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Comparative Analysis between Two Standards TCVN 5574:2018 and TCVN 5574:2012

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Abstract: *In the new standard TCVN 5574:2018, replacing TCVN 5574:2012, there are significant changes in structure, materials and calculation methods compared with the old version TCVN 5574:2012. The standard TCVN 5574-18 has approached EC2 and ACI standards to increase international integration, and it has also changed the perspective of computational modeling, converted from stress model to strain model. This article analyzes and compares two standards to highlight new points, helping designers to distinguish easily and conveniently apply TCVN 5574:2018 in practice.*

Keywords: *TCVN 5574:2018, TCVN 5574:2012, Reinforced concrete, Standard, Strain model.*

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I. INTRODUCTION

The design standards of reinforced concrete structures of countries around the world are often updated and changed regularly. The period for updating and modifying is usually about every 3 years and renewal about every 10 years. The current standard for the design of concrete and reinforced concrete structures TCVN 5574:2018 [2] took effect from December 10, 2018, and replaces the old version of TCVN 5574:2012 [1]. TCVN 5574:2012 [1] was published in 2012. It has been moved from TCXDVN 356:2005 [3] and had been retained in its entirety, only renamed. Furthermore, TCXDVN 356:2005 is translated from the Russian standard SNIP 2.03.01-84 which was made more than 30 years ago. Thus, we had used too old standards compared with the progress of science and technology in the world. This problem had caused many inadequacies in the design process. Standard [1] stipulates the use of steels (such as CI, C-II, C-III...) according to the old standards before, so it is not linked with the new standards of Vietnam. as standard on current reinforcement steel, or prestressed steel (pre-stressed): TCVN 1651:2008 [4], TCVN 6284:1997 [5, 6, 7], TCVN 6288:1997 [8].

Therefore, to update new information in the field of design of concrete and reinforced concrete structures, standard [1] has been replaced by TCVN 5574:2018 [2]. This standard has been written mainly based on the Russian standard SP 63.13330.2012. With this approach, it will not cause much confusion in teaching and designing practice. In this new standard [2], it has many new points that deserve attention: the calculation perspective is changed from the stress model to the strain model (accepting the flat section assumption), calculating Puncture math and other new points are presented below.

II. COMPARATIVE ANALYSIS BETWEEN TWO STANDARDS

2.1 General issues

The new standard consists of 12 sections and 13 annexes which has been studied towards the EC2 standard approach. The whole structure in the new standard [2] is not the same as the structure of the old standard [1], it separates 3 separate parts for concrete structure, non-prestressed reinforced concrete and reinforced concrete pre-stressed. At the same time, it adds some new content such as: more detailed reinforcement classification, reduced calculated strength; require more complete reinforcement structure; requirements for the restoration and reinforcement of reinforced concrete structures are more concise; considering reinforcement to limit horizontal deformation; member subjected to eccentric compression according to nonlinear strain; change the calculation method for inclined, bending, torsion sections.

Table 1. Comparison of General Issues

Numerical order	TCVN 5574:2018	TCVN 5574:2012 (356-2005)
1	Clearly distinguish four types of reliability coefficients: load, material, working condition factor; importance factor.	The reliability coefficient is not well defined.
2	Strength grade of concrete (tensile, compressive) and reinforcement	Durability of concrete and reinforcement.
3	Working height h_0 of section	Useful height h_0 of the cross-section
4	Resistance, durability: ensure that the reinforcement is used	Force-resistance

	normally throughout the term.	
5	Article 5.2. Calculate reinforced concrete according to durability. - Reinforced concrete structural members with M, N effects: Calculated according to the nonlinear deformation model. - Reinforced concrete structural members with simple cross-section (T, I, rectangular): Calculated according to limited internal force (same as old standard). - Calculated on inclined cross section, space section: According to limited internal force (same as before). - Short structure calculation: according to the model of virtual truss bar. - Nonlinear strain model: the strength criterion on the perpendicular section is the relative strain in concrete or reinforcement reaching the limit value.	Article 5.2. - All are calculated according to the internal force limit. $M \leq [M]$ (1) $N \leq [N]$ $Q \leq [Q]$

2.2 *About materials*

The term "nonlinear strain model" is a computational model that takes into account the elastic-plastic properties of concrete in compression tension. Therefore, the relationship between stress and strain is not linear (constant), but linear for each segment; Replace the word “endurance grade” with “strength grade”; The limit applies to concrete with strength grades up to B100; Substitute the values of the working condition coefficient, conversion factor, and reliability factor (steel, concrete, load) so that the calculated strength of concrete is reduced; More types of reinforcement with different origins and features; The calculated intensity value is reduced. Both reinforcement and concrete use a confidence (safety) factor of 1.15, instead of multiple values as before. This problem facilitates the design as well as reduces confusion in use.

