ELASTO-PLASTIC BEHAVIOUR OF CYLINDRICAL STEEL SHELLS UNDER UNIAXIAL COMPRESSION

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1. Introduction

Elastic behaviour of cylindrical shells under uniaxial compression has been studied by many researchers for many years. The studies were investigated the effect of initial geometric imperfection, diameter-to-thickness and length-to-thickness ratios. These geometric parameter were used to predict the collapse load due to large deflection of structures, nonlinear material, or a combination of those [1−2]. Several design curves and formula concerning the above parameters were suggested [3].

In this study, steel material that has three states, i.e., elastic, perfectly plastic and plastic one with strain hardening is used to investigate the behaviour of cylindrical shell under uniaxial compression. The study is focused on load-displacement relationship, ultimate strength, and effect of strain hardening on ultimate strength and ductility.

2. Analytical Method [4]

In order to predict the numerical results, finite displacement analysis in the basis of degenerated shell element was used. The element has eight nodes. Each node has five degrees of freedom. Normal reduced integration technique is advocated in this analytical method. Geometric nonlinearity due to large displacement and large rotation of structures are considered in this study. Nonlinear material is formulated following von Mises yield criterion and Prandtl-Reuss flow rule.

3. Analytical Model

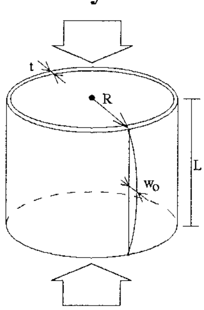


Fig. 1 Cylinder under axial compressionl

Stress-strain relationship of steel material is assumed to have three clear states, elastic, perfectly plastic, and plastic one with strain hardening. A power equation which consists of three constants b, c, and is adopted to express the strain hardening state in the following equation.

$$\sigma/\sigma_Y = b(c + \varepsilon/\varepsilon_Y)^n \qquad (1)$$

in which σ_Y and ε_Y are yield normal stress and yield strain, respectively.

The numerical analysis of cylindrical steel shells under uniaxial compression is carried out using 4x6 element mesh as shown in Fig.1. One half of the longitudinal direction is idealized by four elements and one quarter of tangential direction is divided by six elements. The cylinder has hinge supported ends. The initial imperfection is introduced in the longitudinal directions as a sinus function with maximum amplitude equal to w_0.

Two kinds of material are considered, i.e., mild steel with yield strength equal to 3000kgf/cm^2, and high tensile strength steel SM570 as shown in Table 1. Two kinds of geometric characteristics of structures also considered in this study. The first model is a cylinder with Batdorf coefficient $Z(=\sqrt{1-\nu^2}\cdot L^2/Rt)$ and radius-to-thickness ratio R/t equal to 5 and 350, respectively.

Tabel 1 Mechanical Properties of Steel

Steel	σ_Y (kgf/cm^2)	σ_U (kgf/cm^2)	ε_H	b	c	n
Mild steel	3000	3000	−	−	−	−
High strength steel SM570)	4600	4600	0.0123	0.7578	0.0	0.1604

Tabel 2 Geometric Parametrs of Analytical Models (cm)

	R	L	t
Model 1	350	42.8	1.00
Model 2	40.0	40.0	4.00

The second is a cylinder with Batdorf coefficient and radius–to–thickness ratio equal to 9.54 and 10, respectively. L, R, and t are listed in Table 2.

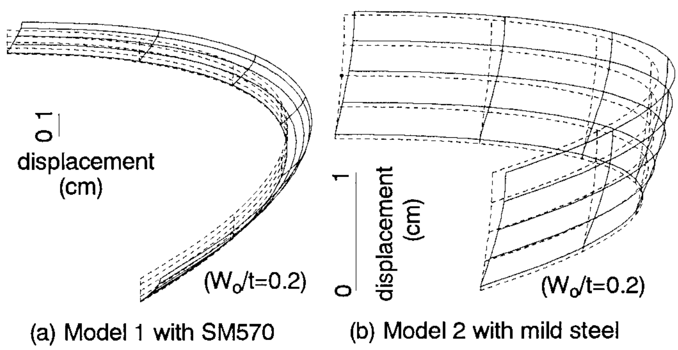
4. Results and Discussions

Fig. 2 shows shape of deflection at ultimate load in the case of model 1 and model 2. Load–displacement curves are shown in Fig. 3. In the figures, solid lines show load–deflection curves, and broken lines do load axial displacement ones.

In the case of model 1, similar load–displacement curves are obtained. After reaching the ultimate loads, the curves immediately reduce to the same path, because increasing bending stresses due to large deflection dominate the effective stresses. The curves also show the influence of initial imperfection on decreasing ultimate load is very sensitive. The bending stresses are dominant around the center of cylinder, whereas membrane stresses are dominant around its supported ends.

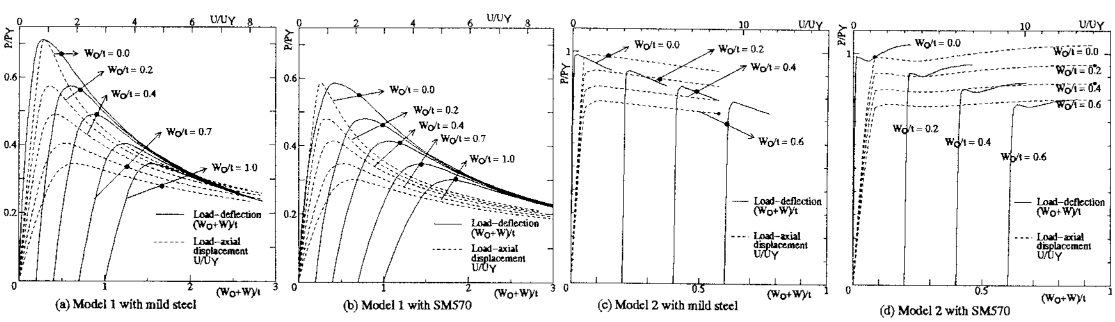
Ultimate axial loads of model 1 with mild steel are higher than those with SM570 because of difference in normalized slenderness. On the other hand, due to large plastic plateau of mild steel, load–displacement curves of model 1 with mild steel reduce more rapidly than those with SM570.

Steel SM570 improves ductility of the cylinders for model 2 with small slenderness in comparison with mild steel, as shown in Fig. 3 (c) and (d).



(a) Model 1 with SM570 (b) Model 2 with mild steel

Fig. 2 Shape of deflection at ultimate load



(a) Model 1 with mild steel (b) Model 1 with SM570 (c) Model 2 with mild steel (d) Model 2 with SM570

Fig. 3 Load–displacement curves

References

1. Bushnel, D., "Plastic Buckling of Various Shells", Journal of Pressure Vessel Technology, Vol. 104/51 (1982).
2. Yasukawa, W., Kawakami, H. and Yoshikawa, T., "Elasto–Plastic Finite Element Analysis of Imperfect Short Cylinder under Axial Compression", Journal of the Society of the Naval Architects of Japan, No. 153, pp. 218–225, 1983.
3. Samuelson, L.A. and Eggwertz, S., "Shell Stability Handbook", Elsevier Science Publisher, 1992.
4. Rizal, F., Nara, S. and Moriwaki, Y., "Elasto–Plastic Analysis of Steel Shells", I–564 Annual Meeting of JSCE, 1993.