NANYANG TECHNOLOGICAL UNIVERSITY

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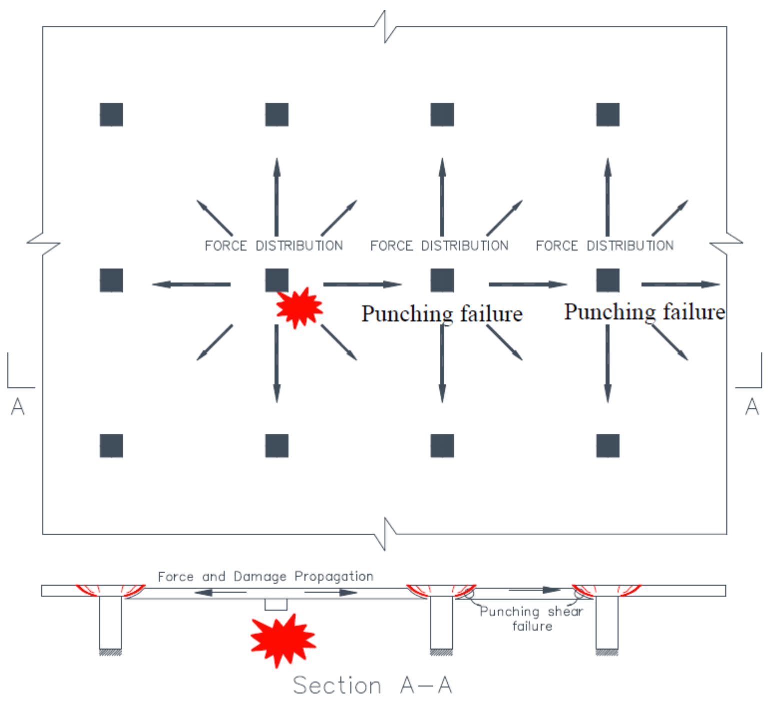
Robustness Assessment of Flat Slab Buildings against Disproportionate Collapse

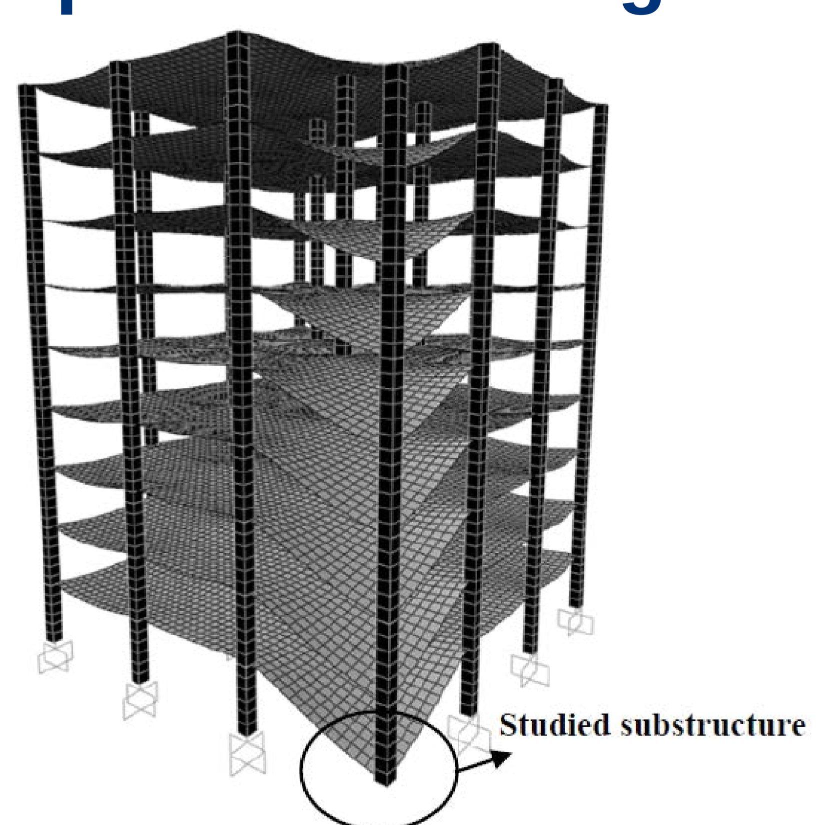
Flat slab structures are more vulnerable to progressive collapse compared to beam-column –slab structures as there are no beams that could assist in redistributing the load previously carried by the lost column. Moreover, when one of the columns was lost due to unexpected extreme load, load redistribution will result in significantly increased the shear force at surrounding columns, which may result in punching failure occurred in adjacent column-slab connections. The punching failure of adjacent column-slab connections may require further load redistribution and result in disproportionate collapse or complete collapse of flat slabs.

