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Cora's Lesson

La leçon de Cora

Die Lehre von Cora

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1. INTRODUCTION.

Since 25 years we have been acquainted with the development of optimization-techniques for the design of structures. The first programs were mainly based on the "mechanism" approach of limit analysis.
After a general matrix theory for structures became available about 1966, design-programs based on the equilibrium method were developed [1].
Formulating a minimum-weight design, based on the equilibrium method, with only stress-limitations as constraint conditions, leads to a problem of linear programming (L.P.).
In practice, however, a design with only stress-limitations is not acceptable. The building codes require a number of additional constraint conditions, for instance with relation to stability and rotation capacity (fig. 3). Often these special conditions are strongly non-linear and they can be linearized only in the neighbourhood of a solution, so that one has to pass on to a non-linear programming technique.

2. CORA.

Recently a design program has been developed in the Netherlands (named CORA) for the design of braced steel frames. The designs meet the requirements by the national authority. Moreover, it is possible to distinguish between welded joint connections with or without stiffeners. Given an accepted input of geometry and loading (fig. 1), the program automatically produces the design of the frames using a sequential linear programming formulation (fig. 2). The introduction of the special constraint conditions means that a very large linear programming problem has to be solved a number of times. The solution has been found in applying a sophisticated L.P. algorithm and in the approximation of the constraint conditions by one plane with the aid of the method of least squares. Instead of five sets of constraint conditions (fig. 4) only one set has to be taken into consideration (fig. 5). It proved that 3 or 4 iterations were sufficient to obtain the theoretically exact values of the solution.

Problems arose from the wish to develop an instrument which will really be used in practice. This means that it should not be too expensive in use and that it should fit realistic structures. The more difficult problems however were formed by the codes themselves. In drawing up these codes the committee has had in mind of course a more or less sensible structural engineer and a proper structure. But in applying these rules and codes in an automated design program irrevocably gaps and inconsistencies prove to be present in the codes. The computer is not a sensible structural engineer and he stumbles in the pitfalls caused by these gaps. Especially a mathematical optimization technique is a master in finding the inadmissible minima, as we noticed to our regrets several times.

3. THE LESSON.

The experience gained with this program has led us to the insight that if, in developing a design-process, one has to make allowance for requirements made by the government or a local authority, the design-program has to be separated from these prescriptions or codes. This applies to computer-aided design and the more so to computer-automated design. The reasons for this opinion - which we believe should be generally accepted - are:

a. The codes and prescriptions contain gaps and inconsistencies, which will always be recognized by the optimization-technique and unfortunately exploited.

b. The programmer who builds the design-program is not allowed to improve these inconsistencies.

c. By integrating the code into the design-program the program becomes dependent on this code. Codes have a temporary character. Adapting a design-program to code-changes will in general be very expensive or even impossible.

d. Working up codes into a form which is understandable by the computer is a lot of work which can best be left to those who draw up the codes instead of to every individual programmer.

4. CONCLUSION.

If - at least for the Building Industry - we want to leave behind us the more or less trivial examples, to proceed with our design-techniques to real life structures, we have to create the possibility to develop C.A.D.-programs that are independent from the codes. Therefore the codes have to be brought into a computer-readible form for instance in the way - indicated by Fenves [3] - by means of Decision Logic Tables. If this effort has led to success, the codes can be changed without consequences for the design-program (of course it will have consequences for the design itself).
Because the programs will be less vulnerable, software development for C.A.D. will become more popular. Two consequences seem to be of particular importance:

a. To develop C.A.D.-programs that can make codes of different countries accessible. This will make the software less dependent and less "national".

b. To study beforehand the effect of proposed code-changes, e.g. on economics or safety.

5. ACKNOWLEDGEMENT.

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6. REFERENCES.

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SUMMARY

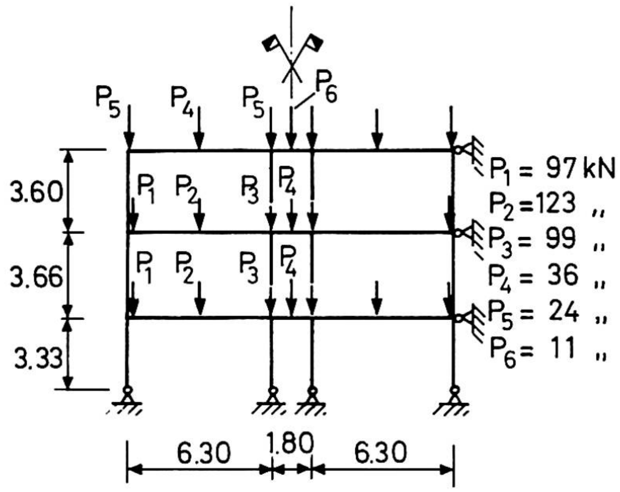
During the last three years a computerprogram (CORA) has been developed in the Netherlands for the design of braced steelframes. The frames designed with this program meet the requirements, made by the national authority. The building code requirements have been integrated into the design program, which has led to a very complex problem. The experience gained by solving this problem, has led to the insight, among other things, that design programs should be separated from rules and requirements in the building codes.

