Appendix

1. Deduction of Equations (1), (2) and (23)

These equations were established based on the yield-line theory. The yield-line pattern is shown in Fig. A.1. The positive moment hinge at the beam end F and negative yield line along edge CD are ignored due to the free boundary conditions. Assume that the deflection at the column removal location equals to 1, the internal work done due to the rotation in plastic hinges (*A, J, K, D, E*) and along the yield lines (AA_1, *BJ* and *KC*) are given by (For simplicity, the length of AA_1 is assumed to be l):

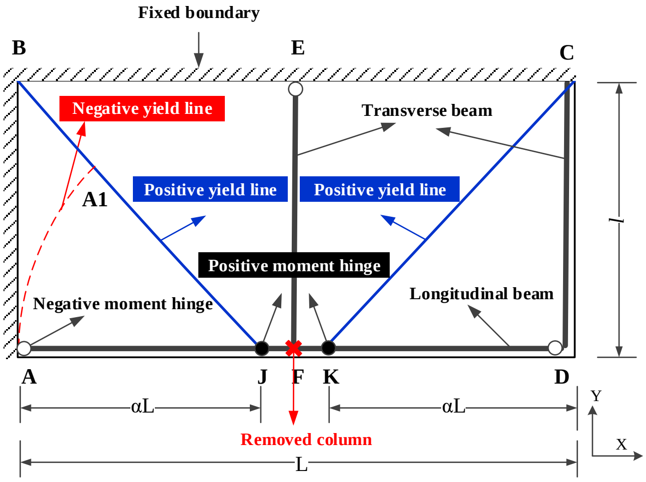

Fig. A.1 Yield-line pattern of the substructure due to a PS column loss

$$W_{in} = \frac{2\alpha M_y L}{l} + \frac{2M_x l}{\alpha L} + \frac{M_x^{'} l}{\alpha L} + \frac{2(M_{LN} + M_{LP})}{\alpha L} + \frac{M_{TN}}{l} \tag{A-1}$$

where $M_x^{'}$ and M_x are the negative and positive yield bending moment (unit width) of the slab about *Y*-

direction, respectively; M_y is the positive yield bending moment (unit width) of the slab about *X*-direction; M_{LN} and M_{LP} are the negative and positive plastic moment of the beam in *X*-direction, respectively; M_{TN} is the negative plastic moment of the beam in *Y*-direction.

For the concentrated load, the work done by the external force is given by:

$$W_{ext} = F \tag{A-2}$$

Thus the yield load can be expressed as:

$$F = \alpha B + \frac{A}{\alpha} + \frac{M_{TN}}{l} \tag{A-3}$$

where

$$A = \frac{2M_x l + M_x^{'} l + 2M_{LN} + 2M_{LP}}{L} \qquad \mathrm{B} = 2\frac{M_y L}{l} \tag{A-4}$$

Thus Equations (2) and (22) are obtained.

The parameter α can be determined as follows:

$$\frac{dF}{d\alpha} = 0 \tag{A-5}$$

The solution to Eq. (A-5) is given by:

$$\alpha = \sqrt{\frac{A}{B}} \tag{A-6}$$

Therefore, Equation (1) is obtained.

2. Deduction of Equation (5)

Fig. A.2 shows the deformation configuration of steel beam FD due to a vertical displacement *v*. The internal work done by this extension can be calculated as

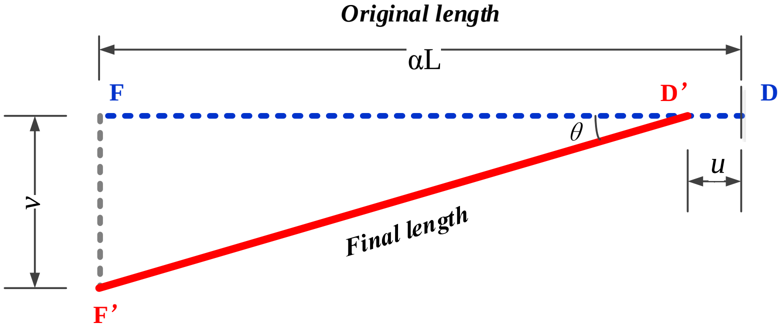

Fig. A.2 Deformation of steel beam FD

$$W_{in1beamFD} = F_{uL}\Delta_{FD} = F_{uL}(\sqrt{(\alpha L-u)^2+v^2}-\alpha L) = F_{uL}\frac{v^2+u^2-2u\alpha L}{\sqrt{(\alpha L-u)^2+v^2}+\alpha L} \tag{A-7}$$

3. Deduction of Equations (6) and (7)

As shown in Fig. A. 3, when the mid-span section of the simplified truss suffers from a unit vertical load, the corresponding vertical displacement Δ_1 at the mid-span F is calculated as:

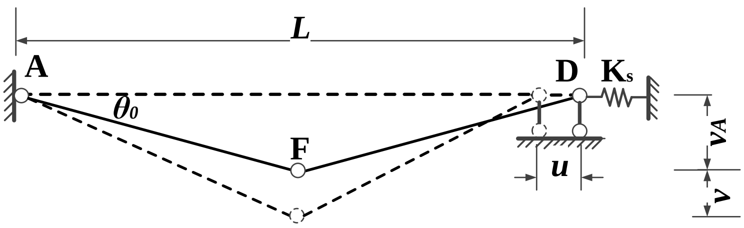

Fig. A.3 Simplified truss model

$$\Delta_1 = \frac{1}{2K_L \sin^2 \theta_0} + \frac{1}{4K_s \tan^2 \theta_0} \tag{A-8}$$

where K_s is the lateral stiffness provided by the peripheral beam CD and corner column D; K_L is the axial stiffness of the beam AF and FD.

The horizontal displacement Δ_2 at the beam end D is given by:

$$\Delta_2 = \frac{1}{2K_s \tan \theta_0} \tag{A-9}$$

Therefore, when the mid-span section of the truss suffers from a vertical displacement *v,* the corresponding horizontal displacement at the beam end D can be proportionally determined as:

$$u = \frac{\Delta_2}{\Delta_1} v = \frac{1}{\left(\frac{1}{K_L \sin^2 \theta_0} + \frac{1}{2K_s \tan^2 \theta_0}\right) K_s \tan \theta_0} v \tag{A-10}$$

Based on the geometric relationship:

$$\sin \theta_0 = \frac{v_A}{\sqrt{(v_A)^2 + (\alpha L)^2}} \qquad \tan \theta_0 = \frac{v_A}{\alpha L} \tag{A-11}$$

Substituting Equation (A-11) into Equation (A-10) yields:

$$u = \frac{1}{\frac{K_s((\alpha L)^2 + v_A^2)}{\alpha K_L v_A L} + \frac{\alpha L}{2v_A}} v \tag{A-12}$$