From AIAA 38th Structures, Structural Dynamics and Materials Conference, AIAA Paper 97-1142

OPTIMUM DESIGN VIA PANDA2 OF COMPOSITE SANDWICH PANELS WITH HONEYCOMB OR FOAM CORES

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(This is an abridged version. See the full-length paper for more: panda2.papers/1997.sandwich.pdf)

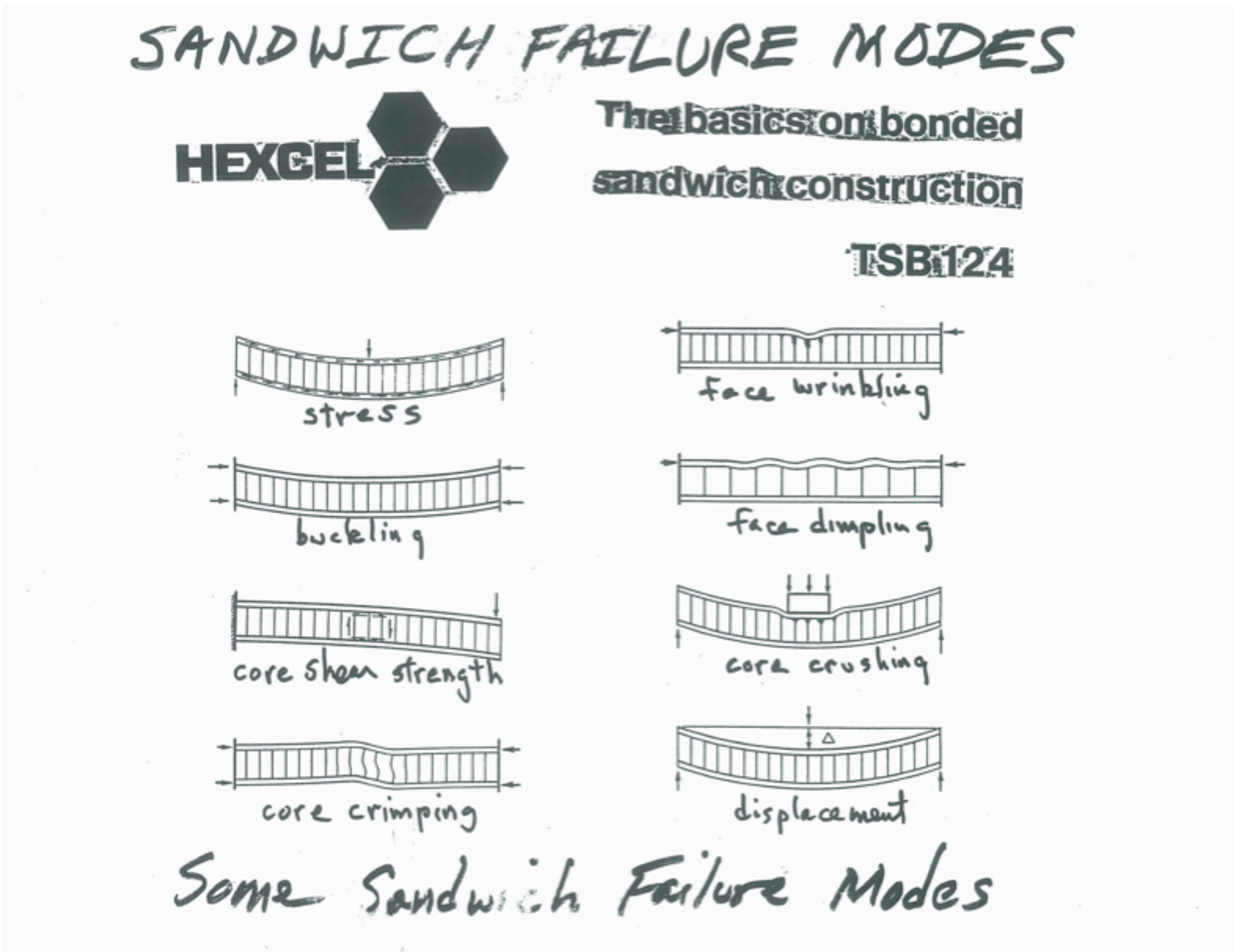
ABSTRACT

PANDA2 has been extended to handle panels with sandwich wall construction by inclusion of the following failure modes in addition to those previously accounted for: (1) face wrinkling, (2) face dimpling, (3) core shear crimping, (4) core transverse shear stress failure, (5) core crushing and tension failure, and (6) face sheet pull-off. Transverse shear deformation effects are included both for overall panel buckling and for local face sheet dimpling and face sheet wrinkling. The new PANDA2 code will optimize stiffened sandwich panels in which the stiffener segments as well as the panel skin may have sandwich wall construction. The effects of panel buckling modal initial imperfections as well as initial face sheet waviness are accounted for during optimization cycles. The updated PANDA2 code will also handle optimization of a panel supported by an elastic Winkler foundation. Examples are presented for a uniformly axially compressed perfect and imperfect unstiffened panel without and with a uniform temperature gradient through the panel wall thickness. Initial face sheet waviness and initial overall buckling modal imperfections both have major influence on optimum designs of sandwich panels with honeycomb cores.

INTRODUCTION

Brief Review of the Literature: Noor, Burton, and Bert [1] provide a recent survey of the state-of-the-art with regard to sandwich panels. Stein and his colleagues [2-4] have contributed several papers. The work reported here is based on earlier work by Vinson [5-7], Hoff and Mautner [8], Plantema [9], Hetenyi [10], and Bitzer and his