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HYSTERETIC BEHAVIOR OF BEAM TO COLUMN JOINTS: COMPARISON AND INTERPRETATION OF EXPERIMENTAL RESULTS

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SUMMARY

Aim of this paper is to analyze the cyclic behaviour of beam-to-column joints with particular reference to the experimental tests in order to point out different questions: why and how to carry on experimental tests, what we have to measure during a test, how to compare or to interpretate these experimental data to detect information on the behaviour of different types of connections. The results of a complete test programme is briefly presented; by means of a selection of behaviour parameters, according to the ECCS document on cyclic tests, a comparison of experimental results is provided to try to give a general rule, also if qualitative, of the joints behaviour. Furthermore some critical observations are given on the validity of these general assumptions.

INTRODUCTION

Modern researchs efforts have been and are devoted to the study of the behaviour of steel frames under cyclic loads to obtain informations for the evaluation of the structure q factor and its use. For this reason the real behaviour of the connection, to-day defined as "semirigid", and its modelling become important in the field of seismic resistant structures. The joints modelling can be really semplified (pin or fixed connection) in the elastic analysis of the structure, but become more complex in the post-elastic or cyclic behaviour. Not less important is the problem of mechanical properties deterioration of the joint together with the law which interpretates the energy dissipation. In the field of steel structures the restrain conditions of the beams are important also in the elastic analysis. In fact the values of elastic deformability (Ref. 1),different for different connections, modifies the global rigidity with the effect of a different dynamic response. The analysis of hysteretic behaviour of structures has been carried on by different authors (Ref. 2) groupped in:

a) experimental programs on joints behaviour;
b) mechanical or analytical model to interpret the real behaviour of the joint;
c) mathematical model of bars with elastic springs at the end to study framed structures (Ref. 3).

Committee TWG 1.3 - Seismic Design - (Ref. 4) of the European Convention of Constructional Steelwork (ECCS) has been looking into this matter for some time. An examination of the collected results shows that the experimental analysis of structural details under cyclic conditions arises at the first position. ECCS Committee has drawn up recommendation on a testing procedure (Ref. 5) with the indication of the load application sequences and of the main parameters to be measured during the test.

Experimental test results my be utilized in two ways:

- introduction of the behaviour law of the structural detail in the full structural scheme by an analytical model able to describe the costitutive law of the tested structural detail (Ref. 6);
- to try to extrapolate from the test results on one element, the data to be used for other elements of similar type but with different geometrical properties.

Aim of this paper is to point out the problems concerned with this second matter and in detail:

- compare the results obtained from different categories (category A,B,C,D in Fig.1 and 2) and inside the same category from different structural arrangements (addition of stiffeners etc.; A4, A3, A2 respect to A1);
- try to detect some general rules on the structural behaviour and to understand the possibility to extend them .

COMPARISON OF EXPERIMENTAL RESULTS
CHOICE OF BEHAVIOUR PARAMETERS

We refer to results of a numerical analysis carried out on the data obtained by a test program (Ref.7,8) on cyclic behaviour of steel beam-to-column joints. We will not describe the test program, on the base of which the numerical model coefficients were calibrated, or all the variations introduced among the joints of each category (fully welded joints, bolted joints using angles, cover plates, flanges....) as stiffeners, reinforsing plates and so on deeply treated in Ref 7 and 8 . We wish only to point out how to arrange the comparison of the structural tests results obtained closely following ECCS procedure (Ref. 5).

The data from the experimenta tests can be analysed following two different ways:

- compare the experimental values of the leading dimensional parameters measured at the joint collapse;
- compare the shapes or particular values of the behaviour functions, suggested in Ref. 5, obtained measuring during whole test adimensional quantities. In the first case, for instance the (A) category, we can give some hystograms (Fig.3) built up with the joints code on the horizontal axis repeated for the parameters
- the energy absorption (area of all cycles (Ω);
- the maximum strength reached during the test (F_{max});
- the strength at collapse (F_u);
- the maximum imposed displacement and cycle (v, n);

and on vertical axis the values of the parameters, referred to the same ones of the base joints A1.

In the second case we can draw the curves of the functions (Fig.5), also in the case of A category of joints, of the ECCS test code. With more details:

- relative resistance function (ε);
- resistance drop function (ε^*);
- relative rigidity function (ξ);
- relative absorbed energy function (η);
- full ductility function (ψ).

