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Post-buckling of Simply-Supported Square Plates

Voilement post-critique de tôles carrées à support articulé

Überkritisches Beulen einfach aufgelegter Quadratplatten

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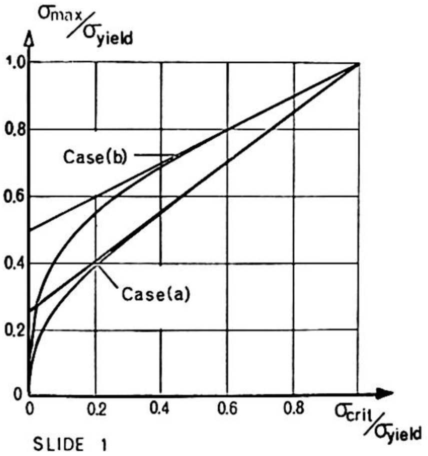
This contribution is concerned with the post-buckling behaviour of simply supported square plates. The in-plane conditions are that the loaded edges are straight and for unloaded edge we take
Case (a) the edges are free to wave; Case (b) the edges are straight but may move bodily.

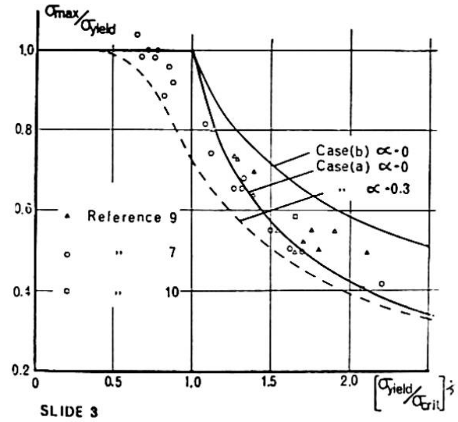
The problem is formulated mathematically in terms of the von Kármán equations which are then reduced to a series of simultaneous cubic algebraic equations by assuming series for the deflection and the stress function. Now, however, instead of solving these algebraic equations exactly we use a perturbation method to obtain a sequence of approximations which may be shown to give results almost identical to those of Levy and Coan who solved the equations by successive approximations. The advantage of the perturbation technique is that it results in explicit expressions for the deflection and stress distribution in terms of the applied and critical loads for the plate.

By employing a simple collapse criterion, namely that collapse occurs with the onset of yield on the longitudinal edge, it is possible to obtain explicit expressions for the collapse loads. Slide (1) shows the results; in this the straight lines come from the first approximation in the perturbation technique, the second approximation may be shown, by comparison to previous results, to be sufficiently accurate up to a load three to four times the critical load. It should be noted here that the parameters $\frac{\sigma_{max}}{\sigma_{yield}}$, $\frac{\sigma_{crit}}{\sigma_{yield}}$ occur naturally in the mathematics of the problem and fully confirm Chilver's intuitive use of them.

A generalised geometric imperfection may be included in the analysis such that its amplitude is proportional to the reciprocal of the buckling stress, then for Case (a) we obtain the dotted line in Slide (2). In this α is·the



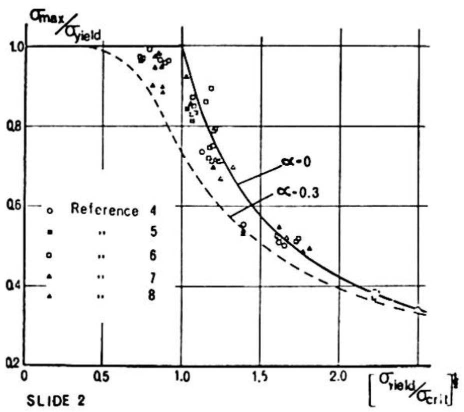
SLIDE 1



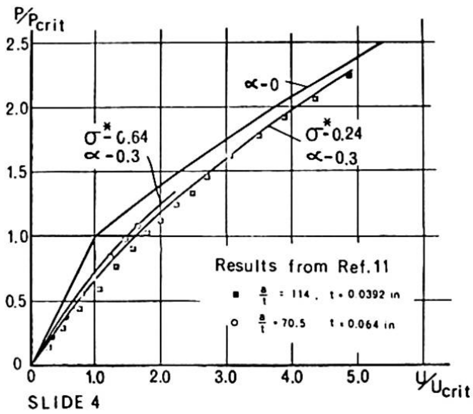
SLIDE 3

constant of proportionality and α = 0 is of course the results for a perfect plate. The experimental results in this figure are for square tubes, both aluminium and steel. Slide (3) shows corresponding results for steel and aluminium plates. The greater scatter is attributed to defective edge boundaries.

Slide (4) shows results of Case (a) for non-dimensional end shortening plotted against non-dimensional load. The results are for mild steel plates.



SLIDE 2



SLIDE 4

It should be emphasised that this perturbation technique is general and may be extended to other more complex boundary and loading conditions by using a digital computer and some discretization method such as finite elements. The simple cases outlined here were chosen only for clarity of presentation.

A full report of this work is to be published in the Aeronautical Quarterly where the references are listed.

Nomenclature

a = plate width, t = plate thickness,
P = total applied load, P_{CRIT} = theoretical buckling load,
U = end shortening, U_{CRIT} = end shortening corresponding to P_{CRIT}
α = generalised imperfection parameter,
σ_{CRB} = average stress, σ_{MAX} = average applied stress at collapse,
σ_{YIELD} = material yield stress,
σ^* = non-dimensional buckling stress, $\sigma^* = \sigma_{CRIT}/\sigma_{YIELD}$