe there is business value in sustainability (the first document in this series, *SIP 101: Sustainability Overview*, addresses why we think there is), then the next step is to put belief into action.

This document describes specific sustainable practices at the corporate/organizational, project delivery, and project levels that can be implemented using today's technology and know-how. Put another way, this document is a catalogue of sustainable practices. Think of it like an "idea book" for home remodeling, or, if you're into it, a Pinterest page for sustainability. Use it as a source of inspiration to guide you in identifying sustainable practices you want to put into action or to help you recognize ones you may already be doing. Each sustainable practice is detailed with enough information to define it, reasons it might be a good idea to consider, and a key resource or two that more fully explains the concept.

As with any idea book, not all these sustainable practices will be appropriate for every company or every project. We are relying on your expertise and knowledge to determine which ideas work best for your situation and how they might best be practiced.

This document organizes sustainable practices into the following main categories:

1. **Corporate/Organizational.** Sustainable practices at the corporate or organization level.
2. **Project Delivery.** Sustainable practices that can be required, incentivized, or included in project procurement and contracting.
3. **Materials Production.** Sustainability ideas that can be accomplished in materials production. These are often ideas that are not required by a project, but make good business sense to do anyway, so long as they are allowed.
4. **Construction.** Sustainability ideas for pavement construction. Many are ideas for project requirements that improve quality or provide greater flexibility to the contractor to be efficient. Many are also items not covered by contractor requirements that make good business sense to do.
5. **Pavement Design.** Pavement designs with sustainability implications. Design methods are not addressed in detail.

For each sustainable practice in this document you will see:

- **Summary.** A brief overview of the idea and why it might be worthwhile to pursue.
- **Motivation.** The potential motivations for using the sustainable practice. This is limited to three categories:
    - *Goodwill.* Friendly, helpful, or cooperative practices generally done by organizations as part of their community involvement efforts.

    - *Project requirement.* Practices required by a project that likely represent an expense for the contractor that must be reimbursed by the owner. These are generally sustainable practices where the contractor incurs expense (for example, building an open-graded friction course), but does not directly get the benefits (reduced splash and spray, better friction, lower tire–pavement noise).
    - *Business opportunity.* Practices that can result in increased revenue or market share, reduced expenses, increased employee productivity, or reduced risks. Often, these items are not required by contract, but may be done by contractors so long as they are allowed.

- **Reference.** One or more key references that best describes the practice and its benefits.

"Cost" is often not addressed because it is highly dependent upon a project or company's context, it can be difficult to directly quantify, it has never been quantified, or the associated benefits are poorly quantified.

1. Corporate/Organizational

Sustainability starts at the corporate and management level. As with most things in a business, strong support from management is essential to success. In other words, a company or organization must really want to do it and support it through its values, beliefs, principles, and actions. This section addresses organizational actions in support of sustainability, but does not address general values, beliefs, and principles, which are covered in a lot of general writing on sustainability. Specifically, this section overviews corporate/organizational sustainability in two broad categories: general goodwill and management, policies, and programs.

1.1 General Goodwill

As goodwill (or charity), sustainability is essentially a donation for the greater good. Much corporate goodwill in the asphalt industry focuses on community involvement: being a generous, caring, and contributing member of the community. NAPA's Community Involvement Award annually recognizes outstanding programs in community relations. Integral to this award and company goodwill in general are (1) help to multiple groups and/or focus areas and (2) employee participation. In general, goodwill often involves:

- **Charitable donations, fundraising, volunteering, and leadership.** For example, matching employee donations with equal company donations, providing staffing and financial support to charitable events, purchasing school supplies for those in need, veteran support, scholarship programs, blood drives, serving on non-profit boards.
- **Local community events.** For example, running open houses, sponsoring community events (barbeques, celebrations, carnivals).

- **Materials/expertise for community projects.** For example, donating materials and construction expertise for a community pathway or sport court, fixing/upgrading non-profit equipment and space, and assisting Habitat for Humanity with materials and labor.
- **Education/mentoring programs.** For example, participating in school career days, internship programs, donating hours for elementary school tutoring, donating hours to local Boys & Girls Clubs.

Goodwill is integral to community relations both personally and professionally. The choice of how to express this goodwill is up to each individual and the company for which they work. While goodwill may create a positive image for the company and can increase employee morale, it seems that the choice of engaging in goodwill is genuine: the main reason for doing it is the positive impact it has on the community.

Impacts on Sustainability:

- Workers
- Neighbors & Stakeholders
- Pollution
- Local Ecosystem & Habitat
- Economic Development/Employment

1.2 Management, Policies, and Programs

Meaningful management, policies, and programs are what give definition to an organization's commitment to sustainability. By themselves, they do little to ensure successful sustainability efforts; however, they provide the high-level direction and commitment needed to focus an organization's efforts.

Impacts on Sustainability:

- Workers
- Pollution
- Local Ecosystem & Habitat
- Consumption
- Climate
- Project Budget
- Maintenance & Operations
- Economic Development/Employment

1.2.1 Include Sustainability in Organizational Mission

At the highest level, sustainability ought to be included in an organization's mission if it is to be taken seriously by the organization. Many organizations have aspects of sustainability mentioned in their mission, vision, and values, but have not yet incorporated "sustainability" as a specific term.

Motivation

- Business Opportunity
- Project Requirement

The following pages include examples of how sustainability shows up in organizational vision, mission, and value statements on the websites, annual reports, and other materials of four organizations associated with the asphalt pavement industry: Washington State Department of Transportation, construction and building materials company CRH PLC, construction and construction materials company Granite Construction Inc., and civil infrastructure project company Salini Impregilo S.p.A.

Washington State Department of Transportation (WSDOT)

CRH PLC

CRH Annual Report and Form 20-F | 2017

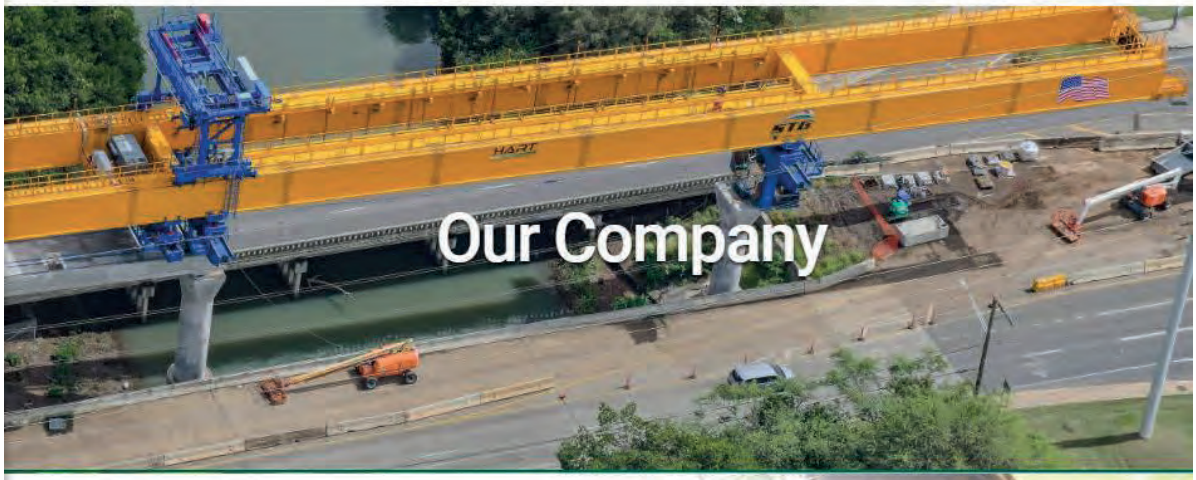
Sustainability

Achieving long-term success through sustainability

We believe that a strong sustainability performance is fundamental to achieving our vision of becoming the leading building materials business in the world. As part of our strategy to maximise long-term value and deliver superior returns, we embed sustainability principles in all areas of our business. As we deliver on our strategy, we have a unique opportunity to contribute to some of the key sustainable development challenges facing society.

Granite Construction Inc.

GRANITE™



Sustainability

The work we do today will have an impact on countless future generations—and we don't take the responsibility lightly. We follow a comprehensive approach to sustainability, one that reduces our environmental impact and fosters positive community interactions in all aspects of our business. It is our instinct to constantly seek out new solutions and to create meaningful and sustained change today, tomorrow and for years to come.

Read More >

Salini Impregilo S.p.A.

1.2.2 Corporate Sustainability Reporting

The Global Reporting Initiative (GRI) describes a sustainability report (a.k.a. a Corporate Social Responsibility — CSR — report) as "… a report published by a company or organization about the economic, environmental, and social impacts caused by its everyday

activities. A sustainability report also presents the organization's values and governance model and demonstrates the link between its strategy and its commitment to a sustainable global economy." This sort of report also serves as a focal point in the management of sustainability efforts and a tool for communicating sustainability performance and impacts. The Governance & Accountability Institute reports that in 2017 82% of S&P 500 companies did some form of sustainability reporting; however, the GRI (2008) states that sustainability reporting is not as well established in the construction sector.

The most popular standards for sustainability reporting are from the GRI, the Sustainability Accounting Standards Board (SASB), and the International Integrated Reporting Council (IIRC). GRI, at about 80% of the market, is the dominant sustainability standards resource across all industries and continents.

Motivation

- Business Opportunity
- Project Requirement

Reference

GRI (2008). A Snapshot of Sustainability Reporting in the Construction and Real Estate Sector. Global Reporting Initiative, Amsterdam, Netherlands.

Global Reporting Initiative. www.globalreporting.org

International Integrated Reporting Council. integratedreporting.org

Sustainability Accounting Standards Board. www.sasb.org

1.2.3 Greenhouse Gas Reporting

Independent of CSR reporting, tracking greenhouse gas (GHG) emissions can be a proactive way of managing environmental risk and energy use. GHG reporting should be done to a commonly accepted standard, such as that described by The Climate Registry or CDP (the Carbon Disclosure Project). These organizations offer toolkits and step-by-step processes for GHG reporting. NAPA also offers a free GHG calculator for asphalt plants that uses emission factors from The Climate Registry.

Motivation

- Goodwill
- Business Opportunity

Reference

CDP Worldwide. www.cdp.net/en

NAPA GHG Calculator. www.asphaltpavement.org/GHGC

The Climate Registry. www.theclimateregistry.org

1.2.4 Management Systems

Actively manage efforts that affect sustainability. Quality, safety, and environmental-management systems have been in existence for decades and provide a systematic way to define, measure, improve, and document these important considerations. The International Organization for Standardization (ISO) provides standards for these types of management systems and a certification process. Sustainability management systems are a new concept with little formal guidance.

Motivation

- Business Opportunity
- Project Requirement

Reference

ISO 9001 Quality Management Systems

ISO 14001 Environmental Management Systems

ISO 45001 Occupational Health and Safety Management Systems

BS OHSAS 18001 Occupational Health and Safety Assessment Series

1.2.5 Employee Assistance and Rewards

Employee assistance and reward programs contribute to their well-being. Some practices include:

- Employee development, retention, and education programs.
- Targeted hiring for minority contractor employees near a job.
- Hiring low-risk formerly incarcerated people and supporting pre-training.
- Healthy living programs (exercise, produce buying, etc.).
- Employee assistance programs, such as suicide prevention programs.
- Share bonuses.

Motivation

- Business Opportunity
- Project Requirement

Reference

Construction Industry Alliance for Suicide Prevention. pages.cfma.org/alliance-interest

1.2.6 Recycling Program

Recycling of reclaimed asphalt pavement (RAP), lead–acid batteries, used oil, and spent solvents is very common in the asphalt industry. But some companies overlook more common office materials, such as cardboard, paper, bottles & cans, food waste (composting), and common dry-cell batteries. An office recycling program can help reduce waste disposal costs, reduce GHG emissions, and establish sustainability as a core part of corporate culture.

Motivation

- Business Opportunity

Reference

EPA (2018). *Managing and Reducing Wastes: A Guide for Commercial Buildings*. U.S. Environmental Protection Agency, Washington, D.C. www.epa.gov/smm/managing-and-reducing-wastes-guide-commercial-buildings

1.2.7 Establish a Wildlife Conservation Area

Commercial and industrial facilities can designate a portion of their property to benefit wildlife. This can be as extensive as a woodland reserve, which can also help screen the facility from neighboring properties, or as small as pollinator gardens outside an office. Programs managed by the Wildlife Habitat Council, the National Wildlife Federation, the Audubon Society, and similar organizations can certify wildlife conservation areas. For example, Preferred Materials Inc.'s Winter Springs, Florida, Asphalt Plant earned a 2013 Wildlife at Work certification (re-certified in 2015) from the Wildlife Habitat Council for its 8-acre wildlife habitat site, where they restored approximately 2.5 acres of the property to a wildflower meadow and pollinator gardens.

Motivation

- Goodwill

Reference

National Audubon Society. www.audubon.org

National Wildlife Federation. www.nwf.org

North American Butterfly Association. nababutterfly.com

Wildlife Habitat Council. www.wildlifehc.org

1.2.8 Recognize Sustainability Efforts

Recognition for sustainability efforts can range from individual appreciation for a single act to certification of an organization or project by an independent third party. Several sustainability rating systems offer independent third-party certification for projects, and the NAPA awards program specifically honors key sustainability values: quality, safety, community involvement, and ecology. NAPA's Diamond Achievement Sustainable self-certification provides a framework for assessing and documenting sustainable activities at asphalt plants.

Motivation

- Business Opportunity
- Project Requirement

Reference

Envision v3. www.sustainableinfrastructure.org

Green Globes v1.5. www.thegbi.org/green-globes-certification

Greenroads Rating System v2. www.greenroads.org

INVEST v1.3. www.sustainablehighways.org

LEED v4. new.usgbc.org/leed

NAPA Diamond Commendation Program. www.asphaltpavement.org/diamond

NAPA Operational Excellence Awards Program. www.asphaltpavement.org/awards

2. Project Delivery

"Project delivery" refers to procurement, contracting, and delivery methods used for a project. For the purposes of this document, project delivery is limited to practices directly related to paving projects and contractors. More general project delivery sustainable practices, such as public private partnerships (PPPs or P3s) used for project financing and the use of alternative contracting, are not addressed.

2.1 Procurement

"Procurement" is the purchasing process for projects. Sustainability can be a project component that is directly assessed during procurement, or provisions can be made to accept alternate designs to improve performance and save money. Document three in this series, *SIP 103: Procuring & Evaluating Sustainability*, goes into greater detail about sustainability and the project procurement process.

Impacts on Sustainability

- Neighbors & Stakeholders
- Users
- Pollution
- Local Ecosystem & Habitat
- Consumption
- Climate
- Project Budget
- Maintenance & Operations

2.1.1 Include Sustainability in Best-Value Procurement

Best-value procurement is a procurement process where factors beyond initial price are considered in contractor selection. These factors can include schedule, financial requirements, contractor past experience/performance, safety record, key personnel, small business participation, subcontractors, management plan, quality management, design alternates, technical proposal, and environmental considerations. They rarely include sustainability as a defined evaluation criterion. While "environmental considerations" is close, it usually refers to methods of meeting environmental regulatory requirements only. If

defined well (see work in NCHRP Project 10-91A), sustainability could be included as a separate evaluation category in a best-value procurement process and, therefore, become part of the project selection criteria.

Motivation

- Project Requirement

Reference

Molenaar, K.R., N. Sobin, & E.I. Antillón (2010). A Synthesis of Best-Value Procurement Practices for Sustainable Design-Build Projects in the Public Sector. *Journal of Green Building*, Vol. 5, No. 4, pp. 148–157. doi:10.3992/jgb.5.4.148

Scott III, S., K.R. Molenaar, D.D. Gransberg, & N.C. Smith (2006). *NCHRP Report 561: Best-Value Procurement Methods for Highway Construction Projects*. Transportation Research Board of the National Academies, Washington, D.C.

2.1.2 Alternative Technical Concepts (ATCs)

A request by a project proposer (contractor, design–build team, etc.) to modify a contract requirement. Typically, an ATC must be of equal or better value than the original contract requirement, and it is often done to reduce project price or complexity to the benefit of the proposer (competitive advantage during bidding or money savings during construction) and owner (money savings). ATCs are most frequently used in design–build project delivery, but have also been successfully used in design–bid–build project delivery. Key ATC issues are: (1) confidentiality of the proposed ATCs (protecting them from public disclosure), (2) design liability arising from ATCs, (3) minimizing protest risk from a non-traditional procurement feature, and (4) who owns ATCs submitted by non-winning bidders. The key sustainability feature in ATCs is getting contractor involvement in a project's design.

Motivation

- Business Opportunity
- Project Requirement

Reference

Gransberg, D.D., M.C. Loulakis, & G.M. Gad (2014). *NCHRP Synthesis 455: Alternative Technical Concepts for Contract Delivery Methods*. Transportation Research Board of the National Academies, Washington, D.C.

2.1.3 Alternate Design/Alternate Bid (AD/AB)

AD/AB is a method where alternative pavement designs (nearly always asphalt and concrete) can be bid for the same project. Sometimes, a life-cycle adjustment factor is applied to the bid based on predicted future maintenance and rehabilitation costs. A construction schedule bidding component (for example, A+B bidding) is also sometimes considered to account for different construction times. The general sentiment is that AD/AB may increase competition and provide cost savings (Gransberg et al., 2017). However, to ensure best value, it is critical that alternative pavement designs be functionally equivalent

and that inputs for a life-cycle adjustment factor (if used) be based on high-quality, performance-based data.

Motivation

- Project Requirement

Reference

Epps, J.A., & D.E. Newcomb (2015). *Considerations and Case Studies in Rapid Highway Construction Using Asphalt Pavements*. Texas A&M Transportation Institute, Texas A&M University, College Station, Texas.

Gransberg, D.D., A. Buss, I. Karaca, & M.C. Loulakis (2017). *NCHRP Synthesis 499: Alternate Design/Alternate Bid Process for Pavement-Type Selection*. Transportation Research Board of the National Academies, Washington, D.C.

2.2 Contracting

"Contracting" refers to the written agreement to design/build a project. Certain provisions can be made in the contract that improve a contractor's flexibility in employing resources, increase productivity and safety on the job, elevate sustainability to a managed element of the contract, reduce work zone user delays, and make environmental impacts more transparent.

Impacts on Sustainability

- Workers
- Neighbors & Stakeholders
- Users
- Pollution
- Consumption
- Climate
- Project Budget
- Maintenance & Operations
- Economic Development/Employment

2.2.1 Productivity

Practices that improve productivity can have a significant effect on project sustainability, particularly in terms of reducing the length and timing of road closures, which helps minimize user delay and other traffic impacts.

2.2.1.1 Flexible Start Time

A contract provision that allow the contractor to choose the construction start date within given limits. For instance, the Florida DOT normally requires a contractor to begin work within 15 days of receiving notice to proceed (NTP), but with a flexible start that date may be extended (usually up to 100 days). A flexible start date can allow the contractor to more

efficiently use workforce, equipment, and subcontractors across a variety of projects. Owner requirements to coordinate multiple projects and other factors may limit flexible start options.

Motivation

- Business Opportunity
- Project Requirement

Reference

Caltrans (2018). Section 3-803B. *Construction Manual*. California Department of Transportation, Sacramento, California.

WSDOT (2018). Flexible Start Date. Washington State Department of Transportation, Olympia, Washington. www.wsdot.wa.gov/Projects/delivery/alternative/FlexibleStart.htm

2.2.1.2 Full-Road Closure

Using full-road closures for roadway work zones can result in positive public sentiment, better productivity, improved safety, reduced project duration and, in some cases, cost savings (FHWA, 2003). Longer individual closures (either partial or full), but fewer overall closures may achieve similar results in some circumstances. The Rapid Road Rehabilitation (R3) suite of scoping tools (formerly CA4PRS) can be used to quickly estimate productivity and traffic impacts for multiple closure scenarios.

Motivation

- Business Opportunity
- Project Requirement

Reference

Caltrans (2018). Construction Analysis for Pavement Rehabilitation Strategies: Caltrans "Rapid Rehab" Software. California Department of Transportation, Sacramento, California. www.dot.ca.gov/newtech/roadway/ca4prs/

FHWA (2003). Full Road Closure for Work Zone Operations: A Cross-Cutting Study (FHWA-OP-04-009). Federal Highway Administration, Washington, D.C.

2.2.2 Sustainability Measurement and Tracking

Most state DOTs have language that refers (either directly or indirectly) to sustainability as a value. Sustainability becomes a manageable practice once it is consistently measured. Absent formal tracking or accountability, sustainability for a project or organization becomes something between (1) a low-priority task and (2) a series of carefully selected, unverifiable stories. Document three in this series, *SIP 103: Procuring & Evaluating Sustainability*, goes into greater detail about measuring sustainability efforts.

2.2.2.1 Rating Systems

Sustainability rating systems can (1) identify appropriate sustainable practices, (2) provide independent third-party verification of sustainability efforts, (3) measure and manage sustainability efforts, and (4) communicate sustainability efforts to project stakeholders.

Usually, it is beneficial to have staff trained and accredited by a rating system before using it. Often this can be worth points within the rating system. Rating systems typically used in the U.S. are: Envision, Greenroads, and INVEST, as well as LEED and Green Globes (both building rating systems). The following table lists prominent U.S. rating systems, and how they address asphalt pavements.

	Envision v2	Greenroads v2	Green Globes v1.5 for NC	INVEST v1.3 PD only	LEED v4 BD+C NC
Type of Rating System	Infrastructure	Road	Building	Road	Building
Third-Party Certification Available	Yes	Yes	Yes	No	Yes
Total Points Available	809	130	1,000	171	110
Total Pavement-Related Points	247	63	31	61	19
Fraction of Points for Pavements	31%	48%	3%	36%	17%

Motivation

- Business Opportunity
- Project Requirement

Reference

Envision v3. www.sustainableinfrastructure.org

Green Globes v1.5 for NC. www.thegbi.org/green-globes-certification

Greenroads v2. www.greenroads.org

INVEST v1.3. www.sustainablehighways.org

LEED v4 BD+C NC. new.usgbc.org/leed

NAPA (2018). *Asphalt Pavements and LEED v4: Credits and Opportunities* (SIP 001). National Asphalt Pavement Association, Lanham, Maryland.

2.2.2.2 Sustainability Management Plan

A written plan to manage quality. As of this publication, sustainability management plans are uncommon in the road industry, but may emerge as a reasonable way to consolidate and document contractor sustainability requirements, efforts, and results. Essential elements of a sustainability management plan are:

1. Designated contractor representative responsibility for sustainability.
2. Statement of major sustainability goals of the project (in terms of aspects of sustainability that are a priority).
3. Description of project sustainability features. These should address the goals in #2 and should be clearly identified to the project team.

4. Procedure to follow when a sustainability feature (identified in #3) is changed or eliminated. This may include permission from project management, written documentation, or something simpler, such as an information-only process.
5. Short set of metrics by which the project can be judged for sustainability efforts. These should be directly related to #2 and #3.
6. Monthly reports/submittals from the contractor that report metrics from #4, any sustainable practices addressed in the previous month (for example, 2,500 tons of open-graded friction course placed) and provide explanations for any sustainable practices removed via change order or not accomplished.
7. Final report/submittal that summarizes the contractor's sustainability performance on the project and provides final results from the #4 metrics.

Motivation

- Project Requirement

2.2.3 Reduce User Delay

User delay can be a major contributor to overall project financial impact, especially in congested urban areas where the cost of work zone user delays can easily exceed the contract price of the work. Reducing user delay by accelerating construction can be incentivized in contracting. The major impacts of doing this are (topics from Fick et al., 2010):

- **Cost.** Accelerated construction generally costs more. Contractors typically spend more to achieve an incentive. Therefore, achieving the incentive is important to the profitability of the project.
- **Contract time measurement.** If payment is linked to faster completion, contract time measurement and adjustments for excusable delays have added importance.
- **Staffing.** Accelerated construction generally requires more working hours per day/week which contributes to mental and physical fatigue.
- **Quality.** Incentives for construction speed may compromise quality if time must be sacrificed for quality.
- **Safety.** While safety standards are not compromised for construction speed, fatigued staff could be compromised.

LaMondia et al. (2018) highlights ways to calculate a total work zone impact cost, which includes user delay costs, crash mitigation costs, and local business impact costs. Quantification of these kinds of impacts can be used as supporting evidence for accelerated construction or A+B bidding or incentives/disincentives to reduce construction time.

Accelerated construction is typically measured against a baseline determined by the owner, so faster contractor construction may be a result of an owner-offered incentive, or it may reflect a conservative baseline set by the owner. This section addresses A+B bidding and incentives/disincentives, but there are many other similar methods for the owner to

communicate to the contractor that they are willing to pay a premium for accelerated construction.

Reference

Fick, G., E.T. Cackler, S. Trost, & L. Vanzler (2010). *NCHRP Report 652: Time-Related Incentive and Disincentive Provisions in Highway Construction Contracts*. Transportation Research Board of the National Academies, Washington, D.C.

LaMondia, J., M. Fisher, R. Turochy, & W. Zech (2018). *Calculating Road User, Crash Mitigation and Local Business Impact Costs Generated by Pavement Rehabilitation, Maintenance and Other Roadway Reconstruction Projects*. Auburn University, Auburn, Alabama.

2.2.3.1 A+B Bidding

A bidding method that places a cost on the duration of a project or portion of a project. An A+B bid contains the contract price (item A) as well as a time to complete the contract. This time is converted to a monetary value (item B) and the overall bid is evaluated as the total cost of the contract plus the time cost (A+B). This method places value on project duration (which impacts roadway user costs) and often results in (1) shorter project durations than estimated by the owner and (2) somewhat higher costs than those associated with a standard schedule (Minchin Jr. & Chini, 2016). A+B bidding has a greater impact when user delay is a major cost, such as in urban areas or major freight corridors, and works best with an associated incentive/disincentive clause based on actual construction duration vs. the contractor's promised duration in the bid.

Motivation

- Business Opportunity
- Project Requirement

Reference

Anderson, S.D., & J.S. Russell (2001). *NCHRP Report 451: Guidelines for Warranty, Multi-Parameter, and Best Value Contracting*. TRB, National Research Council, Washington, D.C.

Epps, J.A., & D.E. Newcomb (2015). *Considerations and Case Studies in Rapid Highway Construction Using Asphalt Pavements*. Texas A&M Transportation Institute, Texas A&M University, College Station, Texas.

Minchin Jr., R.E., & A.R. Chini (2016). *Alternative Contracting Research: Final Report* (FDOT Contract Number BDV31-977-40). Florida Department of Transportation, Tallahassee, Florida.

