An Ultimate Strength of Varied Thickness Plates under In-Plane Uniform Compression

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1. INTRODUCTION

Recently, Longitudinally Profiled (LP) steel plates with varied thickness had been used as compressive flanges in view of rationalization in structure design. Also, the non-homogeneous thickness reduction due to corrosions causes the strength reduction. It has been becoming more serious problem for the steel structures used commonly for a long term. To evaluate the load-carrying capacity of corroded steel structures are needed for maintenance management. In this study, to investigate basic properties of compressed tapered rectangular plates are analyzed. Numerical results of buckling, postbuckling and load-carrying capacities of these plates are obtained using elastic buckling analysis and elasto-plastic finite displacement analysis.

2. ANALISYS MODELS

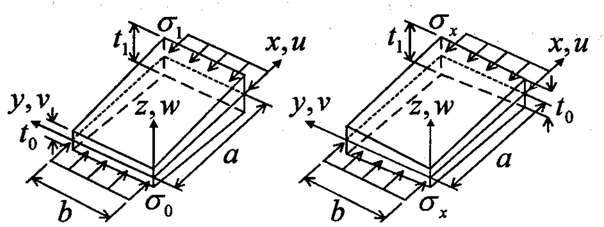
The analysis models of tapered plates under in-plane compression are shown in **Fig.1**. In which, t_1 is the maximum thickness, t_0 is the minimum thickness, a is the length of plate, and b is the width of plate, respectively. The tapered thickness are assumed to vary linearly in the loading or unloading direction.

The boundary conditions of these plates are all edges simply supported and the aspect ratio being the ratio of length to width of plate is definitely constant to be one (a=b=1000mm). To compare an influence of the tapered direction on elastic buckling, post-buckling and ultimate strength, two types of tapered directions are investigated. One case is in the loading direction (**Fig.1 (a)**) and another case is in the unloading direction (**Fig.1 (b)**). Material properties of tapered plate are shown in **Table 1**.

Furthermore, in order to evaluate an influence of varying thickness on ultimate strength, plate taper ratios TP (equal to t_1/t_0) and plate slenderness parameter R_{av} with average thickness t_{av} are adopted as analytical parameters. Such parameters are summarized in **Table 2**. The plate slenderness parameter R_{av} is defined as follows:

$$R_{av} = \frac{b}{t_{av}}\sqrt{\frac{\sigma_y}{E}\frac{12(1-\nu^2)}{\pi^2 k}} \tag{1}$$

where b is the width of plate, t_{av}=$(t_0+t_1)/2$ is the average thickness, σ_y is the yield stress, ν is the Poisson's ratio, E is the Young's modules, and k=4 is the constant buckling coefficient. The shape of initial deflection of tapered plate is assumed to be the same as the corresponding first buckling mode. The maximum magnitude of initial deflection is specified to be b/150 according to the JSHB. Residual stresses and the changes of yield stress during a rolling-procedure are not considered herein.



(a) Loading direction (b) Unloading direction

Fig.1 Analysis model of tapered plates

Table 1 Material properties

Young's modules [GPa]	205.8
Poisson's ratio	1/3
Yield stress [MPa]	235.2

Table 2 Analysis parameters

t_{av}(mm)	R_{av}	TP (t_1/t_0)
6	2.93	
9	1.95	
12	1.46	1, 1.125, 1.250, 1.375
16	1.10	1.500, 1.625, 1.750
21	0.84	
32	0.55	

3 ULTIMATE BEHAVIOR

The relationships between compressive load P/P_y and in-plane displacement U/U_{cr} are shown in **Fig.2** in the case of loading-direction. This shows the results for values of TP=1, 1.125, 1.250, and 1.500 at R_{av}=1.46. In which, P_y is the yield force calculated using the cross sectional area with average thickness t_{av}, and U_{cr} is the critical in-plane displacement when the buckling occurs.

Even if the taper ratio TP varies, the initial in-plane rigidity is almost constant and can be able to evaluated using that for the constant-thickness plate (TP=1). The in-plane behavior depends on the taper ratio TP in the elasto-plastic finite deformation range. On the other hand, in the case of unloading-direction taper, there is little influence of TP for the in-plane behaviors independently on values of plate slenderness parameter R_{av}.

