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# A Detailed Seismic Performance Assessment Procedure for RC Structures

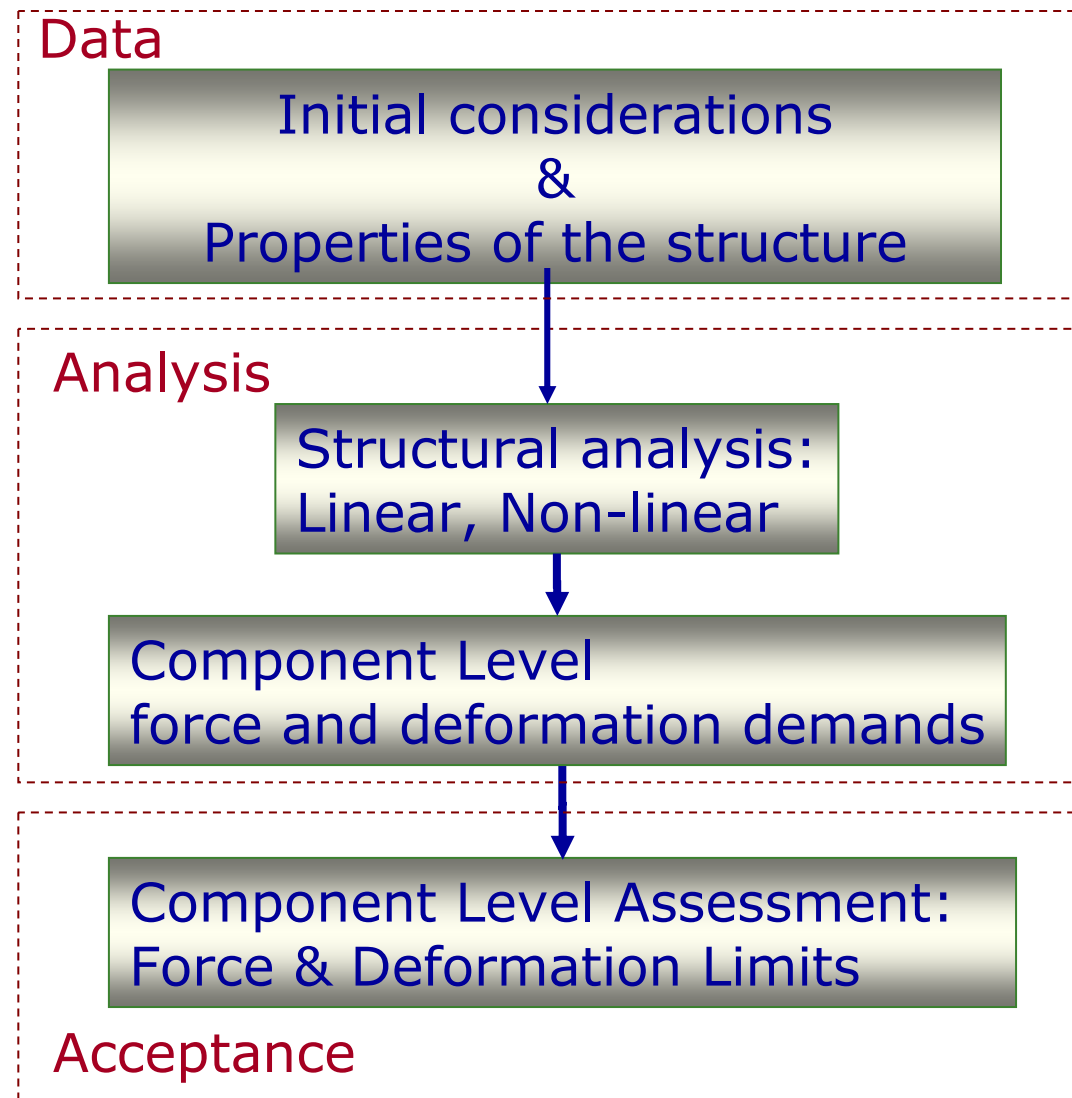
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# Seismic Performance Assessment



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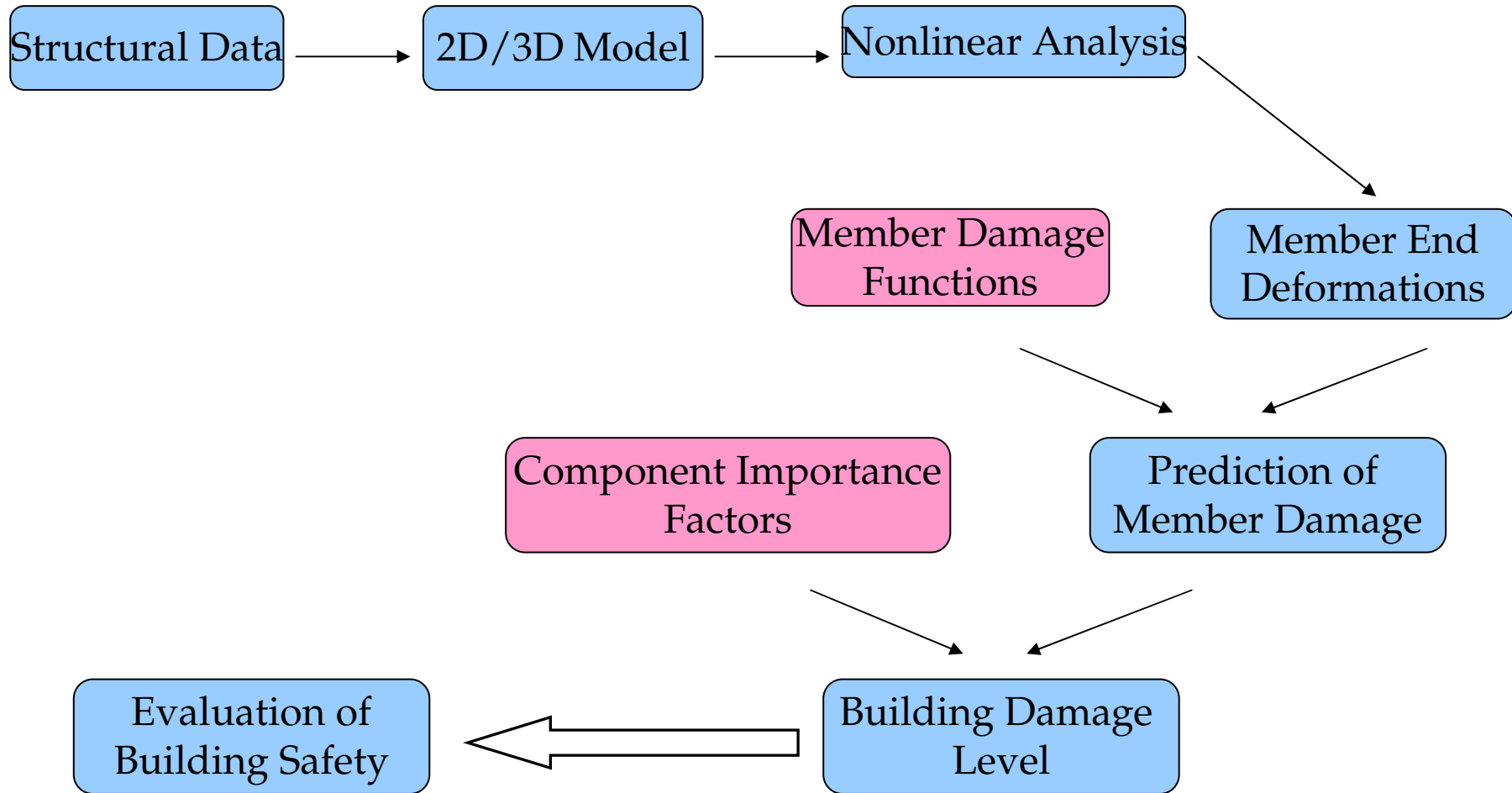
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## FEMA, ATC and Eurocode