WSDOT (2018). A+B Bidding. Washington State Department of Transportation, Olympia, Washington. www.wsdot.wa.gov/Projects/delivery/alternative/

2.2.3.2 Lane/Ramp Rentals or Charges

A bidding method where charges for closing a lane or ramp are established by the owner and deducted from contractor revenues. Either the contractor is paid for an estimated lane

rental amount and then actual lane rental is deducted from revenues, or lane/ramp rental/charges can be included as a contract pay item.

Motivation

- Business Opportunity
- Project Requirement

Reference

Anderson, S.D., & J.S. Russell (2001). *NCHRP Report 451: Guidelines for Warranty, Multi-Parameter, and Best Value Contracting*. TRB, National Research Council, Washington, D.C.

Fick, G., E.T. Cackler, S. Trost, & L. Vanzler (2010). *NCHRP Report 652: Time-Related Incentive and Disincentive Provisions in Highway Construction Contracts*. Transportation Research Board of the National Academies, Washington, D.C.

Minchin, R.E., & A.R. Chini (2016). *Alternative Contracting Research*. FDOT Contract Number BDV31-977-40. FDOT, Tallahassee, Florida.

2.2.3.3 Incentives and Disincentives to Reduce Construction Time

Contractual incentives and disincentives (I/D) are commonly used to encourage early project completion and minimize user delay cost. Standard practice usually involves (1) incentives to finish early and (2) disincentives (penalties or liquidated damages) for finishing late.

Motivation

- Business Opportunity
- Project Requirement

Reference

Fick, G., E.T. Cackler, S. Trost, & L. Vanzler. (2010). *NCHRP Report 652: Time-Related Incentive and Disincentive Provisions in Highway Construction Contracts*. Transportation Research Board of the National Academies, Washington, D.C.

LaMondia, J., M. Fisher, R. Turochy, & W. Zech (2018). *Calculating Road User, Crash Mitigation and Local Business Impact Costs Generated by Pavement Rehabilitation, Maintenance and Other Roadway Reconstruction Projects*. Auburn University, Auburn, Alabama.

2.2.4 Environmental Product Declarations (EPDs)

A concise, verified eco-label for a product (for example, an asphalt mixture) that quantifies its key environmental impacts, an EPD is a declared life cycle assessment (LCA) that follows a standard process, called a product category rule (PCR). The NAPA Emerald Eco-Label EPD tool provides asphalt mixture producers a way to quantify their environmental impacts with a verified EPD. While EPDs are relatively new to the paving industry, their use is likely to increase as rating systems award points for their use and owners investigate ways to use them. As of 2019, the industry is still working through EPD issues and best uses. Some have started to use the

Emerald Eco-Label Tool to evaluate and optimize the environmental impacts of raw material supply chains and plant operations.

Motivation

- Business Opportunity
- Project Requirement

Reference

Harvey, J.T., J. Meijer, & A. Kendall (2014). *TechBrief: Life Cycle Assessment of Pavements* (FHWA-HIF-15-001). Federal Highway Administration Washington, D.C.

Harvey, J.T., J. Meijer, H. Ozer, I.L. Al-Qadi, A. Saboori, & A. Kendall (2016). *Pavement Life Cycle Assessment Framework* (FHWA-HIF-16-014). Federal Highway Administration, Washington, D.C.

NAPA Emerald Eco-Label EPD tool. www.asphaltepd.org

2.2.5 Anti-Idling Specifications and Policies

Many states have regulations that limit engine idling (a 2006 EPA accounting lists 30 states and D.C.) and many construction contracts have similar limits; however, the federal government does not. Typical maximum allowed idle times are 15 minutes or less. Equipment idling uses fuel and emits pollution while the equipment is not engaged in productive work. It also accelerates engine wear and shortens warranty coverage. In operations involving queuing (for example, asphalt mix delivery trucks) short allowable idle times can actually increase fuel use and emissions because of the delays and reduced production associated with stopping and starting equipment (Abbasian-Hoseini et al., 2016). In these cases, it is better to exempt queuing and similar tasks (for example, trucks waiting to offload asphalt mix) from anti-idling specifications. Companies located in regions without mandatory anti-idling regulations can develop and implement their own anti-idling policies.

Motivation

- Business Opportunity
- Project Requirement

Reference

Abbasian-Hosseini, S.A., M.L. Leming & M. Liu (2016). Effects of Idle Time Restrictions on Excess Pollution from Construction Equipment. *Journal of Management in Engineering*, Vol. 32, No. 2. doi:10.1061/(ASCE)ME.1943-5479.0000408

EPA (2006). *Compilation of State, County, and Local Anti-Idling Regulations* (EPA420-B-06-004). U.S. Environmental Protection Agency, Washington, D.C.

Jackson, T. (2014). Creating an Anti-Idling Policy. *Equipment World*, Vol. 26. No. 4, pp. 51–52. www.equipmentworld.com/how-to-save-money-protect-equipment-by-creating-an-anti-idling-policy-at-your-construction-company/

3. Materials Production

"Materials Production" refers to raw materials, processes, and equipment associated with the production of asphalt mixtures. For the purposes of this document, materials production is limited to aggregates, recycled materials, and hot- and warm-mix asphalt, as these are the materials most paving contractors produce. Similar to other construction materials, energy consumption and emissions are important considerations in asphalt mixture production. Asphalt pavements have been successfully recycled back into new asphalt pavements since the 1970s. This requires careful mix design and quality control to assure good mix performance. Both conventional and specialty asphalt mixtures can be produced to offer many sustainable benefits. Several of the items described in this section reduce environmental impacts as measured by EPDs.

3.1 Energy and Emissions

In the future, asphalt plants are expected to continue a long-term trajectory of becoming more fuel-efficient while producing less emissions. Today energy and emissions are key considerations in material production at asphalt plants. Using RAP, managing moisture in aggregates and RAP, and plant management with a focus on energy consumption are all important sustainability considerations.

Impacts on Sustainability

- Neighbors & Stakeholders
- Consumption
- Climate
- Budget
- Worker Safety
- Maintenance & Operations

3.1.1 Aggregate Moisture

Reducing the moisture content of the aggregates and RAP fed into a hot plant is an effective means of reducing production costs and increasing the production rate for materials with relatively high moisture, like washed fine aggregates and RAP. It takes about 24,000 Btus to remove 1% moisture from 1 ton of aggregate. Methods available for reducing moisture include grading and paving under stockpile areas, covering stockpiles, and taking material from stockpiles 2 to 3 feet above the bottom of the pile where moisture collects. For every 1% reduction in moisture content, drying cost is reduced by slightly more than 10%, and the plant production rate can be increased by over 10%. If aggregate/RAP blend moisture is reduced by 2% at a plant with a drying cost of $2.50/ton, the cost savings is $50,000 per 100,000 tons of production. Also, increasing productivity at the plant can often increase productivity at the jobsite during periods of peak production.

3.1.1.1 Grading, Paving Under, and Covering Stockpiles

Grading with a slope of about 4% under a stockpile of aggregate or RAP will promote drainage away from the face of the stockpile from which material is being fed to the plant. Paving will accelerate the rate of drainage, reduce standing water, and prevent it from wicking up into the stockpile. With graded and paved stockpile areas, maintenance and equipment operating costs will be reduced also. Subgrade compaction before paving is critical to success as any subsidence (due to the weight of stockpiles or otherwise) could cause water pooling in localized low points beneath stockpiles. With a 2% reduction in moisture at a typical asphalt plant producing 300,000 tons annually, the cost savings from using drier aggregates could amount to about $150,000, depending on the fuel cost. If it costs $50,000 to grade and pave a stockpile area, this cost would be recovered within a fraction of a year.

Covering stockpiles is more costly; it takes about three years to recover the cost of the investment. Therefore, covering is normally only done for RAP and fine aggregates that are not free draining, especially in locations where rain is common. Examples of covers include open metal or pole buildings, simple trusses, and fabric-roof structures. It is important for air be able to move in the stockpile area. Covering stockpiles directly with plastic tarps is not effective for this reason.

Motivation

- Business Opportunity

Reference

Simmons Jr., G.H. (n.d.). *Stockpiles* (Technical Paper T-129). Astec Inc., Chattanooga, Tennessee.

Young, T.J. (2007). *Energy Conservation in Hot-Mix Asphalt Production* (QIP-126). National Asphalt Pavement Association, Lanham, Maryland.

3.1.1.2 Real-Time Aggregate Moisture Measurement

In most stockpiles and environments, aggregate moisture content is variable to some degree. Asphalt plant controls compensate for moisture on aggregates when supplying asphalt binder in the drum. This requires the plant operator to input a representative moisture content for the material going over the weighbridge on the collector belt feeding the dryer. For a mixture with a target asphalt content of 5%, if there is a difference of 0.5% between the actual moisture content and the moisture content in the plant controls, then the asphalt content of the produced mixture will be either 0.2% low or high. If too high, the mix production cost is unnecessarily increased and if too low the durability of the mix could be compromised. At the same time, variability in aggregate moisture content will result in variability in asphalt content test results, potentially reducing the mix pay factor. A reliable real-time aggregate moisture measurement system will allow for more frequent and timely adjustments to asphalt plant control settings and reduced risk for both the asphalt producer and mix customer. The equipment is relatively new, so information for determining the time to recover the initial investment cost is not available.

Motivation

- Business Opportunity
- Project Requirement

Reference

Dep, L., C. Thao, S. Glidden, & D. Porter (2019). A System for Real-Time Measurement of Moisture in Aggregate Mixes During Asphalt Production. In *Asphalt Paving Technology 2018: Journal of the Association of Asphalt Paving Technologists*, Vol. 87, pp. 348–359.

3.1.2 Plant Management

There are several business opportunities associated with efficient plant management. It's important to recognize that many investments in plant management that reduce energy consumption will be recovered in one to two years, after which annual savings continue at no cost. Details of nine energy-reducing hot plant production alternatives with details on investment and recovery can be found in NAPA publication QIP-126, *Energy Conservation in Hot-Mix Asphalt Production*. Additional brief examples can be found in NAPA publication QIP-127, *101 Ideas to Reduce Costs and Enhance Revenue*.

3.1.2.1 Maintain the Baghouse

Emissions of particulate matter (PM) from an asphalt plant are controlled primarily by the baghouse. Baghouse efficiency can be monitored regularly using a black light leak test or EPA Method 5 testing. Air permits typically require one or both of these tests on a periodic basis, but increasing the frequency can help ensure the baghouse is performing as designed, as well as prevent small problems from becoming enforcement issues.

Motivation

- Business Opportunity
- Project Requirement

Reference

Astec (2004). *Baghouse Black Light Test* (Service Information Letter #018). Astec Inc., Chattanooga, Tennessee. www.astecinc.com/images/file/service/018-Blacklight.pdf

Mansfield, C. (2016). How to Properly Maintain the Baghouse. *Asphalt Contractor*, Vol. 30, No. 2, p. 62. www.forconstructionpros.com/asphalt/article/12152096/how-to-properly-maintain-the-baghouse

EPA (2017). *Method 5 — Determination of Particulate Matter Emissions from Stationary Sources*. U.S. Environmental Protection Agency, Washington, D.C.

3.1.2.2 Insulate Plant Components

Insulation of plant components, such as tanks, dryer drums, silos, and piping, will reduce heat loss to the environment and thereby reduce production cost. Something as simple as putting 1½ inches of insulation on 3-inch asphalt pipe with typical flanges and hot-oil jumper lines can reduce costs over $10,000 per 100 feet of pipe per year. Additional sustainable

benefits include reductions in energy needed for production, conservation of natural resources, reduction of GHG emissions, and safer worker exposure conditions.

Motivation

- Business Opportunity

Reference

Hansen, K.R., & R. Sandberg (2008). *101 Ideas to Reduce Costs and Enhance Revenue* (QIP-127). National Asphalt Pavement Association, Lanham, Maryland.

May, J., T. Wilkey, M. Swanson, J. Daub, G. Farrow, J. Clayton, D. Clum, M. Moon, B. Eley, & F. Eley (2003). *Heating and Storing Asphalt at HMA Plants* (Technical Paper T-140). Heatec Inc., an Astec Industries Company, Chattanooga, Tennessee.

Young, T.J. (2007). *Energy Conservation in Hot-Mix Asphalt Production* (QIP-126). National Asphalt Pavement Association, Lanham, Maryland.

3.1.2.3 Use Alternative Fuels

Asphalt plants can efficiently operate on multiple fuel types. Traditionally, natural gas, fuel oils, liquid propane (LP), and coal have been used. Key considerations when evaluating alternative fuels are emissions, fuel cost, capital equipment cost, maintenance cost, and availability. Emissions have to be considered first as federal, state, and local regulations will define allowable levels. In urban areas, clean fuels (natural gas, LP) coupled with low-emission burners may be required. However, some renewable energy sources, such as biodiesel, biomass, wind energy, and solar energy are becoming available. In many locations No. 4 to No. 6 fuel oils and recycled fuel oils are economically available. It is possible to burn these fuels with most burners today via a manifold change and/or tuning. Burning them may require additional equipment, such as a fuel tank, in-line heater, and filter. Because the fuel cost is lower, recovery of the equipment investment can often be realized in six to 12 months. Cost comparisons for burning different fuel sources need to be done based on heating value of the fuels (Btu/gal, Btu/therm, etc.). NAPA publication QIP-126, *Energy Conservation in Hot-Mix Asphalt Production*, contains a simple table for making these comparisons.

Motivation

- Business Opportunity

Reference

Swansen, M.S. (2017). *Traditional & Alternative Energy for Hot Mix and Warm Mix Asphalt Plants* (Technical Paper T-147). Astec Inc., Chattanooga, Tennessee.

Young, T.J. (2007). *Energy Conservation in Hot-Mix Asphalt Production* (QIP-126). National Asphalt Pavement Association, Lanham, Maryland.

3.1.2.4 Fix Air Leaks

Air leaks will negatively impact production rates at an asphalt plant, increasing required fuel consumption to maintain the same production rate. They will commonly occur at the

breeching on the drum, recycle collar, and ductwork, especially where angles exist in the ductwork. A dollar invested in air-leak repairs will return 2 to 3 dollars in savings. The repair costs are typically low, so the return on investment is not huge, but the return on investment accumulates with every ton produced.

Motivation

- Business Opportunity

Reference

Hansen, K.R., & R. Sandberg (2008). *101 Ideas to Reduce Costs and Enhance Revenue* (QIP-127). National Asphalt Pavement Association, Lanham, Maryland.

3.1.2.5 Conduct an Energy Audit

An energy audit allows you to assess the efficiency of fuel use and electricity. Energy audits are typically conducted by a third party who specializes in industrial electrical and energy efficiency. The U.S. Department of Energy's *Guide to Energy Audits* provides detailed information that can assist companies in developing contracts for third-party energy audits. A directory of third-party energy professionals who hold credentials as Certified Energy Auditors and Certified Energy Managers is available in the Association of Energy Engineers (AEE) *Certified Professionals Directory*. Small- and medium-sized companies that meet certain criteria can utilize Industrial Assessment Centers (IACs), which provide no-cost energy audits.

Motivation

- Business Opportunity

Reference

AEE *Certified Professionals Directory*. portal.aeecenter.org/custom/cpdirectory/index.cfm

Baechler, M., C. Strecker, & J. Shafer (2011). *A Guide to Energy Audits*. Building Technologies Program, U.S. Department of Energy, Washington, D.C. www.pnnl.gov/main/publications/external/technical_reports/PNNL-20956.pdf

Energy Star. www.energystar.gov/buildings/facility-owners-and-managers/industrial-plants

U.S. Department of Energy Industrial Assessment Centers. www.energy.gov/eere/amo/industrial-assessment-centers-iacs

3.1.2.6 Utilize Renewable Energy

Installation of solar panels, wind turbines, or other renewable energy solutions can reduce energy costs and your company's greenhouse gas footprint. If this is not feasible for a specific plant site, most electric utilities allow a customer to purchase renewable energy through pre-defined programs. Facilities can also purchase renewable energy certificates (RECs) regardless of who their electric supplier is.

Motivation

- Business Opportunity
- Goodwill

Reference

U.S. EPA Green Power Partnership. www.epa.gov/greenpower/renewable-energy-certificates-recs

3.1.2.7 Tune the Burner

Efficient combustion of the burner requires an optimum air/fuel ratio, which can only be achieved through routine tuning of the burner. Untuned burners can also increase gaseous emissions, cause blue smoke in the stack, coat the baghouse with hydrocarbons, and even create a fire hazard. Asphalt plant and burner manufacturers have tuning guides, and specialists can be brought in to help as well.

Motivation

- Business Opportunity

Reference

Young, T.J. (2007). *Energy Conservation in Hot-Mix Asphalt Production* (QIP-126). National Asphalt Pavement Association, Lanham, Maryland.

3.1.2.8 Monitor Fuel Consumption

Monitoring fuel consumption can help identify issues with aggregate moisture, burner tuning, veiling efficiency, air leaks, and other production issues. The simplest method is to compare your monthly fuel bill to the plant's production to determine the average amount of energy it takes to produce one ton of asphalt. Some producers have installed real-time fuel monitors that integrate with the plant's control system, allowing the plant operator to find the most efficient plant configuration and production rate. Monitoring fuel consumption of other equipment, such as hot oil heaters and on-site power generation equipment, can yield similar results.

Motivation

- Business Opportunity

Reference

Young, T.J. (2007). *Energy Conservation in Hot-Mix Asphalt Production* (QIP-126). NAPA, Lanham, MD.

3.1.2.9 Optimize Veiling Efficiency

Efficient operation of a dryer depends on proper veiling of the aggregates. When the flights wear down with age, or recycled content changes, veiling efficiency can be impacted. Improper veiling is often identified by high stack exit gas temperatures in the dryer. Routine maintenance of the flights and reconfiguring the flights can help optimize veiling efficiency and reduce fuel consumption.

Motivation

- Business Opportunity

Reference

Young, T.J. (2007). *Energy Conservation in Hot-Mix Asphalt Production* (QIP-126). NAPA, Lanham, MD.

3.1.2.10 Re-Use Waste Heat

The waste heat emitted though the stack of a hot oil heater can be captured using a heat exchanger, reducing the amount of fuel and cost needed to keep asphalt tanks and piping hot.

Motivation

- Business Opportunity

Reference

Young, T.J. (2007). *Energy Conservation in Hot-Mix Asphalt Production* (QIP-126). National Asphalt Pavement Association, Lanham, Maryland.

3.1.2.11 Install Variable-Frequency Drives (VFDs) on Large Motors

Energy can be conserved by installing VFDs on large motors, like burner fans, exhaust fans, and slat conveyor motors. A VFD simply changes a fixed-speed motor to a variable-speed motor through a frequency change that reduces energy consumption. A classic example is using a VFD to slow a baghouse motor instead of using a damper to reduce flow at constant motor speed. The investment in a VFD will be recovered within about two years for a typical asphalt plant, and even sooner with utility company rebates and reductions in demand charges. Noise level is also reduced with the installation of the VFD and elimination of the damper, too.

Motivation

- Business Opportunity

Reference

Hansen, K.R., & R. Sandberg (2008). *101 Ideas to Reduce Costs and Enhance Revenue* (QIP-127). National Asphalt Pavement Association, Lanham, Maryland.

Young, T.J. (2007). *Energy Conservation in Hot-Mix Asphalt Production* (QIP-126). National Asphalt Pavement Association, Lanham, Maryland.

3.1.2.12 Produce Warm-Mix Asphalt (WMA)

Warm-mix asphalt technologies allow asphalt pavement mixtures to be produced at significantly lower temperatures than HMA, offering several sustainable benefits, as well as improved constructability and worker conditions. An NCHRP study (West et al. 2014) found that the performance of WMA and HMA is virtually identical and indicated that little or no rutting, no evidence of moisture damage, and very little indication of transverse or longitudinal cracking was observed on a series of field projects. Energy consumption, asphalt plant and paver emissions, and worker exposure to fumes were extensively measured on three multiple WMA technology projects and found to be lower than with HMA

due to the reduced WMA production and paving temperatures. There are tools available, such as the NAPA Greenhouse Gas Calculator, to determine reductions in energy consumption and GHG when producing WMA.

Motivation

- Business Opportunity
- Project Requirement

Reference

NAPA Greenhouse Gas Calculator. www.asphaltpavement.org/ghgc

Prowell, B.D., G. Hurley, & B. Frank (2012). *Warm-Mix Asphalt: Best Practices, Third Edition* (QIP-125). National Asphalt Pavement Association, Lanham, Maryland.

West, R.C., C. Rodezno, G. Julian, B.D. Prowell, B. Frank, L.V. Osborn, & T. Kriech (2014*). NCHRP Report 779: Field Performance of Warm Mix Asphalt Technologies*. Transportation Research Board of the National Academies, Washington, D.C.

3.1.2.13 Manage Trucking Operations

One of the most common complaints from neighbors is the impact of trucking operations from a nearby asphalt plant. Sometimes, trucking can be avoided by siting an asphalt plant in a location where raw materials can be delivered by rail or barge. If this is not possible, other options are available, such as creating designated haul routes to avoid sensitive or congested roads or neighborhoods, enforcing speed limits through the use of GPS systems on fleet vehicles, establishing off-street areas for waiting/queuing of trucks, and establishing policies that do not allow early arrival of trucks prior to the facility gates opening. Traffic studies can evaluate potential impacts of truck traffic and offer recommended mitigation measures.

Motivation

- Goodwill

Reference

McRae, J., L. Bloomberg, & D. Muldoon (2006). *Best Practices for Traffic Impact Studies*. Oregon Department of Transportation, Salem, Oregon. www.oregon.gov/ODOT/Programs/ResearchDocuments/BestPracticesforTraffic.pdf

3.1.2.14 Use Locally Available Aggregates

Many agencies have aggregate quality requirements that are the same for use in all asphalt pavement mixtures, regardless of mix type, location in the pavement structure, and anticipated traffic loading. However, for lower volume roads and for base and intermediate courses good performance can be achieved using aggregates with less stringent quality requirements that can sometimes be satisfied with local aggregate sources. Shorter aggregate transport distances can save money, as well as reduce fuel use and associated greenhouse gas emissions.

Motivation

- Business Opportunity

3.1.2.15 Minimize Light Pollution

Improperly designed outdoor lighting can impact wildlife, such as migratory birds, waste energy, and obscure visibility of the natural night sky. Installation of dark sky-friendly lighting can help reduce the impacts of outdoor lighting without compromising illumination of a facility. This can reduce a plant's potential impact on endangered species and help with community relations.

Motivation

- Goodwill

Reference

International Dark Sky Association. darksky.org

3.1.2.16 Reduce Noise

Noise associated with an asphalt plant can distract workers and contribute to hearing loss. For plants located near residential or commercial areas, noise can be a major concern by neighbors. Noise surveys conducted by a qualified acoustician can ensure regulatory compliance with local noise ordinances and provide specific recommendations to reduce noise pollution.

Motivation

- Goodwill

Reference

Knauer, H., & S. Pedersen (2006). *Construction Noise Handbook* (FHWA-HEP-06-015). John A. Volpe National Transportation Systems Center Acoustics Facility, U.S. Department of Transportation, Cambridge, Massachusetts. www.fhwa.dot.gov/environment/noise/construction_noise/handbook/

NAPA (1977). *Noise in and Around Asphalt Plants* (IS-75). National Asphalt Pavement Association, Lanham, Maryland.

3.1.2.17 Minimize Odor

Asphalt plants are sometimes like airports. At the time they are built, they are located well away from residential development, but over time changes in population and development patterns occur and new residential developments become close neighbors. Asphalt plants emit odors that some neighbors do not appreciate. In extreme cases, residents can get frustrated with this and go to the local press with their complaints, tarnishing the asphalt plant owner's reputation, or even file legal action, which is costly to resolve. There are odor-capture systems available for tanks, as well as natural odor neutralizing agents that do not rely on harsh chemicals or masking fragrances. An odor-mitigation strategy using these

types of tools can improve worker conditions and relationships with residential neighbors to preserve or rebuild goodwill and acceptance by the local community.

Motivation

- Business Opportunity
- Goodwill

Reference

Haupert, L., & R. Mulford (2016). Laurel Asphalt Paves the Way for Reducing Odors and Keeping Neighbors Happy. *Asphalt Contractor*, Vol. 30, No. 7, pp. 70–73. www.forconstructionpros.com/asphalt/article/12196593/laurel-asphalt-paves-the-way-for-reducing-odors-and-keeping-neighbors-happy

3.2 Materials Quality

Good pavement performance is directly related to the quality of the asphalt mix. Asphalt producers can impact mix quality through both mix design and production quality control processes.

Impacts on Sustainability

- Consumption
- Climate
- Budget
- Maintenance & Operations

3.2.1 Mix Design

Getting good mix performance starts with the selection of raw materials and optimization of recycled materials in the mix design process. The industry has been responsibly focusing on mix durability since the Great Recession that started in the late-2000s. Increased asphalt binder cost at that time sparked rapid increased use of recycled materials, which led to some durability challenges. The outcomes have been material standards and laboratory tests to help ensure good mix quality.

3.2.1.1 Balanced Mix Design Process

The FHWA Expert Task Group on Mixtures and Construction defined balanced mix design (BMD) as “asphalt mix design using performance tests on appropriately conditioned specimens that address multiple modes of distress taking into consideration mix aging, traffic, climate and location within the pavement structure.” The BMD process incorporates mechanical tests to determine the rutting- and cracking-resistance of a mix so that the mix is “balanced” to optimize both rutting and cracking performance. Most agencies are successfully using the Hamburg Wheel Tracking test to evaluate rutting and moisture sensitivity along with a cracking test(s) that is most appropriate for the geographic conditions. BMD evaluates final mix properties rather than individual raw materials, allowing for optimization of recycled materials and assurance of good mix performance for producers.

Motivation

- Business Opportunity
- Project Requirement

Reference

NCHRP Project 09-58 (2019). *The Effects of Recycling Agents on Asphalt Mixtures with High RAS and RAP Binder Ratios.* Final report due for publication by third quarter 2019. apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3645

NCHRP Project 20-07/Task 406 (2018). *Development of a Framework for Balanced Asphalt Mixture Design.* Report currently under review. apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4324

3.2.1.2 Optimize Mix Design to Increase RAP and RAS

A 2013 NCHRP project evaluated the field performance of many high RAP mixtures in comparison to low RAP or virgin mixes. It illustrated that equal performance can be achieved with responsible use of RAP. The ongoing NCHRP Project 09-58 has evaluated both high RAP and reclaimed asphalt shingles (RAS) mixtures, focusing on asphalt binder, rejuvenators, and blended binder properties. This work is also indicating that with proper virgin binder and rejuvenator selection, good mix performance can be achieved with high RAP, though the required rejuvenator doses are up to 10%, as opposed to the 3% commonly used. The project also illustrates that RAS can be used responsibly in low doses when the mix design is engineered properly and produced and constructed with best practices.

