Computers & Structures Vol. 27, No. 4, pp. 541-563, 1987

THEORETICAL BASIS OF THE PANDA COMPUTER PROGRAM FOR PRELIMINARY DESIGN OF STIFFENED PANELS UNDER COMBINED IN-PLANE LOADS

David Bushnell, Lockheed Palo Alto Research Laboratory, 3251 Hanover St., Palo Alto, CA 94304

(This is an abridged version. See the full-length paper for more: panda2.papers/1987.panda.pdf)

ABSTRACT

A theory based on minimum potential energy for the bifurcation buckling of elastic or elastic-plastic isotropic or elastic composite, flat or cylindrical, ring- and stringer-stiffened panels subjected to combined in-plane loads is derived. Equations are given for general instability, panel instability and local instability of panels with fully populated 6 x 6 thickness-integrated constitutive matrices. Also derived are equations for crippling and rolling of stiffeners. The theory has been implemented in user-friendly, interactive computer programs called PANDA and PANDA2 for the minimum-weight design of panels. These programs have been described in previous papers. (2011 NOTE: The original PANDA program is no longer maintained or distributed. It has been superseded by PANDA2. As part of its collection of solutions of buckling problems, PANDA2 includes the PANDA formulas However, PANDA2 also includes many other more elaborate buckling models, as described in other papers on PANDA2.)

INTRODUCTION

Background

An overview of the PANDA computer program is given in [1]. A brief review of the literature on buckling and optimization of stiffened panels appears in that paper and therefore will not be repeated here. However, the theory on which PANDA is based has never been published. Since the PANDA program is widely used for preliminary design, and since much of the theory of PANDA has also been incorporated into PANDA2 [2], it seems appropriate to describe more fully the theoretical basis of PANDA. That is the purpose of this paper.

In PANDA buckling loads are calculated by use of simple assumed displacement functions. For example, general instability of panels with balanced laminates and no shear loading is assumed to occur in the familiar $w(x,y) = C \sin(ny)\sin(mx)$ mode. In the presence of in-plane shear and/or unbalanced laminates, both local and general buckling patterns are assumed to have the form

$$w(x, y) = C\{\cos[(n + mc)y - (m + nd)x] - \cos[(n - mc)y + (m - nd)x]\}$$

in which either c or d are zero, depending on the geometry and the stiffness of the entire panel or whatever portion of the panel is under consideration.

The skin is cylindrical with radius R and the stiffeners are composed of assemblages of flat plate segments the lengths of which are large compared to the widths and the widths of which are large compared to the thicknesses. These flat plate segments are oriented either normal or parallel to the plane of the panel skin.

Figures 1 and 2 show typical panel and stiffener geometry, loading, wall construction and coordinates. The overall dimensions of the panel are *(a, b)* and the spacings of the stiffeners are (a_0, b_0).

