Vertical Irrégularités (ASCE-05)

Vertical Irregularity:

Structures having one or more of the irregularity types are listed in Table 12.3-2 shall be designated as having vertical irregularity.

Exceptions:

a) Vertical Structural irregularities of Types 1a, 1b or 2 in Table 12.3-2 do not apply where no story drift ratio under design lateral seismic force is greater than 130% of the story drift ratio of the next story above. Torsional effects need not to be considered in the calculation of story drifts. The story drift ratio relationship for the top two stories of the structure are not required to be evaluated.

Vertical Irrégularités (ASCE-05)

Vertical Irregularity:

Structures having one or more of the irregularity types are listed in Table 12.3-2 shall be designated as having vertical irregularity.

Exceptions:

b) Irregularities Types 1a, 1b and 2 of Table 12.3-2 are not required to be considered for one storey building in any SDC or two storey building assigned to SDC B, C or D.

Vertical Irrégularités (ASCE-05)

TABLE 12.3-2 VERTICAL STRUCTURAL IRREGULARITIES

	Irregularity Type and Description	Reference Section	Seismic Design Category Application
1a.	**Stiffness-Soft Story Irregularity** is defined to exist where there is a story in which the lateral stiffness is less than 70% of that in the story above or less than 80% of the average stiffness of the three stories above.	Table 12.6-1	D, E, and F
1b.	**Stiffness-Extreme Soft Story Irregularity** is defined to exist where there is a story in which the lateral stiffness is less than 60% of that in the story above or less than 70% of the average stiffness of the three stories above.	12.3.3.1 Table 12.6-1	E and F D, E, and F
2.	**Weight (Mass) Irregularity** is defined to exist where the effective mass of any story is more than 150% of the effective mass of an adjacent story. A roof that is lighter than the floor below need not be considered.	Table 12.6-1	D, E, and F
3.	**Vertical Geometric Irregularity** is defined to exist where the horizontal dimension of the seismic force–resisting system in any story is more than 130% of that in an adjacent story.	Table 12.6-1	D, E, and F
4.	**In-Plane Discontinuity in Vertical Lateral Force-Resisting Element Irregularity** is defined to exist where an in-plane offset of the lateral force-resisting elements is greater than the length of those elements or there exists a reduction in stiffness of the resisting element in the story below.	12.3.3.3 12.3.3.4 Table 12.6-1	B, C, D, E, and F D, E, and F D, E, and F
5a.	**Discontinuity in Lateral Strength–Weak Story Irregularity** is defined to exist where the story lateral strength is less than 80% of that in the story above. The story lateral strength is the total lateral strength of all seismic-resisting elements sharing the story shear for the direction under consideration.	12.3.3.1 Table 12.6-1	E and F D, E, and F
5b.	**Discontinuity in Lateral Strength–Extreme Weak Story Irregularity** is defined to exist where the story lateral strength is less than 65% of that in the story above. The story strength is the total strength of all seismic-resisting elements sharing the story shear for the direction under consideration.	12.3.3.1 12.3.3.2 Table 12.6-1	D, E, and F B and C D, E, and F

Vertical Irrégularités (ASCE-05)

