The 2014 World Congress on
Advances in Civil, Environmental, and Materials Research (ACEM14)
Busan, Korea, August 24-28, 2014

Development of Shear Strength Model for Pre-stressed Reinforced Concrete beams

*Jong-Chan Kim[1)], Kyoung-Kyu Choi[2)], and Hong-Gun Park[3)]

[1), 2)] *School of Architecture, Soongsil University, Seoul 153-743, Korea*
[3)] *Department of Architecture & Architectural Engineering, Seoul National University, Seoul 151-744, Korea*
[1)] *aczzang79@ssu.ac.kr*

ABSTRACT

An Analytical model was developed to predict the shear strength of pre-stressed reinforced concrete beams. In the proposed model, the shear contributions of concrete, transverse reinforcement, and pre-stressing tendon were defined separately. The shear contribution of concrete along diagonal tension cracking, for the diagonal tension failure usually occurring in the slender concrete beams, was defined with concrete tensile strength and cracking angle. For the shear compression failure usually occurring in deep concrete beams, the shear contributions of concrete was defined addressing concrete crushing additionally. The cracking angle was determined based on Rankine's failure criteria to addressing the relationship of shear stress and normal stress distribution in cracking surface. In addition, the proposed model was based on fundamental theory including force equilibrium and deformation compatibility using a mechanical model of cracked concrete. The model verified by comparison to existing test results.

1. INTRODUCTION

In pre-stressed concrete beams, the compressive stress, developed by pre-stressing force, occurs in a cross section and counteracts tensile stress in tension zone after external force is applied to beams as shown in Fig. 1. Thus, the pre-stressing force improves the flexural capacity of beams. In addition, according to existing experimental results, it is reported that the pre-stressing force improves shear capacity of beams. (Sozen et al. 1959) In the present study, the proposed model considered the effects of pre-stressing in the two points of view. 1) In case of concrete beams with inclined pre-stressed tendon, vertical components of pre-stressing force contributes directly to shear resistance of beams. 2) Since pre-stressing force applies to cross

[1)] Graduate Student
[2)] Assistant Professor
[3)] Professor

section of beams as compressive force, the shear contributions of concrete is increased as growth in compression zone of beams.

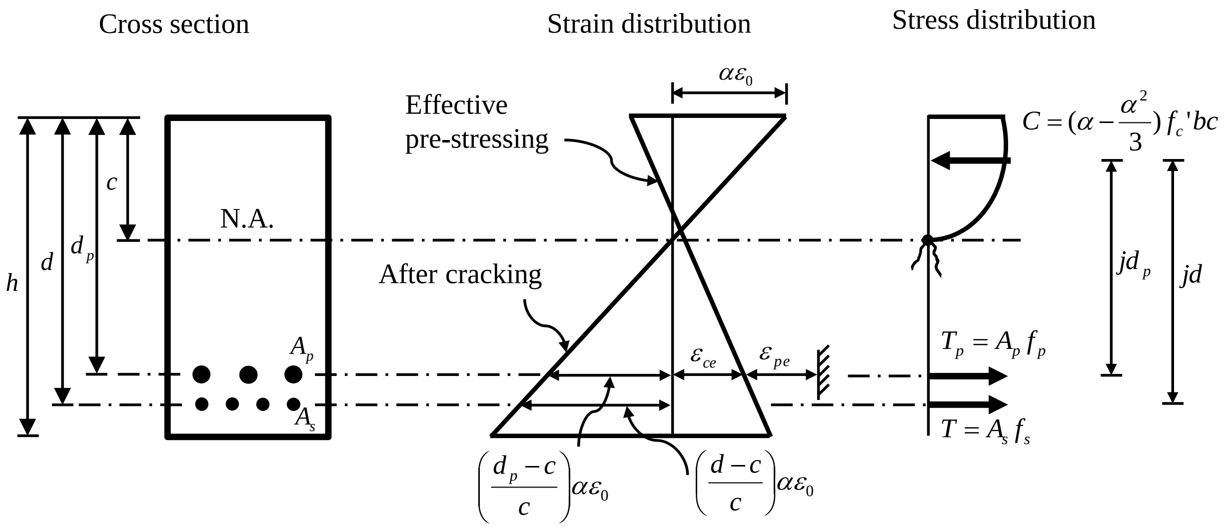

Fig. 1 Strain and stress distributions in cross section of pre-stressed concrete beams

