Available online at www.sciencedirect.com
SCIENCE DIRECT®
Cement & Concrete Composites 28 (2006) 587–588
Cement & Concrete Composites
www.elsevier.com/locate/cemconcomp

Editorial

Although cement and concrete composites are generally thought to be complex materials, satisfactory safety and durability performance are routinely obtained for ordinary structural applications. The design procedures for such cases have been developed through extensive laboratory testing, the use of basic theories, and the monitoring of field performance. For critical structures and structures exposed to severe mechanical and/or environmental loadings, however, ensuring satisfactory performance is still an area of research and development for many practical applications. To appreciate this remark, one only needs to look at the state of disrepair of various components of the civil infrastructure in many developed countries. Furthermore, the growing recognition of environmental constraints on human activity is promoting alternative material and structural designs to reduce the loads on the environment. When considering such developmental needs, model-based simulation is an attractive means for supplementing physical test data, which are generally quite limited by practical restrictions on the number, range, and nature of the test parameters.

Most research and development endeavors include a modeling component, in which the model represents the object of study and assists in the understanding, prediction, and control of its behavior. There is intrinsic value in constructing models, as the process requires the establishment of formal, quantitative connections between relevant parameters and their effects on system behavior. The aforementioned complexity of cement and concrete composites makes it difficult to establish such cause-and-effect relationships from experimental and field observations alone. Indeed, model-based simulation can be viewed as a type of experimentation that aims to validate theories or hypotheses of actual behavior, and then use the theories to predict behavior for parameter settings outside of the validation set. Given the extensive efforts in these directions, however, it is surprising that little attention has been given to formal processes of verifying and validating models of cement and concrete composites. The utility of data extracted from model-based simulation depends on the conceptual and operational validity of the model. For the effective third-party use of a model, users must have confidence in the model's validity.

The dictionary definitions of verification and validation are not dissimilar and the two words tend to be used interchangeably in some technical literature. For the purposes of establishing confidence in and improving simulation models, however, each word is assigned a different meaning. From the seemingly distant field of computational fluid dynamics, *Verification* is "the process of determining that a model implementation accurately represents the developer's conceptual description of the model". *Validation* is "the process of determining the degree to which a model is an accurate representation of the real world from the perspective of the intended uses of the model" [1].

Verification tends to be a low-level activity that is concerned mainly with the question: is the model built right? During model construction, attention is given to the inner workings and consistency of the model. Validation considers the question: has the right model been built? Attention is given to the conceptual basis of the model, and its accuracy and predictive capabilities in solving problems within the intended field of application.

When determining the operational validity of a model, it is important to consider whether the events and objects of study in the actual system are observable (i.e. whether one is able to collect relevant data with some degree of accuracy). When that is the case, validation most often involves a comparison of the simulation results with the performance of the actual system, or other valid models including established theories. Care should be taken when validating through comparisons with laboratory testing, since such testing is generally a simulation of actual field conditions. The approaches to determining the operational validity of the model can be either subjective or objective. For the latter case, statistical tests (e.g., hypothesis tests and confidence intervals) are often used as objective measures of validity. When there are two or more valid models of equal quality, the choice of model can be made according to Occam's razor, which would select the simplest of the models. Another deciding factor is the robustness of a model (i.e. the model's ability to provide intelligible solutions even for large variations, or possibly faults, in the model input parameters). In recent years, there have been a number of benchmark studies in which the predictive capabilities of various models were compared, relative to

0958-9465/$ - see front matter
doi:10.1016/j.cemconcomp.2006.07.001

confidential test results for the load-deformation behavior of structural concrete. Such activities are valuable as they provide independent comments on the degree of validity of the individual models.

As noted above, in addition to gaining insight into system behavior, a main goal of model-based simulation is to predict system behavior. By definition, however, prediction implies model application to situations for which the model has not been validated. In those situations, the accuracy of the simulation cannot be directly determined, but only indirectly inferred through the quality of previous verification and validation steps. It can be exciting when a model indicates new, unexpected behavior. For such cases, in particular, the question of model validity is of the utmost importance.

Verification and validation of simulation models is an active area of research, with the degree of maturity of the research depending on the field of study. For fields that have strong mathematical bases (e.g. computational fluid dynamics), the research on verification and validation tends to be more developed, as evidenced by the numerous papers on the subject and related editorial standards. With respect to cement and concrete composites, there are extraordinary modeling challenges related to the time variant material structure–property relationships, material interactions with the environment, degradation mechanisms (including fracture), variability of the material constituents and processing methods, and so forth. Accordingly, the advancement of verification and validation practice requires close collaboration between model developers, experimentalists, and theoreticians, as well as engineering professionals to better define the areas for model application. Without acceptance and third-party usage of the models (i.e. usage by those outside of the model development team), the potential for model-based simulation of cement and concrete composites will remain largely unexplored.

Reference

[1] Guide for the verification and validation of computational fluid dynamics simulations. AIAA G-077-1998; 1998.

J.E. Bolander
Department of Civil and Environmental Engineering,
University of California–Davis, Davis,
CA 95616-5294, United States
Tel.: +1 530 752 8226; fax: +1 530 752 7872
E-mail address: jebolander@ucdavis.edu