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Research of Vertical Spring Rigidity Coefficient Equation Fitting for Rectangular Steel Tube Column and Concrete

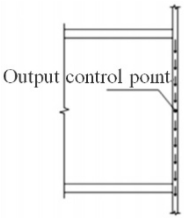
Na XU [a,1], Tao CHEN [2]

[a] *Guangdong Polytechnic of Science and Technology, Zhuhai, Guangdong, China*
[2] *Chongqing City Infrastructure Construction Ltd., Chonghqing, China*
[1] Corresponding Author's email: 174600556@qq.com

Introduction

The regression total fitting equation and error analysis were carried out to solve the solution of vertical spring stiffness, providing a basis for effectively solving the work bearing coefficient of concrete.

Definition of Vertical Spring Stiffness of Steel Pipe



$$k_s = \frac{q_s h_w t_w}{\Delta_s}$$

$$k_s = \xi_s E_s/(A_s H)$$

Relationship between Vertical Spring Stiffness Coefficient of Steel Pipe and Influencing Factors

Table1. The fitting of ξ_s to t_s

t_s / m	Simulation result	Fitting result	Relative error/ %
0. 020	0. 428	0. 428	0. 00
0. 025	0. 429	0. 428	0. 23
0. 035	0. 430	0. 430	0. 00
0. 045	0. 431	0. 431	0. 00
0. 055	0. 433	0. 432	0. 23
0. 065	0. 434	0. 434	0. 00
0. 075	0. 435	0. 435	0. 00
0. 085	0. 437	0. 436	0. 23

Table 2. The fitting to ξ_s to b

b /m	Simulation result	Fitting result	Relative error/ %
0. 8	0. 435	0. 434	0. 23
1. 0	0. 423	0. 422	0. 24
1. 5	0. 396	0. 394	0. 51
2. 0	0. 372	0. 369	0. 81
2. 5	0. 350	0. 346	1. 14
3. 0	0. 331	0. 326	1. 51

Table 3 The fitting of ξ_s to h

h / m	Simulation result	Fitting result	Relative error/ %
1. 0	1. 067	1. 058	0. 84
1. 5	0. 955	0. 957	0. 21
2. 0	0. 859	0. 865	0. 70
2. 5	0. 776	0. 781	0. 64
3. 0	0. 705	0. 706	0. 14
3. 5	0. 643	0. 639	0. 62
4. 0	0. 589	0. 581	1. 36
4. 5	0. 543	0. 531	2. 21
5. 0	0. 502	0. 490	2. 39
5. 5	0. 467	0. 457	2. 14
6. 0	0. 435	0. 433	0. 46

$$\xi_s\,(t_s)=\mathrm{A}+\mathrm{B}t_s=0.425+0.133\,t_s \tag{3}$$

$$\xi_s\,(b)=\mathrm{A}+\mathrm{B}b+\mathrm{C}b^2=0.485-0.0668b+0.005b^2 \tag{4}$$

$$\xi_s(h)=\mathrm{A}+\mathrm{B}\,h+\mathrm{C}h^2=1.285-0.244h+0.017h^2 \tag{5}$$

$$\xi_s(H)=\mathrm{A}+\mathrm{B}H+\mathrm{C}H^2=0.161+0.065H-0.002H^2 \tag{6}$$

Table 4. The fitting of ξ_s to H

H /m	Simulation result	Fitting result	Relative error/ %
3. 0	0. 338	0. 338	0. 00
4. 0	0. 388	0. 389	0. 26
5. 0	0. 435	0. 436	0. 23
6. 0	0. 478	0. 479	0. 21
7. 0	0. 515	0. 518	0. 58
8. 0	0. 548	0. 553	0. 90
9. 0	0. 578	0. 584	1. 03
10. 0	0. 604	0. 611	1. 15

Modified fitting equation

The pairwise coupling between the following groups of factors is mainly considered.

