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Local Buckling of Web-Core and Foam-Core Sandwich Panels

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***Abstract*—**Sandwich construction is widely accepted as a method of construction especially in the aircraft industry. It is a type of stressed skin construction formed by bonding two thin faces to a thick core, the faces resist all of the applied edge loads and provide all or nearly all of the required rigidities, the core spaces the faces to increase cross section moment of inertia about common neutral axis and transmit shear between them provides a perfect bond between core and faces is made.

Material for face sheets can be of metal or reinforced plastics laminates, core material can be metallic cores of thin sheets forming corrugation or honeycomb, or non metallic core of Balsa wood, plastic foams, or honeycomb made of reinforced plastics.

For in plane axial loading web core and web-foam core Sandwich panels can fail by local buckling of plates forming the cross section with buckling wave length of the order of length of spacing between webs.

In this study local buckling of web core and web-foam core Sandwich panels is carried out for given materials of facing and core, and given panel overall dimension for different combinations of cross section geometries.

The Finite Strip Method is used for the analysis, and Fortran based computer program is developed and used.

***Keywords*—**Local Buckling, Finite Strip, Sandwich panels, Web and foam core.

I. Introduction

ADVANTAGE of low weight combined with high stiffness and continuous development in material, design and methods of fabrication made sandwich construction widely accepted type of construction especially in aircraft industry and in aerospace.

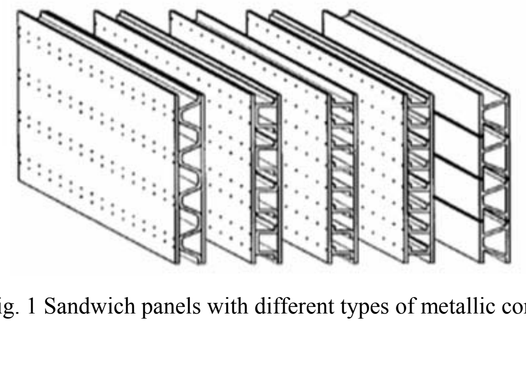

Fig. 1 Sandwich panels with different types of metallic cores

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A structural sandwich panel is a three-layer plate, consisting of two face sheets and a core. Two thin, stiff and strong faces are separated by a thick, light and weaker core [1]. Such construction provides high strength-to-weight ratio and high stiffness. Reference [2] investigated the potential of sandwich construction as candidate for an Integral Thermal Protection System (ITPS) for space vehicle, Traditionally, sandwich structures are made up of two face sheets and a core made from web and/ or expanded materials such as, foam or metallic foil, plastic and composite (honeycomb). Study of overall buckling using orthotropic equivalent properties is carried out [3], local buckling of thin walled structures is investigated using Finite Strip Method [4], theoretical and experimental study of steel webs supported by elastic medium along both sides is carried out in [5]. Using (FSM) authors studded the problem of buckling of plates on foundation [6].

By properly choosing material of construction, proper sizing of cross section and by proper methods of fabrication, we can achieve sandwich panels with high stiffness to weight ratio.

For proper sizing, modes of failure of sandwich construction must be studied.

Web core and web-foam core sandwich panels subject to in plane axial loading can fail by local buckling of plates forming the cross section with buckling wave length of the order of length of spacing between webs.

In this paper Finite Strip Method (FSM) will be used to study local buckling of sandwich panels which are built from two face sheets held apart by web of the same material normal to the two face sheets, then the study is extended to web-foam core Sandwich panels.

A Fortran computer program is developed based on Finite Strip Method (FSM) to carry out the analysis of the following cases:

