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DESIGN METHOD STEEL AND COMPOSITE JOINTS OF BUILDINGS

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Abstract: *This paper forms an integrated in order to predict the hysteretic moment-rotation curve and determine the cyclic which can be used in the seismic design. In the first step the design method of EC3 and EC4 is studied. The standard design model has significant uncertainty, which underestimates the moment resistance, overestimates the initial stiffness and in certain cases the design failure mode does not follow the experimental one. An improvement of the EC3 resistance and stiffness model is proposed. An improvement of the EC3 resistance and stiffness model of the joints in large deformation regions, an extension of the model is proposed. In the second step of the analytical studies a semi-empirical method is proposed to predict the cyclic hysteretic behavior of the tested joints. The proposed method applies polygonal approximation of the hysteretic curve and coincides well with the experimental cyclic curve and shows a good agreement for absorbed energy during the increasing cycles. Intensive experimental research work has been done on the cyclic behavior of the joints.*
Key words: *design method, moment resistance, behavior, model, polygonal approximation, buildings, joint`s.*

1. INTRODUCTION

The joint's ductility can be characterized numerically by cyclic parameters, which are derived from the cyclic moment, rotation relationship of the joint by standardized procedures. Cyclic testing of the joint can be done following international standards [2] and the cyclic parameters, resistance can be determined from these test results. In the seismic design of dissipative steel, composite and steel-concrete mixed moment resisting framed structures the cyclic behavior of joints has important role. The local ductility of joints has a significant effect on the global ductility of the structure. The ULS design model concentrates on the moment resistance calculation considering (i) the specialties of the cold-formed section using the Euro code 3 (EN 1993-1-3, 2005) and (ii) the partial shear connector method of the Euro code 4 (EN 1994-1-1, 2004). The Euro code models are extended, and the proposed model is based on the plastic resistance of the composite cross-section, assuming elastic-plastic stress-strain distribution, considering the local buckling of the cold-formed section and the effects of the partial shear connectors. The main features of the design model are summarized in the followings, more details can in Euro code 4 the bending and the longitudinal shear resistances can be checked in a combined way on the basis of the moment resistance diagram. This diagram defines the moment resistance of any cross-section of the beam on the basis of the longitudinal shear length and the full moment capacity of the composite cross-section (assuming full composite action). The composite beam the longitudinal shear is zero, and the moment resistance is equal to the moment resistance of the steel cross-section part. In the cross-sections, with a suitable distance from the end in which the longitudinal shear can create the required compressive force in the compressed part of the section for full plasticity the moment capacity equals to the full plastic resistance [3]. In between the moment resistance can be calculated on the basis once the moment capacity at any cross-section is known, the design can be carried out by comparing the actual bending moment and the moment resistance. The longitudinal shear forces can be calculated by the assumption of plastic distribution of the forces between the individual shear connectors, so it is equal with the sum of the forces belong to the yielding of the shear connectors from the end to the given cross-section. The shear resistance of the composite connection is determined by the tests.

2. STUDIED STEEL CONCRETE COMPOSITE JOINTS

The specimens are tested in the arrangements as shown in Fig. 1. The set-ups for steel and composite joints are the cantilever type arrangement the specimens are connected to a rigid foundation, and the displacement controlled actuator applied the cyclic horizontal load.

