PROPOSAL TITLE  Characterization of Unbound Materials for Mechanistic-Empirical Pavement Design for NDOT Districts 2 and 3

SUBMITTED TO  Nevada Department of Transportation
Research Section
Attn: Manju Kumar
1263 S. Stewart Street
Carson City, NV 89712

PROPOSING AGENCY  Oklahoma State University

PRINCIPAL INVESTIGATOR  Debakanta (Deb) Mishra

TITLE OF PRINCIPAL INVESTIGATOR  Associate Professor

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PERIOD OF PERFORMANCE  24 months

ANTICIPATED START DATE  October 1, 2020

PROJECTED END DATE  September 30, 2022

TOTAL FUNDS REQUESTED  $210,396
**PROBLEM DESCRIPTION**

The Nevada Department of Transportation (NDOT) has recently invested significant time and effort towards the implementation of Mechanistic-Empirical (M-E) Pavement Design practices. Outlined in the Mechanistic-Empirical Pavement Design Guide (MEPDG) and incorporated into AASHTOWare Pavement M-E Design (PMED), this design approach focuses on mechanistic analysis of pavement sections under traffic and environmental loading; critical pavement response parameters thus calculated, are then used along with empirical transfer functions to predict pavement performance throughout its service life. The M-E pavement analysis and performance prediction approach relies heavily on Resilient Modulus (MR) as a critical input parameter for unbound materials (aggregate base/subbase layers as well as the subgrade soil).

The primary method of establishing the MR properties of a soil or aggregate is by running the repeated load triaxial test as described in specifications such as the one in AASHTO T 307. The repeated load triaxial test is a complex test procedure, is time consuming, and requires significant investment towards equipment procurement and personnel training. Accordingly, majority of state and local highway agencies seek alternative approaches to establish the MR properties of unbound aggregates and soils encountered during pavement construction.

During a recently conducted survey of all fifty US state departments of transportation as well as corresponding agencies in all Canadian provinces, only fourteen (14) out of a total of forty-six (46) responding agencies indicated performing some form of resilient modulus testing on unbound aggregates and/or soils (Tutumluer, 2013). However, follow-up conversation with the 14 agencies indicated that those who were indeed conducting resilient modulus testing, were mostly doing it on subgrade soils, and not aggregate base/subbase materials. The primary reason given, was that testing aggregates for resilient modulus required a significantly larger specimen (at least 6 in. diameter x 12 in. height); several state agencies do not possess a triaxial cell of that size. Moreover, several DOTs also reported that preparing aggregate specimens for resilient modulus testing was cumbersome, and often did not result in consistent results between specimens even when tests are performed by the same operator.

Design and construction of long-lasting, sustainable pavement systems is greatly dependent on accurate characterization of the base/subbase as well as the subgrade layers. In the absence of repeated load triaxial test data, agencies often rely on pre-established correlation equations to predict the MR values using other “easy-to-establish” index values. NDOT currently uses such an equation to predict the MR values for subgrade soils from R-value. However, this equation was not originally developed for Nevada, and therefore, can lead to significant overestimation/underestimation of the MR values. A recently finished research effort by Sebaaly et al. (2018) developed new MR prediction equations for soils and aggregates obtained from NDOT District 1. It is now important to undertake a similar effort for District 2 and 3 materials so that NDOT can have a complete database of MR values for soils and aggregates encountered in pavement applications across the state of Nevada.

**BACKGROUND AND SUMMARY**

The impact of MR on the response of a flexible pavement structure to the combined actions of climate and traffic loads is highly significant. Level 1 in the current M-E design framework requires
the $M_R$ property to be measured in the laboratory under repeated load triaxial (RLT) conditions (although, the current version of PMED does not allow Level 1 inputs for unbound materials). Level 2 allows the determination of $M_R$ through correlations with other empirical properties of the unbound materials such as the Resistance value ($R$-value). Level 3 allows the use of $M_R$ default values established on the basis of soil classification, etc. The current version of Nevada’s Pavement ME Design manual (Hajj et al., 2015) uses the following equation to calculate the resilient modulus value for a subgrade material to be used in a new flexible pavement design:

$$M_R \text{ (psi)} = 145 \times 10^{0.0147R-1.23}.$$ For base materials, on the other hand, constant modulus values are recommended (see Table 1) based on the aggregate type and class.

### Table 1: Resilient Modulus Values for Unbound Aggregate Base Layers Recommended by the Current Version of NDOT Pavement Design Guide (Extracted from Hajj et al., 2015)

<table>
<thead>
<tr>
<th>Aggregate Base</th>
<th>Design Resilient Modulus (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1 Class A (Section 704.03.02)</td>
<td>26,000</td>
</tr>
<tr>
<td>Type 1 Class B (Section 704.03.03)</td>
<td>26,000</td>
</tr>
<tr>
<td>Type 2 Class A (Section 704.03.04)</td>
<td>34,000</td>
</tr>
<tr>
<td>Type 2 Class B (Section 704.03.05)</td>
<td>26,000</td>
</tr>
</tbody>
</table>