colleagues at Hexcell Corporation [11-13]. The PANDA2 computer program for minimum weight design of unstiffened and stiffened flat and cylindrical panels and shells [14-20] is modified as described here. PANDA2 supersedes an earlier code PANDA [21] and contains algorithms adapted from BOSOR4 [22] in which the equations valid for branched shells of revolution ear transformed to those valid for prismatic structures. PANDA2 will handle optimum designs of panels for which the panel skin-stiffener module (module = one stiffener base plus panel skin on either side of the stiffener of total width equal to the stiffener spacing, as shown in Fig. 1) is in its locally postbuckled state (local buckling of the panel between adjacent stiffeners and of the stiffeners). The postbuckling theory in PANDA2 represents an extension of a theory first set forth by Koiter in 1946 [23]. Optimization is performed with use of the ADS software developed several years ago by Vanderplaats and his colleagues [24-25]. Although the examples presented here are for "classical" (non-composite) materials, PANDA2 will handle both regular and sandwich panels composed of laminated segments of advanced composite material [18,19]. PANDA2 consists of a "bundle" of executable processors, the most significant of which are:

BEGIN	(user supplies starting design, material properties, boundary conditions)
DECIDE	(user chooses decision variables and lower and upper bounds for optimization)
MAINSETUP	(user supplies loads, strategy parameters, type of analysis to be performed, etc.)
PANDAOPT	(mainprocessor execution is launched)
CHOOSEPLOT	(user chooses what to plot)
DIPLOT	(plots are generated)
CHANGE	(user changes selected quantities or archives an optimized design)
SUPEROPT	(like PANDAOPT, except it attempts to find a global minimum-weight design [20])
STAGSUNIT	(a finite element model to be used in an execution of STAGS [17, 26, 27] is generated from an optimum design by PANDA2)