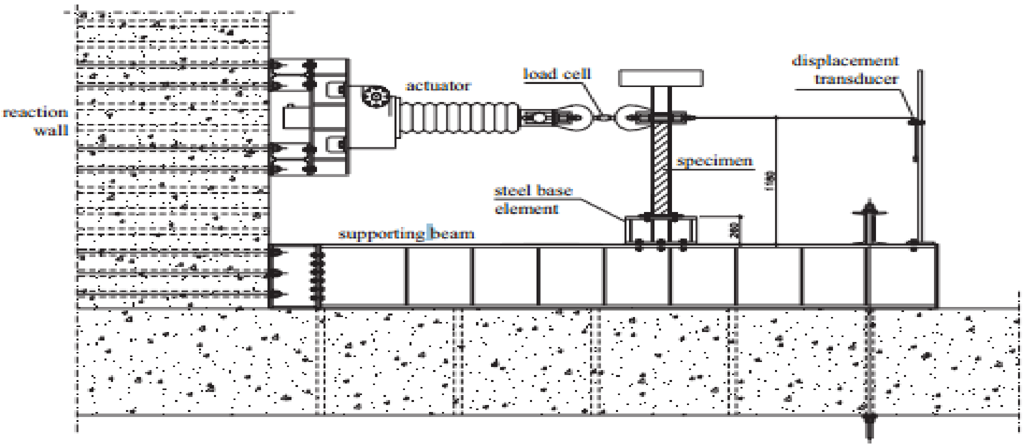


Figure 1: Test arrangement.

In the case of steel-concrete composite specimens, the separation between steel flange and concrete filling is observed in the early cycles and is due to the different axial deformations. The elastic flange buckling happens on the various positions of the compressed flange in an asymmetrical buckling pattern, due to the supporting effect of the concrete (Fig.2b). In the increasing cycles, the phenomenon becomes plastic plate buckling and turns into a yield mechanism with three main yield lines. The final collapse is caused by the cracking and fracture of the tension flange due to low cycle fatigue, after the significant deterioration of the filling concrete. The nonlinear cyclic behavior for this failure mode is significantly influenced by the applied composite action. In the case of specimens with reinforcement in the concrete several small cracks are developed, while when only headed studs are used one dominant crack is occurred. Although the two types of specimens had almost the same moment capacity, in the rotational capacity and degradation characteristics, however, the specimens with reinforcement showed better performance [4].

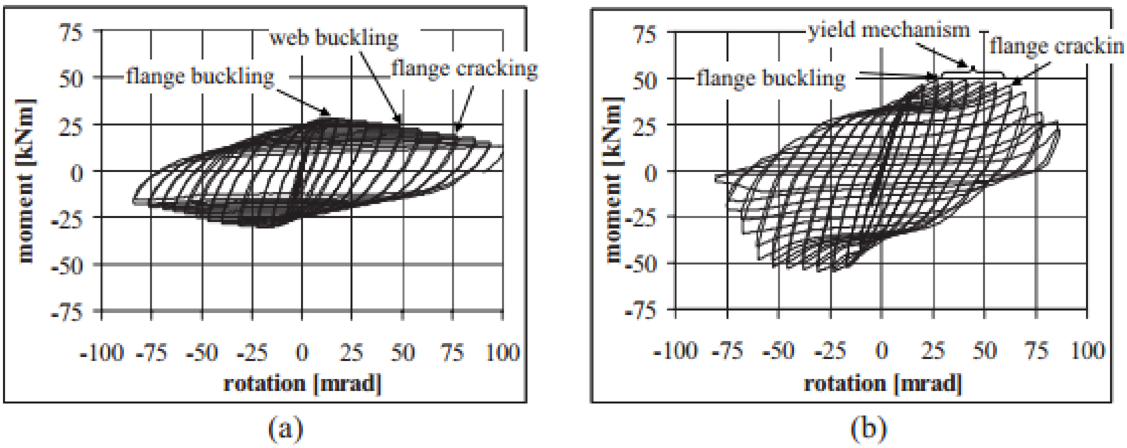


Figure 2: a) Plate buckling moment-rotation curves, b) steel and composite specimens.

The two types of cyclic local buckling phenomena are evaluated in detail [4]. In Fig. 3, the cyclic parameters (absorbed energy and resistance ratios) show the quantitative difference in the cyclic buckling behavior. In the stable cycles less than 10% degradation of the resistance ratio is observed in the case of composite specimens, while it is higher for steel specimens (about 20%), what shows the favorable effect of concrete filling.

