EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

NP Internal Report 75-9
12 September 1975

# NOTE ON THE STRESS DISTRIBUTION BETWEEN A BRITTLE WINDOW AND A PLASTIC SEAT

H. Bargmann, R. Baum and K. Ley

## ABSTRACT

Spherical shell windows for photomultipliers have been successfully used since several years at CERN. An elastic quartz window is placed into a quasi-conical plastic seat. The same design has recently been adopted by other people. It is in view of the safety hazards of these high-pressure installations that the formulae and rules for a correct design have been reported (Ref. 2). This note presents the outcome of a simple experiment which supports the theoretical predictions in Ref. 2.

GENEVA
1975

## 1. INTRODUCTION

Spherical shell windows for photomultipliers have been successfully used since several years at CERN$^{1)}$. Here, an elastic quartz window is placed into a quasi-conical plastic seat. The design of such a brittle window must ensure that no tensile stresses occur which could lead to catastrophic failure.

The same design has recently been adopted by other people. It is in view of the safety hazards of these high-pressure installations that the formulae and rules for a correct design have been presented$^{2)}$. To this end, the stress distribution between elastic window and plastic seat had to be studied in detail, and theoretical results have been derived. These results are not trivial; moreover, they are not necessarily unique. To simulate the actual window-seat structure, a simple experiment has been set up. In this note we present the experimental outcome which indicates the actual validity of the theoretical results.

## 2. ELASTIC WINDOW AND PLASTIC SEAT

We consider the problem of an elastic, spherical, shell-type window placed into a plastic conical seat, subjected to uniform external pressure. In addition to the membrane stresses, bending stresses will occur within the window which are essentially created by the friction between window and seat. Both edge friction and bending moment depend on the local stress distribution at the edge, which again depends on the plastic deformation of the seat.

As a simplified model we may consider the deformation of the plastic seat to be close to plane strain, and use the stress distribution which corresponds to the case of a plastic mass compressed between two rigid and rough plates whose planes are inclined to each other at a small angle $\alpha > 0$ $^{2)}$:

$$\left.\begin{aligned} \frac{\sigma_r}{k} &= -\frac{\pi}{2} - \frac{1}{\alpha}\log\frac{r}{a} + 2\sqrt{1-\left(\frac{\phi}{\alpha}\right)^2} \\ \frac{\sigma_\phi}{k} &= -\frac{\pi}{2} - \frac{1}{\alpha}\log\frac{r}{a} \\ \frac{\tau}{k} &= \frac{\phi}{\alpha} \end{aligned}\right\} a \le r \le a + \frac{h}{2} \qquad (1a)$$

$$\left.\begin{aligned}\frac{\sigma_r}{k} &= -\frac{\pi}{2} - \frac{1}{\alpha}\log\frac{b}{r} + 2\sqrt{\left(1-\frac{\phi}{\alpha}\right)^2}\\ \frac{\sigma_\phi}{k} &= -\frac{\pi}{2} - \frac{1}{\alpha}\log\frac{b}{r}\\ \frac{\tau}{k} &= 1 - \frac{\phi}{\alpha}\end{aligned}\right\} a + \frac{h}{2} \le r \le b \qquad (1b)$$

where $Y_s \sim 2k$ denotes the (tensile) yield strength of the seat material. This stress distribution and the corresponding slip lines are given in Fig. 1. Note that towards the ends of the slab there is a maximum shear deformation at one side (at the inner side of the upper end, at the outer side for the lower end), whereas at the opposite side the shear deformation is negligible. Naturally, Eqs. (1) cannot hold at the very ends of the slab, which are stress-free, nor they can hold at the centre. The theoretical prediction for the corresponding deformation of a quasi-orthogonal grid is shown in Fig. 2.

