STI SHEARWAL V3.2.1 BR430 vertical force balance explanation

An option was added in SHEARWAL to allow the use of an alternative vertical force balance in the strain compatibility calculation. (This explanation uses the old way of reporting M_u and φM_n. See the explanation for BR760 to see how this changes in V3.2.1.)

The sum of the factored vertical loads (P_u in the following discussion) now can be divided by φ before it is used in the vertical force balance calculation. The concrete compression force, C, calculated this way is subsequently used in the moment and shear capacity calculations.

Shearwal was originally developed without the φ factor in the force balance. The original equation for the force balance calculation is

$$T + P_u = C \qquad (1)$$

where

$T = \Sigma(A_s\, \varepsilon\, E_s)$ with $(\varepsilon\, E_s) \leq f_y$

$P_u = \Sigma(1.2D + 1.6L)$ (or user-specified load factors) for vertical loads

$C = 0.85\, f'_c\, \beta_1\, c\, b$ (actually the parabolic equivalent) with c found by iteration so that the left and right sides of equation (1) are equal.

Then T, C and P_u are applied at their respective distance from the centroid to calculate M_n , M_p and M_u about the centroid. φM_n is compared to M_u (= [$1.0M_E$ or $1.4M_W$] + M_p) or, again, a user-specified load factor with the user-specified applied moment. M_p is the moment about the centroid due to factored vertical loads.

The shear capacity (V_n) for the wall (actually the joint supporting the wall) is then found by sliding friction based on a coefficient and the compression force, or, the area of the compression region and a maximum shear stress. φV_n is compared to V_u (= [$1.0V_E$ or $1.4V_W$]) and either an OK or a requirement for additional shear connections is given.

The option in the new version is to calculate C from

$$T + P_u/\varphi = C \qquad (2)$$

This comes from setting $C - T = P_n$ and then using $P_u = \varphi P_n$. It has the effect of increasing C and T by up to approximately 10% (for $\varphi = 0.9$) and subsequently M_n and V_n increase about the same.

In some cases, the change increases the vertical load value in the force balance enough to move the analysis from the tension controlled state into the transition or even compression controlled state and then, with the reduced φ applied to the final M_n, the calculated moment capacity actually decreases.

In Table 1 we've collected the calculated moment and shear capacity from an ad-hoc collection of problems. Each problem was run with both options. Two load cases are checked for each run. So, using the 00_Example1 problem, comparing φM_n values for LC1 by the two calculation methods, we find 3938 k-ft for the original force balance and 4255 k-ft for the alternate force balance, an ~8% increase with the changed calculation.

Table 1: Sample moment and shear values calculated using both force balance options.

	φM_n from original force balance		φM_n from alternate force balance		φV_n from original force balance		φV_n from alternate force balance	
File	LC1	LC2	LC1	LC2	LC1	LC2	LC1	LC2
00-Example...	3938	2913	4255	3130	191	137	209	148
358-Inter...1C	12471	8702	13601	9539	507	335	562	372

	φM_n from original force balance		φM_n from alternate force balance		φV_n from original force balance		φV_n from alternate force balance	
File	LC1	LC2	LC1	LC2	LC1	LC2	LC1	LC2
358-Inter...1I	10368	7138	11342	7846	409	269	453	299
430-lateral-e...	32034	26925	33195	27588	810	810	810	810
430-PCI7-E...	7880	5948	8377	6244	343	260	367	272
430-Shear-w...	2464	2172	2258	2287	752	388	1081	418
541-NA-iter...	52174	47529	53727	48589	901	817	928	836
576-OT-mo...	21405	17371	22900	18521	484	359	530	394
810-Exampl...	114	108	116	109	13.3	12.6	13.6	12.7
927-steel-rev...	4970	4370	5134	4472	106.7	106.7	106.7	106.7

The one example with φM_n lower for the alternate force balance (430-Shear-w..., LC1) has relatively high vertical loads without any eccentricity on a small wall which puts the alternate into a compression controlled condition ($\varphi = 0.65$) while the original is in a transition condition ($\varphi = 0.71$) and thus the original has the higher φM_n value.