Zeitschrift: IABSE congress report = Rapport du congrès AIPC = IVBH Kongressbericht

Band: 13 (1988)

Artikel: Imperfections of structural details and behaviour of steel frames

Autor: Iványi, Miklós

DOI: https://doi.org/10.5169/seals-13075

Imperfections of Structural Details and Behaviour of Steel Frames

Imperfections des détails de construction et comportement de cadres métalliques

Imperfektionen von Konstruktionsdetails und Verhalten von Stahlrahmen

Miklós IVÁNYI
Prof. Dr. Sc.
Technical University
Budapest, Hungary

Miklós Iványi, born in 1940, received his civil engineering degree at Technical University, Budapest, 1963, where he is Professor of Structural Engineering and Head of the Department of Steel Structures. His main fields of activity are the stability of steel structures and plastic design in steel.

SUMMARY
Within a development program of mass-produced simple industrial steel structures a series of full-scale failure tests has been carried out. Effects of change in geometry, local instability and initial imperfections were analyzed.

RÉSUMÉ
Des essais à la ruine en vraie grandeur ont été effectués au cours d'un programme de développement de constructions industrielles en acier, simples produites en série. Les effets du changement de forme de la structure, du voilement local et des imperfections initiales ont été examinés.

ZUSAMMENFASSUNG
Im Verlaufe eines Entwicklungsprogramms für Serienfertigung einfacher industrieller Stahlbauten wurden Bruchversuche im Originalmasstab durchgeführt. Einflüsse von Biegemomenten zweiter Ordnung, Plattenbeulung, Kippen und Anfangsimperfektionen wurden analysiert.

1. INTRODUCTION

The increasingly powerful experimental and computational tools of structural design require a well-defined design philosophy. As its basis generally the concept of limit states is accepted in many countries. Limit states are usually divided into the two following groups:

1st group - limit states of carrying capacity / ultimate limit states /
2nd group - limit states of seviceability

Checking serviceability at working load level the traditional and well tried out methods of structural analysis are used. The quite frequent tests on original structures show as a rule a relatively good accordance with calculated stress patterns or even better with predicted deflections /apart from the occasional effect of lack of fit at connections/.
On the other hand, structural response in the vicinity of peak load can be extremely complex. The early and very simple methods of plastic limit analysis /based on the concept of rigid-plastic materials which are in principle completely insensitive regarding any forms of initial imperfections/ are confined to a very limited class of structures, built up of bulky elements. As soon as global and even more as local instability plays role in failure,

- the effect of initial geometric imperfections is enhanced,
- the residual stresses /remaining regularly latent at lower loads, interacting with growing active stresses/ result in premature plastic zones, and /last but not least/
- the usual and widely accepted tools of analysis - as beam theory /based on Bernoulli-Navier hypothesis/, small deflection theory of plates and so on - cannot describe exactly enough the structure's response at failure.

The simplified model is not elaborate enough to reflect real structural behaviour, so that a secondary, more detailed local model is introduced to depict the mostly critical part of the structures, by which more realistic quality parameters can be deduced from the already known primary parameters.
Because of the interaction of local and global behaviour this pattern cannot be followed in the case of hyperstatic structures, as the additional information gained by the secondary, local model is to be fed back to the calculation of primary parameters as well. For this purpose, if - as very often - the secondary model can be analysed by numerical methods or only experimentally, the results have either to be re-interpreted to obtain mathematically treatable, simple enough rules, or the secondary model has to be simplified to get well-usable results. In both cases the validity or accuracy has to be proved by /usually very expensive/ failure tests on the whole structures.
To sum up, it seems that because of frequent uncertainties in predicting failure load, the double check of structures - at different load levels - not only reflects different aspects of stuctural behaviour, but contributes to a safer design procedure as well.

2. TEST PROGRAM

The experimental research project was carried out in the Laboratory of the Department of Steel Structures, Technical University, Budapest.

Fig. 1. gives a brief summary of the full-scale tests and dimensions of the specimens, indicating the loads and the characteristics of the loading process. [2]
The second part of the program was a representative part of a multi-purpose, pinned, pitched roof industrial hall: a building section consisting of 3 frames, bracings with pinned elements, light gage purlins and wall beams with corrugated steel sheeting. /Fig. 2./ [4]

3. COMPUTATIONAL MODEL

Instead of the plastic hinge the "interactive plastic hinge" has been introduced for mounting base constructed from plates which are of a much higher degree of freedom than the previous ones as they also embrace the effects of strain hardening of the steel material, of the residual deformation, as well as of the plate buckling bringing about the "descending" characteristics. [3]
The element of the bar is considered to be built up of plate elements /following the pattern of steel structures/ instead of a compact section.