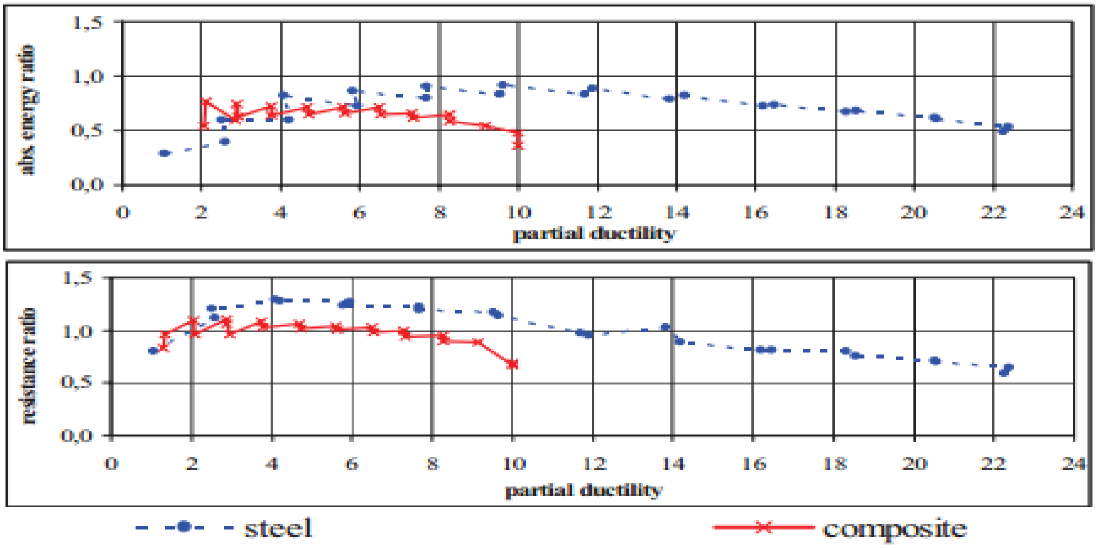
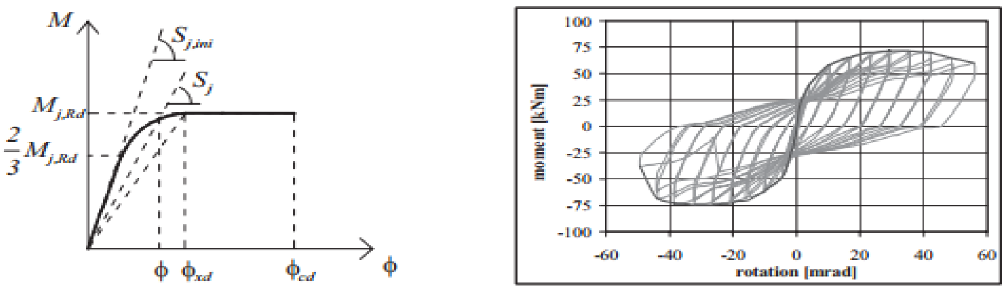


Figure 3: Cyclic parameters of plate buckling failure steel and composite specimens.

3. CYCLIC DESIGN MODELLING OF COMPOSITE JOINTS

The results of the cyclic tests of composite joints showed the constructional arrangements which exhibit advantageous behavior. The extension of the experimental experiences for design application is done by cyclic design modeling. It consists of two parts, as follows: First hereinafter EC3 and EC4, notes that previous, draft versions of the standards are used. In the second part, starting from the monotonic design curve, using the experimentally determined performance parameters the cyclic moment-rotation curve is predicted [2]. The EC3 defines the moment-rotation relationship of the joint with the design moment resistance (M, Rdj), the rotational capacity (cd) and initial rotational stiffness (S, inij), as shown in Fig. 4a. During the tests the specimens are imposed by cyclic loading, the joints are described by the envelope curves that belong to the cyclic moment-rotation diagrams (Fig. 4b).



(a) standard M(Θ) diagram (b) cyclic and envelope curves

Figure 4: Moment-rotation diagram.

4. COMPARASION OF DESIGN AND EXPERIMENTAL RESULT

From the comparison of design and experimental results it is found that in case of the connecting element type failure modes the model uncertainty (Rd M Rd, M j,Rd / " exp ! , the ratio of the test and design moment resistance) is significant 51,1 ! Rd $ 47, 1, the moment resistance of the joint is underestimated and in certain cases the design and the experimental failure modes are different. In case of the presented experimental program the standard EC3 procedure overestimates the initial stiffness in all cases, the ratio of the test and design initial stiffness) and the results have large [1]. The aim is to improve the resistance model with the modification of the design model characteristics, but keeping the basic EC3 formulas, to have design values closer to the experimental results. It is found that the modification of the lever arm, in accordance of the experimental observation a better coincidence can be achieved. The proposed modification is shown in Fig. 5.

