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Experimental evaluation of E-stubs under shear

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***Abstract*— Current European standard of steel structures (Eurocode 3), establishes the necessity of taking into account the rigidity and resistance of joints in the overall calculation of the structure. This normative uses the method of the components. One of the components with greater influence on the behavior of the joint is the column web in shear. In 3D joints with additional plates, a new component, called E-Stub, appears. This component has been studied in regards to their behavior under axial load. However, the behavior of the E-stub when it is subjected to shear, has not been yet studied.**

In the present work, a test of a 3D joint with additional plates subjected to shear forces is conducted. During this process, measurements of strain gauges, inclinometers, and load cells are carried out. In this way, it is possible to determine the moment_rotation curves of the different panels composing the joint (web of the column and additional plates). The test is conducted in the elastic range, in order to determine the E-stub shear stiffness. The aim is to understand the mechanisms of deformation for the shear E-stub component.

These results will be used for calibrating the FEM models of the joints. This work will allow a parametric analysis with the aim of characterizing the different parameters that influence in the comportment of the E-stub under shear.

***Keywords*— E-stub, Experimental Evaluation, Semirigid Joints, Method of the Components.**

I. Introduction

The characterization of steel joint behaviour and properties has been a matter of research for a number of years, and all the accumulated knowledge has been compiled to a large extent in currently available structural steel design codes. One important aspect is the behaviour of the column panel subjected to the shear forces arising from the moments of the adjacent beams as well as the shear forces acting on the columns. A correct definition of the column panel zone deformations under static conditions is of great importance due to its influence on the overall sway behaviour of the frame. An increase in frame drift due to panel zone shear deformation may render the frame unserviceable. This may even happen for commonly considered rigid joints. Modelling of the column panel is also important for the avoidance of local failure under ultimate limit state conditions.

Krawinkler et al [1] reported the importance that panel shear deformations have on the frame behaviour under lateral loads, and proposed a formulation for the stiffness and resistance of shear panels of beam to column connections with beams of equal depths. An alternative formulation has been proposed in the Eurocode 3, part 1.8 [2] following the component method. Castro et al. [3] have studied the comportment of the panel zone in steel and compo- sites frames. Charney and Downs [4] analysed the modelling procedures for panel zone deformations in moment resisting fames. Girao et al. [5] have studied the numerical modelling of high strength steel column web shear panel behaviour. Bayo et al. [6] and Lopez et al. [7] have analized the shear behaviour of trapezoidal column panels, and more recently Loureiro et al. [8] have studied the shear behaviour of stiffened double rectangular column panels.

Work remains to be done to characterize the behaviour of the E-stub under shear in joints with additional plates welding to the flanges of the column. In this paper, experimental work results are presented that provide important information to characterize and model this component. The research presented concentrates on the shear comportment of the E-stub component.

The aim is to understand the mechanisms of deformation for the shear E-stub component.

II. Experimental work

The experimental work has been carried out in the prototype whose overall scheme is illustrated in Fig. 1. The column is totally fixed at both ends and actuation is applied on the attached beam. The distance from the point of actuation of the force and the column flanges is exactly 1000 mm. Table 1 shows the beam and column sizes in the test, and Fig. 2 depicts a picture of the experimental set up.

