APPLICATION OF RECYCLED PLASTIC MODIFIED ASPHALT IN CREATING SUSTAINABLE ROADWAY INFRASTRUCTURE

CONTRIBUTIONS OF LEAN CONSTRUCTION TECHNIQUES TOWARDS SUSTAINABLE ROADWAY INFRASTRUCTURE BY REDUCING SOCIAL AND ENVIRONMENTAL COSTS OF CONSTRUCTION PROJECTS

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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General Research Problem: Moving Towards Sustainability in Roadway Infrastructure

What does it mean for roadway infrastructure to be sustainable? How can this be achieved?

Our societies are moving towards sustainability in every facet of life, and this has put a spotlight on how unsustainable the construction industry has been and can be. Construction, buildings, and infrastructure are one of the largest consumers of resources worldwide (Huovila & Koskela, 1998). In the United States alone, buildings accounted for 39% of total U.S. energy consumption in 2021 (U.S. Energy Administration, 2022) and 600 million tons of construction and demolition debris were generated in 2018 (U.S. Environmental Protection Agency, 2022). Sustainable construction techniques set out to reduce the environmental, social, and cultural impacts caused by traditional construction methods, and therefore meet the goals of sustainable development (Huovila & Koskela, 1998). Sustainable development, as defined by the Brundtland Report, is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Environmental, societal, and economic growth and management are three of the key objectives for sustainable development (Pezzey, 1992). These objectives can be further broken down into criteria such as energy efficiency, non-toxics, recyclability, use of local resources, and mobility considerations among many others (Huovila & Koskela, 1998). In the effort of achieving sustainable development, the construction industry is moving towards more environmentally friendly, energy efficient, and waste conscious methods of construction (Marhani, Jaapar, Bari, & Zawai, 2013).

Looking solely at the construction of roadway infrastructure, this paper aims to give two methods by which American roadways can be made more sustainable in their environmental, social, and cultural aspects. The first of these is modifying asphalt mixes with the addition of

recycled plastic as a supporting aggregate, which would be a potential solution for both a plastic crisis and a failing road infrastructure system in the United States (Willis, Yin, & Moraes, 2020). The second is implementing lean construction (LC) techniques, originally derived from the manufacturing industry, which aim to minimize site waste, construction time, and overall construction costs through better project management (Marhani, Jaapar, Bari, & Zawai, 2013). While LC techniques are not typically associated with ideas of sustainable development, they both focus on minimizing resources used and promoting efficiency in construction projects. The similarities of the motives and methods for each of these techniques will be examined by way of a literature review of several projects completed with LC methods.

Sustainable Roadways and the Use of Recycled Plastic Modified Asphalt

How could recycled plastic modified asphalt make roadways more sustainable?

Asphalt is one of the most recycled materials in the United States, with more than 89 million tons of asphalt mixtures recycled back into new asphalt mixtures in 2019 (Willis, Yin, & Moraes, 2020). The idea of adding recycled plastic to asphalt mixes, otherwise known as recycled plastic modified (RPM) asphalt, is not a new one. There have been legislative acts such as the Save our Seas 2.0 Act, Section 305, and the Green Real Deal that both discuss transforming postconsumer and postindustrial plastics into new materials such as asphalt (Willis, Yin, & Moraes, 2020). However, there has been pushback on these legislative efforts as further research is needed to determine whether RPM asphalt is a viable solution for ageing infrastructure and an accumulation of plastic. The existing literature on this subject shows an abundance of lab testing conducted on RPM samples with the conclusion that RPM asphalt

performs better than conventional; however, the research is lacking on whether RPM asphalt will continue to perform as well as conventional asphalt in a long-term study.

Working with the Virginia Transportation Research Council (VTRC), this study aims to supplement VTRC's knowledge of RPM asphalt mixes with the goal of showing that RPM asphalt is a better candidate than conventional asphalt in terms of both performance and sustainability. Asphalt consists of two parts: aggregate and binder. For this study, milled recycled plastic will be incorporated into the asphalt as an aggregate replacement, also known as the "dry process." Once these samples have been created, tests will be performed in the VTRC lab to determine if RPM asphalt has a superior performance over conventional asphalt in short-term studies. To see if RPM asphalt also performs better in the long term, where knowledge is currently lacking, the team will visit locations in Richmond, Virginia where the Virginia Department of Transportation has paved roads with RPM asphalt in the very recent past to conduct in-field assessments of the pavement conditions. The last component of the project is constructing a life cycle assessment of RPM asphalt, which, when compared to a life cycle assessment of conventional asphalt, will show if the addition of plastic is a legitimately sustainable decision. It is also important that sustainability is measured for three criteria: economic, environmental, and social sustainability.

