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Knowledge FOR Resilient soCiEtY

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CODE APPROACHES FOR SEISMIC DESIGN
OF PLAN IRREGULAR STRUCTURES

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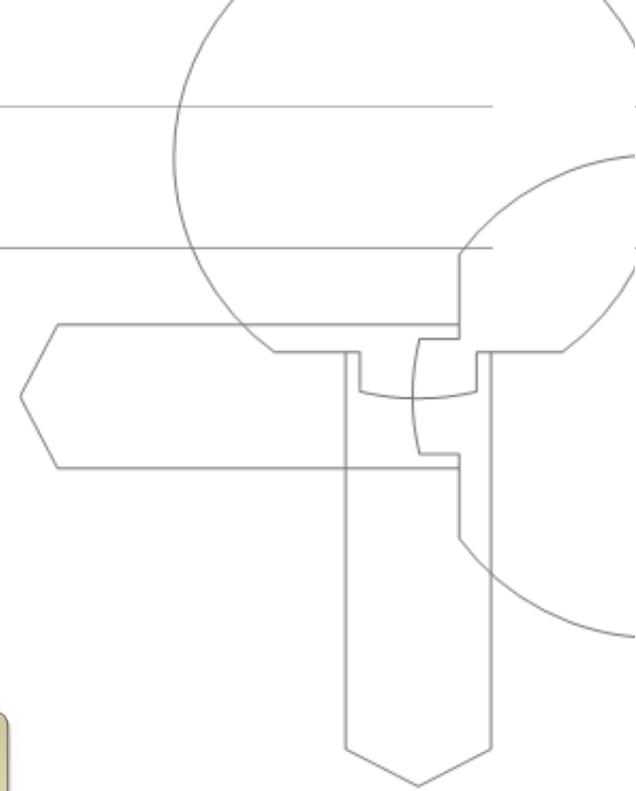
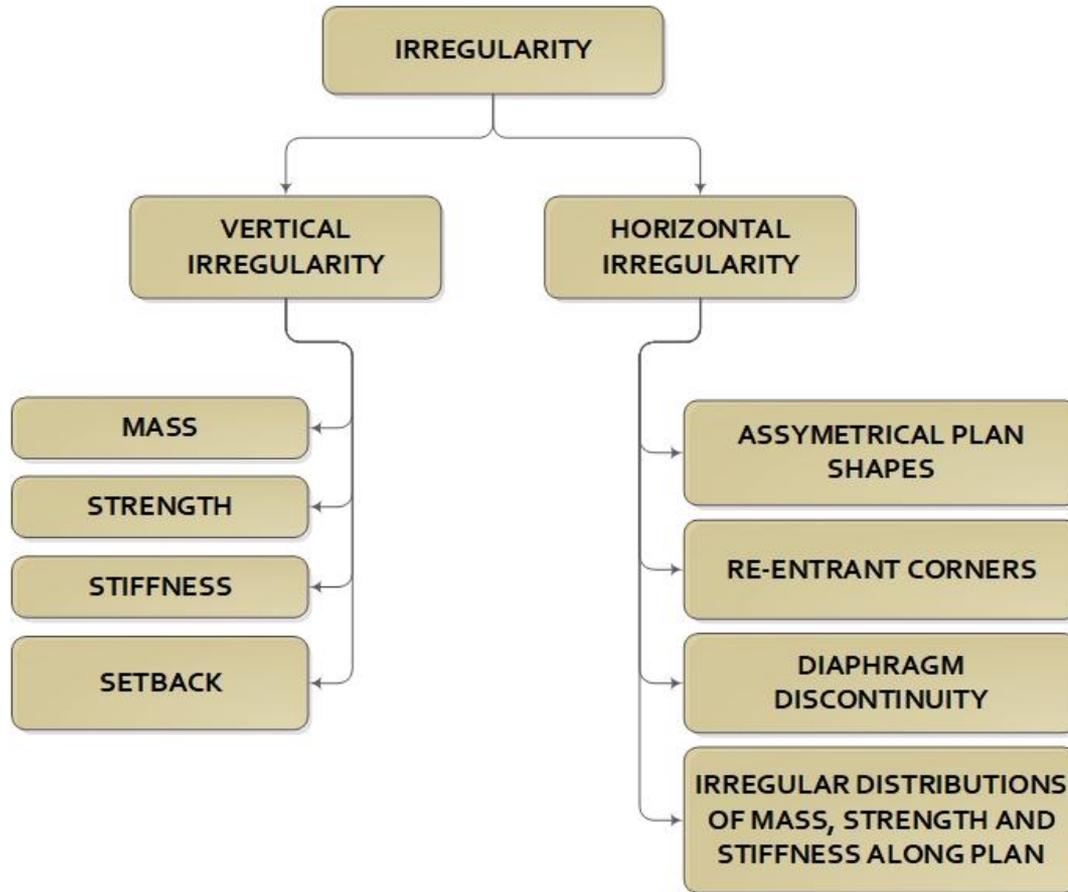