Motivation

- Business Opportunity

Reference

West, R., J.R. Willis, & M. Marasteanu (2013). *NCHRP Report 752: Improved Mix Design, Evaluation, and Materials Management Practices for Hot Mix Asphalt with High Reclaimed Asphalt Pavement Content*. Transportation Research Board of the National Academies, Washington, D.C.

3.2.2 Materials Quality Control

Effective quality control (QC) processes in the production/processing of aggregates, recycled materials, and asphalt mix are essential to good mix quality.

3.2.2.1 RAP Materials QC

In addition to routine aggregate and mix quality control, RAP QC is of particular importance today to manage risk and optimize consistency, quality, and payment bonus. Close inspection of materials to be recycled is critical. Inbound RAP can be contaminated with undesirable materials that can only be caught through rigorous inspection. Contaminants can include glass (for example, from the allowance of recycled glass in previous mixtures), porcelain tile, geotextiles from milling operations, and other construction materials like

aggregate base and PCC. In addition, undesirable materials — like mix made with highly absorptive aggregates or sulfur-extended asphalt — need to be identified and managed. Once inbound RAP is free of contaminants, RAP quality can be improved through blending, crushing, fractionating, and QC testing. Some successful operations separate plant waste (from mix changes on the fly), millings, and contaminated RAP for processing and stockpiling to maximize RAP use and quality. There is cost associated with managing multiple RAP stockpiles, but this cost can be recovered by improving the consistency of RAP, which can allow for increased RAP use.

Motivation

- Business Opportunity

Reference

West, R.C. (2015). *Best Practices for RAP and RAS Management* (QIP-129). National Asphalt Pavement Association, Lanham, Maryland.

3.2.2.2 QC Department Resources and Operations

Asphalt mixture design and production have become much more complex since the 1950s. Today, highly qualified QC department staff are needed to understand the specifications, design requirements, mechanical and conventional test methods, as well as to analyze the related results for success. This means that engineers and well-trained technicians are becoming the norm in successful QC operations. There are national, regional, and state materials technician qualification or certification programs that assure competency and consistency, similar to the professional engineer requirements for QC managers that allow the asphalt producer to confidently rely on in-house QC. Similarly, the AASHTO Accreditation Program (AAP) formally audits and recognizes the competency of testing laboratories performing construction materials tests. AAP is the largest and most widely accepted accrediting body in the construction materials industry. There are also relatively inexpensive QC database software packages available that can help reduce testing time and calculation errors. More importantly, such software can send real-time notifications of results to operations staff immediately upon completion of tests, as well as automatically generate and distribute specification test results and trend analyses. Engineering licensure, technician certification, laboratory accreditation and use of database software provide for confidence, credibility, efficiency, and effectiveness in QC. The investment is worth it.

Motivation

- Business Opportunity

Reference

AASHTO Accreditation Program. www.aashtoresource.org/aap/overview

3.2.3 Recycle/Reuse

The asphalt industry is a proud leader in recycling with nearly all end-of-life asphalt being diverted from landfills and back to beneficial use in new pavements.

3.2.3.1 RAP and RAS in Asphalt Mixtures

Reductions of more than 20% in greenhouse gas production and over 45% in energy consumption have been reported by using RAP and RAS in asphalt mixture production. Mix quality can be maintained with proper design, especially when optimized for the layer where the mix will be used in a pavement structure. Today most asphalt plants have the necessary hardware to use RAP, although increasing the percentage used could lead to additional costs for processing (fractionation); additional hardware, such as a second RAP cold-feed bin; and/or using recycling agents or grade bumping to softer asphalt binders. Published RAP cost savings range significantly because many variables impact the actual cost at a given location and RAP percentage used. Cost savings estimates of 6% at 15% RAP, 10–20% at 25% RAP, and 29–40% at 50% RAP have been published. Estimates of $2.50/ton at 15% RAP and $4–$5/ton at 25% RAP have also been published. Every situation is unique and should be closely evaluated.

Motivation

- Business Opportunity

Reference

Newcomb, D.E., E.R. Brown, & J.A. Epps (2007). *Designing HMA Mixtures with High RAP Content: A Practical Guide* (QIP-124). National Asphalt Pavement Association, Lanham, Maryland.

West, R.C. (2015). *Best Practices for RAP and RAS Management* (QIP-129). National Asphalt Pavement Association, Lanham, Maryland.

3.2.3.2 In-Place Recycling

In some cases, particularly in rural areas far from aggregate and asphalt production facilities, in-place recycling can be a viable, sustainable use for end-of-life asphalt pavements. Hot in-place, cold in-place, cold-central plant, and full-depth reclamation have all been successfully employed to recycle asphalt mixture sustainably.

Motivation

- Project Requirement

Reference

ARRA (2015). *Basic Asphalt Recycling Manual, Second Edition* (FHWA-HIF-14-001). Asphalt Recycling & Reclaiming Association, Annapolis, Maryland.

3.2.3.3 Other Recycled Materials: The Three Es

Other waste materials and industrial byproducts, including recycled tire rubber, blast furnace and steel slag, fly ash, and recycled cellulose fiber have also been successfully used in

asphalt pavement mixtures. However, to ensure true sustainability, it is important that any new material added to an asphalt pavement mixture deliver engineering, environmental, and economic benefits and performance. This is referred to as “The Three Es.” Although public interest and policy goals may be served by adding new waste materials to pavements, without proper evaluation, testing, and mix design, it is impossible to ensure that road owners and the public will receive the same or improved performance and pavement life as with virgin materials or proven technologies.

3.2.4 Specialty Mixes

Several types of asphalt mixtures can be produced and used to provide good performance and unique benefits for specific applications and locations in a pavement structure. The NAPA–FHWA publication IS-128, *HMA Pavement Mix Type Selection Guide*, is an excellent tool for identifying the best use of specialty mixes.

3.2.4.1 Porous Asphalt

Porous asphalt pavements are unique in that they are used to construct pavements, but they also serve as stormwater storage and infiltration systems. They are attractive to planners and public works officials wanting storm water management systems that promote infiltration, improve water quality, and ground water recharge while maintaining peak and total water volume of flow at or below pre-development levels. Porous asphalt pavements can be especially cost-effective in situations near water bodies (oceans, lakes, and streams), where drainage structures and filtration systems can be eliminated with the use of porous asphalt pavement.

Motivation

- Project Requirement

Reference

Hansen, K.R. (2008). *Porous Asphalt Pavements for Stormwater Management* (IS-131). National Asphalt Pavement Association, Lanham, Maryland.

Schwartz, C.W., & K.D. Hall (2018). *Structural Design Guidelines for Porous Asphalt Pavements* (IS-141). National Asphalt Pavement Association, Lanham, Maryland.

3.2.4.2 Open-Graded Friction Course (OGFC)

OGFC is an open-graded mix that provides improved surface drainage during rainfall due to its interconnecting air voids structure. Water can drain vertically through OGFC to the underlying dense-graded mix where it drains laterally to a day-lighted edge. OGFC wet weather advantages include reduced hydroplaning, increased surface friction, reduced vehicle splash and spray, enhanced visibility of pavement markings, and reduced nighttime surface glare in wet weather. OGFC also provides reduced tire–pavement noise in dry weather conditions.

Motivation

- Project Requirement

Reference

Kandhal, P.S. (2002). *Design, Construction, and Maintenance of Open-Graded Asphalt Friction Courses* (IS-115). National Asphalt Pavement Association, Lanham, Maryland.

3.2.4.3 Polymer-Modified Asphalt (PMA) in Surface Course Mixes

Polymer-modification of surface courses can improve surface course durability and longevity at acceptable cost. Especially for high-traffic pavements, many DOTs either directly specify polymer-modified mixes or have implemented testing that often requires polymer modification to pass. Von Quintus et al. (2007) found that polymer-modified mixtures significantly improve rutting, fatigue, and fracture performance of asphalt pavements.

Motivation

- Project Requirement

Reference

Von Quintus, H.L., J. Mallela, & M.S. Buncher (2007). Quantification of Effect of Polymer-Modified Asphalt on Flexible Pavement Performance. In *Transportation Research Record: Journal of the Transportation Research Board*, *No. 2001*, pp. 141–154. Transportation Research Board of the National Academies, Washington, D.C. doi:10.3141/2001-16

3.2.4.4 Rubberized Asphalt in Surface Course Mixes

Rubberized asphalt mixes have been used in warm climate states as a high-performance surface course that is highly resistant to reflective cracking. The predominant rubberized asphalt mix type is ½-inch nominal maximum aggregate size (NMAS) gap-graded with high design asphalt binder content (7–8%) containing about 20% ground tire rubber. Recent variations on this include ⅜-inch (9.5 mm) NMAS mixes and dense-graded mixes with about 10% terminal-blended fine tire rubber. The California Department of Transportation, considered a leader in rubberized asphalt use, will place asphalt rubber mix at half the thickness of conventional dense-graded mix due to its superior reflective-cracking resistance. The high cost of the mix is offset by the reduced thickness required.

Motivation

- Project Requirement

Reference

Way, G.B., K.E. Kaloush, & K.P. Biligiri (2011). *Asphalt Rubber Standard Practice Guide, First Edition*. Rubber Pavements Association, Phoenix, Arizona.

3.2.4.5 Stone-Matrix Asphalt (SMA) for Surface Course Mixes

SMA is a high-performance asphalt mix that provides excellent rutting resistance and durability for surface courses in demanding situations. It is primarily used for high-volume

interstate and U.S. highway routes. It has also been used for special situations where heavy, slow-moving traffic exists, such as industrial areas, and for studded-tire wear resistance. These gap-graded mixes have a stable stone-on-stone skeleton with a rich mastic composed of asphalt binder, filler, and fibers and/or asphalt modifiers. SMA is a premium mix with higher initial cost that should be offset by improved performance life in heavy-loading situations. Beyond improved durability and fatigue and rutting resistance, SMA has been reported to be more resistant to reflective cracking and to improve wet-weather friction compared to conventional asphalt surfaces.

Motivation

- Project Requirement

Reference

Garcia, J., & K.R. Hansen (2001). *HMA Pavement Mix Type Selection Guide* (IS-128). National Asphalt Pavement Association, Lanham, Maryland.

Hughes, C.S., & P.S. Kandhal (2002). *Designing and Constructing SMA Mixtures — State-of-the-Practice* (QIP-122). National Asphalt Pavement Association, Lanham, Maryland.

4. Construction

"Construction" refers to all processes and equipment associated with the construction of asphalt pavement systems. This includes the initial construction of new pavement systems, as well as subsequent maintenance and rehabilitation efforts. For the purposes of this document, construction activities are limited to actions and equipment within the project limits and materials transported to and from the project site. Production of mixtures is addressed in the Materials Production section.

4.1 Construction Quality

Construction quality influences pavement life, required rework, and the amount and frequency of maintenance and rehabilitation. These items directly influence the use of non-renewable natural resources and contribute to human health and happiness (think about added traffic delay and safety risks due to rework and additional maintenance resulting from poor quality). In many sustainability metrics, the quality of construction is largely ignored, often because it is difficult to find a useful universal metric for quality.

Impacts on Sustainability

- Workers
- Users
- Consumption
- Climate
- Budget
- Maintenance & Operations

4.1.1 Density

Density can be considered the best singular indicator of asphalt pavement construction quality. While many other efforts contribute to construction quality, none have more direct and proven influence on pavement life. State DOTs and other large owners with adequate resources pay close attention to density and often pay bonuses or assess penalties based on density. Smaller owners with fewer resources tend to trust contractor practices with less verification.

4.1.1.1 Higher In-Place Density

A 2017 FHWA demonstration project examined the impact of higher density on asphalt pavement durability. A survey of the literature found that in laboratory testing higher densities (93–94% Rice density compared to typical specification values of 91–92% Rice density) generally result in better fatigue life and less rutting. Field demonstrations in 10 states generally found densities in the 93–95% range are possible using a combination of methods, including multiple rollers, WMA, and reduced gyration levels. The general claim is that a 1% decrease in air voids is estimated to extend service life by 10% (an idea first put forward in 1989 by Linden et al.). As of 2018, demonstration projects attempting to determine the benefits of higher in-place density are ongoing in the U.S.

Motivation

- Project Requirement

Reference

Aschenbrener, T., E.R. Brown, N.H. Tran, & P.B. Blankenship (2017). *Demonstration Project for Enhanced Durability of Asphalt Pavements Through Increased In-Place Pavement Density* (NCAT Report 17-05). National Center for Asphalt Technology at Auburn University, Auburn, Alabama.

Linden, R.N., J.P. Mahoney, & N.C. Jackson (1989). Effect of Compaction on Asphalt Concrete Performance. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1217*, p. 20–28. Transportation Research Board of the National Academies, Washington, D.C.

4.1.1.2 Intelligent Compaction (IC)

IC is usually presented as a way to monitor compaction effort in near real time. IC uses accelerometers on rollers to measure compaction effort and material response to estimate in-place density. GPS is used to locate data and systems often show maps of estimated density in near real time. While the reliability and accuracy of IC asphalt pavement density estimates still needs improvement, the GPS output showing roller location and roller passes can be useful. Additionally, IC can be used in subgrade compaction to identify soft areas, allowing project teams to proactively repair these areas to prevent future maintenance issues.

Motivation

- Project Requirement

Reference

FHWA Intelligent Compaction Website. www.fhwa.dot.gov/pavement/ic/

4.1.1.3 Non-Nuclear Field Density Measurement

The standard for in-place density is a field core tested in the laboratory. However, for quicker density results, the nuclear gauge has been used since the 1970s. While a properly calibrated nuclear gauge can give density readings within minutes, its radioactive source requires licensing, a radiation safety program, gauge safety certification training, gauge security/control, calibration, and proper disposal procedures. Gauges without nuclear sources (or sources small enough to be exempt from controls), usually electromagnetic gauges, can be quicker to use and are subject to fewer rules; however, numerous studies have shown these gauges to have poor correlation with core and nuclear densities, large variability in measurements, and be quite dependent on calibrated and consistent dielectric values. Work to improve and evaluate these gauges is ongoing.

Motivation

- Business Opportunity

Sargand, S.M., S.-S. Kim, & S.P. Farrington (2005). *A Working Review of Available Non-Nuclear Equipment for Determining In-Place Density of Asphalt* (FHWA/OH-2005/18). Ohio Research Institute for Transportation and the Environment, Ohio University, Athens, Ohio.

4.1.1.4 Variable Density Standards Based on NMAS

Research from NCAT and elsewhere shows a relationship between NMAS, density, and permeability. In general, as NMAS increases the density required to achieve an impermeable asphalt pavement increases. For instance, ⅜ and ½-inch NMAS mixtures may become permeable below about 92–93% Rice density, while ¾-inch NMAS mixtures become permeable below about 94.5% Rice density. If an impermeable asphalt pavement is wanted (and it usually is), the required density to achieve this should vary with NMAS.

Motivation

- Project Requirement

Reference

Cooley Jr., L.A., E.R. Brown, & S. Maghsoodloo (2001). *Development of Critical Field Permeability and Pavement Density Values for Coarse-Graded Superpave Pavements* (NCAT Report 01-03). National Center for Asphalt Technology at Auburn University, Auburn, Alabama.

4.1.2 Lift Thickness ≥ 4 × NMAS

NCHRP research from NCAT recommends the minimum paving depth be at least three times NMAS for fine-graded mixes (including Thinlays) and at least four times NMAS for coarse-graded and SMA mixes. This allows enough room for aggregate to rearrange in the

mixture from the weight and vibration of the screed and rollers. Thinner lifts cool rapidly making roller placement close to the paver even more important (for instance: a 2-inch lift cools twice as fast as a 2.5-inch lift). At mat thicknesses less than about 1.5 times NMAS, the screed may be supported by the large aggregates in the mixture rather than floating on the mixture as a whole.

Motivation

- Project Requirement

Reference

Brown, E.R., M.R. Hainin, A. Cooley, & G. Hurley (2004). *NCHRP Report 531: Relationship of Air Voids, Lift Thickness, and Permeability in Hot Mix Asphalt Pavements*. Transportation Research Board of the National Academies, Washington, D.C.

NAPA (2002). *Paver Operations for Quality* (IS-125). National Asphalt Pavement Association, Lanham, Maryland.

4.1.3 Longitudinal Joints

Longitudinal joints are a focal point for asphalt pavement quality because low compaction and surface irregularities at the joint can be more common and lead to premature cracking and raveling. Ideally, the joined area between two passes of asphalt mixture should be an integral part of the pavement structure and as durable as any other part of the finished mat. Work at NCAT, subsequently expanded by others, investigated and recommended several best practices, including proper joint overlap, rolling from the hot side 6 inches away from the joint, and using rubberized joint material and notched wedge joints. Other useful techniques are cutting back the cold edge (often done in airfield work) and echelon paving to create a hot joint.

Motivation

- Project Requirement

Reference

Buncher, M.S., & C. Rosenberger (2012). *Best Practices for Constructing and Specifying HMA Longitudinal Joints*. Asphalt Institute, Lexington, Kentucky.

Kandhal, P.S., T.L. Ramirez, & P.M. Ingram (2002). *Evaluation of Eight Longitudinal Joint Construction Techniques for Asphalt Pavements in Pennsylvania* (NCAT Report 02-03). National Center for Asphalt Technology at Auburn University, Auburn, Alabama.

NAPA (2002). *Paver Operations for Quality* (IS-125). National Asphalt Pavement Association, Lanham, Maryland.

4.1.4 Eliminate Segregation

Segregation is a separation of coarse and fine aggregate particles during the production and laydown process. The result is a non-uniform mat that, in places, will not conform to the original job mix formula and will perform poorly. Eliminating segregation requires effort

throughout production and laydown, including stockpiling, plant operations, truck loading, paver operations, and material-transfer vehicle use.

Motivation

- Project Requirement

Reference

Brock, J.D., J.G. May, & G. Renegar (2003). *Segregation: Causes and Cures* (Technical Paper T-117). Astec Inc., Chattanooga, Tennessee.

4.1.5 Smoothness

Smoothness is a defining quality characteristic for asphalt pavement. Smoother pavements indicate higher construction quality and reduce vehicle operating costs and emissions, and there is evidence that pavements built to a higher initial level of smoothness are more durable.

4.1.5.1 Construction Practices

Tactics for achieving smoothness include surface preparation (including leveling courses and cold planing), reducing paver stops, uniform mix temperature, grade control for pavers, compaction efforts, and joint construction.

Motivation

- Business Opportunity
- Project Requirement

Reference

Brock, J.D., & J. Hedderich (2007). *Pavement Smoothness* (Technical Paper T-123). Roadtec, an Astec Industries Company, Chattanooga, Tennessee.

4.1.5.2 Use a Smoothness Specification

About three-quarters of state DOT asphalt pavement specifications have smoothness requirements based on International Roughness Index (IRI) measurements and about 90% of those involve incentive/disincentive pay adjustments based on statistical analysis. About half of smoothness is related to the roughness of the underlying layer, and improvements in smoothness per lift are on the order of 40–65% at most. For states that base pay on smoothness, the upper limit for full pay (higher IRI values would result in a penalty) ranges from 43–100 inches/mile. Incentive/disincentive specifications for smoothness should also allow for construction methods to improve smoothness, such as a leveling course and milling of the existing surface.

Motivation

- Project Requirement

Reference

Merritt, D.K., G.K. Chang, & J.L. Rutledge (2015). *Best Practices for Achieving and Measuring Pavement Smoothness, a Synthesis of State-of-Practice* (FHWA/LA.14/550). Louisiana Transportation Research Center, Baton Rouge, Louisiana.

4.1.6 Mat Temperature

Construction-related temperature differentials (sometimes called "thermal segregation") are isolated cooler areas of the mat that may not be adequately compacted using a rolling pattern designed for the majority mat temperature. Thus, they can result in isolated areas of low density that fail prematurely by raveling and cracking. Often, these areas are caused by the top surface of the mix in the dump truck cooling during transit and then passing through the paver and being placed in mat relatively intact.

4.1.6.1 Infrared Monitoring of Mat Temperature

Infrared (IR) equipment can readily detect isolated areas of low temperature as they happen. Infrared temperature measuring devices and thermal imaging cameras can both be used, with more expensive options having better mat coverage, data retention and processing, and visual displays.

Motivation

- Business Opportunity
- Project Requirement

Reference

Fernández Cerdas, S. (2012). *Thermal Segregation: Causes and Effects on In-Place Density and Fatigue Performance of Asphalt Mixtures* (Master's thesis). Auburn University, Auburn, Alabama.

4.1.6.2 Use a Density Differential Specification

Some state DOTs use a specification to identify and correct isolated areas of low density in the mat, usually caused by construction-related temperature differentials that do not get adequately compacted. These isolated spots of low density may not be captured by normal random sampling but can still lead to early pavement failure. Specifications usually require a "thermal profile" (temperature measurements taken along a short distance: 100–500 feet). Areas significantly cooler than the surrounding mat require further investigation with density testing.

Motivation

- Project Requirement

Reference

TxDOT (2015). *Tex-244-F: Test Procedure for Thermal Profile of Hot Mix Asphalt*. Texas Department of Transportation, Austin, Texas.

WSDOT (2017). WSDOT SOP 733: Determination of Pavement Density Differentials Using the Nuclear Density Gauge. *Materials Manual* (M 46-01.30). Washington State Department of Transportation, Olympia, Washington.

4.1.7 Tack Coat

Although flexible asphalt pavements are built in layers, the structural strength of the pavement system owes much to the bond between those layers. A variety of tack coat products are available, and following best practices helps ensure they provide the bond strength the pavement needs for good performance.

4.1.7.1 Pay for Tack Coat Separately

Tack coat can be paid for as a separate item or included as incidental to the bid price of the asphalt material. Tack coat as a separate pay item is done by 66% of U.S. DOTs (33 out of 50) as of 2017. Paying for tack as a separate item best aligns the goals of owner and contractor: the owner can ask for more tack coat, and the contractor can be properly compensated for providing the additional material. Tack coat represents a small job expense (usually less than 0.5% of bid price) but incorrect application and potential failure due to de-bonding is an extreme consequence.

Motivation

- Project Requirement

Reference

Gierhart, D., & D.R. Johnson (2017). *NCHRP Synthesis 516: Tack Coat Specifications, Materials, and Construction Practices*. Transportation Research Board of the National Academies, Washington, D.C.

4.1.7.2 Control Tack Coat Dilution

Often, slow-setting (SS) tack coats are diluted with water to help the tack truck more evenly apply the tack coat emulsion because it is better at metering the higher flow needed to obtain the right residual rate. However, dilution must be closely controlled because an inaccurately determined dilution rate will result in the incorrect residual asphalt application. As of 2017, 48% of state DOTs allow dilution. If dilution is allowed, only do so at the emulsion supplier's terminal, where it is better controlled. It is best to verify the dilution rate before applying tack coat so that a proper residual asphalt rate will result. It may be easiest to disallow dilution, thereby eliminating the issue.

Motivation

- Project Requirement

Reference

Gierhart, D., & D.R. Johnson (2017). *NCHRP Synthesis 516: Tack Coat Specifications, Materials, and Construction Practices*. Transportation Research Board of the National Academies, Washington, D.C.

Mohammad, L.N., M.A. Elseifi, A. Bae, N. Patel, J. Button, & J.A. Scherocman (2012). *NCHRP Report 712: Optimization of Tack Coat for HMA Placement*. Transportation Research Board of the National Academies, Washington, D.C.

4.1.7.3 Use Non-Tracking Tack Coat

Construction machinery that drives on tack coat may pick up the tack with their rubber tires and remove the emulsion material from the intended pavement surface, which can reduce bond strength in the wheel paths. Since the mid-2000s, non-tracking (or *trackless*) tack coats have been available from some manufacturers. Not all owners allow non-tracking tack, but when properly applied, it appears to largely prevent tracking.

Motivation

- Business Opportunity
- Project Requirement

Reference

Mohammad, L.N., M.A. Elseifi, A. Bae, N. Patel, J. Button, & J.A. Scherocman (2012). *NCHRP Report 712: Optimization of Tack Coat for HMA Placement*. Transportation Research Board of the National Academies, Washington, D.C.

4.1.7.4 Tack Coat Best Practices

NAPA publication QIP-128, *Best Practices for Emulsion Tack Coats*, provides best practice guidance on emulsion tack coats, covering storage, handling, sampling, testing, distributors, hand application, surface preparation, residual determination, application rate, break and set, and tack tracking/pick up.

Motivation

- Business Opportunity
- Project Requirement

Reference

Decker, D.S. (2013). *Best Practices for Emulsion Tack Coats* (QIP-128). National Asphalt Pavement Association, Lanham, Maryland.

4.1.8 WMA as a Compaction Aid

A variety of warm-mix asphalt (WMA) additives and processes have been found to aid compaction at normal construction temperatures. In some instances, WMA additives have been specified as compaction aids for particularly stiff mixes (for example, high PG 82 grades, asphalt rubber mixtures, open-graded mixtures requiring hand work).

Motivation

- Business Opportunity
- Project Requirement

Reference

Kristjánsdóttir, Ó. (2006). *Warm Mix Asphalt for Cold Weather Paving* (WA-RD 650.1). Master's thesis, University of Washington, Seattle, Washington.

Prowell, B.D., G. Hurley, & B. Frank (2012). *Warm-Mix Asphalt: Best Practices, Third Edition* (QIP-125). National Asphalt Pavement Association, Lanham, Maryland.

4.1.9 Pay for Asphalt Binder Separately

The asphalt binder in asphalt pavement can be paid for as a separate item or included as incidental to the bid price of the asphalt pavement. Paying for asphalt binder as a separate item best aligns the goals of owner and contractor: the owner can ask for more asphalt binder and the contractor can provide it and be properly compensated for the additional material.

Motivation

- Project Requirement

4.1.10 Use a Warranty

Some U.S. owners and many international ones have extensive experience with pavement warranties. Stated reasons for their use are (1) improved quality and (2) reduced owner oversight during construction. While either may happen, neither is a necessary result of a pavement warranty. Essentially, a warranty is an added upfront expense (warranties are priced and bid accordingly) to hedge against the risk of a costlier expense later. A warranty price can be a differentiator for a contractor who builds a superior quality product that reduces the risk of later repairs.

Motivation

- Project Requirement

Reference

Scott III, S., T. Farragut, M. Syrnick, & S. Anderson (2011). *NCHRP Report 699: Guidelines for the Use of Pavement Warranties on Highway Construction Projects*. Transportation Research Board of the National Academies, Washington, D.C.

4.1.11 Use a Construction Quality Control Plan

A construction quality control plan is intended to document the structure, responsibilities, and procedures to effectively manage construction quality. While plans do not ensure actions, properly developed plans do provide a framework and guidance for good quality control practice.

Motivation

- Business Opportunity
- Project Requirement

Reference

FLH (1998). *Contractor Quality Control Plans: Contractor Guidelines and Example Quality Control Plan*. Federal Lands Highway Office, Federal Highway Administration, Washington, D.C.