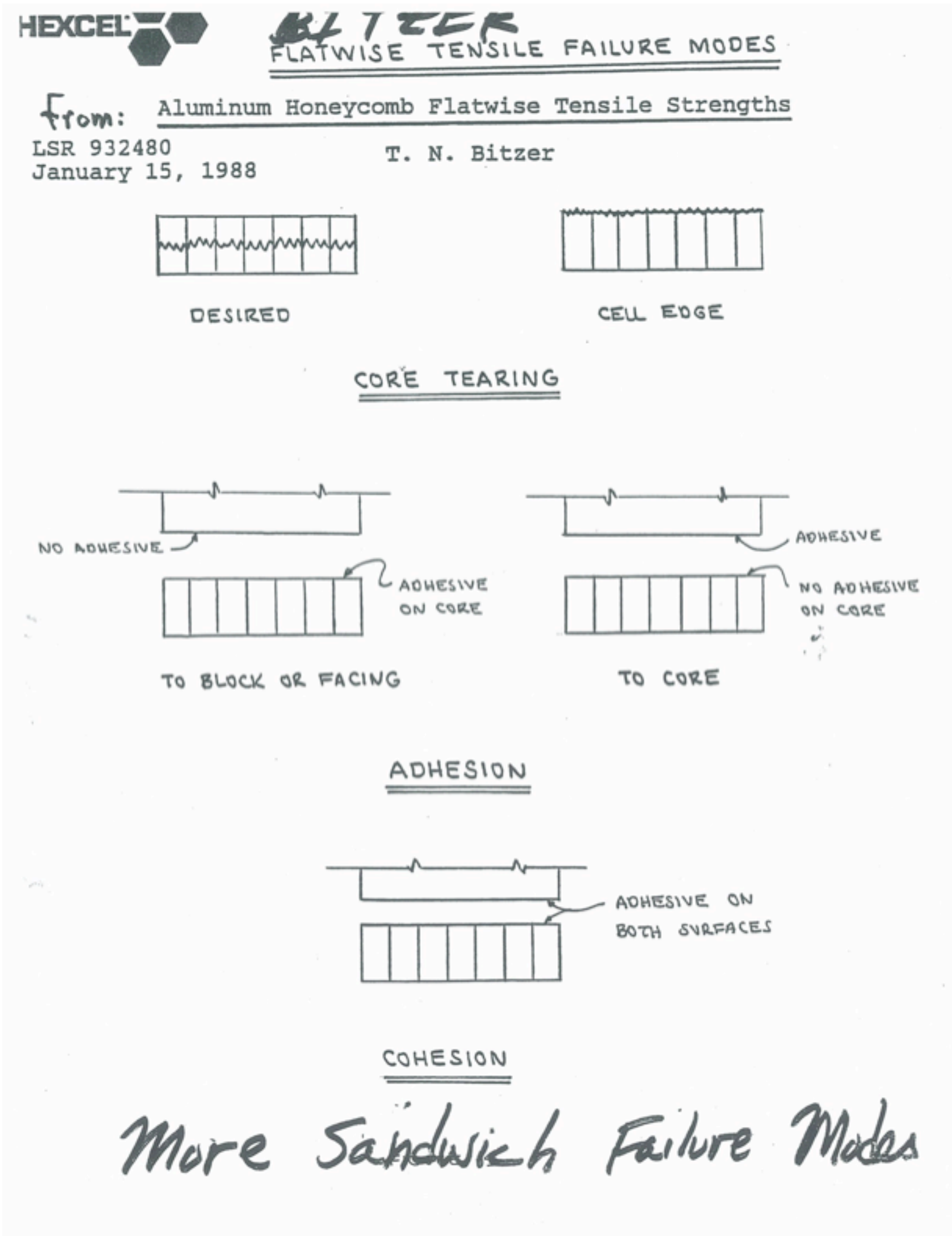


sandwich.ppt 5: Several modes of behavior of sandwich walls which correspond to design margins that are accounted for in the PANDA2 computer program for optimum design of stiffened and unstiffened panels and shells. (sandwich.ppt is a PowerPoint presentation of the "sandwich" paper. "5" is the slide number in that PowerPoint presentation.)

REFERENCES:

Anonymous, "The basics of bonded sandwich construction", Hexcel Corporation, Dublin, California, Report TSB 124, January 1988

