Regularity of buildings:
a brief summary

according to EN1998-1 (EC8): Seismic design §4.2.3

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Structural Regularity Categorization

Building structures are categorized as follows:

- **Regular**
- **Non-regular**

Separate consideration is given to the regularity characteristics in **plan** and in **elevation** for both directions x & y separately.

The implications on the seismic design of a building following the above categorization are,

- The selection of the structural model
- The method of analysis and
- The behavior factor *q* (20% decrease for non-regular in elevation, see 4.2..3.3)

Table 4.1: Consequences of structural regularity on seismic analysis and design

Regularity		Allowed Simplification		Behaviour factor
Plan	Elevation	Model	Linear-elastic Analysis	(for linear analysis)
Yes	Yes	Planar	Lateral force[a]	Reference value
Yes	No	Planar	Modal	Decreased value
No	Yes	Spatial[b]	Lateral force[a]	Reference value
No	No	Spatial	Modal	Decreased value

[a] If the condition of **4.3.3.2.1(2)**a) is also met.

[b] Under the specific conditions given in **4.3.3.1(8)** a separate planar model may be used in each horizontal direction, in accordance with **4.3.3.1(8)**.

Regularity in plan

The following conditions are required for a building to classify as regular in plan:

- The building shall be approximately symmetrical in plan with respect to two orthogonal axes.
- Plan outline shall be compact (i.e. each floor should be enclosed by a polygonal convex). Any existing set-backs should not affect the floor stiffness and their area should not exceed 5% of the floor area.
- The in-plan stiffness of a floor shall be sufficiently large compared to the lateral stiffness of the vertical elements (columns).
- The slenderness ratio $\lambda = L_{max}/L_{min}$ of the building in plan shall not be higher tha 4.
- The structural eccentricity e_o at each level and direction x,y and the torsional radius r shall satisfy
  - $e_{ox,y} \leq 0,30\ r_{x,y}$ (4.1a)
  - $r_{x,y} \geq l_s$ (4.1b)

Where $e_{ox,y}$ = distance between center of stiffness and mass

$r_{x,y}$ = √ (torsional stiffness)/(lateral $stiffness_{y,x}$) - "torsional radius"

l_s = radius of gyration of the floor mass in plan

(usually all calculations are carried out by a computer software)

Basically, it is preferable to avoid any torsional effects on the building.

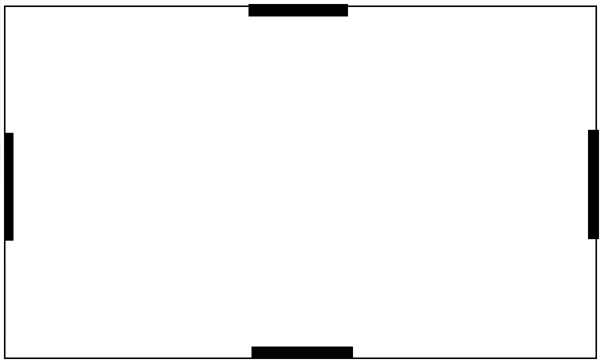
Building failure due to torsional effects

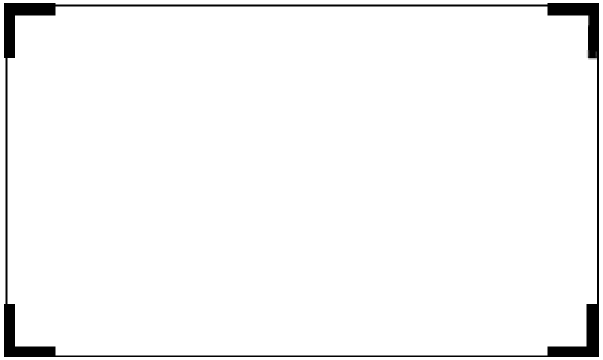
Complete collapse of a building due to its poor torsional response. Stiff vertical elements at one side and flexible elements on the other. (Athens, 1999 earthquake)

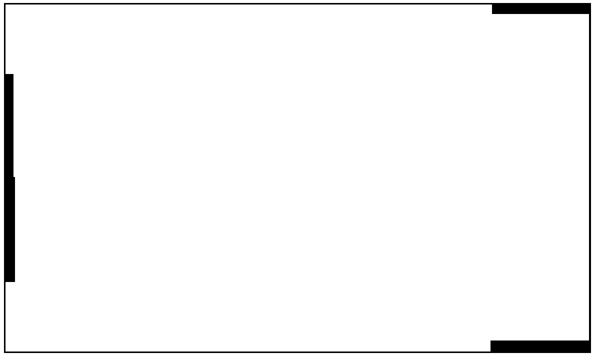
Providing torsional stiffness w.r.t vertical axis

Shear walls or strong frames at the perimeter of floor plans

Examples of correct plan configurations:







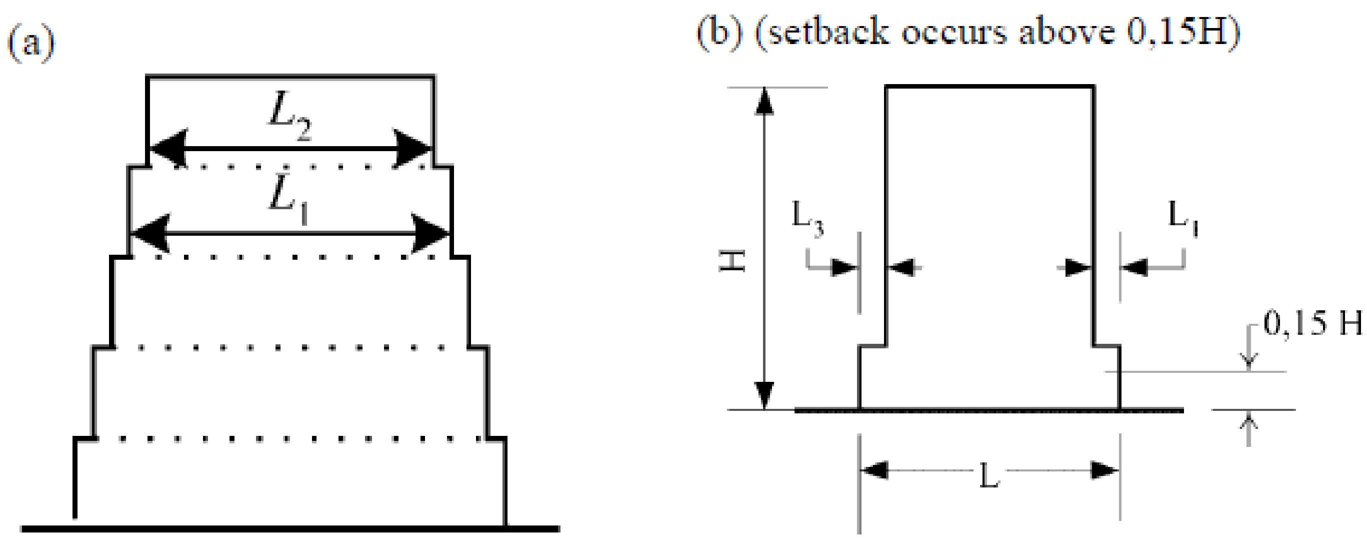
not so favorable

In the case of a non-regular in plan building which is also assessed as torsionally flexible (like example in page 4), the behavior factor can be reduced up to 50% thus significantly increasing lateral seismic design forces with design uncertainty and risk as well as building costs.

Regularity in elevation

The following conditions are required for a building to classify as regular in plan:

- All lateral load resisting vertical elements (columns) shall run without interruption from the top of the building (or top of setback) to the foundations.
- The lateral stiffness and mass of floors shall remain constant or reduce gradually (without abrupt changes) from the base to the top.
- The actual storey resistance (considering masonry infills) should not vary disproportionately between adjacent storeys.
- When setbacks are present the following must apply:



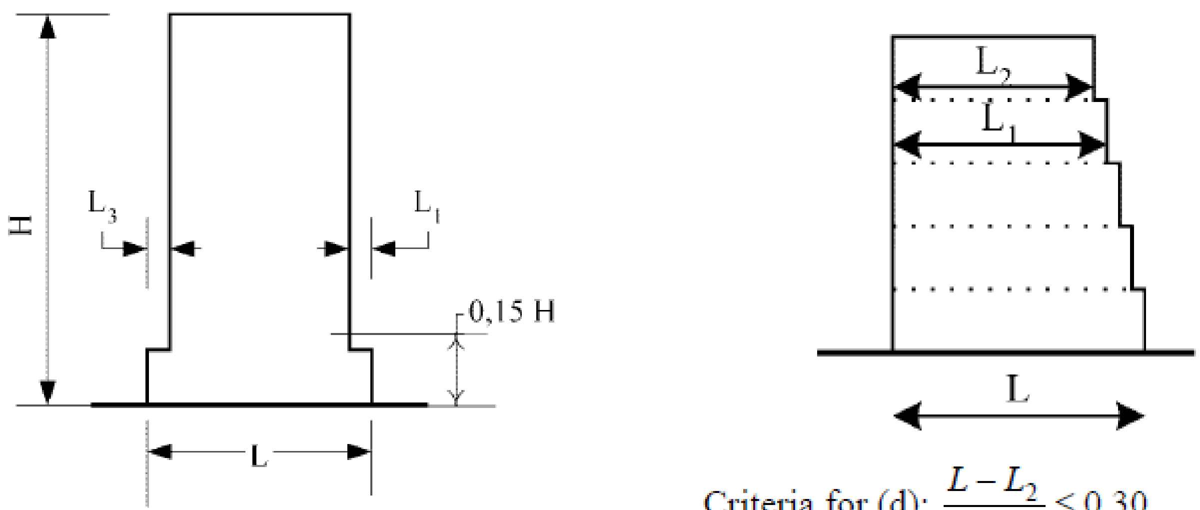
Criterion for (a): $\frac{L_1 - L_2}{L_1} \leq 0{,}20$

Criterion for (b): $\frac{L_3 + L_1}{L} \leq 0{,}20$

Regularity in elevation (continued)

(c) (setback occurs below 0,15H)

d)



Criterion for (c): $\frac{L_3 + L_1}{L} \leq 0{,}50$

Criteria for (d): $\frac{L - L_2}{L} \leq 0{,}30$

$$\frac{L_1 - L_2}{L_1} \leq 0{,}10$$

Figure 4.1: Criteria for regularity of buildings with setbacks

Further implications of non-regularity

- Strongly irregular arrangements of infills in plan should be avoided. In the case of severe irregularities in plan due to infills, spatial models including the infills should be used for the analysis. Unfavorable torsional response may occur caused by the infills and should be considered.
- In the case of irregularity in elevation (drastic reduction of infills – soft storey, large setbacks etc.) the seismic action forces in the vertical elements of the respective floor shall be increased by:

$$\eta = (1+\Delta V_{RW} / \Sigma V_{Ed}) \leq q \qquad (4.26)$$

if $\eta \leq 1.1$ no need for increase in action effects.

also, in multi-storey buildings and in cases of non-regularity in plan, formation of a soft storey plastic mechanism shall be prevented by,

$$\Sigma M_{RC} \geq 1.3 \Sigma M_{Rb} \qquad (4.29)$$

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