

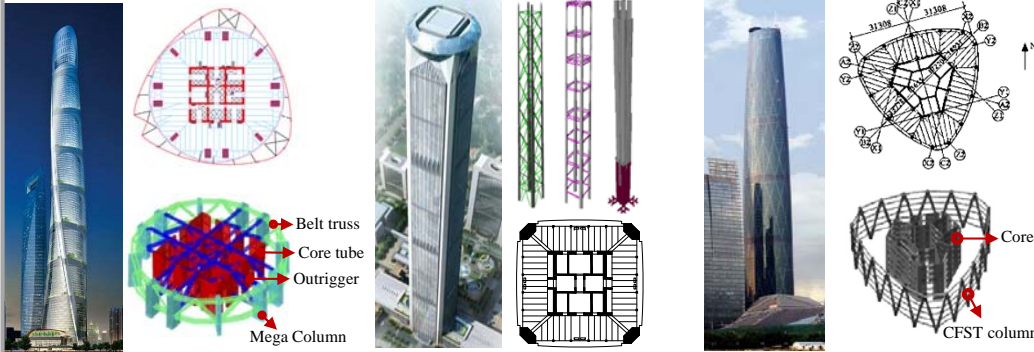
Damage Assessment of Steel Members and Application to Super High-rise Buildings

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Introduction

◆ A growing number of **super high-rise buildings** are built worldwide. About **40%-50%** are located in China, like Shanghai Tower in Fig.1.

- ◆ Super high-rise buildings comprises traditional **steel members, concrete members and most importantly steel-composite members.**
- ◆ In order to study the damage behavior of super high-rise buildings, damage evaluation method of steel members are studied, based on Park-Ang damage model.



Perspective view and typical story

Perspective view and structural plan

Perspective view and local layout

Fig. 1. Shanghai Tower (632m). Mega frame-core tube-outrigger.

Fig. 2. Tianjin Goldin 117 Tower (597m). Braced mega frame-core tube.

Fig. 3. Guangzhou International Financial Center (432m). Diagrid tube-core tube.

Tubed mega frame structure for super high-rise buildings

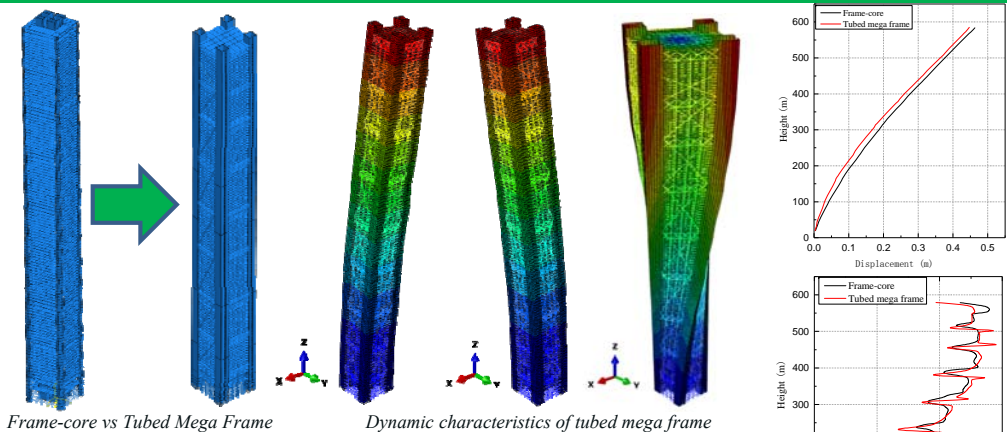


Fig. 4. Finite element model of typical frame-core-outrigger and tubed mega frame structure. Dynamic characteristics (1st order X, Y translation and torsion) of tubed mega frame.

- ◆ Tubed mega frame structure is mainly composed of **shear wall tubed column, steel truss mega beam, and steel mega braces.**
- ◆ In order to evaluate the damage of the structure, the **damage evaluation method for steel members** is discussed, while that for shear wall is still under study.

