

# Performance Based Seismic Design

- Design for the achievement of specified results rather than adherence to prescribed means.
- Key elements of the implementation of PBSD:
  - definition of seismic design actions for multiple design levels
  - formats that are closely related to the structural and non-structural damage, that the PBSD framework specifically aims to control

# Performance Based Seismic Design

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP SYNTHESIS 440

Performance-Based Seismic Bridge Design

*A Synthesis of Highway Practice*

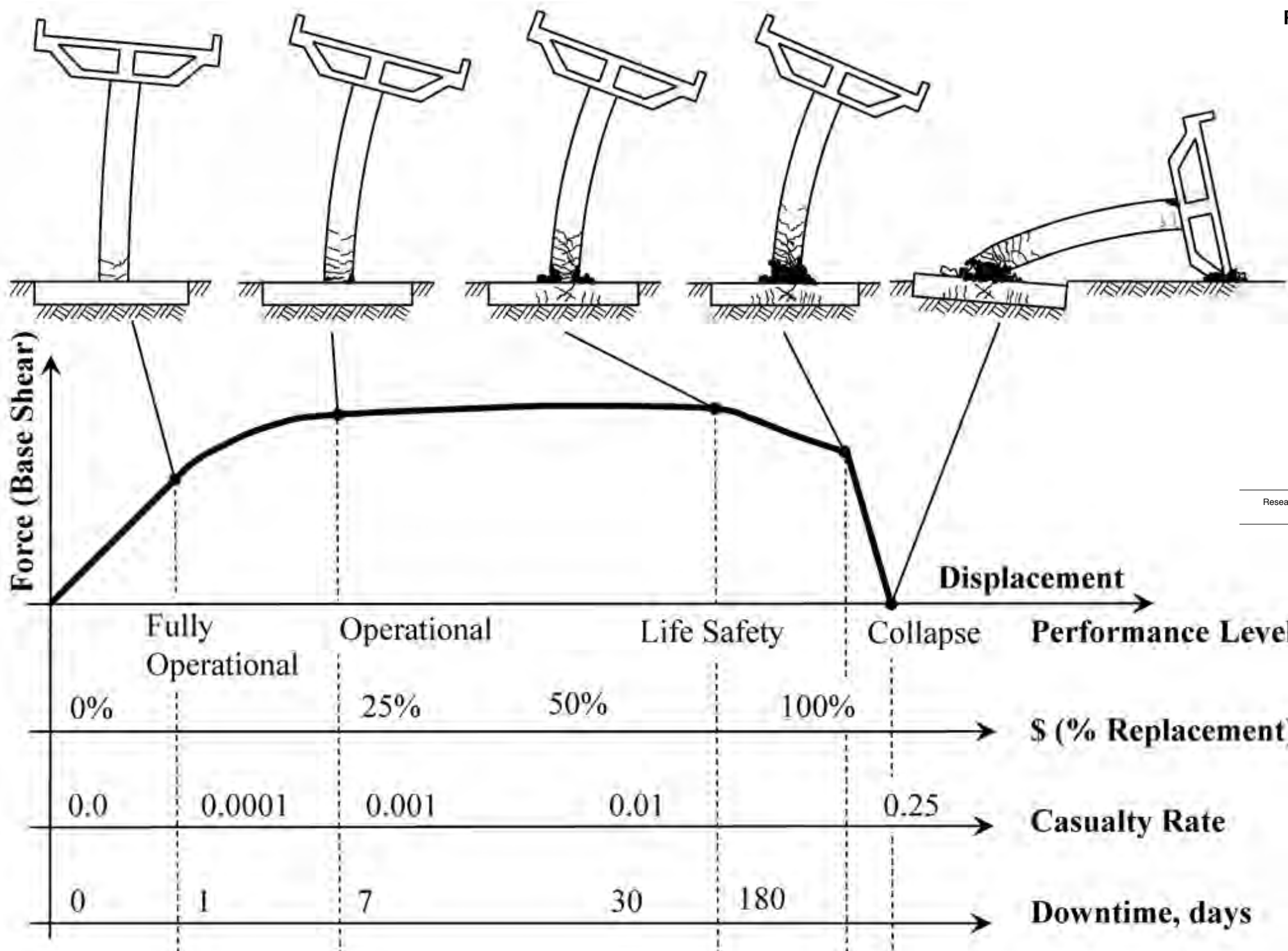
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in Cooperation with the Federal Highway Administration