OUTLINE

- Structural Irregularities*
- Damages of Structures*
- Criteria for Plan Irregularity*
- Comparison of the Criteria for Plan Irregularity*
- Conclusion*



Structural Irregularities



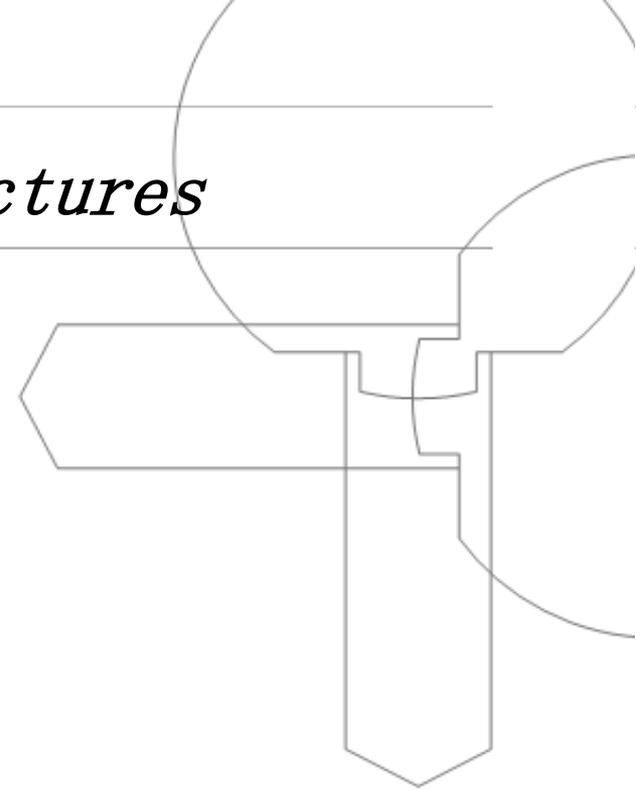
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Damages of Plan Irregular Structures



*Damage of three storey building during
1978 Mi-jagi-Ken-Oki earthquake*



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Damages of Plan Irregular Structures



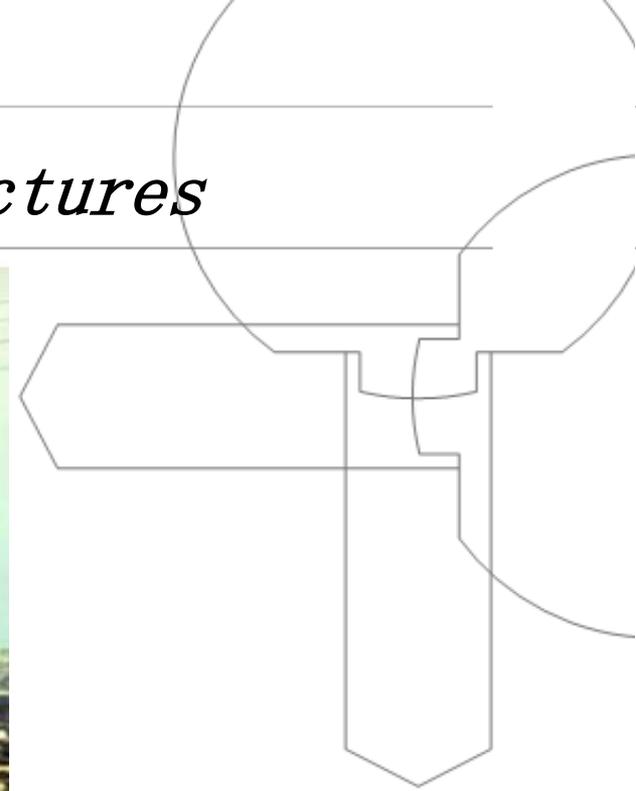
Collapse of a building due to torsional response, Athens (1999) earthquake



