FR 8400208

7. Conference on structural mechanics in reactor technology
Chicago, IL (USA) 22-26 Aug 1983
CEA-CONF--6979

APPLICATION OF A GLOBAL PLASTICITY MODEL TO DETERMINE THE ULTIMATE STRENGTH OF A REINFORCED CONCRETE SLAB

A. HOFFMANN - A. MILLARD - G. NAHAS

Département des Etudes Mécaniques et Thermiques
CEA - Centre d'Etudes Nucléaires de Saclay
91191 GIF SUR YVETTE CEDEX (FRANCE)

In order to predict the behaviour of composite beams and shells loaded up to failure, a global method has been developped.

This method is based on a generalized stress approach, formulated in terms of moment-curvature relations.

The case of a reinforced concrete slab subjected to uniform pressure has been considered. It is shown that numerical results compare fairly well with experimental data . Some improvements to the model are also suggested.

1. Introduction

In order to account for non linear behaviour of composite beams and shells, at a reasonable computer cost, global methods have been derived, based on a generalized stresses approach [1] [2] [3] . Such models are best fitted to carry out the limit analysis of structures, which is often required in view of nuclear safety requirements. One of the main advantages of the method is to use a generalized stress-strain curve in terms of moments and curvatures variations. The elaboration of such a global curve makes it possible to account for the local material properties at each point of the cross-section.

In fact, this technique can be seen as a particular application of an homogenization process. In order to demonstrate the efficiency of the method, it has been applied to the calculation of a reinforced concrete slab, for comparison with the experimental results.

2. Description of the experiment

2.1 - Geometry

A square plate, made of reinforced concrete, has been tested by the French Research Center for Civil Engineering (CEBTP) [4] . The plate was 250 cm large and 10 cm thick. It was simply supported on its boundary and clamped at the four corners. Since the plate was to be loaded by a uniform pressure, reinforcements had been placed close to the side which was supposed to be tensed (see fig. 1). Additionnal reinforcements had been placed at the four corners in order to prevent any untimely local fracture by punching, which would have reduced the limit load of the plate.

2.2 - Material

Stress-strain laws have been plotted either for the concrete in compression and for the reinforcements interaction. They are shown on figures 2 and 3. Moreover, concrete specimens have been made in order to measure the concrete tensile strength by a bending test. It was found to be :

$$\sigma_t = 2.15 \text{ MPa.}$$

2.3 - Loading and measurements

The plate was loaded through a step by step increase of the uniform pressure (see table 1). Deflections were measured at various points, as well as the crack openings along lines which had been drawn beforehand. Stresses in the reinforcements were also recorded. It may be noted that the reinforcements were initially compressed because of the concrete shrinkage.

3. Calculation

The calculation has been performed by means of the BILBO code [5] of the CEASEMT system. In view of the symetry, only a quarter of the plate has been meshed using 200 triangular thin shell elements and 121 nodes (see figure 4). Vertical translations were impeded on two edges, as well as all displacements at the outer corner.

Accounting for the isotropy of the reinforcements, the bending moment - curvature variation curve has been made for a unit width cross-section using the program SAMSON [3] . The main hypothesis in this process is that the cross-section remains plane. The non linearities due to the plasticity of the reinforcements, to the compressed concrete, and to the fracture of the tensed concrete, require an iterative scheme to calculate the neutral axis position. Afterwards, the bending moment corresponding to a prescribed curvature variation is computed by integration over the cross-section. (see figure 5)

Here, 30 integration points have been used ; two global curves have been determined, one using the measured tensile strength of the concrete, and the other assuming a zero tensile strength in order to account for existing precracks. It is clear that the real behaviour lies between these two curves, which are shown on figure 5 bis.

In the calculation, the large displacements effects have been accounted for.

4. Results

The calculated central node deflection has been compared, for the two previous global behaviour laws, to the experimental values.

From figure 6, the following remarks can be made :

- the non zero tensile strength hypothesis leads to a better description of the beginning of the load-deflection curve. This may be due to the fact that the concrete was not yet cracked.
- For large deflections, the experimental curve lies between the two calculated ones. This shows that the stiffness of the concrete between two cracks has an influence.

The development of fracture lines has been observed during the test : the first cracks appear at the center of the plate, and then spread around until new crack areas appear at the corners. When the pressure increases, these areas amalgamate along the diagonals of the plate. Figure 7 shows the final state of the unpressurized face. It compares well with the isocurves of the equivalent Von Mises stresses plotted on figure 8.

Knowing the generalized stresses in the elements, it has been possible, using the SAMSON code, to come back to the local stresses at the various points of the cross-section, and in particular in the reinforcements. They have been compared to some measured values, in the vicinity of the center of the plate (see figure 9).

The agreement is rather acceptable if the experimental curve is shifted to origin because of the initial compression.

5. Conclusion

The global method is a tool which is very well adapted to the limit analysis of non homogeneous shells and beams, as it is the case for reinforced concrete. Some improvements can be brought to the model :

- use of a criterion of "Johansen" type instead of a Von Mises Criterion. In the present study, the difference should not be important because of the isotropy of the reinforcements,
- use of various global behaviour laws in order to account for anisotropy of reinforcements and influence of twisting moments
- accounting for the shear forces in the yield criterion
- accounting for an adhesion loss between the concrete and the reinforcements.

References

[1] HOFFMANN A., "Modèles globaux de plasticité - Analyse limite de matériaux composites", Report CEA/EMT/75-36

[2] HOFFMANN A., LIVOLANT M., ROCHE R., "Plastic analysis of shells by finite elements methods - global plasticity model for any shapes of shells", Paper L 6/2-SMIRT 2, 1973

[3] HOFFMANN A. and al, "Quelques considérations simples sur les modèles globaux de plasticité"

[4] ROCHE R., HOFFMANN A. , "Global plastic models for computerized analysis" SMIRT 4, 1977

[5] MEROUANI C., Doctor-Engineer Thesis, Institut de Recherches Appliquées du Béton Armé, Paris, 1967

[6] CHARRAS T., "Programme BILBO - Système CEASEMT - Notice d'utilisation"