1Section 70 of the 2014 Standard Specifications for Road and Bridge Construction

As seen from the above table, three of the aggregate types are assigned the same $M_R$ value (26,000 psi), whereas the fourth aggregate type (Type 2, Class A) is assigned a higher $M_R$ value. No justification for this approach was found, except for possible correlation with material gradation. As an improvement over this approach, a research study was undertaken at the University of Nevada Reno (Hajj et al, 2018) to develop resilient modulus prediction models for rehabilitated flexible pavement sections. Subsequently, Sebaaly et al. (2018) extended this effort and proposed models for both new as well as rehabilitated flexible pavement designs. The following equations were proposed by Sebaaly et al. (2018) as the design modulus values for the base layer.

$$\ln\left( M_{R,CAB\text{-New}} \right) = 7.3224 + 0.0366 \times (R-Value) - 0.0656 \times (P#40)$$

$$+ 0.0256 \times \left( P#\frac{3}{8} \right) - 0.0893 \times OMC - 0.0270 \times H_{eq}$$

$$\ln\left( M_{R,CAB\text{-Reh}} \right) = 8.0140 + 0.0261 \times (R-Value) - 0.0485 \times (P#40)$$

$$+ 0.0161 \times \left( P#\frac{3}{8} \right) - 0.0659 \times OMC - 0.0089 \times H_{eq}$$

Most terms in the above equation are self-explanatory, with OMC standing for Optimum Moisture Content, and $H_{eq}$ being the equivalent thickness calculated for the layer being analyzed. As already mentioned, the work by Sebaaly et al. (2018) primarily focused on NDOT District 1 materials, and their model development effort did not incorporate any material from Districts 2 or 3.

Von Quintus et al. (2014) reported that the stress states at which the laboratory-measured resilient modulus value equaled the computed elastic modulus value, were much lower than most of the repeated axial stresses and confining pressures specified in AASHTO T 307, even for thin
HMA layers. They also highlighted that the design resilient modulus values established from their analyses were significantly different from default Level 3 values specified in PMED. Therefore, they strongly recommended every state DOT to establish a material library of resilient modulus test results through repeated load triaxial testing. In light of the importance of unbound material resilient modulus values to ensure accurate prediction of pavement response and performance using PMED, and the fact that correlation equations established for one state is not likely to work very well for materials in another state, it is important for every state to develop a database with unbound material properties relevant for M-E pavement design.

The Idaho Transportation Department (ITD) recently completed a research study titled, “Unbound Material Characterization for Pavement ME Implementation in Idaho” to achieve this objective. Deb Mishra (PI for the current proposal) served as the PI for this project, that involved extensive laboratory characterization of sixteen different subgrade soil types, and eighteen different aggregate materials. Soil and aggregate samples were collected from across the state of Idaho; laboratory tests carried out included: (1) Particle Size Distribution; (2) Atterberg’s Limits; (3) Moisture-Density Characterization; (4) Unconfined Compressive Strength (for subgrade soils); (5) California Bearing Ratio (CBR); and (6) Resilient Modulus Testing per AASHTO 307. This project developed a database of relevant soil/aggregate properties as well as resilient modulus test values and model parameters that can be used by ITD engineers in the future during pavement design using PMED (Mishra et al., 2019). Moreover, Mishra et al. (2019) attempted to develop correlation equations for predicting MR from less expensive laboratory test results such as index properties, CBR, R-value and unconfined compressive strength, as well as particle size distribution and parameters from moisture density tests. The study successfully predicted the resilient modulus values of aggregates with an R² value of approximately 0.90. However, because of wide variety of soils available in Idaho, none of listed properties showed any significant correlation with MR except for percentage finer than 200 sieve. Therefore, it was recommended that for subgrade soils, ITD engineers should use laboratory test results (compiled in the database) corresponding to the district in which a particular pavement section is being designed.

It should be noted that the above example was for soils and aggregates collected across the state of Idaho. It is quite possible that for unbound materials in another state, some of the index properties can be successfully related to design resilient modulus values. As already mentioned, Sebaaly et al. (2018) and Hajj et al. (2018) successfully correlated soil and aggregate MR values from NDOT District 1 with certain gradation parameters, Optimum Moisture Content, and R-value.

The logical next step for NDOT involves laboratory testing of soils and aggregates collected from NDOT Districts 2 and 3 to assess whether the correlations developed for District 1 can be applied to all districts, or not. The developed models should be modified as needed to facilitate state-wide implementation of M-E pavement design practices.

PROPOSED RESEARCH

Overall Research Philosophy
While planning the tasks for the proposed study, it is important to adopt an approach that would
be consistent with future planned upgrades/modifications to be implemented into PMED. For example, the recently completed NCHRP Project 1-53 (Lytton et al., 2019) proposed several enhancements to the models used in PEMD to characterize unbound material behavior. Any research being conducted by states DOTs should have a vision to be applicable in the long-run as well. The objective of such research efforts should be to immediately improve the quality of Level 2 design (using PMED) being carried out by the agency, while at the same time, preparing the agency for future incorporation of Level 1 capabilities for unbound materials in PMED.

The tasks proposed to be carried out under the scope of this study have been conceived following the above research philosophy. Accordingly, the ultimate goal for the tasks would be to immediately equip NDOT with correlation equations to predict the design resilient modulus of soils and aggregates for new and rehabilitated pavement sections. At the same time, the tasks would also prepare NDOT for future implementation of Level 1 design capabilities into the unbound materials module of PMED.

