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Post-Earthquake Fire Performance of Tall Special Steel Concentrically Braced Frames

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1. Introduction

Despite the post-earthquake fire potential as a source of extensive damage on construction structures, that is not considered a loading case in current seismic design approaches. Hitherto limited researches have been done on the global response of steel moment resisting frames under post-earthquake fire but the response of concentrically braced frames under fire loading has not been studied yet.

In this paper, in order to provide an insight into the effects of post-earthquake fire in steel structures, using finite element simulation, the behavior of the special steel concentrically braced frames exposed to this loading is examined. Simulation of the structure under earthquake load was performed using nonlinear time histories analysis. By placing the post-earthquake structure as the initial condition, the mechanical-thermal analysis was carried out by applying the temperature-time diagram on exposed elements. This analysis provides a realistic representation of the expected seismic and fire demands.

2. Numerical simulation

Simulating post-earthquake fire scenarios requires the use of multi-stage and sequential analysis. In this study, this analysis consists of the following separate analysis steps performed by the numerical finite element models, developed using the commercial software ABAQUS. In order to model material behavior, an elastic-perfectly plastic material model was used for the steel. The variation of strength and stiffness and other steel specifications with variation of temperature was modeled in accordance with the Eurocode.

FEMA P695 was used to perform nonlinear time-history dynamic analysis to simulate the effects of earthquake on structur. Five records were used in the analyses according to the informations of FEMA P695. Moreover, temperature–time diagrams were used to simulate fire load in the numerical analyses. The EC parametric fire diagram, shown in Figure 1, was used in this study. The temperature of the exposed steel elements was considered to be based on the assumption of uniform temperature distribution across the section.

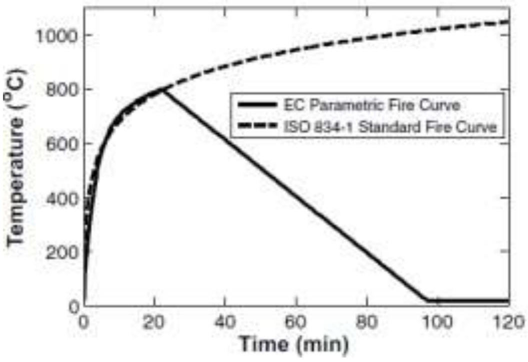

Figure 1. EC parametric fire diagram

Different scenarios are implemented in this study as it is not possible to determine where the fire occurs. The assumed scenarios are fire occurrence on the (a) ground-floor, (b) fourth-floor and (c) eight-floor. The considering frame was unprotected, and fire applied to the through of elements exposed to fire under the assumption that fireproofing lacked or fireproofing spalled during the seismic events. Moreover, for comparison, three fire scenarios were applied directly to the structure without a previous earthquake.

3. Numerical analysis

In this study, one case of designed steel braced frame in NIST was selected to evaluate the performance of tall braced frames exposed to the fire. This prototype was designed to study their response to an event which may cause progressive collapse. The building is designed for moderate Seismic Design Category, which results in SCBFs as defined in the AISC Seismic Provisions. The plan views of the buildings are shown in Figure 2.

The prototype building was idealized using two-dimensional plane frame models. The gravity loads are divided into two parts. First, the gravity loads associated with the braced frame are applied as distributed vertical forces along the beams at each story level. Second, the gravity loads associated with the interior gravity frames per tributary area are applied as concentrated loads to the

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leaning columns at the corresponding story levels. The representation of the gravity frames with the leaning columns is needed to account for the P-Δ effects.

The structural performance of the frames under earthquake is evaluated acording to ASCE 41-06. The structural performance level of the steel braced frame subjected to records introduced corresponded to CP.

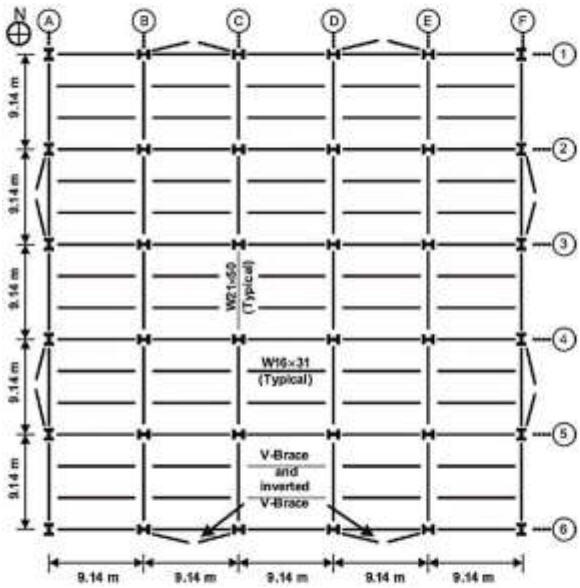

Figure 2. Plan layout for braced frame systems

The fire resistance of the structure to post-earthquake fire (pef) and direct fire (df) based on different scenario were persente. The fire resistance is defined as a time at which the displacements, either globally or locally, go beyond the chosen thresholds. The thresholds were identified by curve of displacements versus time merging towards the vertical asymptote by a 1% error.

To investigate the braces behavior, the history of the internal axial forces developed in some heated braces for a scenario under df load and pef load are extracted. Moreover, the buckling load as well as the tensile capacity of the braces are calculated according to AISC 340 05 and illustrated in the diagrams.

4. Summary and conclusion

The following conclusion can be drawn from the analyses:

1. By comparing the results of post-earthquake fire resistance under different records, it can be seen that, there is no significant difference in their post-earthquake fire resistance and the time of structural fir resistance under post earthquake fire, regardless of the record characteristi.
2. Examination of internal forces of the braces in the event of a post-earthquake fire show that their internal forces have exceeded their tensile and compressive capacities due to the earthquake, and the braces have deformed. Moreover, a comparative investigation between the resistance of the braces under high heat and the overall fire-resistance of the structure shows that the fire resistance time of the structure is proportional to the tensile failure time of the heated braces at the end of the heated fire phase.
3. By examining the resistance time of structures under post-earthquake fire and the resistance time of structures under only fire load in different fire scenarios it was observed that this time at lower levels is much less than higher levels, because with increasing gravity load at lower levels, the effect of P-Δ was intensified. As a result, the post-earthquake fire scenario in the lower floors can have the potential for the risk of early structural damage.