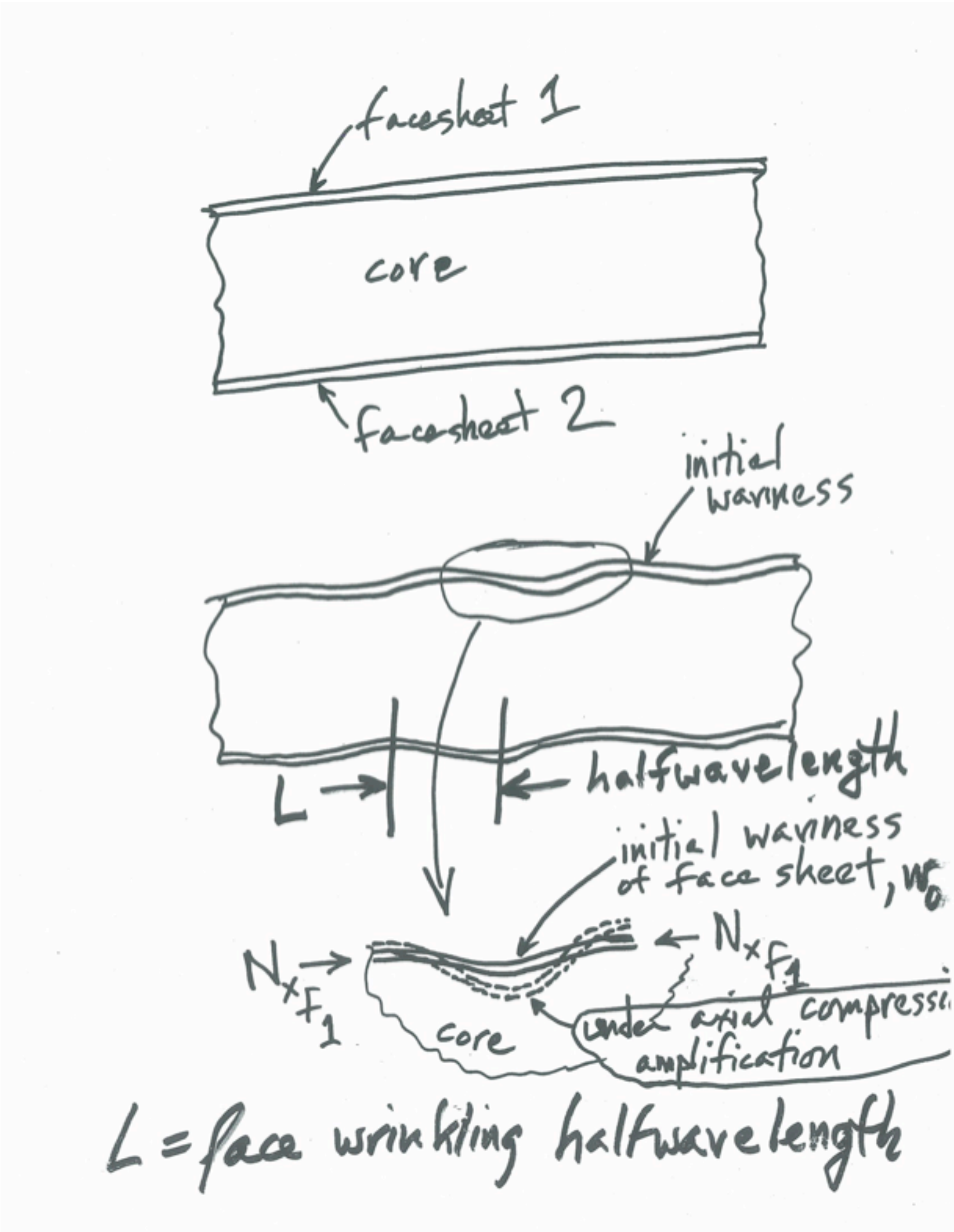
Anonymous, "Mechanical properties of honeycomb material", Hexcel Corporation, Dublin, California, Report TSB 120, January 1988



sandwich.ppt 6: More failure modes pertaining to sandwich wall construction. PANDA2 includes two margins corresponding to the five behaviors depicted here: core tensile failure, and face sheet pull-off. (sandwich.ppt is a PowerPoint presentation of the "sandwich" paper. "6" is the slide number in that PowerPoint presentation.)