Motivation

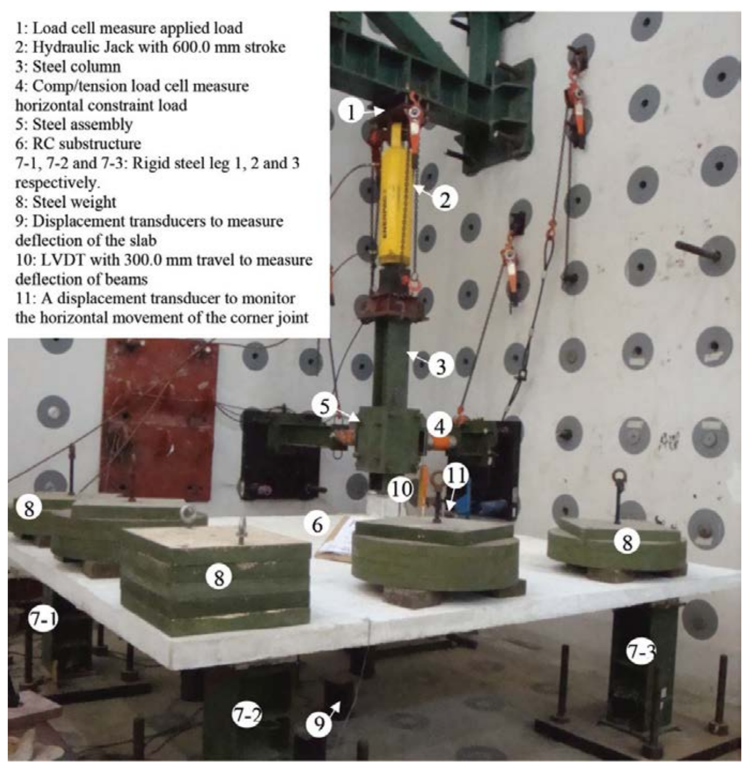


Schematic damage propagation in typical flat slab

Experimental Program

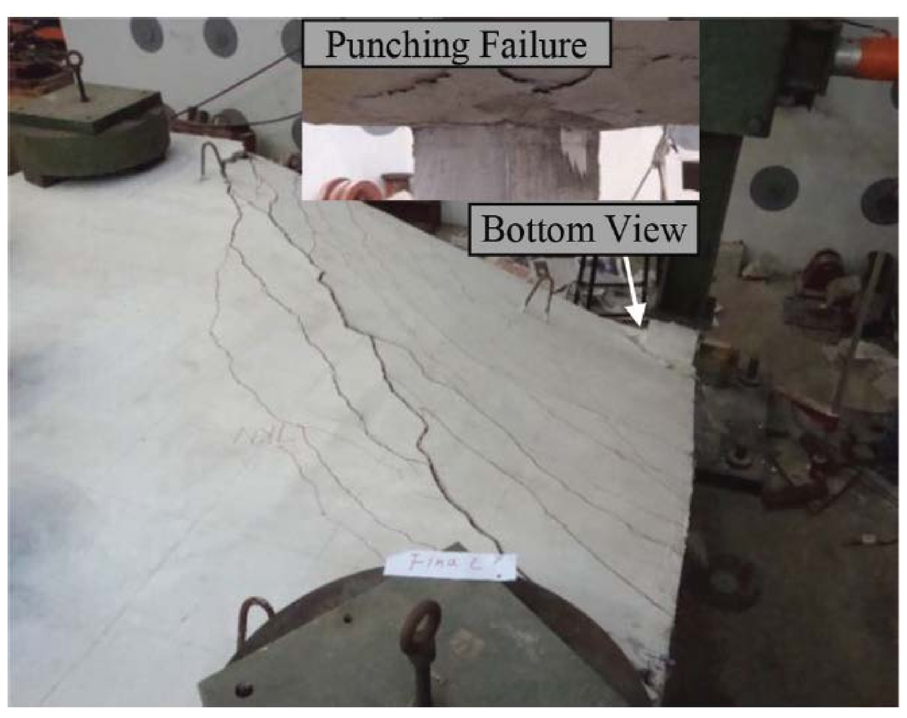


Deformation shape of prototype frame

