

Development and Implementation of Digital Specimen and Digital Tester Technique for Infrastructure Materials

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ABSTRACT: The proposed supplement request is to support the following activities: 1) Dr. Wang's stay at the University of Cambridge for three months; 2) One graduate student's stay at the Delft University of Technology (DUT) for six months; and 3) Dr. Wang's short visit of Delft University of Technology for student advising and collaboration with Dr. Tom Scarpas. This arrangement is considered more beneficial to the current project. The long-term objective of these activities is to establish a strong triangle among three research groups, the Virginia Tech group, the Cambridge Group and the Delft group with focus on microstructure, micromechanics and computational simulation of asphalt concrete and other stone-based infrastructure materials. The specific technical objectives include a) joint development of an aggregate-binder interface model by Wang and Cebon; b) development of representation techniques for 3D complex shapes for efficient computational simulation by the graduate student co-advised by Wang and Scarpas. These technical objectives are directly related to the PFI (Partnership for Innovation) project (EEC-0619969, Expiration Date 09/30/2008, Development and Implementation of Digital Specimen and Digital Tester Technique for Infrastructure Materials) and present the potential to extend the partnership to include European participants. In addition to the technical objectives, participation in their cultural and engineering practice events is also planned, which will enable a better understanding of the driving force for engineering research and education in European countries.

INTRODUCTION

The NSF 0637550 project is a supplement under IREE to Virginia Polytechnic Institute and State University. The work carried out under the current NSF award (EEC-0619969) includes 1) development of the digital specimen and digital test techniques; 2) application of the techniques developed to solve real problems in material characterization and performance evaluation. Two Ph.D. students participated in the project development and completed their degrees. A number of publications [1,2,3,4,5,6] and presentations were made by the PIs of the project and the student participants.

The digital specimen and digital test techniques focus on the characterization of the microstructure of the materials, development of models to simulate the behavior of individual constituents and computational simulation of the mixture properties and behavior. A critical enhancement over the current method to model the aggregate-binder interface as a perfect interface is to characterize the interface structure and use Molecular Dynamics to simulate its behavior. The other critical enhancement is to minimize the number of elements for representing complex three-dimensional (3D) structures. The IREE supplement is to make use of the facilities and expertise of two international laboratories, one at the University of Cambridge of the United Kingdom and the other at the Delft University of Technology of the Netherlands, to enhance the current project.

The Cambridge group has been well recognized internationally in developing micromechanics, failure criteria of asphalt concrete, and vehicle-road interactions. Its leader, Dr. Cebon is a fellow of the Royal Academy of Engineering. He has published numerous papers and been invited for keynote speeches at many important conferences. The Delft group is internationally recognized in macroscopic modeling of asphalt concrete and computational simulations of pavement performance. Its leader, Dr. Tom Scarpas has been chairs of many workshops, organizers of major conferences, and invited keynote speakers for many important occasions. He has been recently appointed as the chair of the FHWA (Federal Highway Administration) Expert Task Force on Fundamental Properties and Advanced Modeling. Wang's work on integration of microstructure into micromechanics modeling and computation simulation uniquely fits into the two European groups and presents a great synergy potential. Micromechanics and computational techniques demonstrate commonality in other stone based materials and composite materials and represent the state-of-the-art methodology of the new era.

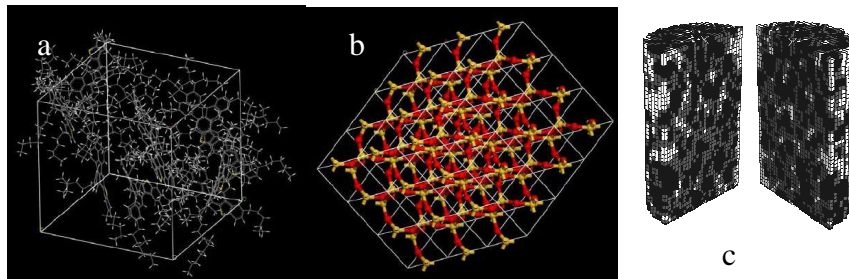
The direct short-term research outcomes include an interface model and an optimization method to represent the 3D microstructure of complicated composite materials. The direct short-term education outcome includes the gaining of experience of a graduate student in performing research in an international environment, and learning cultural differences. The long-term benefits are two-fold, technique and personnel development. It should be noted that Wang's research expertise and focuses are complementary to the Cambridge and the Delft groups', which is the basis for a potential long-term partnership. The expertise and achievements at Cambridge and Delft will allow Wang's group to extend its capability at a faster pace. The collaboration will be also very beneficial to the personal development of the faculty. The international partnership to establish through this supplement will potentially place an international platform for the PI, a junior faculty.

The two researchers supported by the IREE supplemental award are Dr. Linbing Wang who made the travel during part of the summer semester of 2007 and Ms. Ashley Standord who is currently still with the Delft University of Technology.