- n Major drawback: No connection between component evaluations and global performance
- n Only component based assessment is performed

# Outline of the Proposed Procedure



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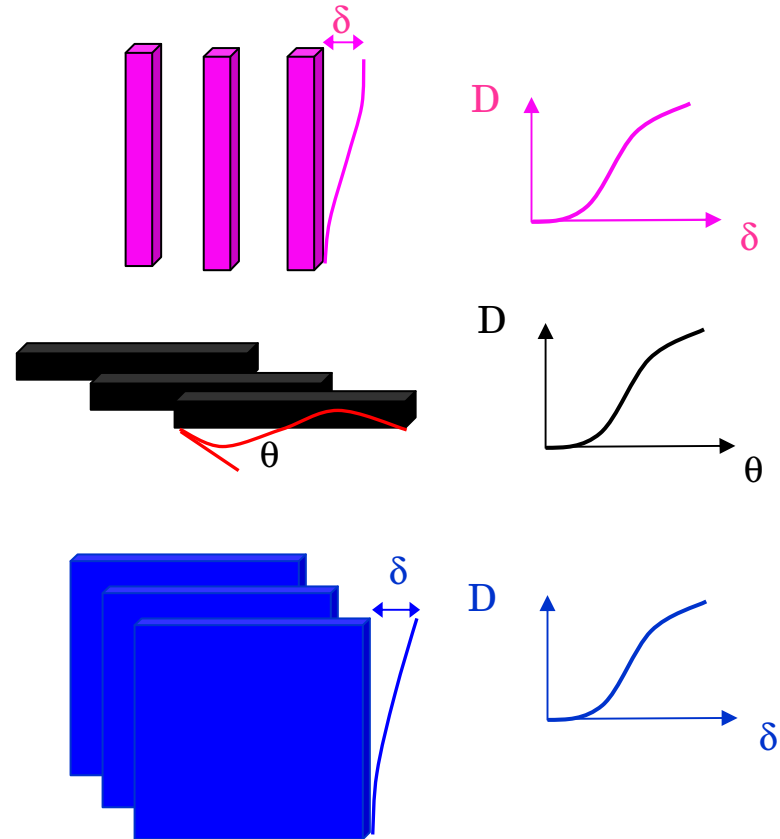
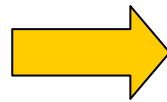
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# Component Damage Functions

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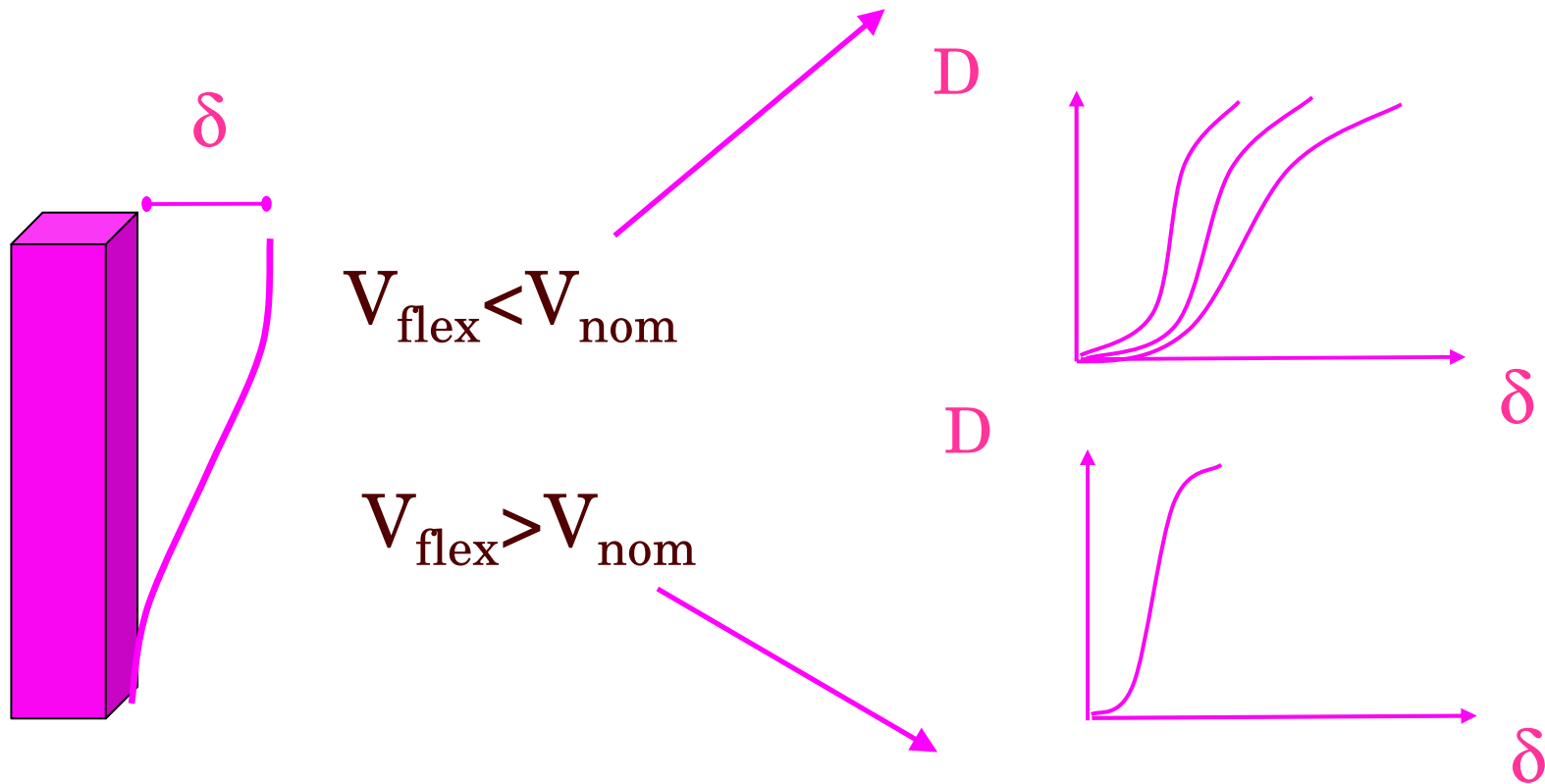
# Component Damage Functions