However, this factor is higher for reinforcements that have yield strength (the old standard was from 1.05 to 1.07) and lower for reinforcements that have yield strength. convention (the old standard was 1.2). This problem makes the calculated strength of reinforcement lower than actual reinforcement with yield strength and higher than that of reinforcement with conventional yield strength;

The values of the strain characteristics are significantly variable. The new standard [2], it uses strain diagrams of concrete and reinforcement for nonlinear calculations. The calculation according to the limited internal force, clearly specifies the deformation values (including limited deformation) of concrete and steel.

For reinforcement, in the new standard [2], it is allowed to use curve charts, approximate actual strain charts of reinforcement, but it is recommended to use two-segment diagrams in preference. straight line (for reinforcement with actual yield strength) and a three-segment diagram (for reinforcement with conventional yield strength).

Table 2. Material comparison

Numerical order	**TCVN 5574:2018**	**TCVN 5574:2012 (356-2005)**
1	Strength grade of heavy concrete under compressive: B15; 20; 25; 30; 35; 40; 45; 50; 55; 60; 70; 80; 90; 100	Strength grade of heavy concrete under compressive: 20; 25; 30; 35; 40; 45; 50; 55; 60;
2	Strength grade of heavy concrete under tension: B0.8; 1.2; 1.6; 2; 2.4; 2.8; 3.2; 3.6; 4	Strength grade of heavy concrete under tension: B0.8; 1.2; 1.6; 2; 2.4; 2.8; 3.2
3	$R_{b,n}$; $R_{b,ser}$: Standard strength of concrete under compression; constant; regulated to B100	$R_{b,n}$; $R_{b,ser}$: Standard only specified up to B60
4	$R_{bt,n}$; $R_{bt,ser}$: Standard strength of concrete under tension: reduced value, specified up to B100.	$R_{bt,n}$; $R_{bt,ser}$: Standard only specified up to B60
5	R_b: Calculated strength of concrete under compression; unchanged, specified to B100.	R_b: Standard only specified up to B60
6	R_{bt}: Calculated strength of concrete under tension; value increases, specified to B100 .	R_{bt}: Standard only specified up to B60
7	The limit relative strain value of concrete is precisely determined. - when the load is short-term: $\varepsilon_{bo} = 0.002$ – axial compression; $\varepsilon_{bto} = 0.001$ – axial drag. - when the load is acting long-term, see table 9: values of ε_{bo}, ε_{bto} are higher in the case of short-term loads.	This value is not specified.
8	E_b – Initial elastic modulus of concrete in compression, up to B100 – Table lookup.	The E_s lookup table has up to B60 – the value is almost the same

<table>
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<td>$E_{b,t}$ – Initial elastic modulus of concrete in tension (lower value)

$$E_{b,\tau} = \frac{E_b}{1 + \varphi_{b,cr}} \qquad (2)$$

$\varphi_{b,er}$: The creep coefficient of concrete (see Table 11, according to the average moisture content (40-70%)) $E_{b,t} < E_b$</td>
<td>$E_{b,t} = E_b$ (3)</td>
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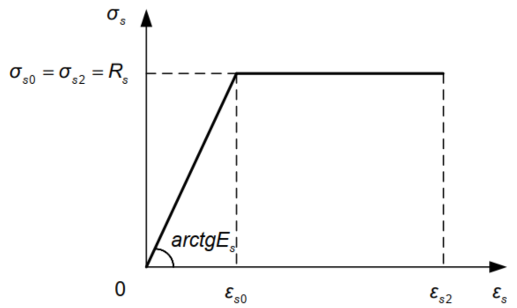
<td>10</td>
<td>Strain diagram of concrete according to linear deformation model (new standard similar to EC2 and ACI 318).
- Two-segment form (most common).