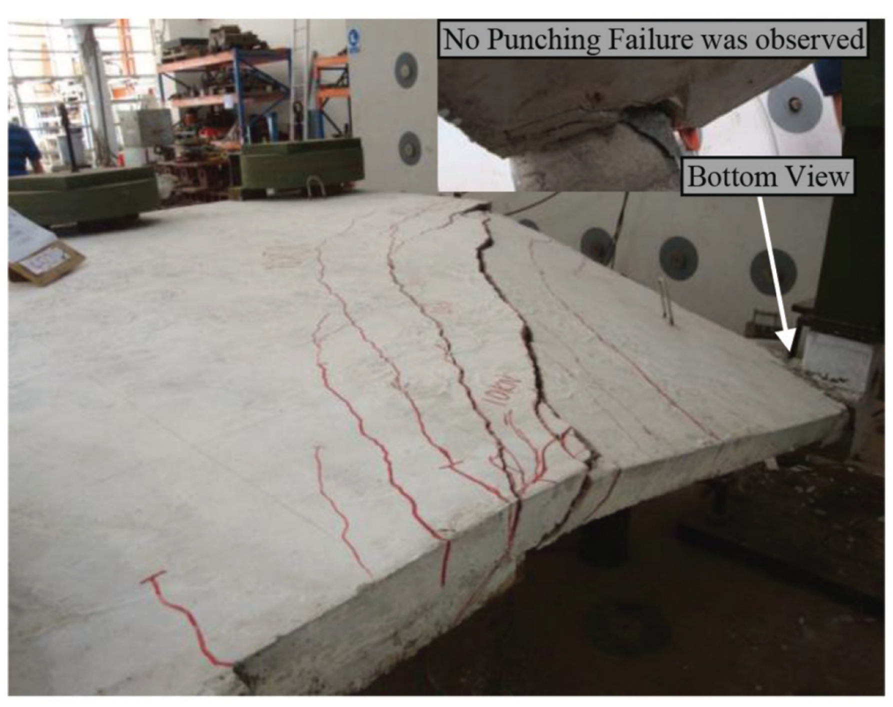


Experimental Setup

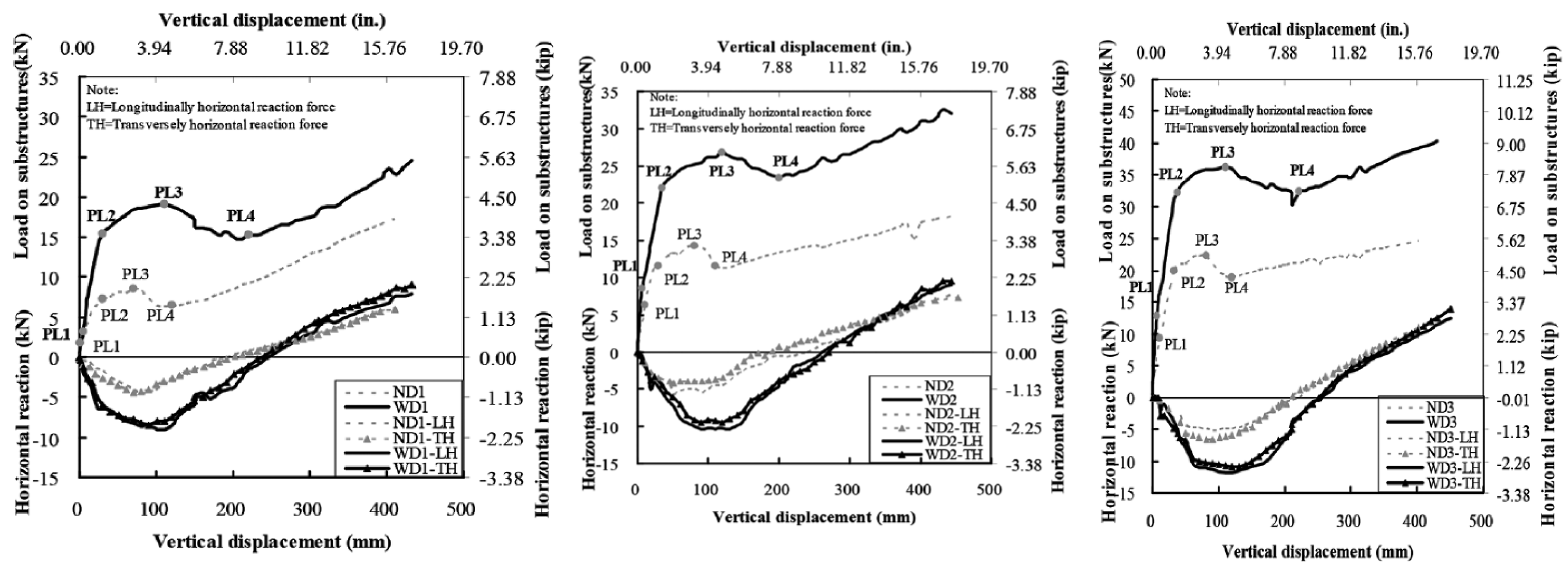
Test Results



Failure mode of ND2

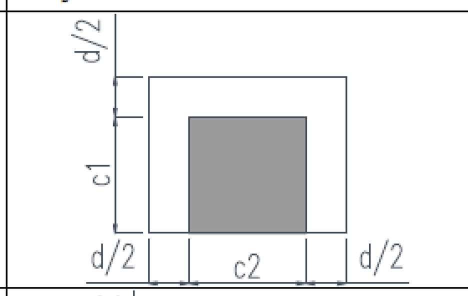
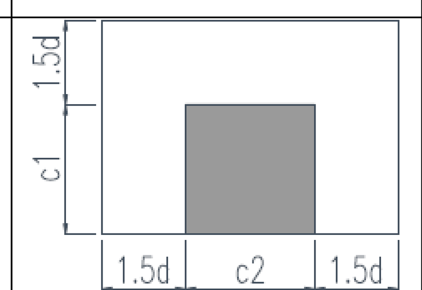
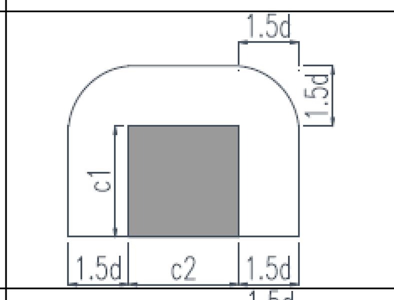
