Pavement Lifecycle Asset Management

Pavement design and management is a complicated and context-specific profession. This write up is largely taken from content provided by Oregon Department of Transportation (ODOT) subject matter experts and interviews with researchers and practitioners of pavement management for greenhouse gas (GHG) reductions. Good Company relays these suggestions humbly and with the understanding these ideas are not an attempt to shore up weaknesses, rather it is offered to support the program advancing to another level of environmental efficiency. ODOT's Pavement group provides this description of their program's development:[1]

> *[ODOT] historically has done well managing Oregon's roads through an active Pavements program. A centralized Pavement Services Unit utilizing close integration of Pavement Management, Design, and Construction and Materials has paid dividends from an asset management perspective – with Oregon ranking 10th in the most recent highway condition rating by the US Bureau of Transportation Statistics at a pavement funding level relatively low compared to other states. (https://www.bts.gov/road-condition)*
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> *ODOT has been aggressive in incentivizing asphalt pavements that are both high in recycled content and long-lasting. Through sound management practices over decades, the current condition of Oregon's highway network makes pavement reconstruction rare. This allows less intensive rehabilitation projects to be prevalent. Requiring lower energy usage during construction may be feasible in certain situations, provided it is not accompanied by a reduction in pavement quality which would lead to increased cost and GHG emissions over time. Currently, ODOT is conducting internal testing and validation of the research ODOT has funded promoting balanced mix design. As new processes are tested and implemented over the next 2-5 years, it is expected to both increase pavement life and increase recycled contents. Both items will provide tangible and measurable results towards reducing overall GHG emissions.*

Scaling Pavement Emissions and GHG Inventory Highlights

Figure 1, on the next page, is meant to provide a *sense-of-scale comparison* of prioritizing pavement preservation (smooth highways), versus reducing the footprint from embodied (manufacturing) emissions. Figure 1 compares driver emissions from fuel combustion while traveling on Oregon's highway system (grey) to the estimated climate benefit from Oregon's pavement lifecycle optimization and management program (orange) to ODOT's average annual operational GHG emissions (blue).

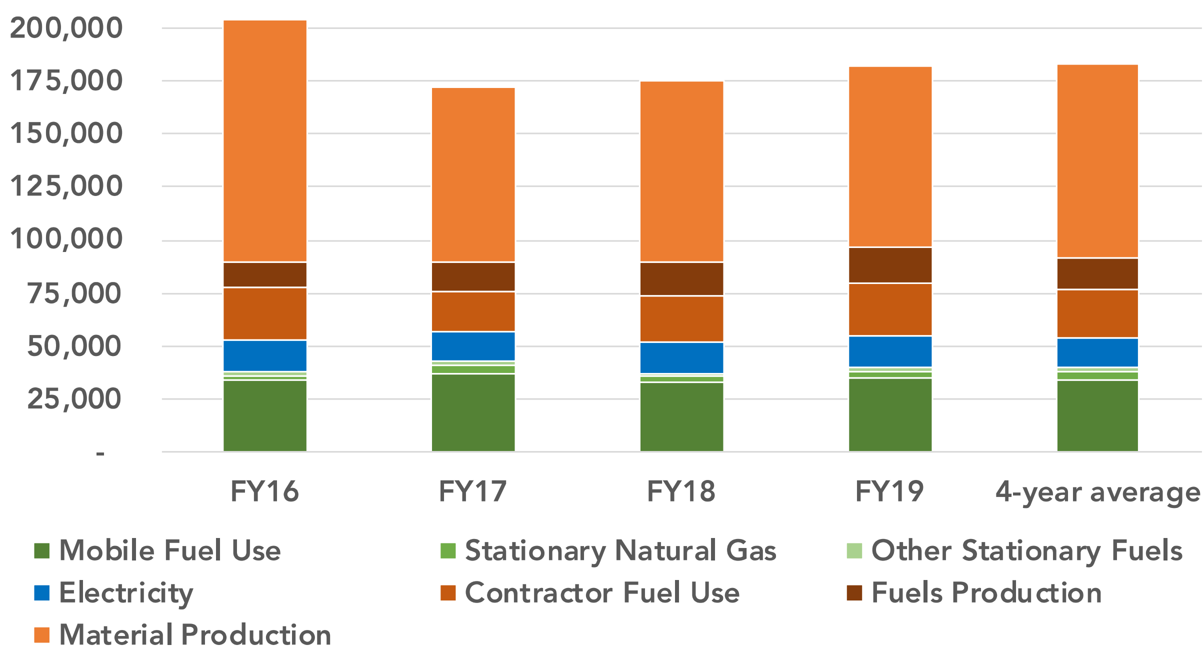
Both pavement preservation (smoothness) and durability are priorities for GHG benefits. The more durable the surface is, the lower per year embodied emissions are per lane-mile. Life cycle management of pavement through timely preservation treatments benefits smoothness and durability and reduces the emissions over time.