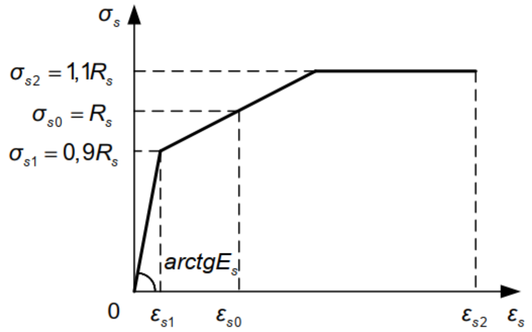
Figure 1. Diagram of two straight segments of concrete when compressed.
- Three-segment form (more complex).


Figure 2. Diagram of three straight segments of concrete when compressed.
- Curve chart format, including descending branch: precise but complex, purely theoretical, rarely used (see appendix table of standard 5574-12).
In which: The relationships σ - ε are established according to each selected line segment, changing each short-term or long-term applied load - see details.
- This strain chart is also assigned to different compressive and tensile concrete.
- Used for complex cross-sections, when calculating:
+ Reinforced concrete structure according to the first limit state.
+ According to the formation of cracks or widening of perpendicular cracks.
+ Calculation of deformation when the section is not cracked.</td>
<td>The deformation chart of concrete is not specified.</td>
</tr>
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<td>11</td>
<td>Reinforcing steel is denoted differently from TCVN 1651-1-2008 and 1651-2-2018.
- CB 240T: 240 (210) Mpa and belt reinforcement 170Mpa.
- CB 300T và CB300V: 300 (260) Mpa and belt reinforcement 210 Mpa
- CB 400V: 400 (350) Mpa and belt reinforcement 260 Mpa</td>
<td>Ordinary steel reinforcement:
CI, AI: 235 (225) Mpa
CII, AII: 295 (280) Mpa
CIII, AIII: 390 (355) Mpa
Cable 12.7 and 15.2: 1500 (1250) Mpa</td>
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2.3 About calculation

Standard 5574:2018 has updated new solutions, gradually approaching the EC2 standard. The new method is based on simple but versatile computational models. It has reduced the experimental coefficients in the formula and taken into account the world's published reliable verified experimental results.

The basic foundation for the calculation of concrete and reinforced concrete members which are subjected to bending moments and forces along with the limit state groups (first and second) is a nonlinear strain model (both of concrete and reinforcement). In which, in addition to using the balance equations, the deformation conditions are still followed with the assumption of flat cross-section and the complete strain diagram of concrete and reinforcement. This model allows calculations on the same view for any concrete and reinforced concrete members with different cross-sectional shapes. It also allows the different arrangement of longitudinal reinforcement and takes into account the elastic-plastic properties of concrete and reinforcement and the stress-deformation state of reinforced concrete members. In addition, the members with simple and popular cross-sections such as rectangular, T-shaped, and I-shaped sections, in the new standard [2], it is also possible to use simpler calculation methods.

