

WP 27: Advancements in experimental and numerical study of braced steel frames subjected to fire after earthquake

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Keywords

Fire following earthquake, earthquake engineering, fire engineering, concentrically braced steel frames, large-scale tests, pseudo-dynamic testing, sub-structuring.

Figures

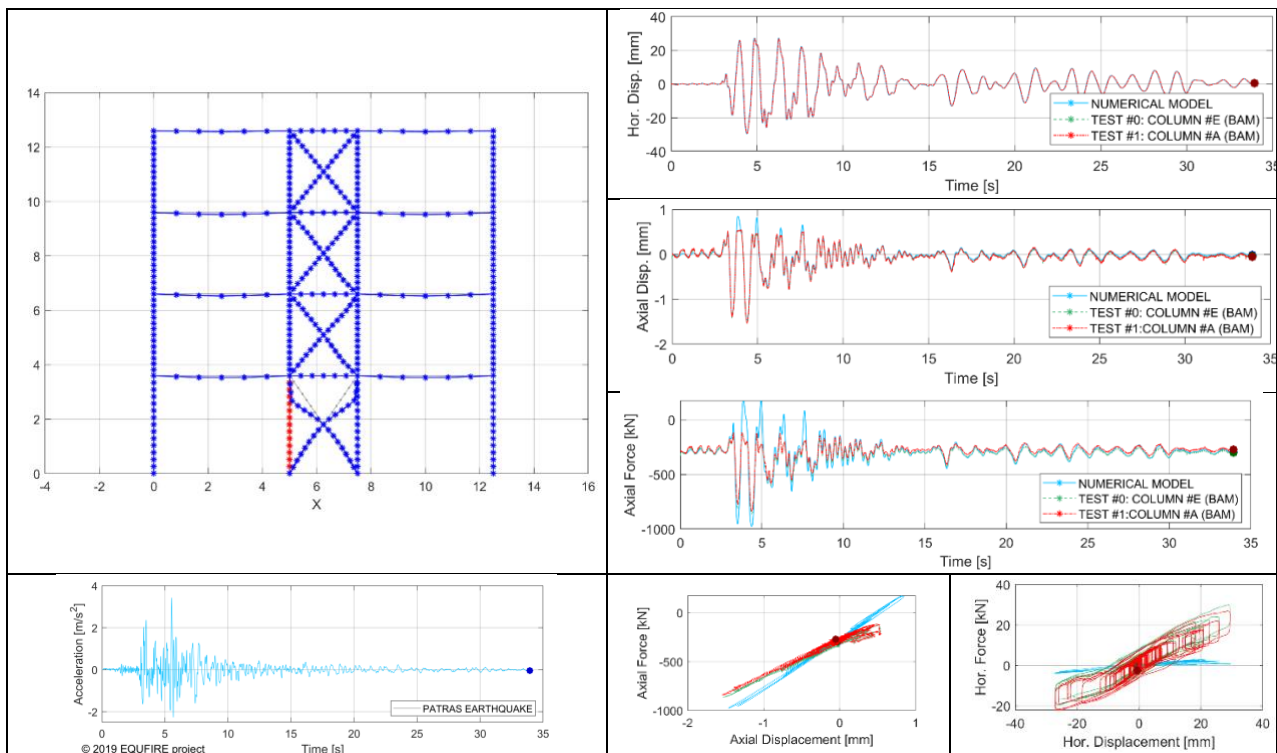


Figure 1a Test #0 and #1. Comparison between results obtained after the seismic hybrid test on column without fire protection and the numerical model before the calibration (Positive axial force is tension and negative axial force is compression).