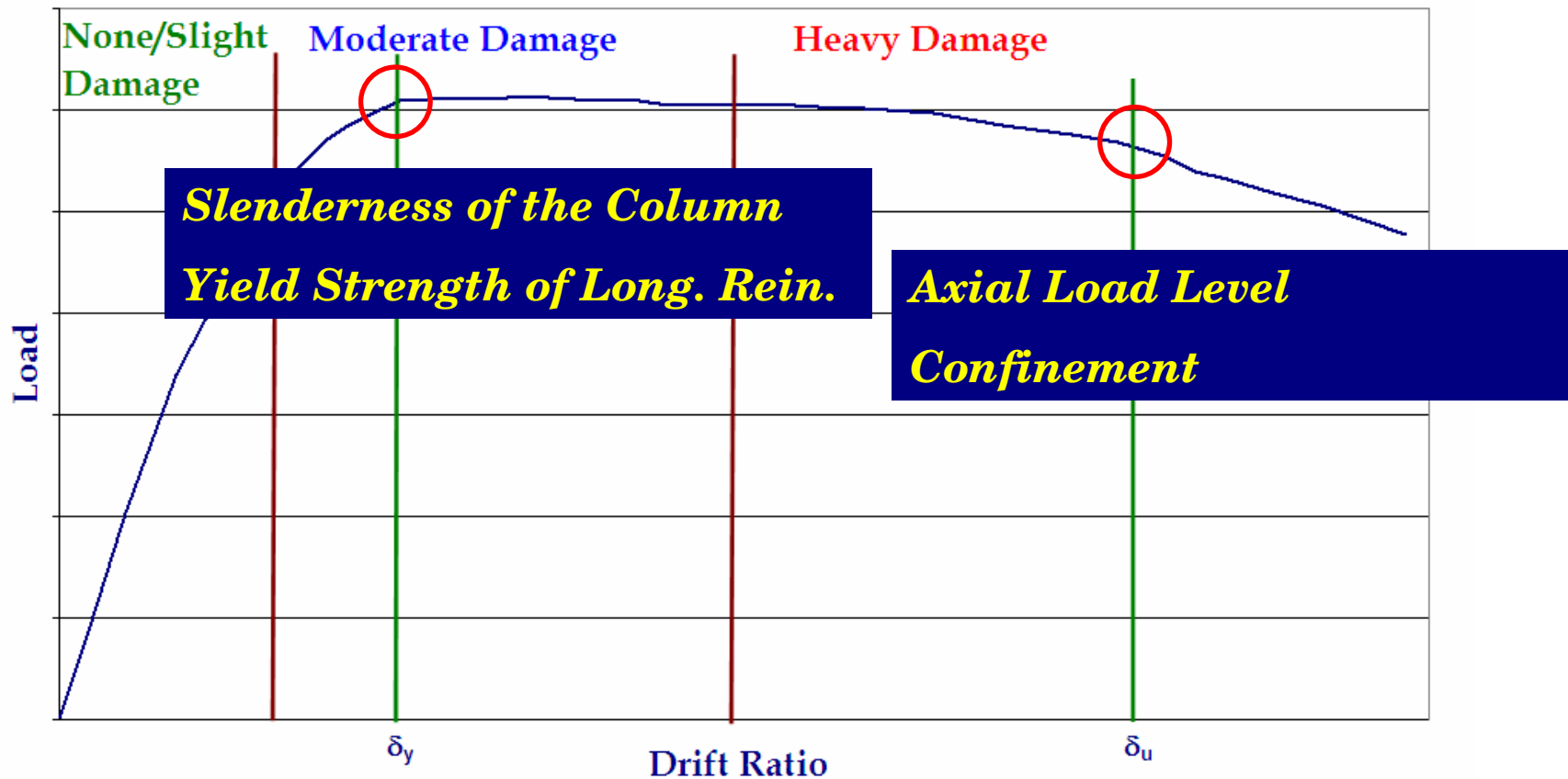
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# Damage Functions for RC Columns



