ENAC / PROJET DE MASTER 2018-2019
SECTION DE GÉNIE CIVIL

Seismic Retrofit of Existing Steel Concentrically Braced Frames with Intentional Eccentricity Braces

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1. Objectives

Evaluate the seismic-resisting performances of an existing Concentrically Braced Frame (CBF) by comparing three different retrofit solutions.
Two recently developed high-performance steel braces with intentional eccentricity are compared to a commonly retrofit solution using Conventionally Buckling Braces (CBBs).

2. Intentional Eccentricity Braces Model Validation

It exists two different types of intentional eccentricity braces: Braces with Intentional Eccentricity (BIE) and Naturally Buckling Braces (NBBs). Due to the initial eccentricity, these braces are able to:

- Develop high post-yielding stiffness to prevent soft-story mechanism
- Distribute stress and strain along the brace to avoid or delay local buckling
- Reduce elastic stiffness in order to attract less energy input from ground motion.
- Provide ultimate strength similar to CBBs.

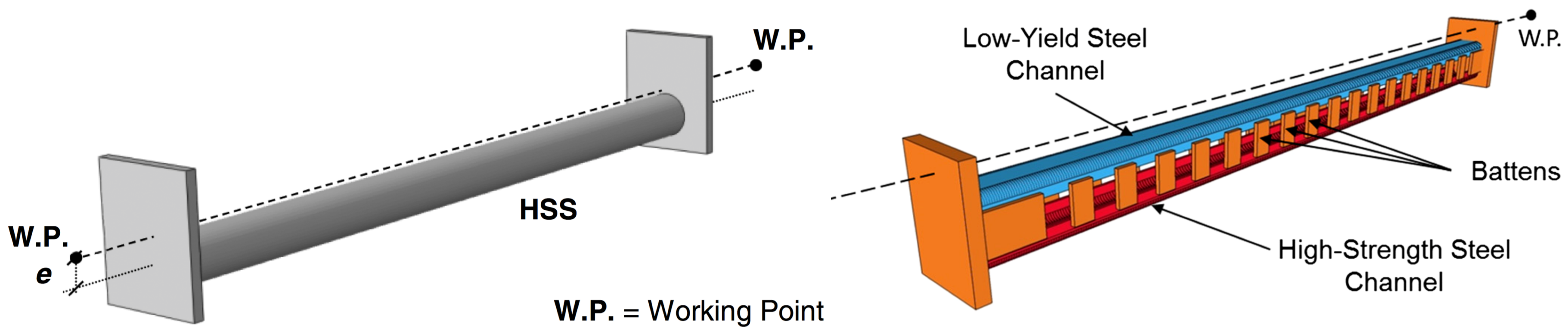

Fig 1. Braces with initial intentional eccentricity: BIE (left), NBB (right) – Figures from Skalomenos (2017) and Hsiao (2015)

Both braces are implemented in the computer software *OpenSEES*; to validate the models, numerical simulations are compared to experimental test results carried out in previous works by Skalomenos (2017) for BIE and by Hsiao (2015) for NBBs.