Task 1: Identification of Soils and Aggregates for Testing and Material Collection
The research team will work with NDOT personnel to identify appropriate sources for soils and aggregates to be tested in this project. It is anticipated that a total of 10 aggregate types and 10 subgrade soil types will be tested under the scope of this study. While selecting the materials for testing, special care will be taken to incorporate all different soil and aggregate types encountered during pavement construction projects in NDOT districts 2 and 3. Prior to selecting locations for subgrade material collection, the research team will use web-soil survey portals such as the one developed by Arizona State University (under the scope of NCHRP 9-23b) or the one developed by the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS). Candidate locations will be presented to NDOT project advisory panel, and soil samples will subsequently be collected keeping practicality and cost of excavation in mind. As far as unbound aggregate materials are concerned, the research team will work with NDOT engineers to identify quarries that primarily supply aggregates for pavement construction projects in Districts 2 and 3. Aggregate samples will be collected directly from the quarries. The research team will work with NDOT personnel to schedule the shipment of the aggregate and soil samples to the Oklahoma State University (OSU) laboratory. Deliverable: A technical memo summarizing the procedure adopted for material selection and sample collection.

Task 2: Laboratory Characterization of Selected Materials
Once samples of the identified materials have been collected and shipped to OSU laboratories, an extensive set of laboratory tests will be conducted. All tests to be conducted have been listed in Table 2 along with the corresponding AASHTO and NDOT (if applicable) test specification numbers. It is anticipated that the tests will be carried out following the NDOT test specification if any difference exists between the AASHTO and NDOT procedures.
Table 2: List of Laboratory Tests to be Conducted on the Soils and Aggregates Collected Under the Scope of the Proposed Study

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Test Specification Number</th>
<th>Subgrade Soils</th>
<th>Base/Subbase Aggregates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AASHTO</td>
<td>Nevada DOT</td>
<td></td>
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<tr>
<td>Particle Size Distribution</td>
<td>AASHTO T88</td>
<td>T 206G</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>AASHTO T27</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Atterberg’s Limits</td>
<td>T 89</td>
<td>T 210J</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>T 90</td>
<td>T 211J T212J</td>
<td>✓</td>
</tr>
<tr>
<td>Moisture-Density Characteristics</td>
<td>T 99</td>
<td>T 108B</td>
<td>✓</td>
</tr>
<tr>
<td>California Bearing Ratio (CBR)</td>
<td>T 193</td>
<td>N/A</td>
<td>✓</td>
</tr>
<tr>
<td>R-Value</td>
<td>T 190</td>
<td>T 115D</td>
<td>✓</td>
</tr>
<tr>
<td>Unconfined Compressive Strength</td>
<td>T 208</td>
<td>N/A</td>
<td>✓</td>
</tr>
<tr>
<td>Resilient Modulus Testing</td>
<td>T 307</td>
<td>N/A</td>
<td>✓</td>
</tr>
<tr>
<td>LWD Testing in Proctor Molds</td>
<td>N/A*</td>
<td>N/A</td>
<td>✓</td>
</tr>
</tbody>
</table>

*Schwartz et al. (2017) proposed a method for LWD testing in Proctor molds, which has not been implemented into an official AASHTO specification yet

**Task 2-1: Light Weight Deflectometer Testing in the Laboratory**

Besides the conventional tests listed in the project Request for Proposal (RFP) document, the research team will also conduct Light Weight Deflectometer (LWD) testing of the soil and aggregate samples inside Proctor molds. This newly developed method was used by Schwartz et al. (2017), who also proposed a draft AASHTO specification to facilitate its implementation into practice. As is relatively well-known, almost all highway agencies in the country run moisture-density tests on soils and aggregates using some version (standard or modified or a derivative thereof) of the test procedure originally developed by Proctor. The same samples being used to establish the moisture-density curves can be tested using an LWD (inside the Proctor mold), and a modulus value ($E_{LWD,Mold}$) can be established corresponding to each point on the moisture-density curve. This results in a modulus vs. moisture curve, which is similar in shape to a moisture-density curve. Figure 1 shows an example curve established by the PI (Mishra) through his previous work with ITD. As seen from the figure, the modulus curve “attains” a peak value on the dry side of OMC, and the modulus value falls rapidly on as the moisture content is increased beyond the OMC. Establishing such curves in the laboratory will facilitate the implementation of modulus-based compaction control practices. However, for the sake of the current project, a different outcome of this LWD testing will be of significance.
The LWD-measured modulus values can also be used to as a predictor variable to estimate the unbound material (soil and aggregate) design resilient modulus value for M-E pavement design. Jibon and Mishra (2020) investigated whether or not the LWD-measured modulus value in a Proctor mold can be used with reasonable accuracy to predict the laboratory-measured resilient modulus values. For this purpose, they used the concept of Summary Resilient Modulus (SMR) as defined by NCHRP 1-28A to extract one representative modulus value from AASHTO T 307 test results. Eight different subgrade soil types were tested at three different moisture contents (90% OMC, OMC, and 110% OMC) using both the LWD as well as AASHTO T 307 approaches. Figure 2 shows the excellent correlation between $E_{LWD,\text{Mold}}$ and SMR observed by Jibon and Mishra (2020) for different moisture contents.