# Damage Functions for RC Columns



# Damage Functions for RC Columns

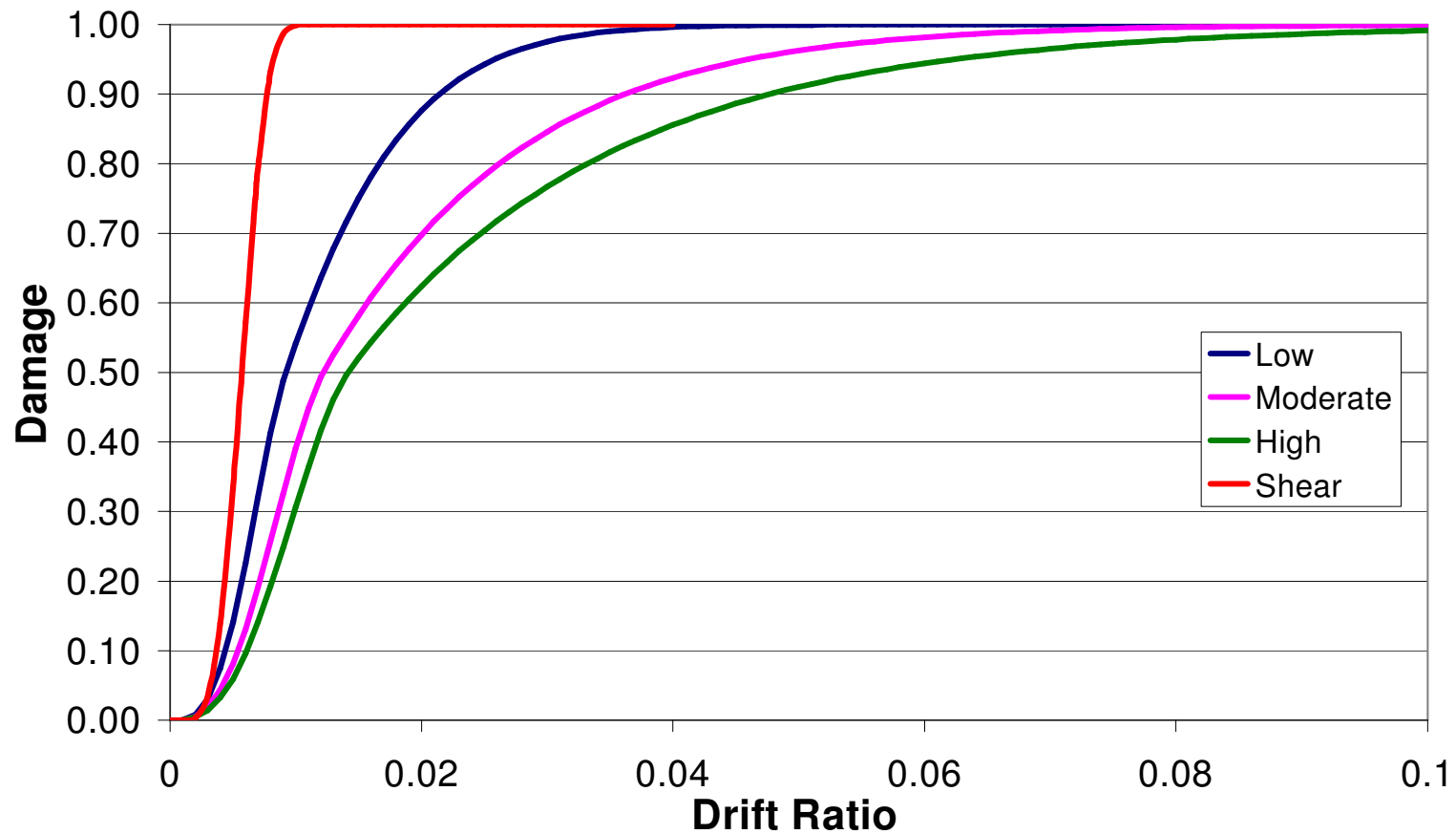
n The columns analyzed are grouped into three according to their  $\rho_s / (N/N_o)$  values:

q  $\rho_s / (N/N_o) \leq 0.05$  Low Ductility

q  $0.05 < \rho_s / (N/N_o) \leq 0.10$  Moderate Ductility

q  $\rho_s / (N/N_o) > 0.10$  High Ductility

# Damage Functions for RC Columns



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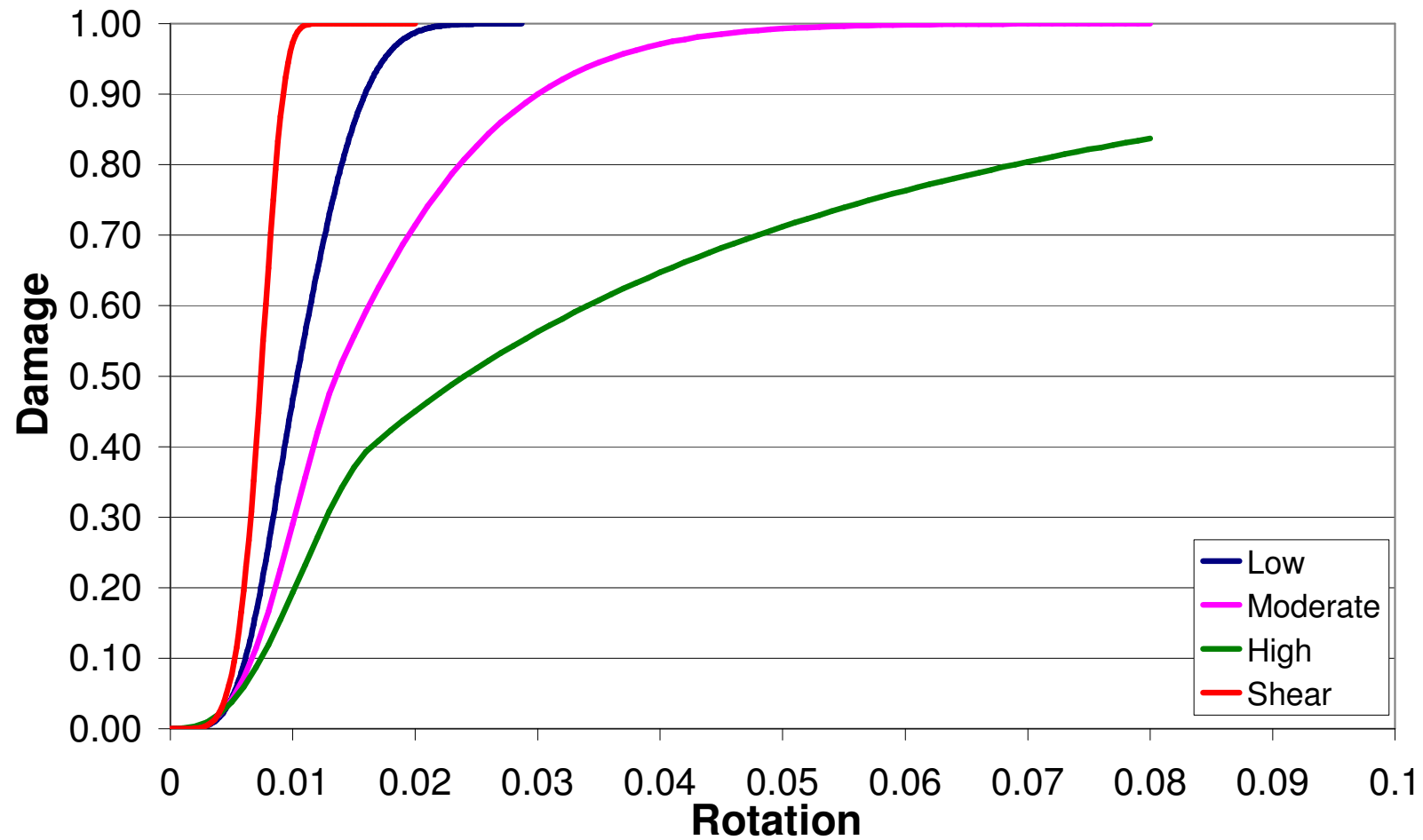
# Damage Functions for RC Beams

