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Supplement - Complément - Ergänzung

A Generalised Method of Analysis of Elastic Plane Frames[1])

Une méthode généralisée d'étude des charpentes élastiques planes

Verallgemeinerte Berechnung ebener, elastischer Stabwerke

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It is important to note that the type of calculations described in the main paper can only be done by the use of a digital computer, i. e. that such a detailed description of the behaviour of a truss has not previously been obtained by any more formal type of mathematical analysis. Such an investigation differs from the process of using computers to speed up calculations which could otherwise be done by formal methods. The calculations are expensive to do and must be justified by studying whether or not the better physical picture obtained is worth the effort. Further information from the use of the program is therefore presented in this discussion.

Fig. 6 is similar to Fig. 5 but the computations are carried out for increased values of the load parameter. It is to be noted that the load in the compression member 5—3 remains substantially constant above W = 12 tons approximately, further increase of shear in the panel is carried by the tension web member 2—6. Similarly in the next panel the load in member 4—2 remains substantially constant above W = 15 tons, the additional shear being carried by member 1—5.

Fig. 7 presents load-rotation curves for the various joints as obtained by two types of analysis:

(a) Stability only,
(b) Stability bowing.

For the first type of analysis the distribution of axial loads in the members is based on the axial stiffness of the members when the effect of bowing is ignored. At low values of the load parameter the two types of analysis give substantially the same results but as the load parameter increases the beneficial effect of the transfer of axial loads due to bowing in reducing rotations can be clearly seen.

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[1]) See "Preliminary Publication" — voir «Publication Préliminaire» — siehe «Vorbericht», Ia 5, p. 87.

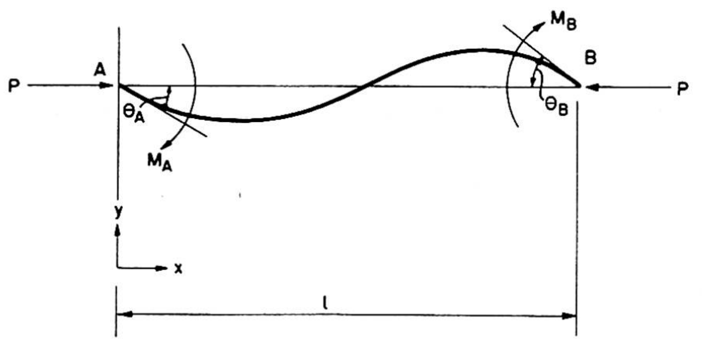

Fig. 1.

