SPR RESEARCH PROGRAM
SECOND-STAGE PROPOSAL SUMMARY

PROBLEM NUMBER AND TITLE

24-43 Achieving Longer Lasting Asphalt Pavements with Lower Cost and Environmental Impact Through Engineered Aggregate Skeletons

PROBLEM SUMMARY

There is an absence of studies looking at the optimization of aggregates using Oregon aggregates. Most durability issues are addressed by modifying and improving the asphalt binder properties, which may not be possible for all cases (or may not be cost-effective in a limited-budget environment). For these reasons, methods and strategies should be developed to combat durability issues through innovations in aggregate properties.

ODOT OBJECTIVES

This research seeks to determine the most effective aggregate properties and gradation for improved cracking and rutting asphalt pavement resistance. The properties to be investigated include aggregate shape, texture, angularity, and others. The gradations to be investigated include dense and stone-matrix asphalt gradations.

BENEFITS

The primary benefit resulting from this research is to develop an optimized aggregate gradation that results in pavements that are more durable than pavements built using traditional gradations.

SCHEDULE, BUDGET, AND AGENCY SUPPORT

Estimated Project Length: 24 months.
Estimated Project Budget: $285,000
ODOT Support:
Chris Duman, Interim State Pavement Engineer, Christopher.L.DUMAN@odot.oregon.gov
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FOR MORE INFORMATION
For additional detail, please see the complete STAGE 2 RESEARCH PROBLEM STATEMENT online at:
https://www.oregon.gov/odot/Programs/ResearchDocuments/24-43.pdf

SPR RESEARCH PROGRAM
SECOND-STAGE PROBLEM STATEMENT
FY 2024

PROBLEM NUMBER AND TITLE
24-43 Achieving Longer Lasting Asphalt Pavements with Lower Cost and Environmental Impact Through Engineered Aggregate Skeletons

RESEARCH PROBLEM STATEMENT
According to the research conducted by the American Society of Civil Engineers (ASCE) in 2020, $4.59 trillion in infrastructure funding is needed before 2025. Although the budget for some of this required investment is currently available, about $2 trillion is still unfunded. According to the ASCE's assessment, highways and bridges in the U.S. received an *"ASCE Grade:**D**"*, which is the lowest rating out of all other infrastructure components (Railroads: Grade **B** and Electrical Grid: **D+**). Traffic delays and high roadway roughness due to inadequate levels of paving are costing the U.S. several billion dollars annually in wasted fuel, road user time, and vehicle maintenance costs. For all these reasons, durable, innovative, and environmentally friendly roadway construction materials with lower maintenance costs are required to combat the aging infrastructure issue.

According to the 2022 ODOT Pavement Condition Report, the current ODOT pavement program is significantly underfunded, which is expected to result in a significant decline in pavement conditions in Oregon within the next couple of years. The current annual funding needed in Oregon for maintenance, rehabilitation, and reconstruction is about $280M, while the expected 2024-2027 and 2027-2030 STIP funding levels are $110M/year and $65M/year, respectively (almost 2.5 to 4 times less than the needed amount). According to the report, *"Preservation resurfacing mileage programmed in the STIP through 2027 only provides an equivalent resurfacing cycle time in excess of 50 years, which is more than twice as long as pavement lasts……… Historically, pavement funding has allowed for maintaining pavement on most of the system but rising costs are eroding the number of miles that can be preserved for the same dollar."* Since these funding projections did not consider the future increases in oil prices (which directly controls asphalt paving costs) and inflation rates, it is expected that the condition of the Oregon roadway network will even get worse than the 2022 predictions. The report ends with the following impactful statement:

"Inflationary factors coupled with deep cuts to pavement repair budgets in both the STIP and Maintenance programs will lead to rapid declines in pavement condition over the next decade. This will result in diminished safety and higher vehicle repair costs for Oregonians traveling on rutted and potholed roads. Also, Oregonians will pay more to repair failing pavement than it would have cost to preserve and maintain them in a state of good repair."