- Web core sandwich panel
- Web-Foam core sandwich panel

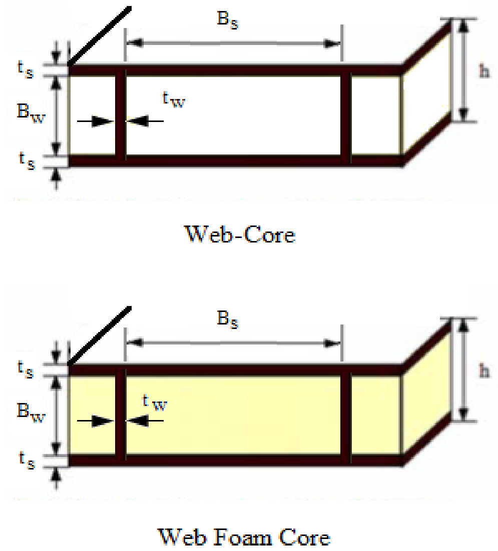

Fig. 2 Cells of web core and web foam sandwich panel cross section geometry

For the analysis of The Web-Foam core sandwich panel core material is assumed to be linearly elastic and completely glued to the skin, has young's modulus E_C in the direction normal to the skin to provide continues support to panel faces, to oppose deflection in that direction, the resulting modulus coefficient K_f is computed from

$$K_f = E_c / 0.5 B_w \qquad (1)$$

where B_w is the panel skin spacing depth.

For this study a panel with length a=800mm, width b=400mm, height B_w=40mm, is considered, skin thickness t vary with B_w/t=30 to 60 and B_w/Bs vary from 0.5 to 1.0 where B_w is web height and B_s is skin width, see (Fig. 2), the results of the analysis are given in non dimensional form.

II. Finite Strip Method for Local Buckling of Sandwich Panels

The structural stability problem of sandwich panels is based on expression the elastic stiffness of the panel as sum of elastic stiffness $\mathbf{K_e}$, core stiffness $\mathbf{K_f}$ and geometric matrix $\mathbf{K_g}$.

Each of the overall matrices mentioned above is formed from the matrices of the single strips as in a standard Finite Strip Method procedure; the finite strip matrices to be used in this analysis are as follow:

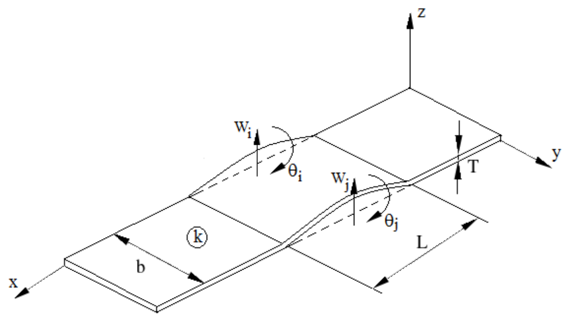

Fig. 3 Typical finite strip "k" with nodal displacements at i (w_i, θ_i) and nodal displacements at j (w_j, θ_j)

A. *Finite Strip Elastic Stiffness Matrix* $\boldsymbol{k_e}$

A single strip is as shown in Fig. 2, with two nodal displacements at each edge, W for out of plane displacement and θ for rotations, in the program displacement and rotation will be expressed by U.

The finite strip elastic stiffness matrix $\mathbf{k_e}$ given as follow [4]:

$$\boldsymbol{k_e} = \boldsymbol{k_{e1}} + \boldsymbol{k_{e2}} + \boldsymbol{k_{e3}} \qquad (2)$$

where

$$\boldsymbol{k_{e1}} = \frac{\pi^4 Ebt^3}{10080(1-\nu^2)L^3}\begin{bmatrix} 156 & & & \\ 22b & 4b^2 & Sym. & \\ 54 & 13b & 156 & \\ -13b & -3b^2 & 1-22b & 4b^2 \end{bmatrix}$$

$$\boldsymbol{k_{e2}} = \frac{\pi^2 \ Et^3}{360(1-\nu^2)bL}\begin{bmatrix} 36 & & & \\ (3+15\nu) & 4b^2 & Sym. & \\ -36 & -3b & 36 & \\ -13b & -b^2 & -(3+15)b & 4b^2 \end{bmatrix}$$

$$\boldsymbol{k_{e3}} = \frac{ELt^3}{10080(1-\nu^2)L^3}\begin{bmatrix} 12 & & & \\ 6b & 4b^2 & Sym. & \\ -12 & -6b & 12 & \\ 6b & 2b^2 & -6b & 4b^2 \end{bmatrix}$$

where *b* is strip width and *L* buckling wave length.

