CHAPTER 4 Reinforced Concrete

Add a new Section

402.14 Frame Members Not Part of the Lateral-force-resisting System.

Modify: ***UBC Section 1921.7.1*** *by adding the following sentence to the end of the Section:*

Slab-column connections shall comply with Sections 1921.7.5 through 1921.7.7. Conformance to Section 1921.7 satisfies the deformation compatibility requirements of UBC Section 1633.2.4.

Modify: ***UBC Section 1921.7*** *by adding the following three new subsections after subsection 1921.7.4:*

1921.7.5 Reinforcement to resist punching shear shall be provided in accordance with UBC Sections 1911.12, 1921.7.5.1, and 1921.7.5.2 at slab-column connections where story drift ratio exceeds $[0.035 - 0.05(V_u/\_V_c)]$. Shear reinforcement need not be provided where $V_u/\_V_c$ is less than 0.2, or where the story drift ratio is less than 0.005, except as required in UBC Section 1911.12 for gravity loads without consideration of seismic effects. V_u equals the factored punching shear from gravity load excluding shear stress from unbalanced moment. V_u is calculated for the load combination $1.2D + f_1L + f_2S$ of UBC Section 1612.2.1.

1921.7.5.1 The slab shear reinforcement shall provide V_s not less than $3.5\sqrt{f'_c}$.

1921.7.5.2 The slab shear reinforcement shall extend not less than 5 times the slab thickness from the face of the column.

1921.7.6 Bottom bars or wires within the column strip shall conform to ACI Section 13.3.8.5 except that splices shall be class B.

1921.7.7 Within the effective slab width defined in UBC Section 1913.5.3.2, the ratio of non-prestressed bottom reinforcement to gross concrete area shall not be less than 0.004. Where bottom reinforcement is not required to be continuous, such reinforcement shall extend a minimum of 5 times the slab thickness plus one development length beyond the face of the column or terminate at the slab edge with a standard hook.

1921.7.8

Commentary CHAPTER 4 Reinforced Concrete

Add a new Section

C402.14 Frame Members Not Part of the Lateral-force-resisting System.

Provisions for slab-column connections are added to UBC Section 1921.7. The added provisions aim to prevent punching shear failures that can occur when flat-slab gravity systems are subjected to earthquake deformation. Such punching shear failures resulted in un-repairable earthquake damage in the Northridge earthquake and could lead to slab collapse in cases where integrity reinforcement is insufficient. With the added provisions, UBC Section 1921.7 covers columns, beams, and slabs that are not designated as part of the lateral-force-resisting system.

UBC Section 1633.2.4 requires all structural elements not designated as part of the lateral-force-resisting system to be designed to support gravity loads while subjected to the lateral design displacement Δ_m. For concrete structures, meeting UBC Section 1921.7 satisfies this requirement for the columns, beams, and slabs of the gravity system.

The principle of Section 1921.7 is to allow flexural yielding of columns, beams, or slabs under the lateral design displacement, and to provide sufficient confinement and shear strength in elements that yield. Columns and beams are assumed to yield if the induced moment from the displacement Δ_m exceeds the moment strength, or if the induced moment is not calculated. Requirements for transverse reinforcement and shear strength are provided according to axial load and whether or not the member yields.

The procedure for checking slabs at columns does not require a calculation of induced moments, and instead is based on (a) the story drift corresponding to the lateral design displacement, and (b) the level of gravity-load shear stress on the punching-shear perimeter. Figure C402-5 illustrates the criterion of Section 1921.7.5, which requires shear reinforcement to be provided where the combined effect of story drift and shear stress could result in a punching shear failure. The criterion derives from test data of slabs subjected to gravity load and lateral displacement [Megally and Ghali 2000, Pan and Moehle 1992].

Section 1921.7.5.1 defines the quantity of shear reinforcement required, and Section 1921.7.5.2 defines the length over which the shear reinforcement shall extend. Sections 1921.7.6 and 1921.7.7 give requirements for slab bottom reinforcement that may yield as a result of seismic deformation. Section 1921.7.6 requires Class B rather than Class A lap splices, and Section 1921.7.7 provides for a minimum amount of bottom reinforcement in the region of the column.

Megally, Sami, and Amin Ghali, 2000. "Punching Shear Design of Earthquake Resistant Slab-Column Connections," *ACI Structural Journal*, Volume 97, No. 5, September-October.

Pan, Austin D., and Jack P. Moehle, 1992. "An Experimental Study of Slab-Column Connections," *ACI Structural Journal*, Volume 89, No. 6, November-December.