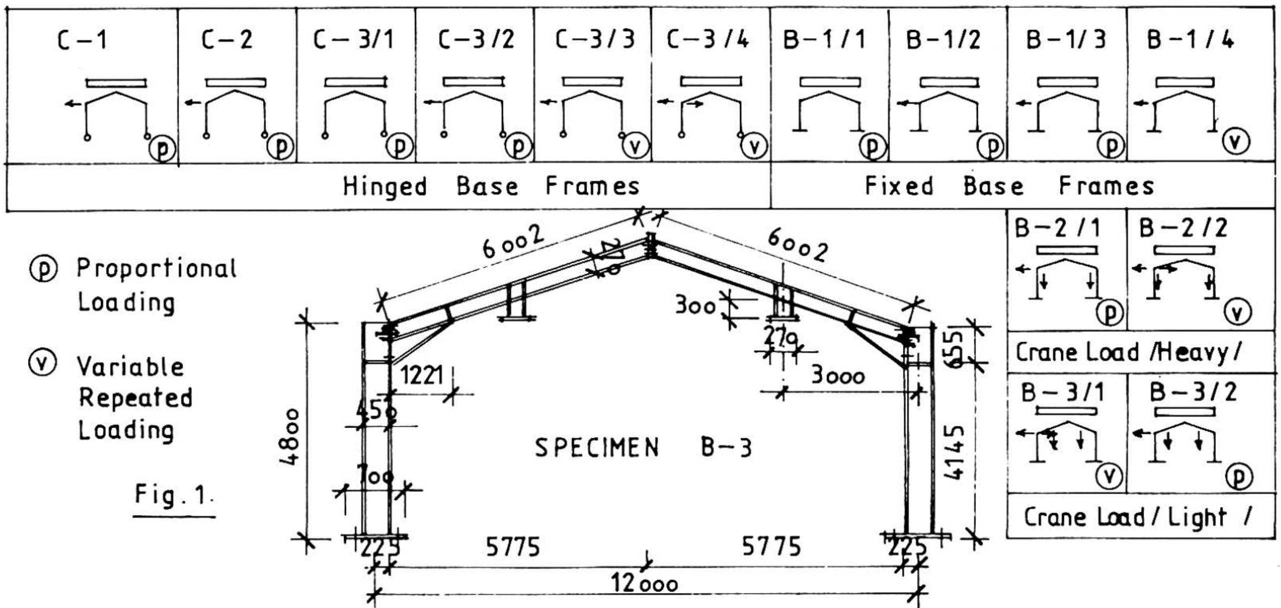


Fig. 1.

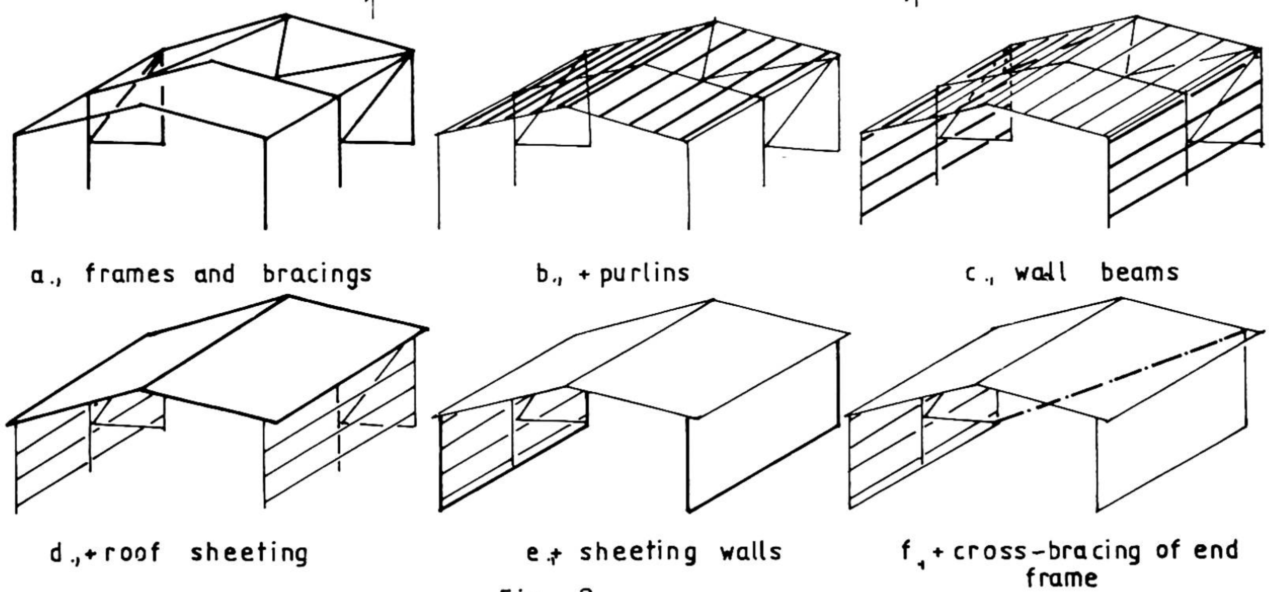


Fig. 2.