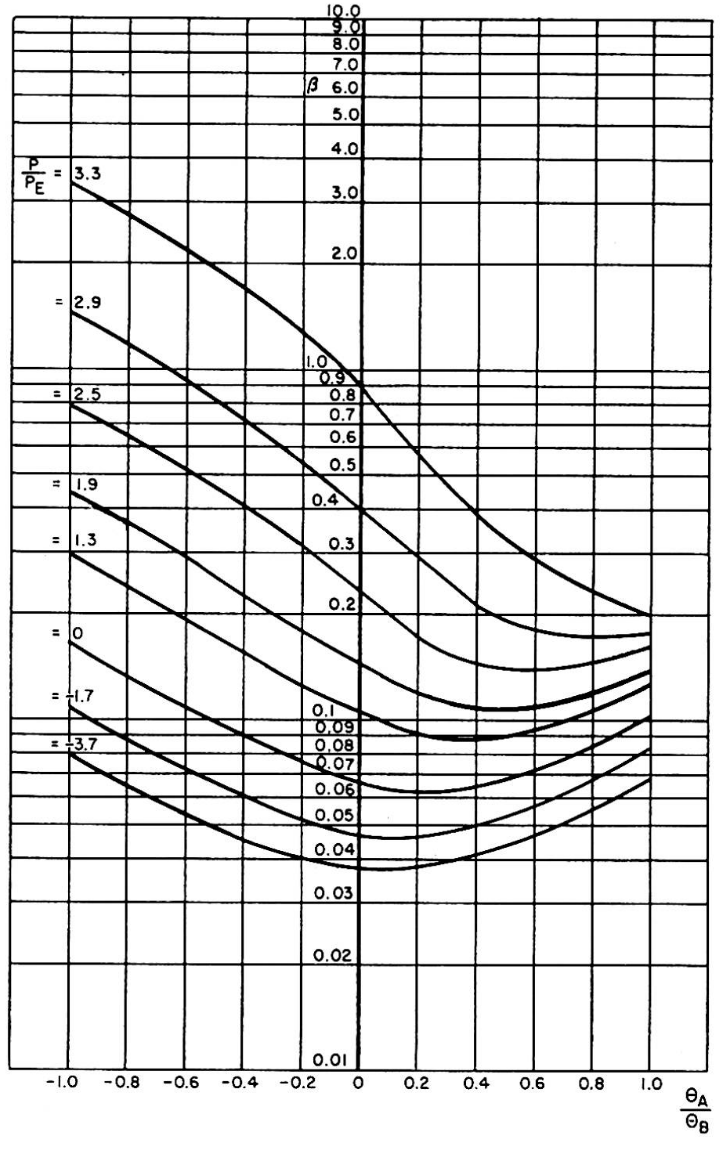

Fig. 2.

Fig. 8 presents the same information as Fig. 7 but in a different form. The Southwell plot method of estimating the critical loads of structures is well known [1]. For the Southwell method a plot is made of Δ/W against Δ where Δ is a typical deflection and over the region in which the component of the deflected shape of the structure in the first buckling mode predominates a straight line is obtained whose inverse slope is the critical load. For the same

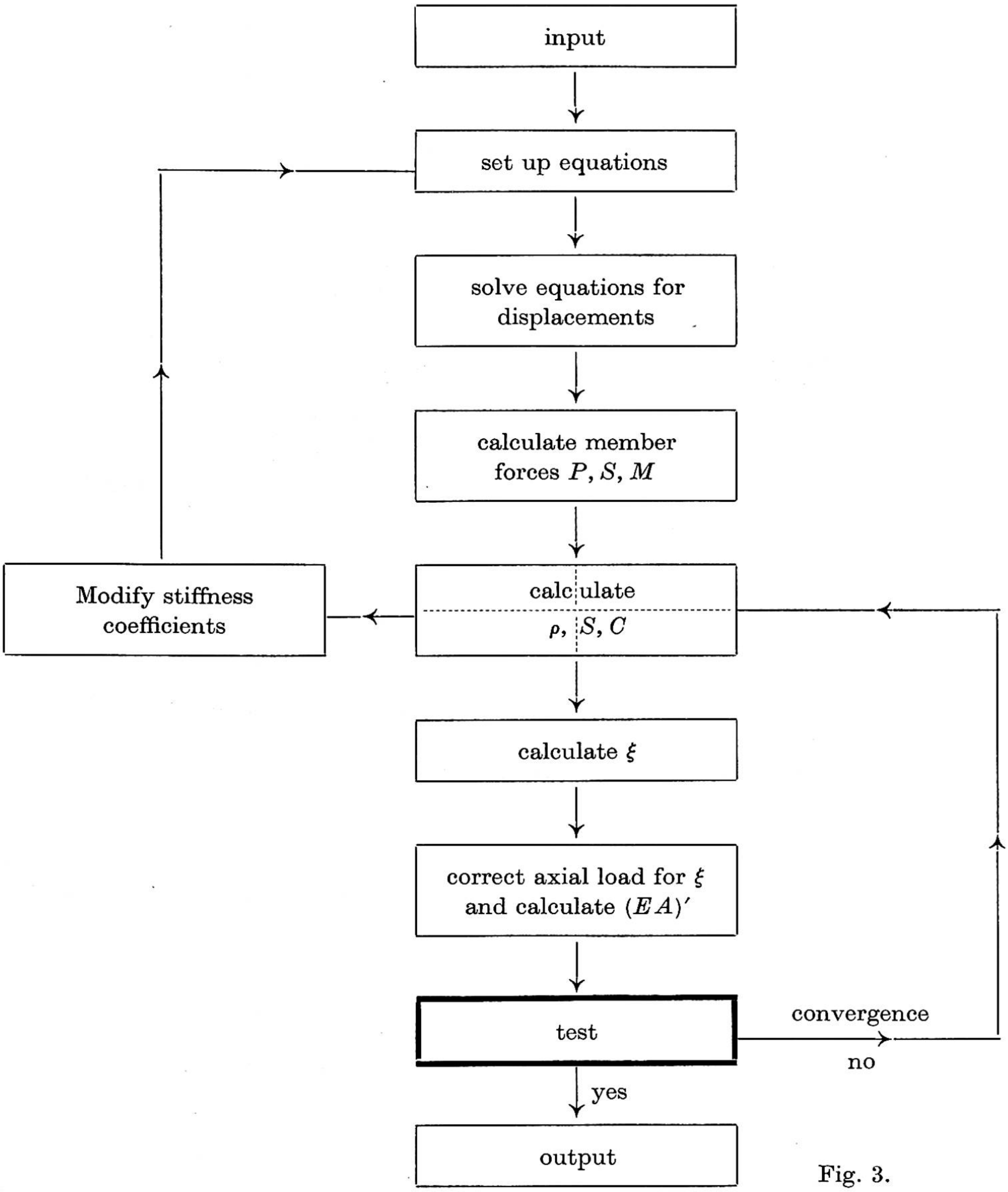
input
set up equations
solve equations for displacements
calculate member forces P, S, M
calculate ρ, S, C
Modify stiffness coefficients
calculate ξ
correct axial load for ξ and calculate (EA)′
test
convergence
no
yes
output