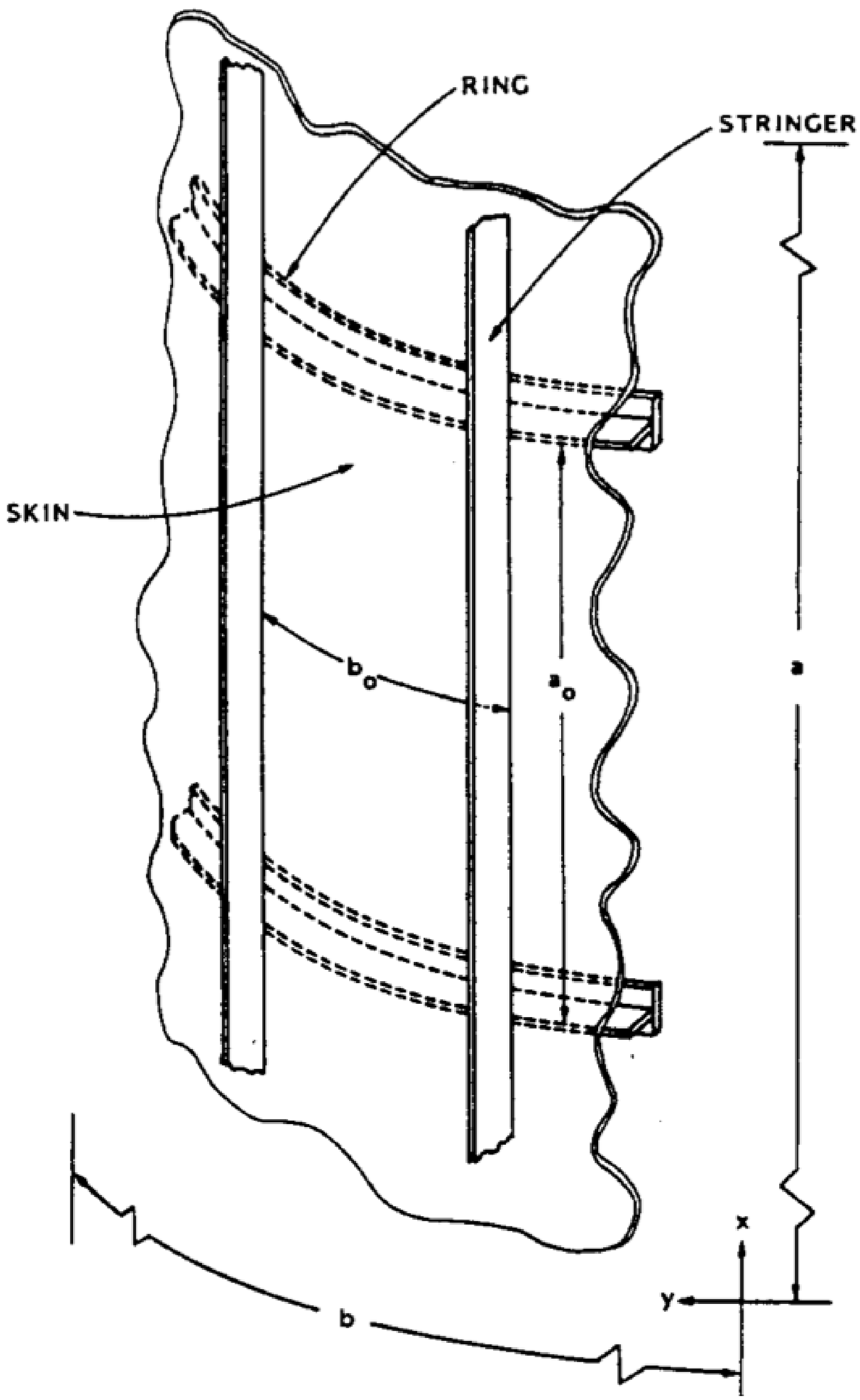

Fig. 1 Stiffened cylindrical panel with overall dimensions (a,b), ring spacing (a_0) and stringer spacing (b_0) (from Computers & Structures, Vol. 27, No. 4, pp. 541-563, 1987)

