SUMMARY

Influence of material and construction solutions on the ductility of axially compressed columns

The first part of this thesis describes the problem of structural resistance to accidental actions and reviews implicit methods of incorporating ductility of structures at the design stage. Measures of horizontal and vertical ductility, used in the literature to assess the deformability of structural elements, were characterized and the state of the art in vertical ductility of composite CFST columns was presented.

The following chapters provide original analyses of the dynamic stability of axially compressed columns on the basis of their equilibrium paths. In light of different material properties of steel and concrete, which affect the post-peak behavior of columns made thereof, two methods of design transformation of equilibrium paths were proposed. The importance of the vertical ductility of columns was discussed in the context of their stability under accidental loads. Based on the concept of ultimate bearing capacity of columns in the accidental design situation, a novel vertical ductility measure of axially compressed columns was proposed.

Examples of dynamic analysis of structures subjected to seismic and accidental loads were presented. An idealized three-parameter mathematical model of a viscoelastic ideally plastic oscillator with one degree of freedom was employed to illustrate how the required vertical ductility of columns arising from an explosion blast wave or a vertical seismic action could be calculated. Moreover, a bi-linear approximation of the vertical equilibrium path was used to formulate simple guidelines for the verification of column stability, including its vertical ductility.

A series of experiments was carried out on axially compressed reinforced concrete, steel and composite columns. In total, 21 composite, 5 steel and 12 reinforced concrete elements were tested. A comparative analysis of the vertical ductility of tested specimens was conducted. The variable parameters were: structural solution - steel elements made of rectangular cross-section, composite CFST and reinforced concrete, column's slenderness, wall thickness, concrete strength and class of the structural steel. The experimentally obtained equilibrium paths, failure modes and strains of steel jackets, aquired using digital image correlation method, were analyzed for comparative purposes. The test results allowed for the validation of the advanced numerical model developed in Abaqus/Explicit software and utilized for numerous parametric analyses. In order to further identify the post-critical behavior of steel and composite columns, the validated numerical models were used to simulate a vehicle crashing into a building column. An analytical model of a rigid-plastic column enabling calculation of equilibrium paths of axially compressed slender tubular steel columns was also presented.

The conducted analyses showed that the key feature influencing the ductility of axially compressed columns is their ability to dissipate the energy of imposed loads. The larger the volume of a material in the element that may permanently deform (in the case of steel) or crush (in the case of concrete) and consequently dissipate the energy, the greater this ability. Both steel and composite columns are able to carry loads in the post critical state. Due to the confinement of a concrete core by a steel jacket and, most importantly, the limitation of local buckling of the steel cross-section by the concrete core, composite columns show greater ductility than their steel counterparts. The ductility of axially compressed reinforced concrete columns is low compared to steel or composite columns of comparable load bearing capacities.

Keywords: ductility, equilibrium paths of columns, steel – concrete composite columns, CFST, accidental loads, seismic loads, overloading.