$$\rho_s \frac{f_{ck}(\rho' / \rho)}{f_{yk} \rho} < 0.25\% \quad \text{Low Ductility}$$

$$0.25\% < \rho_s \frac{f_{ck}(\rho' / \rho)}{f_{yk} \rho} \leq 1\% \quad \text{Moderate Ductility}$$

$$\rho_s \frac{f_{ck}(\rho' / \rho)}{f_{yk} \rho} > 1\% \quad \text{High Ductility}$$

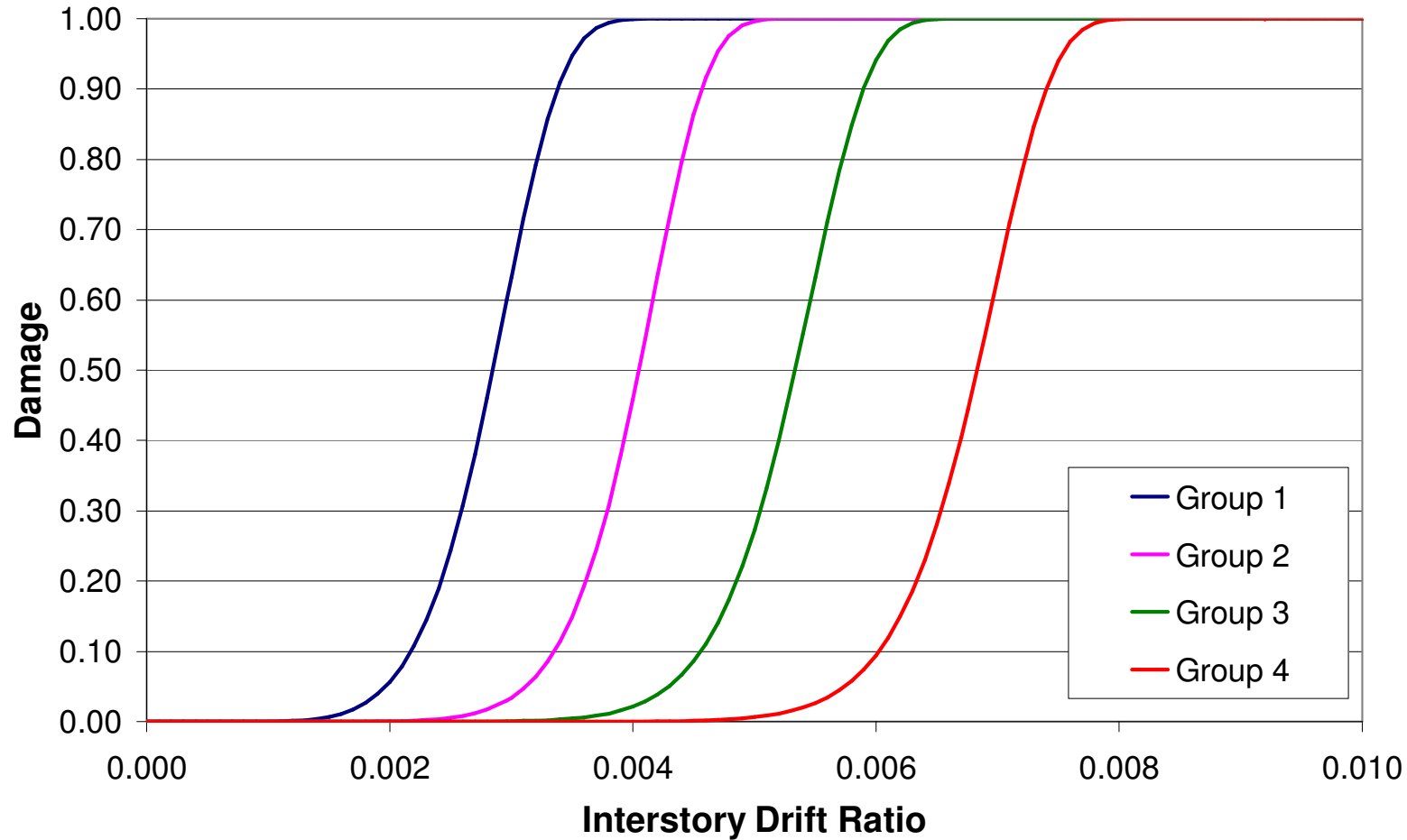
# Damage functions for beams



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# Damage Functions for Infills



