ESSENTIAL FEATURES OF ROBUSTNESS DESIGN OF MULTI-STOREY STEEL FRAMED BUILDINGS

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KEYWORDS: collapse control, robustness, progressive collapse, steel frame, extreme loading

ABSTRACT

Buildings should have enough robustness to avoid progressive collapse due to localized failures in case of extreme events, e.g. those which are outside of the design envelope: *abnormal/accidental loads (fire,* explosion, impact, collision, and combination of them, e.g. fire after explosion), design/construction errors, occupant misuse. However, in what concerns standards available in Europe, design for robustness is rather generic and does not deal for example with types of constructions. As a result, extensive research in the field of structural robustness has been undertaken over the past few years [1], [2], [3].
In the present study, we investigated the essential features of robustness and the application of the Collapse Control Design concept for evaluating the capacity of multi-storey steel frame structures to resist the progressive collapse following the loss of a column. The case study building has a three-bay, four-span, and six-story steel structure, see Fig. 1. Structure was calculated for the effect of gravity loads and lateral loads (wind and seismic actions), using the Eurocodes. The structure with pure steel beams is *denoted as S* and the composite beams structure is *denoted as C*. Structure with full strength and full rigid joints is *type I* and structure with partial strength and semirigid joints is *type II*. Five different column loss scenarios were considered: a) corner column (A1), b) edge column (A3), c) internal column (B2), d) corner and penultimate column (A12), and e) two consecutive edge columns (A23). The capacity for supporting additional gravity loads for a specific column loss scenario was expressed using the so called “robustness” index, Ω, calculated as the ratio of the failure load to the nominal gravity load. The progressive collapse of the structures was investigated using ELS [4] by means of the alternate path method AP [5].

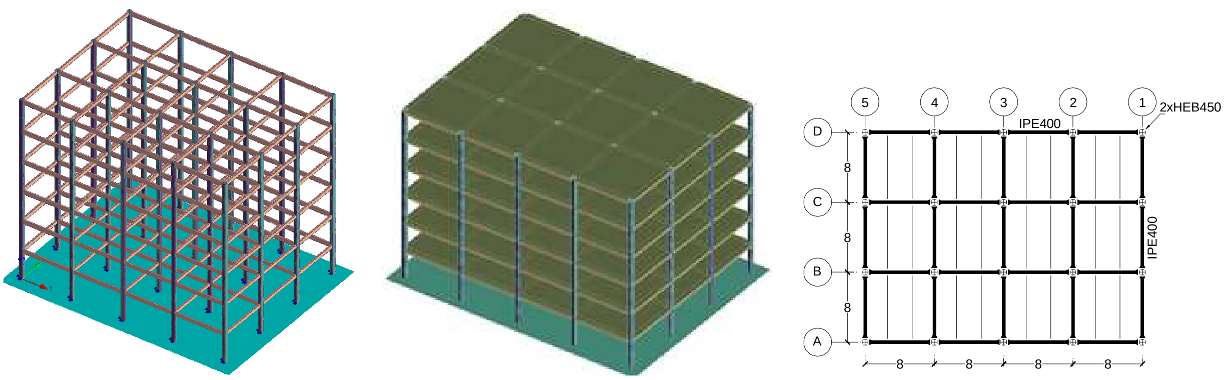
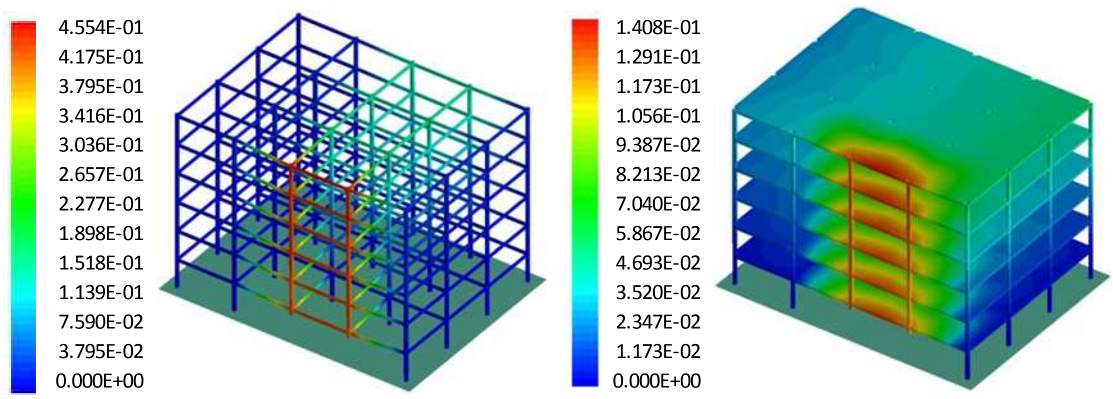


Fig. 1. a) General view of the model; b) plan layout

Fig. 2 shows the deformed shapes after 1.0 s for scenario A23. To identify the critical components of the resistance to progressive collapse, the gravity loads were gradually scaled up until collapse was attained. Table *1*1 summarizes the values of the robustness index, Ω. The minimum degree of robustness was obtained in case of S-II-B2, where Ω = 1.05. For the same scenario, the structure S-I-B2 showed an improved robustness, and Ω index increased to 1.2. The effect of the composite action is more effective for internal spans, where the catenary action in the beams is accompanied by the development of membrane action in the concrete floor.



a) b)

Fig. 2 Deformed shape after 1.0s for scenario A23: a) Structure S-II; b) Structure C-II (displacements are in meters)

Table 1. Values of robustness index, Ω

Scenario	Ω	Scenario	Ω	Scenario	Ω	Scenario	Ω
S-I-A1	2.3	S-II-A1	2.05	C-I-A1	2.83	C-II-A1	2.66
S-I-A3	1.8	S-II-A3	1.6	C-I-A3	2.83	C-II-A3	2.75
S-I-B2	1.2	S-II-B2	1.05	C-I-B2	2.91	C-II-B2	2.58
S-I-A12	1.2	S-II-A12	1.1	C-I-A12	1.60	C-II-A12	1.58
S-I-A23	1.15	S-II-A23	1.15	C-I-A23	1.94	C-II-A23	1.91

CONCLUSIONS

The numerical results showed the seismic design leads to robust structure and a good selection of structural system, materials and detailing may help the structure to avoid collapse in the event of an extreme load event. Strong connections and also the use of composite floor beams reduce the risk of collapse in case of a column loss. For validation of numerical models, a large test program on connection components, joints and assemblies is in progress. The results of the study will allow the development of a Collapse Control Based Design procedure for a more economical and safer design of structure to resist extreme load events.

ACKNOWLEDGMENT

Partial funding for this research was provided by the UEFISCDI, Romania, under grant PN II PCCA 55/2012 “Structural conception and COllapse control performance based DEsign of multistory structures under aCcidental actions” CODEC (2012-2016).

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