“Plastotough”

Title: **Plastotough – Modern Plastic Design for Steel Structures**
Fund: Research Fund for Coal and Steel (RFSR-CT-2005-00039)
Partners: National Technical University of Athens (NTUA), Aachen University (RWTH), Peiner Träger GmbH, Germany (PTG), materials and Metallurgical Research Ltd., Ostrava, Czech Republic (Vitkovice)
Coordinator: Professor I. Vayas (NTUA)
Research group: Karlos V., Spiliopoulos A.
Duration: 01/07/05 - 31/12/08
Budget: 710.769,00 €

Summary

The research project was focused on analytical methods that would allow the prediction of the time and the place of crack initiation in steel structures under both static and cyclic loading. The steel structures laboratory of the NTUA was responsible for the numerical analyses of steel welded beam-to-column joints in moment resisting frames under cyclic loading. The relevant experiments took place at the University of Aachen. The applied loading history was derived through analyzing the response of structures with different geometries under various earthquake accelerograms. A manual was compiled that contains proposals on ways to choose a material of proper quality for structural details that may suffer from premature cracking.

Publications

Journals:

1. Karlos V., Vayas I., “Ultra-Kurzzeitermüdung geschweisster Träger-Stützen Knotenverbindungen aus Stahl”, Bauingenieur, Springer VDI Verlag, Berlin, Band 87, p.130-136, 2012.
2. V. Karlos , M. Feldmann, B. Eichler, D. Schäfer, G. Sedlacek, I. Vayas, and A. Spiliopoulos (2011) “Toughness requirements for plastic design with structural steel”, Steel Construction, Volume 4, Issue 2, pp. 94-113, 2011.
3. V. Karlos, M. Feldmann, B. Eichler, D. Schäfer, L. Amlung, B. Hoffmeister, M. Lippe, Z. Kubon, I. Vayas, A. Spiliopoulos, “Modern Plastic Design for Steel Structures“, JRC Scientific and Technical Reports, EUR 24227 EN, ISBN: 978-92-79-14601-5, 2010.

Conferences:

1. Karlos V., Vayas I., “Crack Initiation at Steel Welded Connections” European Conference on Steel Structures "EUROSTEEL 2011", Budapest, Hungary, 31 August-2 September, 2011.
2. V. Karlos , M. Feldmann, D. Schaefer, B. Eichler, A. Spiliopoulos, I. Vayas, “An Upper Shelf Criterion for the Choice of Steel based on Damage Mechanics”, 33rd IABSE Symposium, Bangkok, Thailand, 9-11 September, 2009.
3. V. Karlos , A. Spiliopoulos, I. Vayas, “Prediction of Crack Formation at Steel Welded Beam-to-Column Joints under Cyclic Loading” STESSA 2009, Behaviour of Steel Structures in Seismic Areas, Philadelphia, 16-20 August, 2009.
4. V. Karlos , A. Spiliopoulos, I. Vayas, “Prediction of ductile/brittle failure of steel joints”, European Conference on Steel Structures "EUROSTEEL 2008", Graz, Austria, 3–5 September, 2008
5. A. Spiliopoulos, V. Karlos, I. Vayas, “Inelastic deformation requirements for steel buildings”, European Conference on Steel Structures "EUROSTEEL 2008", Graz, Austria, 3–5 September, 2008.
6. V. Karlos, I. Vayas, “ Crack initiation prediction of welded joints under seismic loading ” 7th National

Conference of Steel Structures, Volos, Greece, 29–30 September, 2011.
7. V. Karlos, A. Spiliopoulos, I. Vayas, “Ductile/brittle failure at welded beam-to-column joints under seismic loading ” 3o National Conference on Earthquake Engineering and Engineering Seismology, Athens, Greece, 5–7 November, 2008.
8. A. Spiliopoulos, V. Karlos, I. Vayas, “Deformation requirements of steel structures in seismic regions” 3o National Conference on Earthquake Engineering and Engineering Seismology, Athens, Greece, 5–7 November, 2008.

Description of the research project PLASTOTOUGH

Level 1: Analysis on overall frames

It was conducted an investigation of the non-linear structural response of 8 building configurations (Moment Resisting Frames or Centrically Braced Frames) for 10 seismic records by means of incremental dynamic analysis (IDA). From the analyses the deformation requirements in terms of plastic hinge rotation histories were derived and served as the input for the large scale tests and the numerical investigations that followed.