Molenaar, K.R., D.D. Gransberg, & D.N. Sillars (2015). *NCHRP Report 808: Guidebook on Alternative Quality Management Systems for Highway Construction*. Transportation Research Board of the National Academies, Washington, D.C.

Rath, T. (2017). *Trans Mountain Expansion Project: Quality Management Plan* (Document #01-13283-GG-0000-RPT-CM-0002). Kinder Morgan Canada Inc., Calgary, Alberta, Canada. apps.neb-one.gc.ca/REGDOCS/File/Download/3179049

4.2 Equipment

Equipment operation influences productivity, fuel use, and the health of workers and neighbors. These items directly influence pollution, resource consumption, and project cost, as well as contribute to human health and happiness (think of the effects of construction noise on workers — hearing loss prevention — as well as its effect on neighbors — annoyance and stress). This section presents several sustainable practices that go beyond improving productivity.

Impacts on Sustainability

- Workers
- Neighbors & Stakeholders
- Pollution
- Consumption
- Climate
- Budget

4.2.1 Tier 4 Engines

By 2015, EPA Tier 4 diesel engines were phased in for non-road equipment. They reduce diesel NO_x and particulate exhaust emissions by 90% compared to engines manufactured prior to implementation of the standard. Existing equipment may continue to operate, but new equipment must meet Tier 4 engine standards. While not yet common in the paving industry, some projects place requirements on the age and emissions performance of the project's equipment fleet. Starting in 2018, large equipment fleets are prohibited from adding any more Tier 2 engine vehicles.

Motivation

- Business Opportunity
- Project Requirement

Reference

EPA (2018). *Regulations for Emissions from Heavy Equipment with Compression-Ignition (Diesel) Engines*. U.S. Environmental Protection Agency, Washington, D.C. www.epa.gov/regulations-emissions-vehicles-and-engines/regulations-emissions-heavy-equipment-compression

4.2.2 Alternatives Fuels

Diesel from fossil fuel is the overwhelmingly predominant fuel source for construction equipment. However, price, environmental, and future supply risks may make alternative fuels a viable option. Limited use of biofuel is already allowed, and research continues on other alternative fuels. B20 (20% biodiesel) is usually the maximum recommended for current diesel engines, but some specialty contractors do use B100 (100% biodiesel) even though current costs and reduced power make it less competitive. Other alternative fuels must address refueling logistics and the high energy-density fuel requirements of construction equipment. For example, while natural gas has gained in overall U.S. market share, it has an energy density that is two to five times less than diesel, which limits its use in heavy construction equipment.

Motivation

- Business Opportunity
- Project Requirement

Reference

David, J. (2015). Growing the Demand for Biofuels in Off-Highway Equipment Applications. *Equipment Today*, Vol. 51, No. 4. www.forconstructionpros.com/equipment/fleet-maintenance/article/12056642/growing-the-demand-for-biofuels-in-offhighway-equipment-applications

FPT Industrial. (2015). Fuel for Thought: Diesel Alternatives for the Non-Road Sector. *Sustainable Construction*, Winter 2015. www.forconstructionpros.com/sustainability/article/12122157/fuel-for-thought-diesel-alternatives-for-the-nonroad-sector

4.2.3 Reduce Noise

Hearing loss is the top injury reported by highway construction workers. Additionally, noise is a major complaint by construction site neighbors. Generally, construction site noise is regulated by local ordinances, to which some variations may be allowed. Sustainability generally represents innovation in meeting or exceeding existing regulations. The FHWA's *Construction Noise Handbook* (Knauer & Pedersen, 2006) contains some basic ideas for mitigating construction noise during roadway construction.

Motivation

- Project Requirement

Reference

Knauer, H.S., & S. Pedersen (2006). *Construction Noise Handbook* (FHWA-HEP-06-015). U.S. Department of Transportation, John A. Volpe National Transportation Systems Center Acoustics Facility, Cambridge, Massachusetts.

4.2.4 Automated Grade Control

Hybrid laser-GPS systems are capable of tightly controlling paving and milling grades. This is beneficial especially for projects with variable-depth paving and milling in that it (1) saves the surveying step of marking variable depths on the pavement, and (2) eliminates manual machine control required for variable elevation and cross-slope changes.

Motivation

- Business Opportunity

Reference

Asphalt Contractor (2012). All in a Weekend's Work. Vol. 26, No. 9, www.forconstructionpros.com/asphalt/pavers/article/10785573/automated-grade-control-system-holds-milling-and-paving-grade-during-fasttrack-paving-project

4.3 Work Zone Traffic Delay and Impacts

Work zone traffic delays can have a major impact on the indirect costs of construction, especially in urban areas where traffic volumes are generally higher. Road user costs in work zones include vehicle operating costs, motorist/passenger/freight delay costs, and crash costs. These are real, quantifiable costs, but are generally not tracked as part of the construction cost beyond the cost of traffic management itself. However, for larger urban roadway projects the economic impact can be several times larger than the cost of the project. 23 CFR 630, Subpart J establishes baseline requirements for work zone safety and mobility but stops short of requiring specific practices.

Impacts on Sustainability

- Workers
- Neighbors & Stakeholders
- Users
- Pollution
- Consumption
- Climate
- Project Budget

4.3.1 Reduce/Mitigate Work Zone Traffic Delay

Much has been written about work zone traffic delay, its impacts, and practices for reducing or mitigating those impacts. Anderson & Ullman (2000) categorize these practices into:

1. **Programming and planning.** For example: interagency coordination, traffic management plans, road user cost considerations, safety, public perception
2. **Design.** For example: constructability reviews, materials, prefabrication
3. **Contracting.** For example: lane rental, cost + time (A+B), incentives/disincentives, flexible start times
4. **Construction.** For example: preconstruction planning, construction equipment/techniques, materials, partnering, value engineering

5. **Maintenance.** For example: work restrictions, traffic management and lane control, methods and materials, work planning, public communications.

Motivation

- Project Requirement

Reference

Anderson, S.D., & G.L. Ullman (2000). *NCHRP Synthesis 293: Reducing and Mitigating Impacts of Lane Occupancy During Construction and Maintenance*. TRB, National Research Council, Washington, D.C.

FHWA. (2017). Work Zone Traffic Management, ops.fhwa.dot.gov/wz/traffic_mgmt

4.3.2 Use R3 to Model Construction Plan Productivity and Delay

Rapid Road Rehabilitation (R3, formerly CA4PRS) is an online set of software applications to help quickly analyze schedule, traffic, and cost options for highway projects. It can provide quick analysis using planning-level input values for productivity and closure scenarios.

Motivation

- Business Opportunity
- Project Requirement

Reference

Caltrans (2018). Construction Analysis for Pavement Rehabilitation Strategies: Caltrans "Rapid Rehab" Software. www.dot.ca.gov/newtech/roadway/ca4prs/

4.4 Waste Management

Construction produces waste from unsuitable, temporary, and short-use materials, as well as clearing/grubbing, demolition, and packaging. The EPA estimates 534 million tons of construction and demolition waste were generated in the United States in 2014, which is more than the amount of municipal solid waste (a.k.a. garbage or trash) generated. Road construction waste can be significant: the EPA estimates 14% of construction and demolition waste is asphalt concrete, however nearly all of this is diverted from landfills. Waste directly impacts pollution and the local ecosystem; not recycling/reusing this material increases consumption of virgin materials.

Impacts on Sustainability

- Pollution
- Local Ecosystem & Habitat
- Consumption

4.4.1 Reduce/Eliminate Waste to Landfill and Document

The asphalt pavement industry does well recycling old asphalt pavement. The EPA notes that more C&D debris is generated by roads and bridges (234 million tons) than buildings

(166 million tons), but nearly all (99%) of asphalt pavement C&D debris is diverted from landfills with the intention of reusing it in new asphalt pavements or base layers. Thus, making pavement construction a documented zero-waste activity is a realistic possibility. From a consumer perspective, the “zero waste” idea (sometimes called “closed loop”) is that manufacturers should take back their product in a free and convenient way when it reaches the end of its useful life, and then recycle the material in a safe and responsible way. This is asphalt pavement; only the documentation is missing.

Motivation

- Business Opportunity
- Project Requirement

Reference

UL 2799: Zero Waste to Landfill standard. standardscatalog.ul.com/standards/en/standard_2799

Van Dam, T.J., J.T. Harvey, S.T. Muench, K.D. Smith, M.B. Snyder, I.L. Al-Qadi, H. Ozer, J. Meijer, P.V. Ram, J.R. Roesler, & A. Kendal (2015). *Towards Sustainable Pavement Systems: A Reference Document* (FHWA-HIF-15-002). Federal Highway Administration, Washington, D.C. (Chapter 8 covers zero waste/closed loop.)

Williams, B.A., A. Copeland, & T.C. Ross (2018). *Asphalt Pavement Industry Survey on Recycled Materials and Warm-Mix Asphalt Usage: 2017, 8th Annual Survey* (IS-138). National Asphalt Pavement Association, Lanham, Maryland. www.asphaltpavement.org/recycling

4.5 Project Management and Control

Project management and controls often determine the profitability of a project and the owner’s satisfaction with the work. This section focuses on tools and equipment available to assist in project management and control; it does not address general management science (for example, what it takes to be a good manager). Tools and equipment are generally able to provide more data from more sources (for example video, audio, QR codes) at a higher quality and in a more timely manner. Such technology can be used to reduce project risk, provide more insight into project issues, better track materials and metrics, and keep the entire project team better informed. Project management and controls impact efficiency, risk and awareness, all of which can result in better decisions and lower costs.

Impacts on Sustainability

- Project Budget

4.5.1 Enhanced Information Technology

Enhanced information technologies (IT) encompass mobile and wearable devices, cloud-based technology, real-time information availability, and multimedia tools. The FHWA and AASHTO promote e-Construction, which is “… the collection, review, approval, and distribution of highway construction contract documents in a paperless environment.”

Importantly, the goal of “enhanced IT” is not just making existing processes paperless but enabling better processes that create more value using available data and connectivity.

Motivation

- Business Opportunity
- Project Requirement

Reference

Shah, K., A. Mitchell, D. Lee, & J. Mallela (2017). *Addressing Challenges and Return on Investment (ROI) for Paperless Project Delivery (e-Construction)* (FHWA-HIF-17-028). Federal Highway Administration, McLean, Virginia.

Yamaura, J., G. White, S. Katara, K. Willoughby, R. Garcia, & M. Beer (2015). *Project Inspection Using Mobile Technology — Phase II* (WA-RD 840.2). Washington State Department of Transportation, Olympia, Washington.

4.5.2 Geospatial Technologies

Geospatial technologies can be used to gather, store, process, and display geographic or spatially referenced information. Systems that use the Global Positioning System (GPS), geographic information systems (GIS), light detection and ranging (LIDAR), and even barcoding and radio frequency identification (RFID) are considered geospatial technologies. These technologies can all assist with locating and tracking pavement construction materials, progress, and data. For example, LIDAR can be used for machine control (paver, milling machine), as-built documentation, quality control, and materials quantity tracking.

Motivation

- Business Opportunity
- Project Requirement

Reference

Olsen, M.J., G.V. Roe, C. Glennie, F. Persi, M. Reedy, D. (2013). *NCHRP Report 748: Guidelines for the Use of Mobile LIDAR in Transportation Application*s. Transportation Research Board of the National Academies, Washington, D.C.

Schwartz, C.W., J.S. Khan, G.H. Pfeiffer, & E. Mustafa (2014). *Radio Frequency Identification Applications in Pavements* (FHWA-HRT-14-061). Federal Highway Administration, McLean, Virginia.

4.6 Work Zone Health and Safety

Work zone health and safety has been a point of emphasis by the FHWA, state agencies, and others for quite some time. In 2016 (most recent data at time of publication), there were about 158,000 work zone crashes. Roadway construction worker fatalities have fluctuated between 100 and 145 per year over the past 10 years. Work zone health and safety is highly regulated, with most practices being mandatory rather than optional. This section only addresses optional, non-standard items that may contribute to construction worker health and safety within the work zone. Regulatory requirements (for example, OSHA and MUTCD

requirements) are not addressed. In general, work zone health and safety efforts are intended to reduce/eliminate work zone injuries and crashes, which affect worker and user health.

Impacts on Sustainability

- Workers
- Users
- Project Budget

4.6.1 Health and Safety Management Plan

A proactive approach to managing workplace safety and health. OSHA provides general guidance for starting and running a health and safety program (OSHA, 2016).
ISO 45001:2018 Occupational Health and Safety describes minimum standards for occupational health and safety performance and offers certification. Like other standards from ISO (for example ISO 9001 for quality management systems and ISO 14001 for environmental management systems), there is effort and cost associated with certification.

Motivation

- Business Opportunity
- Project Requirement

Reference

ISO 45001:2018 Occupational Health and Safety Management Systems — Requirements with Guidance for Use. www.iso.org/obp/ui/#iso:std:iso:45001:ed-1:v1:en

OSHA (2016). *Recommended Practices for Safety and Health Programs* (OSHA 3885). Occupational Safety & Health Administration, Washington, D.C.

4.6.2 Job Hazard (Safety) Analysis

Job hazard analysis is a technique to analyze a job task and identify hazards to determine the safest way to perform the task. OSHA provides basic guidance on how to perform a job hazard analysis (OSHA, 2002). More detailed guidance also exists (for example, Roughton & Crutchfield, 2015); however, job hazard analysis is generally not required by regulation.

Motivation

- Business Opportunity

Reference

OSHA (2002). *Job Hazard Analysis* (OSHA 3071). Occupational Safety & Health Administration, Washington, D.C.

Roughton, J., & N. Crutchfield (2015). *Job Hazard Analysis: A Guide for Voluntary Compliance and Beyond, Second Edition*. Butterworth-Heinemann, Waltham, Massachusetts.

4.6.3 Work Zone Intrusion Alert Systems

Work zone intrusion alert systems refer to a variety of technologies used to notify workers and drivers of unauthorized vehicles entering work zones. Intrusion alarms are most beneficial for temporary work zones with minimal separation from moving traffic. Sensors can range from pneumatic tubes, to impact sensors placed on traffic control devices, to multiple sensors (video, radar, GPS) working in concert. Alarms are typically audible, with some systems also using visual (flashing lights) and haptic methods (wearable units that vibrate). Research and development of these systems is ongoing and progressing rapidly. Current issues are: (1) quantifying the resulting risk reduction, (2) minimizing false alarms, and (3) ensuring drivers and workers notice and react to warnings.

Motivation

- Business Opportunity
- Project Requirement

Reference

Fyhrie, P.B. (2016). *Work Zone Intrusion Alarms for Highway Workers*. California Department of Transportation. Sacramento, California.

Gambatese, J.A., H.W. Lee, & C.A. Nnaji (2017). *Work Zone Intrusion Alert Technologies: Assessment and Practical Guidance* (SPR 790). Oregon Department of Transportation, Salem, Oregon.

Theiss, L., T. Lindheimer, & G.L. Ullman (2017). *Closed-Course Performance Testing of a Work Zone Intrusion Alarm System*. Presented at the 97th Annual Meeting of the Transportation Research Board, Washington, D.C.

4.6.4 Design for Construction Safety (DfCS)

Design for construction safety (DfCS), also known as prevention through design (PtD) or construction hazard prevention through design (CHPtD), is a process to include worker safety considerations in design and constructability review. Improved construction worker safety is the obvious benefit, while designer liability is the major issue.

Motivation

- Business Opportunity

Reference

Toole, M. (2017) Prevention through Design. designforconstructionsafety.org (Overview of DfCS/PtD and available resources)

5. Pavement Design

5.1 New Pavements

New or reconstructed pavements are those built with an entirely new pavement structure. This document addresses selected new pavement design options, but does not address design methods, processes, and other technical inputs for pavement design.

Impacts on Sustainability

- Users
- Consumption
- Climate
- Project Budget
- Maintenance & Operations

5.1.1 Perpetual Pavement

Perpetual Pavement describes a long-lasting pavement structural design, materials selection, construction, and maintenance concept. The Asphalt Pavement Alliance (APA) annually recognizes long-life pavements that meet the Perpetual Pavement ideal with its Perpetual Pavement Award, the criteria for which includes pavements that are:

- Asphalt pavement
- Pavement age of at least 35 years
- No structural failure
- No rehabilitation that has increased total pavement thickness by more than 4 inches
- Resurfacing intervals of no less than 13 years on average

Essentially, asphalt pavements constructed to a minimum structure are not likely to suffer significant structural damage even when subjected to very high traffic over long periods of time. Minimum structure varies with loading and other factors: high-volume highways may be about 12–15 inches of asphalt pavement constructed in specific layers; low-volume local roads may be about 5–8 inches of asphalt pavement. Newcomb et al. (2010) discusses specifics.

Motivation

- Business Opportunity
- Project Requirement

Reference

Newcomb, D.E., J.R. Willis, & D.H. Timm (2010). *Perpetual Asphalt Pavements: A Synthesis* (IM-40). Asphalt Pavement Alliance, Lanham, Maryland.

5.1.2 Specialty Layers

Most asphalt pavements are designed for and built with dense-graded mixtures. However, certain traffic and environmental situations may make alternative mixtures more appropriate and offer sustainability advantages. Specifically:

- **Porous asphalt pavements.** Pavement structures intentionally designed to be permeable so they can serve a stormwater management function. A porous asphalt pavement system can be comparable in cost to an equivalent impermeable pavement combined with the necessary traditional stormwater management system. Porous asphalt pavement systems are generally efficient at removing pollutants (with phosphorus being a notable exception). Most porous pavement systems are designed for light automobile traffic in residential and, especially, parking lot applications.
- **Open-graded friction course (OGFC).** Pavement surfaces constructed of an open-graded (15–25% air voids) asphalt mixture, and typically paved in a thin lift (often ¾–2 inches thick). The main benefits are (1) improved safety due to reduced splash/spray and reduced risk of hydroplaning, (2) improved skid resistance, and (3) potential reduction in tire–pavement noise.
- **Stone-matrix asphalt (SMA).** Gap-graded mixture with strict aggregate specifications, modified asphalt binder, and mineral fillers. SMAs generally cost more than dense-graded mixtures and involve special construction considerations. There is substantial evidence that properly constructed SMA pavements outperform dense-graded equivalents. The Washington State DOT estimated that an SMA pavement must last about 2.5 years longer than a dense-graded pavement to break even on cost (Wen et al., 2016).

Motivation

- Business Opportunity
- Project Requirement

Reference

Cooley Jr., L.A., J.W. Brumfield, R.B. Mallick, W.S. Mogawer, M. Partl, L. Poulikakos, & G. Hicks (2009). *NCHRP Report 640: Construction and Maintenance Practices for Permeable Friction Courses*. Transportation Research Board of the National Academies, Washington, D.C.

Hansen, K.R. (2008). *Porous Asphalt Pavements for Stormwater Management* (IS-131). National Asphalt Pavement Association, Lanham, Maryland.

Hughes, C.S., & P.S. Kandhal (2002). *Designing and Constructing SMA Mixtures — State-of-the-Practice* (QIP-122). National Asphalt Pavement Association, Lanham, Maryland.

Kandhal, P.S. (2002). *Design, Construction, and Maintenance of Open-Graded Asphalt Friction Courses* (IS-115). National Asphalt Pavement Association, Lanham, Maryland.

Schwartz, C.W., & K.D. Hall (2018). *Structural Design Guidelines for Porous Asphalt Pavements* (IS-140). National Asphalt Pavement Association, Lanham, Maryland.

Wen, H., S.T. Muench, S. Chaney, K. Littleton, & T. Rydholm (2016). *Recommendations for Extending Asphalt Pavement Surface Life within Washington State* (WA-RD 860.1). Washington State Department of Transportation, Olympia, Washington.

5.2 Rehabilitation

Pavement rehabilitation is the act of repairing portions or all of an existing pavement to reset the deterioration process. This differs from maintenance (routine service and repairs done to slow the rate of deterioration) and reconstruction (removing and replacing a pavement with an entirely new structure). This document addresses selected non-traditional rehabilitation guidance and methods but does not address design methods and processes or other technical input for pavement design.

Impacts on Sustainability

- Users
- Consumption
- Climate
- Project Budget
- Maintenance & Operations

5.2.1 Use R23 Guidance

The SHRP 2 R23 project provides guidance on rehabilitating existing high volume (≥10 million ESALs) pavements for long life (at least 30 years). rePave (www.pavementrenewal.org) is the associated online scoping tool that allows users to input existing pavement information and provides viable long-term rehabilitation solutions. The rePave scoping tool and its associated resources are based on an extensive review of in-service pavement performance in the U.S. and internationally.

Motivation

- Business Opportunity
- Project Requirement

Reference

rePave. www.pavementrenewal.org

5.2.2 Crack, Seat, and Overlay

To restore ride quality and serviceability, existing deteriorated concrete pavement is often cracked into smaller slabs then overlaid with asphalt pavement. The smaller slabs are less likely to cause reflective cracking in the asphalt pavement overlay. This method is most successful with thicker (greater than 7 inches) asphalt pavement overlays, no evidence of pumping under existing slabs, good subgrade support, and existing drainage. While it is most often done on unreinforced concrete pavement, it can be adapted to reinforced concrete pavement by first sawing the pavement in the transverse direction every 4–5 feet, deep enough to cut the reinforcing steel.

Motivation

- Business Opportunity
- Project Requirement

Reference

rePave (2013). *Flexible Best Practices: Recommendations for the Design and Construction of Long-Life Flexible Pavement Alternatives Using Existing Pavements*. www.pavementrenewal.org/#resources

5.2.3 Rubblization

Existing deteriorated concrete pavement can be turned into rubble by a fracturing process and then overlaid with asphalt pavement. The rubble is left in place and functions as a high-quality base for the asphalt pavement overlay. Rubblization works best when the existing subgrade provides adequate strength, support, and drainage, and there is no evidence of pumping under existing slabs. Long-term performance of rubblized pavements depend on the rubblization quality (all concrete broken, relatively uniform size distribution of rubblized concrete, bottom half of slab size limit of 6–12 inches), subgrade strength (in combination with overlay thickness), and existing moisture problems eliminated. If viable, crack-and-seat is usually preferred to rubblization as it retains more of the existing pavement stiffness.

Motivation

- Business Opportunity
- Project Requirement

Reference

Decker, D.S. (2006). *Rubblization: Design and Construction Guidelines on Rubblizing and Overlaying PCC Pavements with Hot-Mix Asphalt* (IS-132). National Asphalt Pavement Association, Lanham, Maryland.

rePave (2013). *Flexible Best Practices: Recommendations for the Design and Construction of Long-Life Flexible Pavement Alternatives Using Existing Pavements*. www.pavementrenewal.org/#resources

5.2.4 Thin Overlays

Thin overlays and Thinlays™ are thin surface mixes that are 1.5-inch thick or less and placed on a well-prepared surface for use as part of a pavement preservation/management program. Thin overlays are ideally suited for existing pavements with low to medium levels of surface distress and can provide 10+ years of service on asphalt surfaces and 6–10 years of service on concrete surfaces (Newcomb, 2009). Thin overlays can be used earlier in the deterioration cycle of a pavement to preclude the onset of more severe distresses that might make a thicker structural overlay necessary. By using Thinlays, agencies can extend the life of pavements that are in good to fair condition, decreasing life-cycle costs, improving ride, and decreasing roadway noise (Heitzman et al., 2018).

Motivation

- Business Opportunity
- Project Requirement

Reference

Heitzman, M.A., E.R. Brown, & J. Hickey (2018). *Thinlays for Pavement Preservation* (IS-141). National Asphalt Pavement Association, Lanham, Maryland.

Newcomb, D.E. (2009). *Thin Asphalt Overlays for Pavement Preservation* (IS-135). National Asphalt Pavement Association, Lanham, Maryland.

Watson, D.E., & M.A. Heitzman (2014). *NCHRP Synthesis 464: Thin Asphalt Concrete Overlays*. Transportation Research Board of the National Academies, Washington, D.C.

Sustainability in Practice 103

Sustainable Asphalt Pavements: A Practical Guide

Procuring & Evaluating Sustainability

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Sustainable Asphalt Pavements: A Practical Guide

This is the third of four publications in the NAPA Sustainable Asphalt Pavements: A Practical Guide series meant to provide a practical guide to sustainability. That means a focus on what a NAPA member business or asphalt project can do now to address sustainability within the confines of good business practice. The four publications in this series are meant to work together and are organized as follows:

1. **SIP 101: Sustainability Overview**. A practical definition of sustainability and the elements of and reasons for a business approach to sustainability.
2. **SIP 102: Sustainability Specifics**. Specific sustainability actions that can be taken in corporate/organizational strategy, project delivery, mix design, materials production, construction activities, and pavement design.
3. **SIP 103: Procuring & Evaluating Sustainability.** How sustainability is included in public project procurement, and how sustainability efforts are evaluated within the industry.
4. **SIP 104: How to Develop a Sustainability Program**. Important components of a company sustainability program including goals, best practices, implementation, and reporting.

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SIP 103: Procuring & Evaluating Sustainability

If, as a society, sustainability really matters to us (we have made the argument that it does) then we ought to ask for it specifically in infrastructure project procurement, and we should evaluate how effectively it is being integrated into our infrastructure.

Sustainability does not fit well with normal procurement practices. Remember that, by our simple definition, “sustainability” describes efforts above and beyond the minimum. But, for generations we have procured projects by describing the minimum required standards and asked contractors to meet those minimums at the lowest price possible. This system is not ideally set up to ask for more than the minimum and, if necessary, pay for it. However, there are ways to go beyond the minimum.

Evaluating how well sustainability is included in infrastructure projects is important if we wish to manage and improve the process. What gets measured gets managed, as the saying goes. Sustainability rating systems are an increasingly popular way of doing this evaluation. This is because rating systems are flexible metrics; they describe many sustainable practices (more than you would need even to achieve the highest certification standard) and a project is free to pick those that make the most sense within the context of that project. Third-party rating systems also provide credibility; it’s not just you evaluating your own work and declaring it “sustainable” but rather a recognized accomplishment administered by an unbiased third party.

Procuring Sustainability in Public Contracts

If sustainability is valued by an owner, they may ask for sustainability in the procurement process. However, there is little national or international guidance on how to do this best. This section discusses how sustainability is typically procured in public contracts including:

- Specifying sustainability items directly in the contract documents.
- Using change orders to include more sustainable alternatives after contract award.
- Using alternative sustainability bids.
- Alternative technical concepts (ATCs) that favor more sustainable approaches.
- Requiring sustainability qualifications in a qualifications-based selection process.
- Requiring tracking and reporting of certain sustainability metrics.
- Requiring project certification from an independent third-party rating system.

An individual project may use one or more of these approaches. For instance, specifying some sustainability items, including others in an alternative bid, and requiring the tracking and reporting of key sustainability metrics.