It is important to note that the summary resilient modulus value defined by NCHRP 1-28A is different from the field design modulus value defined by Sebaaly et al. (2018). However, the overall concept for this work will remain the same. Once the laboratory-measured resilient modulus values have been transformed to an equivalent “field modulus” value, the next step involves how the “field modulus” value can be predicted with reasonable accuracy without the need to run the cumbersome repeated load triaxial test.
The current research steam STRONGLY believes that if proven to be a feasible, the use of $E_{LWD, Mold}$ to predict the field modulus for unbound materials will have more mechanistic significance compared to correlation equations that involve the use of index properties such as R-value, LL, PI, or gradation parameter. Moreover, this approach using LWD will not be limited to selected soils/aggregates only, but will also be applicable to recycled and marginal-quality materials such as Recycled Concrete Aggregates (RCA) and Recycled Asphalt Pavement (RAP).

Deliverable: A technical memo summarizing findings from the laboratory testing along with a PowerPoint slide set to be used during research progress update meetings.

Task 3: Development of Resilient Modulus Prediction Models

Task 3-1: Establish a Design Resilient Modulus Value

The primary challenge in this task would be to first establish an appropriate design resilient modulus value. Note that different researchers and agencies have adopted different approaches to define a “single” modulus value from resilient modulus test results such as those generated using AASHTO T 307. Two of the most ‘scientific’ ones are:

1. Method developed by Sebaaly et al. (2018) involving the use of ILLI-PAVE Finite Element simulation;
2. Method developed by Von Quintus et al. (2014) that involves the use of a layered-elastic program such as WINJULEA;

Among the two approaches listed above, the approach by Sebaaly et al. (2018) has already been implemented for part of Nevada (for District 1 materials), and may be the most applicable for this research project. However, the proposed study will also study the validity of the approach proposed by Von Quintus et al. (2014) as the elimination of F-E simulation from the process may expedite the adoption of this approach by practicing engineers.

Task 3-2: Develop Statistical Models to Predict the Design Modulus Values

Once the design resilient modulus value has been established, the next task will involve establishing correlation equations between other “easy-to-establish” soil and aggregate properties, and the design resilient modulus. This will involve factors such as unconfined compressive strength ($q_u$) for subgrade soils, R-value for both soils and aggregates, and gradation, moisture-density, and Atterberg’s limits parameters for both soils and aggregates. Another independent variable to be used during development of the statistical models will be, $E_{LWD, Mold}$, established through LWD testing of the soils and aggregates inside Proctor molds. As already mentioned, using the $E_{LWD, Mold}$ value to predict the design modulus will enhance the “mechanistic significance” of the predictive equations. The statistical correlations will be developed using the standard statistical package, R (R Core Team, 2017). The models will be checked for their robustness using statistical tests such as Multi-Collinearity, Variation Inflation Factor (VIF), etc.

Deliverable: A technical memo summarizing the process of selecting the design field modulus values, and detailing the procedure of predictive model development.
Task 4: Compare the Correlation Equations Developed using the Different Approaches
This task will compare the performance of the different predictive equations developed under Task 3. First, the equations developed by Sebaaly et al. (2018) will be used along with the laboratory test results for District 2 and District 3 materials. If a good fit is observed, the validity of the equations established by Sebaaly et al. (2018) for all soils and aggregates across Nevada will be proved. On the other hand, if the previously developed equations do not fit well with the District 2 and 3 material data, new sets of equations will need to be developed. The research team will work with NDOT personnel to get access to the raw data for the study by Sebaaly et al. (2018) generated from testing of District 1 materials. This will facilitate the development of new equations using data from all three districts. At this stage, other models, such as the ones developed by Lytton et al. (2019) from NCHRP 1-53 project, as well as the adequacy of using $E_{LWD,Mold}$ to predict field design modulus will also be assessed.

Task 5: Incorporate $M_R$ Correlations into NDOT MEPDG Guide
Once developed, the appropriate correlations will be incorporated into NDOT’s MEPDG guide.

Task 6: Reporting
This will be the final task in this research study, and will focus on developing the final project report summarizing all findings from the study. Along with the final report, this task will also produce the following deliverables:

1. A database of stress-dependent $M_R$ model parameters for unbound materials in NDOT Districts 2 and 3.
2. Detailed instructions on how $E_{LWD,Mold}$ can be used to predict field design resilient modulus values without having to rely on index properties.
3. Two short instructional videos detailing how the project findings can be used to facilitate M-E pavement design in Nevada for new and rehabilitated flexible pavement sections. The video will show step-by-step instructions on how to utilize the project findings during M-E pavement design.

URGENCY AND ANTICIPATED BENEFITS
It is critical for NDOT to undertake this research study during the current fiscal year. The original model development effort for District 1 soils and aggregates has been complete since 2018. Currently, the $M_R$ properties of unbound materials from NDOT Districts 2 and 3 are still being determined using the old relationship. This relationship was established for a specific group of soil types obtained from specific geographic areas that do not represent the type of materials typically used in NDOT Districts 2 and 3. Pursuing this follow-up study to characterize the soils and aggregates from Districts 2 and 3 will help NDOT engineers during pavement analysis and performance prediction using PMED. Moving away from the currently used generic equations (for subgrade soils) and assumed values (for aggregates) will result in significant cost savings for Nevada DOT’s road users. For instance, Hajj et al. (2018) reported that the cost savings realized due to the new $M_R$ models for NDOT Districts 1 were equivalent to extending the pavement life for about 6 years.