B. *Core Stiffness Matrix* $\boldsymbol{k_f}$

The core is assumed to be formed by elastic isotropic material with elastic modulus =E_c, to be perfectly glued to the skin of the sandwich panel, depth of the core is assumed to be =(B_w/2.0).

Under critical load the panel buckles into a number of half waves and the core material glued to the skin of the panel wrinkle the same way.

At distant (B_w/2.0) from the skin of the panel at the neutral line of the cross section the core remains undisturbed. In practice the core is thick enough for this to be true.

We can assume the spring constant of the core material modulus be computed from

$$K_f = E_c\left(\frac{B_w}{2.0}\right) \qquad (3)$$

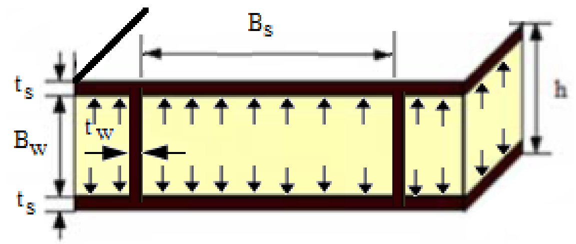

Fig. 4 Core action on sandwich faces

The finite strip matrix representing the action of the core on skin is given as follow [5]:

$$\mathbf{k_f} = \frac{k_{fLb}}{840}\begin{bmatrix} 156 & & & \\ 22b & 4b^2 & Sym. & \\ 54 & 13b & 156 & \\ -13b & -3b^2 & 1{-}22b & 4b^2 \end{bmatrix} \quad (4)$$

C. Geometric Stiffness Matrix for Finite Strip Element

The geometric matrix for a finite strip is given as follow [4]:

$$\mathbf{kg} = \frac{\sigma_x \pi^2 bt}{840L}\begin{bmatrix} 156 & & & \\ 22b & 4b^2 & Sym. & \\ 54 & 13b & 156 & \\ -13b & -3b^2 & 1{-}22b & 4b^2 \end{bmatrix} \quad (5)$$

where σ is the compression stress in x direction.

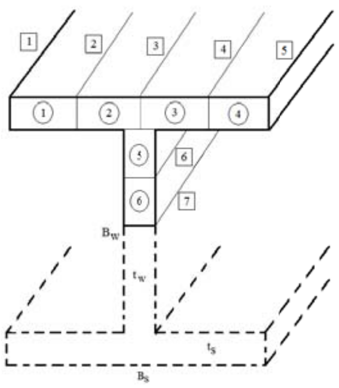

Fig. 5 Sandwich panel idealization with finite strip and nodal numbering

D. The Buckling Equation for the Assembled Structure

The displacement–load equation for the assembled structure constructed from the matrices of single elements Fig. 4 is given from [7]:

$$\boldsymbol{U} = (\boldsymbol{K_e} + \boldsymbol{K_f} + \boldsymbol{K_g})^{-1}\boldsymbol{F} \quad (6)$$

where **U** is column of generalized nodal displacement, and F is column of nodal generalized forces.

Instead of the column matrix **F** we substitute (λ**F′**) where **F′** is the relative magnitude of the applied load column matrix and λ is a constant of proportionality or (load factor) of **F**, and since the geometric stiffness is proportional to the applied load, it can be written as $\lambda \boldsymbol{K'_g}$, with $\boldsymbol{K'_g}$ is the geometric stiffness matrix for unit value of λ.

For small displacement $\mathbf{K_e}$ can be considered constant then the general equation can be written as follow:

$$\boldsymbol{U} = (\boldsymbol{K_e} + \boldsymbol{K_f} + \boldsymbol{\lambda K'_g})^{-1}\boldsymbol{\lambda F'} \quad (7)$$

It follows that for buckling with displacement tending to infinity the determinant=0, or

$$\left|\boldsymbol{K_e} + \boldsymbol{K_f} + \lambda \boldsymbol{K'_g}\right| = 0 \quad (8)$$

This determinant is stability equation used to find the buckling loads and buckling modes.