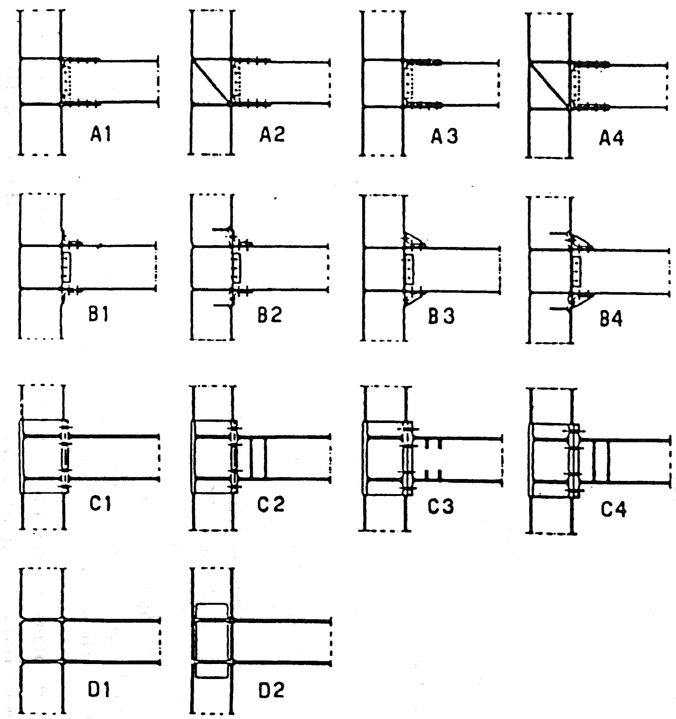

Fig. 1 - Tested specimens

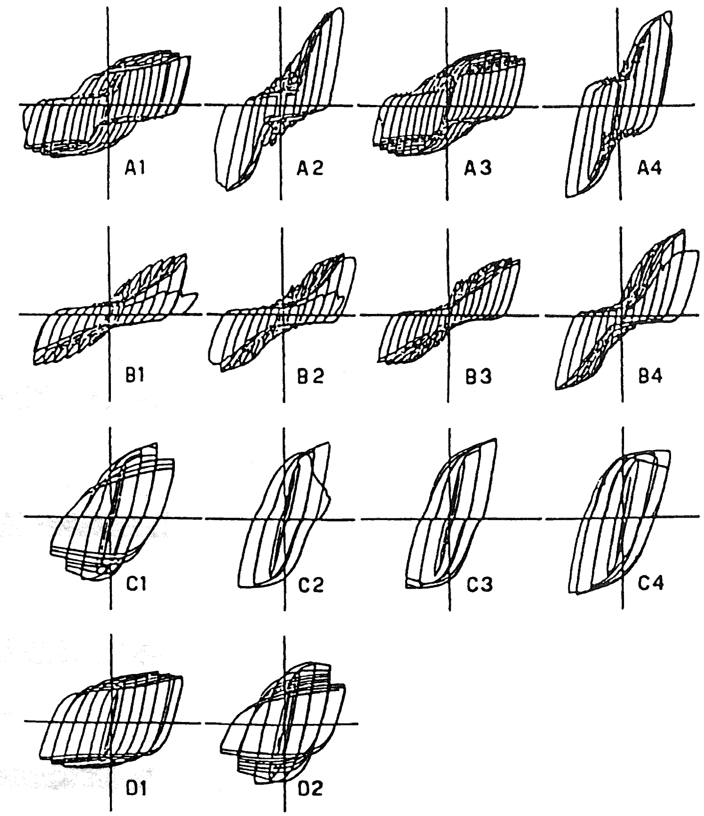

Fig. 2 - Hysteresis loops

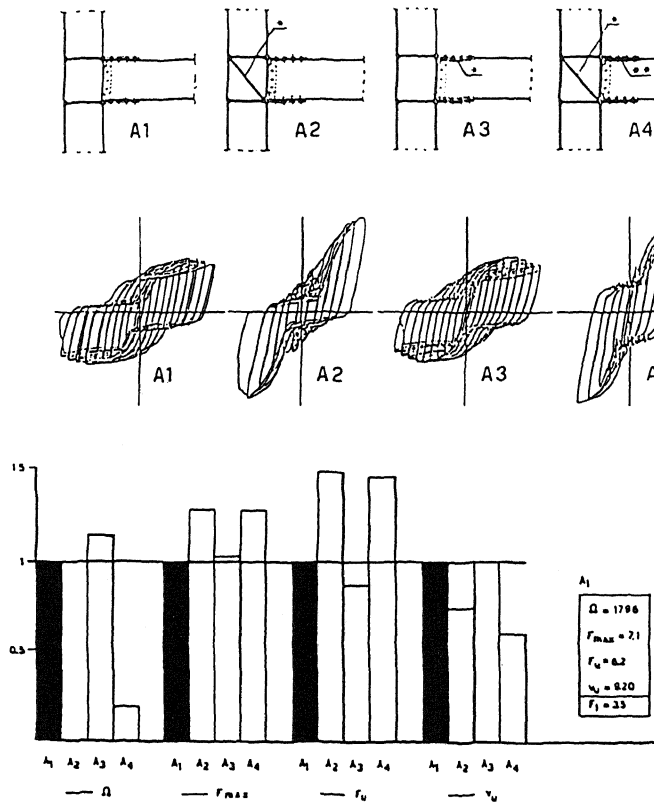

Fig. 3 - Comparison by dimensional parameters

The meaning of these functions can be easly detected by the comparison of Fig.4b and 4c in which are shown the generic cycle of the test and the elasto-plastic cycle model. The last one provides the quantities to use for the adimensional values of the functions.

INTERPRETATION OF EXPERIMENTAL RESULTS

We examine, for instance, the hystograms of Fig.3 (A category). If we look to the energy absorption and to the load level reached and compare A2 to A1 or A4 to A3 we see that the introduction of a diagonal plate in the central panel of the column reduces the energy dissipated and increases the strength. Moreover Fmax is equal to Fu for A2 and A4; this suggestes, for these elements, a brittle type of collapse. On the other hand, for A1 and A3 Fu is less than Fmax showing a ductile type of collapse. If we compare A3 to A1 we note that the increase of thickness of the beam flanges increases the energy dissipated and increases the strength (joints with a ductile type collapse).

If we extend these comparison to the other categories, in dimensional (Fig.3) or adimensional (Fig.5) way, a general qualitative consideration may be derived:

- if stiffeners are added to the parts of the connection which are the most re-

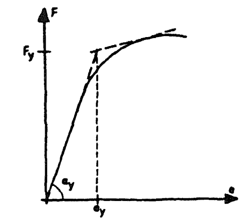

Fig.4a Base parameters

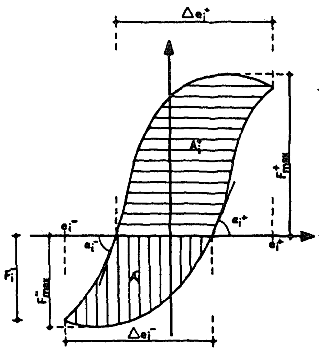

Fig.4b Generic cycle

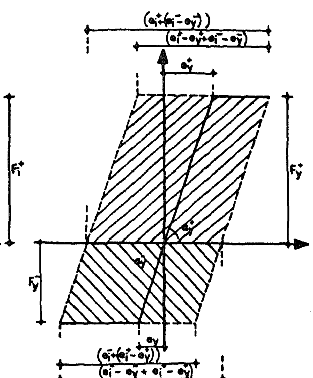

Fig.4c Elasto-plastic cycle model

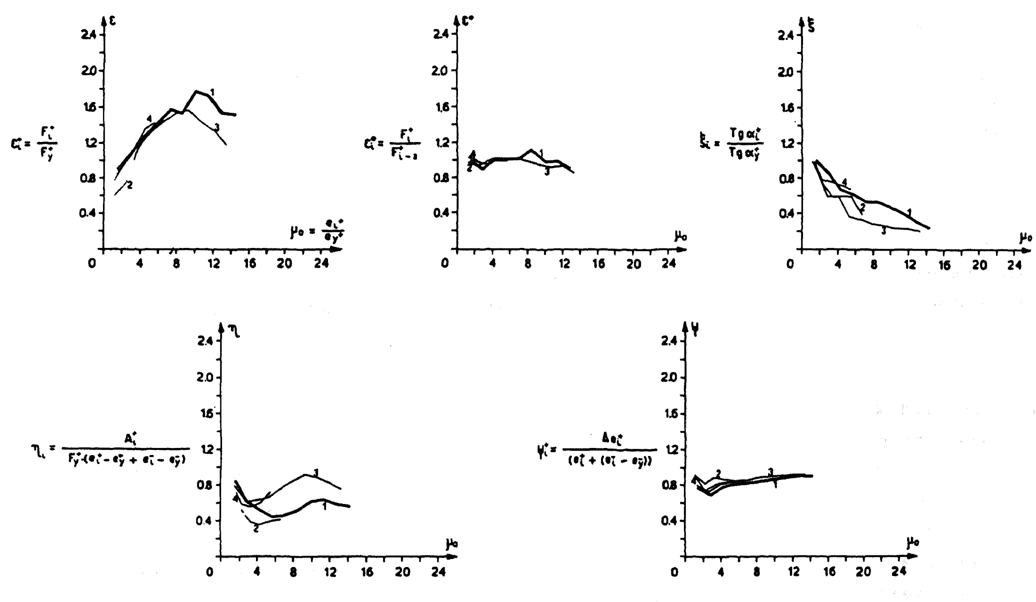

Fig.5 - Comparison by adimensional functions

sponsable of its flexibility, the amount of energy absorption is decreased but the load level is increased;

- if elements are added to a joint which do not substantially modify the evolution of the deformation mechanism but, on the contrary, increase the local strength of structural sub-elements (as for example an increase of thickness), then there will be an increase of energy absorption and load level, on condition that the collapse expected is of ductile type (Fu$<$ Fmax).

CONCLUSIONS AND CONSIDERATIONS

We have seen, also if briefly, how we can compare the structural behaviour of a joint referred to another one of an other category or of the same category but differentially structured. In conclusion we wish to take advantages from this paper to point out different questions which arise when going to a numeric use of the previous parameters as ductility etc. The first question regards the so colled "not supposed resistance"; if we look for the B category, connection obtained by angles bolted to the flanges of beam and of the column with different stiffeners (B2,B3,B4 respect to B1), we can make some observations:

- the connection is particular interesting for the practice and for its economy;
- reaches strength values less than ones of the other categories but surely not neglectable without particular stiffeners; on the contrary they are nearly the same (see B4 with triangular stiffeners in the angle and under the column flanges)
- offers ductility values less than A category joints ones without stiffeners but more than C category ones which have many problems of instability of compressed flanges;