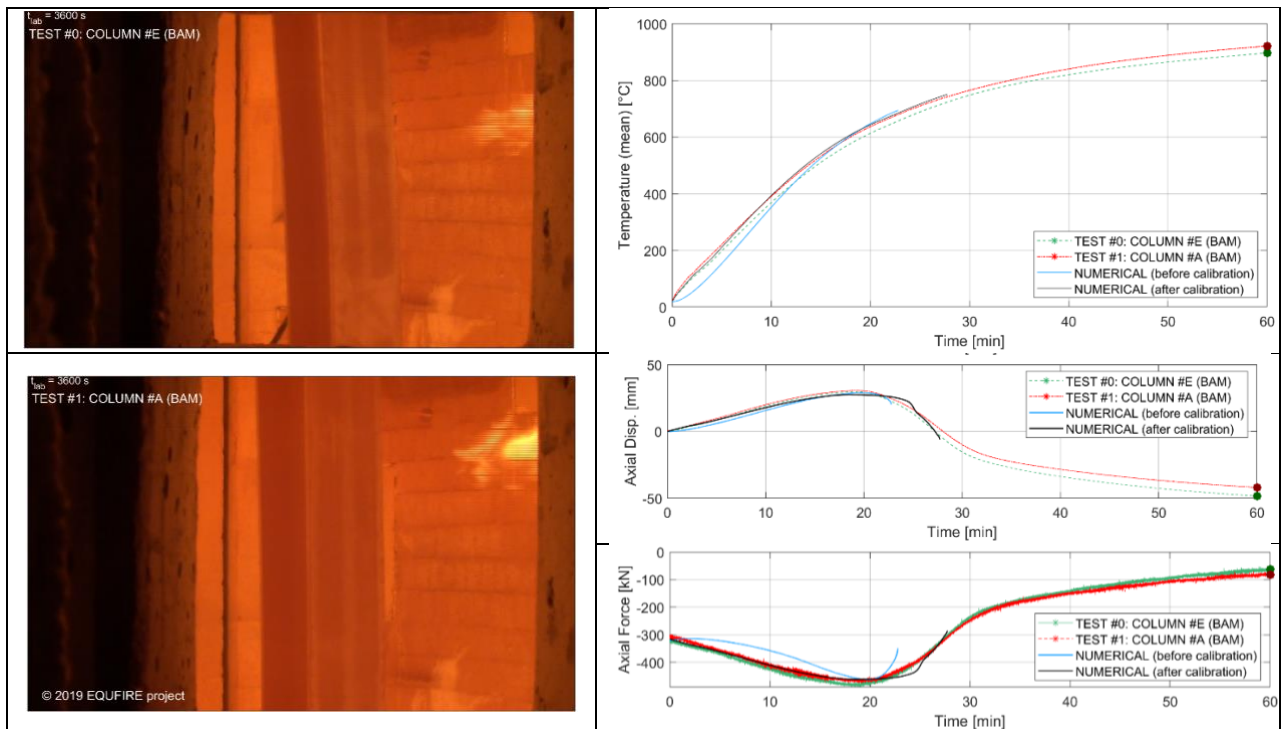


Figure 1b Test #0 and #1. comparison between results obtained from hybrid FFE tests on column without fire protection and the numerical model before and after the calibration. (Positive axial force is tension and negative axial force is compression).

Main Results

The EQUFIRE project aims to study the post-earthquake fire performance of steel frame structures and is part of the Transnational Access activities of the SERA project at the ELSA Reaction Wall of the Joint Research Centre. A four-storey three-bay steel frame with concentric bracing in the central bay illustrated in Fig. 1a was selected as a case study.

The internal column at the ground floor of the braced frame was substructured at the BAM (Federal Institute for Materials Research and Testing / Bundesanstalt für Materialforschung und -prüfung) facilities, while the rest of the structure was numerically simulated. Five fire following an earthquake (FFE) tests were conducted at BAM in October and November 2019:

- Test #0 Column E: “without fire protection system”
- Test #1 Column A: “without fire protection system”
- Test #2 Column B: “fire protection system, PROMATECT-H, seismic installation”
- Test #3 Column C: “fire protection system, PROMATECT-H, normal installation”
- Test #4 Column D: “seismic-resistant sprayed vermiculite-type fire protection”

The mechanical loading of the columns was achieved by six servo-hydraulic control loops representing two rotation degrees of freedom perpendicular to each other for bending at the upper and lower bearing as well as one channel for bottom axial and one for top horizontal loading.

The comparison between the numerical model and the hybrid test demonstrated good agreement between the partitioned solutions under seismic and fire conditions. There is a little difference in negative vertical displacement, due to the fact that tension (negative) axial force was not allowed during the test as illustrated in Fig 1a. That’s because the axial actuator of the furnace is not designed to give tension axial forces to the specimen but only compression axial forces (By way of explanation, the axial actuator of the facility can “push” the specimen but cannot “pull” it).

The test data were used to calibrate the numerical model and they will also serve for the next tests at the ELSA Reaction Wall (JRC). The comparison between experimental and numerical data before and after calibration is presented in Fig. 1b. The calibration process consisted of modelling the base joint based on its actual initial stiffness and of applying the recorded steel temperature evolution in the columns.

Meanwhile, other three FFE tests were carried out with the same specimen proprieties but with different type of fire protections.

The tests with the protected column showed some cracks on the fire protection due to the combination of seismic and fire conditions. However, those cracks are not large enough to compromise fire resistance. In this respect, more damage to the bracing system is expected during the tests at ELSA - JRC. The experimental activities at the ELSA Reaction Wall comprise pseudo-dynamic tests on a full-scale specimen of the first storey of the building, while the upper three storeys will be numerically simulated. The tests will be held at the beginning of 2020.

List of Publications

Abbiati, G., Covi, P., Tondini, N., Bursi, O.S. & Stojadinovic, B. "A Finite Element Tearing and Interconnecting-Based Algorithm for Hybrid Fire Testing" - COUPLED 2019: VIII International Conference on Coupled Problems in Science and Engineering, Sitges (Barcellona), 3-5 June 2019

Abbiati G., Covi, P., Tondini, N., Bursi, O.S & Stojadinović, B. "Real-Time Hybrid Fire Simulation Based on Dynamic Relaxation", Journal of Engineering Mechanics, 2019 (Paper under review)

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