The lowest root (Eigen-value) and the associated eigenvector will be the critical buckling load and buckling mode.

E. Analysis Procedure

In this study since the elastic, core, and geometric matrices are functions of buckling wave length which is unknown, the buckling load and the associated buckling mode are found by an iteration procedure.

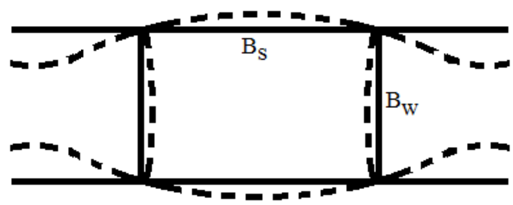

Fig. 6 Local buckling mode shape of web core sandwich panel

For the local buckling analysis of web core sandwich panel with the assumption of edge lines remain straight and plates rotates around edge lines, the expected buckling shape will be as shown in Fig. 6.

For the analysis which will follow the idealization is as shown in Fig. 5 where the skin is divided into four finite strips, with width $B_s/4$ and thickness t_s.

For the web two strips are used each of width $B_w/4$ and thickness equal t_w.

The assembly matrix for the idealized part of the sandwich panel is of order 14×14,the reduced matrix which obtained by introducing the boundary conditions which considers rotation equal zero at nodal lines 1, 5 and 7. And displacement equal zero at nodal line 3.

By eliminating the corresponding rows and columns from the assembly matrix the resulting reduced matrices will be of the order 10×10.

III. Computer Program for Local Buckling

The FORTRAN list is given in Appendix.

The program steps are as follow:

1) RUN=1, geometric stiffness is computed for each strip and assembled to produce assembly geometric matrix and reduced by introduction of boundary condition at node 1,3, 5 and 7.
2) Run=2, step 1 is repeated for elastic stiffness matrix.

3) To Find Eigen-value and Eigenvectors subroutine require positive definite matrix. positions of matrices (**K**$_e$ +**K**$_f$), and **K**$_g$ are interchanged in the characteristic determinant as follow:

$$\left|K'_g + (1/\lambda)(K_e + K_f)\right| = 0 \quad (9)$$

$$\left|K'_g + \lambda'(K_e + K_f)\right| = 0 \quad (10)$$

where λ' is the required Eigen-value

4) An iteration procedure will be used to find the critical buckling load and critical buckling wave length. For start of iteration three value of buckling wave length (L_1=B_s, L_2=0.8B_s, L_3=0.6B_s) are used to find corresponding stresses. By using second order polynomial relating stresses to wave lengths we can find the minimum value of the stress as next step of iteration, in general, six steps found to be enough to converge to the critical buckling stress.
5) The subroutines used for solving the characteristic equation for each step of the iteration process is as follow [8]:

- To find Eigen-values and eigenvectors for the problem in the form **Ax=Bx**.
- The second matrix **B** is decomposed into Land **L**^{t} **B=LL**^{t} by:

(CALL CHOLDC{K$_e$, N, n})

Note **K**$_e$ +**K**$_f$≡B, and **K**$_g$≡A

- The equation **Ax=Bx.** Becomes

(L^{-1}A L^{-1})(L^{-1}x)=(L^{-1}x).

- which can be written as **PY=Y** where **P=**L^{-1} **A** $L^{-1}$is symmetric matrix.

To find matrix **P:**

(CALL PMAT{KEI,KG,KEIT,P,N}).

- Householder's method is used to transform the matrix **P** into tridiagonal matrix.

(CALL TRIDIAG{P,N,DP,EP})

- QL Algorithm is used to find eigenvalues and eigenvectors

(CALL tgli{dP,eP,n,N,z}

IV. Analysis and Presentation of Results

The analysis is based on study of web core and (web foam core) the web core panel is made of aluminum alloy 2024 with young's modules E equal 72,000 N/mm^2,σ_U=300N/mm^2 with panel length A=800mm, and width B=400mm, B_w=40mm, and the following cross section geometric configuration are considered B_w/B_s vary from 0.5 to 1.2 step 0.1mm and thickness t_w/t_s vary from 0.5 to 1.5 step 0.25mm.

