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# Spring-stiffness model for flexible end-plate bare-steel joints in fire

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**Abstract**

This paper describes a spring-stiffness model developed to predict the behaviour of flexible end-plate bare-steel joints at elevated temperature. The joint components are considered as springs with predefined mechanical properties (i.e. stiffness and strength). They are also assumed to follow a trilinear force–displacement relationship. The elevated temperature joint's response can be predicted by assembling the stiffnesses of the components which are assumed to degrade with increasing temperatures based on the recommendations presented in the design codes. Comparison of the results from the model with existing experimental data showed good agreement. Also, the predicted degradation of the joint's stiffness and capacity compares well with the experimental results. The proposed model can be easily modified to describe the elevated temperature behaviour of other types of joint as well as joints under large rotations.



*Keywords:* Bare-steel; Flexible end-plate; Connections; Joints; Elevated-temperature; Fire; Spring-stiffness model; Component model

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## Nomenclature

*Joint's overall response*

| | |
|---|---|
| $E_{st}$ | modulus of elasticity for steel at a given temperature |
| $F_n$ | internal force at a given bolt row |
| $f_{uc}$ | ultimate strength of the joint's component |
| $h_n$ | distance between bolt row $n$ and the centre of rotation |
| $K_{cft}$ | final stiffness of the joint's component at a given temperature |
| $K_{cst}$ | strain hardening stiffness of the joint's component at a given temperature |
| $K_{ct}$ | elastic stiffness of the joint's component at a given temperature |
| $K_{eqt}$ | equivalent single stiffness of all components in the tension zone at a given temperature |
| $K_{tt,n}$ | the spring's stiffness in the tension zone at a given temperature for the bolt row under consideration |
| $M$ | applied moment |
| $S_{cc}$ | joint rotational stiffness in the compression zone at a given temperature |
| $S_{Ct}$ | global joint rotational stiffness of the bare-steel joint for a given temperature |
| $S_{tt}$ | joint rotational stiffness in the tension zone at a given temperature |
| $z$ | distance from the centre of rotation to location of equivalent tension spring (the centre of the tension zone) |
| $\phi$ | rotation of the joint |
| $\mu_s$ | strain hardening coefficient for structural steel |

*Column flange behaviour*

| | |
|---|---|
| $a$ | half the column flange width $= (B_{cf}/2)$ |
| $B_{cf}$ | width of column flange |
| $D$ | flexural rigidity of the plate |
| $F_{cfpt}$ | force that causes yielding within the column flange, at a given temperature |
| $f_{ycft}$ | yield strength of the column flange at a given temperature |
| $K_{cft}$ | out-of-plane stiffness of the column flange at a given temperature |
| $l_{eff\_cf}$ | effective length assuming the column flange to act as an equivalent T-stub |
| $m$ | distance from bolt centre to 20% into the column root radius |
| $s$ | distance from the centre-line of the column web to the centre of the bolt hole |
| $t_{cf}$ | thickness of column flange |
| $\beta$ | dimensionless coefficient |
| $\nu$ | Poisson's ratio for steel ($\approx$0.3) |