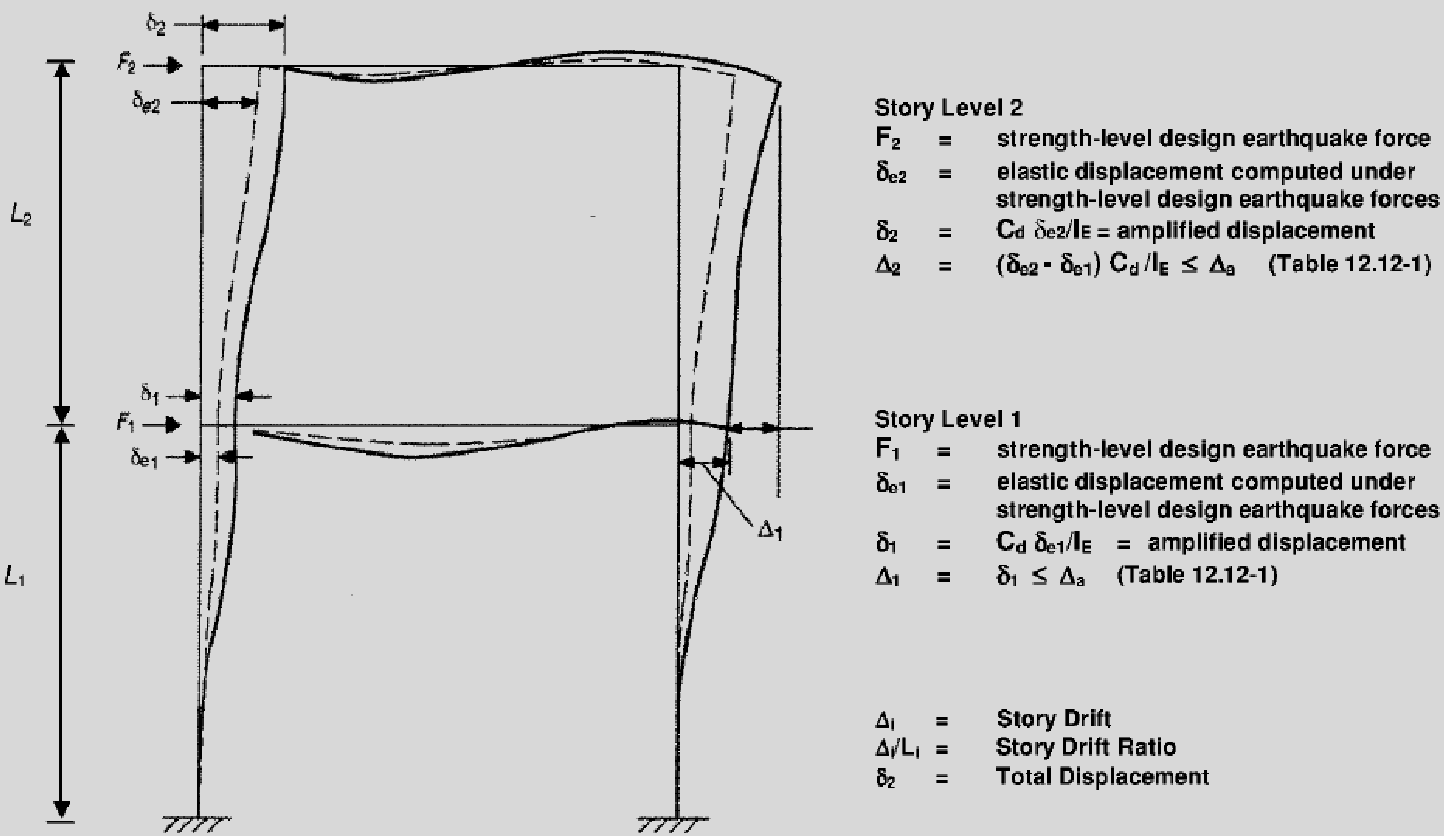


FIGURE 12.8-2 STORY DRIFT DETERMINATION

Vertical Irrégularités (ASCE-05)

TABLE 1613.5.6(1)
SEISMIC DESIGN CATEGORY BASED ON
SHORT-PERIOD RESPONSE ACCELERATIONS

VALUE OF S_{DS}	OCCUPANCY CATEGORY		
	I or II	III	IV
$S_{DS} < 0.167g$	A	A	A
$0.167g \leq S_{DS} < 0.33g$	B	B	C
$0.33g \leq S_{DS} < 0.50g$	C	C	D
$0.50g \leq S_{DS}$	D	D	D

