Locate the center of resistance

The center of resistance is somewhat more complicated to determine and requires an assumption regarding the shear wall stiffness. Two methods of estimating the relative stiffness of segmented shear walls are generally recognized. One method bases the segmented shear wall stiffness on it's length. Thus, longer shear walls have greater stiffness (and capacity). However, this method is less appealing when multiple segments are included in one wall line and particularly when the segments have varying aspect ratios, especially narrow aspect ratios which affect stiffness disproportionately to the length. The second method bases the segmented shear wall stiffness on the shear capacity of the segment, which is more appealing when various shear wall constructions are used with variable unit shear values and when variable aspect ratios are used, particularly when the unit shear strength is corrected for narrow aspect ratios. The method based on strength is also appropriate for use with the perforated shear wall method, since the length of a perforated shear wall has little to do with its stiffness or strength. Rather, the amount of openings in the wall (as well as its construction) govern its stiffness and capacity. Therefore, the method used in this example will use the capacity of the perforated shear wall lines as a measure of relative stiffness. The same technique may be used with a segmented shear wall design method by determining the shear capacity of each shear wall line (comprised of one or more shear wall segments) as shown in Example 6.1.

First, the strength of each shear wall line in the building must be determined. Using the perforated shear wall method and the assumed wall construction given at the beginning of Step 3, the design shear wall line capacities (see below) are determined for each of the exterior shear wall lines in the building. The window and door opening sizes are shown on the plan so that the perforated shear wall calculations can be done as demonstrated in Example 6.2. It is assumed that no interior shear wall lines will be used (except at the shared wall between the garage and the house) and that the contribution of the interior partition walls to the stiffness of the building is negligible. As mentioned, this assumption can overlook a significant factor in the lateral resistance and stiffness of a typical residential building.

PSW 1: F_{psw1} = 7,812 lb (Wall Line D)
PSW 2: F_{psw2} = 3,046 lb (Wall Line E)
PSW 3: F_{psw3} = 14,463 lb (North side wall of house)
PSW 4: F_{psw4} = 9,453 lb (North side of garage)
PSW 5: F_{psw5} = 182 lb (Wall Line A; garage opening)
PSW 6: F_{psw6} = 9,453 lb (South side wall of garage)
PSW 7: F_{psw7} = 9,687 lb (Wall Line B)
PSW 8: F_{psw8} = 11,015 lb (South side wall of house at front)

The center of stiffness on the y-coordinate is now determined as follows using the above PSW design shear capacities for wall lines oriented in the E-W direction:

$$
\begin{aligned}
Y_{cs} &= [(F_{psw3})(Y_{psw3}) + (F_{psw4})(Y_{psw4}) + (F_{psw6})(Y_{psw6}) + (F_{psw8})(Y_{psw8})]/(F_{psw,E\text{-}W}) \\
&= [(14{,}463\text{ lb})(28\text{ ft})+(9{,}453\text{ lb})(26\text{ ft})+(9{,}453\text{ lb})(6\text{ ft})+(11{,}015\text{ lb})(0\text{ ft})]/(44{,}384\text{ lb}) \\
&= 15.9\text{ ft}
\end{aligned}
$$

The center of stiffness on the x-coordinate is determined similarly considering the wall lines oriented in the N-S direction:

$$
\begin{aligned}
X_{cs} &= [(F_{psw1})(X_{psw1}) + (F_{psw2})(X_{psw2}) + (F_{psw5})(X_{psw5}) + (F_{psw7})(X_{psw7})]/(F_{psw,N\text{-}S}) \\
&= [(7{,}812\text{ lb})(42\text{ ft})+(3{,}046\text{ lb})(48\text{ ft})+(182\text{ lb})(-22\text{ ft})+(9{,}687\text{ lb})(0\text{ ft})]/(20{,}727\text{ lb}) \\
&= 22.7\text{ ft}
\end{aligned}
$$

Therefore, the coordinates of the center of stiffness are (22.7 ft, 15.9 ft). Thus, the center of stiffness is located to the right of the center of gravity (force center for the seismic load) by 22.7 ft – 15.7 ft = 7 ft. This offset between the center of gravity and the center of resistance will create a torsional response in the N-S seismic load direction under consideration. For E-W seismic load direction, the offset (in the y-coordinate direction) is only 15.9 ft – 14.3 ft = 1.6 ft which is practically negligible from the standpoint of torsional response. It should be remembered that, in both loading directions, the influence of interior partitions on the center of stiffness (and thus the influence on torsional response) is not considered. To conservatively account for this condition and for possible error in locating the actual center of gravity of the building (i.e., accidental torsion), codes usually require that the distance between the center of gravity and the center of stiffness be considered as a minimum of 5 percent of the building dimension perpendicular to the direction of seismic force under consideration. This condition is essentially met in this example since the offset dimension for the N-S load direction is 7 feet which is 10 percent of the E-W plan dimension of the house and attached garage.

Distribute the direct shear forces to N-S walls

The direct shear force is distributed to the N-S walls based on their relative stiffness without regard to the location of the center of stiffness (resistance) and the center of gravity (seismic force center), or the torsional load distribution that occurs when they are offset from each other. The torsional load distribution is superimposed on the direct shear forces on the shear wall lines in the next step of the process.

The direct seismic shear force of 8,983 lb is distributed as shown below based on the relative stiffness of the perforated shear wall lines in the N-S direction. As before, the relative stiffness is based on the design shear capacity of each perforated shear wall line relative to that of the total design capacity of the N-S shear wall lines.

Direct shear on PSW1, PSW2, PSW5, and PSW7 is determined as follows:

(total seismic shear load on story)[(F_{psw1})/($F_{psw,N\text{-}S}$)] = (8,983 lb)[(7,812 lb)/(20,727 lb)]
= (8,983 lb)[0.377]
= 3,387 lb

(total seismic shear load on story)[(F_{psw2})/($F_{psw,N\text{-}S}$)] = (8,983 lb)[(3,046 lb)/(20,727 lb)]
= (8,983 lb)[0.147]
= 1,321 lb

(total seismic shear load on story)[(F_{psw5})/($F_{psw,N\text{-}S}$)] = (8,983 lb)[(182 lb)/(20,727 lb)]
= (8,983 lb)[0.009]
= 81 lb

(total seismic shear load on story)[(F_{psw7})/($F_{psw,N\text{-}S}$)] = (8,983 lb)[(9,687 lb)/(20,727 lb)]
= (8,983 lb)[0.467]
= 4,195 lb