[1] ODOT Pavements Approach (2021) from Chris Duman, PE, State Pavement Quality & Materials Engineer ODOT, et al

Figure 1: Comparison by scale of annual driver emissions, pavement optimization benefits, to ODOT operational GHG emissions.

Figure 2, below, takes a closer look at ODOT's Operational Emissions (blue box in Figure 1). Note: after smoothness and durability, the embodied emissions in producing pavement materials and the fuel use associated with installing it are a substantial part of the operational emissions.

Figure 2: Scope 1, Scope 2, and Scope 3 Emissions (MT CO_2e) by fiscal year with 4-year average



Best Practice

Designing pavement roads for smoothness, density and durability generally moves any pavement type toward a lower-carbon future. Subject matter experts interviewed for this project encouraged ODOT to maintain these base principles. Academic professors and industry representatives spoke highly of ODOT's data quality, condition assessments, and encouraged a review of all pavement life cycle - by regions - to determine which has the lowest life cycle impacts. The way to measure life cycle impacts requires knowing which pavement design had the lowest cost and GHGs per service year, per lane mile. It is understood ODOT's records are detailed and individual segments have been optimized, but a question remains: *Of all the optimized individual segments, which have proven themselves to be the best in the geographic, traffic, aggregate supply and weather conditions per year of use?*

Asphalt Concrete Pavement Life Cycle

ODOT provides the following summary of existing approaches, policy and research regarding asphalt concrete pavement lifecycle:

> *ODOT has experimented with even higher Recycled Asphalt Pavement (RAP) contents, and will continue to in the future. In addition to increased recycled product, innovations in materials and construction offer opportunity for reduced greenhouse gas emissions (GHG). However, there is significant risk in rushing to adopt new technologies – a single project failure can offset the GHG emissions and life cycle cost savings of multiple successes. For these reasons, ODOT is in the process of simple, but significant changes in our asphalt concrete pavement specifications. Requiring and incentivizing better construction practices will increase pavement service life. Looking at investment costs on a life cycle or annual cost basis as opposed to simply looking at construction costs is beneficial from a monetary and also GHG perspective. This has been a multi-year effort, and one that appears to be a success.*
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> *The use of RAP has not been without challenges – modifications to ODOT's design process and materials used have been necessary to mitigate some of the negative effects of using high amounts of recycled product. One example is the use of polymer-modified asphalt (PMA). PMA has been used on high–volume roadways almost exclusively since 2008. This is an example of ODOT using a more expensive and energy intensive product. However, these increased costs are a justified investment when analyzed over the life of the pavement. Slight increased cost and energy use is expected, but has been shown to increase pavement life by 2-10 years.*
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> *Increasing the amount of RAP is of particular interest, with much research funded by ODOT and also nationally on how to best accomplish this without sacrificing quality and longevity. Using high RAP contents without requiring other changes produces a brittle asphalt mixture, prone to cracking with a reduction in service life. Asphalt pavements fail by two mechanisms - cracking and rutting. Requiring mixtures that are both crack and rut resistant requires a balanced approach, which is the main principle of Balanced Mix Design (BMD). The research funded by ODOT has been focused on creating test parameters to quantify asphalt mixtures as both crack and rut resistant. The ability to test a mixture in a laboratory prior to placement enables innovation by producers. This innovative process allows the introduction of new technologies, and also an increased usage of recycled products - primarily RAP. ODOT is progressing towards pilot projects using BMD in an upcoming research project.*
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> *Contractors use RAP for paving ODOT highways because of economic benefits of reusing that material. This is due to the structure of our specifications, and has resulted in RAP contents almost always being at the maximum allowed. This is caused by ODOT paying the same amount for mixtures containing asphalt as those without. As we embrace new technologies and processes, it is reasonable to believe that increased RAP contents may be used – if they can be used without detriment to the final product. New products, additives and construction processes may be used – and reduction in overall costs to paving contractors will almost always result in lower GHG emissions.*
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> *…*
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> *Also of significance is the general overall thickness of the pavements managed by ODOT. The thick existing pavements are the product of conservative designs and relatively low asphalt pavement costs in the 1900s (author's note - before 2000). This has and will continue to allow extensive use of chip seals and thinner pavement treatments while avoiding full-depth reconstruction where possible. In addition to high construction costs, reconstructing roadways is an extremely energy intensive process.*