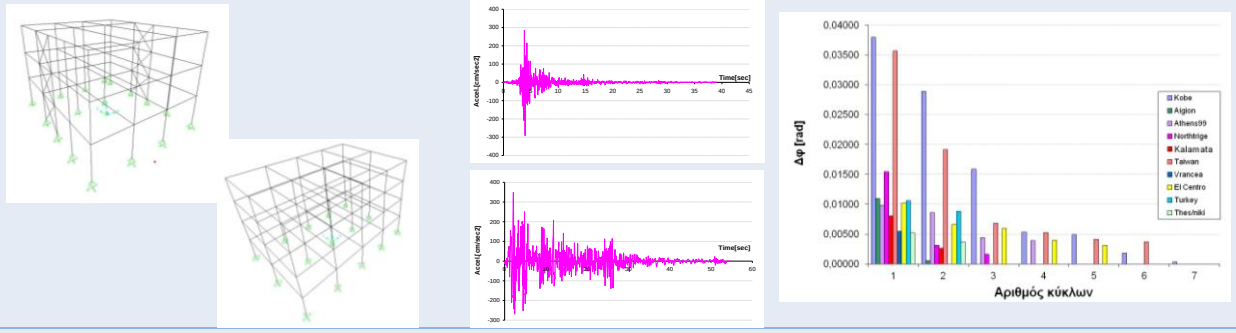

Fig.1 Description of analyses in typical building configurations

Experimental investigations

Level 2a: Large scale experiments

The aim of these experiments is to study the deformation and the fracture behavior of structural details under static and cyclic loading. The specimens that were tested were wide steel plates under monotonic tension and welded beam-to-column joints. The specimens did not had any pre-existing flaws or notches to resemble the presence of cracks.

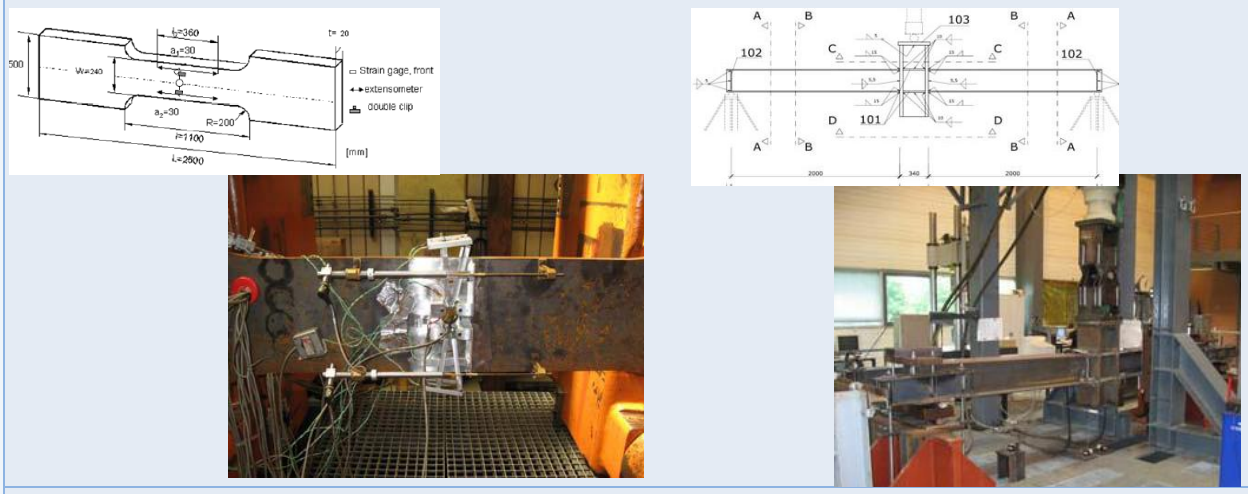

Fig.2 Specimens from large scale tests

Level 2b: Small scale experiments

The aim of these experiments is the determination of the steel characteristics. In detail, the basic material characteristics were defined by means of chemical and microstructural analysis. The mechanical properties were calculated by using the Charpy test and the hardening parameters under monotonic and cyclic loading conditions were determined with tensile tests. Additionally, the material strength in terms of crack initiation was studied by using fracture and damage mechanics tools.