For web foam core B_w/B_s vary from 0.5 to 1.0 step 0.1mm and thickness t_w/t_s vary from 0.5 to 1.5 step 0.25mm. Material stiffness E_c made to vary from 0.0 to 10 step 2.5 N/mm^2

The Fortran list is given in Appendix.

The results of analysis are presented as given in Figs. 7-10.

Non dimensional parameters are used for structural similarity and for generalization of the results.

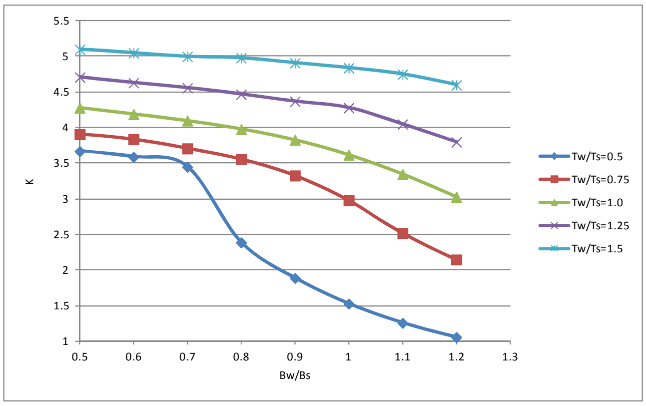

Fig. 7 Local buckling stress coefficient k for web core sandwich panel (E_c/E=0)

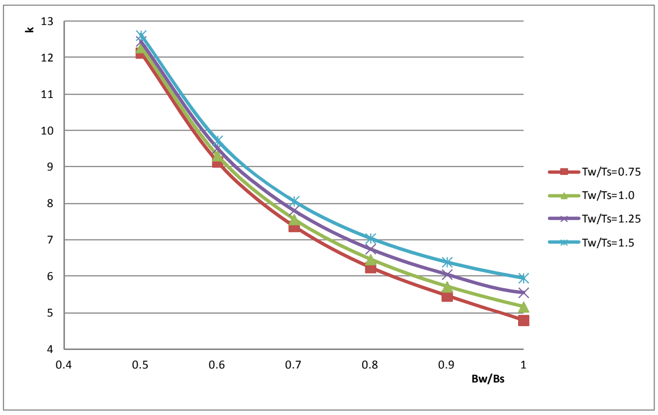

Fig. 8 Local buckling stress coefficient k for web foam core sandwich panel Vs. B_w/B_s for different values of t_w/t_s (E_c/E=6.94×10^{-5}, B_w/t_s=50)

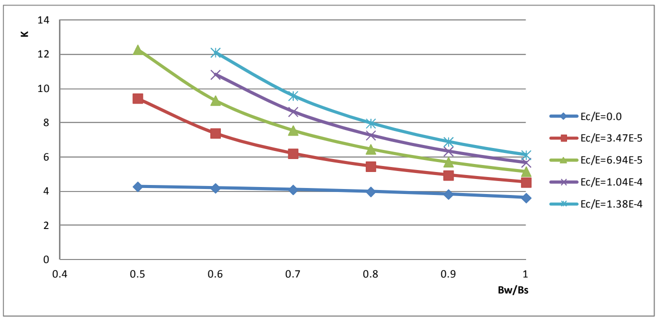

Fig. 9 Critical buckling stress coefficient Vs. $B_w/B_s$for different values of E_c/E and, Bw/t_s=50

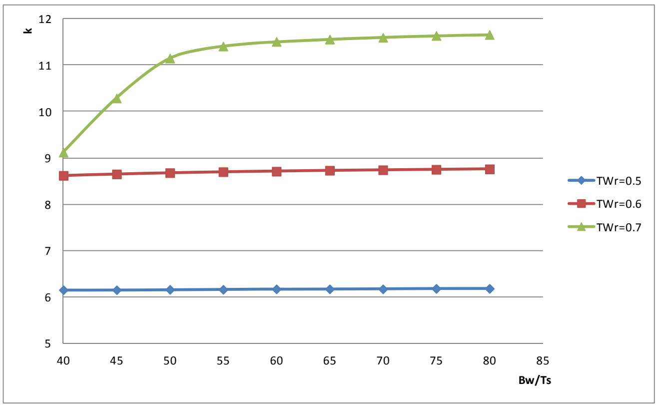

Fig. 10 Critical buckling stress coefficient Vs. B_w/t_s for different values of t_w/t_s and, $E_c/E=6.94\times10^{-5}$