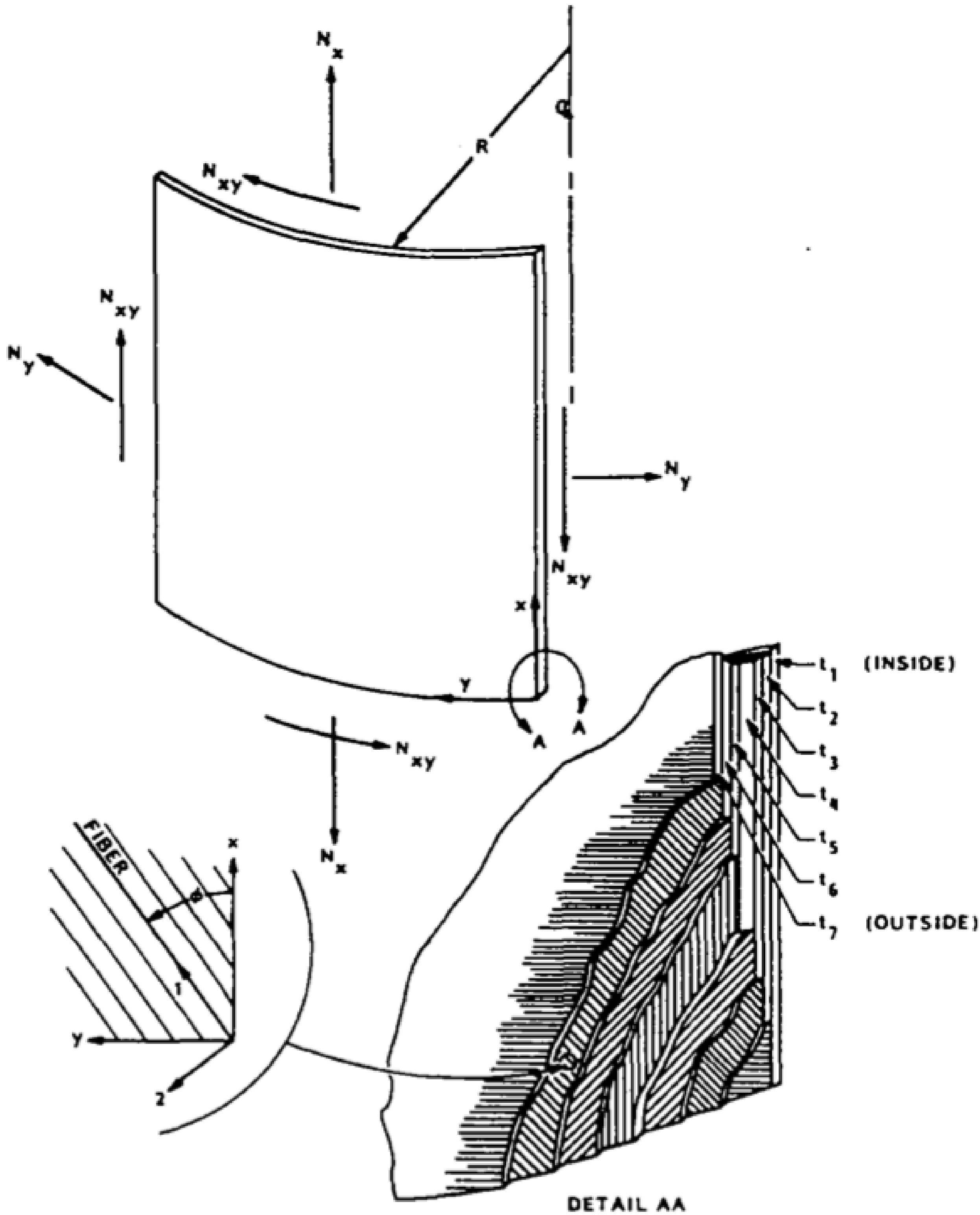

Fig. 2 Coordinates, loading, and wall construction (from Computers & Structures, Vol. 27, No. 4, pp. 541-563, 1987)

