Semi-Annual Progress Report

Project Number and Title: 3.6 Optimal Design of Sustainable Asphalt Mixtures with RAP
Research Area:
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Overview:

Asphalt mix production is a crucial aspect to today's pavement infrastructure deployment. The mobility afforded by pavement systems, but their productions generate a significant proportion of environmental pollution. Thus, constant scrutiny of contemporaneous systems is necessary to establish the most sustainable approach to contemporaneous asphalt mix production. Three key concepts prevail to improve the sustainability of asphalt pavement systems. They encompass increasing asphalt performance/durability, decreasing environmental impacts through enhanced technology mostly, and recycling asphalt pavements. One specific approach would be reusing Reclaimed Asphalt Pavement (RAP) to theoretically decrease disposal costs of old pavements, decrease purchase cost of virgin aggregates, and prevent depletion of virgin aggregate.

The project began with an extensive review of pertinent literature material. Firstly, the performance of RAP relative to virgin Hot Mix Asphalt (HMA) pointed to the general trends observed using different production methods. Findings from varied literature initially pointed to the proportion of residual binder from RAP and virgin binder, the both, affecting the mixtures volumetric and performance properties. Lee et al. (1999), Shen et al. (2007), Al-Qadi et al. (2009), and Lopes et al. (2015) have assumed that aged and virgin binder aggregate will approach complete mixing while Apeagyei et al. (2011), Huang and Bird (2007) and Huang et al. (2005) have assumed and found that the blending affects only a small portion of the aged asphalt binder in RAP. Per Vidal et al. (2013) and Wyman et al. (2012), the moisture content of RAP is higher compared to virgin aggregate, due to the use of water in the milling process of pavement, which may also impact on volumetric and performance properties. Another trend identified was that Flemish plants at times preheat the RAP whereas American plants do not by fear of increases in stiffness. Flemish experts also believe that higher levels of reclamation can be achieved using pre-heated RAP.

Other general trends identified include comparisons in dynamic modulus, strength, rutting resistance, fatigue resistance and thermal cracking resistance between asphalt mixtures with and without RAP. In general, it was determined that warm mix asphalt (WMA) with RAP has shown a propensity to display enhanced performance above virgin HMA that can be sustained at very high levels of reclamation. The present study will utilize environmental assessment used in Netherlands and Sweden for road infrastructure planning process (Kluts et al. 2015).

Life Cycle Assessment (LCA) and Life-Cycle Cost Analysis (LCCA) were also considered pertinent to the present study. Three different methods were identified to conduct LCAs, Process-based LCA, Input-Output LCA and Hybrid LCA. The most effective method for conducting an asphalt pavement LCA is the Hybrid LCA that combines the strength of previously cited methods. With this, the team has narrowed down on the steps necessary to complete the LCA. The first step is to identify the goal and scope of the assessment to conduct. This study will mimic the scope of a majority of previous LCAs completed on asphalt pavements, analyzing their complete life cycle activities starting from initial production of raw materials, to construction processes, uses, maintenance and rehabilitation (M&R) and end of life treatments/final disposals. It will differ from previous study by determining to the extent possibly the expected lifespan of mixes given their laboratory or field performance. Figure 1 shows an image that identifies the main key stages and processes to be included in the LCA in the present study.