V. Conclusion

1) Finite strip can be used efficiently for the analysis of sandwich type of construction with multi parameters geometry and combination of material.
2) Figs. 7-9 show values of local buckling stress coefficients k, very close to the values found by ESDU [9].
3) Local buckling stress for web core sandwich panels can be increased to greater values by including relatively soft core material Figs. 8, 9.
4) Fig. 9 shows that for values of t_w/t_s=0.5, and 0.6 local buckling stress coefficient k remain constant with increase of b_w/t_s, but for t_w/t_s=0.7 the value of k increases rapidly between B_w/t_s=40 and 50 then becomes almost constant at values higher than 55.
5) Future work will be testing program on web foam core sandwich panel to confirm the analytical results found in this paper.

Appendix

```
$DEBUG
C Finite strip
C local Bucling of web core sandwich plate
  DIMENSION
ND(6,2),B(4,4),KS(14,14),KO(14,14),KG(10,10),KE(10,1
0)
  #,NB(4),KEI(10,10),KEIT(10,10),P(10,10),dP(10),eP(
10),Z(10,10)
    #,STR(10),F9(10),FB(6),FK(6),T(6)

     DOUBLEPRECISION
PI,PHA,PHB,PHC,PHD,FLA,B,KO,KG,KE,KS,E,Ec
  DOUBLEPRECISION TT,kei,keit,P,dP,eP,Z,BS,BW,GK1,GK2
  INTEGER RUN,I7,NOD,IND,I9,LL,NEL,QM
  OPEN(1,FILE='LB1.OUT')
  OPEN(2,FILE='LB2.OUT')
  OPEN(3,FILE='LB3.OUT')
C Material Al Alloy  N/mm sq
  E=72000.
  ASTR=300.
  Poison=.3
Ec=5.0
c  Data
  N=10
  LL=2
  IND=7
  NOD=2
  NEL=6
  BL=400.
  AL=2.*BL
C===========
c  nodal numberong
  ND(1,1)=1
  ND(1,2)=2
  ND(2,1)=2
  ND(2,2)=3
  ND(3,1)=3
  ND(3,2)=4
  ND(4,1)=4
  ND(4,2)=5
  ND(5,1)=3
  ND(5,2)=6
  ND(6,1)=6
ND(6,2)=7
c  boundry condition
  NB(1)=2
  NB(2)=5
  NB(3)=10
  NB(4)=14
c  PANEL geometry
   BW=40.
do v6=40,80,5
  TT=Bw/v6
  do TW=0.5*TT,0.8*TT,0.1*TT
222  H=BL/10.
1  BW=40.
    BS=80
    TWr=TW/TT
309  I7=4
 307 UN=0.3
  WRITE(1,'(/,2(2x,I2),/)') ((ND(I,J),J=1,2),I=1,6)
305   IP=1
306   FLA=BS
     QM=1
 303 RUN=1
FLAr= FLA/BS
  GK1=Ec/(0.5*BW)
  GK2=0.0
  FK(1)=GK1
  FK(2)=GK1
  FK(3)=GK2
  FK(4)=GK2
  FK(5)=GK1
FK(6)=GK1
```

```
C  WIDTH OF STRIPS
  FB(1)=BS/4.
  FB(2)=BS/4.
  FB(3)=BW/4.
  FB(4)=BW/4.