$$\xi_s(t_s)=\begin{cases}0.331+0.096t_s & H=3\text{ m}\\ 0.380+0.104t_s & H=4\text{ m}\\ 0.425+0.133t_s & H=5\text{ m}\\ 0.467+0.146t_s & H=6\text{ m}\\ 0.503+0.158t_s & H=7\text{ m}\\ 0.536+0.166t_s & H=8\text{ m}\\ 0.564+0.180t_s & H=9\text{ m}\end{cases}\qquad \xi_s(b)=\begin{cases}0.379-0.055b+0.0046b^2 & H=3\text{ m}\\ 0.435-0.063b+0.0053b^2 & H=4\text{ m}\\ 0.485-0.0675b+0.0054b^2 & H=5\text{ m}\\ 0.531-0.0716b+0.0057b^2 & H=6\text{ m}\\ 0.568-0.070b+0.005b^2 & H=7\text{ m}\\ 0.601-0.070b+0.0047b^2 & H=8\text{ m}\\ 0.630-0.070b+0.0047b^2 & H=9\text{ m}\end{cases}$$

$$\xi_s(h)=\begin{cases}1.324-0.325h+0.027h^2 & H=3\text{ m}\\ 1.306-0.281h+0.0216h^2 & H=4\text{ m}\\ 1.285-0.244h+0.017h^2 & H=5\text{ m}\\ 1.266-0.216h+0.014h^2 & H=6\text{ m}\\ 1.250-0.193h+0.012h^2 & H=7\text{ m}\\ 1.236-0.175h+0.010h^2 & H=8\text{ m}\\ 1.224-0.160h+0.0087h^2 & H=9\text{ m}\end{cases}$$

General equation of vertical spring stiffness coefficient of steel pipe

Through the analysis, the total equation of the vertical spring stiffness coefficient of steel pipe is obtained as follows:

$$\xi_s=\frac{\xi_s(t_s)\xi_s(b)\xi_s(h)\xi_s(H)}{\xi_s(t_s,b,h,H)^3}=\frac{\xi_s(t_s)\xi_s(b)\xi_s(h)\xi_s(H)}{\xi_s(H)^3}=\frac{\xi_s(t_s)\xi_s(b)\xi_s(h)}{\xi_s(H)^2}$$

Where

$$\xi_s(t_s)=\begin{cases}0.331+0.096t_s & H=3\text{ m}\\ 0.380+0.104t_s & H=4\text{ m}\\ 0.425+0.133t_s & H=5\text{ m}\\ 0.467+0.146t_s & H=6\text{ m}\\ 0.503+0.158t_s & H=7\text{ m}\\ 0.536+0.166t_s & H=8\text{ m}\\ 0.564+0.180t_s & H=9\text{ m}\end{cases}\qquad \xi_s(b)=\begin{cases}0.379-0.055b+0.0046b^2 & H=3\text{ m}\\ 0.435-0.063b+0.0053b^2 & H=4\text{ m}\\ 0.485-0.0675b+0.0054b^2 & H=5\text{ m}\\ 0.531-0.0716b+0.0057b^2 & H=6\text{ m}\\ 0.568-0.070b+0.005b^2 & H=7\text{ m}\\ 0.601-0.070b+0.0047b^2 & H=8\text{ m}\\ 0.630-0.070b+0.0047b^2 & H=9\text{ m}\end{cases}$$

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The reasons for the error

(1) The finite element numerical simulation itself has a certain error, and it is better to control the error within 5%.
(2) When analyzing a single factor, this paper does not consider the influence of other factors, which will cause certain error. In general, very simple quadratic equations are used to replace multiple equations or even multivariate equations, ignoring the mutual constraints and coupling between multiple factors.

Conclusion

The influence factors of vertical spring stiffness coefficients are analyzed, and the fitting equations of each factor and vertical spring stiffness coefficient is obtained. Considering the coupling between factors, the fitting equation is modified. On the basis of fitting the equation, the general equation of vertical spring stiffness coefficient with higher accuracy is returned. The error analysis verifies the rationality and effectiveness of vertical spring stiffness coefficient fitting the total equation. The solution of the vertical spring stiffness is effectively solved, which provides a reliable basis for further solving the work bearing coefficient of concrete.

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