TABLE 1613.5.6(2)
SEISMIC DESIGN CATEGORY BASED ON
1-SECOND PERIOD RESPONSE ACCELERATION

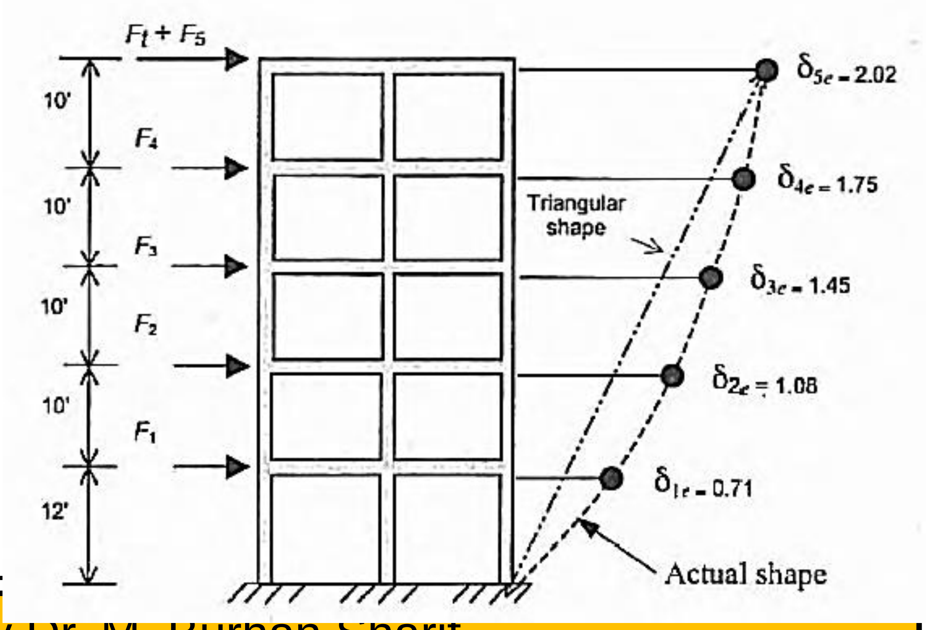
VALUE OF S_{D1}	OCCUPANCY CATEGORY		
	I or II	III	IV
$S_{D1} < 0.067g$	A	A	A
$0.067g \leq S_{D1} < 0.133g$	B	B	C
$0.133g \leq S_{D1} < 0.20g$	C	C	D
$0.20g \leq S_{D1}$	D	D	D

TABLE 16-I—SEISMIC ZONE FACTOR *Z*

ZONE	1	2A	2B	3	4
Z	0.075	0.15	0.20	0.30	0.40

Vertical Irrégularités (ASCE-05)

- A Seismic Design Category D five-story concrete special moment-resisting frame is shown below. The code-prescribed lateral forces Fx have been applied and the corresponding floor level displacements δ_{xe} at the floors' centers-of-mass have been determined as shown below.



Vertical Irrégularités (ASCE-05)

1. **Determine if a Type 1a vertical irregularity from Table 12.3-2 (Stiffness-Soft Story Irregularity) exists in the first story**

1. **To determine if this is a Type 1a vertical irregularity (Stiffness-Soft Story Irregularity) there are two tests**

1. The lateral story stiffness is less than 70 percent of that of the story above.
2. The lateral story stiffness is less than 80 percent of the average stiffness of the three stories above.

Vertical Irrégularités (ASCE-05)

- If the stiffness of the story meets at least one of the two criteria above, the structure is deemed to have a soft story.
- In terms of the calculated story-drift ratios, the soft story occurs when one of the following conditions exists.

When 70 percent of $\frac{\delta_{1e}}{h_1}$ exceeds $\frac{\delta_{2e} - \delta_{1e}}{h_2}$

or

When 80 percent of $\frac{\delta_{1e}}{h_1}$ exceeds $\frac{1}{3}\left[\frac{(\delta_{2e} - \delta_{1e})}{h_2} + \frac{(\delta_{3e} - \delta_{2e})}{h_3} + \frac{(\delta_{4e} - \delta_{3e})}{h_4}\right]$