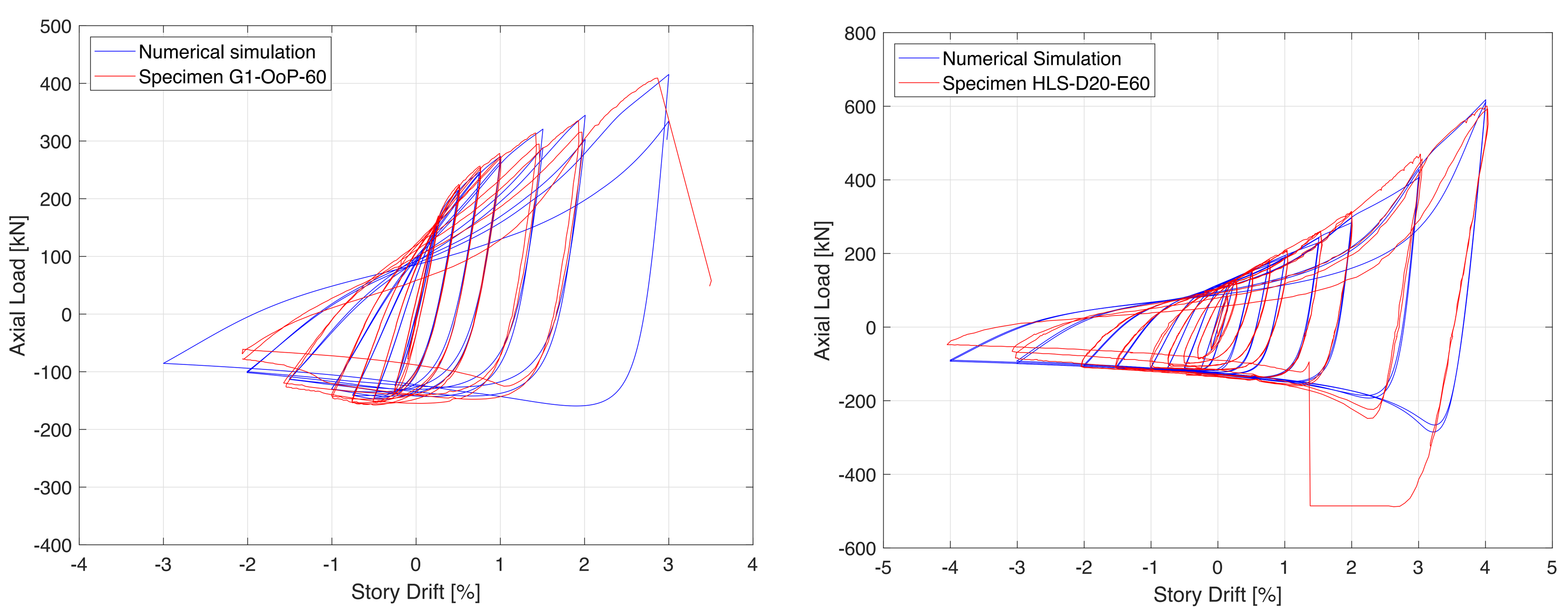

Fig 2. Hysteresis response comparison between test and analysis results: left BIE specimen; right NBB specimen

3. Target Building Overview

The EPFL Civil Engineering (GC) building is considered as case study. Its CBFs do not comply with modern seismic design requirements. Its most critical CBF is pinpointed and retrofitted. The N-S direction 3-story height V-brace CBF located in buildings C&D is selected.