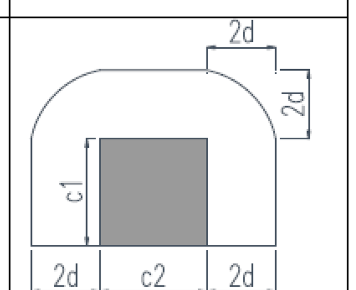
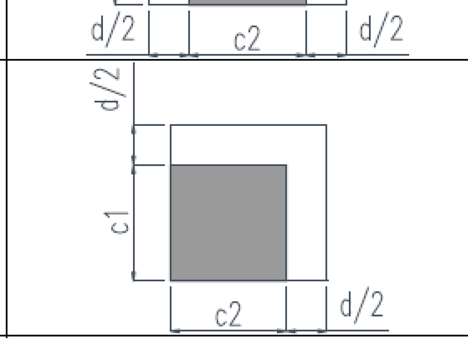
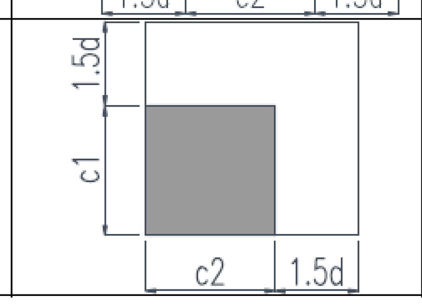
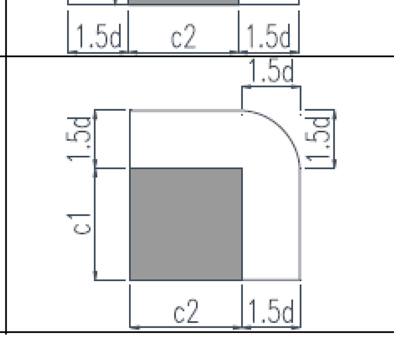
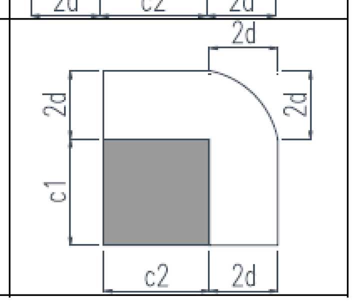