Vertical Irrégularités (ASCE-05)

the story-drift ratios are determined as

$$\frac{\Delta_1}{h_1} = \frac{\delta_{1e}}{h_1} = \frac{(0.71-0)}{144} = 0.00493$$

$$\frac{\Delta_2}{h_2} = \frac{\delta_{2e}-\delta_{1e}}{h_2} = \frac{(1.08-0.71)}{120} = 0.00308$$

$$\frac{\Delta_3}{h_3} = \frac{\delta_{3e}-\delta_{2e}}{h_3} = \frac{(1.45-1.08)}{120} = 0.00308$$

$$\frac{\Delta_4}{h_4} = \frac{\delta_{4e}-\delta_{3e}}{h_4} = \frac{(1.75-1.45)}{120} = 0.00250$$

$$\frac{1}{3}(0.00308 + 0.00308 + 0.00250) = 0.00289$$

Checking the 70-percent requirement:

$$0.70\left(\frac{\delta_{1e}}{h_1}\right) = 0.70(0.00493) = 0.00345 > 0.00308 \ldots \text{NG}$$

$\therefore$ Soft story exists. . .

Note that 70 percent of first story drift is larger than second story drift. Alternately: $0.00493 > (0.00308 \times 1.30 = 0.0040) \ldots$ thus soft story.

Vertical Irrégularités (ASCE-05)

Checking the 80-percent requirement:

$$0.80\left(\frac{\delta_{1e}}{h_1}\right) = 0.80(0.00493) = 0.00394 > 0.00289 \ldots \text{NG}$$

$\therefore$ Soft story exists. . . condition 1a

Alternately: $0.00493 > (0.00289 \times 1.20 = 0.00347)$ . . . thus soft story.

Check for extreme soft story, (Vertical Structural Irregularity, Type 1b)

Checking the 60-percent requirement:

$$0.60(0.00493) = 0.002958 < 0.00308 \ldots o.k.$$

Alternately: $0.00493 > (0.00308 \times 1.4 = 0.004312)$ . . . $o.k.$

Vertical Irrégularités (ASCE-05)

Checking the 70-percent requirement:

$$0.70\ (0.00493) = 0.003451 > 0.00289 \ldots \text{NG}$$

Alternately: $0.00493 > (0.00289 \times 1.3 = 0.00375) \ldots \text{NG}$

Thus: Stiffness-Extreme Soft Story exists – condition 1b.

Vertical Irrégularités (ASCE-05)

- Section 12.8.6 requires that story drifts be computed using the maximum inelastic response displacements δx, , which include the deflection amplification factor C_d
- Where $\delta x = \dfrac{C_d \delta_{xe}}{I}$
- However, for the purpose of the story drift, or story-drift ratio, comparisons needed for soft story determination, the displacement δxe due to the design seismic forces can be used as in this example.
- In the example above, only the first story was checked for possible soft-story vertical irregularity. In practice, all stories must be checked, unless a modal analysis is performed. It is often convenient to create tables to facilitate this exercise.

Vertical Irrégularités (ASCE-05)

Table 4.1 Soft-Story Status 1a

Level	Story Displacement	Story Drift	Story-drift Ratio	0.8x (Story-drift Ratio)	0.7x (Story-drift Ratio)	Avg. of Story-drift Ratio of Next 3 Stories	Soft Story Status 1a
5	2.02 in	0.27 in	0.00225	0.00180	0.00158	—	No
4	1.75	0.30	0.00250	0.00200	0.00175	—	No
3	1.45	0.37	0.00308	0.00246	0.00216	—	No
2	1.08	0.37	0.00308	0.00246	0.00216	0.00261	No
1	0.71	0.71	0.00493	0.00394	0.00345	0.00289	Yes