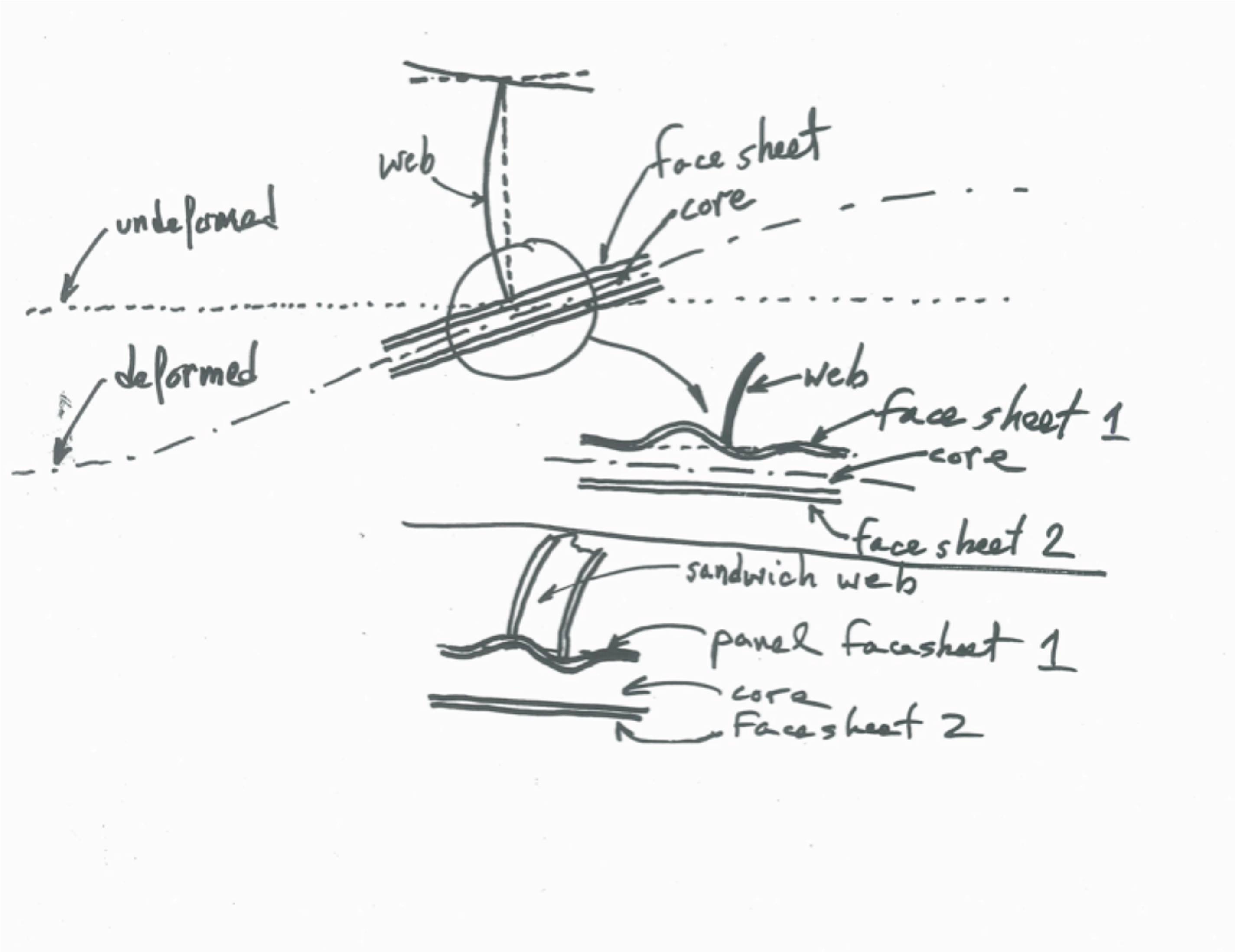
REFERENCE:

Bitzer, T. N., "Aluminum honeycomb flatwise tensile strengths", Hexcel Corporation, Dublin, California, Report LSR 932480, January 1988