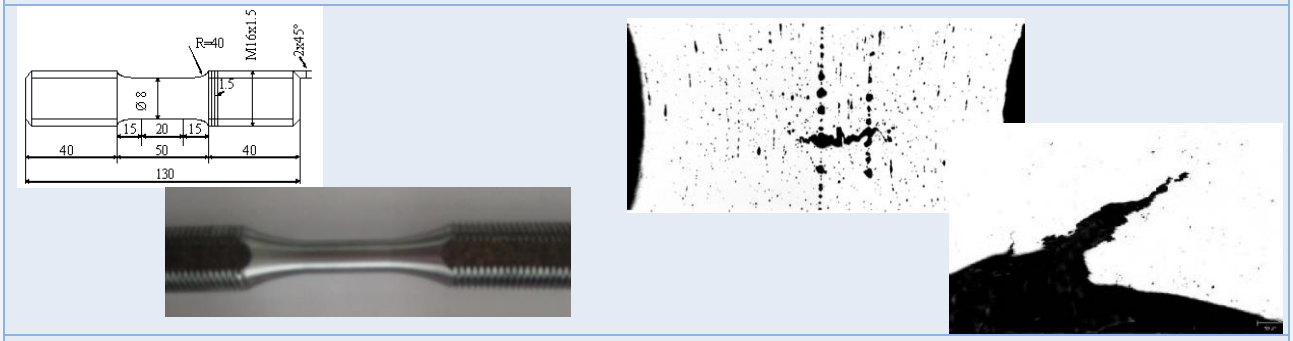

Fig.3 Small scale experiments and crack initiation in specimens

Numerical investigations

Level 3a: Small scale numerical investigations

The aim of these analyses is to study the material's progressive damage because of the mechanisms of void nucleation and coalescence. Different material models based on the concepts of damage mechanics were studied and eventually the damage curves were chosen mainly because of their simplicity and relatively easy construction. The damage curves provide a quantitative relationship between the material plastic strains and stress triaxiality at the moment of crack initiation.

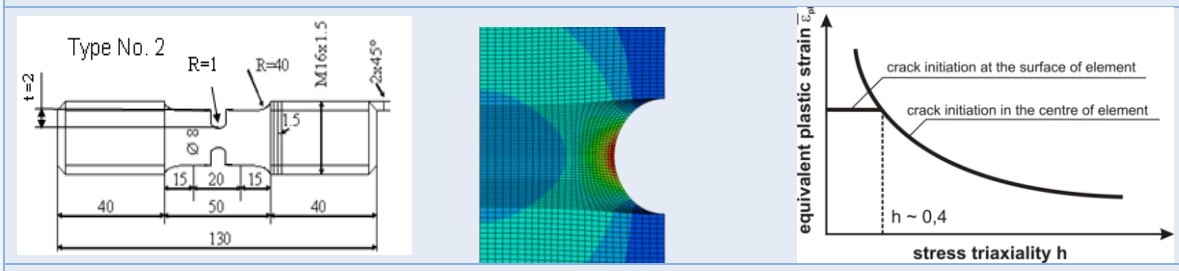

Fig.4 Numerical investigations for small scale experiments

Level 3b: Large scale numerical investigations

The current analyses aim at numerically calculating the time and place of crack initiation at the experimentally tested welded beam-to-column specimens and the steel wide plates. For the case of cyclic loading, the damage accumulation was calculated through the use of the effective damage concept. The results showed that there is a good agreement between the experimental and the numerical investigations.