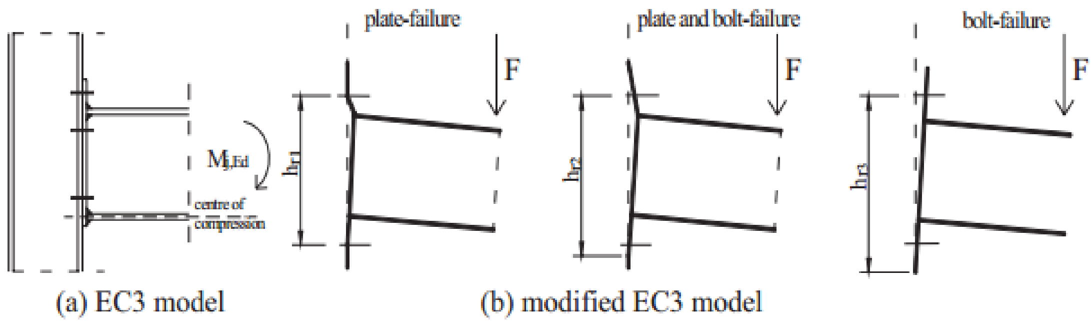


Figure 5: Moment resistance model.

The comparison of the envelope curve and the EC3 and modified EC3 methods with the proposed polynomial function are presented in Fig. 6. It is noted that the design monotonic curve is assumed to be symmetrical about the origin.

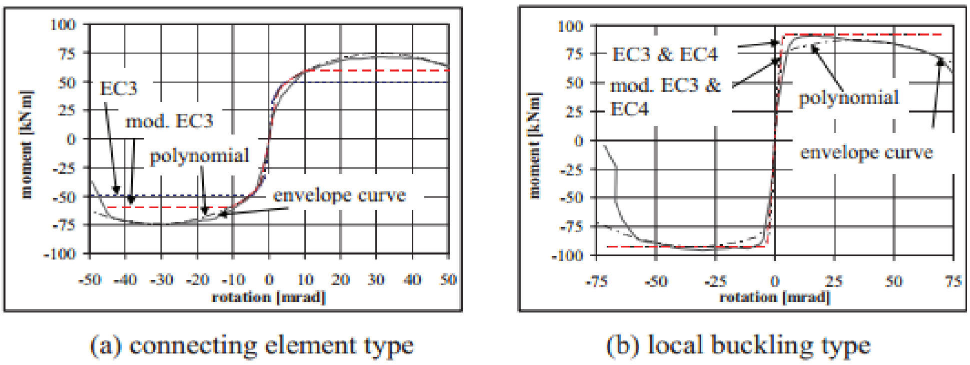


Figure 6: Results of the modified design method – M curve.

5. CONCLUSION

In the research an analytical study is completed in order to predict the hysteretic moment rotation curve and determine the cyclic parameters which can be used in the seismic design. In the first step the design method of EC3 and EC4 is studied. Since the EC3 design procedure does not reflect on the behavior of the joints in large deformation regions, an extension of the model is proposed. In the second step of the analytical studies a semi-empirical method is proposed to predict the cyclic hysteretic behavior of the tested joints. The proposed method applies polygonal approximation of the hysteretic curve and coincides well with the experimental cyclic curve, and shows a good agreement for absorbed energy during the increasing cycles. In the research an analytical study is completed in order to predict the hysteretic moment rotation curve, and determine the cyclic parameters which can be used in the seismic design. In the first step the design method of EC3 and EC4 is studied.. Since the EC3 design procedure does not reflect on the behavior of the joints in large deformation regions, an extension of the model is proposed. In the second step of the analytical studies a semi-empirical method is proposed to predict the cyclic hysteretic behavior of the tested joints.

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