TABLE I

PRESSURES APPLIED TO THE PLATE

Load increment	p (t/m^2)
0	0
1	0.9
2	1.25
3	1.70
4	2.20
5	2.50
6	2.90
7	4.00
8	5.20
9	6.10
10	7.20
11	8.10
12	9.00
13	11.20
14	12.40
15	13.58

- LIST OF FIGURES -

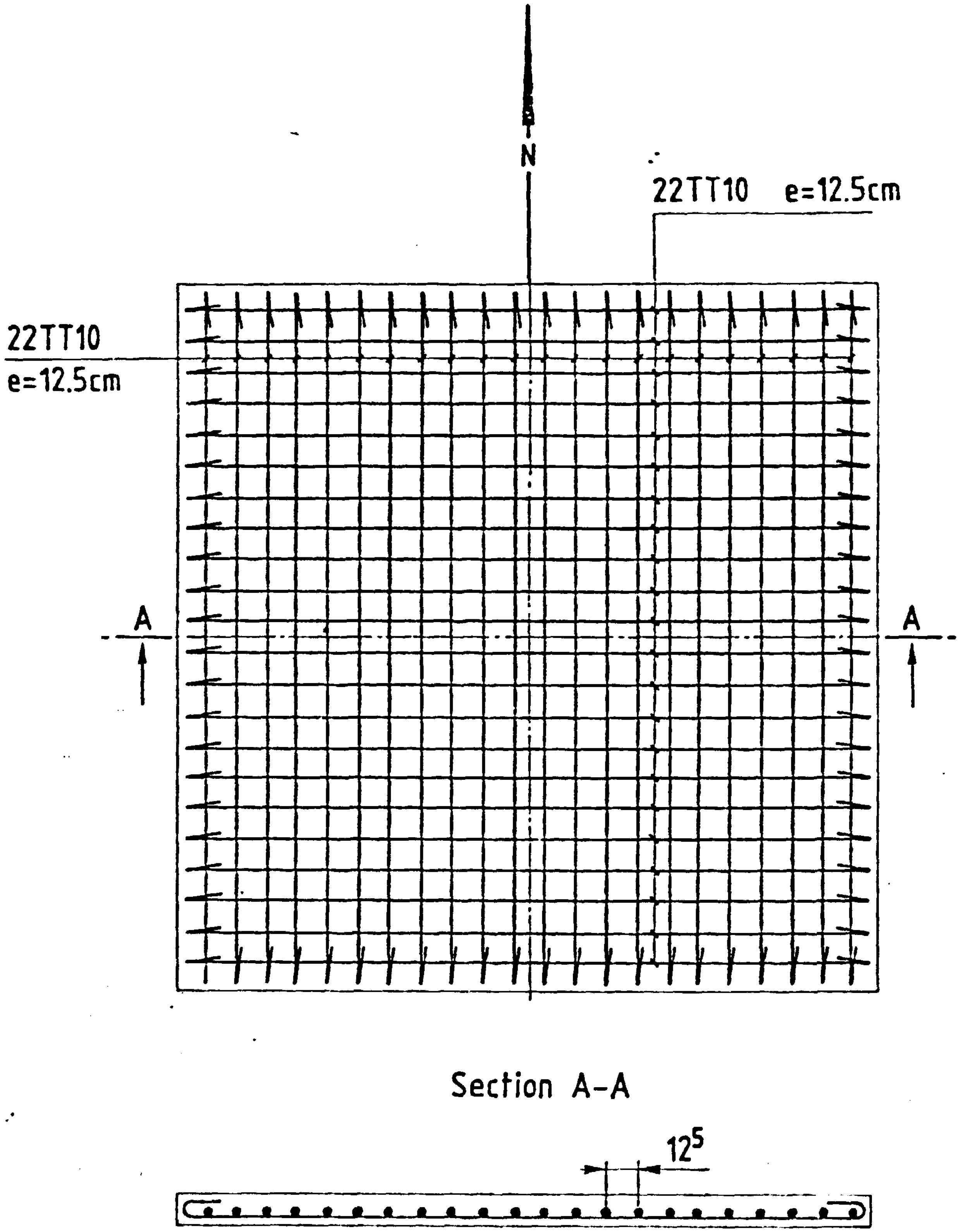
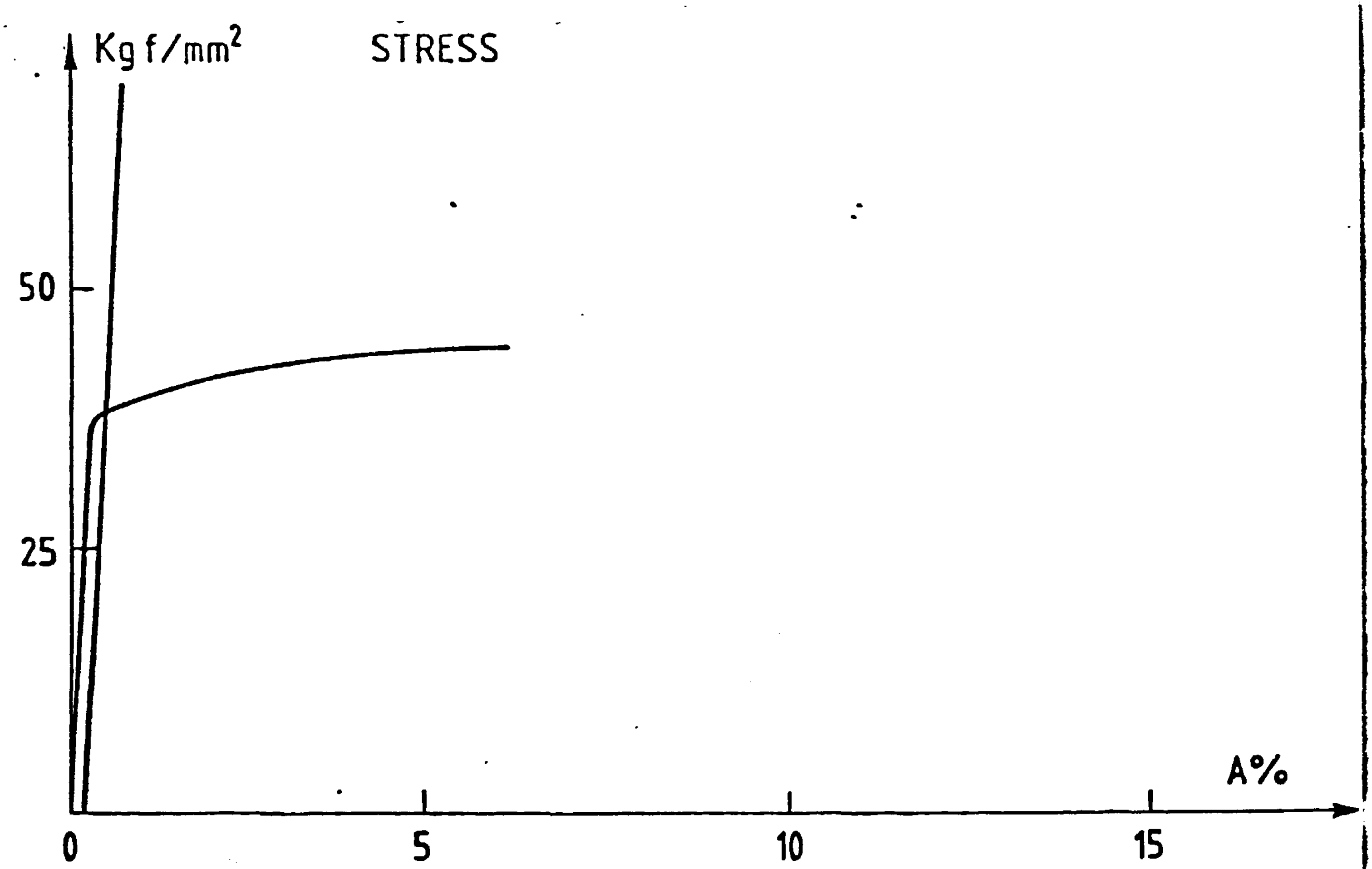
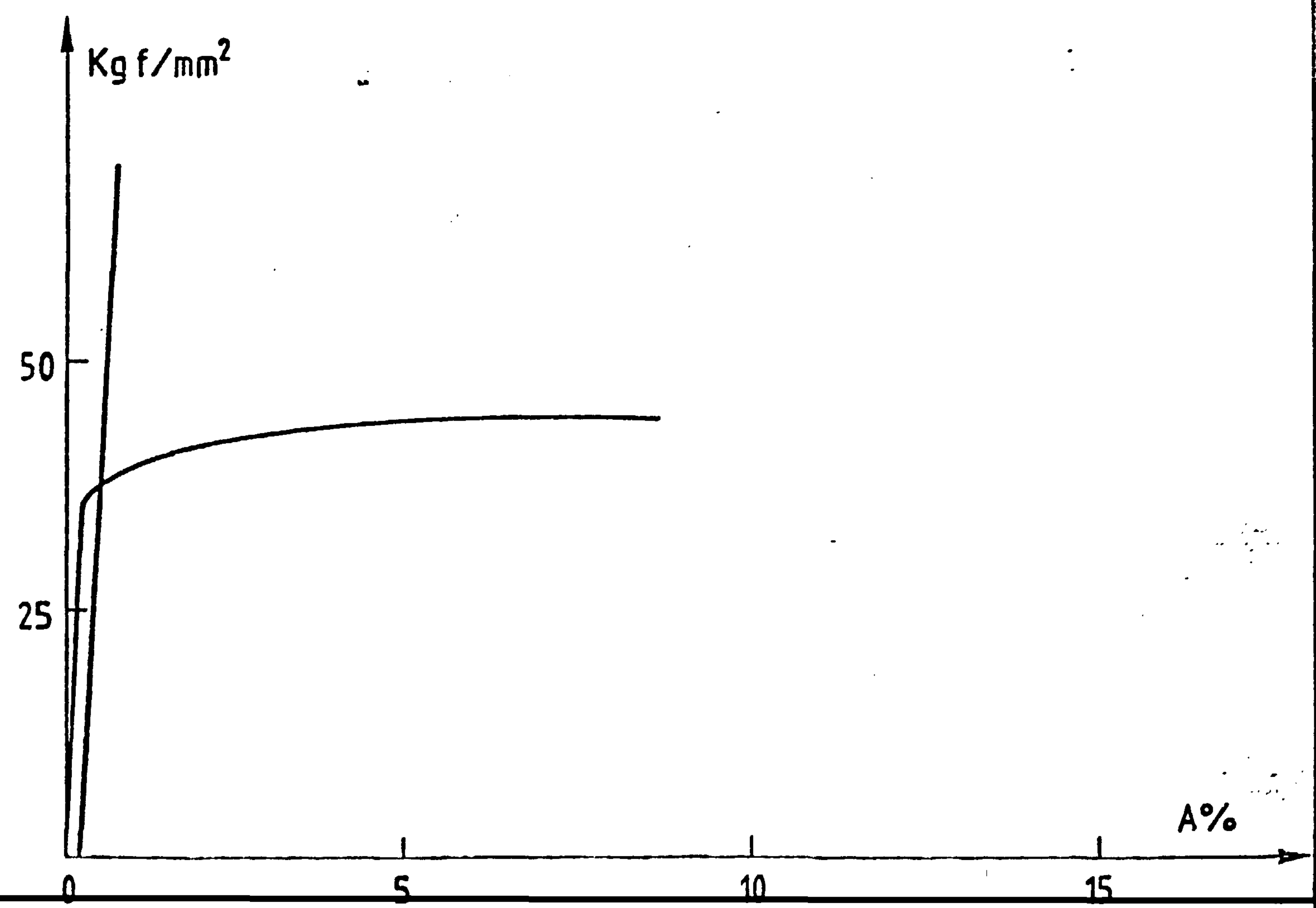


