AXIAL COMPRESSION OF THIN WALLED METALLIC AND COMPOSITE SHELLS

By

R. VELMURUGAN
Department of Applied Mechanics

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CERTIFICATE

This is to certify that the thesis entitled " **Axial Compression of Thin Walled Metallic and Composite Shells** " by R. Velmurugan has been prepared under my supervision and has attained a standard required for a Ph.D. degree of the Institute. The thesis is a record of bonafide research work carried out by him and its contents have not been submitted to any other University or Institute for the award of any degree or diploma.

NKGupta 1.5-96

(N K Gupta)

Professor

Department of Applied Mechanics

Indian Institute of Technology, New Delhi

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R VELMURUGAN

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ABSTRACT

Experiments in axial compression were carried out on aluminium and steel metal tubes, and Composite tubes, cones and domes of different diameters, thicknesses and lengths to identify the various failure modes and to study the energy absorption capacity of these shells. Analysis was carried out in each case and the results obtained have been compared with experiments. A brief description of the work done on metal and composite shells is given below.

Metal tubes :

Annealed aluminium and as received steel tubes of different diameter to thickness ratios [D/t], ranging from 13 to 33, with Height to diameter ratio [H/D] equal to 3, were subjected to axial compression in the Instron machine. These tubes buckled in axi-symmetric concertina mode. Their load-compression curves were obtained on the machine chart recorder, and the mean compressive load was calculated from these curves. The tested tubes were sectioned vertically at their middle to study the deformation mode and to make suitable analytical models. The internal and external fold lengths were measured for all the tested specimens. Tube specimens of identical sizes cut from the same tube (of length 2 m) were tested up to different stages, and their deformation profiles were drawn in a profile projector. The hinge angles corresponding to the four hinges of a fold were measured from the traced profiles and the variation of the limit loads with the average value of the hinge angles were studied

for the tubes, and their variation with different D/t ratios is discussed.

Based on the experimental observations that the tubes fold both internally and externally with respect to the mean tube radius, an analytical model is established to study the post collapse behaviour of the round tubes under axial compression. In this analysis it is initially assumed that one third of the fold goes inside the tube radius and two third forms out side the tube radius. Expressions were obtained to find the post collapse load-compression curve, the mean collapse load and the internal and external fold lengths. The results thus obtained are compared with the experimental results as well as with some of those obtained from different models available in literature [32-34].

Experimental studies however reveal that the folding in an axi-symmetric mode of collapse takes place both internally and externally with respect to the mean radius and the amount of internal folding is a function of D/t. An empirical relation is established to show this variation. A detailed analytical study was carried out to study the effect of internal folding (ratio of internal folding to the fold length that varies between 0 to 1/2) on the fold length, mean collapse load and the post collapse load-compression curve. The analysis is carried out firstly assuming that the hoop strain variation along the profile is piece wise linear and then by considering the variation of the hoop strain along the actual profile. An analysis is also carried out by considering the non-symmetry of folding about the middle plastic hinges by introducing that the four hinge angles corresponding to a fold are different from each other as is observed from experiments. These studies were again carried for both piece wise linear variation and variation of hoop strain along the actual profile. The results are compared with the experimental values and good agreement is found.

Composite shells:

Tubes of different diameter to thickness (D/t) and height to diameter (H/D) ratios, made up of glass fibre woven mats with epoxy resin were subjected to axial compression in the Instron machine. The different failure modes were identified and the energy absorption capacity of the tubes were studied. The specific energy absorption capacity and the crush length (tube length crushed in a crush cycle) of the GFRP tubes were calculated from the load-compression curves. Certain empty tubes were subjected to uni-axial tension to find the tensile strength of the specimens.

Experiments in axial compression were also carried out on GFRP tubes that were filled with Polyurethane Foam. The effect of foam on the deformation mechanism and on the energy absorption capacity of the tubes was studied. Foam blocks of different length, diameter and density were subjected to axial compression and the strength of the foams were obtained from their load-compression curves. These values were compared with the theoretical results.

Based on the experimental observations an analytical model was developed to find the post crush behaviour of the composite tubes by considering the different failure modes involved in the crushing process. Expressions were obtained to find the average crush stress and the crush length. Results thus obtained are compared with the experimental results. Analysis was also carried out to find the average crush stress for tubes filled with foam.

Conical shells, with semi cone angles 15° to 45°, and domes (the generator is a parabola of $H = C R^2$, $C = 0.4$ to 1.2, where H is the height of the shell and R is the radius at the base) were fabricated with short-randomly oriented glass fibre mats and polyester resin. These shells were subjected to axial compression. Experiments were carried out on the shells in both empty and foam filled condition. The mechanics of deformation and the energy absorbing capacity of the shells were studied. Based on the experimental observations, an analysis is carried out to find the average crushing stress and the crush length of the conical shell. The results thus obtained have been compared with the experiments.

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