Progressive Collapse Analysis of Composite Framed Buildings with Encased in Concrete Steel Beams

Simo PELTONEN
Civil Engineer
R&D Director
Peikko Group Corporation
Lahti, Finland
simo.peltonen@peikko.com

Aristidis ILIOPOULOS
Dr.-Ing., Civil Engineer
Seismics and Prog. Collapse
Peikko Group Corporation
Athens, Greece
aristidis.iliopoulos@peikko.com

Panagiotis KIRIAKOPOULOS
Civil Engineer
PhD Candidate
Laboratory of Earthquake Eng.
National Technical University of
Athens, Greece
pkiriakopoulos@teemail.gr

Summary

Encased in concrete steel beams of trapezoidal shape (Deltabeams) are associated with high values of stiffness, strength and ductility. They can be considered as an appropriate solution for class 2b and 3 buildings according to EN 1991-1-7 with demanding robustness requirements. In this paper the dynamic response of a 30-storey steel-concrete composite building with Deltabeams after a sudden column loss is investigated through the implementation of non linear dynamic analysis (alternate path method). It is found that the catenary actions are highly depended from the type of connections and govern the design. They are also considerably higher than the required tying resistance provided by EN 199-1-7. Finally, unexpected failure modes which may endanger the stability of high-risk buildings are discussed and suggestions on the improvement of EN 1991-1-7 are proposed. This paper offers information from a research project on progressive collapse which is conducted by the R&D department of Peikko Group Corporation.

Keywords: Progressive collapse, Deltabeams, alternate path method, non-linear analysis, catenary actions, debris impact, EN 1993-1-1-7

1. Introduction

Progressive Collapse of a structure is defined as the failure sequence which is initiated from a local incident, such as the loss of a structural member that leads to a failure of excessive magnitude; large scale collapse. There are many reasons that may cause progressive collapse of a structure for example a gas explosion, a terrorist attack, collision forces or even a serious construction defect. In 1968 the gas explosion in the kitchen of the 18th floor of a 22-story precast building in UK caused the collapse of a large part of the building and the death of three persons. Till that date it was believed that 'hidden over-strengths' which are not taken into account during design are adequate enough to protect the buildings from disastrous domino effects. After 1968 progressive collapse became an issue and many design codes integrated simplified guidelines for avoiding such terrible incidents. The terrorist attack against the twin towers in 2001 was lethal enough to attract the attention of the engineering society and to make clear that a more sophisticated design especially for the case of high-risk buildings is necessary.

From the previous it can be easily understood that modern buildings should be robust against extreme and unforeseeable loadings. Robustness is associated with many structural characteristics the main of which are redundancy, ductility, stiffness and strength. Redundancy is needed so that internal forces can be redistributed to adjacent structural elements through an alternative load-path. Redistribution of forces requires ductile elements and above all ductile connections. But ductility is activated through large deflections that may lead to additional internal forces and P-Δ effects; thus additional stiffness is needed. Finally, normal forces, shear forces and bending moments during a collapse situation act simultaneously on cross-sections and connections causing an unexpected strength degradation; adequate strength is also necessary.

The design of a robust structure against the threat of progressive collapse is not an easy task. The simplified tying method given in EN 1991-1-7 is for high-rise buildings inappropriate and leads to unsafe results. Elastic analysis is supported by the majority of the commercial softwares but is not realistic since progressive collapse propagates in a non-linear dynamic way. Unavoidably a non-linear dynamic analysis should be employed; alternate path method. Such an analysis is conducted

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