Table 3. Comparison of calculation methods

Numerical order	**TCVN 5574:2018**	**TCVN 5574:2012 (356-2005)**
1	Calculation contents of concrete, reinforced concrete, and prestressed concrete structures are separated.	It was confusing when presenting related contents: concrete properties, reinforced concrete, prestressed concrete.
2	Calculated according to the first limit state: - State the nonlinear deformation model when calculating. - The common cross-sections (rectangular, T, I) still allow calculation according to internal force. - The height of the concrete domain in tension is simpler. $\xi_R = \frac{x_R}{h_0} = \frac{0.8}{1 + \frac{\varepsilon_{s,el}}{\varepsilon_{b2}}}$ (4) $\varepsilon_{s,el}$: Relative strain of tensile reinforcement, when $\sigma_S = R_S \left(\varepsilon_{S,el} = \frac{R_S}{E_S} \right)$ (5) ε_{b2}: Relative deformation of concrete under compression when $\sigma_b = R_b$ - Short load: B ≤ 60: ε_{b2} = 0.0035 B ≥ 70: ε_{b2} is linearly interpolated from 0.0033 (B70) to 0.0028 (B100) and then the factor 0.8 is taken as 0.7. - Long-term load: ε_{b2} according to table 9, depending on humidity (specific number is available). - With flexural members, when checking, there is $\xi > \xi_R$, taking $\xi = \xi_R$, the calculation should be simpler to apply. - With flexural members, place reinforcement symmetrically (meet when checking piles during transportation, crane installation) $M_u = R_s A_s (h_0 - a')$ (7) If x (calculated with $A'_s = 0$) has x < 2a', take x =2a', the calculation continues. - For members subjected to large eccentric compression: additional random eccentricity ea ≥ 10mm. $e_0 = \frac{M}{N} + e_a$ (9) - For members with large eccentric compression, rectangular cross section, (8.1.2.4.1) stated. when $\xi \le \xi_R$: $X = \frac{N + R_S A_S - R_{SC} A'_S}{R_b b}$ (10) when $\xi > \xi_R$: $x = \frac{N + R_S A_S \frac{1+\xi_R}{1-\xi_R} - R_{SC} A'_S}{R_b b + \frac{2 R_S A_S}{h_0 (1 - \xi_R)}}$ (11)	Calculated according to the first limit state.: - Not stating the calculation according to the nonlinear strain model. - Only calculated according to the internal force limit. - The height of the concrete area under compression. $\xi_R = \frac{\omega}{1 + \frac{\sigma_{SR}}{\sigma_{SC,u}}\left(1 - \frac{\omega}{1.1}\right)}$ (6) $\omega = \alpha - 0.008 R_b n$ α = 0.85 for heavy concrete $\sigma_{SR} = R_s$ ordinary concrete $\sigma_{SC,u}$ = $500MPa$ (long term load) $\sigma_{SC,u}$ = $400MPa$ (short-term load) with flexural members, when $\xi > \xi R$, ξ must be redefined, according to the stress value in the reinforcement. $\sigma_S = \frac{0.2 + \xi_R}{0.2 + \xi + 0.35 \frac{\sigma_{sp}}{R_S}\left(1 - \frac{\xi}{\xi_R}\right)} R_S < R_S$ (8) σ_{sp} = 0 if it is ordinary reinforced concrete - Symmetrical steel in rectangular members has not been specified (but TCVN 5574-91 has similar regulations 5574-18). - For eccentric compression members, it is necessary to consider e_a . $e_a \ge l_0$; $e_a \ge h/30$ - With eccentric compression member, $\xi \le \xi_R$: constant. If $\xi > \xi R$ the formulas to calculate x, in terms of σs < Rs , are complicated.
3	The longitudinal coefficient of bending is simpler. $\eta = \frac{1}{1 - \frac{N}{N_{cr}}}; N_{cr} = \frac{\pi^2 D}{L_0^2}$ (12) $D = k_b E_b I + k_s E_s I_s$ (I, I_s calculated for the centroid of the cross-section.)	Calculating the value of $\boldsymbol{\eta}$ is more complicated. $N_{cr} = \frac{6.4 E_b}{L_0^2}\left[\frac{1}{\varphi_1}\left(\frac{0.11}{0.1 + \frac{\delta_c}{\varphi_b}} + 0.1\right) + \alpha I_S\right]$ The coefficients of N_{cr} are more complicated

