Research on the Differences between New and Old Building Codes Based on Frame Column Reinforcement Calculation

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Abstract

Based on the actual building profile, this paper uses the <Code for Design of Concrete Buildings>[1] in 1989 of China and the <Code for Seismic Design of Buildings>[2] in 1989 of China to carry out the steel in the frame column, and compared by the results by the latest two codes[3][4] . Through comparative analysis, it is concluded that compared by the old-fashioned codes, the latest codes optimizes the material mechanical performance index, refines the calculation formula, and increases the safety reserve of the building.

Keywords

Codes; reinforcement in the frame column; material mechanical performance index; formula; safety reserve.

1. Introduction

The frame structure is one of the most widely used building structures in China in the 1980s and 1990s. With the development of society, building codes are constantly updated, and it is followed that old buildings no longer meet the current norms. It is necessary to carry out detailed comparative research on new and old building codes. The research results can provide a theoretical basis for the transformation of old-fashioned frame structures. Based on the actual building profile, this paper uses old-fashioned codes to carry out the reinforcement in the frame, and compares the results by the latest codes.

The length of the column in the frame is 3.2m, the section size is 500mm*500mm, and C30 concrete is used. By calculated of the frame, there are four kinds of bending moment axial force:

$$1)321.991kN\cdot \mathrm{m}+1693.364kN \qquad 2)309.484kN\cdot \mathrm{m}+1679.096kN$$

$$3)99.1748kN\cdot \mathrm{m}+1328.428kN \qquad 4)198.076kN\cdot \mathrm{m}+1356.268kN$$

2. Calculations of longitudinal steel

2.1 By old-fashioned codes.

Calculate 1) bending moment axial force by the old-fashioned codes:

$$\lambda_N=\frac{N}{f_c bh}=0.4516 \tag{1}$$

$$\varepsilon_b=\frac{0.8}{1+\dfrac{f_s-\sigma_{p0}}{0.0033E_s}}=0.53 \tag{2}$$

$$x=\frac{N\gamma_{RE}}{\alpha_1 f_c b}=180.625<\varepsilon_b h_0 \tag{3}$$

This column is under large eccentric compression.

$$e_0=\frac{M}{N}=190mm \tag{4}$$

$$e_a=0.12\times(0.3h_0-e_0) \tag{5}$$

as $e_0 \geq 0.3h_0$, set $e_a = 0$

$$e_i = e_0 + e_a = 190mm \quad (6)$$

$$\xi_1 = \frac{0.5 f_c A}{N} = 1.107. \quad (7)$$

$$\xi_2 = 1.15 - 0.01\frac{l_0}{h} = 1.086 \quad (8)$$

$$\eta = 1 + \frac{1}{1400\frac{e_i}{h_0}}\left(\frac{l_0}{h}\right)^2 \xi_1\xi_2 = 1.0851 \quad (9)$$

$$e = \eta e_i + \frac{h}{2} - a = 436.219mm \quad (10)$$

$$A_s^{'} = \frac{\gamma_{RE} Ne - \alpha_1 f_c bx(h_0 - \frac{x}{2})}{f_y^{'}\left(h_0 - a_s^{'}\right)} = 692.25mm^2 \quad (11)$$

The results of calculation of 2), 3), and 4) by the same way are shown:

Table 1 Results of calculation of 2), 3), and 4) by old-fashioned codes

	λ_N	x	e_0	e_a	e_i	ξ_1	ξ_2	η	e	$A_s^{'}$
2）	0.448	179.104	184.316	0	184.316	1.117	1.086	1.089	430.642	621
3）	0.283	141.699	74.656	7.601	82.257	1.411	1.086	1.251	332.880	<0
4）	0.362	144.669	146.045	0	146.045	1.382	1.086	1.138	396.244	71.479

In summary, the longitudinal steel adopts symmetric reinforcement and selects 4 steel bars with a diameter of 22 mm.

Check bearing capacity by old-fashioned codes (C30 concrete and HRB335 steel are chosen):

$$\varepsilon_b = \frac{0.8}{1 + \frac{f_s - \sigma_{p0}}{0.0033E_s}} = 0.53 \quad (12)$$

Boundary bearing pressure:

$$N_{ub} = \alpha_1 f_c b\varepsilon_b h_0 + f_y^{'} A_s^{'} - f_y A_s = 1828.5kN > 1693.364kN \quad (13)$$

The result is also large eccentric compression.

$$x = \frac{N_{ub} + f_y A_s - f_y^{'} A_s^{'}}{\alpha_1 f_c b} = 243.8mm \quad (14)$$

$$e = \frac{\alpha_1 f_c bx\left(h_0 - \frac{x}{2}\right) + f_y^{'} A_s^{'}\left(h_0 - a_s^{'}\right)}{N_u} = 392.216mm \quad (15)$$

$$M = N_{ub} e = 717.167kN \cdot m > 321.991kN \cdot m \quad (16)$$

The section meets requirements.

