# Finite Element Simulation of Different Failure Modes for Buckling-Restrained Braces Under Cyclic Loading

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**Key words:** buckling-restrained brace, failure mode, cyclic loading, finite element analysis.

**Summary.** *Conventional concentric braces buckle under compressive loading. To overcome this limitation, the Buckling-Restrained Braces (BRBs) were introduced in the mid 70's. They typically consist of a low-yield steel core and a restraining mechanism. In order to achieve enhanced understanding of the BRB inelastic behavior and failure mechanisms, comprehensive experimental efforts are typically needed. When such experimental programs are unfeasible or impractical, other investigative means are valuable. The presented paper explores the most common BRB failure modes observed through detailed nonlinear Finite Element Analysis (FEA). The FEA is carried out using the commercial software ABAQUS taking into consideration both material and geometric nonlinearities. The FE model is maliciously verified against experimental tests reported by the University of California at San Diego [1] and good correlation is observed. The verified FE model is further utilized to simulate different failure scenarios for BRBs under cyclic loading. The considered failure models are: (a) Buckling of steel core flange outside the encasement [Fig.1], (b) Necking of the steel core under tensile loading [Fig.2], (c) Damage under reversed loading after necking [Fig.3], and (d) Encasement failure causing global buckling. The observed failure modes suggest that the stabilizing collar is an essential part of the BRB system. BRBs without collars need significant stiffening of the steel core ends. Furthermore, necking triggers significant internal damage to the BRB causing failure of the entire brace under subsequent compressive load cycles. In such cases, the concrete seizes to provide the needed confinement due to the severe sustained damage. This problem is particularly dominant in short BRBs with high-grade steel cores.*

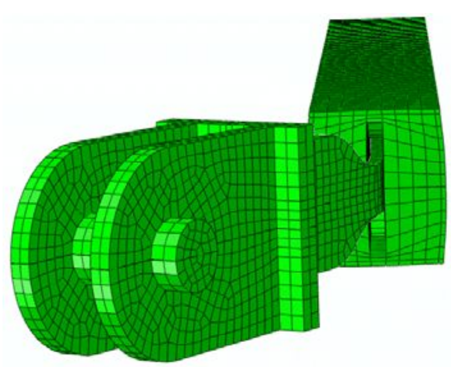

**Figure 1: Buckled core outside encasement**

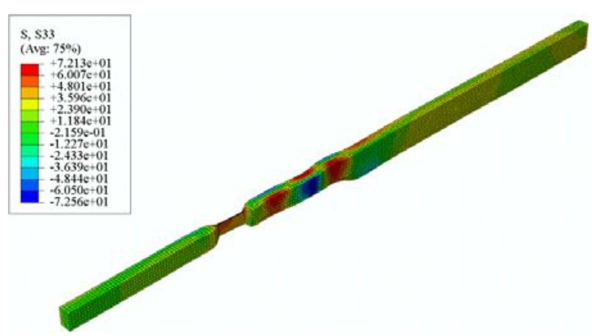


**Figure 2: Von Misses stresses at necking**

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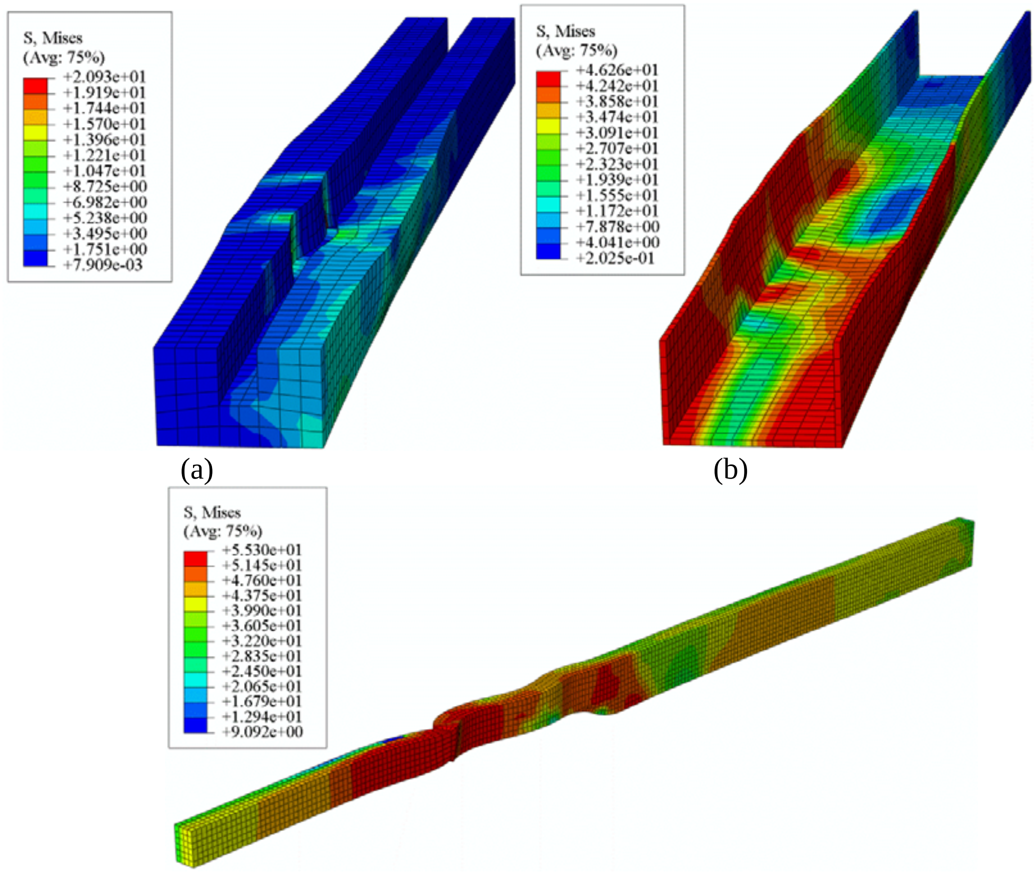


(c)

**Figure 4: Von Misses stresses at load reversal after necking (a) concrete (b) HSS (c) steel core**

## REFERENCES

[1] S. Merritt, C. M. Uang and G. Benzoni, "Subassemblage testing of star seismic buckling-restrained braces. Report TR-2003/04," Structural Systems Research Projects, Department of Structural Engineering, University of California, San Diego, California, 2003.