2. SHEAR FAILURE MECHANISMS OF CONCRETE BEAMS

Since the concrete beams are commonly slender elements, flexural cracking damages extensively occur in the concrete beams before shear failure occur. Some of the flexural cracks propagate the tension zone of beams as inclined cracks or flexural-shear cracks, and then shear failure occurs with the inclined crack fully penetrating the compression zone or with the compressive crushing occurring at the upper compression zone (Kotsovos and Pavlovic 1998, Tureyen and Frosch 2003, and Zararis and Papadakis 2001).

In the present study, the shear strength model was developed pre-stressed concrete beams. The primary assumptions of the proposed model are summarized as follows.

[1] The shear failure of reinforced concrete beams, which varies according to a/d, occurs with diagonal tensile crack fully penetrating the compression zone of beam or with compression crushing in upper compression zone after severe flexural damage.

[2] The shear capacity of RC beams was mainly determined by the resistance of intact concrete in compression zone. The dowel action of longitudinal reinforcement and aggregate interlock in tension zone were not considered in the proposed model.

[3] The shear contribution of concrete in the compression zone is defined in the consideration of the interaction between compressive normal stress and shear stress based on Rankine's failure criteria (Chen 1982).

3. THE SHEAR STRENGTH OF PRE-STRESSED CONCRETE BEAMS

For considering pre-stressing force, the shear strength should be modified with including a shear contribution of pre-stressing. It is expressed as following equations.

$$V_n = V_c + V_s + V_p \tag{1}$$

$$V_p = P_e \tan\theta_p \tag{2}$$

where, V_c = shear contribution of concrete, V_s = shear contribution of transverse reinforcement, V_p = shear contribution of pre-stressed tendon, P_e = effective force of pre-stressed tendon, θ_p = distributed angle of pre-stressed tendon.

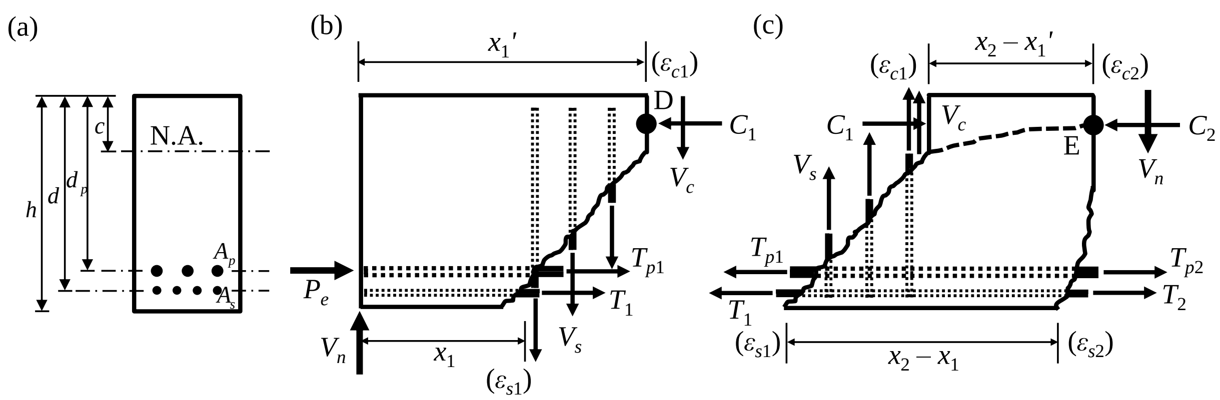

Fig. 2 Free-body diagrams of pre-stressed concrete beams

The shear contribution of compression zone (V_c) should be defined in terms of average compressive normal stress, which is developed in cracking surface. The average compressive normal stress developed in cracking surface of compression zone could be calculated by using a strain of tensile reinforcement, which is defined by using moment equilibrium conditions at points D and E in Fig. 2.

