Critical Review of Shear Design Method for Concrete Members Specified in Russian SNiP Code: Verification

Meirzhan Yerzhanov [1], Aizhan Tukaziban [2], Sung-Woo Moon[3], Dichuan Zhang[4], and *Deuckhang Lee[5]

[1), 2) 3) 4) 5)] *Department of Civil and Environmental Engineering, Nazarbayev University, Astana 010000, Kazakhstan*
[5)] *deuckhang.lee@nu.edu.kz*

ABSTRACT

The shear resistance mechanism of concrete members has been considered as one of challenging and complex engineering problems. Despite numerous ongoing research efforts, the shear design provision of each country is still based on different theoretical and experimental backgrounds. In the authors' previous study, the modification factors were proposed to improve the analytical accuracy of the shear design method for reinforced (RC) and prestressed (PSC) members specified in Russian SNiP code. This study compared the test results with those estimated from four different shear design provisions and modified SNiP model. To this end, the ACI-DAfStb databases for RC and PSC members were utilized, in which a total of 1287 test results were finally selected. The results of this comparative study showed that the modified SNiP code model with the new modification factors can provide an acceptable level of safety and analytical accuracy.

1. INTRODUCTION

SNiP code has been utilized in 15 countries as main structural design provision, and its equation for estimation of shear capacity was proposed in the Soviet era based on PMR principle (plane of minimum resistance). However, one of the basic assumptions of PMR principle is to neglect effect of longitudinal reinforcement ratio. Moreover, the shear equation for SNiP code cannot capture effect of prestressing properly. In order to address these issues, the authors' previous study proposed new modification factors. In this study, verification process of modified shear equation by using 1287 experimental results for RC and PSC members from the ACI-DAfStb shear database was conducted. Moreover, comparing of several international design standards was carried out to examine safety and accuracy levels of modified shear strength equation.

2. SHEAR DATABASE

---

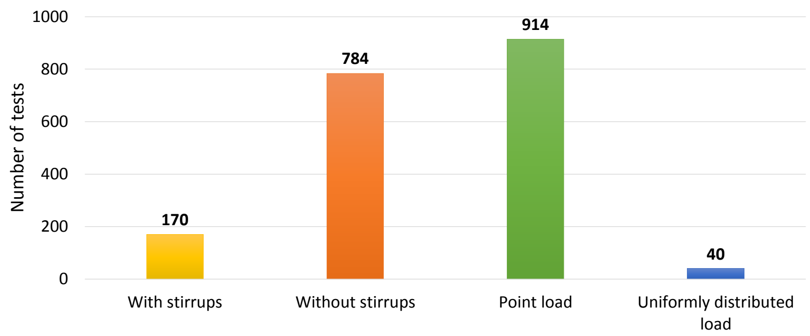
[1] Ph.D. Student
[2] Master Student
[3] Assistant Professor
[4] Professor
[5] Assistant Professor, *Corresponding Author

The ACI-DAfStb shear database by Reineck et al. (2013, 2014) was used to check the shear strength equations. In order to avoid mistakes, the results were filtered by some criteria: the test results should not include a compressive strength of concrete (f_c') less than 12 MPa, the web width of section (b_w) under 70 mm, and the shear span-depth ratio (a/d) under 2.4. In order to escape the effect of arch action, the span-depth ratio was chosen to be greater 2.4. For the evaluation process, all data was used by comparison. In Fig. 1 there are distributions of the key test variables which were used in experimental results.

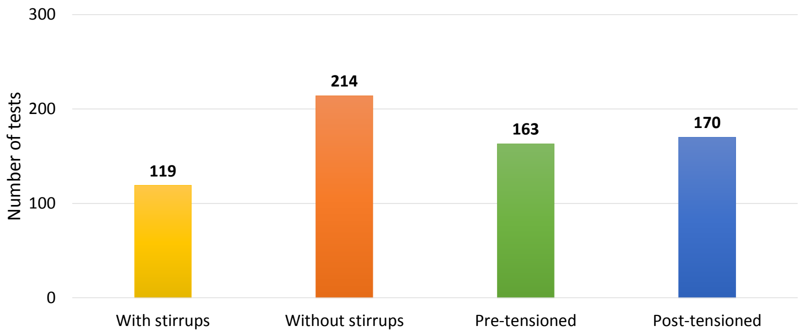
The ACI-DAfStb shear databases by Reineck et al (2013, 2014) are utilized in this paper to verify and check various design standards, including modified SNiP cade. These databases include experimental results of RC and PSC members without and with shear reinforcements. In order to get rid of unrelated and unreliable data, filtration process was applied as follows:

- the width of web concrete (b_w) should be greater than 70.0 mm;
- compressive strength of concrete (f_c') should be higher than 12.0 MPa;
- the shear span-depth ratio (a/d) should be larger than 2.4;
- the ratio between the shear strength and shear force at the nominal flexural strength calculated by ACI 318 (V_{test}/V_{flex}) should be greater than or equal to 1.1

A total number of tests remained after filtration process is 954 and 333 for RC and PSC members, respectively. Fig. 1 shows key information of databases, which were used in experimental results.



(a) Database for reinforced concrete members



(b) Database for prestressed concrete members

Fig. 1 Summary of shear database

3. COMPARATIVE STUDY

In order to conduct comparative study, four international codes models and modified SNiP code were chosen. These code models are SNiP (2012) for the CIS region, Eurocode2 (2004) for European Union, ACI 318 (2014) for United States, and CSA-A23.3 (2004) for Canada. Table 1 shows detailed formula for calculation shear capacity of concrete members.

Table 1 Detail formula of shear design methods

Provisions	V_c	V_s
Current SNiP code	$V_c = \dfrac{1.5\varphi_n f_t b_w d^2}{c}$ where $\varphi_n = 1 + \dfrac{\sigma_{cp}}{f_{cu}}$ for $0 \le \sigma_{cp} \le 0.25 f_{cu}$ $\varphi_n = 1.25$ for $0.25 f_{cu} \le \sigma_{cp} \le 0.75 f_{cu}$ $\varphi_n = 5\left(1 - \dfrac{\sigma_{cp}}{f_{cu}}\right)$ for $0.75 f_{cu} \le \sigma_{cp} \le f_{cu}$	$V_s = 0.75 q_{sw} c_0$ where $q_{sw} = \dfrac{A_v f_{vy}}{s}$
Modified SNiP code	$V_c = \dfrac{\beta_\rho \left(f_t + 0.35\sigma_{cp}\right) b_w d^2}{c}$ where $\beta_\rho = \sqrt{100\rho_{sw}} \le 1.5$	$V_s = 0.75 q_{sw} c_0$ where $q_{sw} = \dfrac{A_v f_{vy}}{s}$
ACI 318-14	RC: $V_c = 0.167\sqrt{f_c'} b_w d$ PSC: lesser of $V_{ci} = 0.05\sqrt{f_c'} b_w d_p + V_d + \dfrac{V_i M_{cre}}{M_{max}}$ and $V_{cw} = \left(0.29\sqrt{f_c'} + 0.3 f_{pc}\right) b_w d_p + V_p$	$V_s = \dfrac{A_v f_y d}{s} \le \dfrac{2}{3}\sqrt{f_c'} b_w d$
Eurocode 2	RC and PSC (Cracked section): $V_c = \left[0.12k(100\rho f_{ck})^{1/3} + k_1\sigma_{cp}\right] b_w d \ge \left(v_{min} + k_1\sigma_{cp}\right) b_w d$ where $v_{min} = 0.035 k^{3/2} f_{ck}^{1/2}$, $k = 1 + \sqrt{\dfrac{200}{d}} \le 2$, $k_1 = 0.15$ and $\sigma_{cp} = f_{se} A_{ps} / A_g$ PSC (Uncracked section): $V_{cw} = \dfrac{I b_w}{S}\sqrt{f_{ctd}^2 + \alpha_1 \sigma_{cp} f_{ctd}}$	$V_s = \dfrac{A_v f_y z \cot\theta}{s}$ $\le \dfrac{\alpha_{cw} b_w z v_1 f_{cd}}{(\cot\theta + \tan\theta)}$ $0.4 \le \cot\theta \le 2.5$
CSA-A23.3	RC and PSC: $V_c = \beta\sqrt{f_c'} b_w d_v$ Where, $\beta = \dfrac{0.4}{1 + 1500\varepsilon_x}\dfrac{1300}{1000 + s_{ze}}$, $s_{ze} = \dfrac{35 s_z}{16 + a_g} \ge 0.85 s_z$	$V_s = \dfrac{A_v f_y d_v \cot\theta}{s}$ $\theta = 29 + 7000\varepsilon_x$

	$$\varepsilon_x = \frac{\frac{M_f}{d_v} + 0.5N_f + V_f - \phi_p V_p - A_{ps} f_{se}}{2\left(E_s A_s + E_p A_{ps}\right)}$$	