The interactive plastic hinge model is suitable for computer computations. The failure of a frame which had been investigated experimentally was simulated by the computer.[1] /Fig. 3./

4. EFFECT OF FABRICATION AND ERECTION

Effect of incorrect geometry was investigated by introducing different initial lateral displacements. Consequences are illustrated by Fig. 4.
The effect of the different values of residual stresses is shown in Fig. 5. The medium curve was in coincidence with test results.
The presented method for the complex analysis of frameworks takes several effects into consideration. /Fig. 6./

5. EFFECT OF STRUCTURAL DETAILS

It seems worthwhile to draw attention to the occasional decisive role of minor differences in structural details on failure as well. Some of the results are reproduced below.

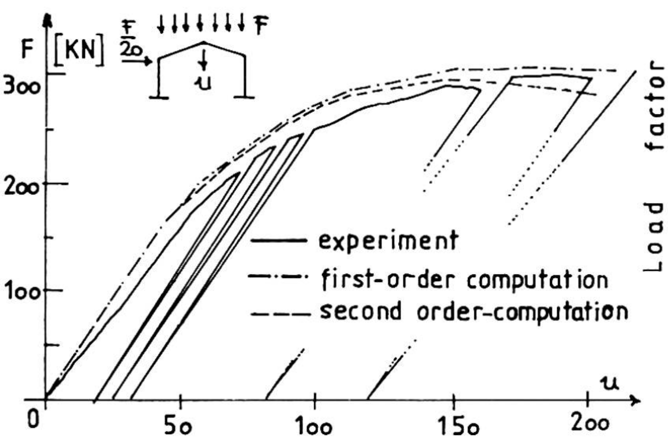


Fig. 3.

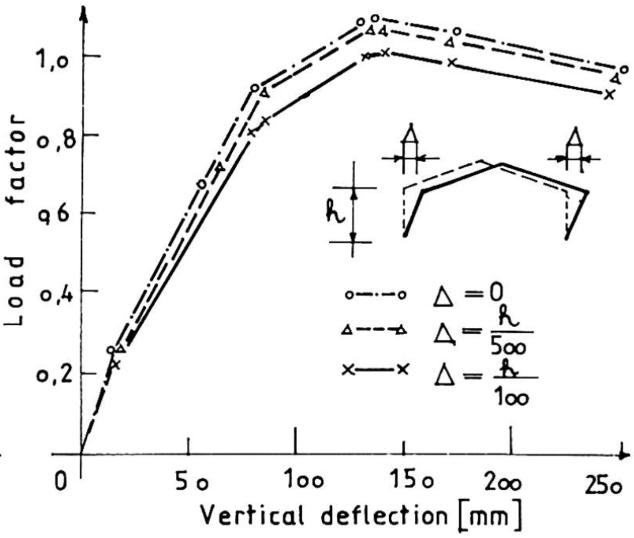


Fig. 4.

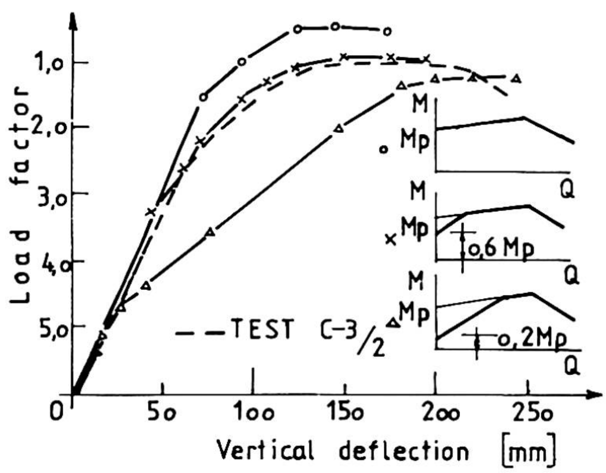


Fig. 5.