Specifying Sustainability Items in the Contract Documents

This method uses specifications to require, allow, or incentivize sustainability items. In some instances it can be difficult to write good sustainability specifications because (1) they are

only infrequently done so there is little available experience, or (2) the standard is often a non-specific “better than usual,” which is difficult to measure. Sustainable practices can be required (you must do it), allowed (do it if you want to), or incentivized (do it for a reward such as compensation). For instance, an owner might *require* a polymer modifier in the asphalt binder to improve durability of the surface course. Or, an owner might *allow* up to 40% RAP in the base course. Or, an *incentive* may be offered for contractor personnel accredited in a certain rating system. If the owner is asking the contractor to do something that costs the contractor money, but benefits the owner, the only sensible way to get it done is to require it and pay the contractor for it. However, if a contractor can do something and benefit from it directly, the owner can just allow it in the specifications and the contractor will do it if, and only if, it makes good business sense. Of course, the owner often benefits indirectly from things it allows but does not require. A good example of this is in the case of RAP: The bid prices for asphalt pavement may decrease over time as contractors pass on their savings from RAP use to the owner by reducing their price in the low-bid process.

Change Order to More Sustainability Alternatives after Contract Award

After a contract is awarded, the owner or contractor may propose, by change order, a more sustainable alternative. This is similar to a value engineering change proposal (VECP) where a contractor proposes changes to reduce either construction or life-cycle costs while maintaining equal functionality. While this may work if the owner communicates its desire for sustainable practices, it is ultimately a passive approach to sustainability since the contractor doesn’t *have* to propose anything. Of course, all of this really depends on there being incentive for the contractor to propose more sustainable alternatives. In the cases where a more sustainable alternative is also less expensive, there is incentive. However, many times this is not the case so unless some sort of incentive structure is put in place it will probably not result in more sustainable approaches that are of equal or greater cost.

Alternative Sustainability Bids

This requires the contractor to bid the project in two ways: one bid for the baseline project, and another for the same project that includes sustainability improvements. An owner can use this to see how much their sustainable alternatives might cost should they choose to pursue them. We have seen this used on at least one Greenroads project.

Alternative Technical Concepts (ATCs)

Typically used in design-build project delivery, this approach allows the proposing design-builder to propose ideas to the owner that are not requested but offer some sort of advantage to the owner (for example: reduced cost, improved design, better schedule, longer pavement life). Including sustainability as a stated priority for the owner in the request for proposal (RFP) could open up ATCs to include sustainable alternatives as well. Doing this can allow proposers to better differentiate their proposal based on sustainability rather than just respond to minimum RFP requirements.

Sustainability Qualifications

The owner can solicit sustainability qualifications and approaches in a qualifications-based selection process. An RFP is used to ask for qualifications, and ideas and proposals are evaluated and awarded points based on their merit. This approach is great for engaging a contractor's innovation and unique attributes to get the best possible sustainable solution, but its use so far has been limited. Too often, the RFP asks for (1) environmental regulation compliance only (not above-and-beyond anything), or (2) a rather undefined "sustainability" approach that leaves contractors confused about what to propose and owners unsure of how to evaluate what is proposed.

Sustainability Metric Reporting

This requires the tracking and reporting of specific sustainability metrics throughout the project. It is an indirect way of asking the contractor for more sustainable processes without specifying actions. Metrics can include fuel use, water and electricity use, waste diversion rates, air quality, community programs, recycling and more. Sometimes these metrics are associated with a specific goal (for example, at least 95% of construction material must be diverted from landfill), and sometimes they are just for accounting purposes. Environmental Product Declarations (EPDs) are a relatively new way of reporting the environmental impact of products (such as asphalt mixtures) in a consistent and verifiable way. NAPA's Emerald Eco-Label program is a verified EPD program for asphalt mixtures.

Sustainability Rating Systems

Owners can require a project to achieve certification in a specific rating system like LEED®, Greenroads®, Envision®, or INVEST. The general idea is that using a rating system rather than specific requirements allows the project more latitude because there are many ways to achieve a certain score and the project team can choose the most sensible one. Rating system certification will likely include items beyond a contractor's control (for example, design features, owner requirements for public involvement, designer/owner qualifications) so achieving a rating system certification is a coordinated effort by the entire project team (owner, designer, contractor as a minimum).

Influence of Project Delivery Method

Alternative project delivery methods are better than design–bid–build. Sustainability can be done using any form of project delivery. However, the best project delivery forms for sustainability are the ones that better allow contractors to have input earlier in the process, which allows them to use their innovation and unique attributes productively and in a more efficient manner for the project. The nature of design–bid–build (hard bid) delivery limits contractor input since the design is done before contractor selection, and the low-bid selection method limits what contractors can or may be willing to do beyond minimum requirements.

In contrast, many alternative project delivery methods allow contractor input at earlier project stages (for example: design–build and Construction Manager/General Contractor (CM/GC))

and allow better communications between designer and contractor. CM/GC project delivery method allows an owner to engage a construction manager during the design process to provide constructability input. This can help integrate sustainable features at the most cost-effective point in project development.

Public private partnerships (P3s). These aren't really delivery methods, but rather ways of financing projects that involve some private money. Usually the payback for the private investors is over a long period of time (often 20–50 years or more), so P3s do encourage long-term thinking, which generally means going beyond bare minimum requirements (our definition of sustainability) to meet long-term goals. Also, some private investors use sustainability as a criterion in their investment decisions. Be careful, though: pavements in P3 contracts can be very small portions of the overall effort and, therefore, be a low priority even though they may be the major maintenance component that drives expenses over the long term. The struggle is often to convince P3 investors and builders of a long-life pavement structure and realistic rehabilitation and maintenance timing.

Evaluating Sustainability Using A Rating System

Rating systems can be used to quantify sustainability for a variety of infrastructure projects. Currently, most emphasis (and publicity) is on buildings; many states, cities, counties, school districts and colleges have standards in place that require sustainable practices in building design and construction. Some public owners have begun to address roads and pavements also, seeing them as important to include in their sustainability goals and values.

If you look hard enough you can find over 20 different sustainability rating systems that have something to do with asphalt pavements. However, in the U.S. there are four that you should focus on: LEED®, Greenroads®, Envision®, and INVEST. Before we get to how these systems stack up, let's cover the rating system basics.

What is a Sustainability Rating System?

A sustainability rating system is a list of sustainability best practices with an associated point system. Points are used to quantify each best practice so that all sustainability best practices (like pollutant loading in stormwater runoff, pavement design life, tons of recycled materials, energy consumed/saved, pedestrian accessibility, ecosystem connectivity and even the value of art) can all be compared by point value. Rating systems weight best practices (usually in relation to their impact on sustainability or their priority), which can assist in choosing the most impactful best practices to use given a limited scope or budget. All rating systems can be used as self-evaluation tools, but some are administered by external organizations and can be used as an independent third-party check on a project's sustainability.

Topics Addressed (and Not) by Roadway Sustainability Rating Systems

No matter what the rating system, there are some common topics that show up in almost all of them (only the pavement-related ones are listed here):

- Construction waste management
- Materials reuse and recycling
- Minimize materials
- Local materials
- Reduce non-renewable energy use
- Reduce greenhouse gas emissions

There are also multiple topics that you might think ought to be addressed in a sustainability rating system, but are actually only addressed in a few, if any. Again, only the pavement-related ones are listed here:

- Work site safety
- Job training
- Prevailing wages
- Materials production emissions
- Durable structures (i.e., long-life pavements)
- Construction quality
- Life cycle assessment (LCA)
- Local employment
- Cost-benefit analysis (including life-cycle cost analysis)

This is concerning since the asphalt pavement industry certainly, and for good reason, values safety (Safety Innovation Award), training (Diamond Paving Commendation), fair wages, long-life pavements (APA's Perpetual Pavement Award), construction quality (e.g., Sheldon G. Hayes, Ray Brown, Larry H. Lemon, and Quality in Construction Awards), and cost.

How LEED®, Greenroads®, Envision®, and INVEST Stack Up

It is helpful to look at the four prominent rating systems in detail to see how they specifically address asphalt pavements. The U.S. Green Building Council's LEED version 4 BD+C NC (Building Design and Construction for New Construction buildings), Greenroads version 2, the Institute for Sustainable Infrastructure's Envision version 2.0, and FHWA's INVEST version 1.2 are examined in more detail. Each rating system was reviewed for credits that are considered "pavement-related credits." This means credits that:

- **Can be satisfied or partially satisfied by a paving contractor**. These involve actions either specific to paving contractors, or generally applicable to any contractor. Sometimes the paving contractor is only one of several entities that need to meet credit requirements to achieve points.
- **Address asphalt pavements in partial or in whole**. These generally involve a materials choice (for example, porous asphalt); materials composition (for example, recycled content), source (for example, locally sourced), and manufacturing methods (for example, warm mix asphalt); and design (for example, long life).

The general results are summarized in Table 1.

Table 1. Pavement-Related Points Available in Some Sustainability Rating Systems

	LEED v4 BD+C NC	Greenroads v2	Envision v3	INVEST v1.3 PD only
Type of Rating System	Building	Road	Infrastructure	Road
Third-Party Certification Available	Yes	Yes	Yes	No
Total Points Available	110	130	999	169
Total Pavement-Related Points	19	63	261	61
Fraction of Points for Pavements	17%	48%	26%	36%

What do Certified Projects Actually Earn with Pavements?

While Table 1 shows what is *available* for pavements, what pavements actually earn through a certification process may be different. Access to detailed data from the first 22 Greenroads certified projects allows a quick look at this at least for Greenroads. While all 22 of these projects were certified with the earlier Greenroads version 1.5, in terms of pavement-related points this version is quite similar to the current version 2 (version 1.5 has 53 of 108 points available for pavements, or 49%). For these 22 projects, the following ranges were observed:

- Total points earned for the project: 32–46 (average of 38)
- Points earned from pavement-related items: 8–23 (average of 16)
- Fraction of earned points from pavement-related items: 20–53% (average of 41%).

This means that pavement-related credits are achieved at about the same fraction as they are included in the system although achievement rates can vary significantly between projects.

Working with Sustainability Rating Systems

Given that you may run into rating systems while doing business, here are four fundamental recommendations for working with rating systems which can benefit your business:

1. **Be familiar with the four big rating systems**. LEED®, Greenroads®, Envision®, and INVEST. Not all of these systems treat asphalt pavement the same. LEED gives it almost no credit (it is a building rating system after all). There are differences in the other three as well. You can get a general feel for a rating system by reading through it and noting which topics are addressed (and not) and for how many points. Also, rating systems are based on project data, so pay attention to the data collection requirements you might have if using a rating system. Some of this data (like how much RAP, in tons, is actually in the mix) may not normally be collected by the owner and evidence (records) from the contractor may be required.
2. **Endorse and use rating systems that best represent asphalt pavements**. There are differences between rating systems. Those that best represent asphalt pavements can be useful marketing tools by (1) advertising the sustainable attributes

of the asphalt pavement industry, (2) independently verifying the value of these attributes (if the system allows for certification), and (3) understanding what projects pursuing certification are going to want from their asphalt pavement.

3. **Use your knowledge of sustainability rating systems for competitive advantage**. It can be advantageous to align your company with a recognized sustainability brand, especially one that is wholly independent of the industry. In general, a membership fee (these can vary greatly) gets you in the door. Ultimately, there are few recognized sustainability credentials in the industry. A record of working on certified projects, an active membership, and accredited professionals (pass a test on the rating system, become accredited) in your company are the best credentials.
4. **Use rating systems to expand specifications**. Often specifications will not allow you to do what you know is possible and more sustainable. Sometimes, pursuing certification on a project can provide leverage for changing a specification.

Summary

Procurement and evaluation are important elements in including sustainability in our infrastructure and, of course, asphalt pavements. There are different ways one can use to include sustainability in procurement, but, so far, there is not much guidance on when or how best to use them. In general, including sustainability in procurement is largely about getting (or allowing) contractor input into the design and construction process. Most commonly, sustainability can be included in these ways:

- **Specification**. Sustainability features can be specified, allowed or incentivized.
- **Change order**. It is, unfortunately, also possible that a sustainable feature is removed via change order.
- **Alternative sustainability bids**. A project that is bid as (1) a typical design, and (2) a similar design in function but with sustainability features. This is a good way for an owner to gauge how much sustainability features are costing or saving (yes, this can and does happen).
- **Alternative technical concepts (ATCs)**. Design-build ideas proposed that were not requested but offer a sustainability advantage.
- **Sustainability qualifications**. A qualifications-based contract RFP that asks for contractor sustainability work experience or ideas.
- **Sustainability metric reporting**. Requiring certain project metrics (for example, fuel use) to be reported.
- **Sustainability rating systems**. Using a rating system to judge sustainability.

In particular, rating systems can be used to evaluate how well sustainability is integrated into a project, however you must know what the rating system being used does and does not consider. Ideally, a rating system should value the key sustainability attributes of asphalt pavements that we know to be important, and it should weight them in proportion to their impact on project sustainability.

Sustainability in Practice 104

Sustainable Asphalt Pavements: A Practical Guide

How to Develop a Sustainability Program

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Sustainable Asphalt Pavements: A Practical Guide

This is the fourth of four publications in the NAPA Sustainable Asphalt Pavements: A Practical Guide series meant to provide a practical guide to sustainability. That means a focus on what a NAPA member business or asphalt project can do now to address sustainability within the confines of good business practice. The four publications in this series are meant to work together and are organized as follows:

1. **SIP 101: Sustainability Overview**. A practical definition of sustainability and the elements of and reasons for a business approach to sustainability.
2. **SIP 102: Sustainability Specifics**. Specific sustainability actions that can be taken in corporate/organizational strategy, project delivery, mix design, materials production, construction activities, and pavement design.
3. **SIP 103: Procuring & Evaluating Sustainability**. How sustainability is included in public project procurement, and how sustainability efforts are evaluated within the industry.
4. **SIP 104: How to Develop a Sustainability Program**. Important components of a company sustainability program including goals, best practices, implementation, and reporting.

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SIP-104: How to Develop a Sustainability Program

To develop an effective sustainability program, a contractor needs an understanding of sustainability specifics relative to the construction industry and of the fundamental change management practices necessary to successfully implement a program.

This document provides details of what a sustainability program should include, based on what is commonly accepted and what makes good sense. It starts with important items to consider when planning the development of a sustainability program and the reporting associated with it. The importance of setting meaningful sustainability goals and measuring them effectively is described next. A summary of existing asphalt industry sustainability documents is also provided to highlight common sustainability plan elements, goals, and reporting practices.

The need to consider and apply change management fundamentals while developing and implementing a sustainability program is then described. Implementing a sustainability program involves change in a company, likely a pretty big change. Managing that change is critical to a program's success. In fact, most implementation failures occur because of poor change management, not poor products or ideas. Ten best practices for sustainability program development, implementation, and reporting, based on interviews with NAPA member-company employees at multiple levels in their organizations, are presented. Finally, many of the resources available for developing, implementing, and reporting on a sustainability program are highlighted with a focus on resources available through NAPA.

Corporate Sustainability Program Planning

Corporate sustainability program planning can be done using the following five basic steps:

1) Pre-Planning
   a) Team
   b) Understand Sustainability
   c) Research Industry Competitors' Plans
   d) Vision or Mission
   e) Communicate & Engage
2) Plan Development
   a) Plan Elements
   b) Goals and Metrics
   c) Action Steps & Resources
   d) Schedule
3) Implementation
   a) Communicate & Engage

4) Reporting
5) Continuous Improvement

These five steps are applicable regardless of company size and aspirations. An initial sustainability plan for a small company that wants to be more intentional in following and communicating sustainable practices doesn't have to be extensive. In fact, starting small and continuously improving the plan is logical. It also allows time for the company to understand and embrace sustainability. Regardless of company size and aspiration, when the decision to develop a sustainability program is made, the decision needs to be well communicated to the employees by the company's senior-most manager. It needs to be clearly communicated that the plan is not a marketing tool for the company, but rather a tool to help make the business more sustainable for the long term by delivering benefits to customers, employees, the environment, and society as a whole.

Pre-Planning

Team

To start sustainability planning, a team within the organization must be identified and charged with delivering a plan. As with any other significant business process, one individual needs to have responsibility for leading the team and communicating with senior management. Selection of the team leader is critical, as the stature of that person in the company sends a message to the rest of the company. Depending on the size of the company and its sustainability aspirations, the team leader assignment may well need to be a full-time assignment lasting for as long as a couple of years (through the first reporting cycle). The team needs to have access to senior management, and senior management needs to communicate its support for the team to both the team and all other company employees. The team may benefit from being identified as a Sustainability Planning Committee or by whatever terminology is commonly used in the company, so it is understood to be an important effort.

The team should include a senior manager with intricate knowledge of the company's core values and future business strategic plans. This person will "carry the torch" once the program is developed. At a minimum, the team should also include mid-level manager(s) in each major company division (i.e., plants, construction); functional leader(s) (i.e., safety, environmental, quality, human resources); and at least one very operationally oriented person from each major company division who has direct access to senior craft employees. Depending on the size of the company, one person may fill more than one role. Outside assistance to the team from a consultant should be considered and, if deemed necessary, engaged during this Pre-Planning step.

Understand Sustainability

The team must develop a common understanding of what sustainability means and why addressing it is important to the company. There are many resources available to support this, including the NAPA *Sustainable Asphalt Pavements: A Practical Guide* series of documents. The sustainability plan being developed should place an adequate focus on the

company operating as a sustainable business because the company will generate value over the long term by integrating sustainability (business, environment, and people) into its core values and strategy. The team leader has a responsibility to be sure a foundation of what sustainability is and how sustainable practices support the sustainability of the company are clearly established.

Research Industry Competitors' Plans

Several NAPA member companies have published sustainability plans and reports as have other companies that work in the materials and transportation industries. These companies are proud of their sustainability efforts and post their plans on the Internet for all to see. Go ahead and review them. These plans are not all the same; the plan elements, goals, and metrics vary. Specific project activities are also highlighted in some plans. Some will be more mature than others and some will even dive into ethics, especially those of publicly held companies. Doing this research after having determined a common understanding of sustainability helps the team set the stage for developing a vision or mission for the company sustainability plan.

Vision or Mission

A vision or mission statement needs to be concise, but broad and flexible enough to allow for adjustments in plan elements, goals, and metrics over time. It is imperative that the vision or mission also support the company's business strategy and plan. They all must be integrated or they will compete with each other and sustainability will lose. Hopworks Urban Brewery (HUB) in Portland, Oregon, provides a good example of a mission statement that reflects both the business and sustainability goals of the company: "Using beer as a force for good. We focus on making world-class beer and food with practices that drive quality, protect the environment, and improve the community we live in" (HUB, n.d.). It is concise yet broad enough to encompass many sustainable practices. For example, the parking lot at the brewery is a permeable pavement, and HUB is the first Salmon-Safe certified brewery in the world.

Figure 1. HUB Mission Statement.

Communicate & Engage

With the team formed and working with a common understanding of sustainability, coupled with a knowledge of other related-industry plans, to develop a mission or vision statement, it is again time to communicate with company employees about the sustainability planning efforts. Transparency throughout the process is important to ensure employee engagement as the plan is developed and implemented. Transparency can also help dispel any rumors about the planning process and what is forthcoming. Without an effective communication plan, misperceptions and hearsay can spread misinformation throughout a company, which has the potential to undermine the overall sustainability effort.

Plan Development

Plan Elements

The first step in the plan development process is deciding what elements/areas to include in the company's plan. Examples may include business resilience, protecting the environment, supporting the community, health and safety, ethics and compliance. Including plan elements addressing employees and families have also become more common. Goals associated with this element may focus on personal development, diversity, and gender equality. The pre-planning efforts will have led to ideas that can be further developed by the committee. Review of the company's strategic plan and assuring alignment between it and the sustainability plan is an important step. Consideration of competitors' sustainable practices and where the company wants to be relative to them and the industry as a whole is also worthwhile.

Hitting the whiteboard with a sketch of the company's major departments, responsibilities, products, and outputs can be a useful exercise. Listing all the sustainable practices the company currently does — but may not necessarily be taking credit for — and making sure most of them have a place in the first round of the plan is also important. *Sustainable Asphalt Pavements: A Practical Guide — Sustainability Specifics* (SIP 102) is a useful reference for identifying sustainable practices. In this process, it is okay to put an emphasis on reducing costs while minimizing environmental impacts; however, it is very important that positive impacts on employees and communities are also included. Depending on the company's aspirations, it may be worthwhile to conduct some research, such as conducting waste and energy audits or a survey of employee perception of benefits, to gauge where the company stands and what opportunities may exist based on them.

Goals and Metrics

Once plan elements are selected, goals can be identified within each. This is a point where the mid-level manager and operationally oriented team members' input become very important, as they will recognize opportunities as well as potential challenges. Potential challenges are more likely to be connected to metrics rather than goals. Some companies state aspirational goals, such as Zero Injuries. They then state actual goals that support the aspirational one. This can be confusing if the two types of goals are not clearly distinguished in the plan. Some companies state short- and long-term goals, for example 5% alternative energy use in two years and 20% in five years.

When identifying goals, it is worth looking at the U.N. Sustainable Development Goals (SDGs) (United Nations, 2015) to see if the identified goals are in alignment, if that is an objective. This may be more important for companies that pursue alternative procurement work where a statement of qualifications could include reference to a sustainability plan that supports the SDGs, such as publicly held companies and/or for companies with both domestic and international operations.

When identifying goals, it is important to consider metrics that can be used to indicate performance relative to goals. A health and safety metric might be an operating unit's OSHA or MSHA recordable incident rate or rate reduction. An environmental metric might be a reduction in the number of environmental violations.

Three important things to remember when selecting metrics are:

- It must be possible to obtain the information necessary to accurately report performance. With some metrics, it may seem that obtaining the needed information would be simple when in practice it is not.
- Normalizing metrics may be necessary and/or beneficial to allow for change or cycles. For example, a goal of reducing energy consumption at an asphalt plant by 5% may not be nearly as meaningful as reducing energy consumption by 5% on a tonnage basis.
- If reporting to a standard, the goals and related metrics need to conform with or be translatable to the standard reporting requirements.

The most commonly used reporting standard among publicly held companies is the Global Reporting Initiative (GRI), an independent international standards organization that helps entities understand and communicate their impact on climate change, human rights, and corruption, among other issues. It is worth reviewing GRI standards while setting goals and metrics. Subsequent sections of this publication provide additional information on both U.N. SDGs and GRI standards.

It is important to do some research on the availability of information, the need to normalize it, the ability to compile it across a company if there are multiple divisions/business units, and how it will be reported when selecting metrics.

Action Steps and Resources

For each plan element and goal, it is worthwhile to identify the action steps necessary to accomplish the stated goal. When the action steps are listed, then the resources required to support them can also be identified. Remember that everyone in the company already has a full-time job. It is important to be realistic about what else, in addition to their regular job, people can be tasked with. If the committee does not do a good job of identifying and quantifying the resource requirements, then it has failed the organization. Underestimating or not providing necessary resources can lead to frustration, push back, and ultimately not meeting the stated goals. This is another reason why it is so important to engage mid-level managers and operationally oriented team members. If they participated in the development of the plan, they can help communicate how it will impact operations and get buy-in to support implementation.

This is a good reality check on what it will take to implement the plan being developed. The feedback can then be used to prioritize goals based on available resources, new resources that must be provided, and, if necessary, plan for staged implementation efforts. It is also a good time to look at what goals senior management set when plan development began and to communicate what it will take to achieve them.

Schedule

All sustainability plans need a schedule to communicate the timing of actions that lead to full implementation and ultimately reporting. The materials and construction industry is very familiar with schedules, so they are a no-brainer for internal company communications. The

importance of involving mid-level managers and operationally oriented team members in development of the timeline cannot be over emphasized. These types of people are also good at identifying critical paths and opportunities for work to be done in parallel, and they have a sense for realistic contingency planning that should be built into the schedule. The timeline needs to be realistic, and these staff members can be the reality-checkers.

Implementation

If a plan is thoughtfully developed using steps similar to those listed above, then smooth implementation according to the planned timeline should be possible. Of course, the plan needs to be documented in a form that can be publicly shared, if that is the goal — and it should be. For the first round of the plan development, there should be two levels of detail documented. The first level is for public information and the second level should include additional details needed for those actually implementing the plan. For example, the detail in terms of action steps, resources, and Gantt charts needed for public communication is far less than the level needed for operational implementation. Graphic artists are often engaged and sometimes get quite creative when developing graphics for sustainability plan documentation. If a diagram is included in a sustainability plan, it should be able to be concisely described by anyone in the company tasked with communicating the plan.

At this point, the sustainability team leader's job has really just begun. No matter how easy or difficult the plan development process was, implementation will take a champion committed to that effort. Senior management's job is to communicate to the entire company that:

- The plan has been developed with input from people at all levels of the company;
- It is aligned with the company's business strategy and exists to make the business more sustainable over time; and
- There are benefits of the plan for the company, all the employees, the environment, and society.

A good time for this communication is once the plan is developed and ready to be shared with employees so they can consume and embrace it. The bulk of the sustainability committee work as a team will be completed from a development perspective, but the reality is each team member can and should still play a role in communicating and promoting the plan. The reality is a little work around planning communications during the initial implementation will go a long way toward generating excitement and support for the implementation, especially when everyone knows what is in it for them as individuals.

Reporting

Reporting on performance of a publicly communicated sustainability plan is very important in creating credibility around it. Transparency is very important today and a sustainability report is also an opportunity to demonstrate a company's commitment to transparency in reporting. Reporting is also the opportunity to share the good things the company is doing both internally and externally.

The current trend on reporting frequency is every two years in the materials/construction industry. Most companies report on the performance over that period and update or state new goals and metrics for the coming period. For the current period, each goal is stated along with the actual performance and commonly some summary graphics indicating extreme success, success, more work needed, or a need for change. This is high level and if someone wants more detail, the goals and metrics are there for closer review.

Sustainability reports are commonly posted on company websites and start with a statement from the company President. She or he usually describes the company's commitment to sustainability and thanks the employees for accomplishing all that they did in implementing sustainable practices which has benefited the company, its customers, the environment, and society. There are several NAPA member companies that post sustainability reports on a regular basis. Their websites are listed in the reference section of this document and portions of most are summarized in a subsequent section of this document.

Continuous Improvement

For any effective plan to remain effective, it must be reviewed on a regular basis to see what is and is not working well. Opportunities for improvement are identified and changes made to make the plan more effective moving forward. For a sustainability plan, the mission, elements, goals, metrics, resources, communication, and value are all items that should be reviewed regularly. This is normally done with each reporting cycle and is an opportunity to communicate with and engage company employees along the way.