Fig. 3.

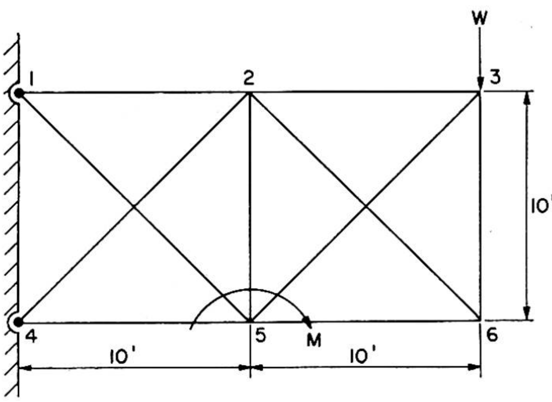
W
1
2
3
4
5
6
M
10'
10'
10'

Fig. 4.

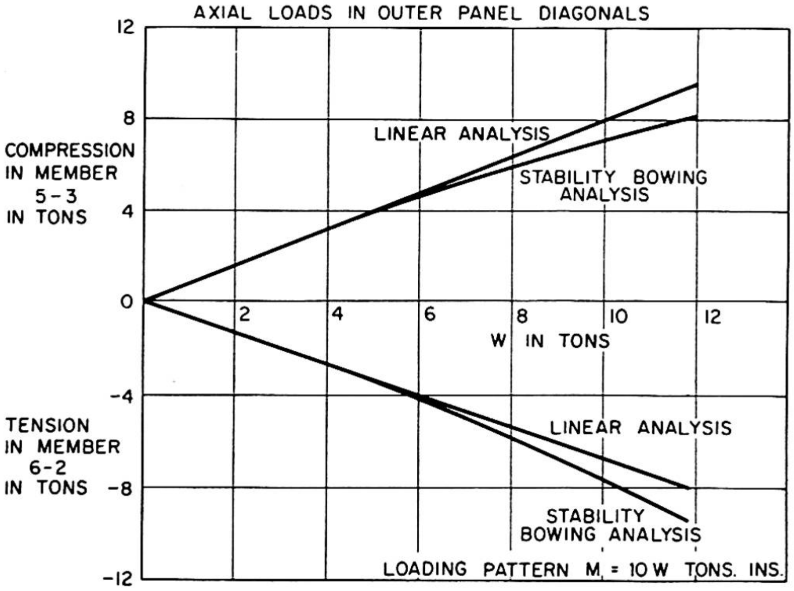

Fig. 5.