  FB(5)=BS/4.
  FB(6)=BS/4.
C THICNESSW OF STRIPS
T(1)=TT
  T(2)=TT
  T(3)=TW
  T(4)=TW
  T(5)=TT
  T(6)=TT
  F9(QM)=FLA
208  PI=3.141593
     I1=1
     NN=IND*LL
     I9=NN-I7
1000 DO 2 L=1,NN
     DO 2 M=1,NN
2    KS(L,M)=0.0
C COMPUTATION OF ELASTIC STIFFNESS OF SINGLE STRIP +FOUNDATION
STIFFNESS  + GEOMETRIC STIFF  CONSTANTS
300   PHA=(PI**4.)*E*FB(I1)*(T(I1)**3.)/(10080.*(1-
UN*UN)*(FLA**3.))
  #+FK(I1)*FLA*FB(I1)/840.
     PHB=PI*PI*E*(T(I1)**3.)/(360.*(1.-
UN*UN)*FB(I1)*FLA)
     PHC=E*FLA*(T(I1)**3)/(24.*(1.-
UN*UN)*(FB(I1)**3.))
     PHD=PI*PI*FB(I1)*T(I1)/(840.* FLA)
 33   IF(RUN-2) 3,4,602
C COMPUTATION OF GEOMETRIC STIFFNESS FOR SINGLE STRIP
 3    B(1,1)=PHD*156.
B(2,1)=PHD*22.*FB(I1)
B(3,1)=PHD*54.
B(4,1)=PHD*(-13.)* FB(I1)
B(2,2)=PHD*4.*FB(I1)*FB(I1)
B(3,2)=PHD*13.* FB(I1)
B(4,2)=PHD*(-3.)*FB(I1)*FB(I1)
B(3,3)=PHD*156.
B(4,3)=PHD*(-22.)* FB(I1)
B(4,4)=PHD*FB(I1)*FB(I1)*4.
  GOTO 11
C ELASTIC STIFFNESS MATRIX FOR SINGLE STRIP
 4     B(1,1)=PHA*156.+PHB*36.+PHC*12.
B(2,1)=PHA*22.*FB(I1)+PHB*(3.+15.*UN)*FB(I1)+PHC*6.*
FB(I1)
B(3,1)=PHA*54.+PHB*(-36.)+PHC*(-12.)
B(4,1)=PHA*(-13.)*FB(I1)+PHB*(3.)*FB(I1)
+PHC*6.*FB(I1)
B(2,2)=4.*FB(I1) *FB(I1) *(PHA+PHB+PHC)
B(3,2)=PHA*13.*FB(I1) +PHB*(-3.)*FB(I1) +PHC*(-
6.)*FB(I1)
B(4,2)=PHA* FB(I1)*FB(I1)*(-3.)+PHB*FB(I1)
*FB(I1)*(- 1.)+
    #PHC*FB(I1)*FB(I1)*2.
B(3,3)=PHA*156.+PHB*36.+PHC*12.
B(4,3)=PHA*(-22.)*FB(I1)+PHB*(-3.-
15.*UN)*FB(I1)+PHC*(-6.)* FB(I1)
B(4,4)=4.*FB(I1) *FB(I1) *(PHA+PHB+PHC)
11  DO 7  I=1,4
     DO 7  J=1,4
 7    B(I,J)=B(J,I)

C PRODUCTION OF ASSEMBLY MATRIX FROM SINGLE COMPONENTS

     N1=1
52    L1=1
50    DO 90 I=1,LL
  DO 90 J=1,LL
     L2=I+(N1-1)*LL
     M3=J+(L1-1)*LL
     L=LL*ND(I1,N1)-LL+I
     M=LL*ND(I1,L1)-LL+J
90    KS(L,M)=KS(L,M)+B(L2,M3)
     L1=L1+1
IF(L1-NOD) 50,50,51
51    N1=N1+1
IF(N1-NOD)52,52,53
53I1=I1+1
  IF(I1-NEL)300,300,320
320  DO 500  L=1,NN
     DO 500  M=1,NN
KO(L,M)=KS(L,M)
500   CONTINUE
  DO 600  II=1,I7
     K=NB(II)
     K=K-II+1
     ITERM=NN-1
     DO 510 L=K,ITERM
     IP1=L+1
     DO 510 M=1,NN
KO(L,M) =KS(IP1,M)
510   CONTINUE
  NM1=NN-1
     DO 540 L=1,NM1
     DO 540 M=1,NN