Many tools and templates are available on the Internet that can be reviewed and potentially used at every step of the sustainability program process — from development of a sustainability program all the way through the continuous improvement cycle. A quick search of "Sustainability Planning Tools" will reveal many of these tools, as well as help identify consultants that offer support of plan development.

Corporate Sustainability Reporting

Corporate sustainability reporting can take different forms and may occur at different frequencies. Regardless of form and frequency, a corporate sustainability report is a culmination of prior planning, implementation, and measurement efforts. It's the opportunity to document positive outcomes of sustainable practices, comparing stated goals with actual performance, and identifying future goals. The reality is sustainability goals are what drive behavior and are thus the foundation of sustainability reports. A description of high-level sustainability goals and reporting standards follows to illustrate future direction. This is followed by a review of asphalt industry sustainability reports looking closely at what elements, goals, and metrics are commonly included in their sustainability plans and reports.

Sustainability Goals

The U.N. Development Programme (UNDP) is the United Nations' global development network advocating for change and connecting countries to knowledge, experience, and resources to help people build a better life (United Nations, 2015). Through the UNDP, leaders from 193 governments came together to develop the Sustainable Development Goals (SDGs), otherwise known as the “Global Goals.” The SDGs are a universal call to action to end poverty, protect the planet, and ensure that all people enjoy peace and prosperity. The 17 SDGs build on the previously established U.N. Millennium Development Goals to include new areas, such as climate change, economic inequality, innovation, sustainable consumption, peace, and justice, among other priorities. Many of these goals are interconnected, so sometimes a key to success for one goal may involve achieving success with one or more associated goals. Figure 2 illustrates the SDGs; some of these are more pertinent to asphalt producers than others, such as Nos. 3, 4, 8, 9, 10, 11, and 12.

Figure 2. United Nations Development Programme Sustainable Development Goals (United Nations, 2015).

The SDGs are global, and many are applicable across many businesses and entities. In addition to being referenced in construction company sustainability reports, the SDGs are referenced in the Bill & Melinda Gates Foundation Goalkeepers Data Report, which is published annually to chart progress toward the SDGs (Gates Foundation, 2019). Figure 3 is an excerpt from a Salini Impregilo sustainability report illustrating the role of infrastructure in support of the SDGs from that company’s perspective and its operations (Salini Impregilo, 2016). It is worth noting that Salini Impregilo companies perform significant heavy civil

construction work. Until late 2018, Salini Impregilo's U.S. subsidiary Lane Construction Inc. owned a substantial portfolio of asphalt plants and was a major paving contractor.

The point is, from a global perspective, sustainable and common goals are applicable to all entities. A summary of several asphalt industry companies' reported sustainability goals is presented in the following section after more background on reporting standards and goal setting examples are provided.

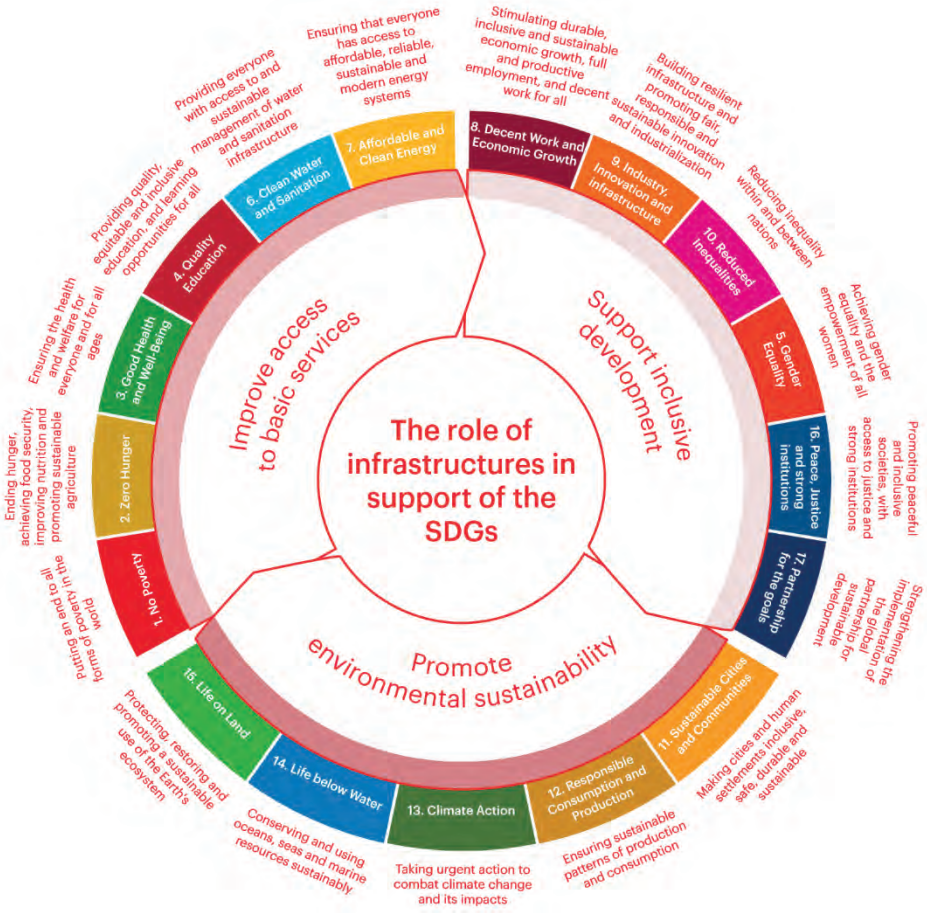


Figure 3. The role of infrastructure in support of the U.N. SDGs per Salini Impregilo (2016).

Sustainability Reporting Standards

The most popular standards for sustainability reporting are from the Global Reporting Initiative (GRI), the Sustainability Accounting Standards Board (SASB), and the International Integrated Reporting Council (IIRC) (GRI, n.d.a; SASB, n.d.; IIRC, 2013). GRI, at about 80% of the market, is the dominant sustainability standards resource across all industries and continents. *Sustainable Asphalt Pavements: A Practical Guide — Sustainability Specifics* (SIP-102), describes specific sustainable practices at the corporate/organizational, project delivery, and project levels that can be achieved using today's technology and know-how along with reference to GRI reporting (Muench & Hand, 2019). A brief overview of GRI and SASB reporting standards and their use in the construction and materials sector is provided below.

GRI is an independent international organization that has taken the lead in sustainability reporting since the late 1990s (GRI, n.d.a). GRI indicates that 93% of the world's largest 250 corporations report on their sustainability performance using GRI Sustainability Reporting Standards. GRI defines a Corporate Social Responsibility (CSR or sustainability report) as "… a report published by a company or organization about the economic, environmental, and social impacts caused by its everyday activities. A sustainability report also presents the organization's values and governance model, and demonstrates the link between its strategy and its commitment to a sustainable global economy" (GRI, n.d.b). A sustainability report serves as a focal point in the management of sustainability efforts and a tool for communicating sustainability performance and impacts.

Category	Economic	Environmental		
Aspects [III]	• Economic Performance • Market Presence • Indirect Economic Impacts • Procurement Practices	• Materials • Energy • Water • Biodiversity • Emissions • Effluents and Waste • Products and Services • Compliance • Transport • Overall • Supplier Environmental Assessment • Environmental Grievance Mechanisms		
Category	**Social**			
Sub-Categories	**Labor Practices and Decent Work**	**Human Rights**	**Society**	**Product Responsibility**
Aspects [III]	• Employment • Labor/Management Relations • Occupational Health and Safety • Training and Education • Diversity and Equal Opportunity • Equal Remuneration for Women and Men • Supplier Assessment for Labor Practices • Labor Practices Grievance Mechanisms	• Investment • Non-discrimination • Freedom of Association and Collective Bargaining • Child Labor • Forced or Compulsory Labor • Security Practices • Indigenous Rights • Assessment • Supplier Human Rights Assessment • Human Rights Grievance Mechanisms	• Local Communities • Anti-corruption • Public Policy • Anti-competitive Behavior • Compliance • Supplier Assessment for Impacts on Society • Grievance Mechanisms for Impacts on Society	• Customer Health and Safety • Product and Service Labeling • Marketing Communications • Customer Privacy • Compliance

Figure 4. GRI standard reporting Categories, Sub-Categories and Aspects within them (GRI, 2015).

The Governance & Accountability Institute reports that in 2017 85% of S&P 500 companies did sustainability reporting (Coppola, 2018); however, GRI states that sustainability reporting is not as well-established in the construction sector (Lamprinidi & Ringland, 2008). Only one

NAPA member company, CRH Americas Materials, indicates it reports to any of the GRI elements. Figure 4 is an excerpt from the GRI reporting principles and standards, showing the three primary reporting categories: economics, environment, and social. It also illustrates four subcategories under the social category. Under each category and subcategory, specific reporting aspects are listed.

SASB is similar to the well-recognized Financial Accounting Standards Board (FASB). FASB is a private, non-profit standard-setting body with the primary purpose of establishing and improving U.S. generally accepted accounting principles (GAAP) in the public interest (FASB, n.d.). SASB connects business and investors to the financial impacts of sustainability (SASB, n.d.). It was founded in 2011 to develop and disseminate sustainability accounting standards, which is important because “other social and environmental measures” are understood to be relevant to financial reporting today. A SASB goal is to have its standards integrated into the U.S. Securities and Exchange Commission (SEC) annual 10-K reporting requirements which are a comprehensive summary of a public company’s financial performance.

SASB has developed industry-specific reporting standards, enabling relevant company comparisons. The SASB website states that “Investors increasingly recognize that environmental, social and governance (ESG) factors can impact a company’s ability to manage risk and deliver financial performance over the long-term.” SASB has created an Investor Advisory Group (IAG) comprised of leading asset owners and asset managers committed to improving the quality and comparability of sustainability-related disclosure to investors. Collectively, the IAG represents more than $21 trillion in assets under management.

The U.N. SDGs, use of GRI reporting standards, and SASB IAG membership are not the norm among relatively small companies working to improve their sustainable practices. However, they are becoming common in larger companies, especially publicly traded companies. They are certain to become more common in the future.

Obtaining Meaningful Data for Sustainability Goal Reporting

When establishing sustainability goals, it is very important to consider what action steps will be required to achieve stated goals and how the information necessary to report on goals will be obtained. In some cases, this could be quite simple. At a very basic level, a goal of reducing energy consumption at an administrative building could be set. Utility company bills could be used to see if the steps taken were effective in reducing energy consumption. Examples of action steps might include conducting an energy audit; replacing incandescent and CFL lightbulbs with LED bulbs when they burn out; turning all office equipment (computers, monitors, printers) off at night; using motion detectors and automatic dimmers for lighting control in hallways and meeting spaces; and using programmable thermostats wisely. The investment in the action steps could be easily quantified while the energy consumption and related cost savings could be obtained from the utility company bills to measure performance. That is pretty straightforward and could easily be reported to the

office occupants, showing the return on investment and reduction in energy use. Details of this and other examples can be found in SIP-102 (Muench & Hand, 2019).

A more challenging example might be a goal to reduce GHGs at an asphalt pavement mixture production facility with action steps of increasing RAP use by 10%, increasing the ratio of warm-mix to hot-mix production by 10%, insulating hot oil lines, and installing variable frequency drives on the slat conveyor and baghouse motors. All of these action steps make sense financially and should also make sense from a GHG reduction perspective. To make the example more interesting, the production site might also have an aggregate plant, equipment shop, quality control lab, regional business office, and a series of 15 temporary offices set up to support a large project nearby that will be removed when the project ends in nine months. Interestingly, there is only one gas meter and one electric meter on the entire site. Quantifying the actual energy consumption and GHG impacts of the logical action steps above could be very challenging, nearly impossible, under these conditions. It could be further complicated if significant swings in annual aggregate and plant production occur, although this could be normalized by reporting relative to production. The point of this example is to ensure goals are well thought out and measurement and reporting are considered when establishing them. This requires involvement in the goal setting process of those who would be charged with doing the measurement.

Examples of Industry Sustainability Programs

To illustrate how these principles are put to use, several asphalt industry company sustainability plans and/or reports were reviewed and are highlighted below. Sustainability program elements, goals, metrics, and reporting frequency were reviewed along with ties to business strategy. Reports from Colas, CRH Americas Materials, Granite Construction Inc., Salini Impregilo S.p.A., Martin Marietta Inc., and Vulcan Materials Co. were reviewed.

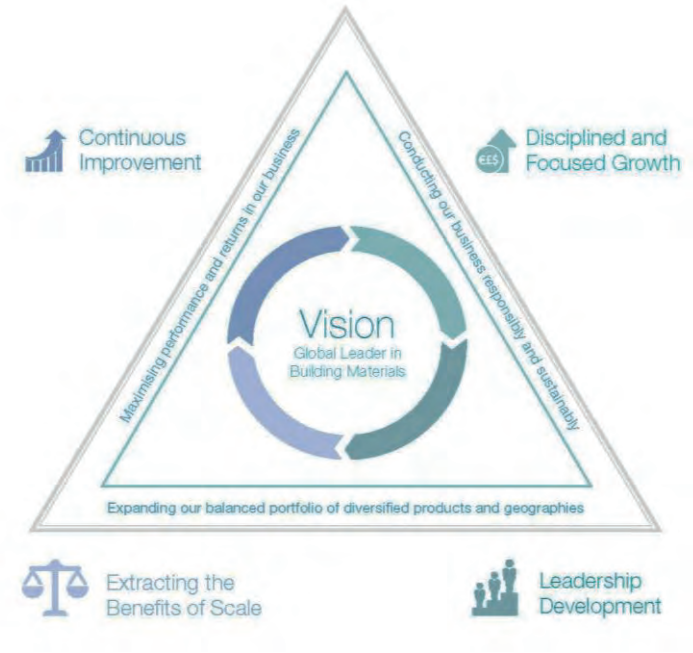


Figure 5. CRH Vision (CRH, 2017)

CRH Americas Materials' Vision from its 2017 annual sustainability report is shown in Figure 5 (CRH, 2017). It illustrates a tie between business strategy and sustainability. The report also includes summary financial reporting. The CRH Americas Materials annual

report was one of two NAPA member reports with reference to any of the U.N. SDGs with specific references to SDGs Nos. 9, 11, 12, and 13.

The CRH report lists 15 goals with one or more of the following elements in its plan: safety, employee engagement, business conduct, community engagement, supply chain, environment, climate, air, waste, water, and biodiversity. The report includes extensive graphics illustrating plan elements and practices associated with the elements. Figure 6 is an example of this from the report.

Figure 6. CRH Americas Materials plan elements and associated practices. (CRH, 2017).

The 2017 Martin Marietta sustainability report included limited financial reporting and focused on performance, although specific goals were not stated (Martin Marietta, 2017). Plan elements were not clearly stated either. Figure 7 is an example from the report illustrating improvement in safety performance.

The 2016 Granite Construction sustainability report included limited financial reporting (Granite, 2016). It included seven elements with clearly stated goals and reported performance. Space was also dedicated to ethics like some of the other plans. Figure 8 is a graphic illustrating the plan elements with safety at the center. Interestingly, it was the only plan reviewed that included infrastructure investment as an element. Additional research revealed that the company is headquartered in California and has significant construction materials and construction resources in that state. The Infrastructure Investment element was likely partially driven by California Senate Bill 1, the Road Repair and Accountability Act of 2017, which provided for significant long-term transportation funding in the state.

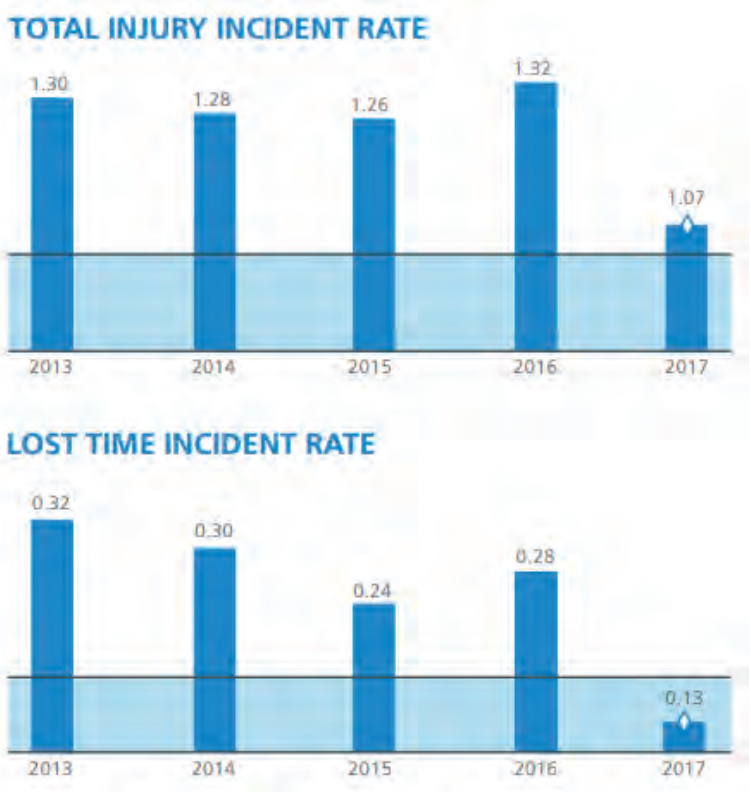


Figure 7. Martin Marietta Safety Performance Example (Martin Marietta, 2017).

Figure 8. Granite's Seven Pillars of Sustainability (Granite, 2016)

Like the CRH Americas Materials report, the 2016 Salini Impregilo sustainability report was extensive and included financial reporting and ethics elements (Salini Impregilo, 2016). It also included reference to the U.N. SDGs (see Figure 3) with direct contribution to SDG Nos. 6, 7, 9, 11 and 13, as well as indirect contribution to the other 12 goals. Figure 9 excerpted from the report shows what is referred to as the "Shared Value Approach," including economic value, social and environmental value that addresses infrastructure needs while addressing sustainable development goals. This clearly illustrates the tie between business strategy and sustainability strategy.

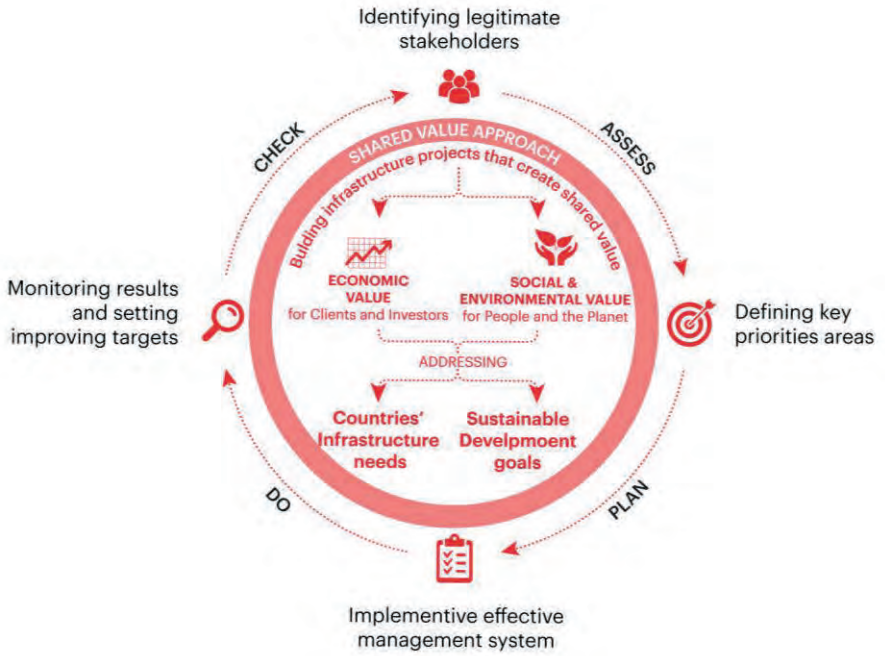


Figure 9. Salini Impregilo's Shared Value Approach (Salini Impregilo, 2016).

It is worth mentioning that graphics can be very useful for communicating information and relationships. However, if they are not well done or communicated, graphics can also create confusion; unfortunately, this is not uncommon when it comes to the graphics sometimes found in sustainability plans and reports.

The elements of the six reviewed corporate sustainability program plans are summarized in Table 1. All six included the following elements: Business and Sustainability Strategies Integration, Safety, Employee, Community Engagement, and Environment. Three included Customers/Quality, and four included Compliance/Risk Management/Ethics. All six included public reporting with metrics.

While there was some consistency in plan elements, the reporting metrics used were not nearly as consistent among the companies reviewed. A few selected examples of the metrics used are summarized by company and sustainability plan element in Table 2. Appendix A contains more detailed lists of metrics they used. The appendix has a table for each company with more detailed lists of the metrics used within each sustainability plan element. The appendix also contains a set of tables organized by sustainability plan

element, showing the companies' metrics together within each sustainability plan element. The Colas, CRH Americas Materials, and Salini Impregilo reports contained the most extensive levels of metrics reporting and complexity. The CRH report was the only one to reference reporting to GRI standards. Colas also included metrics more fundamental or directly related to environment impact, such as CO_2/GHG, energy consumption, water use, and waste generation to name a few examples.

Table 3 illustrates how many asphalt industry corporate sustainability reporting metrics can be directly related to GRI reporting standards. The example shown in the table is for sustainability plan metrics associated with the sustainability plan element Integration of Business and Sustainability Strategies. This example also clearly shows that NAPA member companies could join the more than 80 percent of S&P 500 company reporting to the GRI standard. The same could be done for other sustainability plan element metrics using the summary of all GRI reporting standards categories, subcategories, aspects, indicators, and descriptions presented in Appendix B.

Observations on Industry Company Reports

There is a range of effort and documentation from the companies when it comes to sustainability reporting. Of the sustainability programs reviewed, those with a significant portion of the company business outside the U.S. have the most mature programs. The programs rely on ISO management standards, incorporate U.N. SDGs, and one even reports to the GRI standard with third-party certification of its reporting. Examples are CRH Americas Materials, Colas, and Salini Impregilo.

The U.S.-based companies reporting publicly are obviously not as influenced by European standards and the sustainability climate of Europe. Interestingly, both the U.S.- and Europe-based company plans contain essentially the same plan elements. The sustainability plans of the U.S.-based companies are less mature, simpler, but still include metrics. It is important to note that all the plans reviewed were for publicly traded companies.

For privately held companies working on or considering developing sustainability plans, it would be best to use the reviewed U.S. company plans as a starting point and as an indicator of what will be important over the next five years in the U.S. Then look at the factors the Europe-based company plans contain when considering the direction sustainability planning could take in the U.S. over the longer term. It cannot be emphasized enough that sustainability plan development and reporting can begin with simply taking credit for what a company is currently doing and then building on that over time.

Table 1. Elements of Asphalt Industry Company Corporate Sustainability Programs.

Company	Business & Sustainability Strategies Integrated	Safety	Employees	Community Engagement	Environment	Customers, Quality	Compliance, Risk Management, Ethics	Public Reporting with Metrics
CRH Americas Materials	Building a Resilient and Sustainable Business	Embedding a Culture of Safety	Developing and Empowering Our People	Collaborating and Engaging for Sustainability	Protecting the Environment	Creating Solutions for Our Customers	Yes	Yes (2017)
Martin Marietta	Sustainability Excellence Drives Shareholder Value	Safe Operations	Employee Well-Being	Community Well-Being	Environmental Stewardship			Yes (2017)
Granite Construction	…align our sustainability goals with our five-year Strategic Plan	At Granite our ultimate goal is zero incidents	Our most powerful partnership is the one we have with our employees	…each local community is at the heart of those we serve	We believe that we must be a leader in environmentally responsible operations in our industry	We deliver high-quality projects and materials to meet or exceed our customers' standards…	Named by Ethisphere Institute as one of the "World's Most Ethical Companies" seven years in a row	Yes (2016)
Colas	our commitment to sustainability is an essential part of this strategy	Health, Safety and Wellbeing	Our People	Community	Environmental Sustainability	Customers Suppliers and Partners	Ensuring we comply with regulation and have strong governance and ethics	Yes (2017)
Vulcan Materials	… guide our business conduct as well as our social, environmental and economic activities	Safety Drives and Reinforces Every Action We Take	Committed to Our People	We're in This Together	Responsible Stewards		Upholding ethical business practices	Yes (2016)

Table 2. Examples of Asphalt Industry Company Corporate Sustainability Reporting Metrics.

Company	Business	Safety	Employees	Community Engagement	Environment	Customers, Quality	Compliance, Risk Management, Ethics
CRH Americas Materials	• Financials • GRI Index • Four U.N. Global Sustainability Goals	• Fatalities • Accidents by Injuries and Cause • Contractor site induction • Safety training	• Employee training • Employees by age, gender, and country	• Community engagement plans	• Expenditures on licensing, waste management, restoration & biodiversity, alternative material & fuel use, emissions reduction • CO_2 emissions • Energy use • Waste type & recycling		• Supply chain procurement ethics • Code of Business Conduct training • Compliance training • Board member make up
Martin Marietta	• Awards	• Awards • Injury rate • Lost time rate • Audits	• Female & minority employees • Continuous learning courses • 401(k) participation	• Volunteer hours • Donated materials • Education visits • Meals	• Investment in mobile equipment with reduced GHG • Alternative fuel use in plants • Alternative shipping (rail)		• Ethics training
Granite Construction	• Sustainable infrastructure investment • Senior management engagement in industry • Rating system engagement	• OSHA recordable incident rate • OSHA & MSHA citations • OHSAS 18001 certification	• Wellness program participation • Women in construction support • Retention & turnover rates	• Community outreach engagements • Financial support of non-profits • All business unit disaster relief drive	• ISO 14001 certification • Environmental citations • Green construction materials use • Telematics for reduced fuel consumption • Carbon footprint	• ISO 9001 conformance-Quality staff certifications & licensure • Quality awards	• Ethisphere Most Ethical Company designation • Compliance training • ISO 19600 Corporate Compliance & Ethics conformance

Table 2 (continued). Examples of Asphalt Industry Company Corporate Sustainability Reporting Metrics.

Company	Business	Safety	Employees	Community Engagement	Environment	Customers, Quality	Compliance, Risk Management, Ethics
Colas	• Financials • Growth	• Lost time frequency • Vehicle incidents • Accident frequency • OHSAS 18001 non-conformances	• Workforce • Employee training days • Female management • Turnover • Employee satisfaction	• Community investment volunteer time • Educational events	• ISO 14001 certification • Incident frequency • Prosecution rate • Non-conformances • Recycling rate • CO_2 turnover • GHG • Energy efficiency • Waste • ISO 50001 certification	• Remedial spend • Customer satisfaction • Quality non-conformance rate • Customer quality issues	• Number of suppliers • Supplier performance reviews
Salini Impregilo	• Financials • Total projects • Global presence (total employees, countries, nationalities) • Local procurement	• Injury rate • Lost days rate	• Training hours provided • Master's in International Construction Management program	• Local community meetings • Project visits • Free health interventions	• Climate change mitigation backlog • GHG • Energy, Water and Reuse intensity • Reutilized materials • Supplier evaluations • Goods shipped by sea • Pollution controls • Reforestation		• Code of ethics training • Organizational control and corruption training

Table 2 (continued). Examples of Asphalt Industry Company Corporate Sustainability Reporting Metrics.