IMPLEMENTATION PLAN
The implementation plan will primarily comprise Task 5 of the proposed study titled, “Incorporate $M_R$ Correlations into NDOT MEPDG Guide”. Once suitable models have been identified to predict
the resilient modulus values for soils and aggregates using other “easy to establish” properties, they will be incorporated into NDOT’s current MEPDG guide. Under the implementation plan, the PI will also create short training videos with examples on how findings from this study can be used to establish resilient modulus inputs for unbound materials encountered during the construction of new and rehabilitated flexible pavement sections in the state of Nevada. Upon completion, the proposed research will be at Stage V of research deployment. The PI does not anticipate any additional cost needed beyond the completion of the tasks to ensure full implementation of the research findings.

PROJECT SCHEDULE

It is estimated that all tasks proposed in this study will be completed within a period of 24 months. The Gantt chart presented below assumes a project start date of October 1, 2020.

<table>
<thead>
<tr>
<th>Task #</th>
<th>Project Task</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
</tr>
</thead>
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<tr>
<td>1</td>
<td>Identification of Soils and Aggregates for Testing and Material Collection</td>
<td>OND</td>
<td>JFMAMJ</td>
<td>JASONDJFMAMJ</td>
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<tr>
<td>2</td>
<td>Laboratory Characterization of Selected Materials</td>
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<tr>
<td>3</td>
<td>Development of Resilient Modulus Prediction Models</td>
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<tr>
<td>4</td>
<td>Compare the Correlation Equations Developed using Different Approaches</td>
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<tr>
<td>5</td>
<td>Incorporate Mr Correlations into NDOT MEPDG Guide</td>
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<tr>
<td>6</td>
<td>Reporting</td>
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<tr>
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<th>2022</th>
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<tbody>
<tr>
<td>A</td>
<td>Project Kick-Off Meeting</td>
<td>OND</td>
<td>JFMAMJ</td>
<td>JASONDJFMAMJ</td>
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<tr>
<td>B</td>
<td>Semi-Annual Progress Meetings</td>
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<tr>
<td>C</td>
<td>Submission of Final Project Report</td>
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<thead>
<tr>
<th>Item #</th>
<th>Deliverable Name</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
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<tr>
<td>1</td>
<td>Quarterly Progress Reports</td>
<td>OND</td>
<td>JFMAMJ</td>
<td>JASONDJFMAMJ</td>
</tr>
<tr>
<td>2</td>
<td>Technical Memo on Material Selection</td>
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<tr>
<td>3</td>
<td>Technical Memo and PowerPoint Slides on Laboratory Test Findings</td>
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<tr>
<td>4</td>
<td>Technical Memo on Selection of Design Field Modulus</td>
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<tr>
<td>5</td>
<td>Submission of Final Project Report</td>
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FACILITIES AND EXPERTISE

The PI (Mishra) has been working in the area of unbound material characterization for more than a decade. His Ph.D. study at the University of Illinois focused on extensive laboratory characterization and modeling of unbound aggregates and soils for unsurfaced pavement applications. Mishra recently completed a project titled “Unbound Material Characterization for Pavement ME Implementation in Idaho” for the Idaho Transportation Department (ITD). The ITD project developed an extensive database of unbound material properties for subgrade soils and unbound aggregates commonly used in pavement applications across the state of Idaho. This experience will greatly help the PI accomplish the objectives of this current study. The geotechnical engineering laboratory at OSU has all required equipment to be used in this research.
This includes large bays for material processing, large sieve shakers, triaxial test set-ups capable of accommodating samples up to 6 in. in diameter, as well as multiple LWD units.

PROJECT CHAMPION, COORDINATION, AND INVOLVEMENT (OTHER DIVISIONS)

The PI actively sought feedback from the project’s champions (Dr. Changlin Pan and Mr. Rick Bosch) to understand the overall objective of this project, and what would constitute the ideal outcome from NDOT’s point of view. A conference call was held on 3 February 2020, where the PI got detailed feedback from Dr. Pan about NDOT’s expectations from the project. Also, the PI worked with Dr. Pan to obtain a copy of the current MEPDG Manual used by NDOT. This helped in understanding NDOT’s current approach concerning the assignment of resilient modulus values to soils and aggregates. Upon Dr. Pan’s recommendation, the PI also reached out to Mr. Manjunathan Kumar with questions related to the logistics of research proposals submitted by universities outside the state of Nevada. The stakeholders for this proposed study are: (1) Road Users in Nevada; (2) Different NDOT divisions such as Administration, Engineering, Operations, as well as Planning. However, only personnel from the Engineering and Operations divisions will need to be directly involved during the course of this project to coordinate the material identification and sample collection.