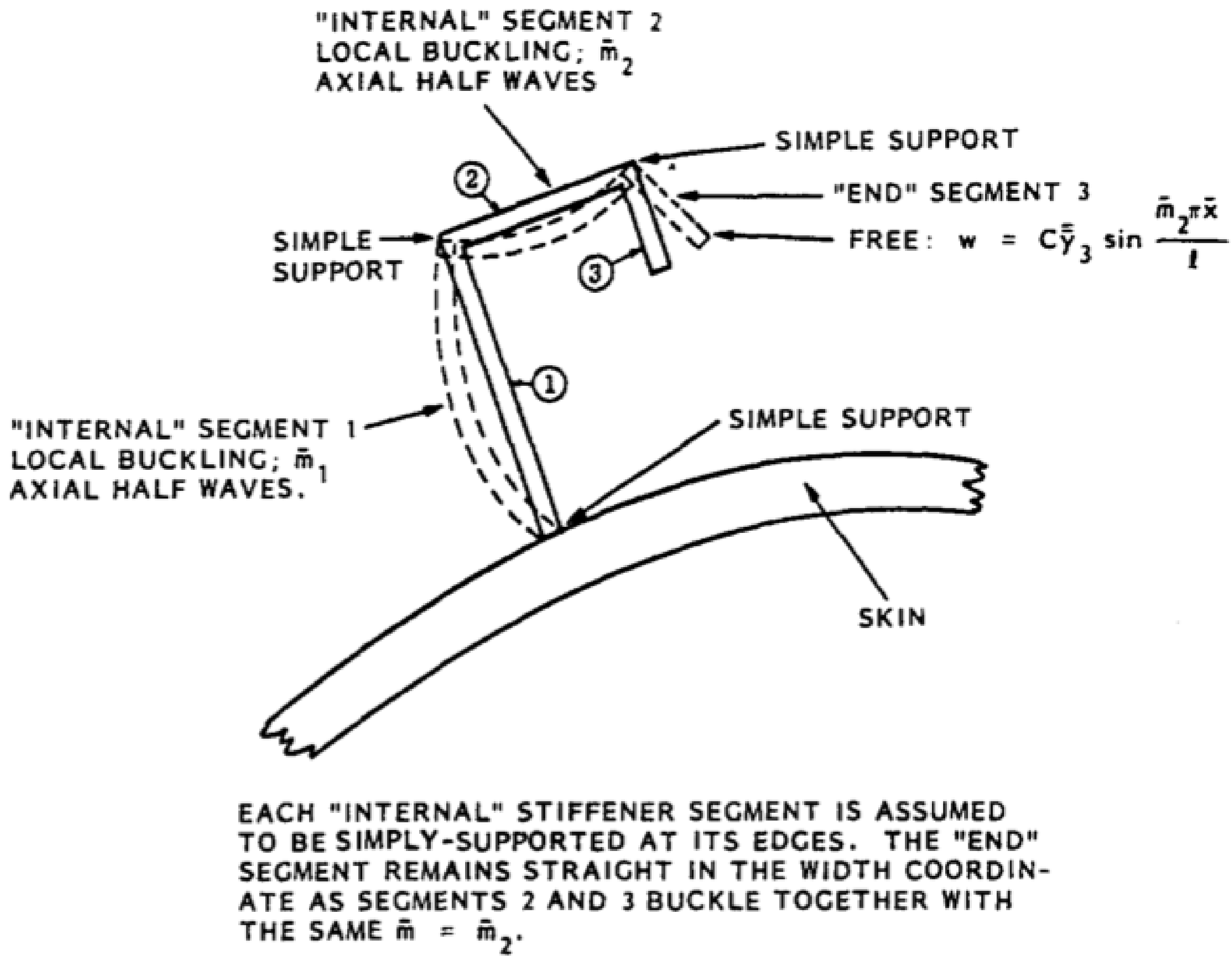

Fig. 5 Local buckling of stiffener segments from PANDA-type (closed form) model (from Computers & Structures, Vol. 27, No. 4, pp. 541-563, 1987)

