Effective Flexural Stiffness for Cracked Moment of Inertia of Concrete Walls

The cracked moment of inertia for tilt-up wall panels can be calculated using different ACI 318 provisions. The following shows the commonly used provisions to calculate the cracked moment of inertia:

1. 0.35 I_g for cracked walls and 0.75 I_g for uncracked walls — ***ACI 318-14 (Table 6.6.3.1.1(a))***
2. When treating the wall as compression member:

$$\left(0.80+25\times\frac{A_{st}}{A_g}\right)\times\left(1-\frac{M_u}{P_u\times h}-0.5\times\frac{P_u}{P_o}\right)\times I_g \le 0.875\times I_g$$ — ***ACI 318-14 (Table 6.6.3.1.1(b))***

3. When treating the wall as flexural member:

$$(0.10+25\times\rho)\times\left(1.2-0.2\times\frac{b_w}{d}\right)\times I_g \le 0.5\times I_g$$ — ***ACI 318-11 (Table 6.6.3.1.1(b))***

4. Using the moment magnification procedure for nonsway frames:

$$\frac{0.2\times E_c\times I_g+E_s\times I_{se}}{(1+\beta_{dns})\times E_c}$$ — ***ACI 318-14 (Eq. 6.6.4.4.4b)***

5. Using the moment magnification procedure for nonsway frames:

$$\frac{0.4\times E_c\times I_g}{(1+\beta_{dns})\times E_c}$$ — ***ACI 318-14 (Eq. 6.6.4.4.4a)***

6. Using the alternative design method of slender walls:

$$n\times A_{se}\times(d-c)^2+\frac{l_w\times c^3}{3}$$ — ***ACI 318-14 (Eq. 11.8.3.1d)***

Equation 11.8.3.1d is adopted and used in the StructurePoint detailed design examples for the analysis and design of tilt-up walls to calculate the cracked moment of inertia for the wall section modeled in spWall. This is intended to best represent the reference approach using the alternative design method to analyze and design a tilt-up wall panel.

The variation in the magnitude of I_{cr} has a significant effect on the analysis results and specifically the wall moments and displacement. In the following table a comparison of the resulting values based on variation of the I_{cr} is summarized for two wall piers in a tilt-up wall panel. The complete discussion including the modeling, analysis, design and deflection calculation can be found in "Reinforced Concrete Tilt-Up Wall Panel with Opening Analysis and Design (ACI 551)" design example. Note that this example uses ACI 318-11 to be consistent with the latest version of ACI 551.2R-15. No major changes on the equations except the citation.

Table 1 – Comparison of I_{cr} Effect on Results											
Method	I_{cr}, in.^{4}		Cracking coefficient (α) for spWall		M_u, kip-ft			$D_{z,service}$, in.		$D_{z,ultimate}$, in.	
	Left	Right	Left	Right	Left	Right	Total	Left	Right	Left	Right
Eq. 1	938	1407	0.350	0.350	17.03	20.03	37.06	0.203	0.164	0.80	0.63
Eq. 2	2345	3517	0.875	0.875	15.66	18.77	34.43	0.203	0.164	0.29	0.24
Eq. 3	607	715	0.227	0.178	18.49	22.43	40.92	0.203	0.164	1.33	1.37
Eq. 4	126	159	0.047	0.040	177.67	121.55	299.22	0.203	0.164	59.8	32.2
Eq. 5	133	200	0.050	0.050	109.04	57.51	166.55	0.203	0.164	34.6	12.3
Eq. 6	291	356	0.109	0.088	29.68	29.79	59.47	0.204	0.164	5.46	3.65
Eq. 6*	218	267	0.081	0.066	32.41	37.85	70.26	0.204	0.164	6.46	6.16
* Eq. 11.8.3.1d in ACI 318-14 with reduction factor of 0.75 (from 11.8.3.1)											

From the table above the following can be observed:

1. The values above reveal the necessity to carefully select I_{cr} value (and the corresponding α value) to ensure the wall moment capacity and estimated deflections are calculated with sufficient conservatism ensuring adequate strength and stability.
2. The $D_{z,service}$ values are unaffected by the method used to calculate I_{cr} since the section is uncracked and the cracking coefficient α is taken as 1 for that example.
3. The $D_{z,ultimate}$, values are calculated however are not used in any calculations and the deflection limits are given for $D_{z,service}$ only.
4. The range of the cracking coefficient and the cracked moment of inertia values vary widely based on the equation used.
5. In the selected example, the spWall model utilized the value of the cracked moment of inertia using the alternative design method equation Eq. 11.8.3.1d with reduction factor from 11.8.3.1.