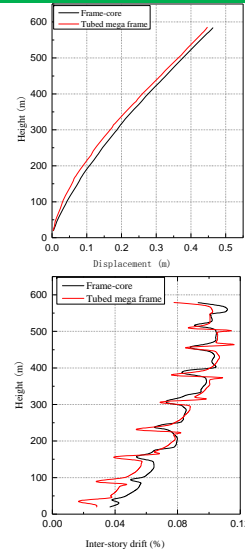


Fig. 5. Displacement and inter-story drift ratio under elastic response spectrum analysis.

Modified Park-Ang damage model for steel members

The **modified Park-Ang damage model**

When $D=1$, then

Regression analysis

$$D = (1 - \beta_s) \frac{\delta_m - \delta_y}{\delta_u - \delta_y} + \beta_s \frac{\int dE}{F_y (\delta_u - \delta_y)} \rightarrow \beta_{s,e} = \frac{F_y (\delta_u - \delta_m)}{\int dE - F_y (\delta_m - \delta_y)} \rightarrow \beta_s = Ax_1 + Bx_2 + Cx_3 + D$$

Test results of 49 steel columns were chosen from the publications.

First, experimental value of $\beta_{s,e}$ is obtained from eq.2. **Secondly**, linear regression analysis of β_s is conducted to get a formula of β_s and parameters of steel members (axial load ratio n_0 , slenderness ratio λ and width-thickness ratio of flange R_f).

$$\beta_s = 0.0427 - 0.1836n_0 + 0.515\lambda + 0.061R_f$$

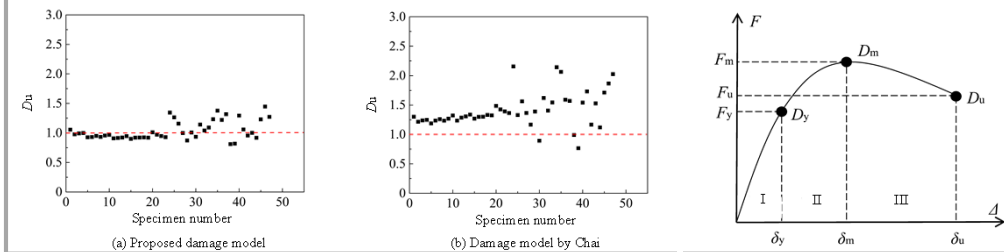


Fig. 6. Comparison of proposed damage model and Chai damage model.

Fig. 7. principle of performance levels.

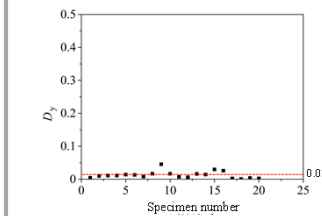


Fig. 8. Damage index at yield point.

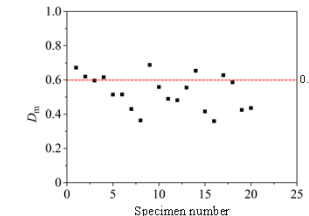


Fig. 9. Damage index at peak point.

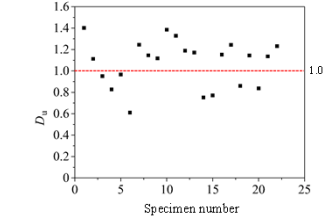


Fig. 10. Damage index at failure point.

Conclusions

1. A modified Park-Ang damage model for steel members is proposed. The **empirical formula of the combination coefficient β** is derived by regression analysis.
2. Performance of steel members is classified into three points: **yield, peak and failure point**, with the corresponding damage index of 0.015, 0.60 and 1.00 respectively.

The study provides a way of damage evaluation for steel members. Based on the damage model of structural members, further study on damage of high-rise structures will be conducted by adding weight factors to the member damage.