2.2 By the latest codes.

Calculate the four bending moment axial forces by the latest codes by the same way, the results are shown by the following table:

Table 2 Results of calculation of 1), 2), 3), and 4) by the latest codes

	λ_N	x	e_0	e_a	e_i	ξ_1	ξ_2	η	e	$A_s^{'}$
1)	0.47	189.47	190.15	-6.26	190.15	1.06	1.09	1.08	435.58	731.56
2)	0.47	187.87	184.32	-5.56	184.32	1.07	1.09	1.08	429.88	658.34
3)	0.37	148.64	74.66	7.60	74.66	1.35	1.09	1.26	324.32	<0
4)	0.38	151.75	146.04	-0.97	146.05	1.32	1.09	1.13	395.31	93.19

In addition, it is noticed that the mechanical properties of the material differs in the old-fashioned codes and the latest codes, as shown:

Table 3 Some differences of the mechanical properties of the material between old-fashioned codes and the latest codes

	f_c of C30 concrete N/mm^2	f_t of C30 concrete N/mm^2	f_y of HRB335 steel N/mm^2
Old-fashioned coeds	15	1.5	310
Latest codes	14.3	1.43	300

Check the section by the mechanical properties of materials and calculation methods in the latest codes:

$$\varepsilon_b = \frac{\beta_1}{1+\frac{0.002}{\varepsilon_{cu}}+\frac{f_{py}-\sigma_{p0}}{E_s\varepsilon_{cu}}} = 0.55 \tag{17}$$

$$N_{ub} = \alpha_1 f_c b\varepsilon_b h_0 + f_y^{'}A_s^{'} - f_y A_s = 1808.95kN > 1693.364kN \tag{18}$$

$$x = \frac{N_{ub} + f_y A_s - f_y^{'}A_s^{'}}{\alpha_1 f_c b} = 253mm \tag{19}$$

$$e = \frac{\alpha_1 f_c bx\left(h_0 - \frac{x}{2}\right) + f_y^{'}A_s^{'}\left(h_0 - a_s^{'}\right)}{N_u} = 386.437mm \tag{20}$$

$$M = N_{ub}e = 699.045kN\cdot m > 321.991kN\cdot m \tag{21}$$

The section also meets requirements.

3. Stirrup calculation

$$h_w = h_0 = 460, \frac{h_w}{b} < 4, V = \frac{321.285+309.484}{3.2} = 197.116kN$$

<Code for Seismic Design of Buildings> in 1989 sets that the maximum spacing of the stirrups in the column encryption zone of Three-level earthquake resistance is the smaller of 8d and 150, and the minimum diameter of the stirrup is 8mm. The amount of stirrups in the non-encrypted area of the column should not be less than 50% of the encryption area, and the pitch of the stirrups should not be greater than 15 times the longitudinal steel diameter. The latest <Code for Seismic Design of Buildings> differs by that the maximum spacing of the stirrups in the column encryption zone of 8d and 150(100 at the bottom of column).

Check the section:

$$0.25 f_c bh_0 = 862.5kN > V = 197.116kN \tag{22}$$

The section meets requirements.

$$\frac{0.2}{\lambda+1.5} f_c bh_0 + 0.07N = 271.868kN > V = 197.116kN \tag{23}$$

As $\lambda=\frac{H_n}{2h_0}=\frac{3.2}{2\times0.46}=3.33>3$

set $\lambda=3$.Select minimum stirrup by structure:

$$\rho_{sv,\min}=0.02\frac{f_c}{f_{yv}}=0.0968\% \tag{24}$$

Take the encryption zone hoop spacing of 150mm.

$$A_{sv}>\rho_{sv,\min}bs=72.6mm^2$$

Non-encrypted zone stirrups useΦ10@300.

Calculating the shear capacity of frame columns according to the non-encrypted area:

$$V_{cs}=0.07f_cbh_0+1.5f_{yv}\frac{A_{sv}}{s}h_0=297.471kN \tag{25}$$

Calculate stirrup by current codes:

$$0.25\beta_c f_cbh_0\text{=}862.5kN>V=197.116kN \tag{26}$$

$$\frac{1.75}{\lambda+1}f_tbh_0+0.07N=262.429kN \tag{27}$$

Select minimum stirrup by structure:

$$\rho_{sv,\min}=0.24f_t/f_y=0.1144\% \tag{28}$$

Encrypted zone stirrup:

$$A_{sv}>\rho_{sv,\min}bs=85.8mm^2 \tag{29}$$

Chose the Φ8 stirrups of double limbs, and $A_{sv}=101mm^2$.

Calculating the shear capacity of frame columns according to the non-encrypted area with old-fashioned codes results of stirrup:

$$V_{cs}=\alpha_{sv}f_cbh_0+f_{yv}\frac{A_{sv}}{s}h_0=266.34kN \tag{30}$$

4. Conclusion

1The mechanical properties of the materials specified in the current codes are smaller than those codes in 1989, and the safety of the building has been improved in terms of material properties.

2 The current code is optimized on the calculation formula than the old-fashioned, and various factors are considered more comprehensively. For example, the influence coefficient of concrete strength adds to the cross-section calculation formula in the calculation of the stirrup, and refines various construction conditions. The result is more precise and realistic.

3 The calculation results show that the current codes have a large safety reserve compared to the old.

References

[1] GBJ 10-89 Code for design of concrete structures [S]. Beijing: China Architecture & Building Press, 1989 (in Chinese))

[2] GBJ 11-1989 Specifications for antiseismic construction design [S]. Beijing: China Architecture & Building Press, 1989 (in Chinese)).

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[4] GB 50011-2010 Code of buildings [S]. Beijing: China Architecture & Building Press, 2016(in Chinese).