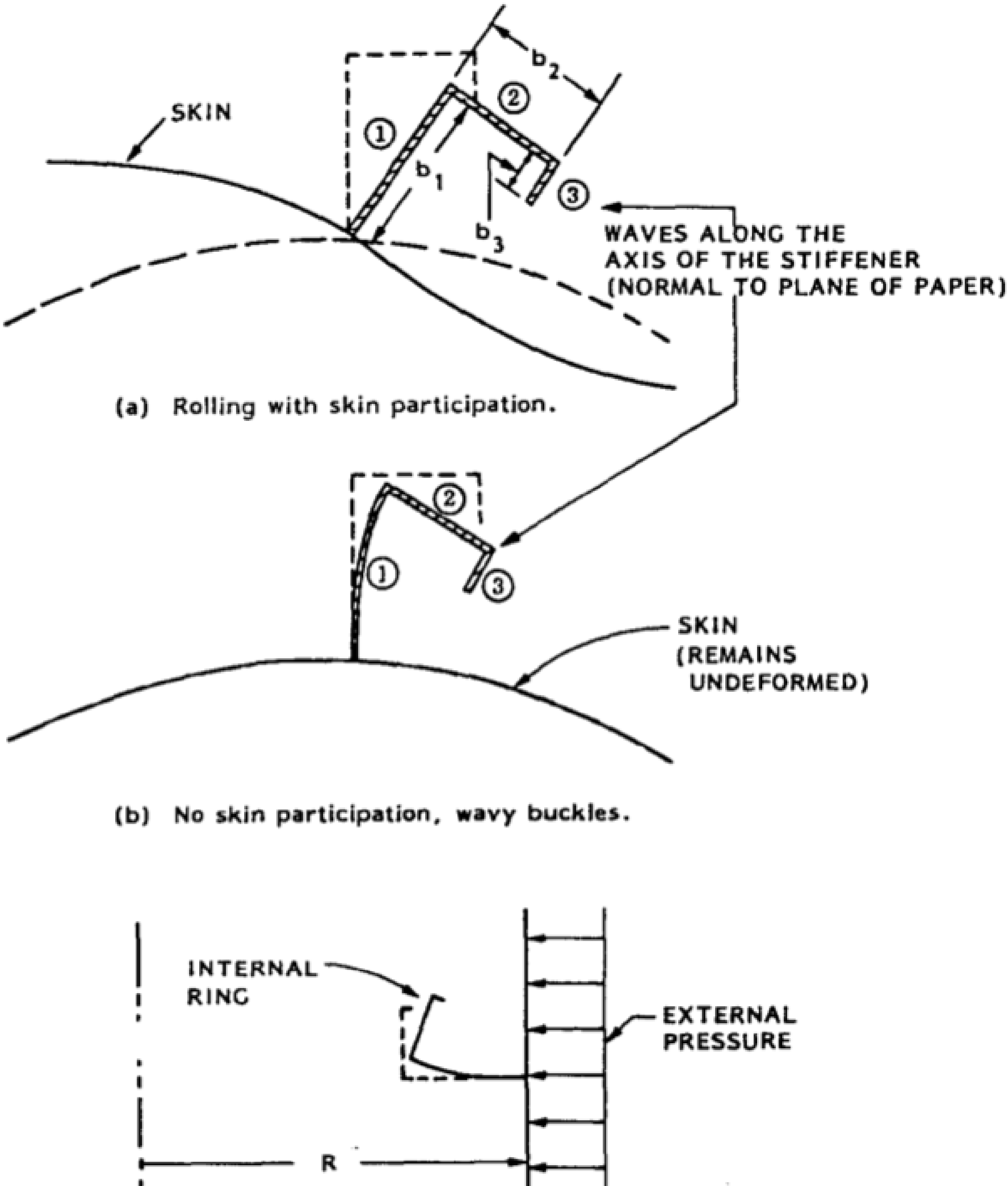

Fig. 6 Three types of “rolling” of a stiffener in the PANDA-type (closed form) analysis (from Computers & Structures, Vol. 27, No. 4, pp. 541-563, 1987)