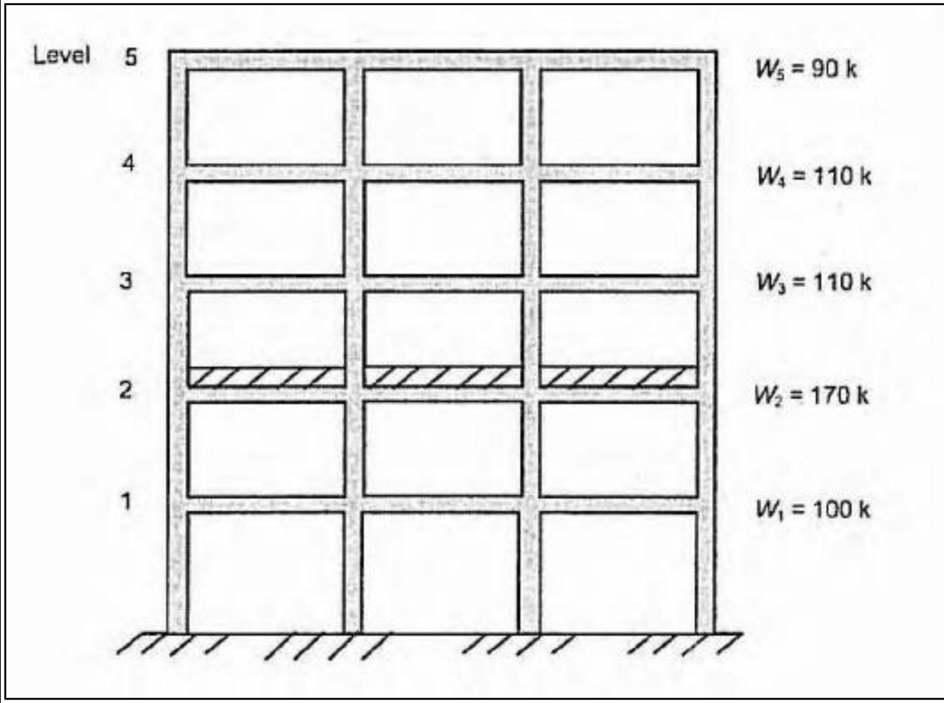
Table 4.2 Soft-Story Status 1b

Level	Story Displacement	Story Drift	Story-drift ratio	0.7x (Story-drift Ratio)	0.6x (Story-drift Ratio)	Avg. of Story-drift Ratio of Next 3 Stories	Soft Story Status1b
5	2.02 in	0.27 in	0.00225	0.00158	0.00135	—	No
4	1.75	0.30	0.00250	0.00175	0.00150	—	No
3	1.45	0.37	0.00308	0.00216	0.00185	—	No
2	1.08	0.37	0.00308	0.00216	0.00185	0.00261	No
1	0.71	0.71	0.00493	0.00345	0.00296	0.00289	Yes

Vertical Irrégularités (ASCE-05)-Type-2

2.	**Weight (Mass) Irregularity** is defined to exist where the effective mass of any story is more than 150% of the effective mass of an adjacent story. A roof that is lighter than the floor below need not be considered.

- The five-story special moment frame office building has a heavy utility equipment installation at Level 2. This results in the floor weight distribution shown below.
- Determine if there is a Type 2 vertical weight (mass) Irregularlty exists



Vertical Irrégularités (ASCE-05)-Type-2

A weight, or mass, vertical irregularity is considered to exist when the effective mass of any story is more than 150 percent of the effective mass of an adjacent story. However, this requirement does not apply to the roof if the roof is lighter than the floor below. Note that it does apply if the roof is heavier than the floor below.

Checking the effective mass of Level 2 against the effective mass of Levels 1 and 3

