The 2018 Structures Congress (Structures18)
Songdo Convensia, Incheon, Korea, August 27 - 31, 2018

Background in Shear Design Code Model of RC Beam Members Used in the CIS Countries

Meirzhan Yerzhanov[1)], Dichuan Zhang[1)], Hyunjin Ju[1)], Jong Kim[1)], and *Deuckhang Lee[2)]

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

ABSTRACT

SNiP code is official design standard for the structural designs of reinforced concrete (RC) structures in the Commonwealth of Independent States (CIS) countries. The shear strength estimation provisions specified in SNiP code was developed about ninety years ago, and the shear design equation was derived in a semi-empirical manner. This means that the available database at that time is critical in its accuracy and level of safety. The main objective of this paper is to suggest a new modification factor for the shear strength model specified in SNiP code. An up-to-date and extensive shear database was introduced to derive a rational modification factor mainly considering the size effect in shear.

1. INTRODUCTION

Russian SNiP code is the common and widely used design standard in Eurasia, North Asia and Eastern Europe countries since the Soviet Union period (United Nations 2011). However, after the cold war, there are some barriers to understanding the structural design of the SNiP code because of the difference in language and culture. Thus, the design code for structures should be improved and developed for such Eurasia countries. Especially, the shear design of reinforced concrete member is one of the most difficult and challenging topics. SNiP code provides the shear strength model which is semi-empirical: its accuracy and margin depend on the results of the shear test. In this study, the shear design method of SNiP is investigated and the modified method is suggested to improve the shear design equation.

2. BACKGROUND OF SNIP SHEAR DESIGN

2.1. Plane of Minimum Resistance (PMR) Approach

Professor Gvozdev (Palaskas and Darwin 1980) who is one of the developers of the SNiP code, conducted extensive investigations, and proposed the concept of the plane of minimum resistance (PMR), as follows:

$$V_c = Kb_w dR_b \tan\varphi = K\frac{R_b b_w d^2}{a} \quad (1)$$

where K is strength modification factor, b_w is the width, d is the effective depth of RC member, a is the shear span length, and R_b is the ultimate flexural compressive stress of concrete. Borishanski (1975) estimated the shear contribution of concrete by adding the components normal to the principal compressive stress direction and drew the trend of the factor K in Eq. (1) for the shear database as shown in Fig. 1.

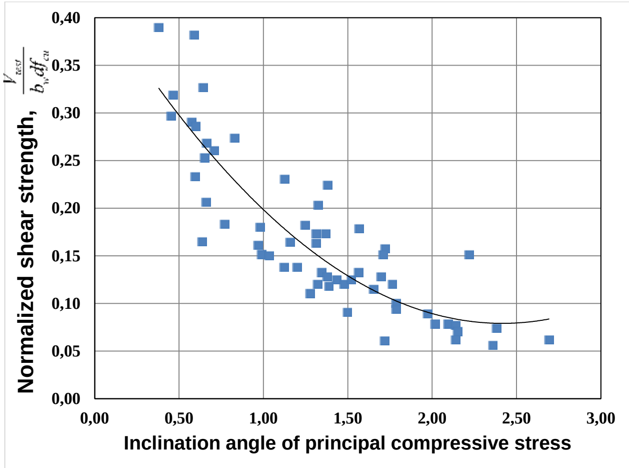


Fig. 1 – Distribution of factor K estimated from Borishanski

On this basis, the PMR model expressed in Eq. (1) was modified, as follows:

$$Q_b = \frac{0.15 f_{cu} b_w d^2}{a} \quad (2)$$

where f_{cu} is the compressive strength measured from cube concrete.

