Precast Panel Anchors & Shear Friction – notes & quotes

ACI 318-08 and -11

These are the core provisions for the panel anchors (or, at least, the ones we always cited before).

§16.5.1.3(b)	"Precast wall panels shall have a minimum of two ties per panel, with a nominal tensile strength not less than 10,000 lb per tie."
§2.1	"N_n = nominal strength in tension, lb"
§16.5.1.4	"Connections that rely solely on friction caused by gravity loads shall not be permitted."

We always pointed to the word "solely" to help show that shear friction was allowed. We said, you can use friction, to keep panels in place, as long as you can ensure the friction will be there.

What I didn't notice, until recently, was that shear friction has *always* been allowed (or at least since the 2008 ACI 318 edition). It was just stated more subtly. Instead of explicitly saying "shear friction," the provision used the shear friction chapter number, 11.6.

§16.6.1.1	"Where shear is the primary result of imposed loading, it shall be permitted to use the provisions of 11.6 [shear friction] as applicable."

ACI 318-14

The core panel anchor provisions are still the same. Panel anchors (vertical integrity ties) still must have a 10,000 lb nominal tensile strength. And friction alone can't be used to resist external shear.

§16.2.4.3	"Vertical integrity ties shall be provided at horizontal joints between all vertical precast structural members, except cladding, and shall satisfy (a) or (b):" … "(b) Connections between precast wall panels shall have at least two vertical integrity ties, with a nominal tensile strength of at least 10,000 lb per tie."
§2.2	"N_n = nominal strength in tension, lb"
§16.2.1.3	"Connections that rely solely on friction caused by gravity loads shall not be permitted."

What changed is that the provisions are (arguably) clearer. Shear friction is now explicitly stated.

§16.2.3.4	"If shear is the primary result of imposed loading and shear transfer occurs across a given plane, it shall be permitted to calculate V_n in accordance with the shear friction provisions in 22.9."
§16.3.3.5	"At the contact surface between supported member and foundation, V_n shall be calculated in accordance with the shear-friction provisions in 22.9 or by other appropriate means."

PCI Design Handbook, 7th Edition

The PCI Design Handbook gives background on shear friction – what it is and how it can be used in precast construction. (ACI 318 references this.) (The bold, underlined text is my emphasis.)

§5.3.6 "A basic assumption used in applying the shear-friction concept is that concrete within the direct shear area being considered will crack in the most undesirable manner. Ductility is achieved by placing reinforcement across this anticipated crack so that the tension developed by the reinforcement will provide a force normal to the crack. **This normal force in combination with friction at the crack interface provides the shear resistance. The shear-friction analogy and shear-friction coefficient μ can be adapted to designs for** reinforced concrete bearing, corbels, daps, composite sections, **connections of shear walls to foundations**, shear connections in precast concrete diaphragms, and other applications."

Essentially, the shear friction concept is for any situation where you need to transfer shear across a joint or crack. It's for any situation where you need to prevent one surface from slipping past another surface. Friction resists the movement. But a clamping force is used to create (or add to) the friction. Friction = (coefficient) x (compressive force between the two surfaces). The clamping force creates or adds to the compressive force between the two surfaces.

With tilt panels, the large weight of the panel already creates a compressive force between the bottom of the panel and the foundation. There's already friction. The clamping force adds to that compressive force and also ensures that the compressive force from the panel weight can't easily be lessened by the panel being picked up (or jumping) during an earthquake. Ultimately, the friction is what prevents the panel from moving horizontally. The panel anchor simply serves a clamp to ensure that friction.

Here's an article that ACI 318-14 references for shear friction. By the date and title, you can see that using shear friction for precast has been around for years.

Birkeland, P. W., and Birkeland, H. W., 1966, "Connections in Precast Concrete Construction," *ACI Journal Proceedings,* V. 63, No. 3, Mar., pp. 345-368.

346 "A basic precept of good monolithic design: To avoid failures, all potential failure planes must be crossed by steel."

357 "shear failure as slippage (not as a tension crack in the usual sense) along a plane of maximum shear"

"The external shear loads V tend to produce slippage along the [failure] plane. […] The slippage is resisted by the friction μP resulting from the external clamping force P."

359 "External tension loads decrease the clamping force, and must be accounted for."