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Damages of Plan Irregular Structures



Damage due to irregularity during Guatemala earthquake 1976



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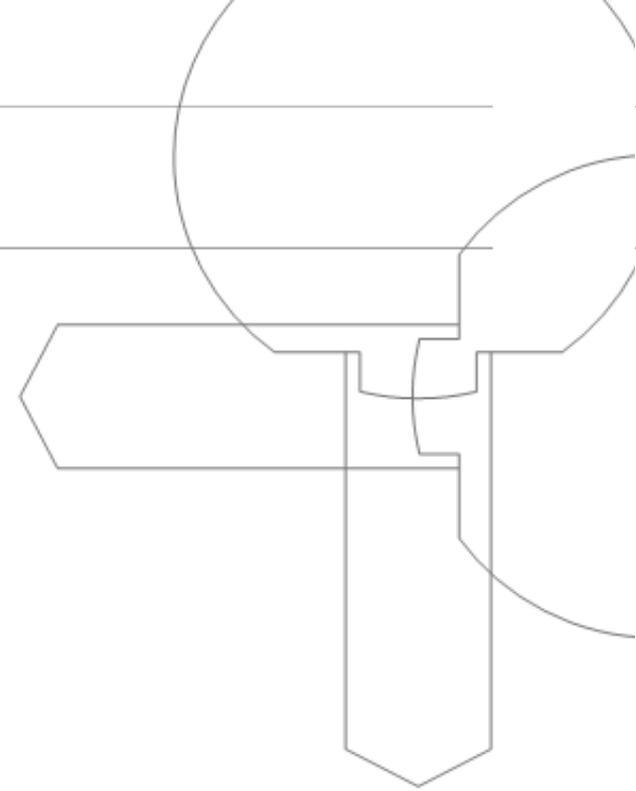
Criteria for Plan Irregularity

Macedonian Seismic Code

Irregularity in plan – no regulations

Recommendations:

-  *Correct and uniform solution in plan*
-  *With uniform mass distribution*
-  *Large structural load – center of mass as low as possible*



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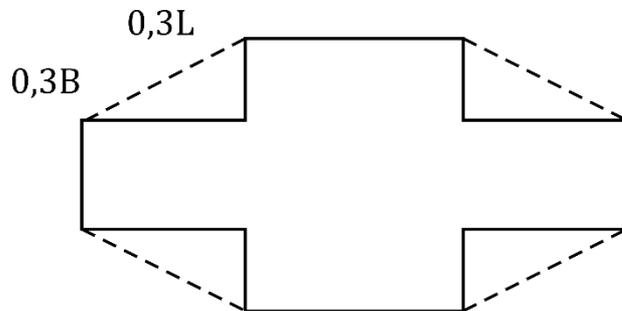
Criteria for Plan Irregularity

EN 1998 - 1

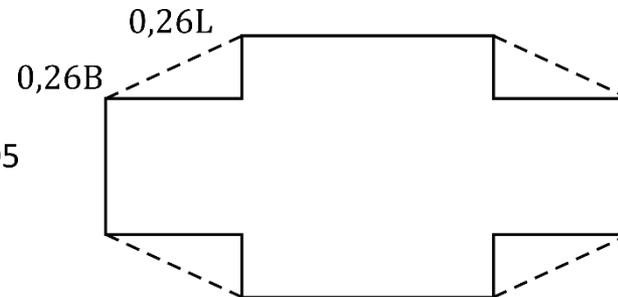
Six different conditions:

● Symmetrical distribution - lateral stiffness and mass

● The plan configuration shall be compact
(no setbacks or re-entrant corners)