An additional, potential aspect of the project scope that is dependent on how much time the components mentioned above take to complete is the construction of RPM asphalt samples made with recycled plastic from the University of Virginia. All the materials recycled by the University of Virginia are hand sorted, ensuring high quality of postconsumer plastics. RPM asphalt currently uses postindustrial plastics as opposed to postconsumer plastics over concerns of nonuniformity in how they contribute to the structural and performative integrity of asphalt. If

time permits, milled postconsumer polyethylene plastic would be taken from the University of Virginia's Ivy Road recycling center and incorporated into RPM asphalt samples made by the project team at VTRC's lab. Tests will be conducted in the VTRC lab to determine how postconsumer plastic contributes to the performance of RPM asphalt relative to samples made with postindustrial plastic. If the University of Virginia's postconsumer plastic could be used in RPM asphalt in Virginia, this would have even more sustainability benefits as materials sourcing is much closer to home and would incentivize additional recycling in Virginia.

Sustainable Roadways and the Cost of Construction

How can roadway infrastructure projects be made more sustainable in terms of lessening environmental and societal impacts through implementation of lean construction techniques?

The infrastructure sector is one of the United States' largest energy users and polluters and is therefore in dire need of sustainable action. It has fallen behind in industry development, as labor efficiency in the construction industry has decreased while efficiency in all other industries (except farming) has at least doubled since the 1960s. Additionally, 70% of construction projects are either over budget or delivered late (Lean Construction Institute, 2022). LC practices, modeled after the lean production theory developed by a Toyota engineer, are meant to solve some of these problems in the construction industry by eliminating waste with minimum cost and maximum value (Amade, Ononuju, Obodoh, & Okorie, 2019), as well as eliminating construction delays.

Most construction projects use either design-bid-build or design-build contracts, which separate stakeholders of a project into smaller projects with their own separate contracts. With LC practices, there is only one contract between the owner, design team, and contractors,

allowing every party to be contractually involved in each step of the design and construction process (Lean Construction Institute, 2022). One of the first projects to use LC in design and construction (although "lean construction" had yet to exist) was the Empire State Building, which went from design to completion in under three years, ahead of schedule and under budget (Lean Construction Institute, 2022). The modern concept of "lean construction" was coined in 1993 by the International Group for Lean Construction (Banna, 2017). The Lean Construction Institute defines LC as such:

> Lean construction is a project delivery process that uses Lean methods of maximizing stakeholder value while reducing waste by emphasizing collaboration between teams on a project. The goal of Lean construction is to increase productivity, profits, and innovation in the industry (Lean Construction Institute, 2022).

LC is not typically seen to have the same goals as sustainable construction, given that sustainable construction pays more attention to reducing negative social and environmental impacts. These two paradigms do share the general ideas of promoting resource efficiency and minimizing waste, meaning that LC could have benefits in terms of environmental and social sustainability (Francis & Thomas, 2020). However, LC might not reflect a positive outcome on the environment or society since it is majority focused on economic benefits. If LC becomes purely focused on the economic benefits in the form of reducing cost and increasing profits, it might lead to negative environmental and societal impacts (Song & Liang, 2011). For this reason, LC needs to be evaluated not just from an economic aspect, but from a sustainability aspect as well.

Parameters for this evaluation involve measuring pollution, waste, natural resource consumption, and emissions (Francis & Thomas, 2020). It is also important to consider those

being affected socially by the construction of roadway infrastructure, a very new concern in the construction industry, as the many low-income or minority communities paved over for the sake of infrastructure progress have come to light in recent years. Social sustainability in construction is described by Herd-Smith and Fewings (2008) as "the engagement among employees, local communities, clients, and the supply chain to ensure meeting the needs of current and future populations and communities." Measures of social sustainability of a construction project involve stakeholder satisfaction, training of disadvantaged people (Valdes-Vasquez & Klotz, 2013), and social impact on a community. After defining the social, economic, and environmental costs of construction, LC techniques will be analyzed to see how each of these negative impacts could either be reduced or heightened in practice. This will be done with a literature review looking at roadway projects completed in the United States where LC techniques were used, from which the environmental, economic, and social impacts of this method will be explored; and summarize how utilizing LC either results in a benefit or cost in sustainable development goals for roadway infrastructure.

Conclusion

With so much emphasis being placed on sustainable development in the construction industry, particularly on roadway infrastructure, the markers of sustainability and the methods by which they will be achieved must be defined. The goal of this paper is to explore two methods that, when implemented, will lead American roadway infrastructure to be more sustainable in its environmental, social, economic, and cultural aspects. One way which sustainable roadway construction can be achieved is by utilizing lean construction techniques, originally developed from manufacturing techniques, to reduce project waste, resources, and cost. This exploration hopes to establish the social and environmental costs of traditional roadway construction before

explaining how lean construction techniques could mitigate these costs by way of a literature review. The second method is modifying asphalt pavement mixes with recycled plastic as a partial aggregate replacement, potentially providing a solution for the United States' overabundance of plastic and failing roadway infrastructure. While incorporating recycled plastic as an aggregate in asphalt has proven to produce pavement with a higher standard of performance, it is unknown if these benefits will continue in a long-term field application or if the production and use of recycled plastic modified asphalt is truly more sustainable than conventional asphalt. The results of these studies will be used as indicators of which sustainable development goals can be obtained in the United States' roadway infrastructure sector and present two potential methods by which they can be realized.

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