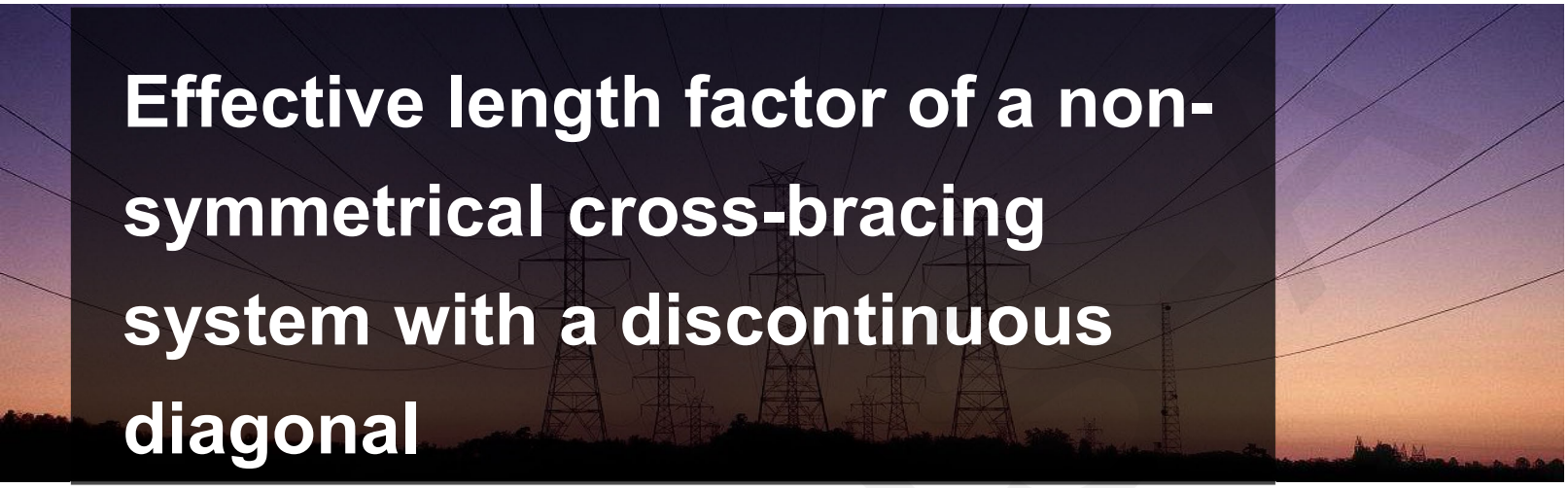
Journal of Zhejiang University-SCIENCE A



Effective length factor of a non-symmetrical cross-bracing system with a discontinuous diagonal

Key words: Non-symmetrical cross-bracing system, Discontinuous diagonal, Out-of-plane buckling analysis, Effective length factor

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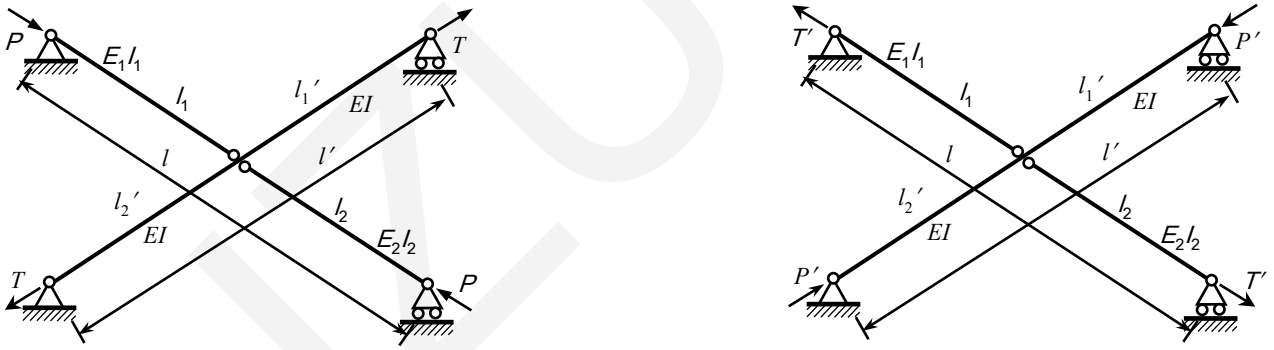
Backgrounds

