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Analytical and Finite Element Post Buckling Analysis of Isotropic Steel Plate Subjected to the in-Plane Loading

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Abstract: ***Disturbance to stability of a member occurs with presence of any external force of different nature than that of the pre-applied load in action or through presence of any eccentric loading. These disturbances includes effects such as buckling in columns and plates which happens when action due to applied load is lesser than the moment due to disturbing agent. This paper investigates the buckling strength of steel plates subjected to loads widthwise, with varying support conditions lengthwise and an effort to trace the load deformation characteristics during post buckling stages, where the transverse strips of plates try to resist the buckling phenomena of longitudinal strips using finite element modeling tool. Hence, resulting in failure of a member at a load greater than that observed during initial buckling stages.***

Keywords: Plate Buckling, Buckling Coefficient, Pre-buckling Phenomena, Post-buckling Phenomena

I. INTRODUCTION

Beams and columns are modelled linearly comparing the considerable difference between the length and width of the member. The members with no much difference between in plane dimensions are termed plate and are modelled as 2D plane members. As discussed about cases of buckling in columns, the same is found to be an intriguing topic when plates are called upon. The difference which makes engineers to broaden their study towards buckling phenomena of plate is its' capacity to substantially resist higher magnitude of loads than its' buckling strength. Efforts have been made to develop analytical solutions for the values of buckling strength for different support conditions and modes. In addition, the ultimate strength of the plate incorporating the effects of transverse restraints have been brought out into picture using concepts of effective width.

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The expression for buckling strength for flat plates simply supported on all four sides and subjected to uniform compressive force N_x per unit length in x direction has been made by solving equilibrium equation of plates given as,

$$\frac{\partial^4 w}{\partial x^4} + 2\frac{\partial^4 w}{\partial x^2 \partial y^2} + \frac{\partial^4 w}{\partial y^4} = \frac{12\left(1-\nu^2\right)}{Et^3}\left(-N_x \frac{\partial^2 w}{\partial x^2}\right)$$

Where, w denotes the deflection in z direction of any point (x, y).

The buckling strength for plates for the condition mentioned above has been determined as,

$$\sigma_c = k\frac{\pi^2 E}{12(1-\nu^2)(b/t)^2}$$

Where,
k = Buckling coefficient
B& t are width and thickness of plate
E = Modulus of Elasticity
v = Poisson's ratio
The value of k depends upon the support conditions, aspect ratio and number of half sine waves formed in the buckled mode. The values of which are presented in the table below.

Table 1 Values of k for Different Load and Support Conditions

Load	Support Condition	Coefficient of Buckling
Uniaxial Compressive Stress (σx)	Hinged to hinged	4.00
	Fixed to fixed	6.97
	Hinged to free	1.27
	Fixed to free	0.43
Shear Stress (τxy)	Hinged to hinged	5.35
	Fixed to fixed	8.99

The ultimate strength is linked to the effective width and is given by,

$$\frac{b_{eff}}{b} = \sqrt{\left(\frac{\sigma_{cr}}{f_y}\right)}\left[1 - 0.22\sqrt{\left(\frac{\sigma_{cr}}{f_y}\right)}\right]$$

Where, f_y is the yield stress and other terms are as defined earlier. The ultimate strength is the product of effective width and the yield stress. In this study, the buckling coefficients have been determined using *Ansys R19.0* for different support conditions for a steel plate and post buckling analysis has been carried out to determine the ultimate strength.

II. SPECIFICATIONS

The steel plate used in the study was fixed to have following specifications:

Table 2 Specifications

CONSTANTS	Values
E	$2.X10^5$ N/mm^2
v	0.3
B	1000 mm
T	10 mm
L	5000 mm

III. RESULTS

The analysis for pre-buckling and post-buckling was carried out using finite element modelling tool as specified above. The results for specific loading stage and support conditions have been grouped below.

A. Pre- Buckling

The pre-buckling analysis for support conditions as mentioned below has been carried out and grouped:

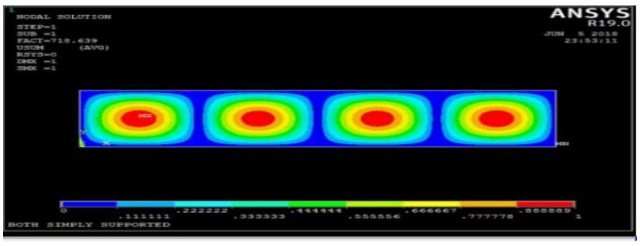
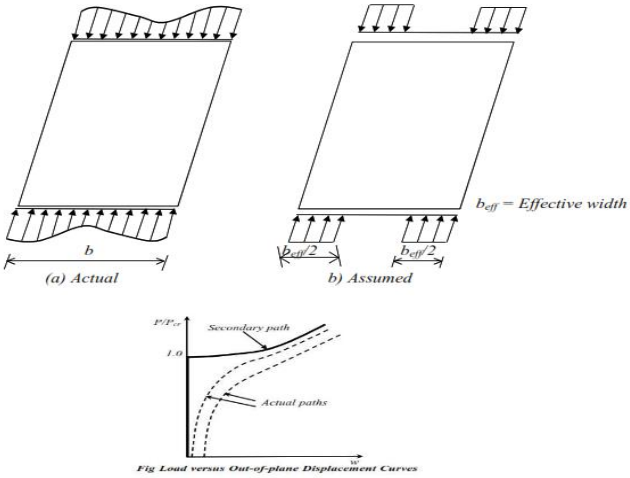