Fig. 1 - View of reinforcements


Kg f/mm2
STRESS
50
25
A%
0
5
10
15


Kg f/mm2
50
25
A%
0
5
10
15

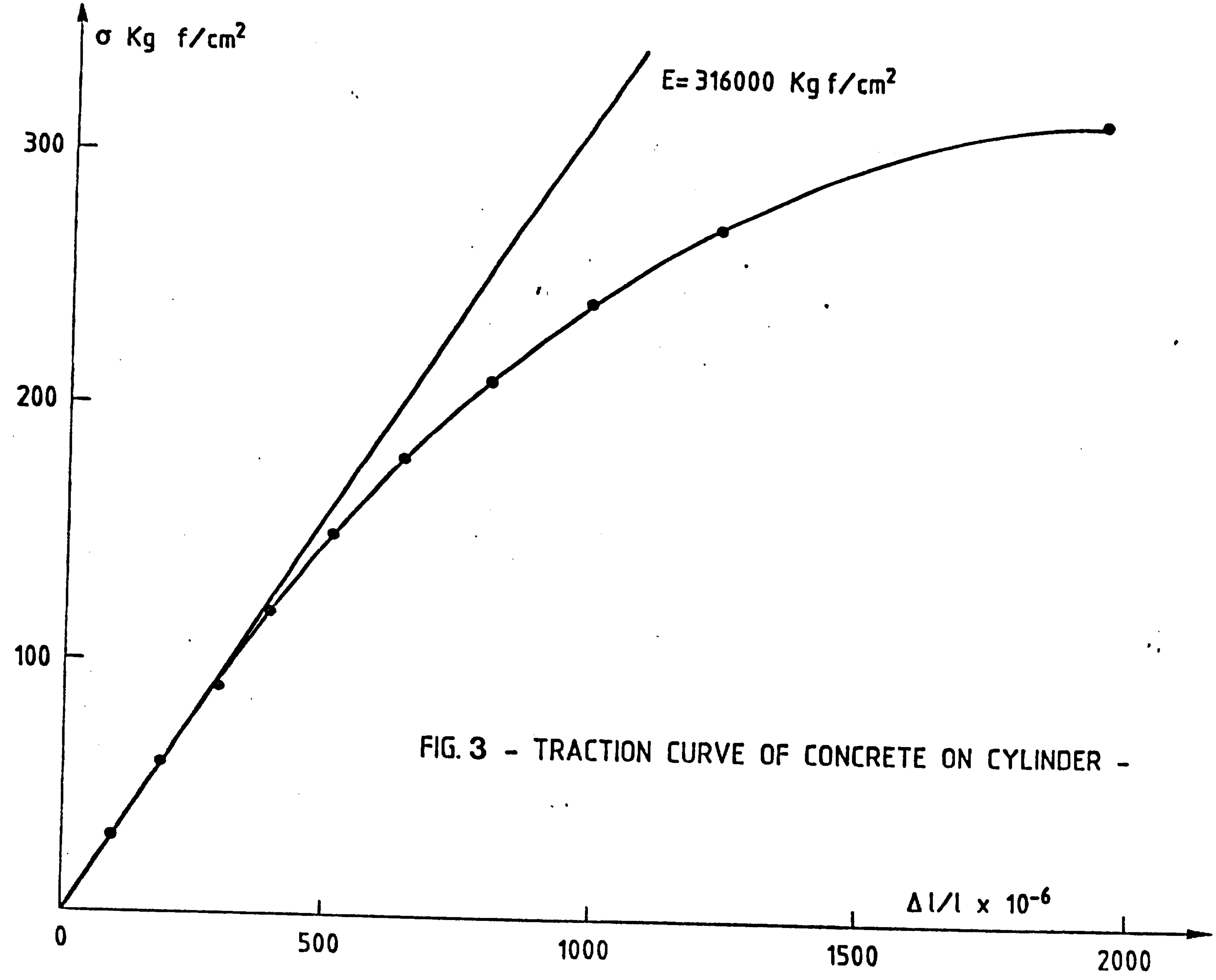


FIG. 3 - TRACTION CURVE OF CONCRETE ON CYLINDER -