REFERENCES


## STANDARD BUDGET ITEMIZATION FOR DEPARTMENT RESEARCH PROJECTS

**Project Title:** Characterization of Unbound Materials for Mechanistic-Empirical Pavement Design for NDOT Districts 2 and 3  
**Project Duration:** 10/01/2020 to 9/30/2022  

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<th>Name</th>
<th>Position / Title</th>
<th>% Fringe Benefit</th>
<th>Total Fringe Benefit</th>
<th>Salary or Wage</th>
<th>Monthly % Salary or Hours</th>
<th>Total Monthly Wage</th>
<th>Total Year 1</th>
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<td>Deb Mishra</td>
<td>Associate Professor</td>
<td>33.39%</td>
<td>$ 3,183</td>
<td>$ 10,833</td>
<td>88%</td>
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<td>To Be Named</td>
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<td>$ 1,006</td>
<td>$ 4,400</td>
<td>50%</td>
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<td>$ 27,406</td>
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<td>$ 1,240</td>
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<td><strong>Year 1 Total</strong></td>
<td></td>
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<td><strong>$ 52,703</strong></td>
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<th>Name</th>
<th>Position / Title</th>
<th>% Fringe Benefit</th>
<th>Total Fringe Benefit</th>
<th>Salary or Wage</th>
<th>Monthly % Salary or Hours</th>
<th>Total Monthly Wage</th>
<th>Total Year 2</th>
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<td>Deb Mishra</td>
<td>Associate Professor</td>
<td>33.39%</td>
<td>$ 3,377</td>
<td>$ 10,833</td>
<td>88%</td>
<td>$ 9,819</td>
<td>$ 13,196</td>
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<th>Name</th>
<th>Position / Title</th>
<th>% Fringe Benefit</th>
<th>Total Fringe Benefit</th>
<th>Salary or Wage</th>
<th>Monthly % Salary or Hours</th>
<th>Total Monthly Wage</th>
<th>Total Year 3</th>
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<td>$ 0</td>
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<td><strong>Year 3 Total</strong></td>
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<td></td>
<td></td>
<td>$ 0</td>
</tr>
</tbody>
</table>

**Year 1** | **Year 2** | **Year 3**  
A. Personnel | $ 52,703 | $ 54,416 | $ 0  
B. Travel  
C. Operating Costs  
D. Final Report Preparation and Submission  
E. Other Costs | $ 5,500 | $ 5,500 |  
F. Subcontracts (Only the first $25,000 on which indirect costs are allowed) | $ 10,000 |  
G. Subtotal of Direct Costs (sum of A thru F) | $ 71,203 | $ 62,916 | $ 0  
H. Total Indirect Cost (% of G at corresponding indirect cost rate) | 49.6% | $ 35,317 | $ 31,206  
I. Student Tuition and Fees (At OSU, Tuition is a direct cost) | $ 4,805 | $ 4,949 |  
J. Subcontractor (in excess of the first $25,000) (At OSU, all sub costs are direct costs) |  
K. TOTAL PROJECT COSTS PER YEAR (sum of G thru J) | $ 111,325 | $ 99,071 | $ 0  

**TOTAL PROJECT COST** | **$ 210,396**

**Notes:**  
1) DEPARTMENT only pays for travel that is essential for the completion of the project and cost are per state rates. Travel costs to professional and other meetings are not allowed. **Out-of-state travel requires DEPARTMENT approval in advance.**
Budget Justification

The principal investigator on this project is Dr. Debakanta (Deb) Mishra of the School of Civil and Environmental Engineering at Oklahoma State University (OSU).

SENIOR PERSONNEL
Support is requested for 1 month at 88% FTE for Dr. Mishra during both years of the project. Dr. Mishra will supervise the overall progress of the research tasks, and will directly supervise the graduate and undergraduate students working on the project tasks. Dr. Mishra will work directly with personnel from the Nevada Department of Transportation (NDOT) to ensure all the project tasks are accomplished as planned. Dr. Mishra will serve as the primary technical contact for this project, and will be responsible for timely completion of all project tasks, and timely submission of the project deliverables.

OTHER PERSONNEL
Support is requested for one graduate research associate (Ph.D.) for the duration of this project (24 months) at 50% FTE. The graduate student will work directly with the project PI (Mishra) on all project tasks such as performing the laboratory tests, analyzing the test results, and drafting the final project report.

Support is also requested for one undergraduate student to work on this project throughout its duration at 50% FTE. The undergraduate student will be helping the graduate student with all material processing, laboratory testing, and data analysis.

FRINGE BENEFITS
Fringe benefits are for health care and other benefits for the employees, faculty and students. Fringe benefit rates are negotiated annually with the Office of Naval Research and will be adjusted accordingly. The proposed FY20 benefit rate for faculty members is 33.39%, the graduate student benefit rate is 3.81% and the undergraduate rate is 0.81%.

As per Oklahoma State University practice, there is an annual increase of 3-percent included for estimation of subsequent years for each employee’s salary, benefits and tuition. The University will document employees’ time based on percent of time effort. The salaries shown are the same as would be paid for performing University functions.

EQUIPMENT
N/A

TRAVEL
Funds are requested for the PI to travel to Nevada for research progress meetings. It is anticipated that a total of four trips will be needed throughout the duration of this project.

Travel expenses will be reimbursed at rates consistent with Oklahoma State University’s approved policies and will not exceed the greater of approved State or Federal rates.

MATERIALS AND SUPPLIES
The laboratory testing component of this project will require expendables such as membranes for triaxial testing, filter papers, porous stones, replacement sieves, etc.
SERVICES
Funds are requested to work with a certified geotechnical testing company to conduct R-value testing on all the soils and aggregates tested in the project. It is projected that a total of 20 different materials (soils + aggregates) will be tested in this project.