the joints of this category appear very good since they offer many advantages with respect to the "real hinged" connection; but a question arises:

- these gifts are really advantages?
- what about this "not supposed behaviour" in the non linear analysis of the structure?

The second question regards the use of numerical values of some parameters: we have to remind that no statistical evaluation is supposed in the code as far as the base material at first; secondly the values of named parameters and functions are deeply dependent from the load sequence imposed: what about?

The third question is just a suggestion on the use of behaviour functions of ECCS test code; many authors developped analytical model able to describe the experimental test strictly; it seems now possible to develop a simplified analytical model able to provide the shape of experimental quality functions.

REFERENCES

1. Ackroyd,M.H.,Gerstle,M.H.,Behaviour of Type 2 Steel Frames, ASCE, Journal of the Structural Division, 108, ST7, 1541-1556 (1983)
2. Jones,S.W.,Kirby,I.A.,Nethercot,D.A.,The Analysis of Frames with Semi-rigid Connections - A State of Art Report, Journal of Constructional Steel Research, vol.3, n°2, 2-13 (1983)
3. Cosenza,E.,De Luca,A.,Faella,C.,Non Linear Behaviour of Framed Structures with Semirigid Joints, Costruzioni Metalliche, n.4, (1984)
4. Study of Design of Steel Building in Earthquake Zones,Doc.ECCS TWG 1.3,47/86
5. Recommended Testing Procedure for Assessing the Behaviour of Structural Steel Elements under Cyclic Loads, Doc; ECCS TWG 1.3 n.45/86
6. De Martino,A.,Faella,C.,Mazzolani,F.M.,Simulation of Beam-to-Column Joint Behaviour under Cyclic Loads, Costruzioni metalliche, n.6 (1984)
7. Ballio,G.,Calado.,L.,De Martino,A.,Faella,C.,Mazzolani,F.M.,Steel Beam-to-Column under Cyclic Loads: Experimental and Numerical Approach, Eighth European Conference on Earthquake Engineering, Lisbon, sept. (1986)
8. Ballio,G.,Calado,L.,De Martino,A.,Faella,C.,Mazzolani,F.M.,Cyclic Behaviour of Steel Beam-to-Column Joints: Experimental Research, Costruzioni Metalliche, n.2 (1987)