Cracking Coefficient and Effective Flexural Stiffness of Concrete Walls

The cracking coefficient for tilt-up wall panels can be calculated using different ACI 318 provisions. The following shows the commonly used provisions to calculate the cracked (or effective) moment of inertia used in the cracking coefficient calculations required for spWall models:

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:

$$0.35\times I_g \le \left(0.80+25\times\frac{A_{st}}{A_g}\right)\times\left(1-\frac{M_u}{P_u\times h}-0.5\times\frac{P_u}{P_o}\right)\times I_g \le 0.875\times I_g$$

ACI 318-14 (Table 6.6.3.1.1(b1))

3. When treating the wall as flexural member:

$$0.25\times I_g \le \left(0.10+25\times\rho\right)\times\left(1.2-0.2\times\frac{b_w}{d}\right)\times I_g \le 0.5\times I_g$$

ACI 318-14 (Table 6.6.3.1.1(b2))

4. Using the moment magnification procedure for nonsway frames:

$$\frac{0.2\times E_c\times I_g+E_s\times I_{se}}{\left(1+\beta_{dns}\right)\times E_c}$$

ACI 318-14 (6.6.4.4.4(b))

5. Using the moment magnification procedure for nonsway frames:

$$\frac{0.4\times E_c\times I_g}{\left(1+\beta_{dns}\right)\times E_c}$$

ACI 318-14 (6.6.4.4.4(a))

6. Using the Alternative Method for Out-of-Plane Slender Wall Analysis:

$$n\times A_{se}\times\left(d-c\right)^2+\frac{l_w\times c^3}{3}$$

ACI 318-14 (11.8.3.1(c))

Equation 11.8.3.1(c) 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 match the reference approach using the "Alternative Method for Out-of-Plane Slender Wall Analysis" to analyze and design the tilt-up wall panels.

The variation in the magnitude of the cracking coefficient has a significant effect on the analysis results and specifically the wall moments and displacement. The following table illustrates the effect of using the above equations on the program results.

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 318-14 – ACI 551)" design example.

Table 1 – Comparison of (I_{cr} or I_{eff}) Effect on Results

Method	I_{cr} or I_{eff}, 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
Table 6.6.3.1.1(a)	938	1407	0.350	0.350	17.03	20.03	37.06	0.204	0.164	0.80	0.63
Table 6.6.3.1.1(b1)	2345	3517	0.875	0.875	15.66	18.77	34.43	0.204	0.164	0.30	0.24
Table 6.6.3.1.1(b2)	670	1005	0.250	0.250	18.08	20.96	39.04	0.204	0.164	1.19	0.91
6.6.4.4.4b	268	402	0.100	0.100	26.56	27.65	54.21	0.204	0.164	4.31	2.99
6.6.4.4.4a	536	804	0.200	0.200	19.11	21.85	40.96	0.204	0.164	1.56	1.19
11.8.3.1c	291	356	0.109	0.088	25.04	29.69	59.73	0.204	0.164	3.75	3.62
11.8.3.1c with reduction factor (from 11.8.3.1d)	218	267	0.081	0.066	32.23	37.64	69.87	0.204	0.164	6.40	6.09

From the table above the following can be observed:

1. The values above reveal the necessity to carefully select I_{cr} or I_{eff} values (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} or I_{eff} since the section is uncracked and the cracking coefficient α is taken as 1.
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 (or effective) 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 analysis method equation 11.8.3.1(c) with reduction factor from 11.8.3.1(d).