Since timely preventive preservation and maintenance of roads are crucial to reducing the life-cycle cost of paving, reduced paving due to inadequate funding is expected to significantly decrease the percentage of the pavements that are in fair or better condition within the next decade. This reduction in pavement conditions is already evident in the 2022 Pavement Condition Report for all 5 regions of Oregon (especially for the regions in highly populated urban areas – See Figure 9 in the report). For these reasons, developing lower-cost yet effective paving strategies for asphalt surfaced roads (which constitute about 95% of the ODOT roadway network) has immense importance to be able to pave more lane miles with a limited budget.

Developing durable paving materials with high recycled material contents that can last longer than current materials is an effective way to combat aging roadway networks with a limited budget. Although aggregates in an asphalt concrete mixture constitute about 93% to 96% of the total weight, studies focusing on improving the aggregate skeleton in an asphalt concrete material to enhance durability, reduce life-cycle costs, and reduce environmental impact are rarely available. The limited studies from other states in the literature on this subject used locally available aggregates that are completely different from those in Oregon. Most durability issues are addressed by modifying and improving the asphalt binder properties, which may not be possible for all cases (or may not be cost-effective in a limited-budget environment). For these reasons, methods and strategies should be developed to combat durability issues through innovations in aggregate properties.

RESEARCH OBJECTIVES

The major objective of this study is to determine ways to achieve the most effective aggregate properties (shape, texture, angularity, etc.) and size distributions (gradations) to improve the cracking and rutting performance of asphalt-surfaced pavements. The major strategies that will be investigated in this study are stone matrix asphalt (SMA) gradation, dense gradation with higher dust content, dense gradation with more cubically-shaped aggregates (also called equidimensional aggregates), larger and smaller nominal maximum aggregate sizes, different aggregate sources, and several other alternatives. Identifying methods to improve aggregate properties will be another major focus of this research project. Some of those potential methods to achieve the desired aggregate properties are: i) better management of crushing operations; ii) using more effective crushing machinery (older versions and the new ones recently acquired by some plants); and iii) using aggregate sources that would provide the highest long-term performance.

WORK TASKS, COST ESTIMATE AND DURATION

1) *Literature review:* A comprehensive literature review will be conducted to summarize the past and current research studies focusing on the improvement of the aggregate skeleton to improve asphalt concrete performance. The major focus of the literature review will be the studies focusing on the impact of aggregate shape, texture, angularity, gradation, and source on long-term pavement performance. The history of SMA mixtures (in Oregon, the U.S., and the rest of the world) to improve rutting and cracking resistance will also be summarized.

2) *Laboratory testing:* Several test specimens with aggregates and asphalt materials sampled from different production plants across Oregon will be produced and tested in the laboratory to determine cracking and deformation resistance for asphalt mixtures with various gradation types, aggregate sources, and properties and asphalt binder contents. Test results will be summarized through statistical analysis to determine the potential cracking and deformation resistance improvements that can be created by using the new engineered aggregate skeletons. The amount of binder content reduction and increase in Recycled Asphalt Pavement (RAP) content that can be created by using the developed engineered aggregate skeletons will also be quantified. For the most promising strategies (in terms of life cycle cost, environmental impact, and performance), the constructability and moisture susceptibility of the final asphalt mixtures will be determined.

3) *Life cycle cost analysis (LCCA) and pavement life cycle assessment (LCA):* The cost-effectiveness and environmental impact (in terms of greenhouse gas emissions and global warming potential) of the most promising strategies from the laboratory testing will be determined by LCCA and LCA, respectively.

4) *Field trials:* The asphalt mixtures with the aggregate skeletons that provided the best performance with the lowest life cycle cost and environmental impact will be used to construct pilot sections across Oregon roadways. The long-term performance of the sections will be monitored via automated pavement condition surveys (APCS) to determine the performance benefits of the developed strategies. The constructibility of the final proposed asphalt mixtures at the field level will also be validated in this task.

