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# Cyclic wind and seismic loading tests of reinforced concrete coupling beams with different amounts of transverse reinforcements

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## ABSTRACT

Core wall systems of high-rise buildings rely on reinforced concrete (RC) coupling beams to provide effective energy dissipation and force transfer between RC shear walls. Structural elements are generally controlled by wind demand which keeps their behaviors remaining in the linear elastic phase in the wind load provisions such as ASCE 7. For RC coupling beam design, no specific design guideline is indicated for the span-depth ratio between two and four, and the contribution of transverse reinforcements on shear strength is not properly considered in ACI 318-19. To understand the shear strength and the effect of transverse reinforcement on the strength of different types of RC coupling beams, four types of RC coupling beams with a span-depth ratio of 2.5 were tested under both seismic and wind loads. The key parameters for each type of RC coupling beam were the number of transverse reinforcements and the layout of main rebars. Test results show that specimens only had minor cracks under conventional wind load protocol and thus wind design can be expanded to the non-elastic phase of deformations. The current project will propose a new modeling methodology for RC coupling beams with more probable shear strength.

## 1. INTRODUCTION

Due to the rapidly growing population and urbanization, more and more high-rise buildings are built in this era. In high-rise buildings, coupling beams are generally designed to open windows or doorways and form a wall system for force transfer and efficient energy dissipation under lateral loads. Unlike seismic design, high-rise buildings are mainly designed to remain in the elastic phase about wind load provisions in ASCE 7. Additionally, Han et al. (2019) found that the ratio of transverse reinforcement had a significant impact on the behavior and failure mode of diagonal coupling beams, whereas ACI 318-19 does not consider it in the design process. Thus, this project aims to investigate the hysteresis behavior of RC coupling beams with a span-depth ratio of 2.5,

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different layouts of main rebars, and different transverse reinforcement ratios tested under both seismic and wind loading protocols.

## 2. BEAM DESIGN

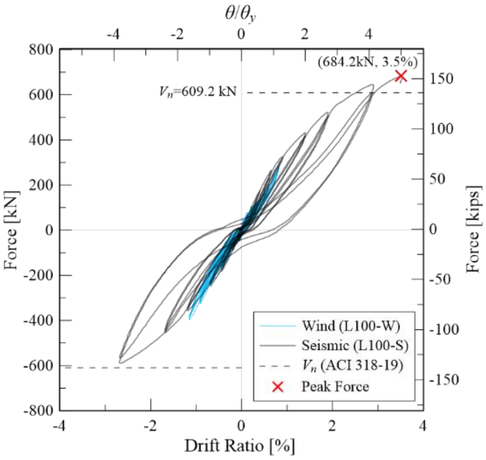
This study examined eight RC coupling beams with a span-depth ratio ($l_n/h$) of 2.5. Based on the minimum requirement of ACI 318-19, two of eight specimens (L100-S & L100-W) were designed with full transverse reinforcement. For two conventional (L67-S & L67-W) and two diagonal (D67-S & D67-W) coupling beams, the amount of transverse reinforcement was reduced by 1/3, and for two diagonal (D50-S & D50-W) coupling beams, by 1/2. The ratio of primary reinforcements for each beam was approximately 1.8 percent, and the average angle of diagonal rebars is about 15 degrees.

## 3. TEST PROCESS

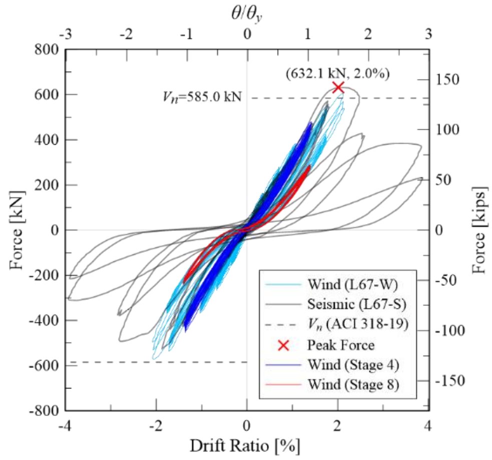
Referring to Lequesne et al. (2013), the test setup was composed of steel frames and two vertical frames with pin connections, where two vertical frames can restrict the moment that may occur, and also apply a slight compression load to coupling beams closely to the real mechanism. In this study, both cyclic seismic and wind loading protocols were used on every type of specimen. The seismic loading protocol was recommended by ACI 374.2R-13. In terms of wind loading protocol, to investigate the actual behavior of RC coupling beams in the plastic deformation phase, the maximum shear force was assumed to result in 1.5 yield rotation ($\theta_y$), which can be developed based on 150 m to 300 m high buildings according to the peak factor ($g_L$) for across-wind load as per KBC 2016. Testing was displacement-controlled for each protocol. The testing time for the wind loading protocol was more than ten hours, and the seismic loading protocol was about four hours.

## 4. CONCLUSION

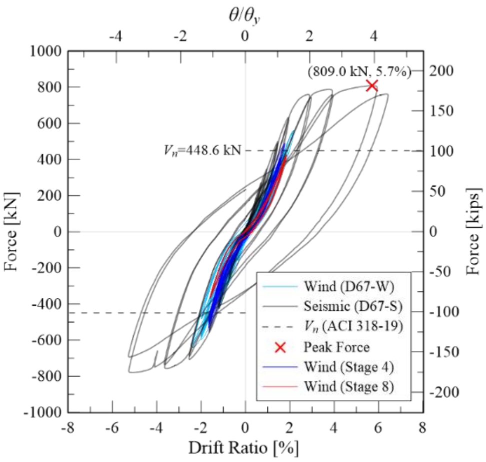
Three conclusions can be drawn according to this study: 1) First, test results (Fig. 1) show that diagonal coupling beams had higher shear strength, deformation capacity, and energy dissipation behavior than longitudinal coupling beams, and maximum shear strengths significantly exceeded the nominal shear strengths of ACI 318-19; 2) Second, coupling beams with lesser ratio of transverse reinforcements had smaller shear strength, meaning that the contribution of transverse reinforcements may need to be considered in the estimation formula; 3) Finally, coupling beams tested under wind loading protocol presented lower stiffness and distinct pinching effects after yielding (blue and red lines), but relatively small amount of cracks were observed without any substantial damage. Therefore, nonlinear performance-based design is likely to be applied to wind design with moderate inelastic response; though more experiments with various parameters and wind load protocols are recommended.



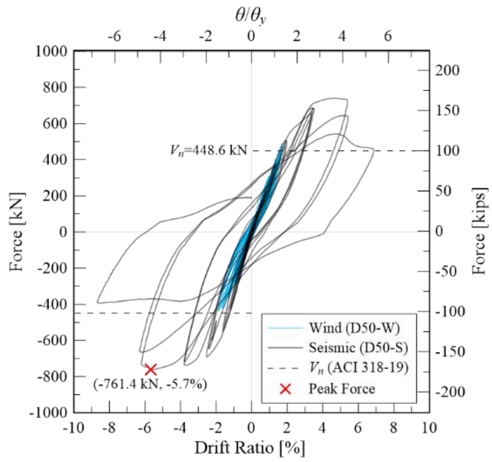

(a) L100 series




(b) L67 series




(c) D67 series




(d) D50 series

Fig. 1 Test results

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