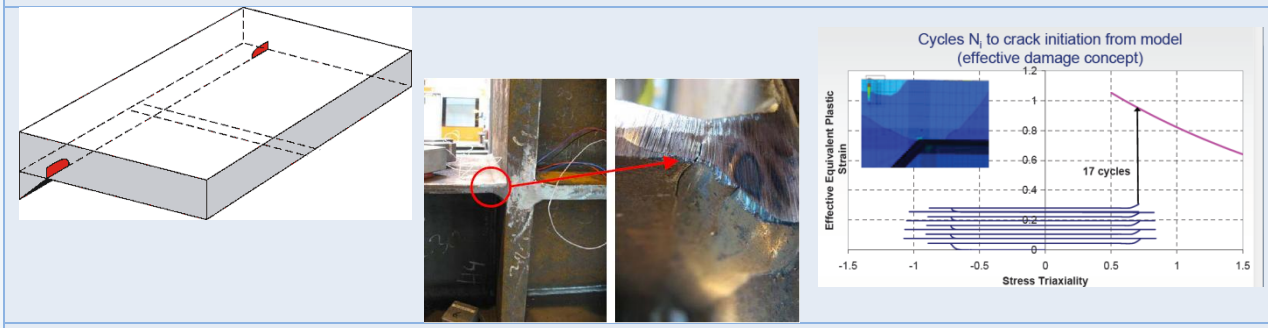

Fig.5 Numerical investigations for large scale experiments

Analyses of results

Level 4: Results post-processing

Within this level, the results from the abovementioned procedure are presented in a way that will make them more usable in modern design practice. In detail, proper diagrams were constructed that relate the applied loading to the number of cycles under which a structural detail of a certain material is expected to crack. The damage accumulation follows a linear rule and the resulting diagrams are similar to the fatigue S-N curves included in EN1993-1-9.

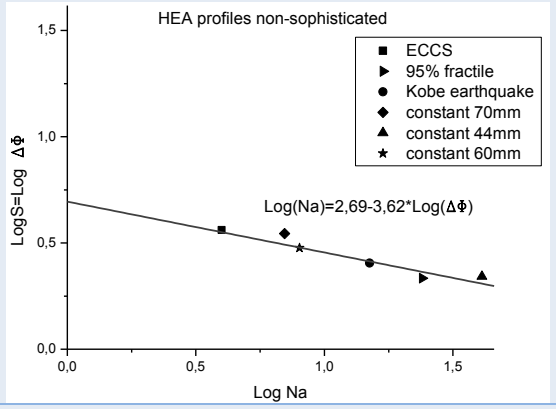

Fig.6 Calculation of S-N curves for the project specimens

Application examples

Level 5: Structural detail applications

The current analyses aim at expanding the current methodology for structural details that are commonly used in design practice and to evaluate their fracture strength. The influence of the weld access hole geometry and the presence of backing bars in moment resisting frame beam-to-column connections was assessed. Alternative geometries were proposed that make the structural detail less susceptible to ductile crack initiation.

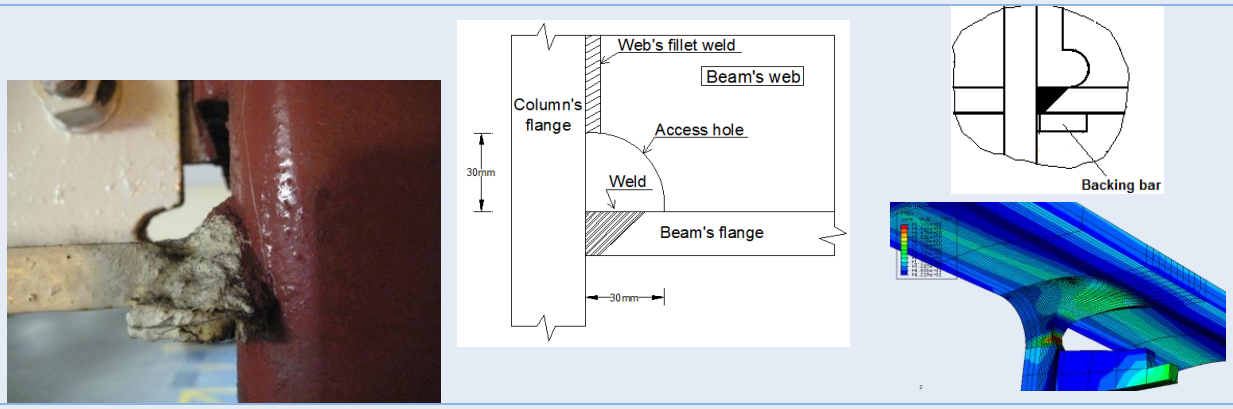

Fig.7 Application of the current methodology for various structural details