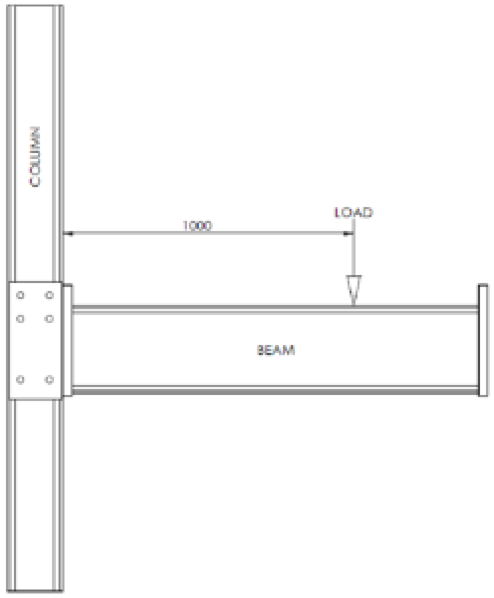

Figure 1: Scheme of the test

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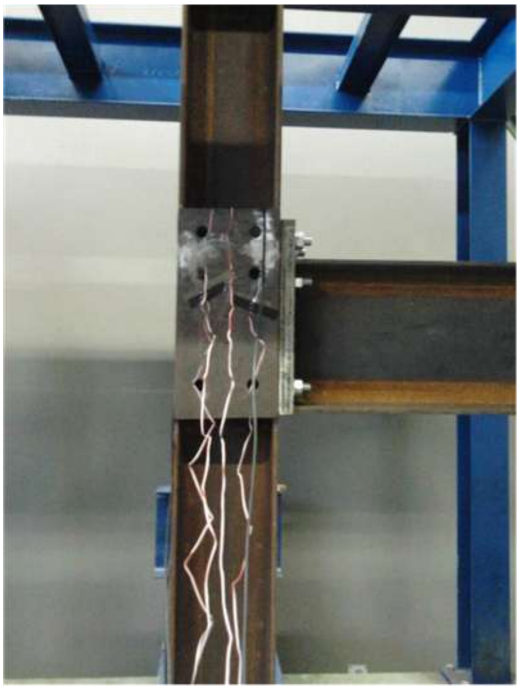

Figure 2: experimental setup of the test

TABLE I. DIMENSIONS OF THE TEST

Test	Dimensions of the test		
	Column	*Beam*	*Additional plates thickness (mm)*
T1	HEA 200	IPE 300	10

The type of steel used for all the parts was S275. The true properties of the material for the column and additional plates were used in the simulation. Table 2 shows those properties.

TABLE II. MATERIAL PROPERTIES

Element	Material properties		
	Material	*Young Modulus (N/mm2)*	*Yielding Stress (N/mm2)*
Column	S275	2.15e5	296
Adittional Plates	S275	2.18e5	305

The test was instrumented with 4 strain gages placed at the corners of the column web and the additional plates as shown in Figures 3 and 4. They served to monitor the strain level in the web panel and in the additional plates, with the aim of ensuring that the experiment is conducted in the elastic range of the materials. Three inclinometers were used as shown in Figures 3 and 4 to obtain the rotations. Two of them were placed vertically at the additional plate and the column web, respectively. And the third one was placed horizontally in the middle of the panel to capture the rotation of the column due to bending. This rotation is subtracted from the other ones to obtain the rotation due to the shear deformations.

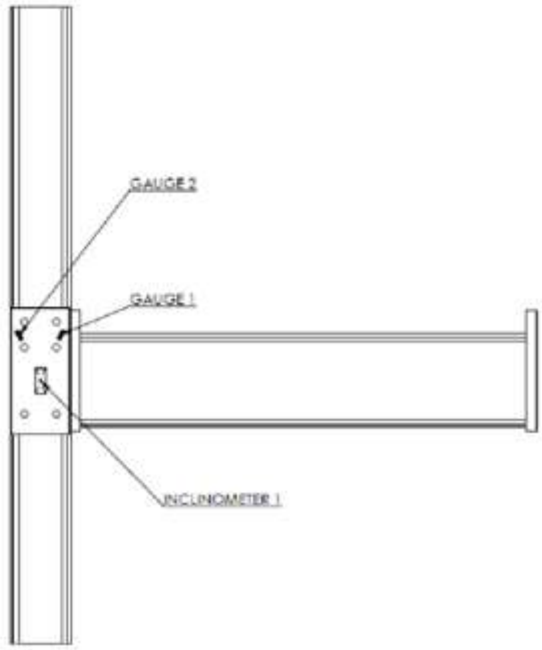

Figure 3: Instrumentation in the additional plate

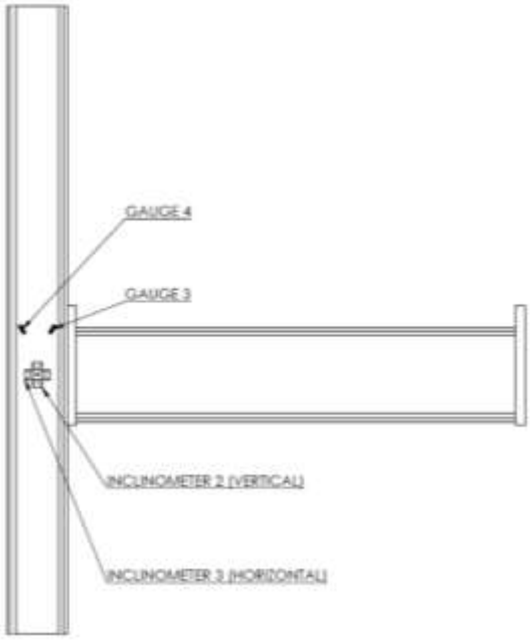

Figure 4: Instrumentation in the column web

For the test, a previous simulation with Abaqus® software has been done in order to detect the load at which plastic behavior begins. These value have been used in the test as the upper limit of the applied force, with the objective of avoiding damage in the web panel and additional plates. The experiment was simulated with the exact dimensions of the elements. The finite element model was refined near the most stressed zones (the panel and adjacent zones) with the aim of assessing correctly the strain and stress fields. The convergence of the model was evaluated to reach good results with a suitable level of meshing, and to allow future parametric studies with a reasonable computational cost.

