ABSTRACT:

Shell structures now days are widely used in constructing hall roofs with long spans, concrete roofs, pipe lines (gas and oil) and large water tanks. So the analysis of theses shell structures become of great interest for designing purposes. For this research lamination technique is adopted as one of the well known type of composite material. This research presents a finite element concept for geometrically linear and nonlinear analysis of laminated shell structures. Only static analysis is performed. At the beginning the theory of linear analysis is presented and then extended to include geometrically nonlinear analysis for large rotations and large displacements. The finite element formulation employed the 8-node degenerated curved shell element of (parabolic) shape. The element has five degrees of freedom per node, (three global translations X, Y & Z and two rotations α and β). Shear locking as one of the famous problem facing the application finite element method is discussed and some solutions are suggested. The nonlinear finite element formulation is based on Total Lagrangian approach using both Green and Geometric strains. The nonlinear equilibrium equations are solved using the Incremental and Newton-Raphson Method. Different seven numerical examples are performed to obtain the geometrically linear and nonlinear behaviour of laminated shell structures. The structures analysed are flat plate, cylindrical shell and spherical shell for different applied load types and various boundary condition. A FORTRAN computer programs are developed and implemented to analyse some laminated shell structures. Results obtained using Green's strain is compared with those obtained when using Geometric strain. Good agreement was observed between the

results obtained by the present formulation and those available in the literature.

TABLE OF CONTENTS

LIST OF TABLES

Table **Page**

LIST OF FIGURES

Figure **Page**

LIST OF SYMBOLS

Symbol	Description
$\mathbf{a}$	Nodal displacement vector
$\mathbf{a}^e$	Nodal element displacement vector
$\mathbf{b}$	Vector of body force per unit volume
$\mathbf{b}_i$	Nodal element body force
$\mathbf{B}_L$	Strain-displacement vector
$\mathbf{B}_o$	Linear strain displacement vector
$\mathbf{C}$	Elasticity matrix
E	Young's modulus
$\mathbf{f}$	Vector of external force
$\mathbf{G}$	Matrix containing shape functions derivatives w.r.t. r, s & t
$\mathbf{J}$	Jacobean matrix
$\mathbf{K}_o$	large displacement stiffness matrix
$\mathbf{K}_L$	Small displacement stiffness matrix
$\mathbf{K}_\sigma$	Initial stress stiffness matrix
$\mathbf{N}$	Shape function displacement matrix
N_i	Shape function at node i
$\mathbf{T}$	Transformation matrix
u,v and w	Global displacements
$\mathbf{v}_1$, $\mathbf{v}_2$ aand $\mathbf{v}_3$	Components of transformation matrix
x, y and z	Cartesian coordinates

$\boldsymbol{\sigma}$	Stress vector
μ	Poisson's ratio
$\boldsymbol{\psi}$	Residual force vector
r, s & t	Element natural coordinate
h	Element thickness

Note: other symbols are defined in text where necessary

LIST OF ABBREVIATIONS

SAP	Structural Analysis Program
STAAD	Structural Analysis and Design Program
MITC	Mixed Interpolation Tensorial Components
FORTRAN	Formula Translation
CLPT	Classical Laminate Plate Theory
FSDT	First Order Shear Deformation Theory
EAS	Enhanced Assumed Strain
ESL	Equivalent Single Layer
ANS	Assumed Natural Strain
FEM	Finite Element Method
NEFAP	Nonlinear Finite Element Analysis Program