Table 2 demonstrates the shear strength ratio (V_{cal} / V_{test}), which were estimated by utilizing different international design models. It should be noted that calculations of shear capacity were made without consideration the strength reduction factors. The current SNiP code provides the most inaccurate results with highest COV value for RC members without shear reinforcement. It can be noticed that prediction accuracy improves RC members with shear reinforcement, except EC2. Results for prestressed concrete members showed approximately same trends. However, all code models provided more conservative results for PSC members compared to RC members. It can be concluded that effect of prestressing still remains underestimated in structural design standards.

Table 2 Verification results of shear design methods

Member type		Reinforced Concrete		Prestressed Concrete	
		Without stirrups	With stirrups	Without stirrups	With stirrups
Number of tests		784	170	214	119
SNiP	Average	0.97	0.88	0.54	0.71
	Std. Derivation	0.45	0.21	0.23	0.18
	COV	0.47	0.24	0.43	0.25
ACI 318	Mean	0.76	0.63	0.62	0.73
	Std. Derivation	0.33	0.17	0.17	0.14
	COV	0.43	0.27	0.27	0.18
EC2	Mean	0.60	0.64	0.49	0.50
	Std. Derivation	0.15	0.21	0.18	0.14
	COV	0.24	0.33	0.37	0.28
CSA-A23.3	Mean	0.85	0.79	0.63	0.73
	Std. Derivation	0.15	0.14	0.18	0.09
	COV	0.17	0.17	0.28	0.12
Proposed method	Mean	0.78	0.80	0.49	0.84
	Std. Derivation	0.26	0.16	0.13	0.16
	COV	0.32	0.20	0.27	0.19

4. CONCLUSION

This study aimed to verify accuracy and safety margin of the modified SNiP code model. In order to do that, four international code model, such as SNiP (the CIS region), Eurocode2 (European Union), ACI 318 (United States), and CSA-A23.3 (Canada) were utilized. According to comparative study, strength predictions of existing SNiP code showed poor analytical accuracy compared to other international design codes. On other hand, improved performance in prediction of shear capacity was shown by modified SNiP code. To be exact, modified model showed more accurate predictions for both RC and PSC members, and it provided better analytical accuracy for concrete members with stirrups, which are mainly utilized in real life practices.

ACKNOWLEDGEMENT

This study was supported by the Social Policy Grant of the corresponding author in Nazarbayev University.

REFERENCES

ACI Committee 318 (2014), Building Code Requirements for Structural Concrete (ACI 318-14) and Commentary (ACI 318R-14). Farmington Hills.

CEN,Eurocode 2: Design of concrete structures (2004), Part 1-1: General rules and rules for buildings. CEN, Brussels.

CSA Committee A23.3 (2004), Design of Concrete Structures, Canadian Standards Association, Mississauga, Ontario, Canada.

Reineck, K.-H.,Bentz, E. C., Fitik, B., Kuchma, D. A., and Bayrak, O. (2013), "ACI-DAfStb Database of Shear Tests on Slender Reinforced Concrete Beams without Stirrups," *ACI Struct. J.*, **110**(5), 867-875.

Reineck, K. H.; Bentz, E.; Fitik, B.; Kuchma, D.A.; and Bayrak, O. (2014), "ACI-DAfStb Databases for Shear Tests on Slender Reinforced Concrete Beams with Stirrups," *ACI Struct. J.*, **111**(5), 1147-1156.

SNIP 2.03.01-84 (2012), *Concrete and reinforced concrete structures*, Ministry of Regional Development of the Russian Federation, Moscow, Russia. (In Russian)