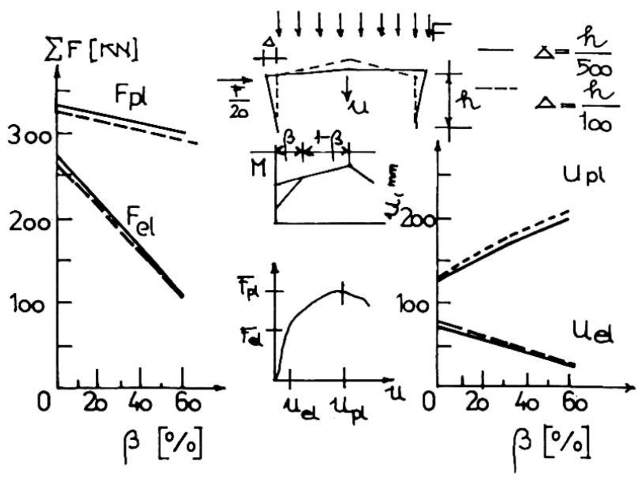
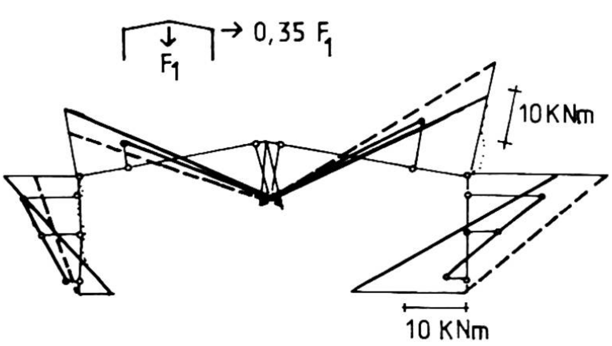


Fig. 6.



Measured and calculated bending moments

Fig. 7.

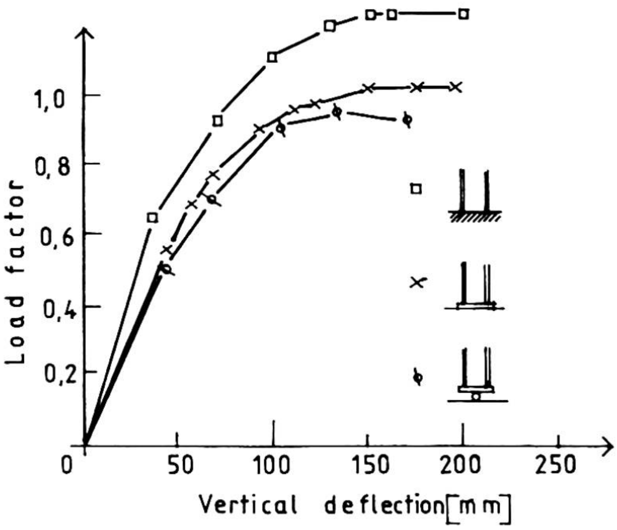


Fig. 8.

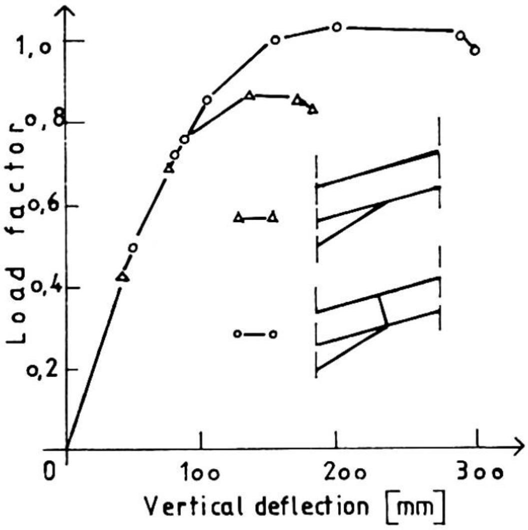


Fig. 9.