4 LOAD CARRYING CAPACITY

4.1 *Strength curves*

Fig.3 shows the strength curves of plates tapered in the case of loading direction. The ordinate shows the dimensionless ultimate strength P_u/P_y, where P_u is the maximum compressive force. The abscissa shows the plate slenderness parameter R_{av}. The present results are compared with such strength curves as Euler (elastic buckling strength), von Karman, Komatsu & Kitada, and JSHB for constant-thickness plates.

The present results can be evaluated using those by Komatsu & Kitada in the smaller value of TP. On the other hand, the ultimate strength is larger than the elastic buckling strength in the bigger value of R_{av}, and the tapered plates have so-called postbuckling strength similarly to constant-thickness plates. In the case of unloading direction, however, the rates of strength reduction are much small. Then, the ultimate strength for such tapered plates is found to be evaluated using a certain representative strength curve.

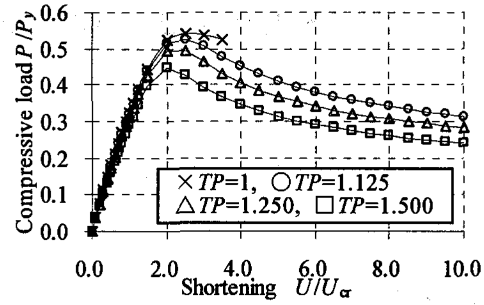


Fig.2 Load-shortening curves (loading direction)

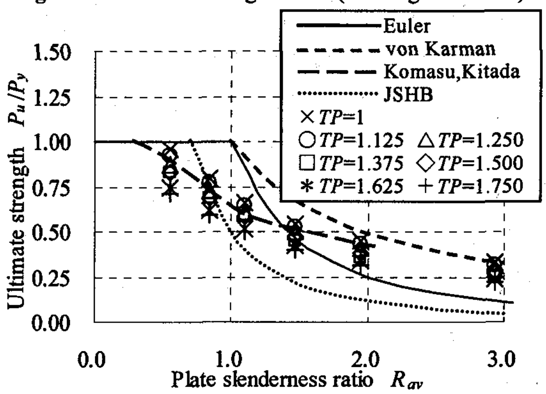


Fig.3 Load-carrying capacity (loading direction)

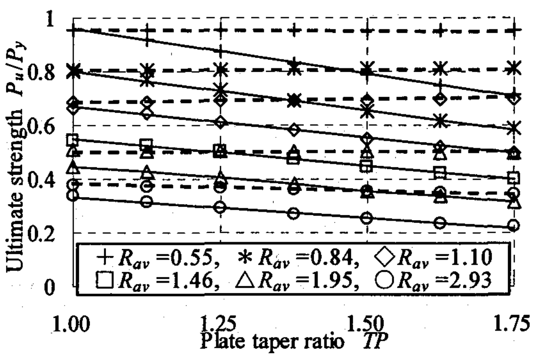


Fig.4 Relation between ultimate strength and TP

4.2 *Influence of taper ratio*

Fig.4 shows the relationship between ultimate strength P_u/P_y and the taper ratio TP. In the case of loading direction shown as dashed lines, the ultimate strength is reduced as the taper ratio TP increases. The ultimate strength is almost linearly proportional to the taper ratio, depending on the plate slenderness parameter R_{av}. In the case of unloading direction shown as solid lines in **Fig.4**, the ultimate strength is not affected by the taper ratio TP. In particular, the strength even increases at about R_{av}=1.46.

Moreover, the correlation of ultimate strength and the difference of thicknesses are found to be significant. The ultimate strength is almost linearly proportional to the difference of thicknesses. This gradient depends on the plate slenderness parameter R_{av}.

5 CONCLUSIONS

(1) The initial rigidity of the tapered plate can be evaluated by that of the constant thickness plate with average thickness t_{av}, and its elasto-plastic finite deformation behavior depends on analytical parameters of TP and R_{av}.

(2) Load carrying capacities of tapered plates using R_{av} can be evaluated by the previous strength curves of constant-thickness plates. Furthermore, the ultimate strength of tapered plates is almost linearly proportional to the taper ratio TP or the difference of thicknesses.