Progressive collapse analysis of composite column under fire and blast extreme loadings

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ABSTRACT

The present work investigate the behavior of the concrete filled composite tubular column under the simultaneous fire and blast loadings. The column dimensions and the magnitude of compressive force are parameterized in order to check the influence of different designs of composite column to the extreme load conditions. The fire load is described herein using the appropriate fire model and the blast load is modeled to be equivalent to the proper explosive charge placed in the distance (again parameterized) from the column.

Many authors focus their attention on the influence of fire to the concrete filled tubular columns under the fire actions. Generally the great contribution to this topic give today Manuel L. Romero, Ana Espins, Antonio Hospitaler (see e.g. [1] [2] [3]) and Hua Yang, Lin-Hai Han (see e.g. [4] [5]). However there is still lack of a direct knowledge about the behavior of the composite concrete-filled steel tubular column under the blast load. It is well known that the composite columns have many advantages with respect to reinforced concrete or steel column, as high bearing capacity or good fire resistance. Therefore it seem to be reasonable to use concrete-filled steel tubular sections in structures which might be subjected to both thermal and blast loads.

The column, in concept, is a part of the multi-storey building which might be exposed to the blast load. One can imagine the compartment in such a building where e.g. the hazardous materials are storage. Today there exist a number of expensive and massive solutions to avoid the propagation of blast wave and fire. One feature connect them all. They are introduced into the structure because of lack of knowledge about the behavior of the classical structural elements in case of such accidental loads. Exploring this field of interests can contribute to the safety of structure and simultaneously decrease the cost of design and production.

Fire and explosion simulations require to use advanced computational tools and numerical models in order to bring them closer to reality. In order to take into account the thermal effect as well as rate dependent stress-strain relation in the material, a special class of the constitutive models need to be employed, namely thermo-elasto-visco-plastic models both for concrete and steel. In this contribution authors present the solution of coupled thermal and displacement analysis of the structure subjected to extreme loads. All numerical investigations are performed in the commercial software Abaqus 6.10 [7]. The explosion is simulated using CONWEP [6] which provides a realistic approximation of the blast wave acting on the structure. The definition of the blast is given just by setting the spatial coordinates of the point where the explosion initiate, and the equivalent mass of TNT. The grow of the temperature generated by explosion is simulated as an external temperature acting on the column surface with an amplitude varying in time. In coupled thermal-displacement analysis, the temperature creates the thermal component of strains and cause a degradation of the material parameters such an Young modulus or/and yield stress.

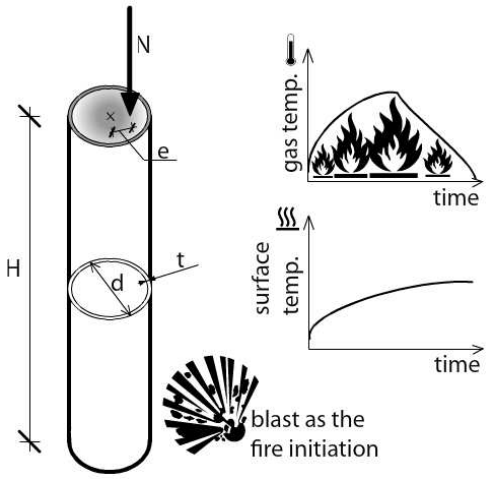

Figure 1: Scheme of the survey process

The thermal effects added to the high speed deformations in the structure, the complicated interface behaviour between concrete and steel, radiation and heat flux, and progressive damage, summed up with a very difficult boundary value problem to be solved. In our contribution we present not only the proper numerical simulations of composite column under described load condition but also we propose the methods of increasing the safety of such structures by appropriate design and efficient protection techniques.

References

[1] Manuel L. Romero, V. Moliner, A. Espinos, C. Ibaez, A. Hospitaler: Fire behavior of axially loaded slender high strength concrete-filled tubular columns. Journal of Constructional Steel Research, Volume 67, Issue 12, December 2011, Pages 1953-1965.

[2] Ana Espinos, Manuel L. Romero, Antonio Hospitaler: Advanced model for predicting the fire response of concrete filled tubular columns. Journal of Constructional Steel Research, Volume 66, Issues 8-9, August-September 2010, Pages 1030-1046.

[3] Ana Espinos, Leroy Gardner, Manuel L. Romero, Antonio Hospitaler: Fire behaviour of concrete filled elliptical steel columns. Thin-Walled Structures, Volume 49, Issue 2, February 2011, Pages 239-255.

[4] Hua Yang, Lin-Hai Han, Yong-Chang Wang: Effects of heating and loading histories on post-fire cooling behaviour of concrete-filled steel tubular columns. Journal of Constructional Steel Research, Volume 64, Issue 5, May 2008, Pages 556-570.

[5] Lin-Hai Han, You-Fu Yang, Hua Yang, Jing-si Huo: Residual strength of concrete-filled RHS columns after exposure to the ISO-834 standard fire. Thin-Walled Structures, Volume 40, Issue 12, December 2002, Pages 991-1012.

[6] U.S. Department of the Army, Structures to Resist the Effects of Accidental Explosions, Technical Manual 5-1300, Nov.1990.

[7] H.D. Hibbitt, B.I. Karlsson, P. Sorensen, Abaqus Users Manual, ABAQUS/EXPLICIT 6.10.