RESUME

Pendant les derniers trois ans un programme d'ordinateur (CORA) a été développé aux Pays-Bas pour le dimensionnement des ossatures en acier. Les ossatures dimensionnées avec ce programme satisfont aux conditions posées par les règles nationales pour les structures en acier. Les règles ont été insérées dans le programme de dimensionnement ce qui a conduit à un problème très compliqué. L'expérience a conduit à la conclusion que les programmes de dimensionnement doivent être séparées des conditions dans les règles ou codes.

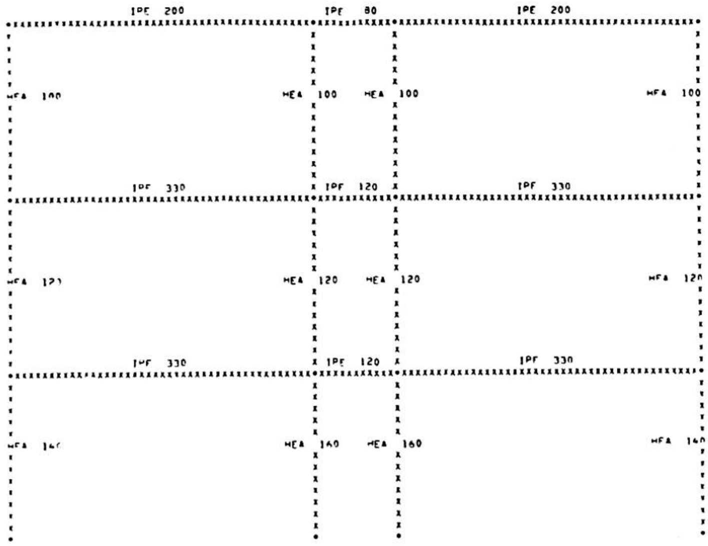
ZUSAMMENFASSUNG

Während der letzten drei Jahre ist in den Niederlanden ein Computerprogramm (CORA) für das Entwerfen von Rahmentragwerke aus Stahl entwickelt worden. Die Tragwerke die mit diesem Programm entworfen sind, erfüllen die Forderungen der nationalen Behörden. Die bautechnischen Anordnungen sind in das Entwurfsprogramm aufgenommen worden, was zu einem sehr komplizierten Problem geführt hat. Die Erfahrungen haben zu der Ansicht geführt, dass Entwurfsprogramme unabhängig und separat von Regeln und Forderungen in bautechnischen Anordnungen sein sollen.



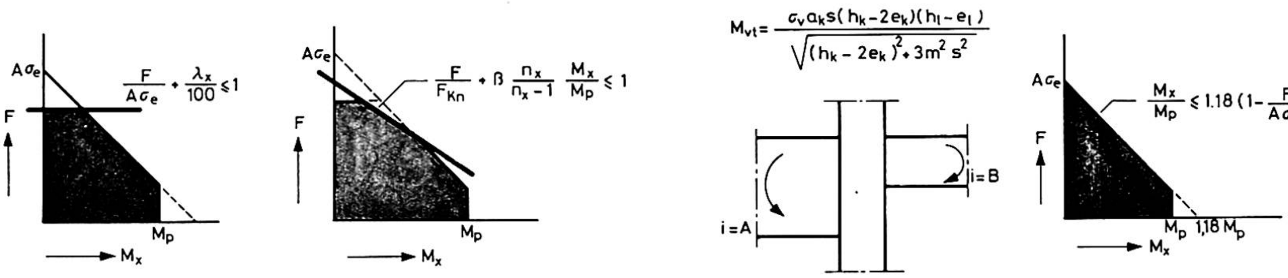
geometry and loading

fig.1



lineprinter plot

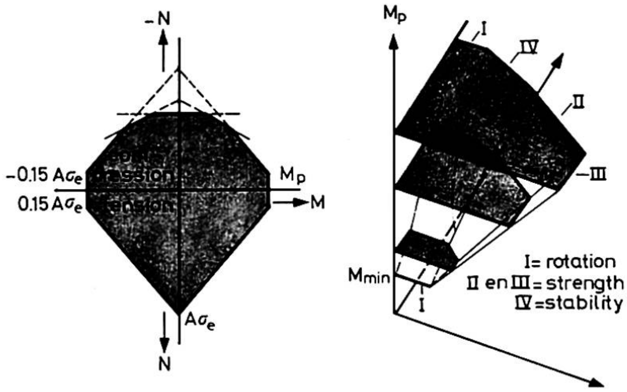
fig.2



rotationcapacity stability stiffeners strength

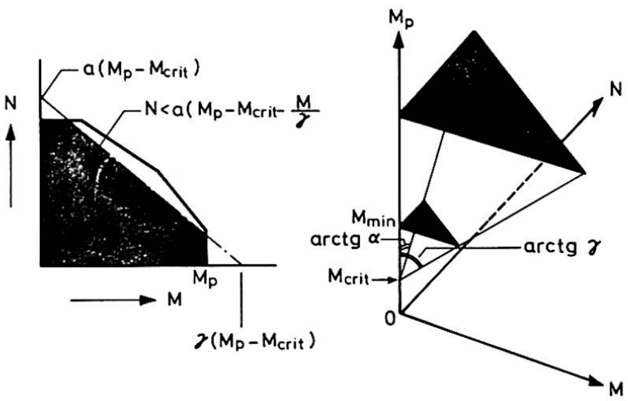
constraints

fig. 3



constraint surface

fig.4



approximate constraint surface

fig.5