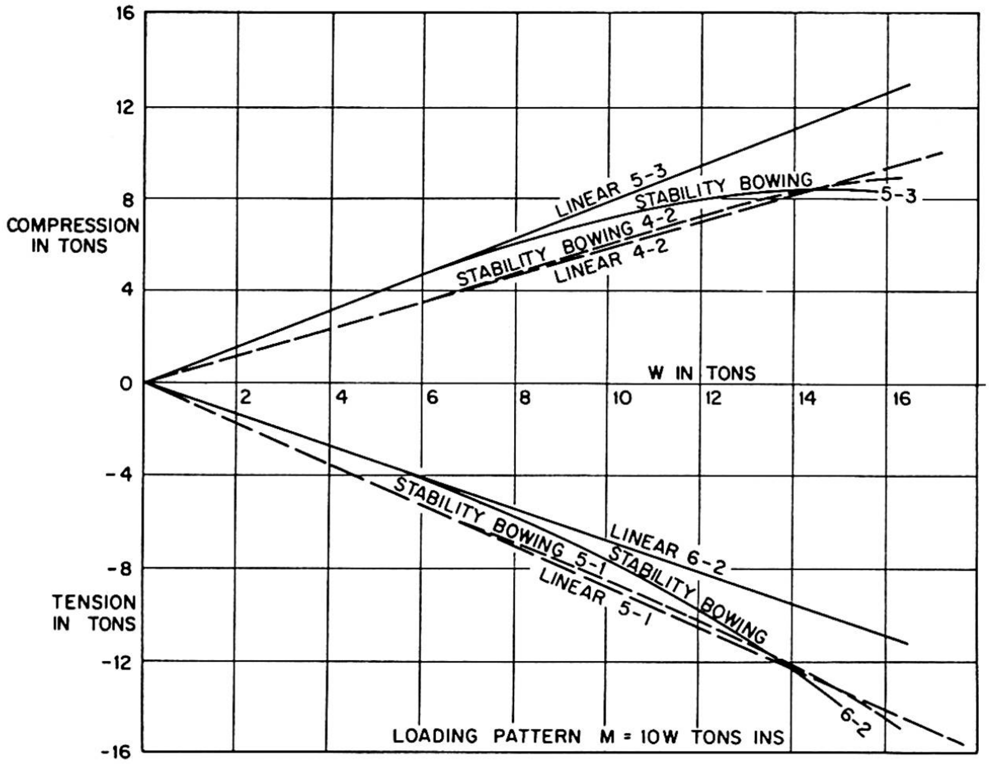

Fig. 6. Axial Loads in Panel Diagenals.

conditions for which the Southwell plot holds a linear plot of Δ/W against W also holds intercepting the load axis at the critical load. This plot is termed the inverse Southwell plot [2] and Fig. 8 shows such curves as determined by the computer. It is to be noted that for the stability analysis only joints 2 and 3 would give a reasonable Southwell plot indicating the critical load over a useful range of the load parameter. In other words the deflected shape of the truss due to secondary stresses does not contain a large component of the first buckling mode. Even where the Southwell plot is not applicable the buckling load is still given by $W/\Delta = 0$ and the beneficial effect of bowing in postponing buckling is clearly seen from Fig. 8.