Vulcan Materials	• Financials	• MSHA & OSHA recordable injury rate • MSHA citation rate • Health testing rate • Dust, silica and noise exposure sampling	• Employees • Tenure • New Hires	• Scholarships awards/funds • School partnerships • Visitors • Plant tours • Dollars donated • Foundation and matching gifts • Matching employee contributions	• Acreage in portfolio • Water stores at former quarry • Wildlife Habitat Council certified sites • Used oil recycled • Products produced from recycled materials		

Table 3. Asphalt Industry Company Corporate Sustainability Reporting Metric Examples for *Integration of Business and Sustainability Strategies* related to *GRI Reporting Standards*.

Company	Business & Sustainability Strategies Integrated	Related GRI Reporting Category > Sub-Category > Aspect
CRH Americas Materials	Financials	Economic > Economic Performance
	GRI Index	
	Four U.N. Sustainable Development Goals (SDGs)	
Martin Marietta	Awards	
Granite Construction	Sustainable infrastructure investment	Economic > Market Presence
	Senior management engagement in industry organizations	
	Promoting sustainable infrastructure funding	Society > Public Policy
	Envision and Greenroads participation	Society > Local Communities
Colas	Financials	Economic > Economic Performance
	Growth	
Salini Impregilo	Financials	Economic > Economic Performance
	Total projects	Economic > Market Presence
	Global presence (total employees, countries, nationalities)	Social > Labor Practices and Decent Work > Employment
	Local procurement	Economic > Procurement Practices
Vulcan Materials	Financials	Economic > Economic Performance

Implementation Best Practices

Industry sustainability program best practices were identified by interviewing key personnel at NAPA member companies with responsibility for developing, implementing, or maintaining sustainability programs. People at different organization levels, ranging from president and CEO to operational managers and craft workers, were interviewed.

Collectively the following 10 best practices were identified through a review of the literature, personal experience, and, most importantly, interviews of industry personnel:

1. How sustainability supports the business strategy must be clear to the company.
2. Senior leadership commitment and communication are essential to implementation.
3. Stakeholders at all levels must be engaged in development to support implementation.
4. Resources necessary for implementation and maintenance must be provided.
5. Management systems should complement and support sustainability programs.
6. External assistance can help with development and continuous improvement.
7. Careful consideration of sustainability plan elements and goal setting.
8. Ability to measure performance is essential.
9. Documentation, measurement, and reporting drive performance.
10. Patience is required and program evolution will occur.

How Sustainability Supports the Business Strategy Must be Clear

It must be very clear how development and implementation of a sustainability program supports the company's business strategy and will provide return on investment in order for buy-in to occur at all levels of the company. Direction from the board of directors or senior management, including the president, without clear communication as to why sustainability is good for employees, shareholders, the environment, and society may not lead to support from those who must make the changes and do the work necessary to accomplish the goals of the program. Once the economic value is clear, it is easy to also illustrate the environmental and social benefits.

Use of simple examples like the use of RAP and even in some cases just meeting owner requirements are an excellent way to do this. Once the conversation begins with the positive financial aspects, which also include positive environmental impacts, then less tangible examples can be communicated, such as program benefits to employees and local communities. Regardless of the path taken to communicate or gain support for a sustainability program, communication must start with the positive financial impact it can have on the company. A copy of the book *Green to Gold: How Smart Companies Use Environmental Strategy to Innovate, Create Value, and Build Competitive Advantage* (Esty & Wilson, 2009) dropped on a few desks afterwards can be helpful also.

Senior Leadership Commitment and Communication Are Essential to Implementation

If senior leadership in a company is not committed to a sustainability program, the effort should not be pursued until they are convinced of its merit. What is important to an employee's boss is normally important to the employee. If senior leadership is committed, it is much easier to obtain commitment from the rest of the company's employees. If the president of a company has the vision to see how sustainable practices can improve business performance and company perception, then he or she clearly has the ingredients necessary to be committed and to communicate that commitment.

Once committed, senior leadership must be unwavering in its commitment. It must lead by example, clearly communicating the company's path and the value the sustainability program will create for the company and its employees. Every company employee is a stakeholder in the program and needs to be engaged for it to be successfully implemented to provide the expected returns. If senior leadership does not make the sustainability program a high priority, communicate that, and "walk the talk" by providing the resources necessary to accomplish it, the likelihood of success will be low. When senior leadership does walk the talk, then commitment will trickle down through the company.

One of the best things senior leadership can do is publicly acknowledge and reward those that show the same level of commitment and at the same time appropriately hold those who are not committed accountable for their actions. This is particularly important at mid-level management and senior craft levels. When a superintendent who has helped make the company successful in the past is openly negative about the sustainability program, they

need to be appropriately addressed so that the crews working for them do not turn negative too. This usually occurs either due to a lack of understanding of the benefits of the program or when appropriate resources have not been provided.

Stakeholders at All Levels Must Be Engaged in Development to Support Implementation

A sustainability program cannot successfully be developed and implemented without involving stakeholders at all levels of a company. Senior management can have a desired or even publicly stated goal, but without input on how to achieve the goal from mid-level managers and, even more importantly, craft-level workers that actually produce products, the desired outcome will not be attainable in the most efficient and effective manner. In fact, management dictation of goals along with how they will be accomplished can result in pushback and disengagement of employees. Conversely, when employees at all levels of a company are involved in identifying goals and setting targets, then they will be more engaged in helping the company achieve them, especially if they can see a tie between the goals and the return on investment for the company and its employees. Using this process also assures different stakeholders will understand how their asks will impact others and vice versa, ultimately eliminating future roadblocks.

Resources Necessary for Implementation and Maintenance Must Be Provided

Whenever a new initiative is begun, it requires resources for development and implementation, as well as maintenance and improvement once established. It is important that those tasked with each of these activities have the resources necessary to accomplish what they are being asked to do. There are always costs and time associated with a commitment of resources, and management needs to walk the talk on resource commitment.

For example, when setting a goal to increase RAP use in asphalt mixtures from 10% to 30%, capital investments may be needed for plant improvements. New mix designs, training of staff, and inventory-tracking process changes will be needed, too. All of this will take time to acquire, shakedown, and effectively implement before the goal can be accomplished. Management needs to recognize this and provide the support needed to reach the goal.

Management Systems Should Complement and Support Sustainability Programs

Many companies successfully leverage ISO management systems to support sustainability program objectives, goals, reporting, and continuous improvement. ISO 9001, ISO 14001, and ISO 45001 are Quality Management, Environmental Management and Occupational Health and Safety Management standards, respectively (ISO, n.d.). All are similar in philosophy and rely on the same basic principles to engage senior management while leading to expected outcomes and continuous improvement.

Many GRI reporting requirements are well aligned with the ISO management standards. A good example with direct comparison between ISO 14001 requirements and GRI reporting requirements can be found in Mileva (2013). Some of the company sustainability reports reviewed, including CRH Americas Materials, Colas, Granite Construction and Salini Impregilo, reference ISO-based, -compliant, or -certified management systems. Taking the time to closely review these companies' sustainability plans and reports can provide insight into the ties between the ISO management standards, goals, and reporting. Some of these companies also rely on Lean and Six Sigma methodologies for continuous improvement. Lean focuses on eliminating waste in processes and production, while Six Sigma focuses on reducing variability in processes and production (George, 2002). The reality is Lean and Six Sigma complement each other and that is why many companies combine the two into what is called Lean Six Sigma for continuous improvement. All these resources can be used to support sustainable operations.

External Assistance Can Help with Development and Continuous Improvement

Several forms of external assistance can be used to help a company develop or improve an existing sustainability program. Examples include hiring someone with experience in this field if no one in the company has it (not necessarily a consultant); benchmarking against peer companies; forming a council of advisors that may or may not be formal; and being intentional in adding a company board of director who worked for a company with an effective sustainability program. Although external assistance can be very helpful, it is essential that someone in the company have "ownership" of the sustainability program as it will ultimately be managed by the company, not a consultant.

Careful Consideration of Sustainability Plan Elements and Goal Setting

A process for considering and selecting sustainability plan elements and key goal selection considerations was described previously in the "Corporate Sustainability Program Planning" section. Confusion around selecting plan elements can occur after the goals, action steps, and metrics associated with them are developed, as they may fall under more than one plan element. This is a common occurrence that forces proposed plan elements to be revisited and revised, which is acceptable. What is not acceptable is getting bogged down and complicating the plan by combining elements to the point so aggressively that only a few elements that are difficult to communicate clearly remain.

Ability to Measure Performance is Essential

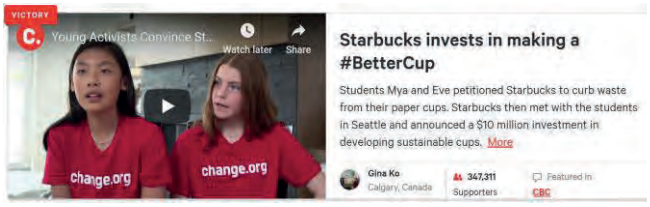
The most meaningful and powerful outcomes of a sustainability program are the measurement and reporting of performance. Reporting performance data clearly demonstrates a company's commitment to sustainability. Therefore, performance measurement data need to be readily obtainable and as accurate as possible. Transparency is confirmed through performance reporting, and no company wants its credibility questioned due to the accuracy of its performance reporting data.

When selecting metrics, it is important to give consideration to what may happen over time to influence the metrics and reporting. For example, a company could acquire additional plants or merge companies. There could be significant swings in plant production tonnage from year to year due to local market conditions, etc. When selecting metrics, it may be best to normalize them, so relative comparisons can be made over time. For example, tracking energy consumption per ton versus total annual energy consumption.

Documentation, Measurement, and Reporting Drive Performance

There are several adages, often incorrectly attributed to management and quality gurus Peter Drucker and/or W. Edwards Deming, that state some variation of "If you don't measure it, you can't manage it or improve it." Regardless of the source, the message is a valuable one for sustainability programs. For a sustainability program and related reports to be of significant value to a company and its customers, the program must be built on facts, not marketing propaganda. Documentation, measurement, and reporting are the keys to credibility. There are several references to this in the works of Andrew Winston (Esty & Winston, 2009; Winston, 2014). In *The Big Pivot: Radically Practical Strategies for a Hotter, Scarcer, and More Open World* (Winston, 2014), in particular, Winston focuses on the importance of companies being truthful and transparent in sustainability reporting.

Winston uses several examples to illustrate how dramatically social media can rapidly damage company reputation and credibility, as well as force a company to take actions. One example is the 2015 Volkswagen emissions scandal, commonly referred to as "dieselgate," which is estimated to have cost the company $18 billion (Boston, 2016). As the scandal erupted, Volkswagen AG stock price rapidly dropped from about $25/share to $11/share. Four year later, it is still trading for about $17/share. Another recent example is students petitioning Starbucks to reduce paper cup waste using the Change.org petition site, leading the company to commit to investing $10 million for development of more sustainable cups (Ko, 2018; Smith, 2018).



Several good examples of sustainability reports from the asphalt industry are referenced in this document. Central to all of them is reliance on the measurement of performance relative to a set of stated goals. The reports reviewed are primarily from larger producers and are based on mature programs developed over many years. If one reviews these company sustainability reports over time, the importance of measuring and reporting performance is very clear. Once reporting starts, no company desires to show a decline in performance. Therefore, documenting goals, measuring performance, and reporting it on a regular basis leads to continuous improvement and commitment of resources needed to accomplish stated goals that evolve with time.

Patience is Required and Program Evolution Will Occur

Development, implementation of, and ultimately reporting on the effectiveness of a sustainability program takes time. It typically takes several years and is an evolutionary process. Recognizing this is important in planning so that a realistic initial scope and expectations over time are set. It is not unusual for a program to start relatively small by simply identifying the sustainable practices the company already does and laying out a program to recognize and take credit for them. This is useful for illustrating to a company's employees how it is already committed to sustainability and how that commitment positively impacts the company, environment, and society. After this initial development, the program can continually improve and grow in scope and at a pace that best suits the company. Introduction and evolution also involves change management, which should be considered, especially when considering the pace of development, implementation, and evolution. The review of publicly available sustainability plans and reports illustrates this.

Resources to Support Contractor Sustainability Programs

There are many resources available to support development of sustainability programs for asphalt mixture producers, construction companies, and related businesses. Tools and templates are available on the Internet that can be reviewed and potentially used when beginning development of a sustainability program. There are many active sustainability consultants, although few are focused on the materials/construction industry. Importantly, NAPA has a significant number of asphalt-focused sustainability resources available that compliment other sustainability resources. Most of these resources can be accessed via the NAPA website, www.AsphaltPavement.org/PracticalGuide, including:

- Annual survey reports on the use of recycled materials and warm-mix asphalt technologies in the United States.
- The Emerald Eco-Label, a web-based tool that allows asphalt mix producers to easily and cost effectively develop plant- and mixture-specific environmental product declarations (EPDs).
- Guidance on the design, production, construction, and maintenance of porous asphalt pavements.
- Information on pavement reflectivity and the urban heat island effect.
- A greenhouse gas calculator tool for asphalt mix production facilities.
- Guidance on how asphalt pavements can help projects earn credits under various green rating systems, such as LEED and Greenroads.
- Numerous reports and fact sheets on the sustainable aspects of asphalt pavements.

The NAPA Online Store includes a complete suite of technical publications that cover everything from managing energy consumption at asphalt plants to designing high RAP mixtures. In addition, links to sustainability webinars, including the 10-part “Specialization in Asphalt Sustainability Implementation” series, that can be viewed on demand are available. The NAPA Sustainability Committee meets twice a year at NAPA’s Annual Meeting and Midyear Meeting, and sustainability topics are regularly included among these meeting’s workshops and sessions. Past conferences have even been dedicated only to sustainability. Finally, multiple NAPA staff members are industry leaders in specific areas of sustainability and are easily accessible and eager to respond to requests.

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Appendix A

Summary of Asphalt Industry Examples of Sustainability Reporting Metrics

Table A1. CRH Americas Materials Example Corporate Sustainability Reporting Metrics (CRH, 2017)

Metrics by Plan Element						
Business	**Safety**	**Employees**	**Community Engagement**	**Environment**	**Customers, Quality**	**Compliance, Risk Management, Ethics**
• Financials • GRI Index • Four UN Global Sustainability Goals	• Fatalities by cause • Accidents by Injuries • Accidents by Cause • Contractor site induction • Safety training	• Employee training • Employees by age, gender, & country	• Community engagement plans	• Expenditures on emission reductions, licensing, waste management, restoration & biodiversity, water use, energy reduction, alternative materials (RAP, RAS, C&D), & fuel use • CO_2 emissions • Energy use • Waste type & recycling		• Supply chain procurement ethics • Code of Business Conduct training • Compliance training • Board member independence, gender, geographic spread, & tenure

Table A2. Martin Marietta Example Corporate Sustainability Reporting Metrics (Martin Marietta, 2017)

Metrics by Plan Element						
Business	**Safety**	**Employees**	**Community Engagement**	**Environment**	**Customers, Quality**	**Compliance, Risk Management, Ethics**
• Awards	• Awards • Injury rate • Lost time rate • Audits	• Female & minority employees • Continuous learning courses • 401(k) participation	• Volunteer hours • Donated materials • Education visits • Meals	• Investment in mobile equipment with reduced GHG • Alternative fuel use in plants • Alternative shipping (rail)		• Ethics training

Table A3. Granite Construction Example Corporate Sustainability Reporting Metrics (Granite, 2016)

Metrics by Plan Element						
Business	**Safety**	**Employees**	**Community Engagement**	**Environment**	**Customers, Quality**	**Compliance, Risk Management, Ethics**
• Sustainable infrastructure investment • Senior management engagement in industry organizations • Promoting sustainable infrastructure funding • Envision & Greenroads participation	• OSHA recordable incident rate • OSHA & MSHA citations • OHSAS 18001 certification	• Wellness program participation • Women in construction support • Retention & turnover rates	• Community outreach engagements • Financial support of non-profits • All business unit disaster relief drive	• ISO 14001 certification • Environmental citations • Green construction materials use • Telematics for reduced fuel consumption • Carbon footprint	• ISO 9001 conformance-Quality staff certifications & licensure • Quality awards	• Ethisphere Most Ethical Company designation • Compliance training • ISO 19600 Corporate Compliance & Ethics conformance

Table A4. Colas Example Corporate Sustainability Reporting Metrics (Colas, 2017)

Metrics by Plan Element						
Business	**Safety**	**Employees**	**Community Engagement**	**Environment**	**Customers, Quality**	**Compliance, Risk Management, Ethics**
• Financials • Growth	• Lost time frequency • Vehicle incidents • Accident frequency & incident rate • OHSAS 18001 non-conformance • CEO/director safety audits • DIY health MOTs	• Workforce • Manager participation in development training • Employee formal training days • Female senior management positions • Turnover rate • Employee satisfaction • Workforce under 25-years-old	• Community investment volunteer time • Educational events	• ISO 14001 certification • Incident frequency • Prosecution rate • Non-conformance frequency • Recycling rate • CO_2 turnover • GHG • Energy efficiency • Waste • ISO 5001 certification	• Remedial spend • Customer satisfaction survey score • Public satisfaction score • Quality non-conformance rate • Customer quality issues • Resident quality issues	• Number of suppliers • Supplier performance reviews

Table A5. Salini Impregilo Example Corporate Sustainability Reporting Metrics (Salini Impregilo, 2016)

Metrics by Plan Element						
Business	**Safety**	**Employees**	**Community Engagement**	**Environment**	**Customers, Quality**	**Compliance, Risk Management, Ethics**
• Financials • Total projects • Global presence (total employees, countries, nationalities) • Local procurement	• Injury rate • Lost days rate	• Training hours provided • Master's in International Construction Management program	• Local community meetings • Project visits • Free health interventions	• Climate Change Mitigation backlog • GHG • Energy intensity • Water intensity • Reuse intensity • HSE expenses • Reutilized materials • Monitoring activities • Audits • Supplier evaluations • WMA use • Goods shipped by sea • Erosion protection • Pollution controls • Noise & vibration • Reforestation		• Code of ethics training • Organizational control & corruption training

Table A6. Vulcan Materials Example Corporate Sustainability Reporting Metrics (Vulcan Materials, n.d.)

Metrics by Plan Element						
Business	**Safety**	**Employees**	**Community Engagement**	**Environment**	**Customers, Quality**	**Compliance, Risk Management, Ethics**
• Financials	• MSHA & OSHA recordable injury rate • MSHA citation rate • Health testing participation rate • Dust, silica, & noise exposure sampling	• Employees • Tenure • New Hires	• Scholarships awarded • Scholarship funds awarded • School partnerships • Visitors • Plant tours • Dollars donated • Foundation & matching gifts • Matching employee contributions	• Acreage in portfolio • Water stores at former quarry • Wildlife Habitat Council certified sites • Used oil recycled • Products produced from recycled materials		

Table A7. Example Corporate Sustainability Reporting Metrics for *Integration of Business and Sustainability Strategies*.

Company	Business & Sustainability Strategies Integrated Metrics
CRH Americas Materials	Financials
	GRI Index
	Four U.N. Global Sustainability Goals
Martin Marietta	Awards
Granite Construction	Sustainable infrastructure investment
	Senior management engagement in industry organizations
	Promoting sustainable infrastructure funding
	Envision & Greenroads participation
Colas	Financials
	Growth
Salini Impregilo	Financials
	Total projects
	Global presence (total employees, countries, nationalities)
	Local procurement
Vulcan Materials	Financials

Table A8. Example Corporate Sustainability Reporting Metrics for *Safety*.

Company	Safety Metrics
CRH Americas Materials	Fatalities by cause
	Accidents by injuries
	Accidents by cause
	Contractor site induction
	Safety training
Martin Marietta	Awards
	Injury rate
	Lost time rate
	Audits
Granite Construction	OSHA recordable incident rate
	OSHA & MSHA citations
	OHSAS 18001 certification
Colas	Lost time frequency
	Vehicle incidents
	Accident frequency & incident rate
	OHSAS 18001 non-conformances
	CEO/director safety audits
	DIY health MOTs
Salini Impregilo	Injury rate
	Lost days rate
Vulcan Materials	MSHA & OSHA recordable injury rate
	MSHA citation rate
	Health testing participation rate
	Dust, silica, & noise exposure sampling

Table A9. Example Corporate Sustainability Reporting Metrics for *Employees*.

Company	Employees Metrics
CRH Americas Materials	Employee training
	Employees by age, gender, & country
Martin Marietta	Female & minority employees
	Continuous learning courses
	401(k) participation
Granite Construction	Wellness program participation
	Women in construction support
	Retention & turnover rates
Colas	Workforce
	Manager participation in development training
	Employee formal training days
	Female senior management positions
	Turnover rate
	Employee satisfaction
	Workforce under 25-years-old
Salini Impregilo	Training hours provided
	Master's in international construction management program
Vulcan Materials	Employees
	Tenure
	New Hires

Table A10. Example Corporate Sustainability Reporting Metrics for *Community Engagement*.

Company	Community Engagement Metrics
CRH Americas Materials	Community engagement plans
Martin Marietta	Volunteer hours
	Donated materials
	Education visits
	Meals
Granite Construction	Community outreach engagements
	Financial support of non-profits
	All business unit disaster relief drive
Colas	Community investment volunteer time
	Educational events
Salini Impregilo	Local community meetings
	Project visits
	Free health interventions
Vulcan Materials	Scholarships awarded
	Scholarship funds awarded
	School partnerships
	Visitors
	Dollars donated
	Foundation & matching gifts
	Matching employee contributions

Table A11. Example Corporate Sustainability Reporting Metrics for *Environment*.

Company	Environment Metrics
CRH Americas Materials	Expenditures on emission reductions, licensing, waste management, restoration & biodiversity, water use, energy reduction, alternative material (RAP, RAS, C&D), & fuel use
	CO_2 emissions
	Energy use
	Waste type & recycling
Martin Marietta	Investment in mobile equipment with reduced GHG
	Alternative fuel use in plants
	Alternative shipping (rail)
Granite Construction	ISO 14001 certification
	Environmental citations
	Green construction materials use
	Telematics for reduced fuel consumption
	Carbon footprint
Colas	ISO 14001 certification
	Incident frequency
	Prosecution rate
	Non-conformance frequency
	Recycling rate
	CO_2 turnover
	GHG
	Energy efficiency
	Waste
	ISO 5001 certification
Salini Impregilo	Climate Change Mitigation backlog
	GHG
	Energy intensity
	Water intensity
	Reuse intensity
	HSE expenses
	Reutilized materials
	Monitoring activities
	Audits
	Supplier evaluations
	WMA use
	Goods shipped by sea
	Erosion protection
	Pollution controls
	Noise & vibration measurements
	Reforestation, tree planting

Table A11 (continued). Example NAPA Member Company Corporate Sustainability Reporting Metrics for *Environment*.

Company	Environment Metrics
Vulcan Materials	Acreage in portfolio
	Water stores at former quarry
	Wildlife Habitat Council certified sites
	Used oil recycled
	Products produced from recycled materials

Table A12. Example Corporate Sustainability Reporting Metrics for *Customers, Quality*.

Company	Customers, Quality Metrics
CRH Americas Materials	
Martin Marietta	
Granite Construction	ISO 9001 conformance
	Quality staff certifications & licensure
	Quality awards
Colas	Remedial spend
	Customer satisfaction survey score
	Public satisfaction score
	Quality non-conformance rate
	Customer quality issues
	Resident quality issues
Salini Impregilo	
Vulcan Materials	

Table A13. Example NAPA Member Company Corporate Sustainability Reporting Metrics for *Compliance, Risk Management, and Ethics*.

Company	Compliance, Risk Management, Ethics Metrics
CRH Americas Materials	Supply chain procurement ethics
	Code of Business Conduct training
	Compliance training
	Board member independence, gender, geographic spread, & tenure
Martin Marietta	Ethics training
Granite Construction	Ethisphere Most Ethical Company designation
	Compliance training
	ISO 19600 Corporate Compliance & Ethics conformance
Colas	Number of suppliers
	Supplier performance reviews
Salini Impregilo	Code of ethics training
	Organizational control & corruption training
Vulcan Materials	

Appendix B

Summary of GRI Sustainability Reporting Standard Categories, Sub-Categories, Aspects, Indicators, and Descriptions

Table B1. GRI Sustainability Rating Details.

Category	Sub-Category	Aspect	Indicator	Description
Economic	N/A	Economic Performance	G4-EC1	Direct Economic Value Generated and Distributed
			G4-EC2	Financial Implications and Other Risks and Opportunities For the Organization's Activities Due to Climate Change
			G4-EC3	Coverage of the Organization's Defined Benefit Plan Obligations
			G4-EC4	Financial Assistance Received from Government
		Market Presence	G4-EC5	Ratio of Standard Entry Level Wage by Gender Compared to Local Minimum Wage at Significant Locations of Operation
			G4-EC6	Proportion of Senior Management Hired from the Local Community at Significant Locations of Operation
			G4-EC7	Development and Impact of Infrastructure Investments and Services Supported
			G4-EC8	Significant Indirect Economic Impacts, Including the Extent of Impacts
		Procurement Practices	G4-EC9	Proportion of Spending on Local Suppliers at Significant Locations of Operation

Table B1 (continued). GRI Sustainability Rating Details.

Category	Sub-Category	Aspect	Indicator	Description
Environmental	N/A	Materials	G4-EN1	Materials Used by Weight or Volume
			G4-EN2	Percentage of Materials Used That Are Recycled Input Materials
		Energy	G4-EN3	Energy Consumption Within the Organization
			G4-EN4	Energy Consumption Outside of the Organization
			G4-EN5	Energy Intensity
			G4-EN6	Reduction of Energy Consumption
			G4-EN7	Reductions in Energy Requirements of Products and Services
		Water	G4-EN8	Total Water Withdrawal by Source
			G4-EN9	Water Sources Significantly Affected by Withdrawal of Water
			G4-EN10	Percentage and Total Volume of Water Recycled and Reused
		Biodiversity	G4-EN11	Operational Sites Owned, Leased, Managed In, or Adjacent To, Protected Areas and Areas of High Biodiversity Value Outside Protected Areas
			G4-EN12	Description of Significant Impacts of Activities, Products, and Services on Biodiversity in Protected Areas and Areas of High Biodiversity Value Outside Protected Areas
			G4-EN13	Habitats Protected or Restored
			G4-EN14	Total Number of IUCN Red List Species and National Conservation List Species with Habitats in Areas Affected by Operations, by Level of Extinction Risk
		Emissions	G4-EN15	Direct Greenhouse Gas (GHG) Emissions (Scope 1)
			G4-EN16	Energy Indirect Greenhouse Gas (GHG) Emissions (Scope 2)
			G4-EN17	Other Indirect Greenhouse Gas (GHG) Emissions (Scope 3)
			G4-EN18	Greenhouse Gas (GHG) Emissions Intensity
			G4-EN19	Reduction of Greenhouse Gas (GHG) Emissions
			G4-EN20	Emissions of Ozone Depleting Substances (ODS)
			G4-EN21	NO_x, SO_x, and Other Significant Air Emissions

Table B1 (continued). GRI Sustainability Rating Details.