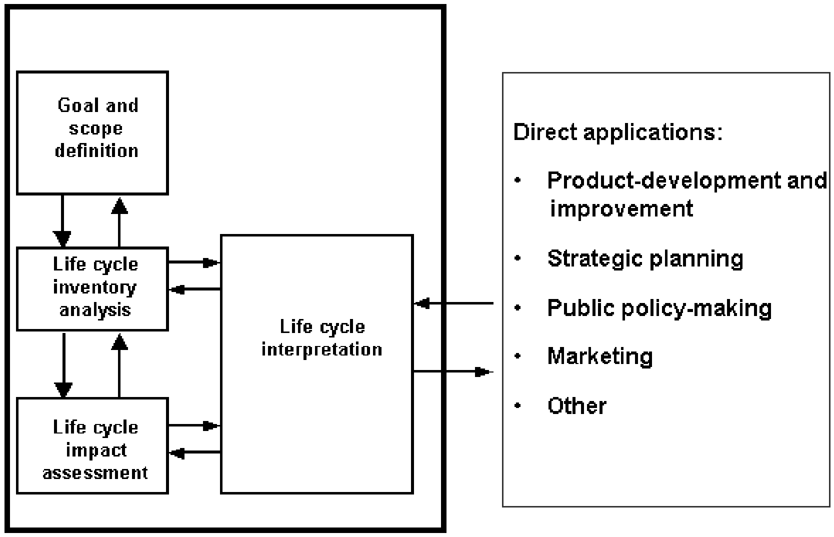

Figure 1: Diagram depicting LCA steps and processes

The life cycle inventory (LCI) will be used to identify the raw materials that are used in the production process. This phase will measure the environmental flow for the asphalt mixtures. Flows identified in this phase will include the flow beginning from the milling phase of the recycled asphalt and the accumulation of the virgin aggregate. From there, all of the aspects used to produce the asphalt mixtures including bitumen, fuel and energy consumption will be accounted for. This data will be produced from a selected database. Literature Review has shown that Eco invent is a commonly used database that is used in the LCA process. Aurangzeb et al. (2014) used this database to complete a hybrid life cycle assessment that compared and analyzed the costs with environmental impacts. Then the LCI will be the impact assessment which measures the environmental impacts of the production process. The main categories of the Life Cycle Impact Assessment (LCIA) that will be measured include resource use, energy use, emissions (GHG such as carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O)), toxicity, water and waste. All these factors are to be accounted for and analyzed using a database. Eco invent is a database that also has values for the energy consumption. Values such as economic yield, price per energy consumption and volume yield can be found within this database. Aurangzeb et al. (2014) went further with their LCA by identifying environmental factors per dollar of economic activity. By doing this, the study was able to identify the production costs of each mix design using RAP, to find which mix was the least environmentally and economically impactful. The trend found shows that increases in percent RAP will decrease the overall production cost.

Further, the study team has identified that the control asphalt pavements for the study are RIDOT's standard HMA with and without 20% RAP level. The costs of these mixes will be used, reflective of performance and inclusive of subjective (per expert opinions) greenhouse gas costs, to compare their cost performance with alternate hot, warm, and cold mixes with and without RAP from the literature and determine avenues to preferred mixes. (Kluts et al. 2015, proved warm and cold mixes to be more economically and environmentally sustainable.) Already, the literature has revealed a formula for greenhouse warming potential that combines all the gases of study interest. This formula expresses the warming potential of the varied gases in term of CO_2 warming potential. This formula or alternate similar ones can be instrumental in establishing the subjective cost of a pre-determined greenhouse warming potential as computed.

$$GWP = CO_2 + (25 * CH_4) + (298 * N_2O)$$

Where: $\text{GWP} = \text{Global Warming Potential (kg} * \text{CO}_2 \text{ equiv.)}$
$\text{CO}_2 = \text{Weight of Carbon Dioxide (kg)}$
$\text{CH}_4 = \text{Weight of Methane (kg)}$
$\text{N}_2\text{O} = \text{Weight of Nitrous Oxide (kg)}$

Our study hopes to achieve something like Aurangzeb's research. Our goal is to create a survey that will be capable of placing subjective numbers on the environmental impacts. This in ways, will create an overlap in the economic and environmental impacts, which will help to identify the best alternative design. Likewise, we will subjectively compare these costs to the performance found in the mix design/ performance process. By doing this, it is possible to produce a stronger/ more durable pavement that will possibly be more sustainable in terms of cost and environment.

Participants and Collaborators:

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Changes:

The URI research team originally planned to begin work on the project in late 2018. Due to administrative reasons, the personnel for the team was not finalized until late December. This adjusted the timeline that accelerated the literature review process.

Planned Activities:

The URI research team is planning to:

1. Narrow down on a software that is capable of completing a LCA of asphalt pavement using RAP
2. Begin to design a survey capable of establishing cost tradeoff between measured environmental impacts and traditional life cycle costs
    - Document similar surveys from literature to compare and improve
3. Document mix designs used for RAP production that will be implementable within RIDOT state regulations

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