	$k_s = 0.7$; $$k_b = \frac{0,15}{\varphi_L (0,3 + \delta_e)}$$ $$\varphi_L = 1 + \frac{M_{L1}}{M_L}$$ (13) M_L is the moment taken with the center of the steel bar most in tension or in least compression (when the entire cross-section is in compression) when subjected to the full load. M_{L1} is the moment taken with the center of the steel bar with the most tension or the least compression (when the entire cross-section is in compression) when subjected to permanent and temporary long-term loads. δ_e is the relative eccentricity value of the longitudinal force (δ_e = e h_0), taken not less than 0.15 and not more than 1.5. Centered compression member: when e_0 is small or $e_0 = 0$: center compression when $e_0 \le h/30$; $L_0/h \le 20$: Small eccentric compression. $$N \le N_u$$ $$N_u = \varphi \left(R_b A + R_{sc} A_{s,tot} \right) \quad (14)$$ -Short-term load: φ linear interpolation. between φ=0.9 with L_0/h =10; φ=0.85 with L_0/h =20. -For long-term loading: see table 16 (5574-18), according to the strength class of concrete. - Calculation length l_0: +For multi-layer frames, each floor is considered as a soft-gap link (the lower end is fixed, the upper end allows a limited angle of rotation); $l_0=0.9h_t$ + Calculation according to the nonlinear deformation model, on the perpendicular section: setting for any symmetrical cross-section, subjected to bending, oblique bending, and oblique eccentric compression at the same time, the algorithm is still complicated, even difficult to understand (due to no accompanying theory). - Rectangular section, T, I (box), allowed to calculate according to limited internal force (same as old standard); The formula for determining $\boldsymbol{\xi}, \boldsymbol{\eta}$ is different.	Compression member at the center: not specified in detail, the longitudinal bending coefficient φ is different. l_0 defined for frames is simple for industrial buildings but complex for trusses and arches; usually $l_0 = 0,7h_t$ The calculation according to the nonlinear strain model is not stated.
4	Calculation of reinforced concrete structure according to inclined section: similar to TCVN 5574-12, three failure diagrams on inclined section are explained more clearly. $$Q \le \varphi_{b1} R_b b h_0 \left(\varphi_{b1} = 0.3 \right) \quad (15)$$ If it does not satisfy the equation, the strength grade or section size must be increased. Do not consider components $Q_{s,inc}$ anymore (reinforcing oblique). Undefined c_0, but it has to be calculated with inclined sections, with h≤ c≤$2h_0$	$$Q \le 0.3 \varphi_{w1} \varphi_{b1} R_b b h_0 \quad (16)$$ If the above conditions are not satisfied, the cross-sectional size or durability level of concrete must be increased. Consider $Q_{s,inc}$
5	Calculation of torsional bending structures: Simpler and completely different. Determine the pure twist formula: $$T \le 0.1 R_b b^2 h \; ; \; T = T_{sw} + T_s \quad (17)$$ Determine the formula for torsion and bending: $$T \le T_0 \sqrt{1 - \left(\frac{M}{M_0} \right)^2} \quad (18)$$ Determine the torsion formula combining shear force: $$T \le T_0 \left(1 - \frac{Q}{Q_0} \right) \; T_0 = 0.1 R_b b^2 h \quad (19)$$	Calculate the member subjected to torsional bending for (M, M_x) and (Q, Q_x).

6	Calculation by puncture condition with reference to ACI 318 and EC2: performed in four cases.	Calculation of puncture: simple, similar to that of a punctured nail. The anti-puncture belt is not strictly regulated, not guaranteed.
7	It allows to check the floor slab according to the shear force if necessary. $\frac{Q_x}{Q_{x,u}} + \frac{Q_y}{Q_{y,u}} \le 1$ $Q_{x(y),u} = Q_b + Q_{sw}$ $Q_b = 0.5 R_{bt} b h_0$ & $Q_{sw} = q_{sw} h_0$ (20)	The slab always meets the shear condition.
8	Flat wall (wall): - Method 1: Cut each flat element 1 x 1 xd (wall thickness), subject to all the applied internal forces (M_x, M_y, N_x, N_y, torque and shear force) along the edges (8.1.7.4) . - Method 2: Divide the flat element into layers (1m wide or more) of concrete in compression and steel in tension. Then calculate each layer under the influence of the normal force and the shear force in the layer. These forces are caused by the general M, T, and N acting in the plane (8.1.7.5). This is quite common. - At this time, the out-of-plane calculation is performed similarly to the steel calculation for the normal slab.	Flat wall (wall): not mentioned.
9	Loss of prestress: 8 types left (reviewed twice)	Prestress loss: 11 types
10	Reinforcement content: Min 0,1% for members subjected to bending, tension and eccentric compression with $l_0/i \le 17$ or $l_0/h \le 5$ (rectangular). Min 0.25% for eccentric compression when $l_0/i > 87$ hay $l_0/h \ge 25$ take double value, when the steel section is arranged according to the circumference.	No details
11	It is necessary to arrange longitudinal reinforcement for flat plates in 2 directions on the lower and upper faces of the plates.	No mention