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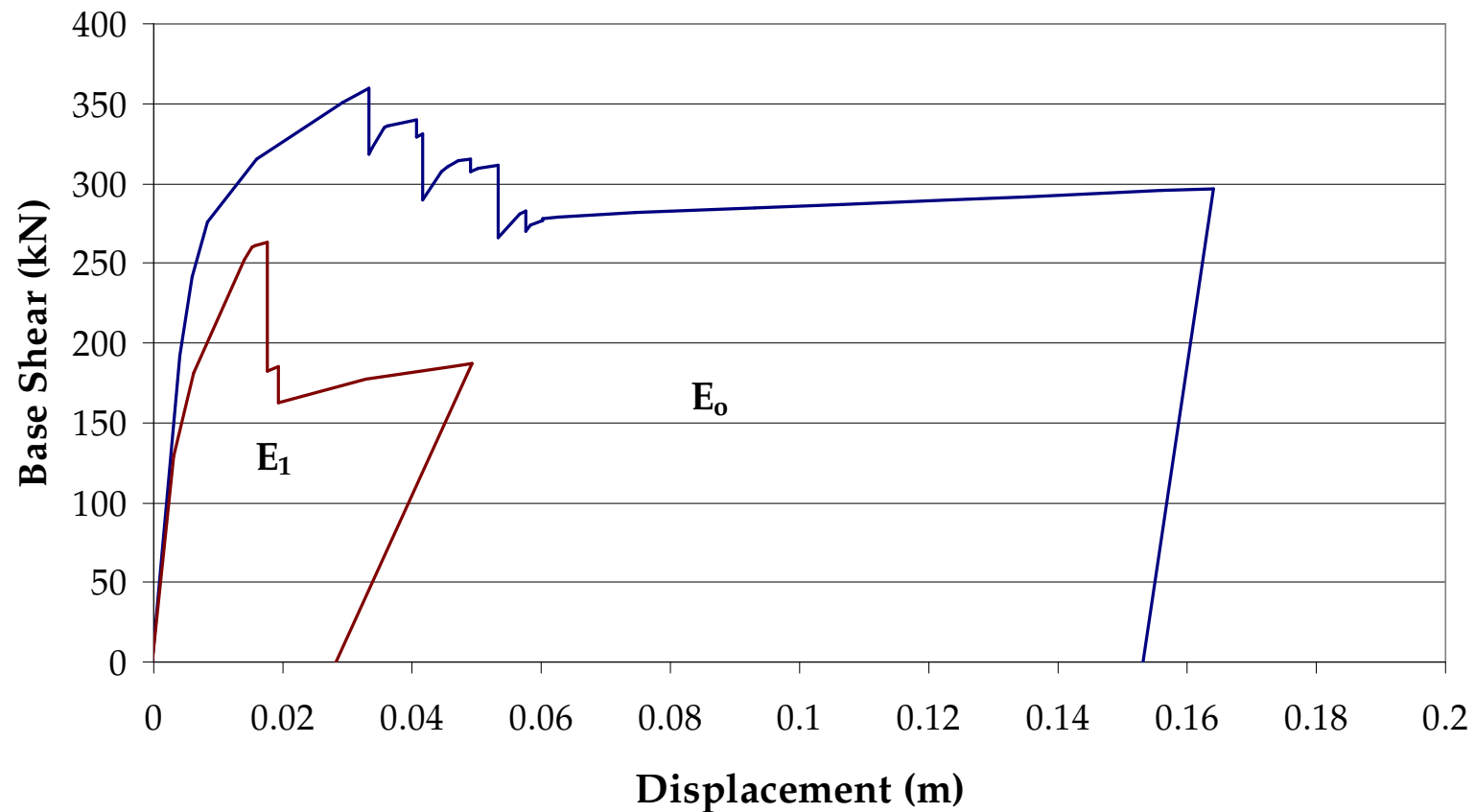
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# Component Importance Factors

	20% (M)	8% (L)	51% (S)	
	11% (M) 45% (M)	5% (L) 30% (M)	1% (L) 61% (S)	39% (S)
	16% (M) 59% (S)	18% (M) 45% (S)		
	22% (M) 70% (S)	25% (M) 65% (S)		
	22% (M) 75% (S)	25% (M) 72% (S)	11% (M) 85% (S)	60% (S)
	25% (M)	32% (M)	15% (M)	65% (S)

What is the damage score (performance level) of this building?

# Component Importance Factors



# Component Importance Factors

$$IF_j = \frac{E_0 / E_j}{\sum_i^{3n} E_0 / E_j}$$

$j$  represents the damage case corresponding to the component of interest and  $n$  is the number of stories.

- $n$  The importance factors computed using this procedure are not for a single member. Instead, they reflect the importance of all the members of the same component type in a single story.

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# Performance Evaluation of Buildings

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# Building Damage Score and Building Performance

- Story damage scores are multiplied by the normalized story importance factors and summed .

Damage Score (%)	Performance
0.0 – 10.0	None/Light Damage
10.0 – 50.0	Moderate Damage
50.0 – 100.0	Severe Damage / Collapse

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# Application to Zeytinburnu

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# Ground Motion

- n The elastic response spectrum proposed by NEHRP (2000) was used to represent a ground motion with a probability of exceedence of 50% in 50 years.
- n  $S_{DS}$  and  $S_{D1}$  values were taken from the study carried out by Bosphorus University
- n Displacement Coefficient Method of FEMA-356 was used to compute the performance point of the building under the given spectrum

# Building Summary\_1

Building ID	Plan Area (m <sup>2</sup> )	# of Stories	$f_{ck}$ (MPa)	$f_{yk}$ (MPa)
BLD 1	165	6	27	420
BLD 2	100	4	9	220
BLD 3	70	5	16	220
BLD 4	98	5	8	220
BLD 5	80	5	10	220

## Building Summary\_2

Building ID	Plan Area (m <sup>2</sup> )	# of Stories	$f_{ck}$ (MPa)	$f_{yk}$ (MPa)
BLD 6	91	4	15	220
BLD 7	147	5	11	220
BLD 8	269	3	16	420
BLD 9	83	6	13	220
BLD 10	145	4	15	220