## 3. EXPERIMENTAL RESULTS AND CONCLUSION

As can be seen in Figs. 3 to 5, two plastic slabs (Plasticine) have been pressed between wedge-shaped elements, with a very small inclination $\alpha = 2°$. Figure 3 shows the undeformed slab with its quasi-orthogonal grid. Figures 4 to 5 give the actual deformations of the grid for successive loading. Note that towards the ends of the slab there is a maximum shear deformation at one side, whereas at the opposite side the shear deformation is negligible. Thus the experimental results are in good agreement with the theoretical prediction, Fig. 2.

## Acknowledgement

We would like to thank G. Muratori for valuable discussions on this matter.

## REFERENCES

1) G. Muratori, Private communication (1974).

2) H. Bargmann and G. Muratori, The design of high-pressure quartz windows (in preparation).

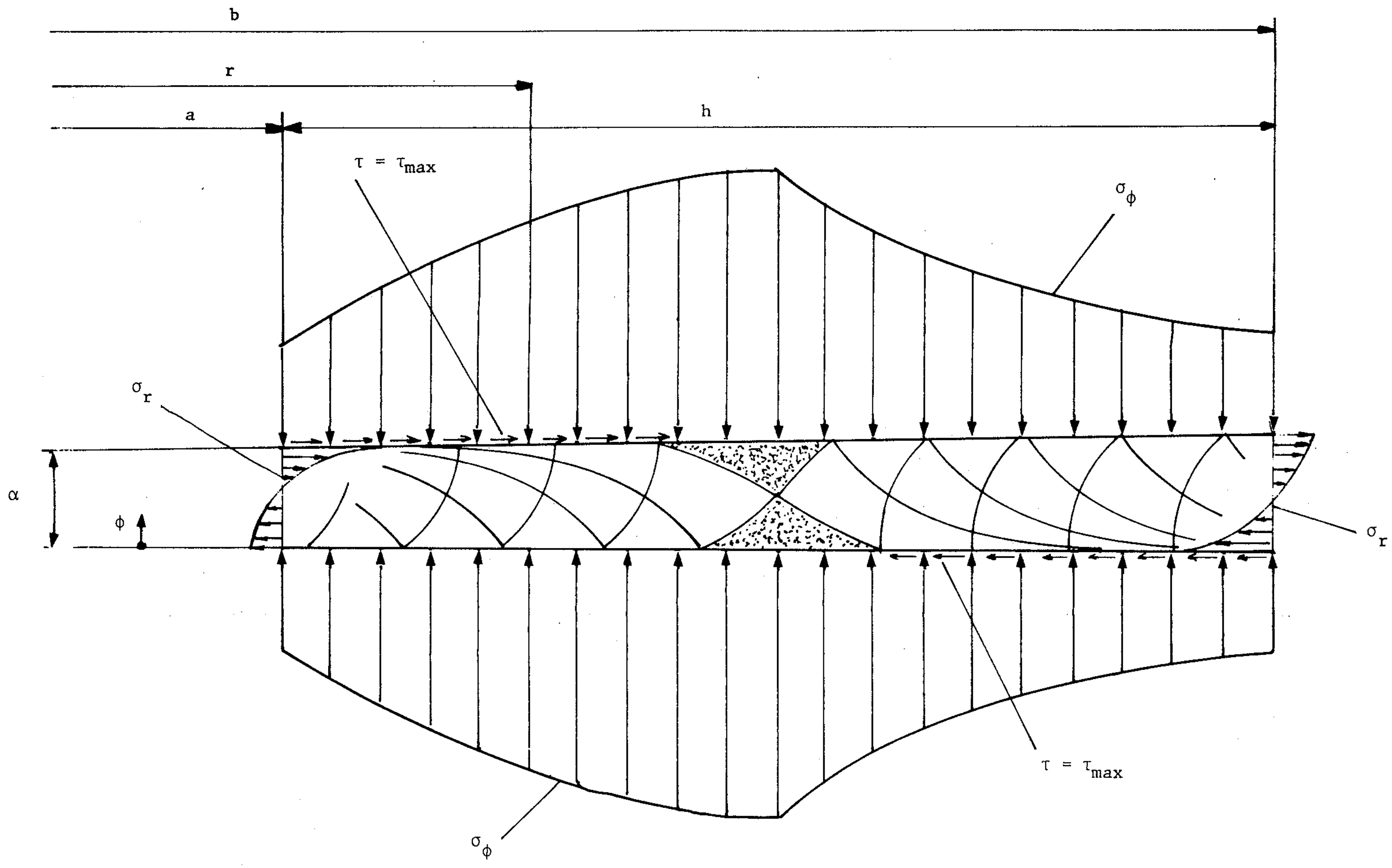

Fig. 1 Predicted stress distribution and slip lines in the plastic mass

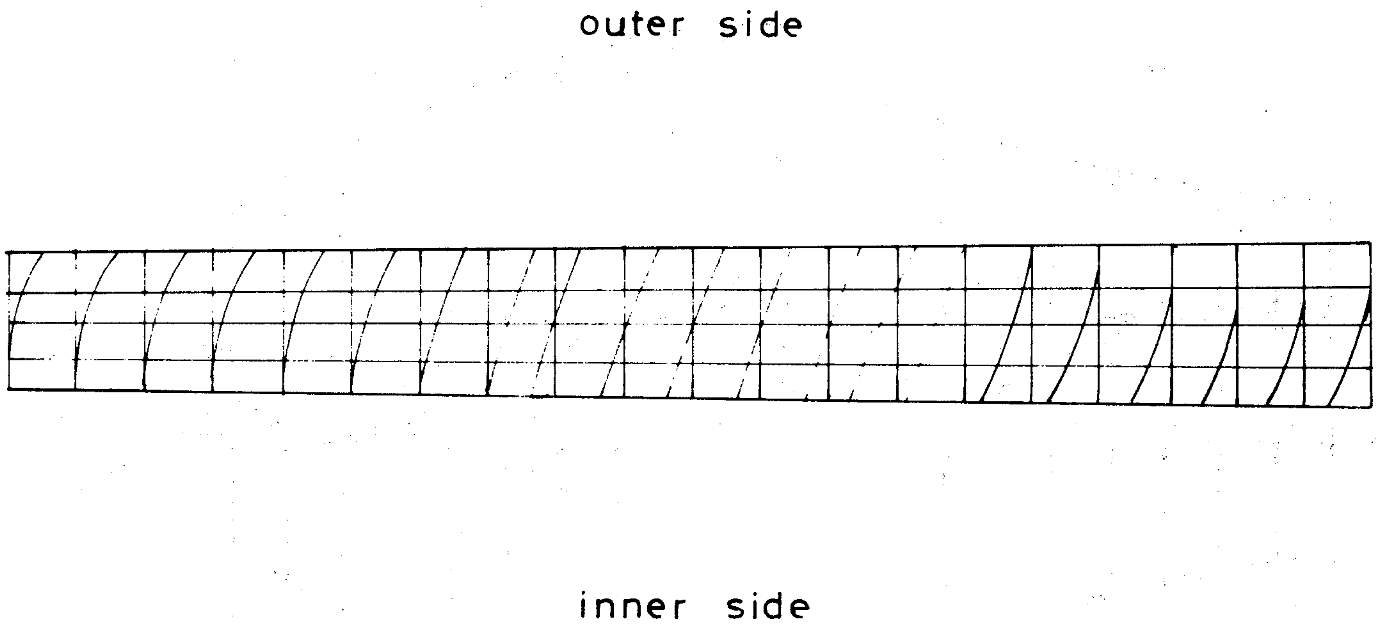

Fig. 2  Predicted shear deformation of the quasi-orthogonal grid

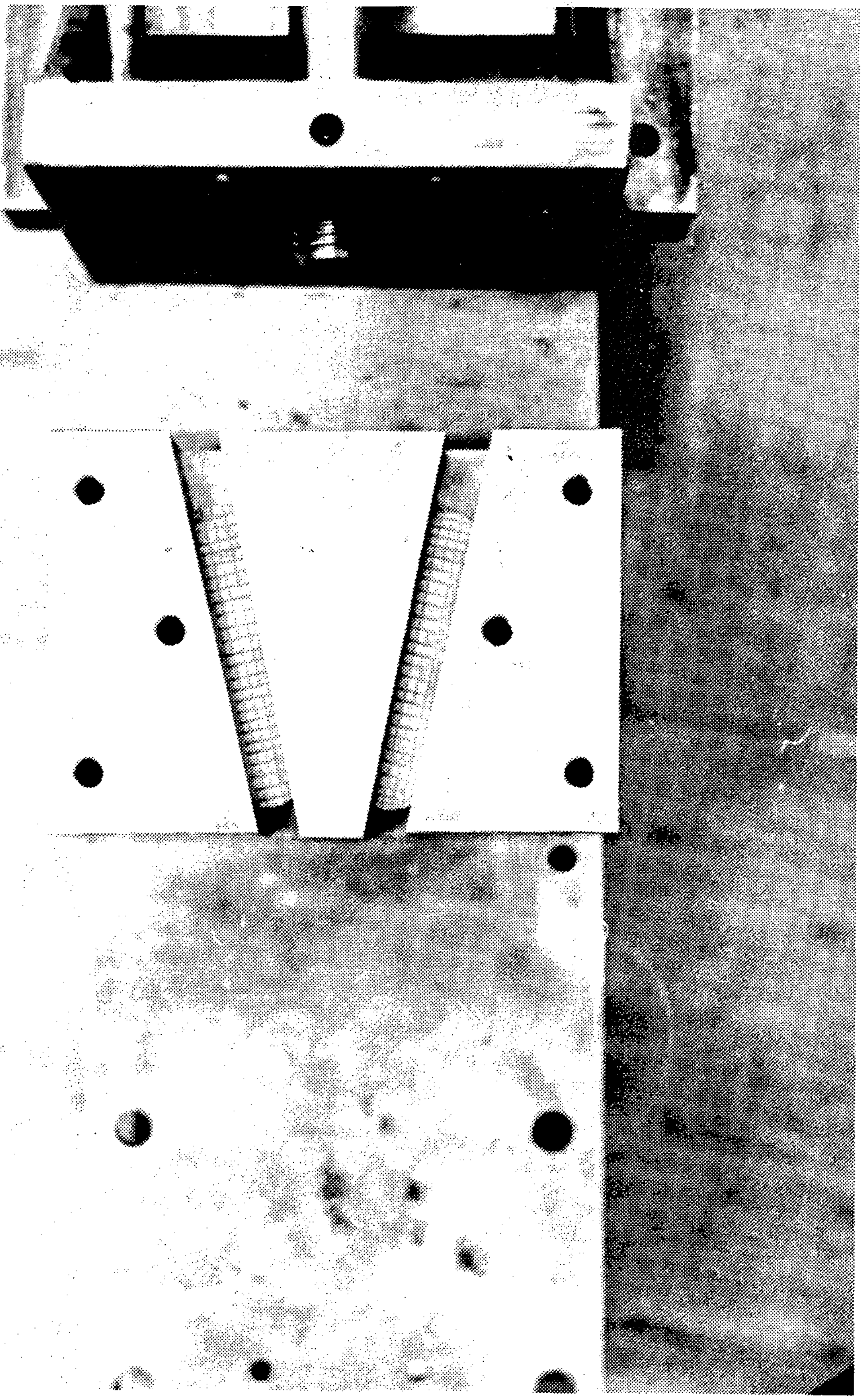