Asphalt Concrete Best Practices

- First, continue to reward smoothness and density in construction specifications to reduce the emissions coming from vehicles due to pavement roughness. Emissions reductions achieve by paving rough roads are estimated to be 3-4% over poorly maintained pavement. This 3-4% represents a rough reduction in fuel use of 88,000,000 gallons of gasoline and diesel reduced by the users of the system (based on 2.2 billion gallons consumed in Oregon each year[2]). At a simple cost of $2.50/gallon this represents a savings to the people of Oregon of $220,000,000 and may justify the additional investment in maintaining more lane miles per year or to provide additional oversight during installation.
- Second, optimize for durability. Use the pavement management system to track how specification changes affect service life across Oregon's varied climates.
- Greater quality control during installation to ensure proper tack layering to prevent delamination of layers.
- Studded tires damage pavement. FHWA rough estimates were $20 to $30 million in repairs per year and Oregon estimates range from $10 to $40 million per year.
- Recycled Asphalt Paving reduces need for aggregate but can have a shorter lifespan than virgin asphalt. The balance point of maximum recycled content that still has a normal life span is not yet known. Rejuvenator technologies (chemical additives) allow for higher recycled asphalt contents that can be used during production without compromising the long-term performance of the pavement.
- Recycled asphalt shingles often fouls other binders and have been ruled out by most DOTs.
- New research is considering the use of hard to recycle plastics as a binder. Proceed with caution on researching this as the most commonly cited plastics for ACP use also are the most commonly recycled and have very high value. Research should focus on the plastics that have zero or negative value and avoid those with high paying existing markets such as low density polyethylene. Also, some initial research indicated that the plastics may make asphalt brittle and subject to cracking.
- Warm mix reduces emissions by a negligible amount, but may have some durability benefits.
- Separate chip seal accounting from ACP accounting.

Literature to Consider:

1. **Demonstration to Advance New Pavement Technologies Pooled Fund** The $10,000 FHWA contribution will be used to provide up to $250,000, up to 100 hours of technical assistance, and resources for developing case study reports and videos for each selected demonstration project.[3]
2. **Mechanistic-Empirical Simulations and Life Cycle Cost Analysis to Determine the Cost and Performance Effectiveness of Asphalt Mixtures Containing Recycled Materials** Life cycle cost analysis of the cost benefits of using binder grade bumping and high binder content in Oregon asphalt mixtures using laboratory derived mechanistic-empirical models.[4]
3. **Predicting excess vehicle fuel use due to pavement structural response using field test results and finite element modelling.** In this study, a comprehensive numerical modelling factorial is developed to determine the response of pavement structures under a wide range of contributing factors with modelling of asphalt pavement energy dissipation due to the viscoelastic structural response.[5]

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[2] Per Oregon 2022 Fuel Supply Forecast. 1.565.3 million gallons of gasoline and 687 million gallons for a total of 2,252
Visit online for details https://www.oregon.gov/das/OEA/Documents/Clean%20Fuels%20Forecast%202022.pdf
[3] https://www.pooledfund.org/Details/Solicitation/1542
[4] https://www.researchgate.net/publication/325371016_Mechanistic-Empirical_Simulations_and_Life_Cycle_Cost_Analysis_to_Determine_the_Cost_and_Performance_Effectiveness_of_Asphalt_Mixtures_Containing_Recycled_Materials
[5] https://www.researchgate.net/publication/335439567_Predicting_excess_vehicle_fuel_use_due_to_pavement_structural_response_using_field_test_results_and_finite_element_modelling

Portland Cement Concrete Pavement Life Cycle

ODOT provides the following summary of existing approaches, policy and research regarding concrete pavement lifecycle:

> *Decisions made long ago have positioned the State's highway systems for long life with less intensive pavement treatments. Oregon was an early adopter of continuously reinforced concrete pavement (CRCP), primarily on interstate highways. While expensive to construct, longer than expected performance has been the norm. In addition, CRCP has allowed thin asphalt overlays as a preservation treatment, economically extending pavements for additional decades. This is not a viable option for jointed concrete pavement, a much more common asset among other state highway agencies (SHA) due to lower initial construction costs – but requiring more costly preservation.*
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> *In the last 20 years, ODOT has funded multiple studies through our Research Section specific to pavement materials. The findings of these research projects have helped to shape our specifications, and will continue to guide us as we move forward. The more recent of these projects have also attempted to compare GHG benefits or detractors of potential changes to pavement materials.*

Portland Cement Concrete Best Practices

- Further develop ODOT's performance based Standard Specifications recognizing regional differences when approving concrete mix designs. See AASHTO PP 84 as well as FHWA's: https://www.fhwa.dot.gov/pavement/pubs/013686.pdf for guidance.
- Do not specify a specific alternate cement as it may require aggregate from farther away and undo the GHG benefits from additional transport.
- Use EPDs to understand the GHG potential and impact of materials used in ODOT's concrete mix designs as well as guide future specification changes.
- Join the National Concrete Consortium and leverage the lessons learned of 37 DOTs.
- Join Innovondi Group with 58 global cement and concrete producers, Oregon State University and Princeton to see latest advances. Leverage OSU's best in class concrete research group.

Literature to Consider:

1. **Concrete Solutions to Climate Change: How Local Policy Can Promote Sustainable Construction Activities** Outline of the climate impacts of concrete and the development and use of low-carbon concrete, and discussion local policies related to its use.[6]
2. **Concrete Performance Engineered Mixtures** Overview of PEM project and different testing measures.[7]

[6] https://rockinst.org/issue-area/concrete-solutions-to-climate-change/
[7] https://cptechcenter.org/performance-engineered-mixtures-pem/