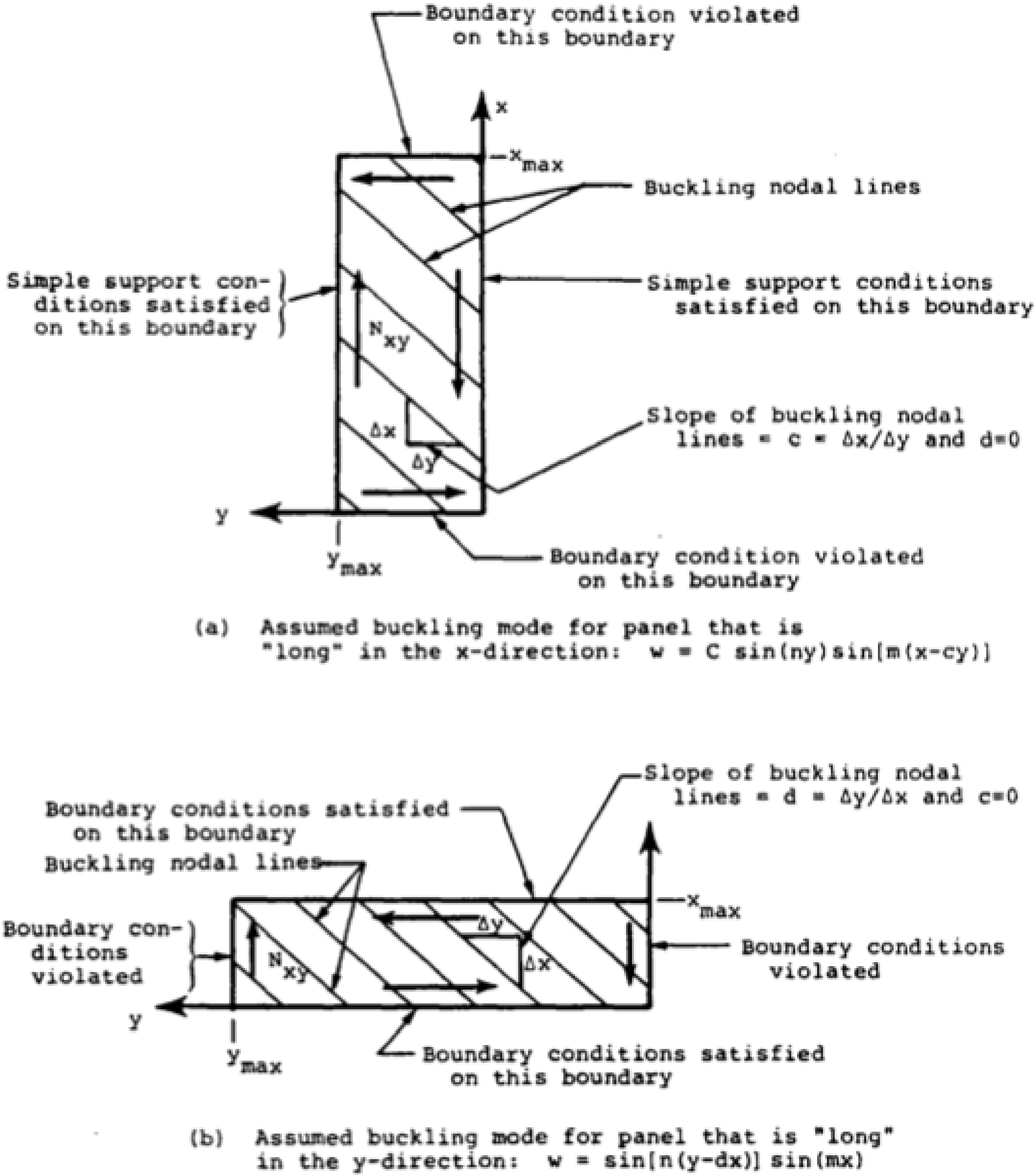

Fig. 9 Assumed buckling modal patterns in the presence of in-plane shear loading and/or anisotropic laminates (from Computers & Structures, Vol. 27, No. 4, pp. 541-563, 1987)