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# Building 4

n Plan Area= 98 m<sup>2</sup>

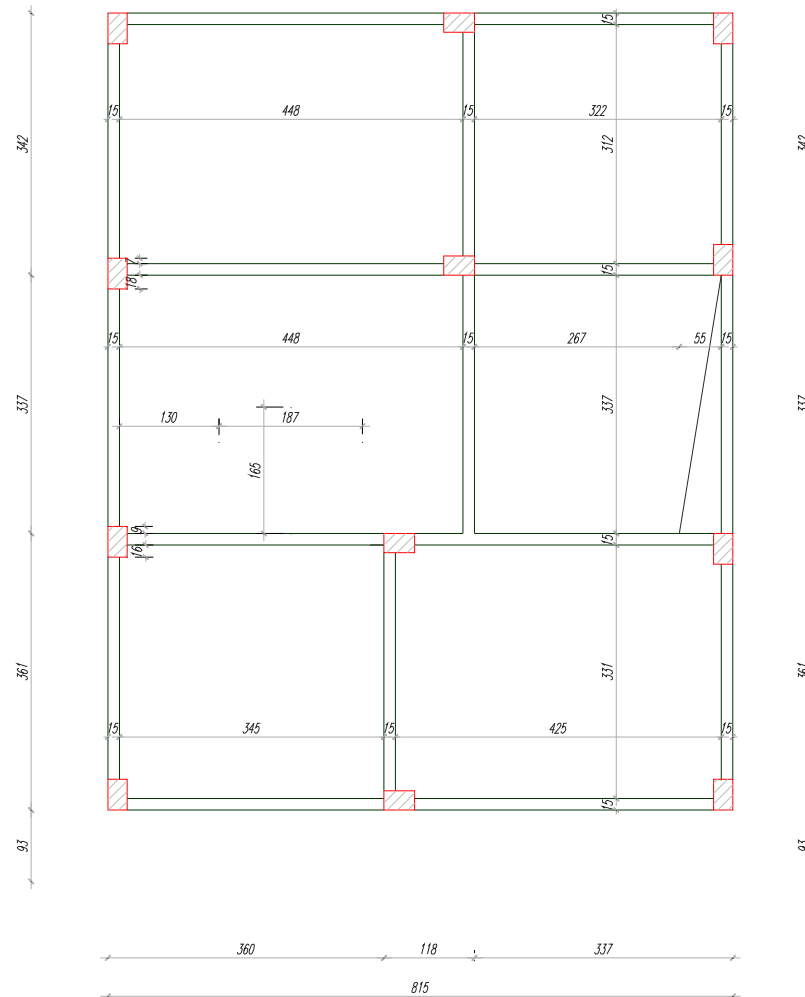
n Number of Stories: 5

n  $f_{ck} = 8$  MPa

n  $f_{yk} = 220$  MPa

n  $S_{DS} = 0.729g$  and  $S_{D1} = 0.432g$

# Plan View

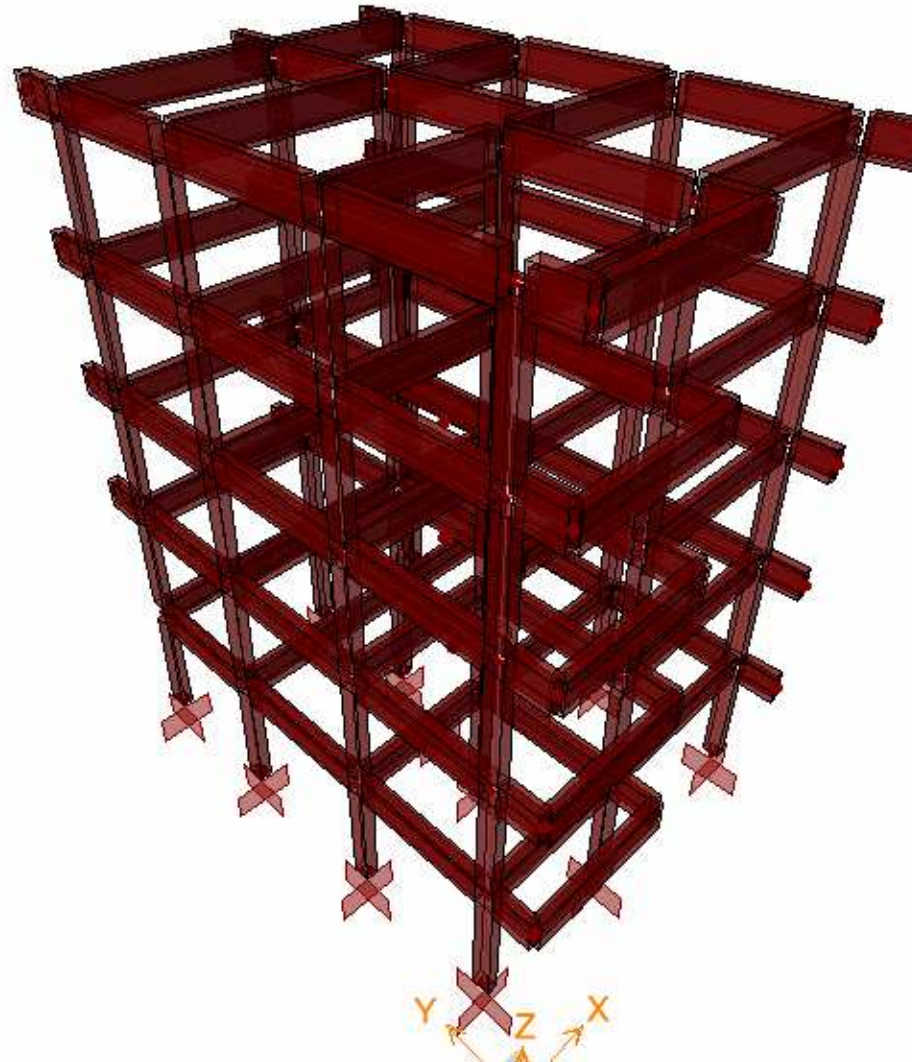


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# Computer Model

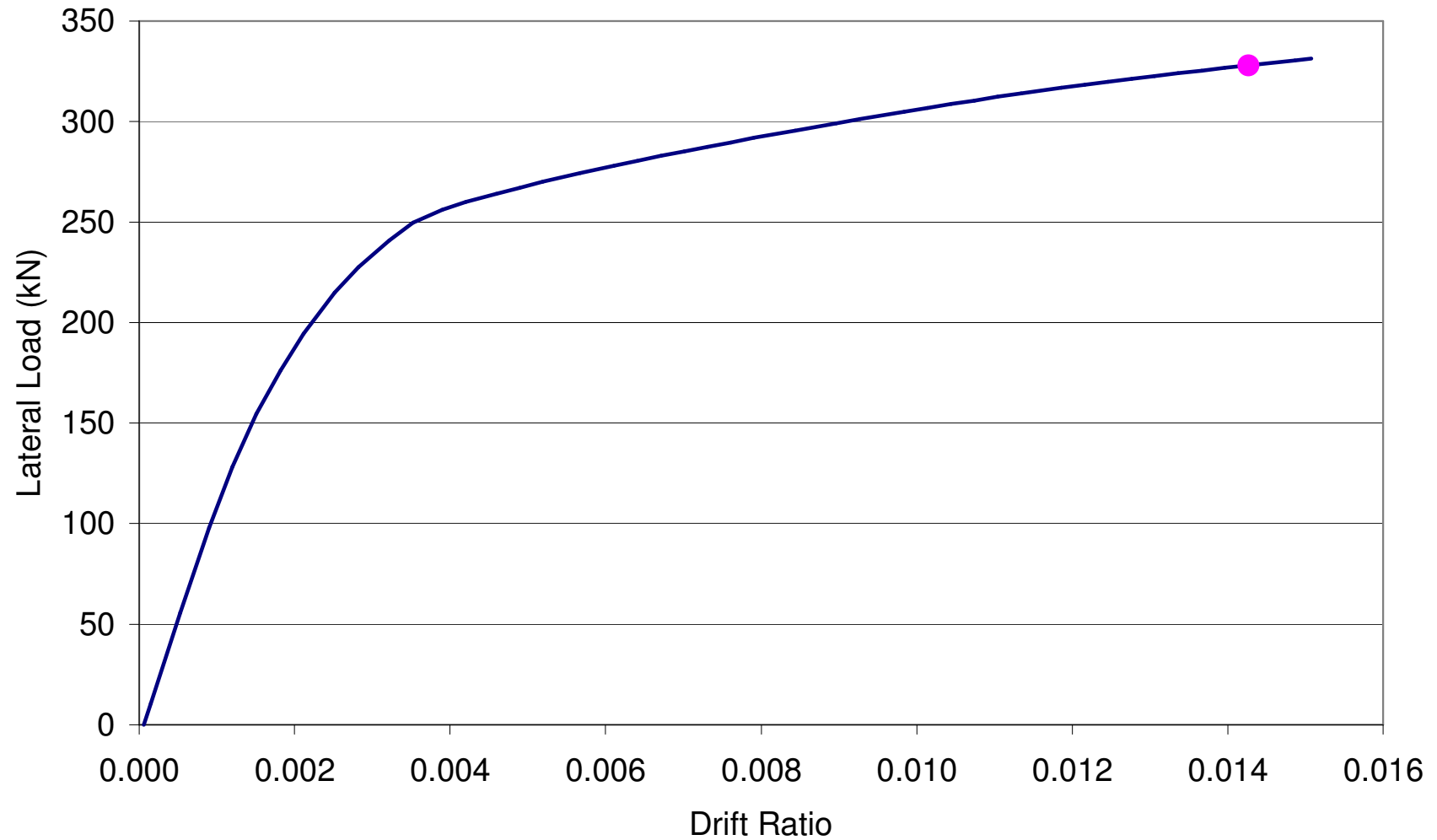


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# Capacity Curve



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# Damage in 1<sup>st</sup> Story Columns

Column ID	b (mm)	h (mm)	Corrected Drift Ratio	Damage (%)
C101	400	250	1.67E-02	80.01
C102	250	400	2.67E-02	95.70
C103	400	250	1.67E-02	80.10
C104	400	250	1.66E-02	79.92
C105	250	400	2.66E-02	95.63
C106	400	250	1.66E-02	79.92
C107	400	250	1.65E-02	79.72
C108	250	400	2.65E-02	95.55
C109	400	250	1.65E-02	79.72
C110	400	250	1.65E-02	79.55
C111	250	400	2.64E-02	95.47
C112	400	250	1.65E-02	79.55

# Building Damage Score

Story	Story IF	Story Damage	Weighted Story Damage
1	0.35	90.05	31.86
2	0.28	20.01	5.57
3	0.21	17.71	3.65
4	0.14	11.70	1.58
5	0.03	0.87	0.02
Building Damage Score			42.67

# Assessment Results

BLD ID	T (sec)	$V_y/W$	$\delta_y$ (%)	$V_u/W$	$\delta_u$ (%)	$\delta_t$ (%)	Max Story Damage (%)	Building Damage core (%)	Perfor.