2.2. SNiP code model

The shear test on 75 RC beams was conducted by professor Gvozdev from the Institute of Concrete and Reinforced Concrete of USSR Academy of Building and Architecture. He proposed a semi-empirical equation for the shear design of an RC beam member (Gvozdev 1975). In this proposed model, there are two assumptions: the longitudinal tension reinforcement has no resistance, and the failure in yielding of transverse reinforcements and concrete shear occur simultaneously. According to SNiP manual (2012), if the tensile strength replaces the cubic strength of concrete in Equ. (1), the derivation of shear resistance specified in SNiP code can be written, as follows:

$$V_c = K_{snip} b_w d f_t \tan\varphi = \frac{K_{snip} f_t b_w d^2}{a} \quad (3)$$

where K_{snip} is the experimental adjustment factor, which can be taken as 1.5, f_t is the tensile strength of concrete specified in SNiP code and φ is the inclination angle of diagonal shear crack. Experiments show that V_c approaches the constant value at small values of the span to depth ratio (a/d):

$$V_{c,\max} = 2.5 f_t b_w d \tag{4}$$

For large values of a/d:

$$V_{c,\min} = 0.5 f_t b_w d \tag{5}$$

Hence, the shear contribution of concrete in SNiP code has some limits:

$$V_{c,\min} \le V_c \le V_{c,\max} \tag{6}$$

2.3. Detailed discussion of physical limitation contained in SNiP code equation

According to the practical SNiP manual (2012) the shear contribution of concrete:

$$V_c = \frac{M_a}{a} = \frac{0.15 b_w d^2 f_{cu}}{a} \tag{7a}$$

$$M_a = 0.15 b_w d^2 f_{cu} \tag{7b}$$

where M_a is a bending moment and *a* is a span length. In order to find the level of the flexural resistance at the shear failure, Eq. (7b) can be equated with the flexural strength of an RC section, as follows:

$$M_a = M_r = 0.15 b_w d^2 f_{cu} = \alpha_1 f_{cu} \beta_1 x b_w \left(d - \frac{\beta_1 x}{2} \right) \tag{8}$$

where α_1 and β_1 are the factors for the equivalent concrete stress block which can be taken as 0.85, and x is the neutral axis depth can be found by using Eq. (3) and (4), as follows:

$$0.36x^2 - 0.72dx + 0.15d^2 = 0 \tag{9}$$

And the neutral axis will be 0.24 from the equation. It satisfies the requirements of the tension-controlled section.

3. PROPOSED MODIFICATION FACTORS

The factor K in the current SNiP code has some limitations. The ACI445-DAfStb shear database presented by Reineck et al. was used to overcome the limitation. Table 1 shows the summary of the ACI445-DAfStb shear database.

Table 1 – Summary of shear database

f_c' (MPa)	0-15	16-20	21-25	26-35	36-50	51-70	71-100	100.0
No. of specimens	21	93	134	272	113	71	73	7
d (mm)	0-150	151-200	201-250	251-300	301-400	401-600	601-1000	>1000
No. of specimens	86	90	84	301	79	59	53	32

The modified new factor K_m can be calculated from the Borishanski equation as follows:

$$K_m = K\cot\alpha = \frac{V_{test}}{f_t b_w d} \quad (10)$$

The K_m was derived based on the tensile strength of concrete specified in SNiP code. Borishanski's effort was to show the effect of the inclination angle of the principal compressive stress on the shear resistance of concrete; however, according to the recent studies, the size effect according to the effective member depth influences significantly on the shear strengths of RC beam members.