At Level 1

$$1.5 \times W_1 = 1.5(100 \text{ kips}) = 150 \text{ kips}$$

At Level 3

$$1.5 \times W_3 = 1.5(110 \text{ kips}) = 165 \text{ kips}$$

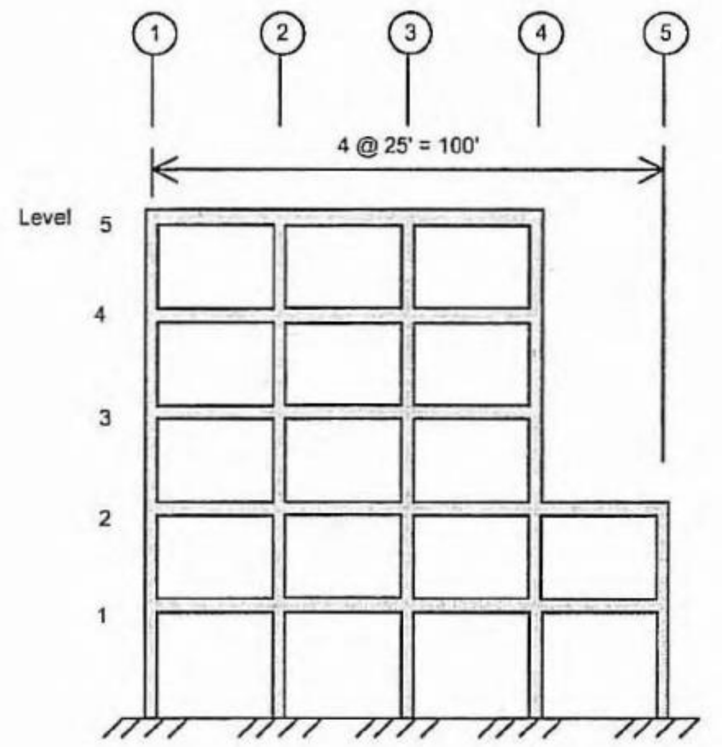
$$W_2 = 170 \text{ kips} > 150 \text{ kips}$$

$\therefore$ Weight irregularity exists.

Vertical Irrégularités (ASCE-05)-Type-3

1. **Determine if a Type 3 vertical irregularity (vertical geometric irregularity) exists**

- The lateral-force-resisting system of the five-story special moment frame building shown below has a 25-foot setback at the third, fourth, and fifth stories.



Vertical Irrégularités (ASCE-05)-Type-3

- A vertical geometric irregularity is considered to exist where the horizontal dimension of the lateral-force-resisting system in any story is more than 130 percent of that in the adjacent story.
- One-story penthouses are not subject to this requirement. In this example, the setback of Level 3 must be checked. The ratios of the two levels are

$$\frac{\text{Width of Level 2}}{\text{Width of Level 3}} = \frac{(100\text{ ft})}{(75\text{ ft})} = 1.33$$

133 percent > 130 percent

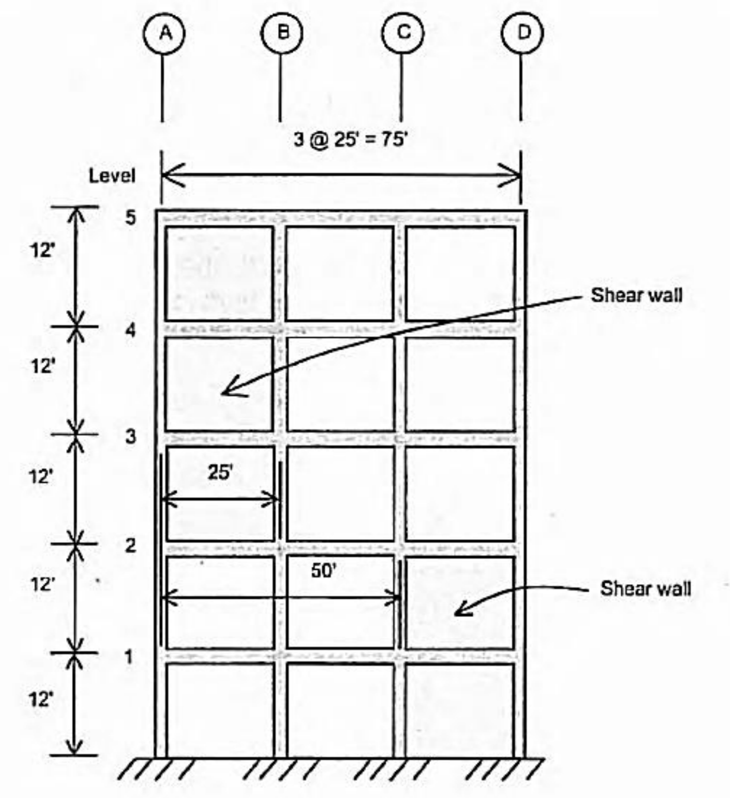
∴ Vertical geometric irregularity exists.

Vertical Irrégularités (ASCE-05)-Type-4

1. **Determine if there is a Type 4 vertical irregularity (in-plane discontinuity) in the vertical lateral-force-resisting element**

- A concrete building has the building frame system shown below. The shear wall between lines A and B has an in-plane offset from the shear wall between lines C and D.