Failure mode of WD2

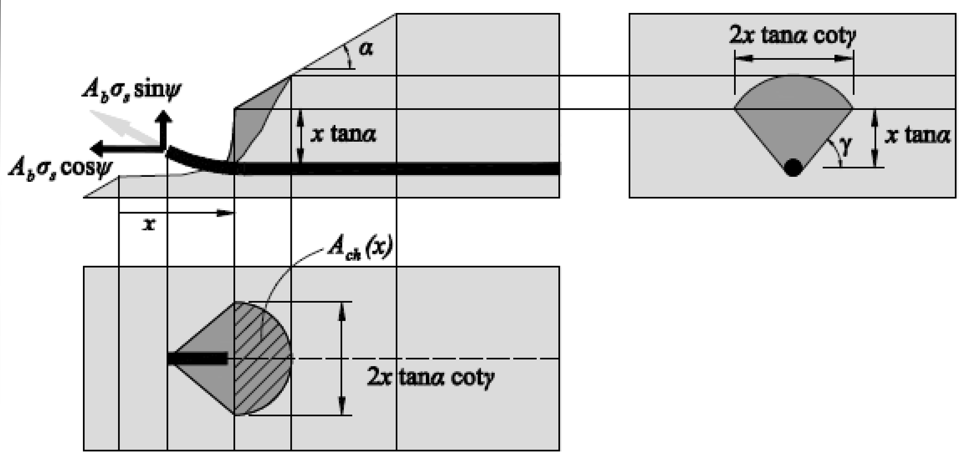


Load-displacement curve

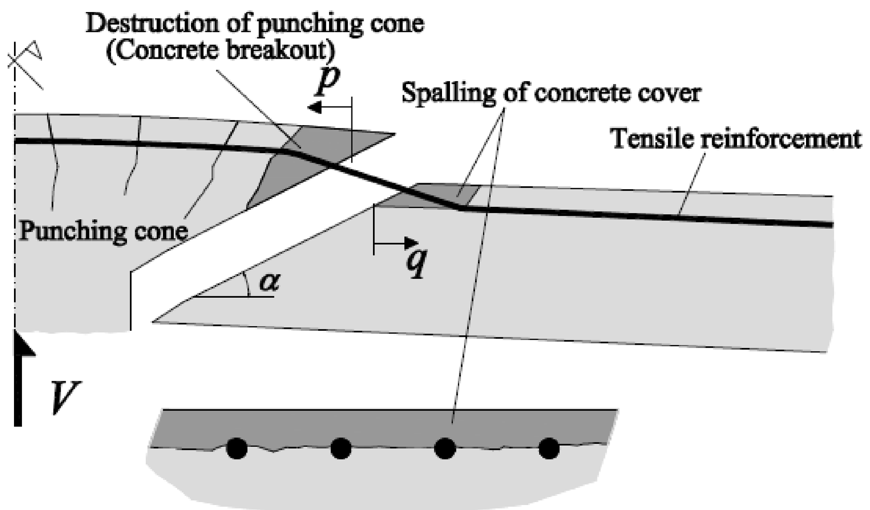
Code Comparison

Design codes	ACI 318-08[12]	BS 8110-97	DIN 1045-1	Eurocode 2
Punching shear strength (MPa)	Minimum of $v_c = 0.083(2+\frac{4}{\beta_c})\lambda\sqrt{f_c'}$ $v_r = 0.083(2+\partial_s\frac{d}{u})\lambda\sqrt{f_c'}$ $v_r = 0.33\lambda\sqrt{f_c'}$ $\alpha_s = 30$ for edge column $\alpha_s = 20$ for corner column	$v_c = 0.79(100\rho)^{1/3}\xi^{0.25}$ $\xi = \frac{400}{d} \geq 1$ $v_c < 0.8\sqrt{f_{cu}}$	$v_c = 0.21k(f_c' 100\rho)^{1/3}$ $k = 1+\sqrt{200/d} \leq 2.0$	$v_c = 0.18k(f_c' 100\rho)^{1/3}$ $k = 1+\sqrt{200/d} \leq 2.0$
Critical section (Edge column)				
Critical section (Corner column)				

Mechanical Model



Resistant from integrity rebar



Resistant from tensile rebar

Conclusions

- **Drop panels could significantly improve the overall performance of flat slabs in resisting progressive collapse.**
- **Punching failure will occur in flat slabs without drop panels while no punching failure occurred in flat slabs with drop panels.**
- **As sufficient integrity reinforcement was installed in bottom slab and passing through the column core, punching failure will not prevent the development of tensile membrane actions in flat slabs.**

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