$A_0/A_f = 0,07 > 0,05$
Irregular



$A_0/A_f = 0,046 < 0,05$
Regular



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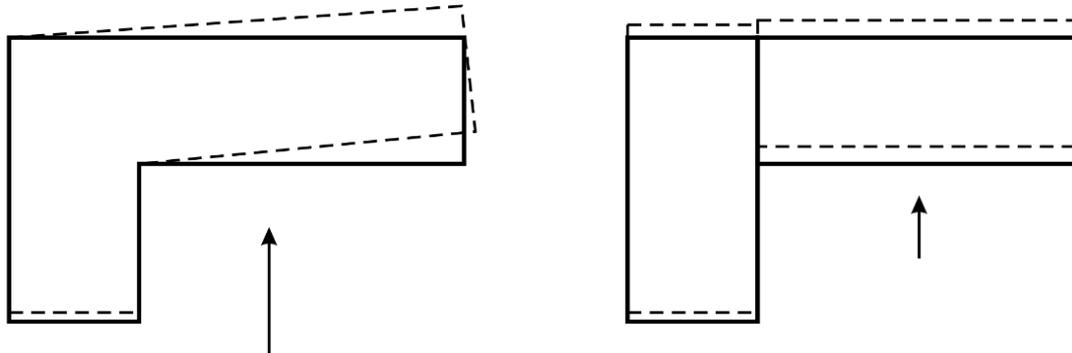


Criteria for Plan Irregularity

EN 1998 - 1

Six different conditions:

- Slenderness ratio - $\lambda = L_{\max} / L_{\min} \leq 4$
- Rigid diaphragms, large in-plane stiffness
(L, C, H, X and I shapes should be carefully examined)



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Criteria for Plan Irregularity

EN 1998 - 1

Six different conditions:



$$e_{x/y} \leq 0,3 \cdot r_{x/y}$$



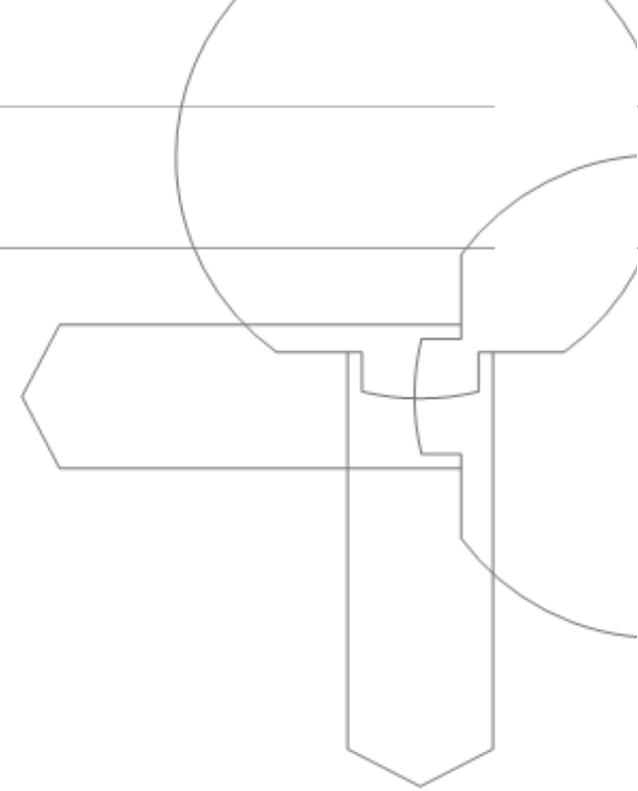
$$r_{x/y} \geq l_s$$

where:

$e_{x/y}$ - eccentricity between CM and CS

$r_{x/y}$ - torsional radius

l_s - radius of gyration

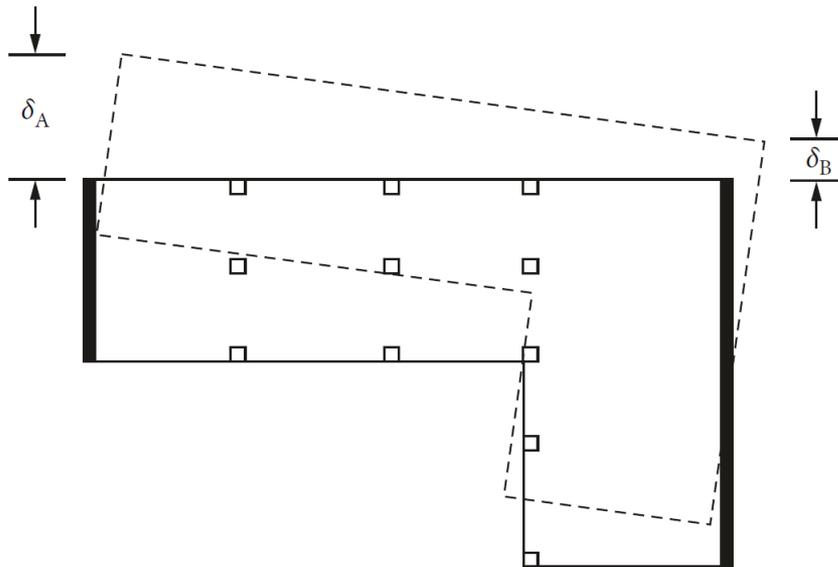


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Criteria for Plan Irregularity