Category	Sub-Category	Aspect	Indicator	Description
Environmental	N/A	Effluents and Waste	G4-EN22	Total Waste Discharge by Quality and Destination
			G4-EN23	Total Weight of Waste by Type and Disposal Method
			G4-EN24	Total Number and Volume of Significant Spills
			G4-EN25	Weight of Transported, Imported, Exported, or Treated Waste Deemed Hazardous Under the Basel Convention, Annex I, II, III, and VIII, and Percentage of Transported Waste Shipped Internationally
			G4-EN26	Identity, Size, Protected Status, and Biodiversity Value of Water Bodies and Related Habitats Significantly Affected by the Organization's Discharges of Water and Runoff
		Products and Services	G4-EN27	Extent of Impact Mitigation of Environmental Impacts of Products and Services
			G4-EN28	Percentage of Products Sold and Their Packaging Materials That Are Reclaimed by Category
		Compliance	G4-EN29	Monetary Value of Significant Fines and Total Number of Non-Monetary Sanctions for Non-Compliance With Environmental Laws and Regulations
		Transport	G4-EN30	Significant Environmental Impacts of Transporting Products and Other Goods and Materials for the Organization's Operations, and Transporting Members of the Workforce
		Overall	G4-EN31	Total Environmental Protection Expenditures and Investments by Type
		Supplier Environmental Assessment	G4-EN32	Percentage of New Suppliers That Were Screened Using Environmental Criteria
			G4-EN33	Significant Actual and Potential Negative Environmental Impacts in the Supply Chain and Actions Taken
		Environmental Grievance Mechanisms	G4-EN34	Number of Grievances About Environmental Impacts Filed, Addressed, and Resolved Through Formal Grievance Mechanisms
Social	Labor Practices and Decent Work	Employment	G4-LA1	Total Number and Rates of New Employee Hires and Employee Turnover by Age Group, Gender, and Region
			G4-LA2	Benefits Provided to Full-Time Employees That Are Not Provided to Temporary or Part-Time Employees, by Significant Locations of Operation
			G4-LA3	Return to Work and Retention Rates After Parental Leave, by Gender

Table B1 (continued). GRI Sustainability Rating Details.

Category	Sub-Category	Aspect	Indicator	Description
Social	Labor Practices and Decent Work	Labor/Management Relations	G4-LA4	Minimum Notice Periods Regarding Operational Changes, Including Whether These are Specified in Collective Agreements
		Occupational Health and Safety	G4-LA5	Percentage of Total Workforce Represented in Formal Joint Management-Worker Health and Safety Committees That Help Monitor and Advise on Occupational Health and Safety Programs
			G4-LA6	Type of Injury and Rates of Injury, Occupational Diseases, Lost Days, and Absenteeism, and Total Number of Work-Related Fatalities, by Region and Gender
			G4-LA7	Workers with High Incidence or High Risk of Disease Related to Their Occupation
			G4-LA8	Health and Safety Topics Covered in Formal Agreements With Trade Unions
		Training and Education	G4-LA9	Average Hours of Training Per Year Per Employee By Gender, and By Employee Category
			G4-LA10	Programs and Skills Management and Lifelong Learning That Support the Continued Employability of Employees and Assist Them in Managing Careers
			G4-LA11	Percentage of Employees Receiving Regular Performance and Career Development Reviews, By Gender and By Employee Category
		Diversity and Equal Opportunity	G4-LA12	Composition of Governance Bodies and Breakdown of Employees Per Employee Category According to Gender, Age Group, Minority Group Membership, and Other Indicators of Diversity
		Equal Remuneration for Women and Men	G4-LA13	Ratio of Basic Salary and Remuneration of Women to Men by Employee Category, by Significant Locations of Operation
		Supplier Assessment for Labor Practices	G4-LA14	Percentage of New Suppliers That Were Screened Using Labor Practices Criteria
			G4-LA15	Significant Actual and Potential Negative Impacts for Labor Practices in the Supply Chain and Actions Taken
		Labor Practice Grievance Mechanisms	G4-LA16	Number of Grievances About Labor Practices Filed, Addressed, and Resolved Through Formal Grievance Mechanisms

Table B1 (continued). GRI Sustainability Rating Details.

Category	Sub-Category	Aspect	Indicator	Description
Social	Human Rights	Investment	G4-HR1	Total Number and Percentage of Significant Investment Agreements and Contracts That Include Human Rights Clauses Or That Underwent Human Rights Screening
			G4-HR2	Total Hours of Employee Training on Human Rights Policies or Procedures Concerning Aspects of Human Rights That Are Relevant to Operations, Including the Percentage of Employees Trained
		Non-Discrimination	G4-HR3	Total Number of Incidents of Discrimination and Corrective Actions Taken
		Freedom of Association and Collective Bargaining	G4-HR4	Operations and Suppliers Identified In Which The Right To Exercise Freedom of Association and Collective Bargaining May Be Violated Or At Significant Risk, and Measures Taken to Support These Rights
		Child Labor	G4-HR5	Operations and Suppliers Identified as Having Significant Risk For Incidents of Child Labor, and Measures Taken to Contribute to the Effective Abolition of Child Labor
		Forced or Compulsory Labor	G4-HR6	Operations and Suppliers Identified as Having Significant Risk for Incidents of Forced or Compulsory Labor, and Measures to Contribute to the Elimination of All Forms of Forced or Compulsory Labor
		Security Practices	G4-HR7	Percentage of Security Personnel Trained in the Organization's Human Rights Policies or Procedures That Are Relevant to Operations
		Indigenous Rights	G4-HR8	Total Number of Incidents of Violations Involving Rights of Indigenous Peoples and Actions Taken
		Assessment	G4-HR9	Total Number and Percentage of Operations That Have Been Subject to Human Rights Reviews or Impact Assessments
		Supplier Human Rights Assessment	G4-HR10	Percentage of New Suppliers That Were Screened Using Human Rights Criteria
			G4-HR11	Significant Actual and Potential Negative Human Rights Impacts in the Supply Chain
		Human Rights Grievance Mechanisms	G4-HR12	Number of Grievances About Human Rights Impacts Filed, Addressed, and Resolved Through Formal Grievance Mechanisms

Table B1 (continued). GRI Sustainability Rating Details.

Category	Sub-Category	Aspect	Indicator	Description
Social	Society	Local Communities	G4-SO1	Percentage of Operations With Implemented Local Community Engagement, Impact Assessments, and Development Programs
			G4-SO2	Operations With Significant Actual and Potential Negative Impacts on Local Communities
		Anti-Corruption	G4-SO3	Total Number and Percentage of Operations Assessed for Risks Related to Corruption and the Significant Risks Identified
			G4-SO4	Communication and Training on Anti-Corruption Policies and Procedures
			G4-SO5	Confirmed Incidents of Corruption and Actions Taken
		Public Policy	G4-SO6	Total Value of Political Contributions by Country and Recipient/Beneficiary
		Anti-Competitive Behavior	G4-SO7	Total Number of Legal Actions for Anti-Competitive Behavior, Anti-Trust, and Monopoly Practices and Their Outcomes
		Compliance	G4-SO8	Monetary Value of Significant Fines and Total Number of Non-Monetary Sanctions for Non-Compliance with Laws and Regulations
		Supplier Assessment for Impacts on Society	G4-SO9	Percentage of New Suppliers That Were Screened Using Criteria for Impacts on Society
			G4-SO10	Significant Actual and Potential Negative Impacts on Society in the Supply Chain and Actions Taken
		Grievance Mechanisms for Impacts on Society	G4-SO11	Number of Grievances About Impacts on Society Filed, Addressed, and Resolved Through Formal Grievance Mechanisms

Table B1 (continued). GRI Sustainability Rating Details.

Category	Sub-Category	Aspect	Indicator	Description
Social	Product Responsibility	Customer Health and Safety	G4-PR1	Percentage of Significant Product and Service Categories for Which Health and Safety Impacts are Assessed for Improvement
			G4-PR2	Total Number of Incidents of Non-Compliance with Regulations and Voluntary Codes Concerning the Health and Safety Impacts of Products and Services During Their Life Cycle, By Type of Outcomes
		Product and Service Labeling	G4-PR3	Type of Product and Service Information Required by the Organization's Procedures for Product and Service Information and Labeling, and Percentage of Significant Product and Service Categories Subject to Such Information Requirements
			G4-PR4	Total Number of Incidents of Non-Compliance with Regulations and Voluntary Codes Concerning Product Service Information and Labeling, by Type of Outcomes
			G4-PR5	Results of Surveys Measuring Customer Satisfaction
		Marketing Communications	G4-PR6	Sale of Banned or Disputed Products
			G4-PR7	Total Number of Incidents of Non-Compliance With Regulations and Voluntary Codes Concerning Marketing Communications, Including Advertising, Promotion, and Sponsorship, by Type of Outcomes
		Customer Privacy	G4-PR8	Total Number of Substantiated Complaints Regarding Breaches of Customer Privacy and Losses of Customer Data
		Compliance	G4-PR9	Monetary Value of Significant Fines for Non-Compliance With Laws and Regulations Concerning the Provision and Use of Products and Services

Table A11. Example Corporate Sustainability Reporting Metric Examples for *Environment*.

Company	Environment Metrics
CRH Americas Materials	Expenditures on emission reductions, licensing, waste management, restoration & biodiversity, water use, energy reduction, alternative material (RAP, RAS, C&D), & fuel use
	CO_2 emissions
	Energy use
	Waste type & recycling
Martin Marietta	Investment in mobile equipment with reduced GHG
	Alternative fuel use in plants
	Alternative shipping (rail)
Granite Construction	ISO 14001 certification
	Environmental citations
	Green construction materials use
	Telematics for reduced fuel consumption
	Carbon footprint
Colas	ISO 14001 certification
	Incident frequency
	Prosecution rate
	Non-conformance frequency
	Recycling rate
	CO_2 turnover
	GHG
	Energy efficiency
	Waste
	ISO 5001 certification
Salini Impregilo	Climate Change Mitigation backlog
	GHG
	Energy intensity
	Water intensity
	Reuse intensity
	HSE expenses
	Reutilized materials
	Monitoring activities
	Audits
	Supplier evaluations
	WMA use
	Goods shipped by sea
	Erosion protection
	Pollution controls
	Noise & vibration measurements
	Reforestation, tree planting

Table A11 (continued). Example NAPA Member Company Corporate Sustainability Reporting Metric Examples for *Environment*.

Company	Environment Metrics
Vulcan Materials	Acreage in portfolio
	Water stores at former quarry
	Wildlife Habitat Council certified sites
	Used oil recycled
	Products produced from recycled materials

Table A12. Example Corporate Sustainability Reporting Metric Examples for *Customers, Quality*.

Company	Customers, Quality Metrics
CRH Americas Materials	
Martin Marietta	
Granite Construction	ISO 9001 conformance
	Quality staff certifications & licensure
	Quality awards
Colas	Remedial spend
	Customer satisfaction survey score
	Public satisfaction score
	Quality non-conformance rate
	Customer quality issues
	Resident quality issues
Salini Impregilo	
Vulcan Materials	

Table A13. Example NAPA Member Company Corporate Sustainability Reporting Metric Examples for *Compliance, Risk Management, and Ethics*.

Company	Compliance, Risk Management, Ethics Metrics
CRH Americas Materials	Supply chain procurement ethics
	Code of Business Conduct training
	Compliance training
	Code of Business Conduct training
	Compliance training
	Board member independence, gender, geographic spread, & tenure
Martin Marietta	Ethics training
Granite Construction	Ethosphere Most Ethical Company designation
	Compliance training
	ISO 19600 Corporate Compliance & Ethics conformance
Colas	Number of suppliers
	Supplier performance reviews
Salini Impregilo	Code of ethics training
	Organizational control & corruption training
Vulcan Materials	

Appendix B

Summary of GRI Sustainability Reporting Standard Categories, Sub-Categories, Aspects, Indicators, and Descriptions.

Table B1. GRI Sustainability Rating Details.

Category	Sub-Category	Aspect	Indicator	Description
Economic	N/A	Economic Performance	G4-EC1	Direct Economic Value Generated and Distributed
			G4-EC2	Financial Implications and Other Risks and Opportunities For the Organization's Activities Due to Climate Change
			G4-EC2	Coverage of the Organization's Defined Benefit Plans Obligations
			G4-EC4	Financial Assistance Received from Government
		Market Presence	G4-EC5	Ratio of Standard Entry Level Wage by Gender Compared to Local Minimum Wage at Significant Locations of Operation
			G4-EC6	Proportion of Senior Management Hired from the Local Community at Significant Locations of Operation
			G4-EC7	Development and Impact of Infrastructure Investments and Services Supported
			G4-EC8	Significant Indirect Economic Impacts, Including the Extent of Impacts
		Procurement Practices	G4-EC9	Proportion of Spending on Local Suppliers at Significant Locations of Operation

Table B1 (continued). GRI Sustainability Rating Details.

Category	Sub-Category	Aspect	Indicator	Description
Environmental	N/A	Materials	G4-EN1	Materials Used by Weight or Volume
			G4-EN2	Percentage of Materials Used That Are Recycled Input Materials
		Energy	G4-EN3	Energy Consumption Within the Organization
			G4-EN4	Energy Consumption Outside the Organization
			G4-EN5	Energy Intensity
			G4-EN6	Reduction of Energy Consumption
			G4-EN7	Reductions in Energy Requirements of Products and Services
		Water	G4-EN8	Total Water Withdrawal by Source
			G4-EN9	Water Sources Significantly Affected by Withdrawal of Water
			G4-EN10	Percentage and Total Volume of Water Recycled and Reused
		Biodiversity	G4-EN11	Operational Sites Owned, Leased, Managed In, or Adjacent To, Protected Areas and Areas of High Biodiversity Value Outside Protected Areas
			G4-EN12	Description of Significant Impacts of Activities, Products, and Services on Biodiversity in Protected Areas and Areas of High Biodiversity Value Outside Protected Areas
			G4-EN13	Habitats Protected or Restored
			G4-EN14	Total Number of IUCN Red List Species and National Conservation List Species with Habitats in Areas Affected by Operations, by Level of Extinction Risk
		Emissions	G4-EN15	Direct Greenhouse Gas (GHG) Emissions (Scope 1)
			G4-EN16	Energy Indirect Greenhouse Gas (GHG) Emissions (Scope 2)
			G4-EN17	Other Indirect Greenhouse Gas (GHG) Emissions (Scope 3)
			G4-EN18	Greenhouse Gas (GHG) Emissions Intensity
			G4-EN19	Reduction of Greenhouse Gas (GHG) Emissions
			G4-EN20	Emissions of Ozone Depleting Substances (ODS)
			G4-EN21	NO_x, SO_x, and Other Significant Air Emissions

Table B1 (continued). GRI Sustainability Rating Details.

Category	Sub-Category	Aspect	Indicator	Description
Environmental	N/A	Effluents and Waste	G4-EN22	Total Waste Discharge by Quality and Destination
			G4-EN23	Total Weight of Waste by Type and Disposal Method
			G4-EN24	Total Number and Volume of Significant Spills
			G4-EN25	Weight of Transported, Imported, Exported, or Treated Waste Deemed Hazardous Under the Basel Convention, Annex I, II, III, and VIII, and Percentage of Transported Waste Shipped Internationally
			G4-EN26	Identity, Size, Protected Status, and Biodiversity Value of Water Bodies and Related Habitats Significantly Affected by the Organization's Discharges of Water and Runoff
		Products and Services	G4-EN27	Extent of Impact Mitigation of Environmental Impacts of Products and Services
			G4-EN28	Percentage of Products Sold and Their Packaging Materials That Are Reclaimed by Category
		Compliance	G4-EN29	Monetary Value of Significant Fines and Total Number of Non-Monetary Sanctions for Non-Compliance With Environmental Laws and Regulations
		Transport	G4-EN30	Significant Environmental Impacts of Transporting Products and Other Goods and Materials for the Organization's Operations, and Transporting Members of the Workforce
		Overall	G4-EN31	Total Environmental Protection Expenditures and Investments by Type
		Supplier Environmental Assessment	G4-EN32	Percentage of New Suppliers That Were Screened Using Environmental Criteria
			G4-EN33	Significant Actual and Potential Negative Environmental Impacts in the Supply Chain and Actions Taken
		Environmental Grievance Mechanisms	G4-EN34	Number of Grievances About Environmental Impacts Filed, Addressed, and Resolved Through Formal Grievance Mechanisms
Social	Labor Practices and Decent Work	Employment	G4-LA1	Total Number and Rates of New Employee Hires and Employee Turnover by Age Group, Gender, and Region
			G4-LA2	Benefits Provided to Full-Time Employees That Are Not Provided to Temporary or Part-Time Employees, by Significant Locations of Operation
			G4-LA3	Return to Work and Retention Rates After Parental Leave, by Gender

Table B1 (continued). GRI Sustainability Rating Details.

Category	Sub-Category	Aspect	Indicator	Description
Social	Labor Practices and Decent Work	Labor/Management Relations	G4-LA4	Minimum Notice Periods Regarding Operational Changes, Including Whether These are Specified in Collective Agreements
		Occupational Health and Safety	G4-LA5	Percentage of Total Workforce Represented in Formal Joint Management-Worker Health and Safety Committees That Help Monitor and Advise on Occupational Health and Safety Programs
			G4-LA6	Type of Injury and Rates of Injury, Occupational Diseases, Lost Days, and Absenteeism, and Total Number of Work-Related Fatalities, by Region and Gender
			G4-LA7	Workers with High Incidence or High Risk of Disease Related to Their Occupation
			G4-LA8	Health and Safety Topics Covered in Formal Agreements With Trade Unions
		Training and Education	G4-LA9	Average Hours of Training Per Year Per Employee By Gender, and By Employee Category
			G4-LA10	Programs and Skills Management and Lifelong Learning That Support the Continued Employability of Employees and Assist Them in Managing Careers
			G4-LA11	Percentage of Employees Receiving Regular Performance and Career Development Reviews, By Gender and By Employee Category
		Diversity and Equal Opportunity	G4-LA12	Composition of Governance Bodies and Breakdown of Employees Per Employee Category According to Gender, Age Group, Minority Group Membership, and Other Indicators of Diversity
		Equal Remuneration for Women and Men	G4-LA13	Ratio of Basic Salary and Remuneration of Women to Men by Employee Category, by Significant Locations of Operation
Social	Labor Practices and Decent Work	Supplier Assessment for Labor Practices	G4-LA14	Percentage of New Suppliers That Were Screened Using Labor Practices Criteria
			G4-LA15	Significant Actual and Potential Negative Impacts for Labor Practices in the Supply Chain and Actions Taken
		Labor Practice Grievance Mechanisms	G4-LA16	Number of Grievances About Labor Practices Filed, Addressed, and Resolved Through Formal Grievance Mechanisms

Table B1 (continued). GRI Sustainability Rating Details.

Category	Sub-Category	Aspect	Indicator	Description
Social	Human Rights	Investment	G4-HR1	Total Number and Percentage of Significant Investment Agreements and Contracts That Include Human Rights Clauses Or That Underwent Human Rights Screening
			G4-HR2	Total Hours of Employee Training on Human Rights Policies or Procedures Concerning Aspects of Human Rights That Are Relevant to Operations, Including the Percentage of Employees Trained
		Non-Discrimination	G4-HR3	Total Number of Incidents of Discrimination and Corrective Actions Taken
		Freedom of Association and Collective Bargaining	G4-HR4	Operations and Suppliers Identified In Which The Right To Exercise Freedom of Association and Collective Bargaining May Be Violated Or At Significant Risk, and Measures Taken to Support These Rights
		Child Labor	G4-HR5	Operations and Suppliers Identified as Having Significant Risk For Incidents of Child Labor, and Measures Taken to Contribute to the Effective Abolition of Child Labor
		Forced or Compulsory Labor	G4-HR6	Operations and Suppliers Identified as Having Significant Risk for Incidents of Forced or Compulsory Labor, and Measures to Contribute to the Elimination of All Forms of Forced or Compulsory Labor
		Security Practices	G4-HR7	Percentage of Security Personnel Trained in the Organization's Human Rights Policies or Procedures That Are Relevant to Operations
		Indigenous Rights	G4-HR8	Total Number of Incidents of Violations Involving Rights of Indigenous Peoples and Actions Taken
		Assessment	G4-HR9	Total Number and Percentage of Operations That Have Been Subject to Human Rights Reviews or Impact Assessments
		Supplier Human Rights Assessment	G4-HR10	Percentage of New Suppliers That Were Screened Using Human Rights Criteria
			G4-HR11	Significant Actual and Potential Negative Human Rights Impacts in the Supply Chain
		Human Rights Grievance Mechanisms	G4-HR12	Number of Grievances About Human Rights Impacts Filed, Addressed, and Resolved Through Formal Grievance Mechanisms

Table B1 (continued). GRI Sustainability Rating Details.

Category	Sub-Category	Aspect	Indicator	Description
Social	Society	Local Communities	G4-SO1	Percentage of Operations With Implemented Local Community Engagement, Impact Assessments, and Development Programs
			G4-SO2	Operations With Significant Actual and Potential Negative Impacts on Local Communities
		Anti-Corruption	G4-SO3	Total Number and Percentage of Operations Assessed for Risks Related to Corruption and the Significant Risks Identified
			G4-SO4	Communication and Training on Anti-Corruption Policies and Procedures
			G4-SO5	Confirmed Incidents of Corruption and Actions Taken
		Public Policy	G4-SO6	Total Value of Political Contributions by Country and Recipient/Beneficiary
		Anti-Competitive Behavior	G4-SO7	Total Number of Legal Actions for Anti-Competitive Behavior, Anti-Trust, and Monopoly Practices and Their Outcomes
		Compliance	G4-SO8	Monetary Value of Significant Fines and Total Number of Non-Monetary Sanctions for Non-Compliance with Laws and Regulations
		Supplier Assessment for Impacts on Society	G4-SO9	Percentage of New Suppliers That Were Screened Using Criteria for Impacts on Society
			G4-SO10	Significant Actual and Potential Negative Impacts on Society in the Supply Chain and Actions Taken
		Grievance Mechanisms for Impacts on Society	G4-SO11	Number of Grievances About Impacts on Society Filed, Addressed, and Resolved Through Formal Grievance Mechanisms

Table B1 (continued). GRI Sustainability Rating Details.

Category	Sub-Category	Aspect	Indicator	Description
Social	Product Responsibility	Customer Health and Safety	G4-PR1	Percentage of Significant Product and Service Categories for Which Health and Safety Impacts are Assessed for Improvement
			G4-PR2	Total Number of Incidents of Non-Compliance with Regulations and Voluntary Codes Concerning the Health and Safety Impacts of Products and Services During Their Life Cycle, By Type of Outcomes
		Product and Service Labeling	G4-PR3	Type of Product and Service Information Required by the Organization's Procedures for Product and Service Information and Labeling, and Percentage of Significant Product and Service Categories Subject to Such Information Requirements
			G4-PR4	Total Number of Incidents of Non-Compliance with Regulations and Voluntary Codes Concerning Product Service Information and Labeling, by Type of Outcomes
			G4-PR5	Results of Surveys Measuring Customer Satisfaction
		Marketing Communications	G4-PR6	Sale of Banned or Disputed Products
			G4-PR7	Total Number of Incidents of Non-Compliance With Regulations and Voluntary Codes Concerning Marketing Communications, Including Advertising, Promotion, and Sponsorship, by Type of Outcomes
		Customer Privacy	G4-PR8	Total Number of Substantiated Complaints Regarding Breaches of Customer Privacy and Losses of Customer Data
		Compliance	G4-PR9	Monetary Value of Significant Fines for Non-Compliance With Laws and Regulations Concerning the Provision and Use of Products and Services

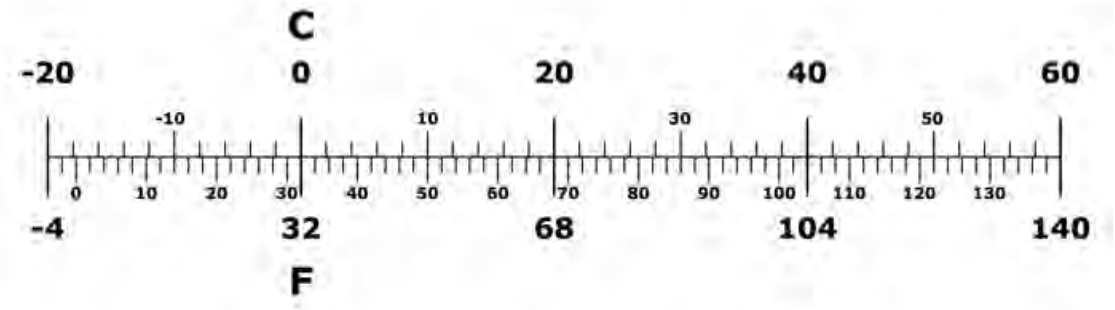
SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSION TO SI UNITS

Symbol	When You Know	Multiply by	To Find	Symbol
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
AREA				
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
VOLUME				
fl oz	fluid ounces	645.2	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: Volumes greater than 1000 L should be shown in m^3				
MASS				
oz	ounces	28.35	grams	g
lbs	pounds	0.454	kilograms	kg
T	short tons	0.907	megagrams	Mg
T	short tons	0.907	metric tonnes	t
NOTE: A short ton is equal to 2,000 lbs				
TEMPERATURE (exact)				
°F	Fahrenheit	$\frac{5(F-32)}{9}$	Celsius	°C

APPROXIMATE CONVERSION FROM SI UNITS

Symbol	When You Know	Multiply by	To Find	Symbol
LENGTH				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
AREA				
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.196	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
VOLUME				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.315	cubic feet	ft^3
m^3	cubic meters	1.308	cubic yards	yd^3
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lbs
Mg	megagrams	1.102	short tons	T
t	metric tonnes	1.102	short tons	T
NOTE: A short ton is equal to 2,000 lbs				
TEMPERATURE (exact)				
°C	Celsius	(1.8×C)+32	Fahrenheit	°F



*SI is the symbol for the International System of Units

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