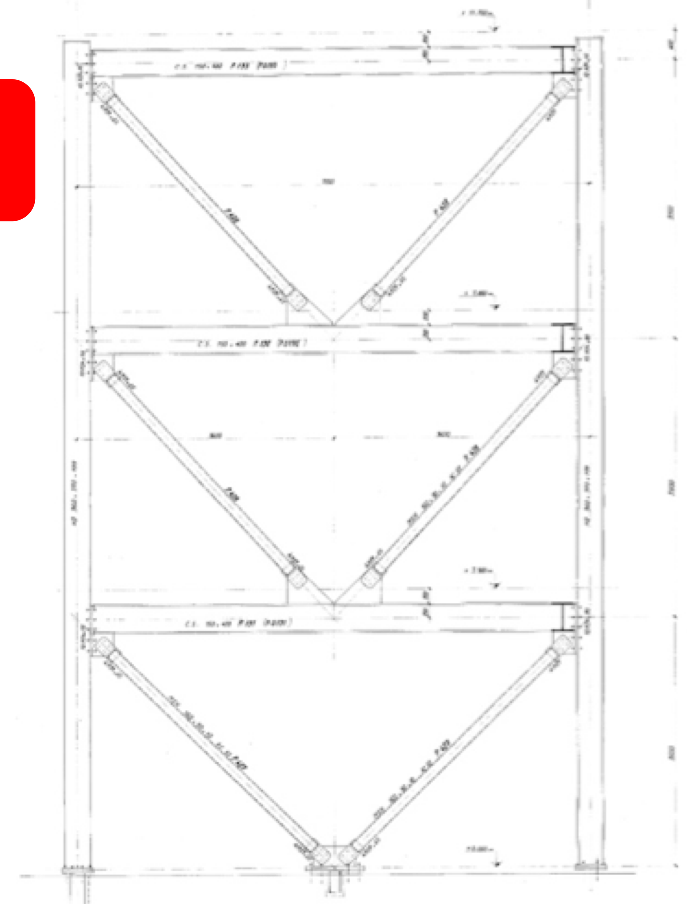

Fig 3. Critical CBF of the GC building

4. Modeling Approach

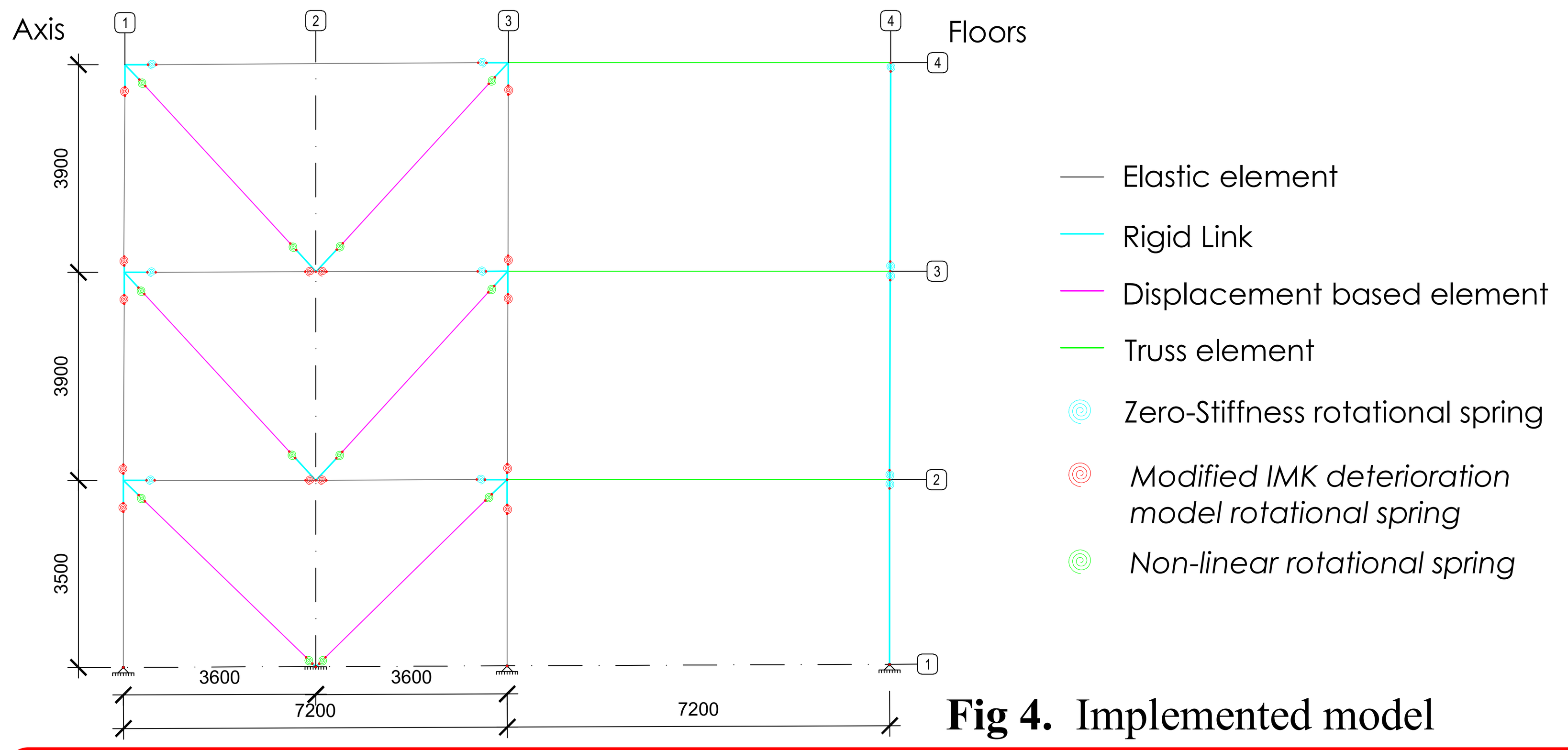

Fig 4. Implemented model

5. Retrofit Design Procedure

- **Retrofit solution using CBBs**: based on guidelines provided in EC-3 and EC-8. Since the work is focused on innovative braced systems, seismic requirements of a new building are considered for the retrofit.
- **Retrofit solutions using BIE & NBBs**: a new design procedure is established. An equivalent brace stiffness is considered: $K_{eq} = P_{in} / d_u$. The same cross-section as CBBs is applied, while the initial eccentricity is defined considering the interstory drift sensitivity coefficient limit $\theta \leq 0.2$

6. Numerical Simulation

From the non-linear response history analysis it is observed that:

- peak and residual interstory drift ratios are almost identical
- peak absolute floor acceleration (PFA) is significantly reduced
- failure probability of non-structural elements is greatly reduced

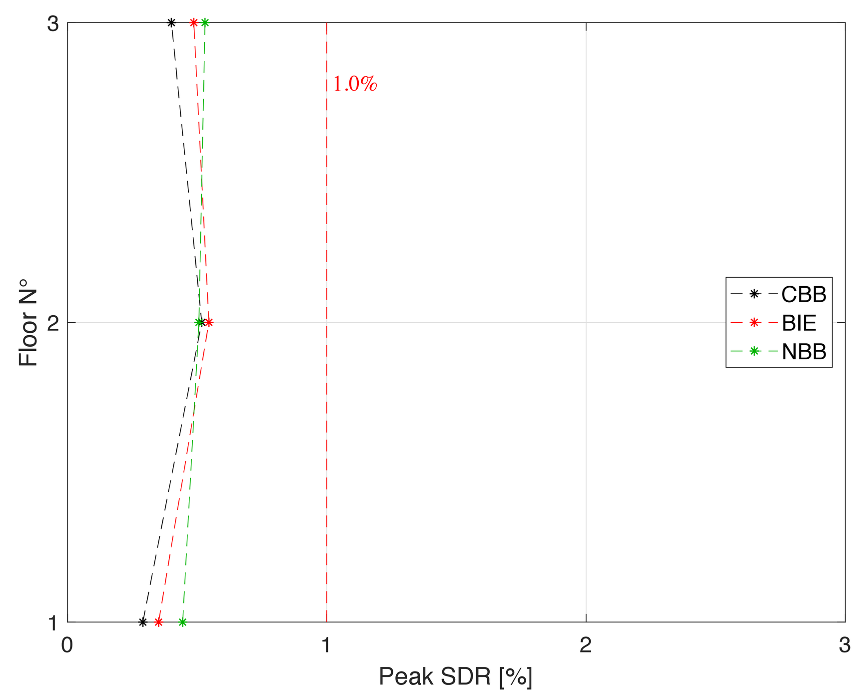

Fig 5. Peak SDR distribution

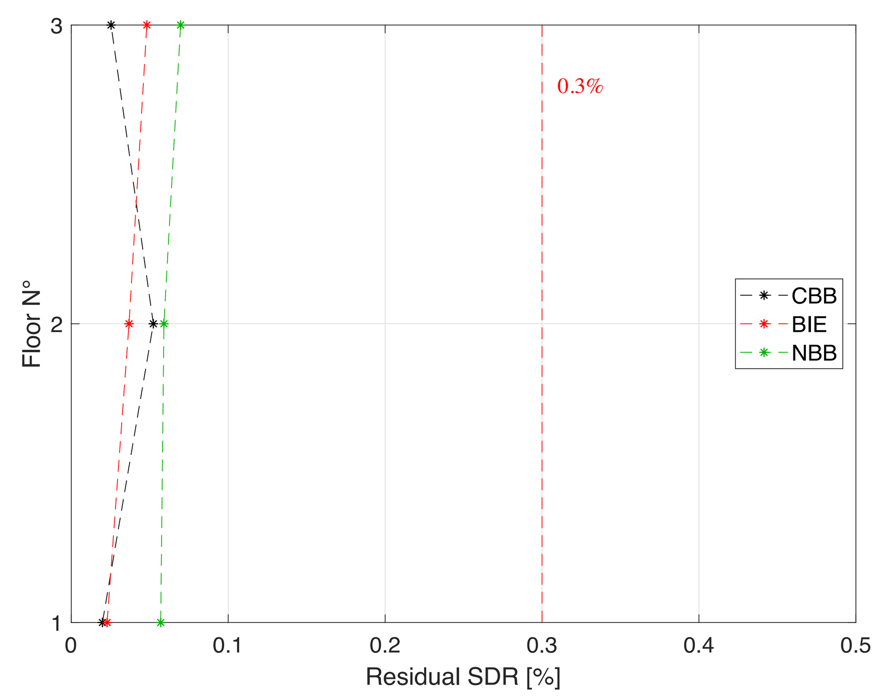

Fig 6. Residual SDR distribution

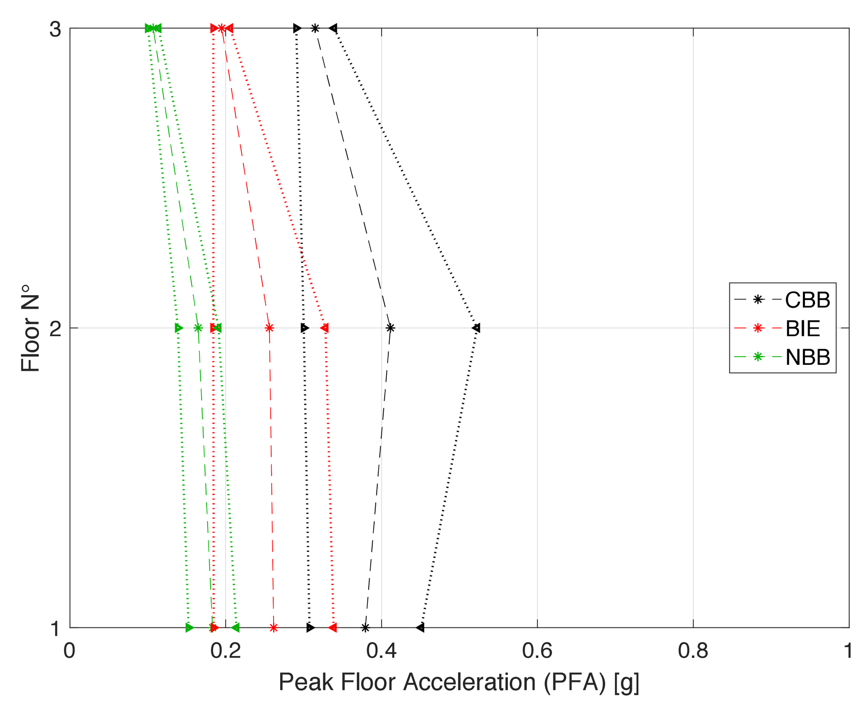

