S_1, S_2 and γ_1, γ_2 are shear force and shear strain respectively; $A_E(\varepsilon, \mathrm{T}), I_1^{\mathrm{E}}(\kappa_1, T)$ and $I_2^{\mathrm{E}}(\kappa_2, T)$ 、 $J_{\mathrm{G}}(\chi, T)$, $A_1^{\mathrm{G}}(\gamma_1, T)$, $A_2^{\mathrm{G}}(\gamma_2, T)$ and T are the loudness of axial force, bending stiffness, torsional stiffness, shear stiffness and temperature, respectively.

Nonlinear beam element is used to simulate the key members between layers, The constitutive model of concrete tensile section (Fig.2 (c)) is adopted for concrete, and the double-broken line model is adopted for steel (Fig.2 (d)), The moment-curvature curve of pier is shown in Fig.2(e)~(f), and the mechanical model of bearing limit block (Fig.2(h)). The generalized beam element is constructed to simulate pier, the constitutive relation is shown as Eq(1). The effect of pile foundation is equivalent to six springs of pier bottom, and the stiffness of spring in six directions is used to simulate the effect of pile foundation (Sun *et al*. 2015) , the translational stiffness of the pile foundation in three directions is:

$$\gamma_{aaz} = \frac{n}{\dfrac{l_0 + \xi h}{EA} + \dfrac{1}{C_0 A_0}} \tag{2}$$

$$\gamma_{aax} = \frac{n\delta_{MMx}}{\delta_{HHx}\delta_{MMx} - \delta_{MHx}^2} \tag{3}$$

$$\gamma_{aay} = \frac{n\delta_{MMy}}{\delta_{HHy}\delta_{MMy} - \delta_{MHy}^2} \tag{4}$$

The rotational stiffness of pile foundation in three directions is:

$$\gamma_{\beta\beta x} = \frac{n\delta_{HHx}}{\delta_{HHx}\delta_{MMx} - \delta_{MHx}^2} + \frac{\sum K_i x_i^2}{\dfrac{l_0 + \xi h}{EA} + \dfrac{1}{C_0 A_0}} \tag{5}$$

$$\gamma_{\beta\beta y} = \frac{n\delta_{HHy}}{\delta_{HHy}\delta_{MMy} - \delta_{MHy}^2} + \frac{\sum K_i y_i^2}{\dfrac{l_0 + \xi h}{EA} + \dfrac{1}{C_0 A_0}} \tag{6}$$

$$\gamma_{\beta\beta z} = \sum \sqrt{\frac{y_i^4}{\left(\delta_{HHx}^{(0)}\right)^2} + \frac{x_i^4}{\left(\delta_{HHy}^{(0)}\right)^2}}_{\,i} \tag{7}$$

Where, $\delta_{HHx} = \delta_{HHx}^{(0)}$, $\delta_{HHy} = \delta_{HHy}^{(0)}$, $\delta_{MHx} = \delta_{MHx}^{(0)}$, $\delta_{MHy} = \delta_{MHy}^{(0)}$, $\delta_{HMx} = \delta_{MHx}$, $\delta_{HMy} = \delta_{MHy}$, $\delta_{MMx} = \delta_{MMx}^{(0)}$, $\delta_{MMy} = \delta_{MMy}^{(0)}$ are the flexibility coefficients of each single pile; K_i is the number of roots installed in row i ; n is the total number of roots of the pile; x_i , y_i are the distance from the origin of each pile to the axis of the pile, respectively; E is the elastic modulus of pile concrete, A is the average cross-sectional area of the pile into