Engineering Structures 33 (2011) 3726–3736

Contents lists available at SciVerse ScienceDirect

Engineering Structures

journal homepage: www.elsevier.com/locate/engstruct

Evaluation of coupled partial models in structural engineering using graph theory and sensitivity analysis

Holger Keitel [a,*], Ghada Karaki [a], Tom Lahmer [a], Susanne Nikulla [a], Volkmar Zabel [b]

[a] Research Training Group 1462, Bauhaus-Universität Weimar, 99423 Weimar, Germany

[b] Institute of Structural Mechanics, Bauhaus-Universität Weimar, 99423 Weimar, Germany

ARTICLE INFO

Article history:
Received 25 March 2011
Received in revised form
14 July 2011
Accepted 1 August 2011
Available online 30 August 2011

Keywords:
Evaluation
Sensitivity
Graph theory
Partial models
Coupling
Model choice
Bridge engineering

ABSTRACT

The process of analysis and design in structural engineering requires the consideration of different partial models of loading, structural material, structural elements and analysis type, among others. All of these, need an adequate modelling as individuals and as coupled sets to catch a behaviour of interest. This paper proposes an innovative algorithm to facilitate quantitative measures to evaluate coupled partial models in structural engineering. Adapting graph theory and utilising variance based sensitivity analysis enable evaluation and drawing conclusions regarding the combinations of partial models in an engineering system. The algorithm is applied in bridge engineering, analysing bridge behaviour considering dynamic loading, creep and shrinkage material models and further considering geometric nonlinear effects.

1. Introduction

The models used in structural engineering to design for serviceability and ultimate limit state, are composed of several partial models (PM). A partial model describes a component of the global model, e.g. loading, material, or the level of abstraction. For one class of PMs, e.g. the material behaviour of concrete, several possibilities of modelling are available. If the material model is relevant to the structural problem, the structural engineer needs to decide, whether a linear or a non-linear material model should be used and whether effects of creep, shrinkage or cracking have to be considered. The evaluation, which is a combination of partial models is suitable for a specific problem, is not straightforward. The intention of this paper is, to combine assessments of partial models to analyse and in particular to design global models of high quality.

A literature review concerning model evaluation in general, leads to the concepts of verification and validation. The first named answers the question, whether the numerical implementation of the mathematical model is correct. The second concept deals with the problem of the adequateness of the mathematical model for describing the physical reality. For a more detailed explanation, see Babushka and Oden [1] or the AIAA guide [2]. Modelling in structural engineering faces the problem, that during the process of modelling, experimental data are hardly available as structures in civil engineering are mainly unique. Thus a validation for a specific design example is hardly possible. The selection of specific partial models, within a class of physically appropriate partial models, needs to be done without having evidence from reality. Also information of the verification process is not helpful for the model choice (MC). Therefore, the approach pursued in this paper uses concepts of sensitivity analyses, see e.g. Saltelli [3,4]. This method investigates, how the uncertainty in the output of a model is apportioned, qualitatively or quantitatively, to different sources of variation in the input of a model. Generally such investigations are limited to the variation of the input parameters, e.g. specific material coefficients, and are applied to individual partial models. Furthermore, [3] proposes to perform sensitivity studies to a group of parameters, to identify the main models that contribute to the parameter uncertainty of the response. First attempts to extend this were made by Most [5], where the influence of the model choice on the uncertainty of the model prediction is investigated. First and total effect sensitivity indices are used. Additionally to the variation of input parameters of different models, a random variable with discrete values accounting for the model choice, is considered.

To make the process of structural analysis more reliable, these ideas are extended to the analysis of coupled partial models. A method is developed, that examines the following problems:

* Corresponding author. Tel.: +49 (0) 3643 584115; fax: +49 (0) 3643 584101.
E-mail address: holger.keitel@uni-weimar.de (H. Keitel).
URL: http://www.uni-weimar.de/grk (H. Keitel).

0141-0296/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.engstruct.2011.08.009