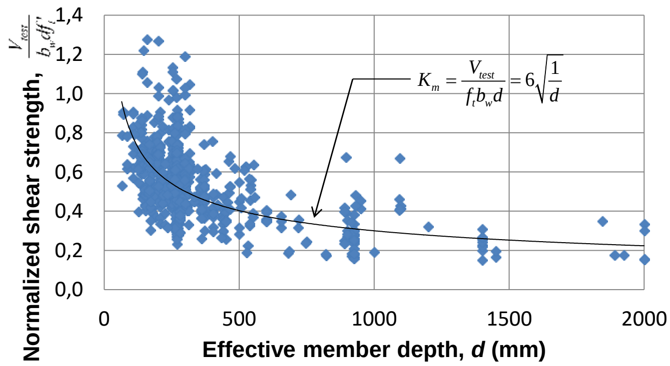


Fig. 2 – Interdependency of shear resistance and effective member depth

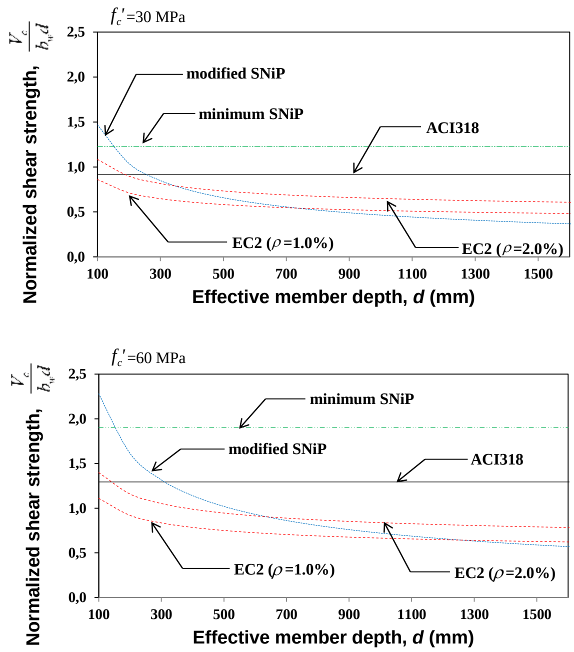
From the Fig. 2, the K_m can be derived as follows:

$$K_m = \frac{V_c}{f_t b_w d} = 6\sqrt{\frac{1}{d}} \quad (11)$$

Then, Eq. (1) can be rewritten as follows:

$$V_c = 6\sqrt{\frac{1}{d}}\, f_t b_w d \quad (12)$$

The shear strength distributions estimated by Eq.(12) was compared with other shear strength distributions which were found using ACI318 (2014), Eurocode2 (2004) and existing SNiP code models (Figs. 3(a) and 3(b)).



(a) f_c'=30 MPa (b) f_c' =60 MPa

Fig. 3 – Comparisons between code models

4. CONCLUSION

This paper had discussed the share design model for RC members in SNiP code and it was thoroughly observed and limitations were found and discussed. According to that, the shear strength RC can be exaggerated by SNiP code model without shear reinforcement. Based on the existing shear database, the modified factor was introduced in order to enhance the analytical accuracy and safety level.

REFERENCES

ACI Committee 318, *Building Code Requirements for Structural Concrete (ACI 318-14) and Commentary (ACI 318R-14).* Farmington Hills, 2014,524 pp.

Borishansky M.S., “Shear strength of reinforced concrete elements,” UDC 624.075.3: 624.012 45.

CEN,*Eurocode 2: Design of concrete structures, Part 1-1: General rules and rules for buildings*. CEN, Brussels, EN 1992-11:2004 2004.

Gvozdev A. A., *Concrete and reinforced concrete*, Moscow, 1975, pp 44-45. (in Russian).

Palaskas, M. N., and Darwin, D., *Shear Strength of Lightly Reinforced Concrete Beams*, SM Report No. 3, University of Kansas Center for Research, Inc., Lawrence, Kansas, September 1980, 198 pp.

SNIP 2.03.01-84, *Concrete and reinforced concrete structures*, Ministry of Regional Development of the Russian Federation, Moscow, Russia, 2012,162 pp.

Tatygulov A. S., Akberdin T. Z., Okonechnikov, V., and Makhambetov, M. S., Report Project Academy, *Kazgor*, 2010, 211 pp. (in Russian).
United Nation (UN), Annex No. 9 to the Treaty on the Eurasian Economic Union Protocol on Technical Regulation within the Eurasian Economic Unions, 2011, 855 pp