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Re-examination of ACI 318 Provisions on Shear Strength of Post-Tensioned Slab-Column Connections

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ABSTRACT

Flat plate system is widely used in commercial and residential buildings due to its cost-effectiveness. In particular, the use of post-tensioned structures in comparison to conventional reinforced concrete structures allows for longer spans in slabs, which can maximize the benefits of the system. However, the flat plate system is vulnerable to shear failure due to the concentration of stresses at the slab-column connections, where shear forces and unbalanced moments are transferred. Compared to the conventional reinforced concrete slab-column connections, the post-tensioned slab-column connections lack experimental data on shear strength, resulting in more restrictions on the nominal shear strength equation of the current ACI 318-19 code. In this study, analyses were conducted on factors influencing shear strength and the restrictions on the provisions of ACI 318-19 to re-examine the nominal shear strength of post-tensioned slab-column connections.

1. INTRODUCTION

The flat plate system is a structural system composed only of slabs and columns and widely used in commercial and residential buildings due to its cost-effectiveness. However, the flat plate system has a weakness at the slab-column connections, where shear forces and unbalanced moments are transferred, which can cause shear failure due to stress concentration. Fig. 1 shows the shear stress distribution at the slab-column connection according to ACI 318-19. Here, v_u (i.e., the maximum factored shear stress calculated around the perimeter of a given critical section) is resisted by v_c (i.e., the stress corresponding to the nominal two-way shear strength provided by concrete) in the absence of shear reinforcement (e.g., stirrup and stud). v_c is calculated differently depending on whether the member is prestressed or nonprestressed. For prestressed two-way members, which have limited experimental data compared to nonprestressed two-way members, numerous restrictions are applied to the nominal shear strength

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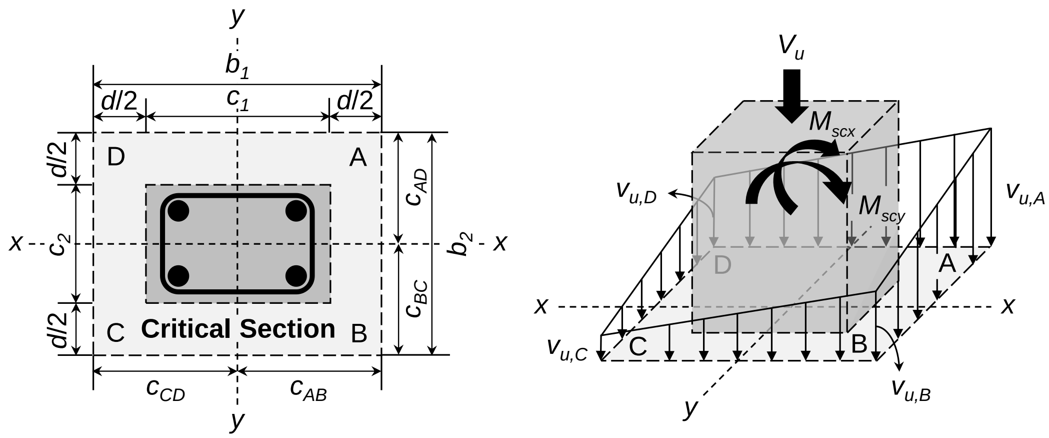
equation for safety purposes.



Interior Connection
Critical Section Centroid = Column Centroid

Shear Stress Distribution
According to ACI 318-19

Fig. 1 Shear stress distribution at slab-column connection (ACI 318-19)

In this study, to evaluate the validity of the restrictions and conservativeness of the norminal shear strength equation on post-tensioned slab-column connections, existing shear test data were re-calculated and re-compiled. Through this, analyses were conducted on factors influencing shear strength and the restrictions on the provisions of ACI 318-19.

2. FACTORS AFFECTING SHEAR STRENGTH

Fig. 2 represents the difference in shear strength based on the loading method, where v_c (i.e., the nominal shear strength of a post-tensioned slab-column connection according to ACI 318-19) was calculated without considering the restrictions on f'_c and f_{pc} values stated in Sections 22.6.5.4 and 22.6.5.5. The total number of specimens in the study was 73, with an average v_u / v_c ratio of 1.16. The nominal shear strength equation in ACI 318-19 Section 22.6.5.5 was found to be safe regardless of the loading method. However, it is worth noting that 11 specimens had a v_u / v_c ratio less than 0.9, and the analysis of these specimens reveals the following causes:

1. In edge connections with distributed tendons, there is a risk of flexural failure before shear failure.
2. Moment reversal may cause tensile stresses in the lower part of the slab near the column, where the nominal shear strength may not be achieved if there is no flexural reinforcement in this area.
3. When the column is rectangular, the formation of strong and weak axes in the critical section may prevent the full achievement of the norminal shear strength.