SUBCONTRACT
N/A

COMMUNICATIONS
All materials (soils and aggregates) tested in this project will need to be shipped from Nevada to the OSU laboratories. The PI (Mishra) will work with NDOT personnel to ensure the material shipment is planned in an efficient and cost-effective manner.

PUBLICATIONS
N/A

TUITION
One graduate students will work on this project. The tuition remission for the graduate research students is requested and is calculated at a rate of 18.20% of GRA salary.

INDIRECT COSTS (F&A)
The allowable Facility & Administrative Cost rate for on-campus research is 49.6% of Modified Total Direct Costs (MTDC) until further amended. This is the predetermined rate negotiated with Oklahoma State University by the Department of the Navy, Office of Naval Research, 800 North Quincy Street, Arlington, VA, 22217-5660, for the Federal Government. Facility & Administrative Costs are calculated on total direct costs less items of equipment, capital expenditures, charges for patient care and tuition remission, rental costs, scholarships, and fellowships as well as the portion of each subgrant and subcontract in excess of $25,000. Fringe benefits applicable to direct salaries and wages are treated as direct costs.

AMOUNT OF THIS REQUEST – $210,396.
This is the total request for the project, computed by adding items Direct and Indirect Costs.
Born in the state of Odisha in India, Deb Mishra has been residing in the US since August of 2004.

Education
Ph.D. Civil Engineering, University of Illinois at Urbana-Champaign (UIUC), 2012; GPA: 4.0
  *Dissertation Title: Aggregate Characteristics Affecting Response and Performance of Unsurfaced Pavements on Weak Subgrade*
M.S. Civil Engineering, Texas Tech University (TTU), 2006; GPA: 4.0
  *Thesis Title: Maintenance Strategies for Protecting Bridge Approaches from Water Intrusion*

Professional Licensure
State of Idaho; License Number: 17362

Professional Experience
08/2019 – Present: Associate Professor, School of Civil and Environmental Engineering, Oklahoma State University, OSU
08/2019 – Present: Faculty Affiliate, Department of Civil Engineering, Boise State University, BSU
08/2014 – 07/2019: Assistant Professor, Department of Civil Engineering, Boise State University, BSU
03/2012 - 07/2014: Post-Doctoral Research Associate, Department of Civil and Environmental Engineering, UIUC
08/2006 - 07/2011: Graduate Research and Teaching Assistant, UIUC
08/2004 - 07/2006: Graduate Research Assistant, TTU

Research Areas
Dr. Mishra has research interests in the generic areas of Infrastructure Materials, Transportation Geotechnics, Pavement Engineering, and Railroad Engineering. In particular, his research has encompassed the following topics: (1) Performance Monitoring of Transportation Infrastructure through Advanced Instrumentation; (2) Design and Development of Advanced Laboratory Equipment for Infrastructure material characterization; (3) Micromechanical Analysis of Coarse-Grained Geomaterials through Discrete Element Modeling; and (4) Numerical and Analytical Modeling of Transportation (Pavement and Railroad) Infrastructure.
Academic courses taught - Course Level
CIVE 3714: Introduction to Geotechnical Engineering, OSU
CIVE 4050/5010: Geotechnical Engineering for Pavements and Railroads, OSU
CE 370 – Transportation Engineering Fundamentals – Undergraduate, BSU
CE 397 – Transportation Engineering Laboratory – Undergraduate, BSU
CE 440/540: Pavement Design and Evaluation, BSU
CE 497/597: Advanced Transportation Materials – Undergraduate/Graduate, BSU
CE 497/597: Introduction to Railroad Engineering – Undergraduate/Graduate, BSU
CEE 310 - Transportation Engineering - Undergraduate, UIUC
CEE 415 - Geometric Design of Roads - Undergraduate/Graduate, UIUC
CPSC 440 - Applied Statistical Methods I - Undergraduate/Graduate, UIUC

Funded Research Grants and Proposals
As Principal Investigator (PI)
  • Sponsor: Interlocking Concrete Pavement Institute Foundation (ICPIF)
  • Budget: $150,000
  • Sponsor: Oklahoma Department of Transportation (ODOT)
  • Budget: $71,889
  • Sponsor: Federal Railroad Administration (FRA; Subcontract through ENSCO Inc.)
  • Budget: $20,991
  • Sponsor: Idaho Transportation Department
  • Budget: $125,000
(2018-2019) “Reduction and Analysis of Pavement Profiler Data to Quantify the Bump at the End of the Bridge”
  • Sponsor: Federal Highway Administration (subcontracted through ESC Inc.)
  • Budget: $86,034
  • Sponsor: Idaho Transportation Department
  • Budget: $50,000
  • Sponsor: Idaho Transportation Department
  • Budget: $130,000
- Sponsor: Idaho Transportation Department
- Budget: $160,000

- Sponsor: Idaho Transportation Department
- Budget: $180,000

- Sponsor: Idaho Transportation Department
- Budget: $50,000

- Sponsor: WIDER PERSIST Partner Project (Boise State University)
- Budget: $29,585