KS(L,M) =KO(L,M)
540   CONTINUE
     DO 520 M=K,ITERM
     JP1=M+1
     DO 520 L=1,NN
520   KO(L,M)=KS(L,JP1)
     NN=NN-1
     DO 545 L=1,NN
     DO 545 M=1,NN
KS(L,M)=KO(L,M)
545   CONTINUE
600   CONTINUE
IF(RUN-2) 16,17,602
C REDUCED GEOMETRIC STIFFNESS:
 16   DO 161 I=1,I9
     DO 161 J=1,I9
161   KG(I,J)=KO(I,J)
C    WRITE(2,991)((KG(I,J),J=1,10),I=1,10)
C991 FORMAT(//,1X,'KG =',/,6('---'),/,10(2X,F10.2))
      GO TO  207
C REDUCED  ELASTICSTRIFFNESS
17    DO 171 I=1,I9
     DO 171 J=1,I9
171   KE(I,J)=KO(I,J)
C      WRITE(2,92)((KE(I,J),J=1,10),I=1,10)
C92  FORMAT(//,1X,'KE =',/,6('---'),/,10(2X,F10.2))
207   RUN=RUN+1
IF(RUN-2)208,208,602

602 CALL CHOLDC(KE,N,I9)

C====== PRINTING LOWER MATRIX OF A =============
C    WRITE(2,992)((KE(I,J),J=1,N),I=1,N)
C  992 FORMAT(//,1X,'LOWER MATRIX IS:',/,6('---
'),/,10(2X,F10.4))

  CALL LMI(KE,KEI,KEIT,N)
  CALL PMAT(KEI,KG,KEIT,P,N)
CALL TRIDIAG(P,N,DP,EP)
  Z=P
     CALL TQLI(DP,EP,N,I9,Z)
C  WRITE(2,97)(DP(I),I=1,N)
  STR(QM)=1./DP(N)
  IF(IP.EQ.8) GOTO 1067
  GOTO 1068
1067 X7=STR(QM)/(E*((TT/BS)**2))
  Y7=F9(QM)/BS
1068 IP=IP+1
IF(IP-08)2933,2933,9903
2933 QM=QM+1
IF(QM-3)3033,3035,9900

3033  FLA=0.8*BS
```

```
       GOTO 303
 3035 FLA=0.4*BS
   GOTO 303
9900 IF(QM-5)9902,9901,9903
9902 DUA=STR(1)*(F9(2)-F9(3))
   DUB=STR(2)*(F9(1)-F9(3))
   DUC=STR(3)*(F9(1)-F9(2))
   FLU=-2.*(DUA-DUB+DUC)
   FLS=F9(1)**2.*(STR(2)-STR(3))-F9(2)**2.*(STR(1)-
STR(3))
   #+F9(3)**2.*(STR(1)-STR(2))
   FLA=FLS/FLU
   IF(FLA.LE.0.00000000) GOTO 9903
   GOTO 9909
9909  IF(QM.GT.10) GOTO 9903
     GOTO 303
9901  QM=QM-1
     EMAX=STR(1)
   K=1
   DO 501 I=2,4
   IF(STR(I).GT.EMAX)GOTO 502
   GOTO 501
502   EMAX=STR(I)
     K=I
501  CONTINUE
IF(K.EQ.4) GOTO 503
    DO 504 I=K,3
    STR(I)=STR(I+1)
    F9(I) =F9(I+1)
504  CONTINUE
503  CONTINUE
     GOTO 9902
   FORMAT(3X,F7.2,3X,F7.2,3X,F7.2,3X,F6.2,3X,1X,F6.2,3X
,F6.2)
9903 WRITE(3,99)TT,BW/TT,TWR,STR(QM),X7,EC
 99
FORMAT(2X,'TT=',F5.2,2X,'BWR',F5.2,2X,'TWR',F5.2,2X,'
STR ',F8.2,2X
    #,'X7= ',F7.2,2X,F5.1)
   END DO
   END DO
     STOP
     END
```

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