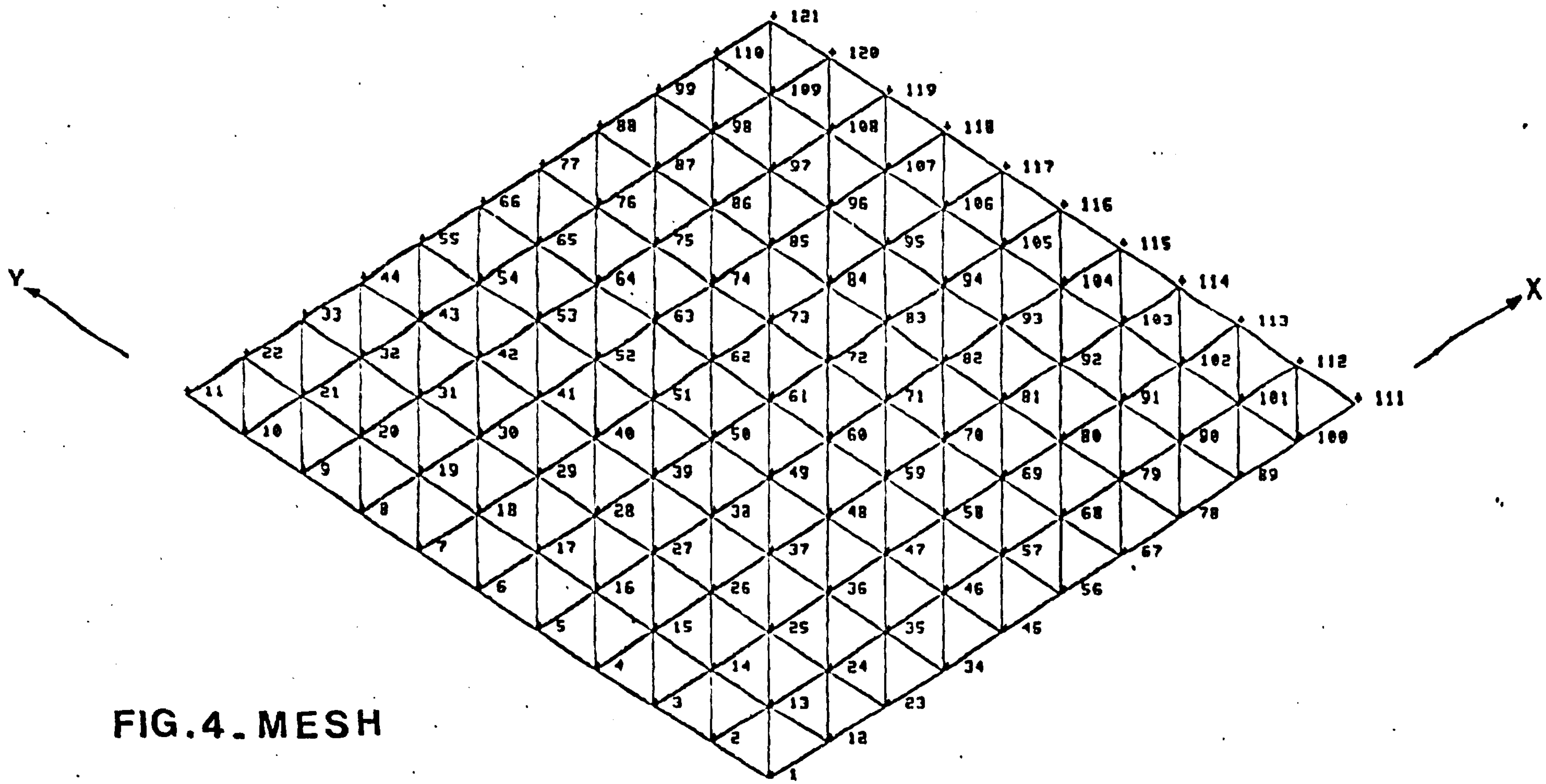


FIG.4. MESH

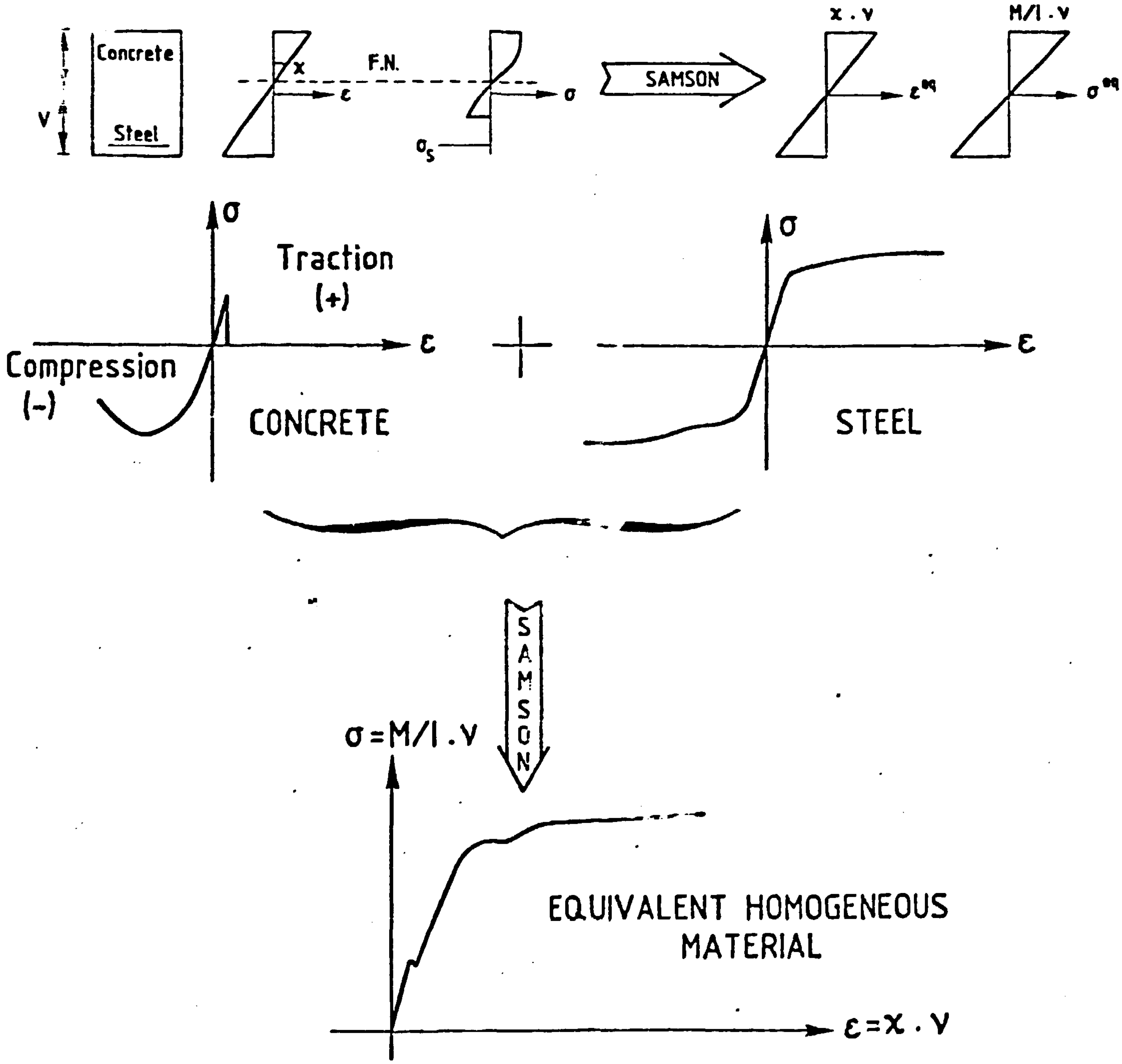


FIG. 5 - SAMSON CODE -

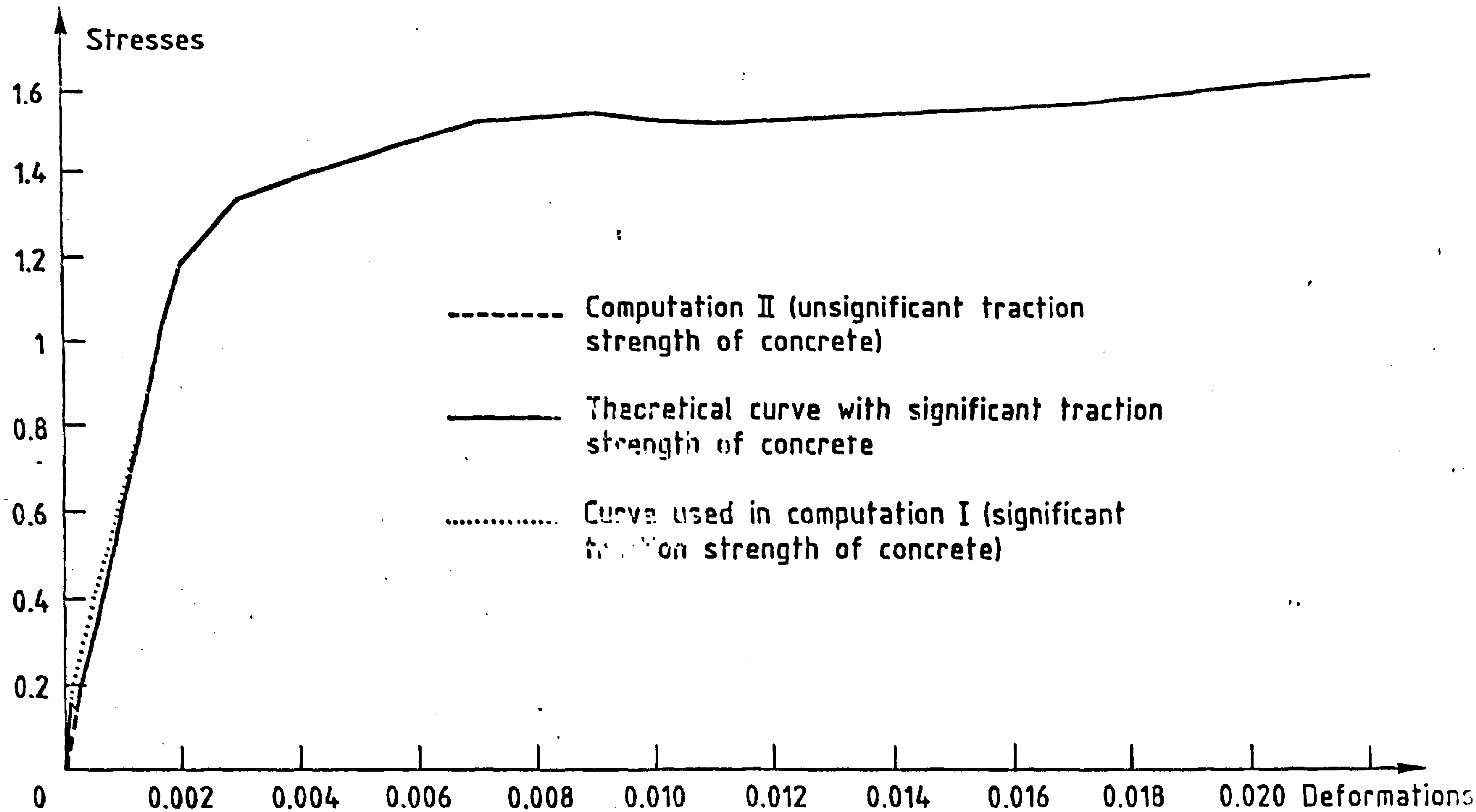