RESEARCH ACTIVITIES AND ACCOMPLISHMENTS OF THE INTERNATIONAL COOPERATION

During summer 2007, Dr. Wang stayed at the Department of Engineering of the University of Cambridge for three weeks. During this period, specific research achievements include 1) development of Molecular Dynamics (MD) models to simulate the properties of binder (Figure 1a) and 2) development of MD models to simulate the properties of mineral aggregates (Figure 1b). Based on these models, an interface model is currently being conceived. Ashley Stanford's fall 2007 semester visit of the Delft University of Technology accomplished an enhancement in random shape representation in the Finite Element Method. Figure 2c represented this achievement. The on-site work is directly improvements over the methods proposed and developed under the current Partnership for Innovation (PFI) project. These improvements enhance the accuracy of model predictions and the computational efficiency of the digital tests.

During these visits, Dr. Wang had regular weekly meetings with the hosting professor Dr. David Cebon and his research group including postdoctoral researchers, M.S. and Ph.D. students. He had detailed discussions with the postdoctoral researchers and the graduate students on their research. Meanwhile had also visited other laboratories, attended their small group discussions, and seminars. During this period, Dr. Wang was also invited to give a seminar (Figure 2a) by the Nottingham Transportation Engineering Center (NTEC) at the University of Nottingham. At NTEC, he visited NTEC's laboratories and facilities and discussed potential collaboration opportunities with Professor Andy Collop. Ms. Ashley Stanford worked with DUT graduate students on a daily basis (Figure 2b). In addition, both Linbing and Ashley were involved with their local cultural activities through attending public speeches, cultural events (Figure 2c) and church activities.



a, b MD Simulation of Binder and Aggregate Properties; c, Microstructure Representation

Figure 1 Technical Achievements

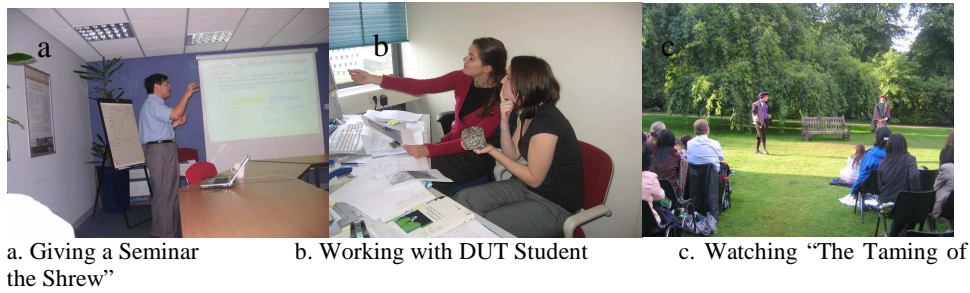


Figure 2 Academic Seminar and Cultural Activities

BROADER IMPACTS OF THE INTERNATIONAL TRAVEL

The supplement award added significant diversity to the project by allowing researchers to experience different facilities, and different perspectives of looking at the same problems. The supplement award also helps expand the original scope of the current award by looking into the interface behavior at nano scale, enabling the researchers to step into a new research area promising a variety of applications.

Through the travel, the relative long-term stay helped the researchers and their foreign partners to better appreciate each other’s research strength, interest, and the areas that collaboration may synergize their individual efforts. Through the travel, several new initiatives were deliberated and joint efforts are being sought to carry out those initiatives. In addition, both researchers have been more familiar with the culture, technological exchange potentials and business opportunities through learning the differences in research methods, industrial practice and values.

DISCUSSION AND SUMMARY

The most significant accomplishments of the international research experience include 1) technical achievements as targeted in the proposal; 2) establishment of tight collaborations with the hosting laboratories; and 3) research mentoring skills. Another accomplishment is historical impact-induced driving force. The University of Cambridge is one of the most prestigious universities in the world. Visiting the colleges where Newton, Darwin and many other science giants had studied indeed has a driving force to prompt one to work harder.

One recommendation is that NSF may integrate its IREE program with the sabbatical plans of faculty so that IREE program can save funds, and the faculty may be able to get extended sabbatical.

ACKNOWLEDGEMENTS

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Dr. Sara Nerlove, the director for the PFI program of NSF has offered many valuable suggestions on the IREE activities.

The two hosting laboratories and their leaders Dr. David Cebon and Dr. Tom Scarpas have devoted significant efforts to the collaboration.

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BRIEF BIOGRAPHIES OF RESEARCHERS

Linbing Wang received a B.S. degree from Hohai University in 1984, an M.S. degree from Tongji University in 1991, and a Ph.D. degree from Georgia Institute of Technology in 1998. His major field is in Civil Engineering. He had

worked in design, research and consulting for eight years in China before starting his Ph.D. program in 1994. Following the completion of his Ph.D. degree, he worked as a project engineer for Law Engineering, Inc. 1998-1999, and as a research associate for Georgia Tech 1999-2000. From 2000 to 2005, Dr. Wang worked as an assistant professor jointly appointed between Louisiana State University and Southern University. Since 2005 he has been working as an associate professor at Virginia Tech.

Ashley Stanford received the BS degree in Civil Engineering from Virginia Tech in 2007. She started her graduate program in Fall 2007 in Civil Engineering with focus on Transportation Infrastructure and System Engineering.