- Cross-bracing systems are widely adopted in offshore structures, transmission towers, to resist lateral loadings such as wind and earthquake.
- non-rectangular frame panels might result in geometrical asymmetry of a cross-bracing system, e.g. cross-bracing systems in transmission tower structures.
- Wind-induced out-of-plane buckling of cross-bracing system may lead to failure or even collapse of a transmission tower.

Out-of-plane buckling collapse of transmission tower

Objectives

- **Elastic out-of-plane buckling of a completely non-symmetrical X-bracing system with a discontinuous diagonal under a general case, i.e. continuous and discontinuous diagonals with different lengths and cross-sections, and intersection points not fixed at their mid-spans**



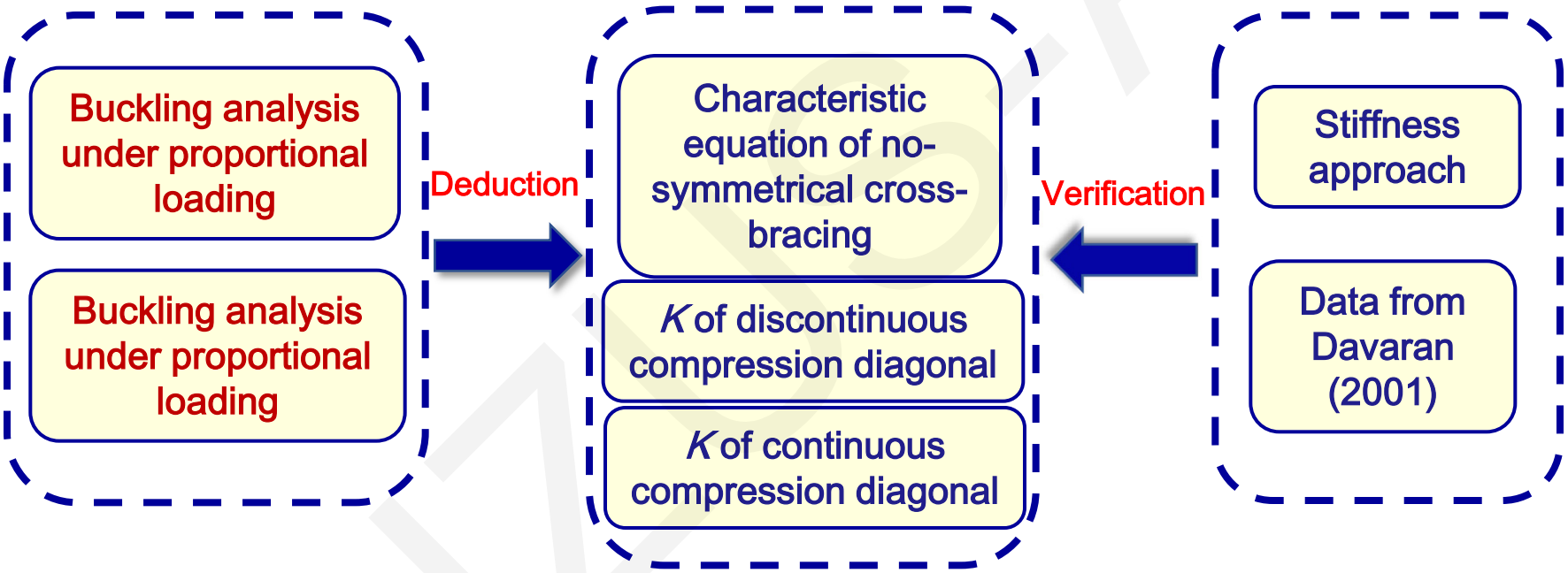
(a) Discontinuous compression diagonal

(b) Discontinuous tension diagonal

A general non-symmetrical X-bracing system with a discontinuous diagonal

Methods

- Cross-bracing system with a discontinuous diagonal -- Effective length factor *K*