Fig 7. Peak absolute floor acceleration

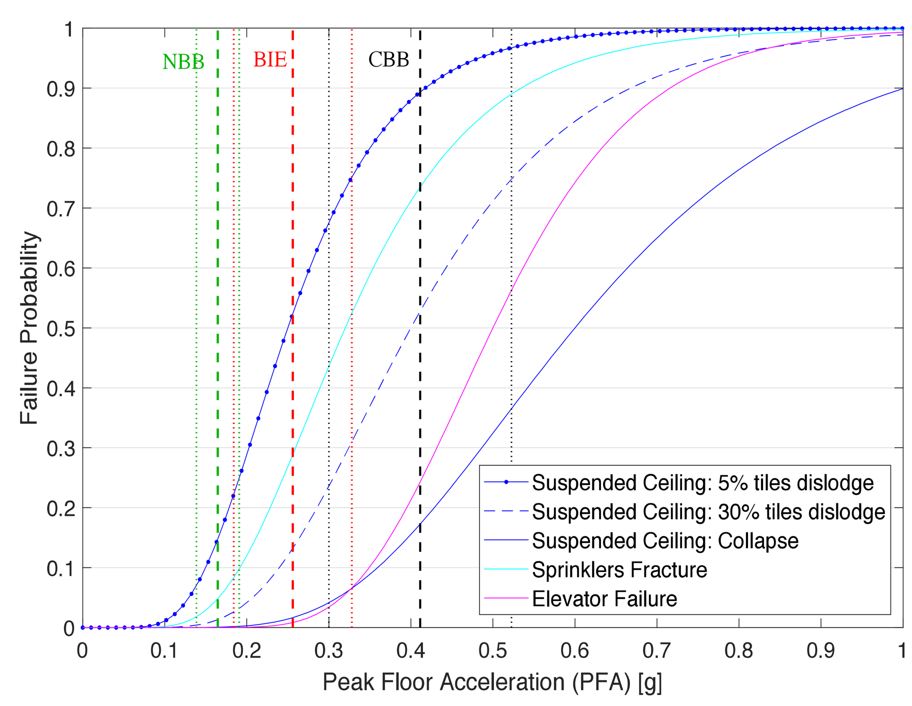

Fig 8. Non-structural components fragility curve

7. Results and Conclusions

This study showed that BIE and NBBs can be successfully implemented and designed in realistic configurations. They appear to be a suitable alternative to CBBs for high-performance steel bracing system.