11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

From tests to real scale simulation: A systematic approach for impact limiter materials

E.M. Kasparek*, R. Scheidemann, H. Völzke

BAM Federal Institute for Materials Research and Testing, Unter den Eichen 44-46, 12203 Berlin,
eva-maria.kasparek@bam.de, www.bam.de

Key Words: *Drop tests, Parameter Identification, Explicit finite elements, Shock absorber*

Impact limiter materials are characterized by high plastic deformation capacities, whereat the corresponding nonlinear stress-strain relations are very often affected by temperature, loading velocities and further boundary conditions of the specific scenario. Thus, the development and adaption of numerical methods for reliably simulating shock absorbing components requires an extensive data base and adequate sophisticated constitutive formulations. Furthermore, a systematic approach is needed to identify and separate all major factors which influence the behaviour of test samples in the experimental as well as in the respective computational configuration and to transfer these findings into finite element parameter settings.
A typical application field of such models is the simulation of casks for radioactive waste in severe accidental scenarios where their integrity and tightness that has to be demonstrated as part of licensing procedures according to national and/or international regulations. In general, the handling area or the cask itself is equipped with impact limiters in order to minimize cask damages, for example, during the 9 m drop prescribed by IAEA regulations. BAM, who is in charge of the mechanical safety assessment of packages for dangerous goods, faced relevant shortcoming of these analyses especially with regard to the impact limiter models. Subsequently a joint research had been carried out together with industry partner that aims to enhance numerical methods for the simulation of polyurethane foam, spruce and damping concrete. An essential component of the 4-year-project, that has just recently been completed, was a three-part experimental program.
In the first phase approximately 1000 cubic samples with 10 cm edge length had been compressed to up to 70% using different constant loading speeds, temperatures, directions and confinement conditions. Following, a more realistic test set up was established by means of a guided drop test facility, where the cubic specimens had been subjected to weights dropped from different heights. As a result, strain rate and temperature dependent flow curves could be generated for all materials investigated considering likewise specimen direction and density if applicable. Typical relations are given in Figure 1. In the last phase, penetration tests with medium and large scale damping concrete specimens have been performed allowing to better understand and to quantify the damage behaviour. The guided drop test facility were used for the first configuration, while the real scale 22 Mg cask was subjected to 5 m of free fall onto a foundation plate of 0.5m height and 2.4 m edge length (Figure 2).
Based on these tests, standard material models with and without damage mechanisms were implemented in commercial finite element codes. Especially for wood a new user material had been developed since no existing formulation met all requirements. While experimental as well as numerical results have already been presented and published separately for foam,

spruce and concrete (e.g. [1], [2] and [3]), this paper is intended to highlight the overall strategy and the fundamental, material-independent methods. Thus, it discusses the principal approach concerning model selection, adaption and optimization and the resulting constant adjustments to the experimental and numerical program. Details are given about the treatment of raw data and its transfer into conservative and representative curves, the scope of different parameter identification procedures as well as about laboratory and computational studies that investigated interfering factors like friction, the deformability of the test facility and geometrical or physical deviations of the specimens.

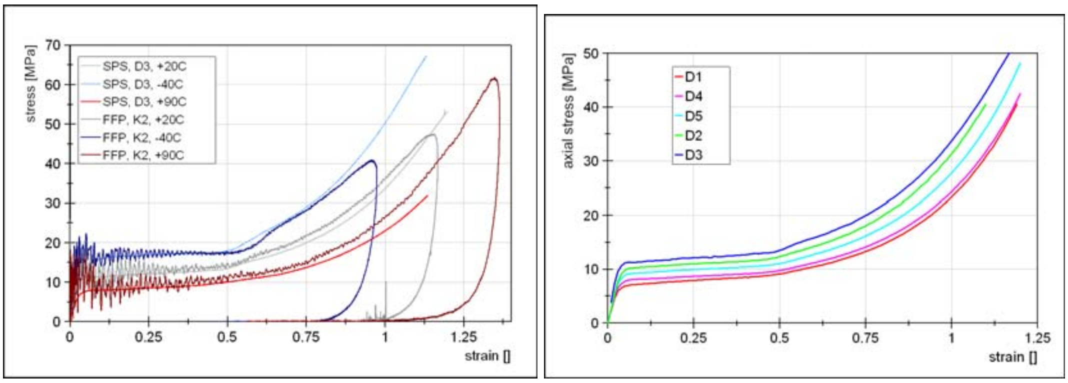

Fig. 1: Results of polyurethane foam FR3718: Influence of temperature (-40°C to +90°C) and test facility (left) and of loading speed ranging from 0.02m/s [D1] to 3m/s [D3] (right)

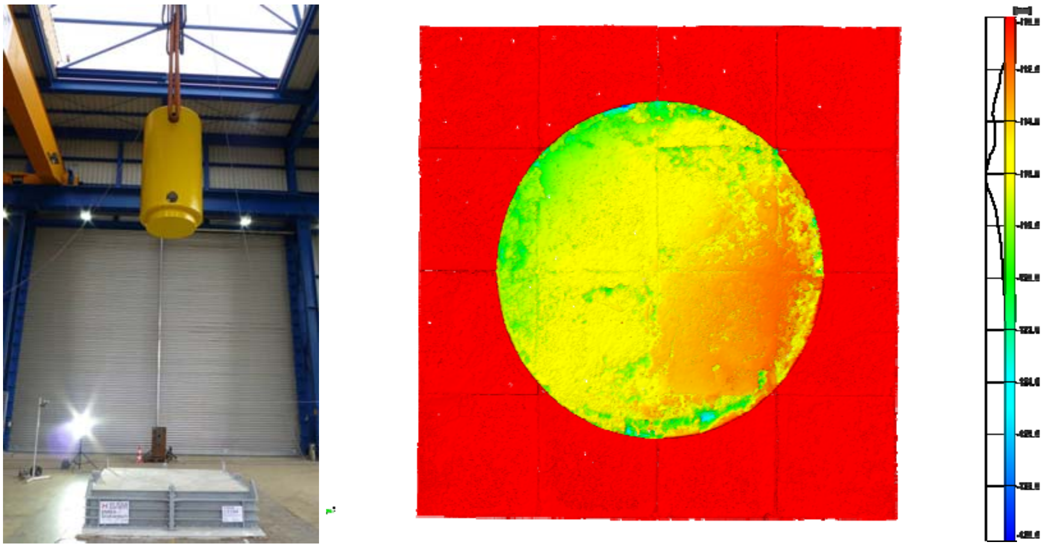

Fig. 2: Test configuration of large scale drop test (left) and 3D measurement of the resulting imprint in the cocndrete foundation (right)

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