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EXAMPLE AND VALIDATION

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Abstract. In the present contribution numerical analyses were performed to predict the collapse of buildings subjected to blast loading. Several possibilities to describe the damaged areas which arise during the collapse are investigated and a validation by comparison of the numerical results and video sequences of real collapse events is accomplished. These investigations are performed within the research unit FOR 500 "Computer aided destruction of complex structures using controlled explosives" funded by the Deutsche Forschungsgemeinschaft (German Research Foundation).

Keywords: collapse analysis, finite element method, explicit time integration, large scale computations

Introduction

The major goals of the Research unit FOR500 is to increase the reliability and efficiency of computational models of complex reinforced concrete buildings subjected to blast loads. For this purpose a special simulation concept is developed that subdivides the analysis of the collapse mechanism into several problem specific analyses. Based on the interaction between these forecasts a reliable prediction shall be achieved. This concept considers the dominant physical and mechanical problems appearing by a demolition and the subsequent collapse mechanism.

In this context large scale numerical analyses of building collapse were performed using the commercial transient dynamic finite element program LS-DYNA [LSTC]. A main goal of these investigations is to support the development of rigid body models [Breidt et al., 2006]. In combination with characteristic resistance curves [Höhler et al., 2006] at the hinges and uncertainty analysis methods [Möller et al. 2004, Liebscher et al., 2006] the developed rigid body models shall then serve as a tool to predict the building collapse, including various uncertainties as of the material and of the geometrical descriptions.

Numerical analyses of building collapse

ANALYSE SOFTWARE

In this analysis the LS-DYNA [LSTC] program was used. This software allows a highly non linear analysis and offers fast contact searching algorithms, which are needed for this kind of collapse simulation. Another important topic is the availability of a parallelized version, so the computation of the partially very huge models can be distributed to several processors and results can be achieved in an acceptable time.

ANALYZED STRUCTURE

The analyzed building - chosen as reference construction - is a real building part of a leather manufacture in Weida (Free State of Thuringia/Germany), a seven stores reinforced concrete structure which was removed

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by blast demolition in 1998. The real demolition was surveyed and documented by a German engineering company [Melzer, Thüringer Sprenggesellschaft]. The video movie of the building collapse generates the base of the validation.

NUMERICAL ANALYSES

The analyzed building was discretized completely with finite elements and computed with the above mentioned software. The current discretization leads to a model with about 150.000 nodes and 80.000 solid elements. The delayed stages of blasting were simulated by removing the specific parts of the columns which were destroyed through the explosion at the corresponding times. The resultant kinematics led to the collapse of the building where local damages were simulated by specific criteria for element erosion (e.g. main stresses, normal- and shear strains). Contact was considered between the parts of the building as well as between building and ground plate which led to a considerable amount of CPU time used for the contact algorithm, especially at the end of process simulated up to 4 seconds. These FE simulations – different parameter studies regarding i.e. erosion parameters were performed – were computed on the HP-XC6000 cluster of the University of Karlsruhe. The focus of the analysis is on the detection of local zones of damaging as well as on the detection of parts with rigid-body-like behavior during the collapse.

PARAMETRIC STUDIES

Very important for the behavior of the structure during the collapse process are those parts, where hinges appear at a specific amount of deformation. To simulate the development of such plastic hinges, it is necessary to establish criteria for element erosion, which means an element is deleted during the simulation when one specific criterion is reached for this element. Element erosion serves here as a simulation feature to model the large deformation behavior allowing to eliminate elements leading to very small time steps. In this case failure criteria like principle stresses, normal- and shear strains are tested and the effect of different values for these failure parameters are compared. First only a simple criterion for failure is selected and the corresponding value is modified, leading to lower and upper bounds for realistic simulation results. For example overly large values for strain erosion may leads to large deformations, which are not possible for concrete structures.

However, as different parts of the structure varying loads are acting, i.e. high pressures at parts falling on the ground plate, or high tension at parts with large moments. Because of this diversity of loading in such a complex structure it is necessary to combine different criteria to achieve a realistic behavior for different kinds of local damage zones. While using such combinations, such elements are deleted, in which one of the given erosion criteria is reached.

A first validation of the results can be made visually, by checking the complete collapse procedure and the local zones with high erosion. A realistic, 'concrete-like' element erosion in these zones, leads rather quickly to a realistic simulation of the complete model.

Validation

A comparison of the kinematics which show up at the beginning of the collapse and of the behavior at the local zones was performed. The simulations are compared with video sequences which were provided by the engineering company, observing the blasting [Melzer]. The pespective and the visual angle in the model are chosen to allow a fairly clear comparison of simulation and reality.

Conclusions

The above mentioned simulations show acceptable visual agreement with the real world behavior of the presented example. The results also allow to some extend to find simple rules how to generally generate rigid body models for building collapse analysis or to modify a rigid body model combined with resistant characteristic curves on the hinges to obtain a realistic collapse behavior.

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