MPC-430
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Project Title:
Implementation of Intelligent Compaction Technologies for Road Constructions in Wyoming

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Research Needs:
The performance of a road is highly dependent on the quality assurance and control of field compaction of each pavement structure. Compaction is a major portion of Wyoming's road construction budget, in which many resources, such as compaction equipment and manpower, are deployed to ensure that the field compaction attains the desired design requirements and specifications. Due to the heterogeneity of pavement materials, variability in compaction equipment and operators, and challenges in maintaining uniform lift thickness and a range of moisture contents for a specified percent of compaction, achieving the required compaction requirement is a daunting task during a road construction (Mooney et al., 2010). Despite the fact that compaction is an important road construction procedure, current compaction quality assurance and control are assessed based on spot test techniques, such as the nuclear gage, the dynamic cone penetrometer and the lightweight falling weight deflectometer, that cover less than one percent of the compacted area.

To elevate the level of achieving and documenting compaction requirements, a new method known as intelligent compaction (IC) is being investigated throughout the United States. Intelligent compaction involves the use of compaction equipment that is equipped with a global positioning system (GPS), machine-integrated measuring sensors and control systems. The integrated GPS provides a complete geographic information system-based record of the construction site. The integrated sensor and control systems provide the capability of adjusting compaction effort (i.e., vibration amplitude and frequency) automatically based on the real-time and continuous feedback of variation in material properties during the compaction process.

Unlike the spot test techniques, IC provides 100 percent coverage for compacted earth materials and pavement conditions as well as continuous assessment of mechanistic soil properties. By having the immediate or real-time evaluation capability, weak-compacted areas during construction can be identified instantaneously and the required mitigation works to improve the compaction can be performed efficiently. In contrast, unnecessary over compaction can be avoided during construction. IC has been evaluated by many state Departments of Transportation (DOTs) as the future quality assurance and control technology to 1) improve our infrastructure performance; 2) lower construction cost and duration; and 3) improve safety. Furthermore, the benefits of intelligent compaction synergizes with the current momentum towards the Accelerated Bridge Construction (ABC) as well as the Every Day Counts (EDC) initiative of the Federal Highway Administration (FHWA).

A research projected 21-09 initiated by the National Cooperative Highway Research Program (NCHRP) was completed by Mooney et al. (2010) to evaluate the reliability of the IC and to develop specifications for the application of IC. As part of this research, five state DOTs construction projects, with each in Colorado, Florida, Maryland, Minnesota and North Carolina, were identified for data collection and analyses. The research has led to the development of preliminary recommended construction specifications for the application of IC in soils and aggregate base materials. Similar research on IC was conducted with three demonstration projects in Iowa by White et al. (2010). The outcomes of this research led to the development of special provisions for using Roller Integrated Compaction Monitoring (RICM) technologies on three hot mix asphalt (HMA) overlay pilot projects in Iowa. Concurrently, other state DOTs, such as Kansas, Mississippi, New York, California, North Dakota, Pennsylvania, Wisconsin, Indiana, Louisiana, Texas, Vermont, Rhode Island, Utah, Tennessee, and Georgia, have piloted their research projects on the IC. For instance, the pilot research project in Texas has enabled the Texas DOT to draft a special specification titled “Quality Compaction Using Intelligent Compaction Rollers” (2012), which outlines the construction and quality assurance/control requirements.

Despite the benefits of IC, it has several limitations that require further research investigations. Notably, the interpretation of IC data is a challenging task that requires a complex process. The stiffness values obtained from IC is influenced by both the layer being compacted and its supporting layers (Von Quintus et al. 2010). With regard to IC of soil, IC cannot eliminate all other volumetric tests during construction, such as moisture content measurement. Other limitations include the influence of lift thickness and the detection of anomalies in the underlying layers. For IC on HMA, the major limitation associated with the sequence of compaction using IC equipment followed by intermediate and final compactions using non-IC equipment, which could destroy the density developed by the IC. For these limitations, IC has not been implemented by any agencies to completely replace the spot test techniques as the quality assurance/control tool for the acceptance and verification of road compactions.

Congruent to the challenges with current spot test techniques in insuring the quality assurance and control of field compaction in Wyoming and recognizing the benefits and limitations of IC, this research is essential for the investigation of the potential adaptation and implementation of IC in Wyoming. The adaptation and implementation processes will be conducted to reflect local design and construction practices in Wyoming. This proposed study will evaluate the viability of

IC technologies in Wyoming, facilitate these processes to turn a routine IC practice into a reality, and identify any future research works to further advance the IC in Wyoming. It is envisioned that the successful implementation of IC in Wyoming will provide the following benefits:

1) Provide a better tool for quality assurance and control of field compaction;
2) Improve overall pavement uniformity, performance and service life;
3) Lower construction cost and duration;
4) Improve environmental sustainability; and
5) Lower overall maintenance cost.

Research Objectives:

With the advent of measurement technology and the integration of GPS, IC provides a complete, efficient and continuous assessment of compacted earthwork and HMA conditions during road constructions. The successful implementation of IC will significantly improve our quality assurance and control of compaction operations. The research project has the following principal objectives:

1) Study the implementation of current IC technologies for road constructions in the State of Wyoming;
2) Evaluate the advantages and challenges with the implementation of the IC technologies for production compaction operations; and
3) Provide a foundation of knowledge for developing IC guidelines/specifications into earthwork and HMA construction practices.

Research Methods:

Research methods are established based on the current needs for implementing advanced IC technologies to improve the efficiency of field compaction assessment and to ensure high quality assurance and control of field compaction operations. It is envisioned that the aforementioned research objectives will be achieved by completing five major tasks described below.