Fig.5bis_Stresses versus deformation of the equivalent homogeneous material for a two beds of steel section

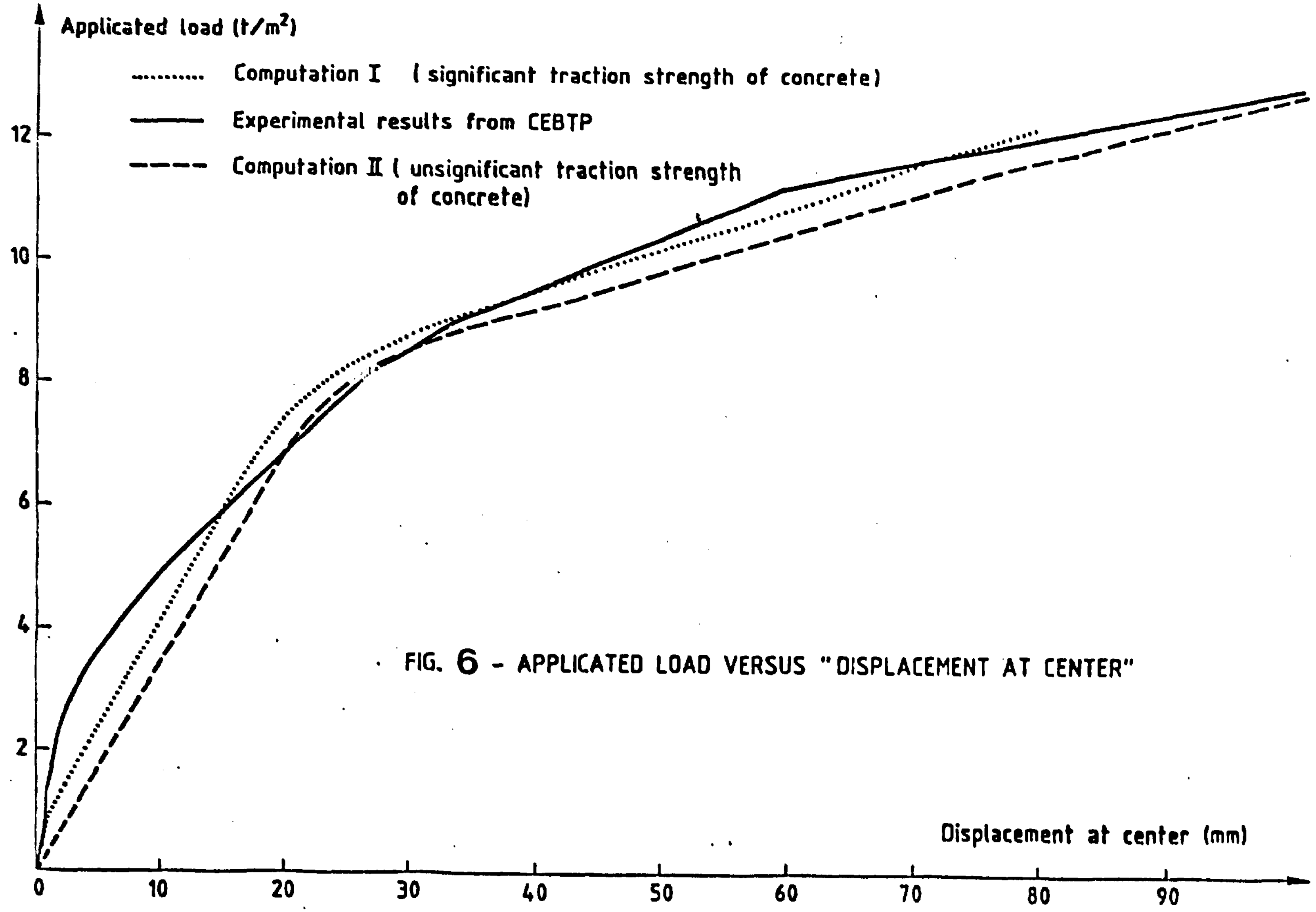


FIG. 6 - APPLICATED LOAD VERSUS "DISPLACEMENT AT CENTER"