The relevance of the redistribution of axial loads depends on at what stage in the growth of the joint rotations interaction with plasticity occurs. Further work is required on this aspect. The information presented in the original paper and this discussion includes a rather large moment applied at joint 5. This was chosen to assist in the convergence of the calculations. Convergence

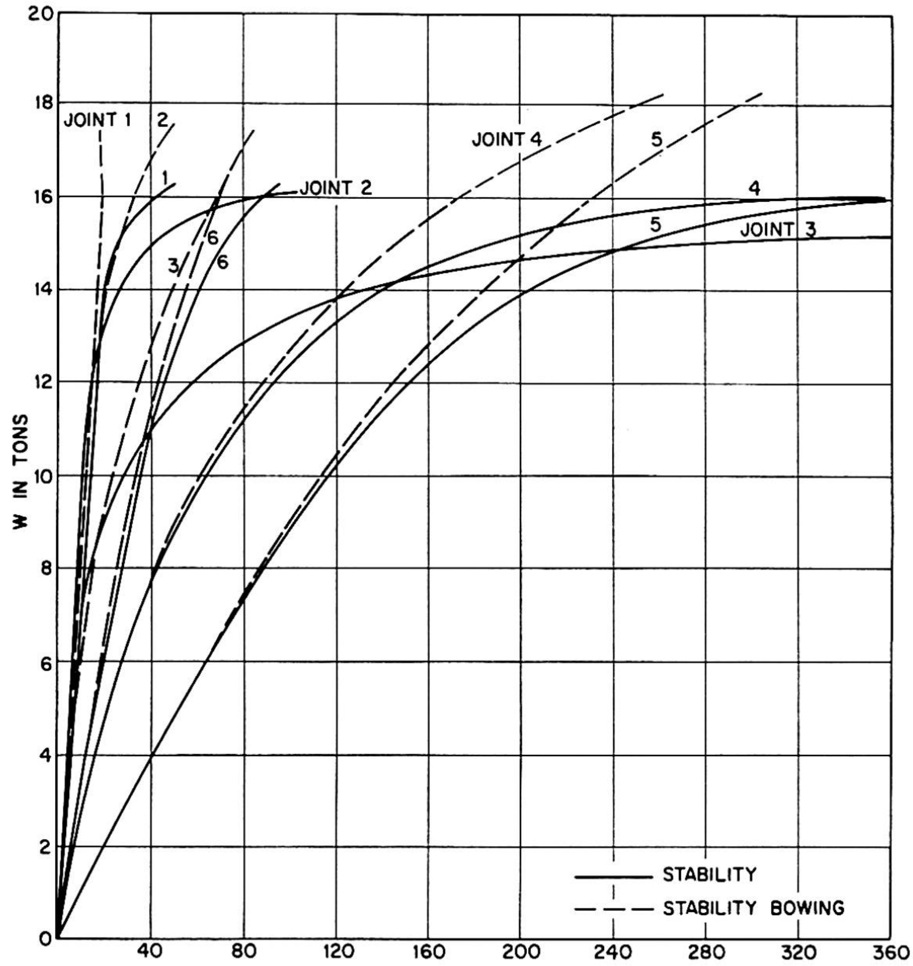

Fig. 7. Joint Rotations in Mins.

has not yet been obtained for the case of no moment at joint 5 and the effect of initial imperfections has also still to be considered. It is submitted that the physical insight obtained by being able to follow the load shedding from compression web members to tension web members numerically justifies the use of digital computers in such investigations.

For the further computation covered by this discussion we are indebted to Mr. M. A. Millar, Experimental Officer in the Department of Structural Engineering.