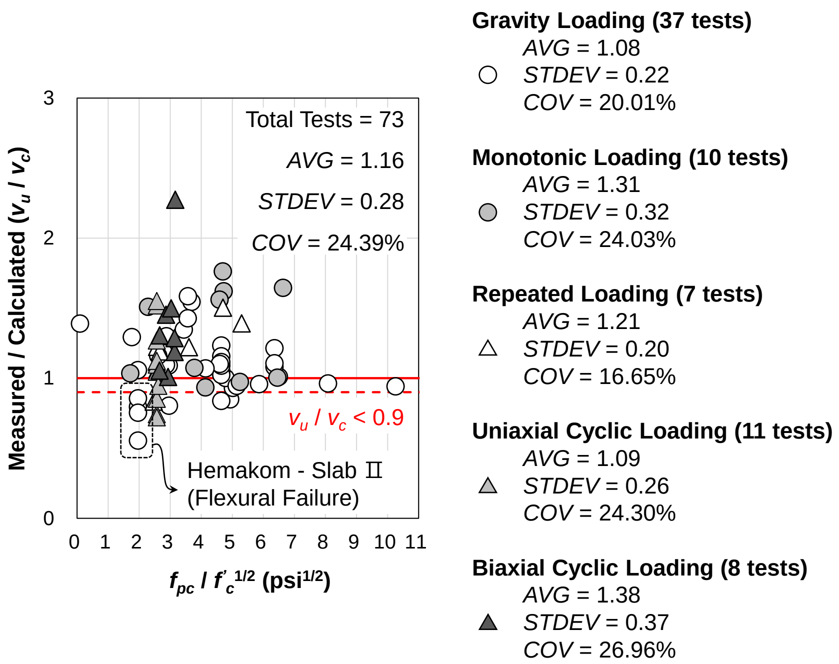


Fig. 2 Difference in shear strength based on loading method
(Representative reference for experimental data: Kang et al. [2008])

3. RESTRICTIONS IN NOMINAL SHEAR STRENGTH EQUATION

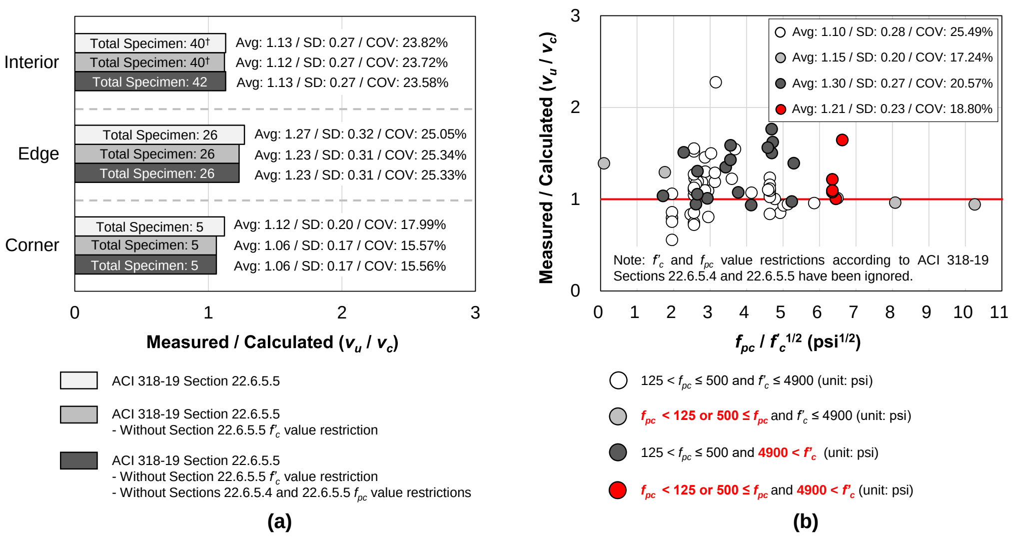


Fig. 3 Safety evaluation of shear strength under value restrictions of f'_c and f_{pc}
(Note: † G-0 and G-2 of Grow and Vanderbilt [1987] were excluded due to ACI's f_{pc} value restriction.)

The norminal shear strength equation for prestressed two-way members in Section 22.6.5.5 of ACI 318-19 is subjected to numerous restrictions. In this study, the impact of the f'_c and f_{pc} value restrictions on the conservativeness of the norminal shear strength equation was analyzed. Fig. 3 shows the safety evaluation of shear strength under the value restrictions of f'_c and f_{pc}. Based on the results from Fig. 3, it can be concluded that even without the f'_c and f_{pc} value restrictions currently applied in ACI 318-19 Section 22.6.5.5, there are no safety issues with the norminal shear strength equation. Therefore, it is deemed necessary to consider relaxing the restrictions on the f'_c and f_{pc} values depending on the amount of experimental data available.

4. CONCLUSIONS

The results of this study are as follows:

1. The nominal shear strength equation in ACI 318-19, Section 22.6.5.5 is deemed safe regardless of the loading method.
2. Additional experiments are needed to analyze the effect of the bottom reinforcement on the shear strength of the post-tensioned slab-column connection under moment reversal and the safety of the nominal shear strength equation of ACI 318-19 Section 22.6.5.5 when the column is rectangular.
3. Even without the f'_c and f_{pc} value restrictions stated in ACI 318-19 Sections 22.6.5.4 and 22.6.5.5, the nominal shear strength equation in Section 22.6.5.5 is still considered safe.

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