2.4 Analysis results

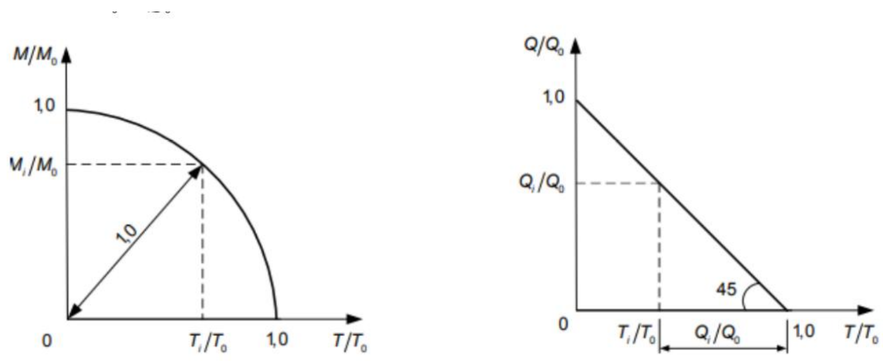
For durability calculation: Calculate according to the internal force limit including the plastic working of concrete and reinforcement in a conventional way. Here, when calculating the perpendicular section, the formula for determining the limit height of the compressive concrete area has been adjusted. The formula for calculating the critical force according to Euler is also rewritten in a more general way, consistent with the representation of many standards around the world.

For calculation according to crack formation, crack expansion, and deformation: Use general principles of structural mechanics and material strength for reinforced concrete structures. Then, to evaluate the crack width, a more physical computational model should be used. It is based on the reciprocal displacement between the reinforcement and the concrete over the length between the cracks. This allows us not to use the empirical approach to perpendicular crack width calculations and strain calculations that were still used in the old standard.

For the calculation subject to the shear force: Still based on the limited internal force using the inclined section model as in [1], but it has been adjusted the calculation formulas and the calculation process to calculate simpler math.

For local compression calculation: Still based on limited internal force and adjusted calculation formulas.

For torsional calculation: Still using the spatial section model as in [1], but it uses interaction diagrams between bending moment and torque, shear force and torque and it is also easier to apply than the old standard [1].



a) Interactive diagram M/M_0 and T/T_0. b) Interactive diagram Q/Q_0 and T/T_0

Figure 3. Interactive diagrams when calculating torsion.

Calculation of puncture: Using the model is applied in the standards of other countries and it takes into account the influence of the acting moment in two directions that in [1] did not mention.

Calculation of the length of reinforcement: The length of the overlap is also determined according to the new formula:

$$L_{lap} = \alpha L_{0,an} \frac{A_{s,cal}}{A_{s,ef}}$$

In which: $A_{s,cal}$, $A_{s,ef}$ is the cross-sectional area of the reinforcement according to the calculation and according to reality, respectively. α = 1.0 and 0.75 for reinforcing bars (without prestressing) in tension and compression, respectively.

III. CONCLUSION

The design standard of concrete and reinforced concrete structures TCVN 5574-18 has gradually approached the EC2 standard and a little approach to ACI (ε_b = 0.003). It has changed the view of computational modeling and has moved from the stress model to the strain model. This model is recommended to be used as a priority for calculation according to limit states (first and second) for members subjected to bending moments and longitudinal forces. It still allows úing the limited internal force method for members with simple cross-sectional shapes such as rectangle, T, and I.

TCVN 5574-18 has added: how to calculate steel for floors and walls; The breakdown calculation allows to take into account the influence of bending moments in both directions, which is different from the previous standard which has not been taken into account. The calculation of local compression is still the same as the previous model, but the calculation formula is adjusted.; The torsion calculation still uses a spatial model according to the limited internal force method, but uses interaction diagrams when the bending moment and the torque, as well as the shear force and the torque, are applied simultaneously; Calculation of the inclined section without including the oblique reinforcement (very true to reality). The shear calculation still uses the inclined section model, but it has adjusted the calculation formula to make the calculation simpler; Calculation of semi-assembled structures will gradually become popular when the construction industry is rapidly industrialized.

TCVN 5574-12 has not been detailed, even omitted, so it was confusing to apply. As it did not state the establishment of calculation equations for members with any symmetrical cross-section, the establishment of calculation equations for other common cross-sections. At that time, the nonlinear deformation model was complicated and difficult to apply in practice, especially in oblique bending, oblique eccentric compression. It has not established the calculation method of tension and compression members eccentrically T, I, box. It also did not establish how to calculate A_s, when there are As, Asp in tension concrete. It did not set l0 for industrial columns, cranes, trusses, and domes. It also ignored the compression force before calculating the inclined section. It also did not consider how to prevent punctures by nails, by load-bearing reinforcement; did not mention the calculation of the break (reinforcing the auxiliary beam on the main girder); did not consider the formation of cracks, widening of oblique cracks; there was no specified level of crack resistance; did not instruct how to calculate steel for hardcore.

Conflict of interest

There is no conflict to disclose.

ACKNOWLEDGEMENT

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