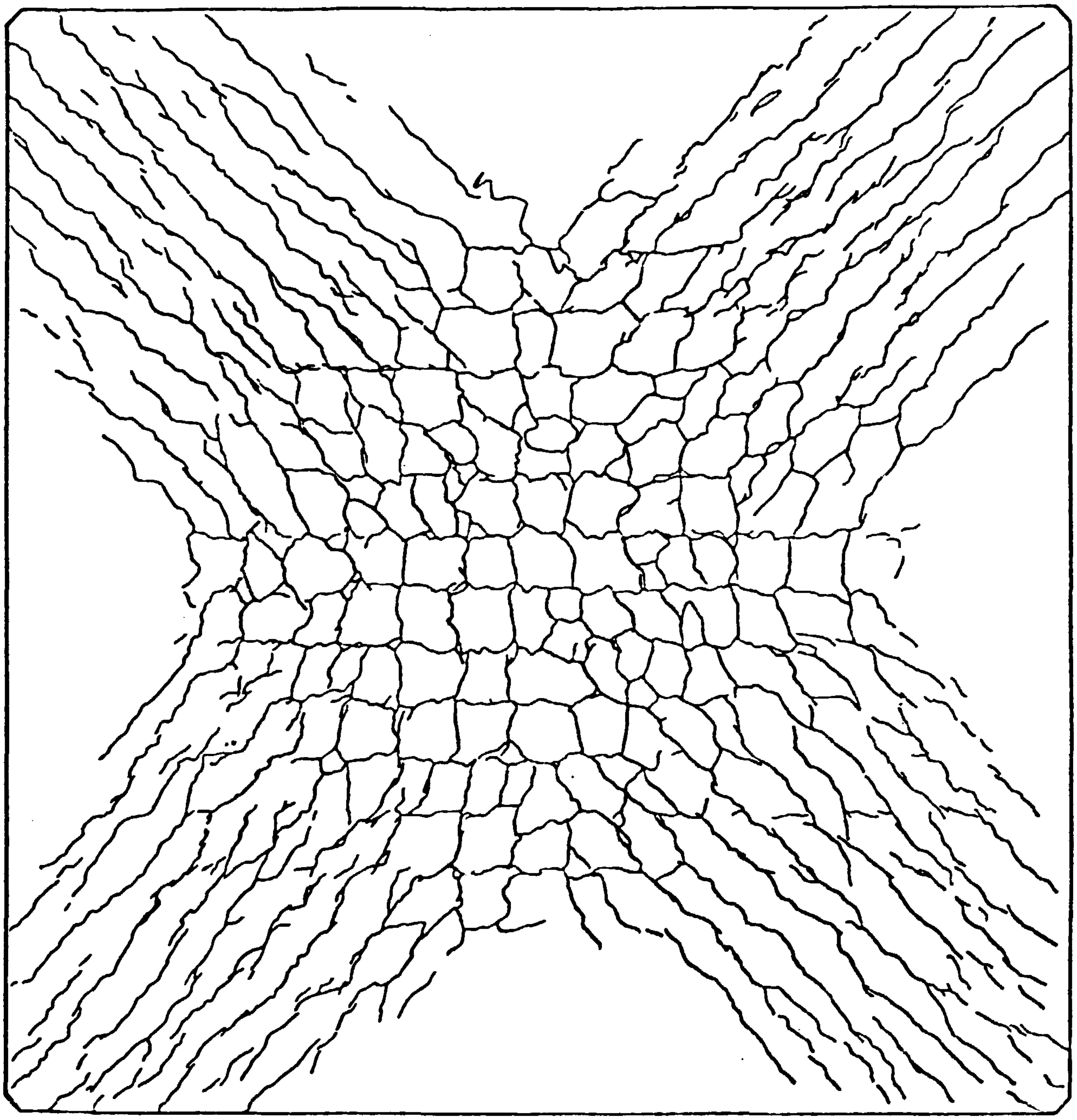


Fig. 7

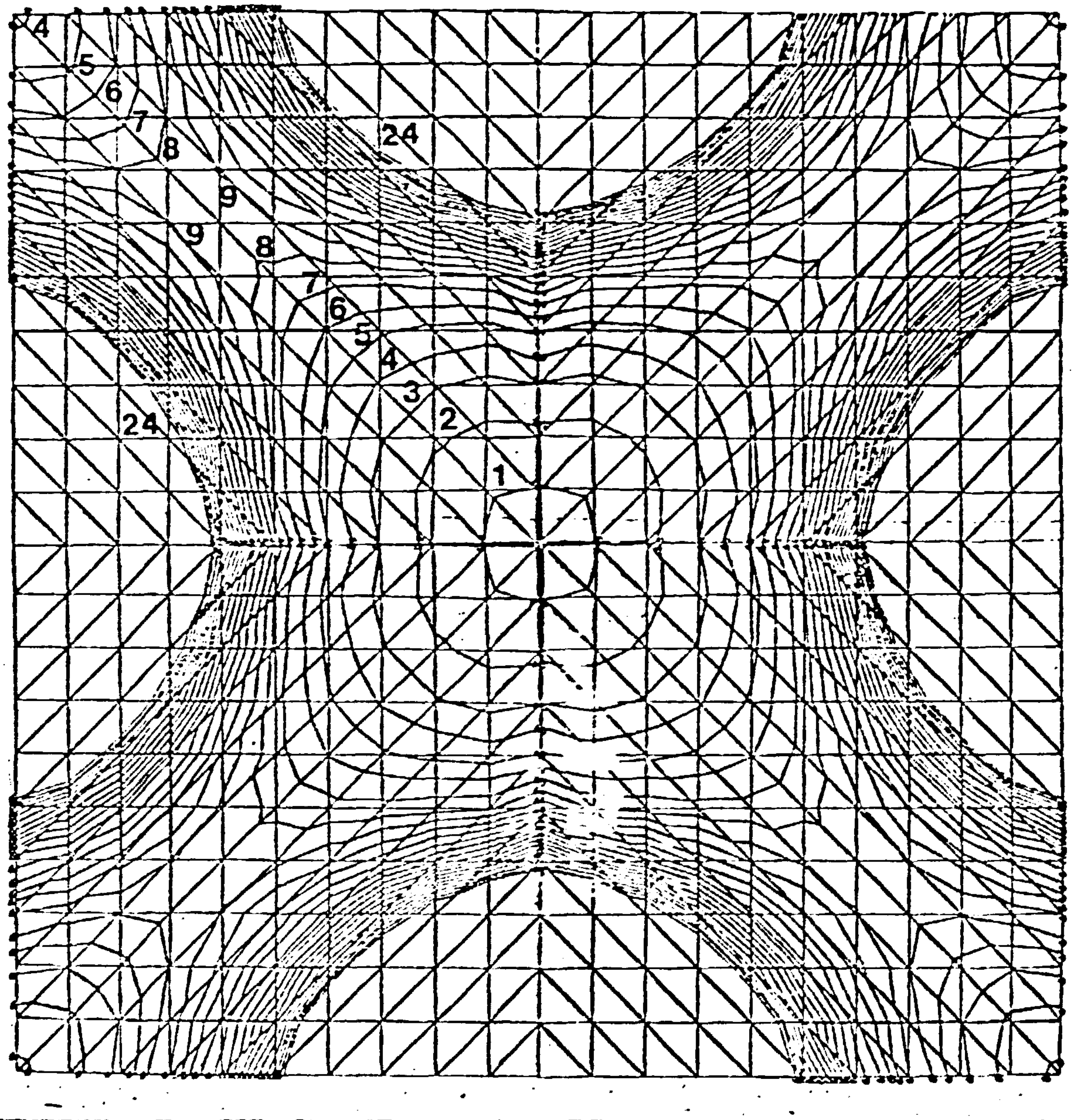


FIG. 8