III. Description and results of the test

The test consisted in loading the prototype on the beam, in a distance of 1000 mm from the column flanges. The aim of the test was to observe the comportment of the web panel and additional plates, under the shear coming from loading the beam. The maximum load applied was 39 kN, and afterwards it was unloaded. A previous finite element analysis had predicted pure elastic behaviour up to that loading level. The deformed shape of the model can be seen in Figure 5. Von Mises and Shear stress distribution obtained from the finite element analysis is illustrated in Figures 6 and 7, respectively, which corresponds to the level of strains just at the end of the loading process.

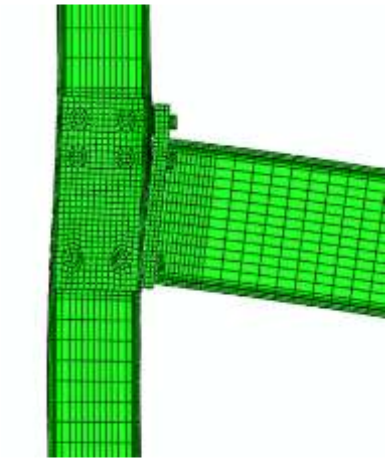

Figure 4: Deformed shape in the finite element model.

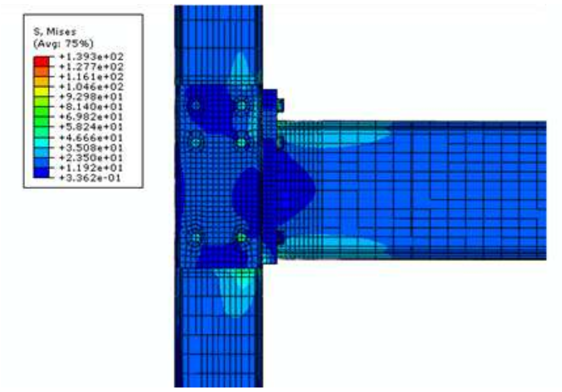

Figure 6: Von Mises Stress diagram

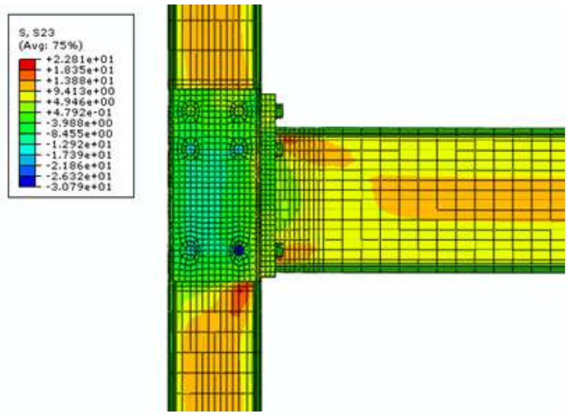

Figure 7: Shear Stress diagram

It may be seen that both Von Mises and shear stresses stay in the elastic range of the material. The readings of the inclinometers have shown that the web panel rotates more than the additional plates, as can be seen in Table 3

TABLE III. ROTATIONS IN THE TEST

Element	**Rotations of the web panel and additional plates (mm)**
Web panel	0.73
Additional plates	0.33

The results from the experiment only provide a perfect elastic comportment of the strain gauges since, as mentioned above, it is only loaded in the linear elastic range (the maximum applied load was 39 KN), and their plots are perfectly proportional to the applied load.

The lectures of the strain gauges have shown that the stresses remain in the elastic range during the loading process.

IV. Conclusions

In this paper we have investigated the shear behaviour of the E-stub component. A previous finite elements model and a test have been done and the main conclusions can be summarized as follows:

- The shear deformation zone corresponds to the rectangular zone adjacent to the beam, for both the web panel and additional plates.
- The mechanics of the deformation has been detected. The shear stresses produce deformations both in the web panel and additional plates, previous bending deformation of the column flanges, due to the tension in the bolts.
- Two degrees of freedom are identified in the elastic range: the rotations corresponding to the web panel, and the rotation corresponding to the additional plates. These degrees of freedom should be considered at the time of characterizing the joint stiffness for frame analyses.

- The finite element analysis predicts the deformation mechanism with good accuracy.
- In a future work, a parametric analysis will permit to obtain the stiffness and resistance of the E-stub under shear.

Acknowledgment

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