Key Deliverables: i) the most effective rock crushing technology and methods; ii) the quantified effectiveness of SMA gradation in achieving higher rutting and cracking performance; iii) the aggregate gradations, properties, and sources that provide the highest long-term performance; iv) the quantified impact of highly angular aggregates on moisture susceptibility of asphalt mixtures; v) the impact of final strategies on asphalt binder and allowable RAP content; and vi) the cost, environmental impact, and performance benefits of final suggested strategies.

Estimated Project Length: 24 months
***Estimated Project Budget:* $285,000**

IMPLEMENTATION

Developing durable paving materials with high recycled material contents that can last longer than current materials is an effective way to combat aging roadway networks with a limited budget. Although aggregates in an asphalt concrete mixture constitute about 93% to 96% of the total weight, studies focusing on improving the aggregate skeleton (via changing the aggregate shape, texture, angularity, gradation, and source) in an asphalt concrete material to enhance durability, reduce life-cycle costs, and reduce environmental impact are rarely available. Most durability issues are addressed by modifying and improving the asphalt binder properties, which may not be possible for all cases (or may not be cost-effective). For these reasons, methods and strategies should be developed to combat durability issues through innovations in aggregate properties which can be achieved by changing the rock crushing operations, crushing machinery, and using better aggregate sources and gradations. The use of higher quality aggregates in the asphalt mixtures has the potential to not only improve the long-term pavement performance but also reduce the cost and environmental impact (by reducing required binder content and improving longevity).

Products and information that will be developed and implemented in this research study are: i) a performance-based balanced mix design method for SMA; ii) the amount of binder content reduction in design that can be created by using engineered aggregate skeletons; iii) the level of increase in RAP content that can be created by using better aggregate skeletons without sacrificing performance; iv) the quantified cost (through life cycle cost analysis) and environmental (through pavement life cycle assessment) benefits of reducing the binder content and increasing the RAP content; v) information related to the constructability of most promising gradations through laboratory construction simulations using a hydraulic roller compactor and field trials; and vi) the quantified impact of higher aggregate angularity on the moisture susceptibility of asphalt mixtures.

POTENTIAL BENEFITS

Asphalt concrete cracking and deformation resistance can be improved by using more robust aggregate skeletons that can be achieved by using innovative aggregate size distributions (called gradation), better aggregate sources, and crushed aggregates with higher angularity and texture. It is also possible to reduce the binder content of the asphalt mixture by improving the properties of the aggregate skeleton. Since the asphalt binder costs increased from about $320/ton to about $700/ton (significantly higher than the aggregate cost of $15-$25/ton) in the last two years due to the significant increase in oil prices, even a slight reduction in the binder content of the mix can result in **substantial cost savings.** Since asphalt binder production has a carbon footprint higher than other components in the mixture, reducing the asphalt binder content through aggregate improvements will also **reduce carbon emissions and the overall environmental impact.** Engineered aggregate skeletons can also allow the use of higher recycled asphalt pavement (RAP) contents in the mixture without sacrificing performance, which will also result in reduced cost and environmental impact.

PEOPLE

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REFERENCES

Coplantz, J. (2023). *2022 ODOT Pavement Condition Report.* Oregon Department of Transportation, Pavement Services Unit and Pavement Management Team.

STAFF REVIEW PAGE

Literature Check

TRID&RIP

☒ A review of TRID & RIP databases found no existing research that answers the research question

Technology & Data assessment

☒ No Identified T&D output

☐ At the end of this project, the implementing unit(s) within ODOT will need to coordinate the adoption of new technology or data in order to realize the full potential of this research.

Cross-agency stakeholders

- List stakeholders or impacted units
  - Only impacted unit is Pavement Services
- Identify any issues of concern raised by an ODOT stakeholder. Note expected mitigation
  - No issues were identified