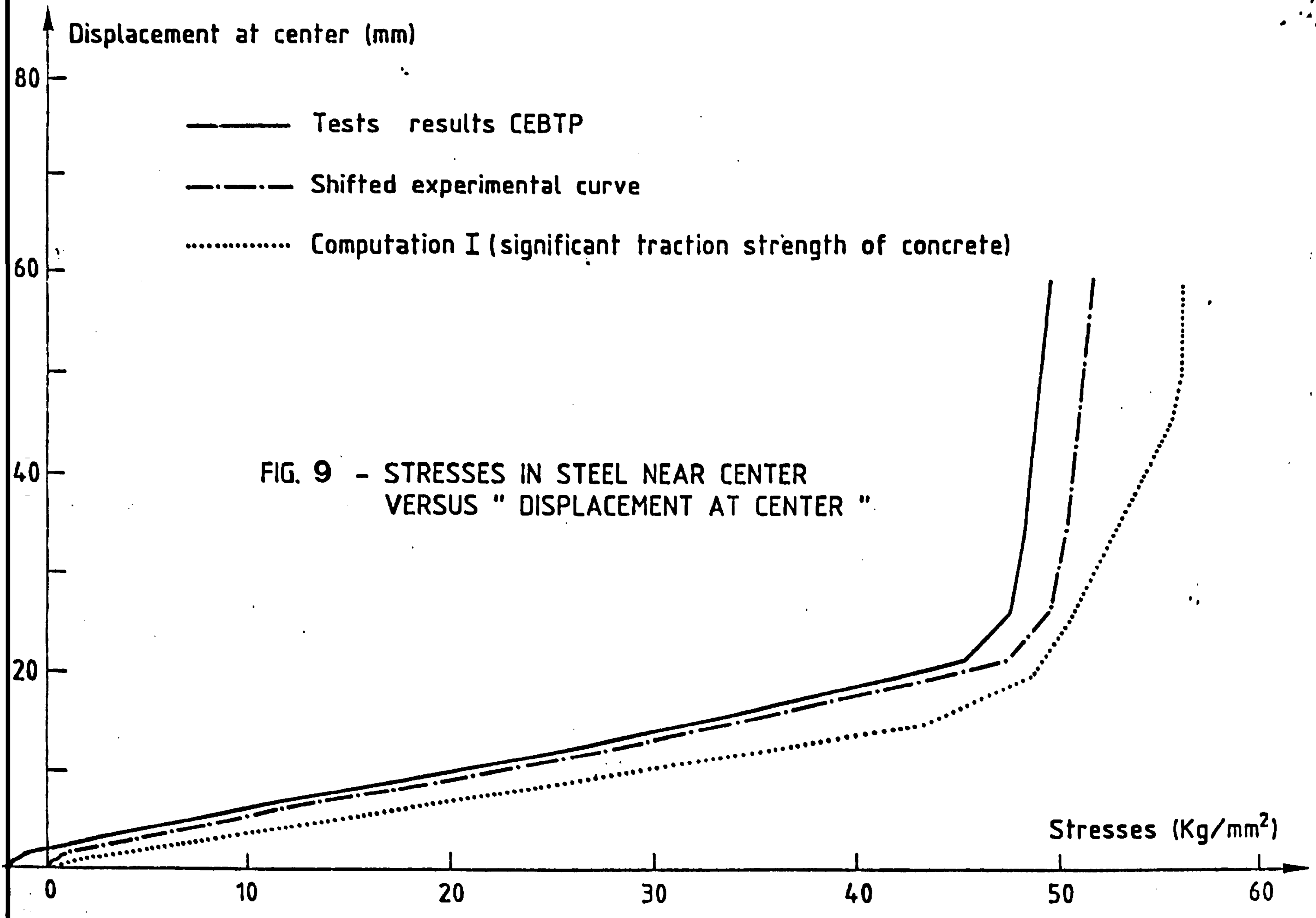


FIG. 9 - STRESSES IN STEEL NEAR CENTER VERSUS " DISPLACEMENT AT CENTER "