Task 1: Literature Review

This task will focus on conducting a comprehensive literature review on IC. The review will include the following: 1) current design and construction practices of earthwork and HMA compactions in Wyoming as well as in the neighboring states; 2) current national and state guidelines and specifications pertinent to compaction testing, assessment, and quality assurance/control; 3) latest knowledge and technology relating to IC; 4) implementation of IC technologies; 5) current national and state guidelines and specifications pertinent to IC; and 6) correlations of compaction parameters obtained from IC and in-situ testing methods. In order to provide adequate details to promote the appropriate use of IC, any national and state DOTs' guidelines and specifications, as well as the latest knowledge and technology developed for IC that can be appropriately adapted and implemented in Wyoming, will be examined.

Task 2: Conduct a Nationwide Survey

A nationwide survey will be conducted to collect information on the following topics: 1) commonly used design and construction practices of earthwork and HMA compactions; 2) challenges with current compaction practices and in-situ compaction testing methods; 3) commonly used pavement types and structures; 4) history of implementing IC; 5) challenges of IC implementation; 6) increases or decreases in construction costs using IC; 7) realized overall

benefits of IC; 8) guidelines and specifications pertinent to IC; 9) any other information related to the project topic; and 10) relevant contact details. This survey will be prepared using online survey software and sent to state and federal agencies. The results of the survey will be compiled, analyzed and reported.

Task 3: Evaluation of IC Monitoring Technologies

This task evaluate the current IC monitoring technologies produced by manufacturers, such as Caterpillar, Sakai and any other manufacturers commonly used in Wyoming. Various and commonly used compaction rollers, such as padfoot, dual-smooth and smooth drum types, as well as the measurement and data acquisition systems will be evaluated. Detailed information about the compaction technologies will be obtained from relevant manufacturers. This task will be conducted in close coordination with the Wyoming Department of Transportation (WYDOT) and Wyoming Contractor Association (WCA) to identify the potential manufacturers and equipment for IC and evaluate the impact of implementing IC in Wyoming.

Task 4: Recommendations and Future Research

Assimilating and analyzing the information obtained from Tasks 1, 2 and 3, recommendations about implementing IC technologies in Wyoming will be suggested. Advantages and challenges of implementation will be highlighted. Potential changes in current design and construction practices, field compaction assessment requirements and compaction quality assurance/control procedures will be identified. Future research to advance the IC technologies and facilitate its full implementation as the quality assurance/control tool for road construction in Wyoming will be proposed. Coordinating closely with WYDOT representatives and Antonio Torres of FHWA, an effort will be made by the research team to bring an IC demonstration project to Wyoming through the FHWA IC program (www.IntelligentCompaction.com).

Task 5: Technology Transfer

To update the progress of the research project, a progress report will be submitted to the Mountain Plains Consortium (MPC). A final report containing all aspects of the proposed research will be prepared and submitted to MPC at the conclusion of the project. The final report will include outcomes of the proposed Tasks 1 to 4 as well as a plan for future research that focuses on advancing the IC technologies and facilitates the implementation of such technologies in Wyoming. The research findings of the project will be disseminated to designers and practitioners in the fields of geotechnical and pavement engineering through technical presentations at local, regional and national conferences.

Expected Outcomes:

The research outcomes will provide Wyoming state agencies, such as WYDOT, the necessary tools to improve pavement design and construction, achieve higher quality compaction during construction, and reduce road maintenance costs in future. Also, the research outcomes will provide the construction industries with a better and advanced technology to efficiently assess compaction operations, satisfy higher quality assurance/control requirements, and potentially lower overall construction costs. It is believed that the research outcomes will be of immediate interest to geotechnical and pavement engineers, supervision and maintenance personnel working for WYDOT and other entities, as well as to earthwork and roadwork contractors in Wyoming.

Relevance to Strategic Goals:
The project outcomes will address several of the strategic goals associated with the MPC program and the U.S. Transportation Research Board as well as the USDOT's requested emphasis areas described as follows:

1) State of Good Repair – Better assessment and quality assurance/control of earthwork and HMA compactions;
2) Safety – Reduce potential road accidents due to road closure or traffic diversion for road maintenances and repairs;
3) Economic – Increase the efficiency of monitoring, assessing, and achieving high quality compaction operations and lower overall construction duration and cost, which aligns with the current momentum towards the Accelerated Bridge Construction (ABC) as well as the Every Day Counts (EDC) initiative of the Federal Highway Administration (FHWA);
4) Environmental Sustainability – Reduce unnecessary compaction operations and uses of non-renewable natural resources, such as fossil fuels, during construction.

Educational Benefits:
A Master-degree student majoring in civil engineering will be enrolled to assist principal investigators to complete this project. An undergraduate student will be hired to assist the graduate student, notably in collecting and compiling the survey results. The IC technologies will be introduced in two required civil engineering courses CE3500: Transportation Engineering and CE3600: Soil Mechanics and will be integrated as part of the curriculum for the civil engineering course CE 4510/5510: Pavement Design for Airports and Highways.

Work Plan:
The projected duration for the research presented in this proposal is 12 months. A detailed schedule per task is shown in Table 1.

Table 1: Detailed schedule proposed for the research tasks

Task		Months					
		1-2	3-4	5-6	7-8	9-10	11-12
1	Literature Review						
2	Conduct a nationwide Survey						
3	Evaluation of IC Monitoring Technologies						
4	Recommendations and Future Research						
5	Technology Transfer						

Project Cost:
Total Project Costs: $82,754
MPC Funds Requested: $41,211
Matching Funds: $41,543 Source of Matching Funds: University of Wyoming

TRB Keywords:
Intelligent Compaction, Quality Assurance and Control, Hot-Mixed Asphalt, Earthwork

References:

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