Fig 1 Ansys Environment

Support Condition	Value of k from Ansys	Value of k from eqn.
Both loaded edges simply supported and unloaded edges both simply supported.	3.97	4
Both loaded edges simply supported and unloaded edges both fixed.	6.95	6.97
Both loaded edges simply supported and unloaded edges one fixed one free.	0.48	0.43

B. Post Buckling

When the compressive stress equals the crucial buckling stress σ_{cr}, the central a part of the plate, like the strip AB, buckles. however, the sides parallel to the coordinate axis cannot deflect within the z-direction and then the strips nearer to those edges still carry the load with none instability. Therefore, the strain distribution across the dimension of the plate within the post-buckling vary becomes non-uniform with the outer strips carrying a lot of stress than the inner strips as shown in Fig



The post-buckling analysis for support conditions as mentioned below has been carried out and grouped:

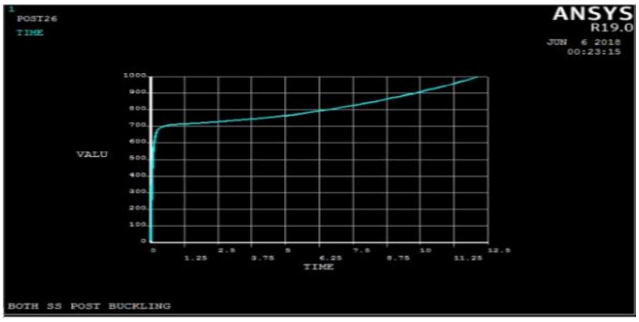


Fig 2 Both loaded edges simply supported and unloaded edges both simply supported.

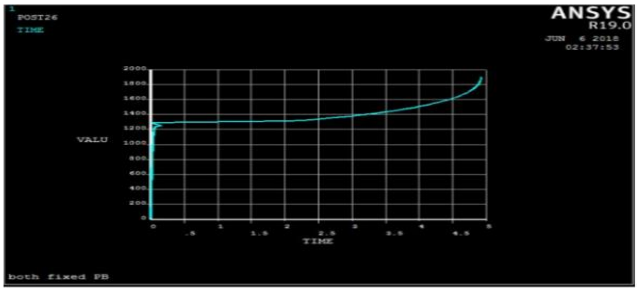


Fig 3 Both loaded edges simply supported and unloaded edges both fixed.

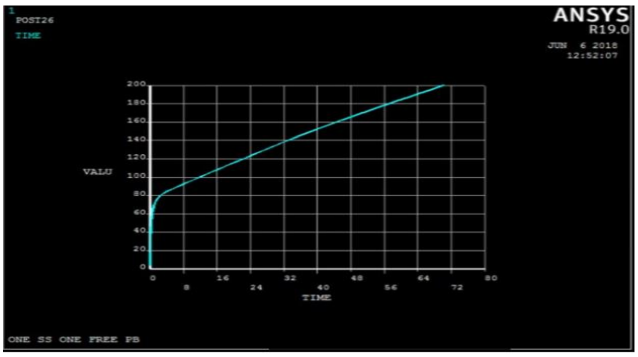


Fig 4 Both loaded edges simply supported and unloaded edges one fixed one free.

IV. CONCLUSION

The collapse of metal plate structures by and large includes either crack or stability limit states. Structures generally involve either fracture or stability limit states. The inelastic local plate buckling are typically preferred over fracture limit states, as they offer greater post-buckling resistance, ductility and the higher energy dissipation.

For seismic design for most of structures fundamental need is an energy dissipation, rather than inherent energy dissipation. Modern design explicitly uses specific elements for energy dissipation. Properly designed thin plate provide reliable energy dissipation under post-buckling

Utilizing the post buckling response of plates these Steel plates are an important example in the application of metal plate for the purposes of energy dissipation

REFERENCES

1. Mimura H, Akiyama H (1977), Load- Deflection Relationship of Earthquake Resistant Steel Shear Walls with a Developed Diagonal Tension Field, Transactions of the Architectural Institute of Japan, Vol.260, 109-114.
2. Thorburn, L J Kulak, G L Montgomery,C J, (1983), Analysis of Steel Plate Shear Walls; Department of Civil Engineering , University of Alberta, Edmonton ,Alberta, Canada. Structural Engineering Report No 107.
3. Xue M, Lu LW (1994), Interaction of Infilled Steel Shear Wall Panels with surrounding Frame Members, Proceedings of the Structural Stability Research Council Annual Technical Session, Bethlehem, PA, pp.339-354.
4. Elgaaly,M, (1998). Thin Steel Plate Shear Walls Behaviour and Analysis. Thin Walled structures, Vol.32, pp.151-180.
5. Aravind Bhashyam and Prashant Sunagar (2017), Advances & Trends in Civil Engineering" ATCE, ISBN: 978-93-87769-06-9, pages 223-228

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