4. VERIFICATIONS

For verifications of the proposed model, the existing test results (Sozen et al. 1982) were used. The experimental study was performed pre-stressed concrete beams without tensile and transverse reinforcement. The shear strength of test specimens were predicted by using proposed model, simplified design equations, and current design code (ACI 318-11 2011) as showed in Fig. 3. It is observed that the proposed model could predict shear strength of pre-stressed concrete beams with better accuracy than current design code.

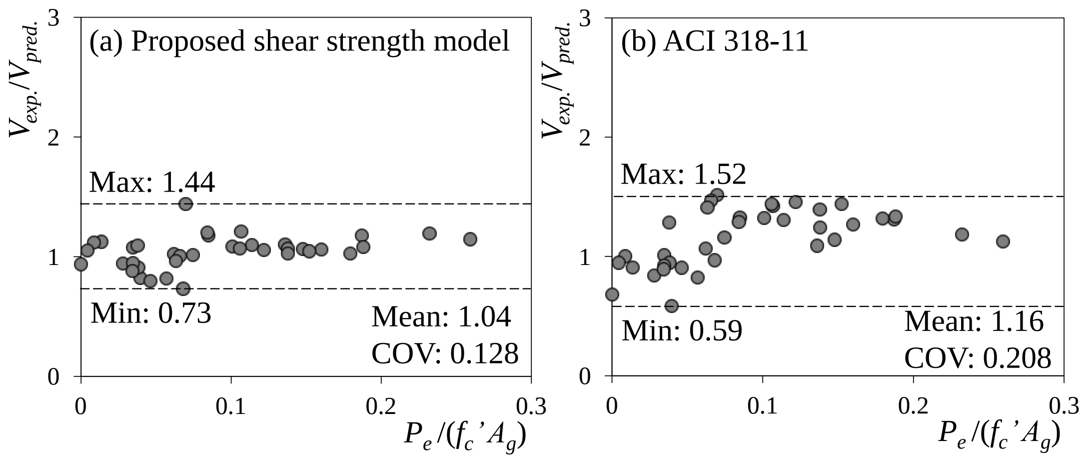

Fig. 3 Shear strength predictions for test specimens

5. CONCLUSIONS

In the present study, the analytical model for the shear strength of pre-stressed concrete beams was developed on the considerations of concrete failure mechanism and effect of pre-stressing. The proposed model assumed the shear strength to be mainly resisted by intact concrete in compression zone rather than tension zone. The proposed model was verified by comparisons with existing experimental results, which were performed about pre-stressed beams without tensile and transverse reinforcement. The comparisons showed that the proposed model could predict the shear strength of pre-stressed concrete beams better than current design method.

REFERENCES

Sozen, M., Zwoyer, E., and Siess, C. (1959), "Investigation of Prestressed Concrete for Highway Bridge, Part1-Strength in Shear of Beams without Web Reinforcement," *Engineering Experiment Station Bulletin*, (452), University of Illinois, Urbana, 69.

Kotsovos, M. and Pavlovic´, M. (1998), "Ultimate Limit-State Design of Concrete Structures: A New Approach," Thomas Telford, London, 208.

Tureyen, A. and Frosch, R. (2003), "Concrete Shear Strength: Another Perspective," *ACI Struct. J.*, **100**(5), 609-615.

Zararis, P. and Papadakis, G. (2001), "Diagonal Shear Failure and Size Effect in RC Beams without Web Reinforcement," *J. Struct. Eng.*, *ASCE*, **127**(7), 733-742.

Chen, W. (1982), "Plasticity in Reinforced Concrete," McGraw-Hill, New York, 204-205.

ACI Committee 318 (2011), "Building Code Requirements for Structural Concrete (ACI 318-11) and Commentary (ACI 318R-11)," USA, 509