2005-2007 LITRE Grant Proposal

1. Project Title:

Development of a Virtual Testing Module for an Undergraduate Course on Materials Design

2. Project Coordinator:

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3. Other Participants:

Y. Richard Kim, Professor of Civil Engineering

4. College or Unit:

Engineering

5. Department:

Civil, Construction and Environmental Engineering

6. Project Description:

Motivation

Considering the importance of effective design of materials, courses related to the understanding and analysis of man-made materials are pervasive in civil, mechanical, aerospace engineering disciplines. The primary instructional objective of these courses is to enable the students to design materials to withstand specified loads while minimizing the cost. The art of effective design is taught primarily by providing the students with a feel for the effect of various design parameters on the performance of the material. To develop such a feel, the students should destructively test numerous specimens fabricated using various combinations of the design parameters. Unfortunately, such laboratory testing demands high cost of materials, fabrication, testing, and time. For this reason, only a few specimens are tested by the students, thus limiting the student's feel for the material behavior. Furthermore, laboratory testing is not well suited for distance learning as the student's understanding of the behavior would be limited by the video images that may not capture all the aspects of the experiment.

In this project, we propose to eliminate the above limitations by developing an instructional module capable of fabricating and testing various specimens in a completely virtual manner, i.e. through computer simulation. Through an

extensive multi-year research effort, the PIs have recently finished the development of such a virtual testing software package for asphalt concrete. The proposed effort is aimed at adopting this research tool in the undergraduate course on the design of asphalt concrete (taught by the co-PI). The resulting instructional tool, due to its virtual nature, would be ideal in a distance learning setting.

Approach

The current virtual testing package takes the design parameters (aggregate gradation and properties of asphalt binder), makes the specimens using an innovative virtual fabrication technique, followed by virtual mechanical testing done using a multi-scale lattice modeling procedure that captures the effect of growing damage and failure. The virtual testing procedure has been utilized to simulate uniaxial tension and indirect tension tests; the predictions of load-deflection curves as well as crack patterns match well with those obtained from laboratory testing, thus illustrating the effectiveness of the virtual testing procedure.

While the existing virtual testing package has been used for research purposes, it cannot be readily used for instructional purposes. The principal drawback of the package is that it requires an expert user because (a) the input parameters are advanced and are known only to a rather involved researcher, and (b) it is a multi-step procedure combining ideas from various fields ranging from geometry, statistics, mechanics, and computing. It is thus important to transform this complex infrastructure into a simpler software package that could be used by a student in a junior-level material design course. The proposed effort attempts to make such transformation by (a) developing a module for converting the input given by an undergraduate student into the input required for the computational infrastructure, (b) combining all the steps to streamline the fabrication and testing, and (c) implementing of an expert system / database with standard mix designs. It is envisioned that the students would first understand the behavior of standard mixes and their respective advantages. They would then experiment with their own variations of the mix design to obtain a deeper understanding of the effects of various parameters, preparing themselves to effectively analyze and design asphalt concrete materials.

It is expected that the proposed virtual testing module will aid in enhancing student learning. Eventually, depending on the success of this project, similar approaches may be developed for other material design courses such as those related to portland cement concrete and other quasi-brittle materials.

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7. Project Objectives:

The short-term objective of the proposed effort is to enhance the undergraduate course CE 332 (materials of construction) by making the students better understand the behavior of asphalt concrete through virtual fabrication and virtual testing. The medium-term goals are: (a) to help develop graduate-level asphalt materials courses into distance-learning courses and (b) to help enhance student learning in other materials related course in the

department, and elsewhere in the university, state and country.

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8. Estimated number of students affected:

The software package would be first used in CE 332 (Materials of Construction course), taught by the co-PI, and would eventually be made available for use in other courses dealing with concrete-type materials at NCSU and elsewhere in the state and the nation. The short-term impact would be on the students of the CE 332 (40-50 undergraduate students per year) and graduate courses (CE 753 and others with10-15 graduate students per year). The long-term impact would be more global, and depending on the effectiveness of the tool, could be on thousands of students at various universities.

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9. Outcomes of the Project:

Considering the complex nature of many man-made materials, it is often impossible to completely understand their behavior in a quantitative manner. It is thus essential for the student to develop a “feel” for the behavior of the material. The single most important outcome of the project is that the student would have improved feel for asphalt concrete. This would instill in the student (a) the knowledge to distinguish between good and bad material designs and (b) intuitive understanding of the effect of various materials. These outcomes will be measured with the help of the assessment tools developed as part of the project (see item 11). While not immediately measurable, the natural outcome of the project is that the students will end up being better performers when they enter the profession of transportation materials design.

Note that the proposed approach need not be limited to asphalt concrete materials. Success of the proposed study would lead to the possibility of developing similar approaches for other types of materials.

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10. Project impact on NCSU:

In addition to the direct impact on student learning, due to its virtual nature, the proposed project would significantly reduce the need for physical testing, saving the department the cost of materials, testing machine and technician time. Furthermore, the tool would aid significantly in offering the material design course in distance learning setting. Due to its visual and intuitive nature, the proposed software package could be utilized in motivating high-school students to join engineering programs (e.g., the SITE program in the college of engineering). Such a possibility will be explored in the future.

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11. Project Assessment Plan:

Electronic survey and evaluation tools would be developed and made a part of the software package. After a set of virtual experiments, the students would be asked to evaluate the software package with respect to usability and learning effectiveness. Once the tool is ready for use by other instructors, we would ask the instructors to assess the software in effective student learning. Appropriate evaluation forms would be developed for this purpose.

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12. Staffing and Support:

One graduate student will be working for one semester on this project. The entire budget will be utilized for the student and the PIs would perform the supervisory activities without charging any time to the project.

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13. Financial Support Requested:

EPA salary total: 0
SPA salary total: 0
Other salary: 7,458
Equipment:
Cost associated with assessment:
Other financial support requested: 2,353
Total Funds requested: 9,811
Additional Explanation of how funds will be used:

The salary will be used for the graduate student developing the software.The student will be paid for four months (February 15, 2005 – June 15, 2005). The “other financial support” is earmarked for the tuition for the same four months.

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14. Funding Breakdown:

Total funding requested for fiscal year 2005-2006: 9,811
Total funding requested for fiscal year 2006-2007: 0

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15. Staff Support and/or Technical Support Requested:

None.

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16. Timetable for Implementation:

Preliminary implementation: June 15, 2006
Software testing and fine tuning: August 15, 2006
Use and Assessment in CE 332: Fall 2006 and later
Final report: March 2007

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17. Human Subjects Protection:

If your proposal project involves research using human subjects, you will need approval from the Institutional Review Board for the Protection of Human Subjects in Research (IRB) prior to final approval. IRB information is available at http://www.ncsu.edu/sparcs/irb

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18. Proposal Release:

By submitting this proposal the applicant grants the LITRE Advisory Board permission to make this proposal available as an example for future grant applicants. All personal information will be removed if this proposal is used as an example.