Results

- The characteristic equation of a general non-symmetrical cross bracing system

$$1=\alpha'(1-\alpha')\beta_0\sqrt{\beta_0\hat{\gamma}_0}\sinh(\sqrt{\beta_0\hat{\gamma}_0})/[(1-\alpha')\alpha'\sqrt{\beta_0\hat{\gamma}_0}\sinh(\sqrt{\beta_0\hat{\gamma}_0})-\sinh(\sqrt{\beta_0\hat{\gamma}_0}-\sqrt{\beta_0\hat{\gamma}_0}\alpha')\sinh(\sqrt{\beta_0\hat{\gamma}_0}\alpha')]$$

- Effective length factor of a non-symmetrical cross-brace with a discontinuous compressive diagonal, *K*

$$K=\begin{cases}\sqrt{\nu}\psi(\xi_1\xi_2+0.5), & \beta_0<\beta_{0\mathrm{cr}}\\ 1, & \beta_0\geq\beta_{0\mathrm{cr}}\end{cases},\quad \xi_1=\frac{\mu_\xi(\alpha')-0.5}{\mu_\xi(0.5)-0.5},\quad \xi_2=\begin{cases}-0.07586\overline{\beta}^4+0.31064\overline{\beta}^3-\\ 0.54441\overline{\beta}^2+0.91557\overline{\beta}, & \beta_0\geq-1\\ -0.0007\overline{\beta}^4+0.0153\overline{\beta}^3-\\ 0.1279\overline{\beta}^2+0.6999\overline{\beta}, & \beta_0<-1\end{cases}$$

$$\mu_\xi(\alpha')=0.897\alpha'^4-1.821\alpha'^3+0.617\alpha'^2+0.300\alpha'+2.836,$$

$$\overline{\beta}=8.593-\frac{8.593}{\mu_\beta(\alpha')+8}(\beta_0+8),$$

$$\mu_\beta(\alpha')=-7.29\alpha'^4+12.94\alpha'^3-9.89\alpha'^2+3.79\alpha'+0.01.$$

- Effective length factor of a non-symmetrical cross-brace with a continuous compressive diagonal, *K'*

$$K'=\begin{cases}\dfrac{1}{1+\kappa(\nu\beta'-1)^\chi}\left(\alpha'-\dfrac{\pi}{\sqrt{\gamma'_\infty}}\right)+\dfrac{\pi}{\sqrt{\gamma'_\infty}}, & \nu\beta'>1\\ 1-\nu\beta'+\nu\beta'\alpha', & \nu\beta'\leq1\end{cases},$$

$$\kappa=(-8.1004+37.6598\alpha'-59.7324\alpha'^2+33.4999\alpha'^3)^{-1},$$

$$\chi=0.8472+0.4438\alpha'.$$

Conclusions

- The characteristic equation of a completely non-symmetrical cross bracing system is similar to the expression of characteristic equation of a geometrically mono-symmetrical system.
- When under compression, the discontinuous diagonal may buckle before the continuous diagonal and is thereby the control case in determining critical loading of a cross bracing system.
- The out-of-plane buckling of the discontinuous compression diagonal will show a pure sway mode on condition that 1) the non-dimensional stiffness is less than a critical value, or 2) the ratio of tension to compression, is less than a critical value.
- For design purposes, Direct closed-form equations of the effective length factor were formulated for a general cross-bracing system and their validity was verified through case studies.