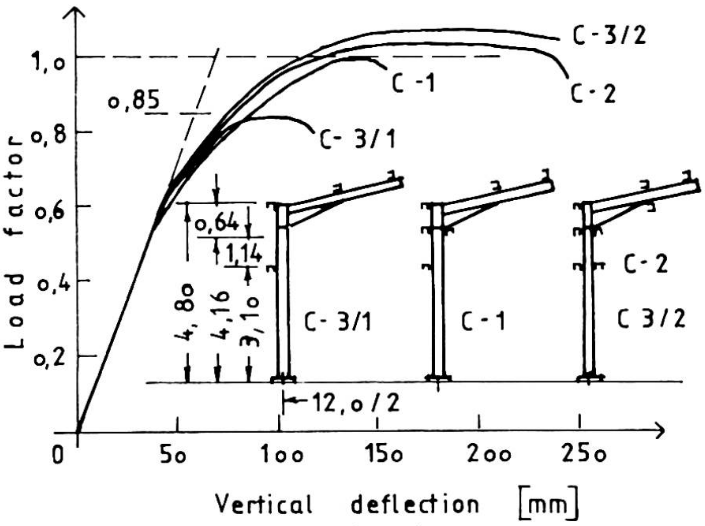


Fig. 10

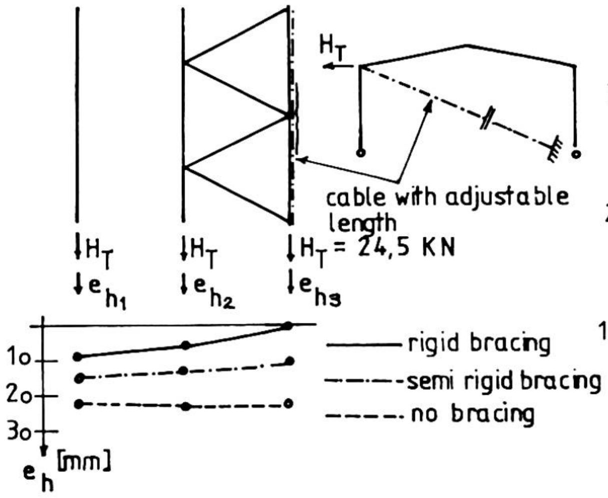


Fig. 11.

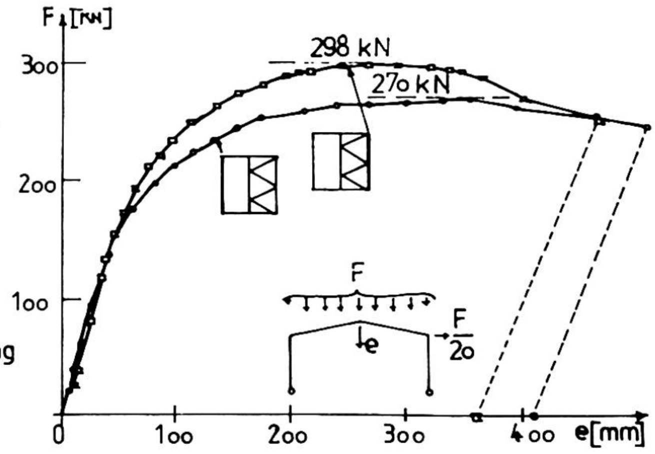


Fig. 12

5.1 Column bases

Column bases were fixed or hinged. The hinges were not ideal : columns could have been rather supported by a bigger base-plates. Fig. 7. compares the measured bending moment due to vertical and horizontal load to the calculated ones assuming pinned /dashed line/ and fixed /solid line/ frame. The corresponding moment-rotation diagram of column base was checked experimentally, its adaption to an interactive plastic hinge, indicating the load-deflection diagrams obtained by different end conditions. /Fig. 8./

5.2 Web-stiffeners

Some secondary elements /such as web-stiffeners/ can be of importance too. Form of failure with and without stiffener is indicated Fig. 9.

5.3 Lateral supports

Spacing and efficiency of lateral supports proved to be of basic importance. Their effect is illustrated by Fig. 10.

5.4 Cross-bracing of the end frame

Measured eaves deflections from uniform horizontal loads are shown on Fig. 11. representing the effect of both semi-rigid and rigid cross-bracing of the end frame.

5.5 Horizontal and vertical bracing system

Finally, load-displacement diagrams of incremental collapse tests are shown in Fig. 12. Ultimate loads are influenced by local loss of stability, previous loadings and the layout of frame-horizontal and vertical bracing connections.

6. CONCLUSION

It seems that because of frequent uncertainties in predicting the failure load of structures approximate models and procedures limited to special structures have to be used, and there is a need for regular experimental checks.

REFERENCES

1. BAKSAI R., IVANYI M., PAPP F., Computer Program for Steel Frames Taking Initial Imperfections and Local Buckling into Consideration. Periodica Politechnica, Vol. 29., Nos 3-4 1985.
2. HALASZ O., IVANYI M., Tests with Simple Elastic-Plastic Frames. Ibid, Vol.23., Nos 3-4 1979.
3. IVANYI M., A New Concept in Limit Design of Steel Structures. Colloquium on "Stability of Metal Structures", Paris. 16-17 nov. 1983, Final Report
4. IVANYI M., KALLO M., TOMKA P., Experimental Investigation of Full-Scale Industrial Building Section. Colloquium on "Stability of Steel Structures", Hungary 25-26 sept. 1986, Final Report