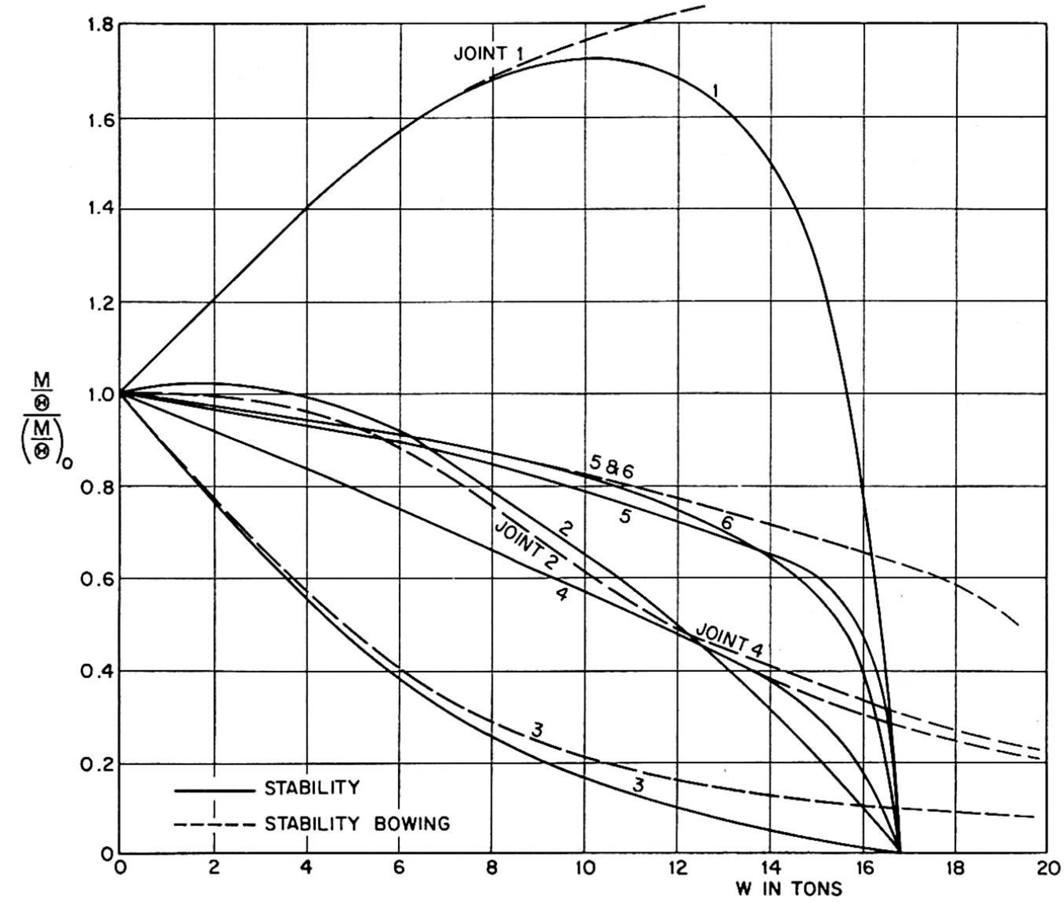

Fig. 8.

References

1. R. V. SOUTHWELL: "Theory of Elasticity". Oxford University Press, 1941.
2. M. R. HORNE and W. MERCHANT: "Stability of Frames". Pergamon Press. To be published 1965.

Summary

This discussion presents further information on the non-linear behaviour of the truss which was described in the main paper. The analysis is extended to the point where the additional shear due to the increase in load is carried entirely by the tension diagonals. Curves of joint rotations and inverse Southwell plots illustrate the beneficial effect of bowing in postponing buckling.

Résumé

Cet exposé fournit quelques renseignements supplémentaires sur le comportement non-linéaire de la ferme décrite dans la première étude. L'analyse s'étend jusqu'au point où l'effort tranchant supplémentaire dû à l'accroissement de la charge est supporté entièrement par les diagonales tendues. Des graphiques donnant les rotations aux nœuds ainsi que les tracés réciproques de Southwell servent à illustrer l'effet favorable qu'exercent sur le flambement les variations de longueur dues à la courbure.

Zusammenfassung

Dieser Beitrag enthält weitere Angaben zum nichtlinearen Verhalten des im Hauptteil der Arbeit behandelten Fachwerkes. Die Untersuchung erstreckt sich auf den Punkt, wo die infolge der Vergrößerung der Last zusätzlich auftretende Querkraft von den Zugdiagonalen allein aufgenommen wird.

Die Darstellung der Knotendrehwinkel im Verhältnis zur Lastzunahme sowie die reziproken Southwell-Diagramme veranschaulichen den günstigen Einfluß der Stabverkürzung infolge der Ausbiegung auf die Verzögerung des Ausknickens.

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