- Sponsor: URETEK USA
- Budget: $22,300

- Sponsor: Idaho Transportation Department
- Budget: $15,083

- Sponsor: Transportation Technology Center, Inc. (TTCI)
- Budget: $33,330

- Sub-Contract through University of Illinois at Urbana-Champaign
- Project Sponsor: Federal Railroad Administration
- Budget: $37,356

(2014) “Implementation of Mobile Technology in Classroom Instruction for Civil Engineering Courses”
- Sponsor: College of Engineering, Boise State University
- Budget: $2000

- Sponsor: Union Pacific Railroad
- Budget: $57,761
- Role: Post-Doctoral Research Associate
- Principal Investigator: Erol Tutumluer (UIUC)
As co-Principal Investigator (co-PI)
- Sponsor: Idaho Transportation Department
- Budget: $29,490
- Principal Investigator: Yang Lu

(2016-2019) “Permeating Sustainability and Resiliency Concepts into Civil Engineering Curricula”
- Sponsor: National Science Foundation
- Budget: $299,492
- Principal Investigator: Bhaskar Chittoori

(2016) “Phase 2: Numerical Analysis of Alternate Cross Sections (Key 19112, US-95, Elephant Butte Swelling Clay”
- Sponsor: Idaho Transportation Department
- Budget: $49,474
- Principal Investigator: Bhaskar Chittoori

(2015-2016) “Alternate Cross-Section Development of I-15 Rehabilitation from Sand Road to IC-89”
- Sponsor: Idaho Transportation Department
- Budget: $50,000
- Principal Investigator: Mandar Khanal

- Sponsor: Idaho Transportation Department
- Budget: $37,844
- Principal Investigator: Bhaskar Chittoori

Awards and Honors
✓ Associate Editor, ASCE Journal of Materials in Civil Engineering; January, 2020 - Present
✓ Chair, 2019 Joint Rail Conference (JRC). Scheduled for April 9 – 12, 2019, Snowbird Summer and Ski Resort, Snowbird, Utah.
✓ Chair, AFP 70(1): Subcommittee on Unbound Aggregate Material; Transportation Research Board; Parent Committee: AFP 70 (Mineral Aggregates); Tenure as Chair: 2016 – Present
✓ Founding Member, Young Transportation Geotechnics Engineers Committee; A committee formed under the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE) Committee TC 202: Transportation.
✓ Fellowship Recipient, Educate the Educators (EtE) Symposium, July 2015, Austin, TX
✓ Fellowship Recipient, Railroad Engineering Educators’ Symposium, June 2015, Philadelphia, PA
✓ Dwight D. Eisenhower Graduate Fellowship (2010). Awarded by the Federal Highway Administration (FHWA) Office of Professional and Corporate Development
✓ List of Teachers Ranked as Excellent by their Students, Fall 2009, UIUC
Scholarship Recipient, Professors’ Training Course on Asphalt Technology (2008). National Center for Asphalt Technology (NCAT), Auburn, Alabama

Journal publications (*Marks Student Author)


27. Mishra, D., E. Tutumluer, and A. A. Butt (2010). “Quantifying Effects of Particle Shape and Type and Amount of Fines on Unbound Aggregate Performance through Controlled Gradation”. In Transportation Research Record 2167, Journal of the Transportation Research Board, Transportation Research Board of the National Academics, Washington, D.C., pp. 61-71. (Voted “Practice Ready” Paper).


Peer-reviewed conference papers (*Marks Student Author)


**Professional Societies and Affiliations**
- Member, Academy of Pavement Science and Engineering (2017-Present)
- Faculty Advisor for the Boise State ASCE Student Chapter (2016 – Present)
- Affiliate of the Transportation Research Board (TRB), 2013-Present
- Currently serves on TRB Committees AFP 70, AR050, Subcommittee AFP 70(1)
- Member of the American Society of Civil Engineers (ASCE)
- Currently serves on ASCE-GeoInstitute’s Pavements Committee, 2012-Present
- Member of the American Railway Engineering and Maintenance-of-Way Association (AREMA), 2013-Present
- President and Inaugural Member, Graduate Student Advisory Committee, Department of Civil and Environmental Engineering, University of Illinois at Urbana-Champaign (2010-11)
President and Founding Member, Society of Pavement Engineers at Illinois, University of Illinois, Urbana-Champaign (2009-2010)

Inaugural member, Geo-Institute Student Presidential Group (GI-SPG). The GI-SPG is a group consisting of seventeen students selected from all over the country, to work closely with the president of the ASCE Geo Institute (2009-2011)

Member, Dean’s Graduate Student Advisory Committee (GSAC). College of Engineering, University of Illinois, Urbana-Champaign (2009-2010)

Professional Development

Regular attendee at several international conferences every year. Example conferences are: Annual Meeting of the Transportation Research Board (TRB), Joint Rail Conference (JRC), and Idaho Asphalt Conference.

Participant, Workshop on Application and Use of AASHTOWare® Pavement ME Design™ Software; April 24-26, 2018, Boise, Idaho.

Participant, Workshop on Introduction to Particle Flow Code, 29 February – 3 March, 2016, Minneapolis, Minnesota

Participant, Summer Course Design Institute, 18-22 May, 2015, Boise State University, Boise ID.

Participant, Workshop on Cement Based Paving Solutions, January 28, 2015, Boise, ID.

Participant, Workshop on Introduction to Abaqus, 11-15 August, 2014, Minneapolis, MN.