- Determine if there is a Type 4 vertical irregularity (in-plane discontinuity) in the vertical lateral-force-resisting element



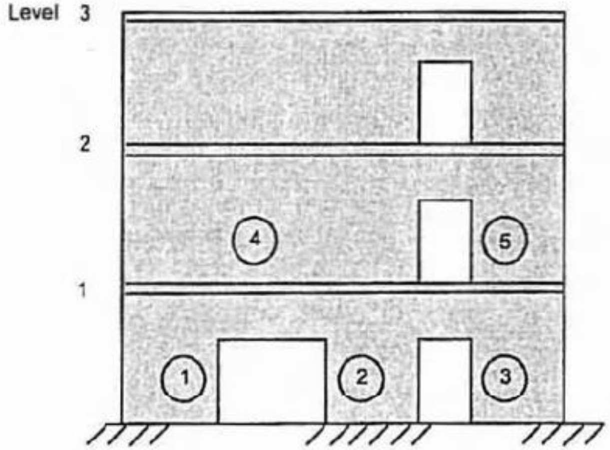
Vertical Irrégularités (ASCE-05)-Type-4

- A Type 4 vertical irregularity exists when there is an in-plane offset of the lateral force resisting elements greater than the length of those elements.
- In this example, the left side of the upper shear wall (between lines A and B) is offset 50 feet from the left side of the lower shear wall (between lines C and D).
- This 50-foot offset is greater than the 25-foot length of the offset wall elements.
- In-plane discontinuity exists.

Vertical Irrégularités (ASCE-05)-Type-5

1. **Determine if a Type 5 vertical irregularity (discontinuity in capacity- weak-story) condition exists**

- A concrete bearing-wall building has the typical transverse shear-wall configuration shown below. All walls in this direction are identical, and the individual piers have the shear contribution given below. Then, V_n, is the nominal shear strength calculated as per ACI procedure and V_m is defined herein as the shear corresponding to the development of the "nominal flexure strength also calculated in accordance with ACI.



PIER	V_n	V_m
1	20 kips	30 kips
2	30	40
3	15	10
4	80	120
5	15	10

Vertical Irrégularités (ASCE-05)-Type-5

A Type 5a weak-story discontinuity in capacity exists when the story strength is less than 80 percent of that in the story above. The story strength is the total strength of all seismic-force-resisting elements sharing the story shear for the direction under consideration.

Using the smaller values of V_n and V_m given for each pier, the story strengths are

First story strength = 20 + 30 + 10 = 60 kips

Second story strength = 80 + 10 = 90 kips

Check if first-story strength is less than 80 percent of that of the second story.

60 kips < 0.8(90) = 72 kips

∴ Weak story condition exists.

Check if first-story strength is less than 65 percent of that of the second story (Irregularity Type 5b).

60 kips < 0.65(90 kips) = 58.5 kips
∴ 60 kips > 58.5 kips

∴ Therefore the lower story is not an extreme soft story, Irregularity Type 5b.

Vertical Irrégularités (ASCE-05)-Type-5

- This irregularity check is to detect any concentration of inelastic behavior in one supporting story that can lead to the loss of vertical load capacity.
- Elements subject to this check are the shear-wall piers (where the shear contribution is the lower of either the shear at development of the flexural strength, or the Shear strength), bracing members and their connections, and frame columns.
- Frame columns with weak column-strong beam conditions have a shear contribution equal to that developed when the top and bottom of the column are at flexural capacity.

Vertical Irrégularités (ASCE-05)-Type-5

- Where there is a strong column-weak beam condition, the column shear resistance contribution should be the shear corresponding to the development of the adjoining beam yield hinges and the column base connection capacity.

- In any case, the column shear contribution shall not exceed the column shear capacity.

- An extreme weak story is prohibited (under 12.3.3.1) for structures more than two stories or 30 feet in height if the “weak story” has a calculated strength of less than 80 percent of the story above.

- A weak-story condition is absolutely prohibited in SDC E and F.