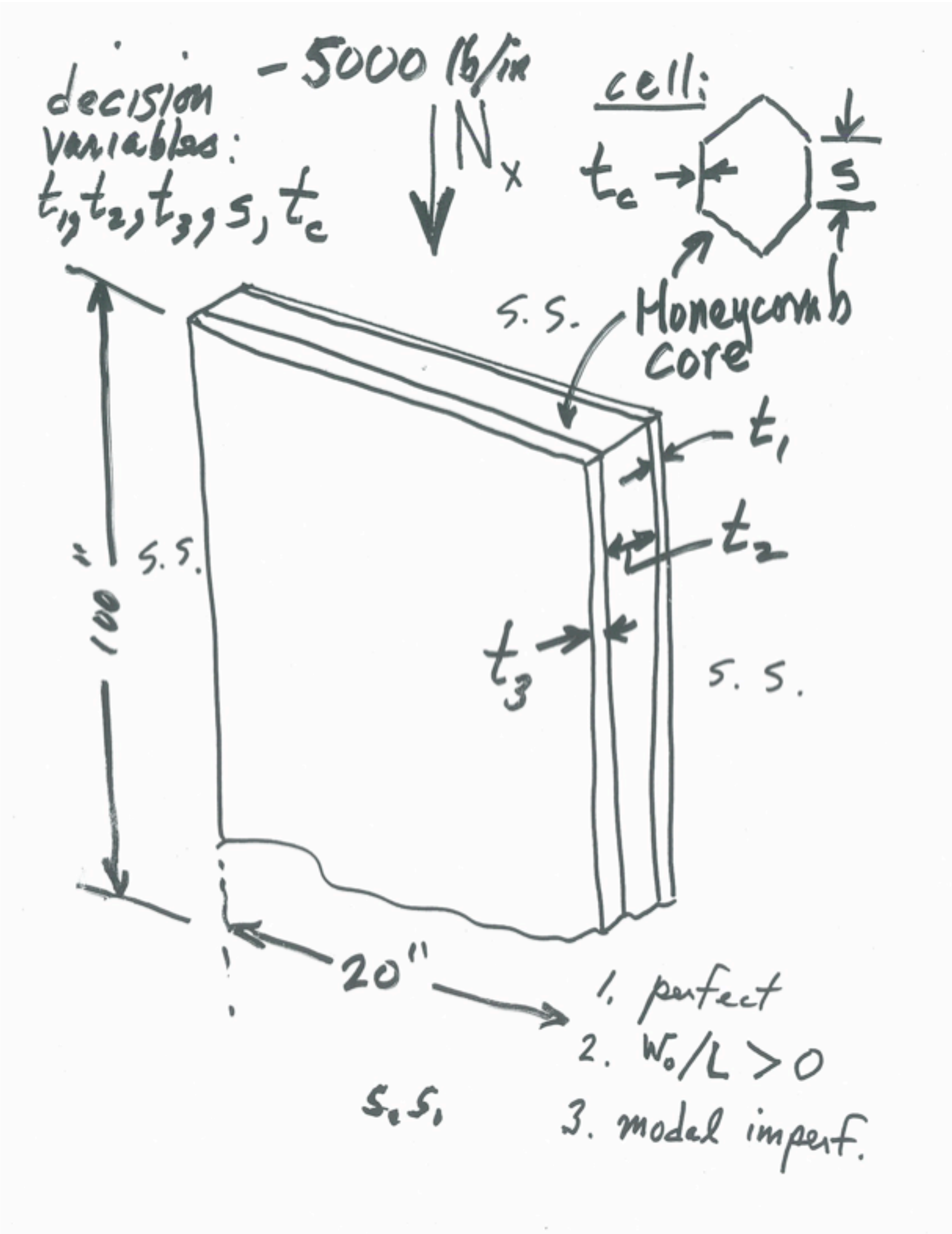


c

sandwich.ppt 7: The effect of initial face sheet waviness, w_0: Under axial compression the amplification of w_0 gives rise to the possibility of core crushing, core tensile failure, face sheet pull-off, core shear failure, and additional bending stresses in a face sheet as the initial face sheet waviness w_0 is amplified by the compressive loading in a face sheet. L=critical buckling (wrinkling) half-wave length. Typical initial wrinkling amplitude, w_0, is given by $w_0/L=0.001$ (Plantema). Amplification of initial face sheet wrinkling during axial compression contributes to core crushing, face sheet pull-off, core shear failure, stress in sheet. **c** = amplification of face sheet waviness under loading. (sandwich.ppt is a PowerPoint presentation of the “sandwich” paper. “7” is the slide number in that PowerPoint presentation.)



sandwich.ppt 9: Effect of the stiffener web root on the top face sheet of the panel sandwich wall. If the web is a simple wall it applies a line moment to the top face sheet of the panel sandwich wall. If the web is also of sandwich wall construction, it imposes equal and opposite line loads where the two face sheets of the web intersect the top face sheet of the panel sandwich wall. The local deformation of the top face sheet is amplified as the applied axial compression is increased, which can cause core crushing, core tensile failure, face sheet pull-off, core shear failure, and additional bending stresses in the top face sheet of the panel sandwich wall. (sandwich.ppt is a PowerPoint presentation of the “sandwich” paper. “9” is the slide number in that PowerPoint presentation.)



sandwich.ppt 21: Axially compressed sandwich plate showing length and width, simple-support (s. s.) boundary conditions, and decision variables, t_1, t_2, t_3, t_c, s. (sandwich.ppt is a PowerPoint presentation of the “sandwich” paper. “21” is the slide number in that PowerPoint presentation.)