ASCE-7.20; NZS 1170.5-2004; TEC 2007



$$\delta_{max} \leq 1,2 \cdot \delta_{avg}$$
$$\delta_{avg} = (\delta_A + \delta_B)/2$$

Displacement condition – torsional irregularity



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Criteria for Plan Irregularity

ASCE-7.20; NZS 1170.5-2004; TEC 2007

Conditions:

-  *Reentrant corner irregularity*
-  *Diaphragm discontinuity irregularity*
-  *Out of plane offset irregularity*
-  *Nonparallel system irregularity*

NZS 1170.5-2004 is the only provision that takes into account the horizontal offset of the columns in the moment frames structural systems and systems with structural walls



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Comparison of plan irregularity criteria

Type of irregularity	EC8 2004	ASCE-7.10	NZS 1170.5-2004	TEC 2007
Re-entrant corners	$R_i \leq 5\%$	$R_i \leq 15\%$	-	$R_i \leq 20\%$
Torsional irregularity	$r_x > 3.33 e_{ox}$ $r_y > 3.33 e_{oy}$ r_x u $r_y > l_s$	$d_{max} \leq 1.2 d_{avg}$ $d_{max} \leq 1.4 d_{avg}$	$d_{max} \leq 1.4 d_{avg}$	$d_{max} \leq 1.2 d_{avg}$
Diaphragm discontinuity	-	$O_a < 50\%$ $S_{dst} < 50\%$	-	$O_a < 33\%$
Horizontal offset of the columns in moment frame structural systems and in systems with structural walls	-	-	$\sum a_j/b_j > 0.1 N_c$ $a_j/b_j > 0.4$	-

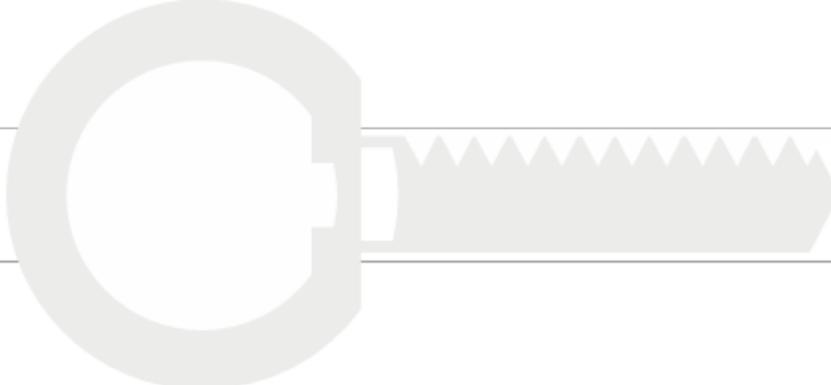
Where:

R_i – re-entrant corners, d_{max} – maximum drift at particular storey level, d_{avg} – average drift at particular storey level, O_a – open area in diaphragm, S_{dst} – diaphragm stiffness, a_j – horizontal drift of the column j, b_j – vertical distance between the base of the upper column and the top of the lower column, N_c – sum of the columns at particular storey level



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Conclusion

The criteria for irregularity of the structure in plan, has important role in the design of seismic resistant structures

The registered damages, from previous earthquakes, it has been noted that the structures with irregularity in plan are significantly more vulnerable than the regular structures. This justify the need of provisions that shall regulate the irregularity in plan.

Although the Eurocode 8 has established criteria for plan irregularity, based on geometric parameters, center of stiffness and torsional radius, it has no defined methodology for their determination. This can lead to some difficulties in its practical implementation. The other codes (ASCE 7-10, NZS 1170.5-2007 and TEC 2007) can determine the plan irregularity during the analysis of the structure.





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