BLD1	0.627	0.32	0.14	0.49	1.32	0.58	10.85	<b>5.60</b>	<b>IO</b>
BLD2	0.644	0.11	0.17	0.13	1.24	0.94	28.22	<b>26.06</b>	<b>LS</b>
BLD3	0.921	0.06	0.19	0.07	1.29	1.01	54.20	<b>25.16</b>	<b>LS</b>
BLD4	1.430	0.04	0.25	0.06	1.51	1.51	<b>90.05</b>	<b>42.67</b>	<b>CP</b>
BLD5	0.996	0.03	0.13	0.04	1.24	1.24	<b>77.12</b>	<b>40.88</b>	<b>CP</b>
BLD6	0.672	0.10	0.23	0.11	1.85	1.75	<b>88.41</b>	<b>52.16</b>	<b>CP</b>
BLD7	0.798	0.09	0.14	0.13	1.28	0.95	63.09	<b>28.77</b>	<b>LS</b>
BLD8	0.519	0.25	0.34	0.29	1.68	0.85	33.71	<b>19.27</b>	<b>LS</b>
BLD9	1.340	0.05	0.29	0.08	2.02	1.36	68.49	<b>31.99</b>	<b>LS</b>
BLD10	0.792	0.11	0.15	0.13	1.04	1.03	<b>71.86</b>	<b>46.01</b>	<b>CP</b>

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# Conclusions

- n The procedure developed for reinforced concrete frames with masonry in-fill walls provides an objective way to assess the performance of an individual building.
- n The decision regarding the expected future performance of an existing building is quite challenging and it is believed that this procedure provides a tool not for only reliable performance assessment but also for performance based design of reinforced concrete buildings with infill walls.