Title: INERD – Two INnovations for Earthquake Resistant Design
Fund: Research Fund for Coal and Steel (Contract number 7210-PR-316)
Partners: Université de Liege (Univ-Liege), Instituto Superior Tecnico "IST" (Lisbon), National Technical University of Athens (NTUA), Politecnico di Milano (Politec Milano), Profilarbed (PROFILARBED), Universita Degli Studi di Trento (UNIV TRENTO).
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Summary

The project develops research work about two innovations. The first innovation consists in promoting one specific construction measure by which the so called "soft storey" mechanism is obviated in the lower storeys of reinforced concrete (R.C.) frames by encasing steel profiles in the R.C. columns in order to provide them with a basic reliable shear, bending and compression resistance. Tests are performed and comparison of the behaviour of reference reinforced concrete specimens and innovative composite specimens are made. Several parameters are studied, like axial load, length of anchorage, stiffeners in the panel zone, weak and strong axis bending, configurations with and without infills. The study results in the definition of practical rules for the design of steel profiles to be encased in ductile R.C. columns, tentative formulas for the behaviour of local strut and tie mechanism in case of configurations with infills and formulas for the calculation of the shear resistance of a composite beam-to-column panel zone in case of configurations without infills.

The second innovation consists in using connections of diagonals of frames with concentric bracing as dissipative elements. Two selected types of dissipative connections are studied: the so-called pin connections, made of bent rounded or rectangular stocky bars, and the so-called U-device connection, made of flexible U bent plates. The behaviour of both connections has been experimentally, analytically and numerically studied on individual connection specimens and on frame specimens. Fatigue curves have been obtained for the connections. Practical design rules have been defined for frames containing the INERD connections, especially for the pin connection. Case studies of realistic buildings are presented.

Publications

Journals:

International conferences:
Description of the INERD pin connection

The INERD pin connections are used in frames with concentric braces to connect the braces with the adjacent members. The pin connections are dissipative and partial-strength compared to the brace, so that energy can be dissipated within the connections, while the braces and other members of the frame are protected from buckling and yielding. The INERD pin consists of two external plates which are connected to the column or beam, and one or two internal plates which are connected to brace. A pin, which can have a rectangular, rounded or circular cross section, passes through all the plates via appropriate-sized holes.
**Experimental investigations**

Tests of the INERD project that were related to the pin connections:

1. **Tests on individual connections (IST Lisbon)**
   - 20 specimens
   - Monotonic loading (4), cyclic loading according to ECCS (4) and constant amplitude cyclic loading (12)

2. **Tests on full-scale frames (Politecnico di Milano)**
   - 8 specimens
   - Cyclic loading according to ECCS (4) and cyclic loading from a seismic event (4)
Numerical and analytical investigations

- Processing of experimental results
- Analytical investigation and development of a simplified analytical model (Fig. 1)
- Development and calibration of FE models based on experimental results (Fig. 2, 3)
- Extensive parametric analysis with FE models (Fig. 4)
- Development of detailed analytical model and a design guide for practical applications (Fig. 5)
- Nonlinear static and incremental dynamic analyses of 2D frames (Fig. 6, 7). Investigation of global behaviour and residual drifts. Comparison between CBF and frames with INERD pin connections. Evaluation of behaviour factor for seismic design.

![Simplified analytical model](image1)

**Fig. 1: Simplified analytical model**

![Finite Element Model](image2)

**Fig. 2: Finite Element Model**

![Calibration between tests and FEA results](image3)

**Fig. 3: Calibration between tests and FEA results**

![Indicative results from parametric FEA](image4)

**Fig. 4: Indicative results from parametric FEA**

![Design guide](image5)

**Fig. 5: Design guide**

![Views of 2D frames under investigation](image6)

**Fig. 6: Views of 2D frames under investigation**

![Base shear, total and interstorey drifts for increasing PGA (6-storey frame with INERD pins)](image7)

**Fig. 7: Base shear, total and interstorey drifts for increasing PGA (6-storey frame with INERD pins)**