Fig. 3  Undeformed quasi-orthogonal grid

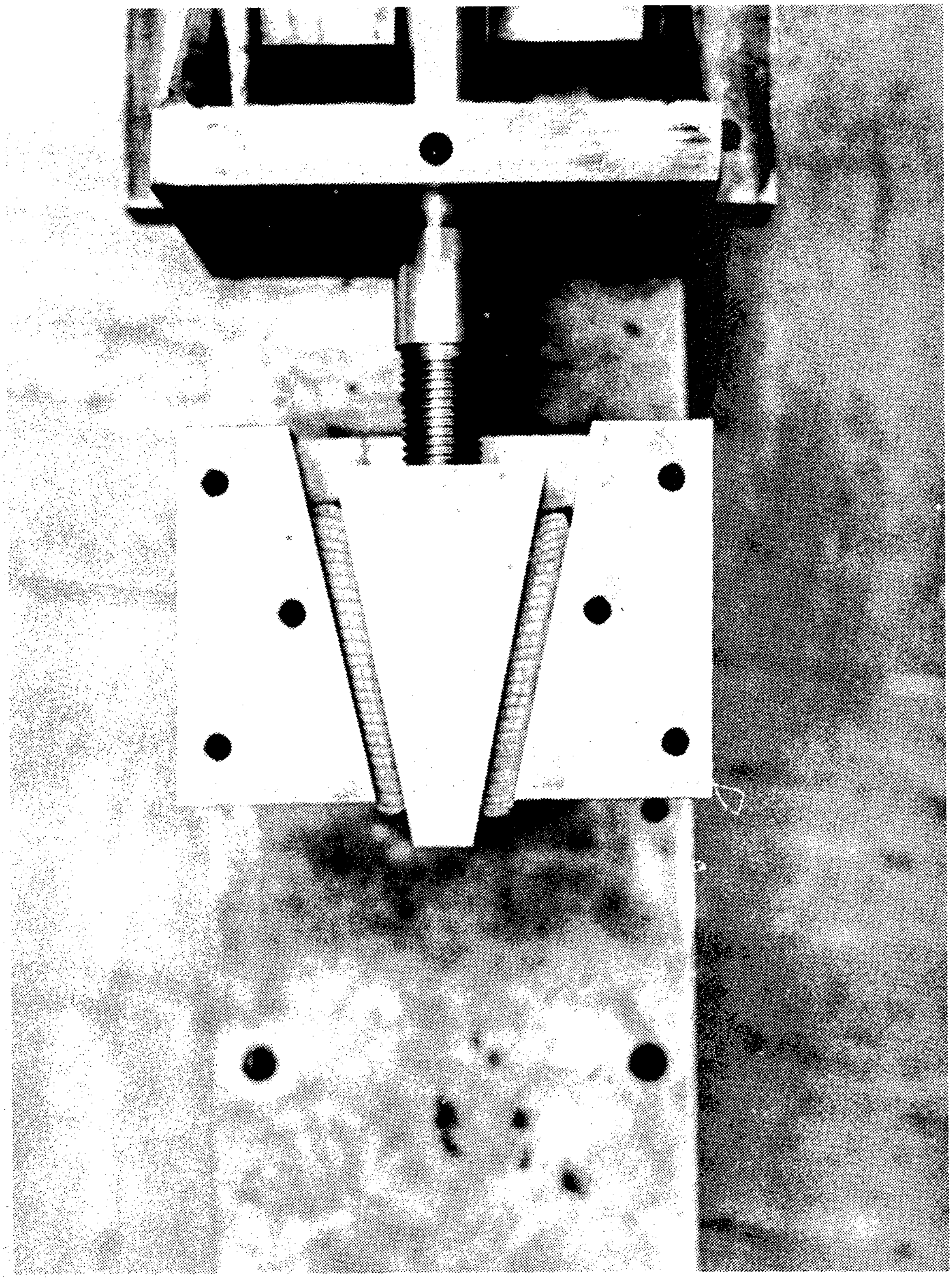

Fig. 4 Actual deformation of the quasi-orthogonal grid for successive loading

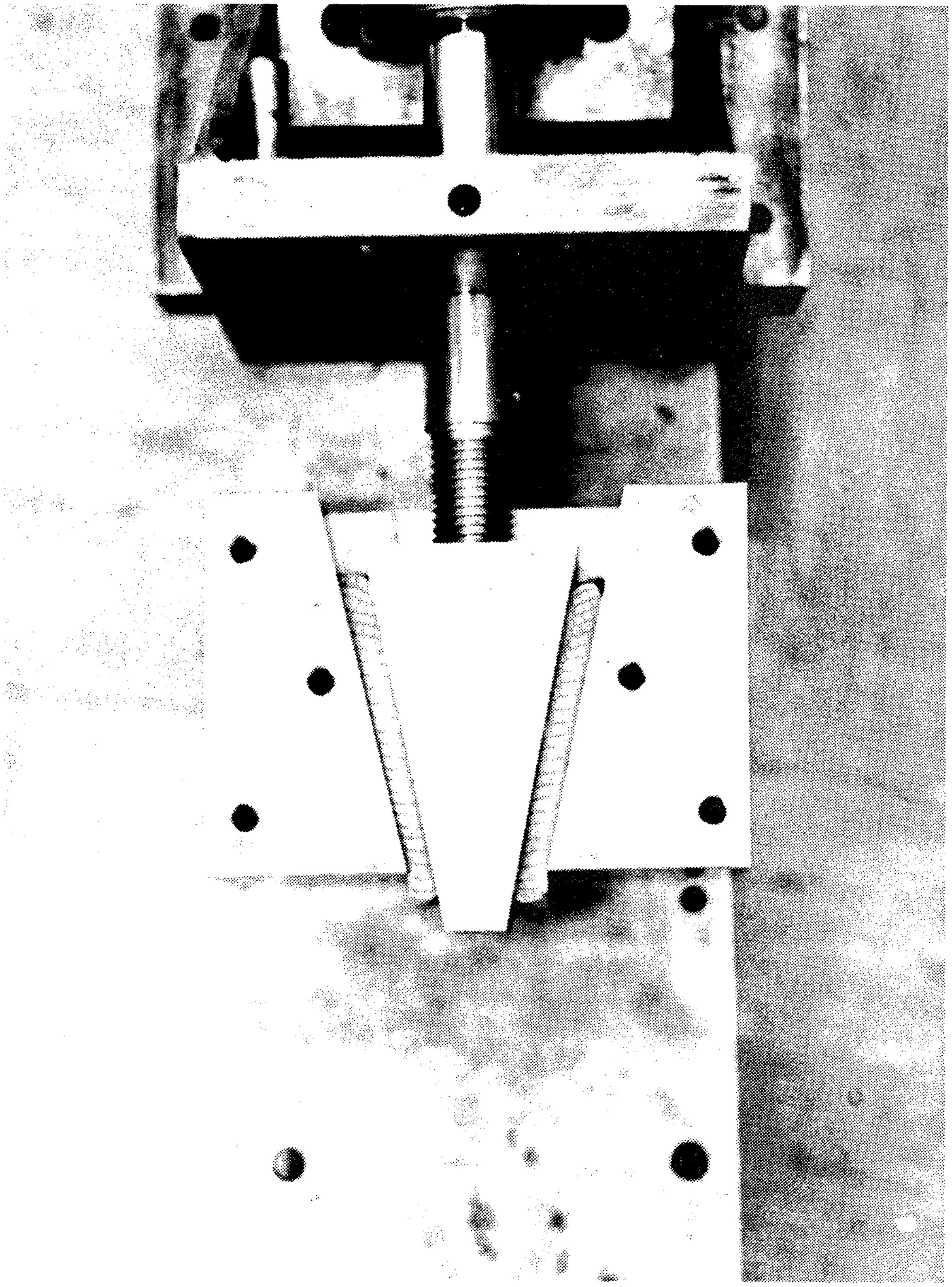

Fig. 5 Actual deformation of the quasi-orthogonal grid for successive loading