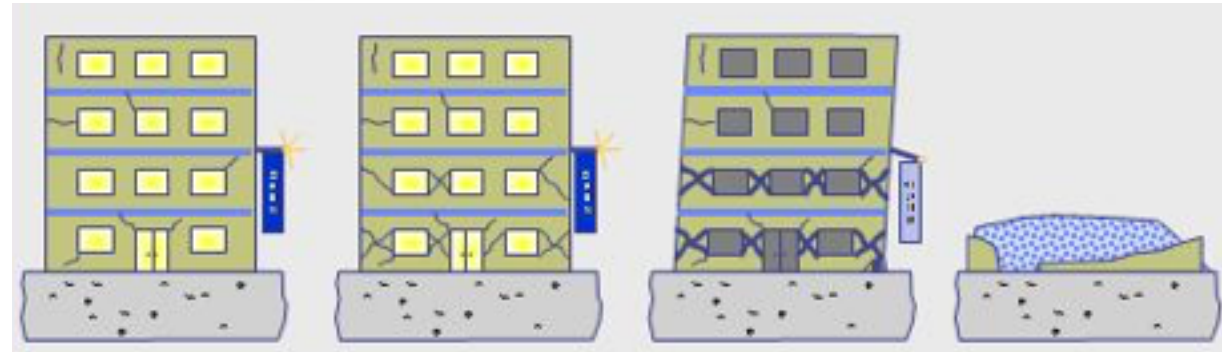
TRANSPORTATION RESEARCH BOARD

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www.TRB.org



# Earthquake Performance Level

OL	Operational Limit
IO	Immediate Occupancy
LS	Life Safety
CP	Collapse Prevention



## Structural Performance Level

Earthquake Hazard Level		Structural Performance Level			
		OL	IO	LS	CP
Earthquake Hazard Level	Frequent $P_{EY} = 50\%/50 \text{ year}$	●			
	Occasional $P_{EY} = 20\%/50 \text{ year}$	●	●		
	Rare $P_{EY} = 10\%/50 \text{ year}$	●	●	●	
	Very Rare $P_{EY} = 2\%/50 \text{ year}$		●	●	●

Ordinary Buildings

Essential Buildings

Hazardous Buildings

# PBD in Italy

- Stati Limite Ultimi (SLU)
- Stato limite di salvaguardia della vita (SLV)
- Stato limite di prevenzione del collasso (SLC)
- Stati Limite Esercizio (SLE)
- Stato Limite di operatività (SLO)
- Stato limite di danno (SLD)

[https://it.wikipedia.org/wiki/Stato\\_limite](https://it.wikipedia.org/wiki/Stato_limite)

# Italian building code (NTC08)

## ● Seismic classification

<http://www.protezionecivile.gov.it/jcms/it/classificazione.wp>

## ● Seismic hazard

<http://zonesismiche.mi.ingv.it>

<http://esse1.mi.ingv.it>

## ● Seismic code (§ 2.\*; 3.2; 7.\*)

<http://www.cslp.it/cslp/index.php>

[http://www.cslp.it/cslp/index.php?option=com\\_content&task=view&id=66&Itemid=1](http://www.cslp.it/cslp/index.php?option=com_content&task=view&id=66&Itemid=1)

[http://cslp.mit.gov.it/index.php?option=com\\_content&task=view&id=79&Itemid=20](http://cslp.mit.gov.it/index.php?option=com_content&task=view&id=79&Itemid=20)

# Fragility function

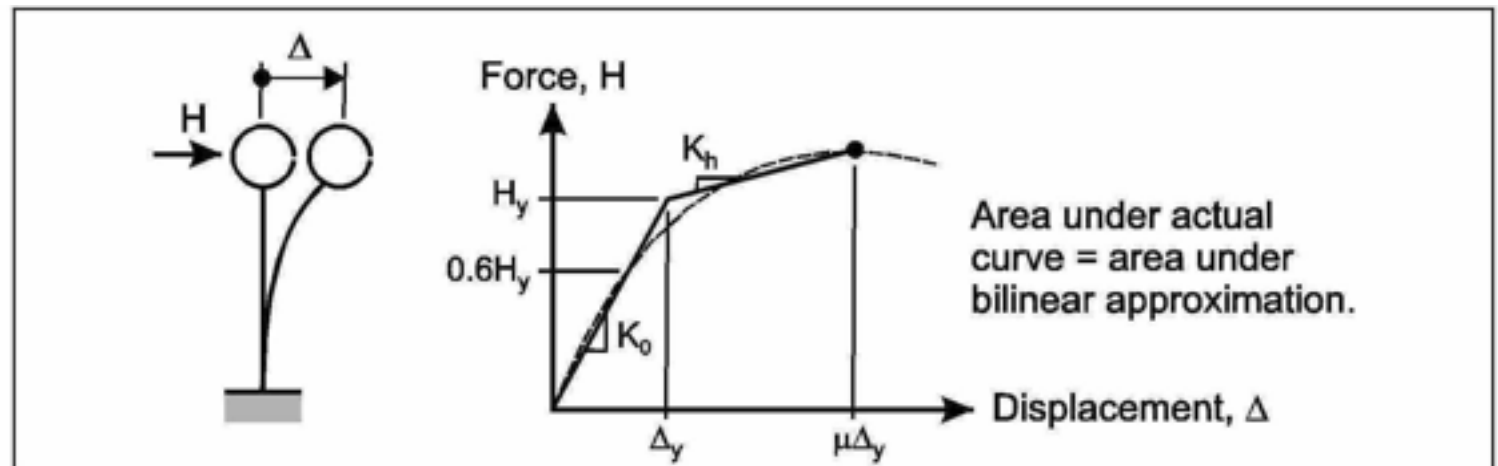
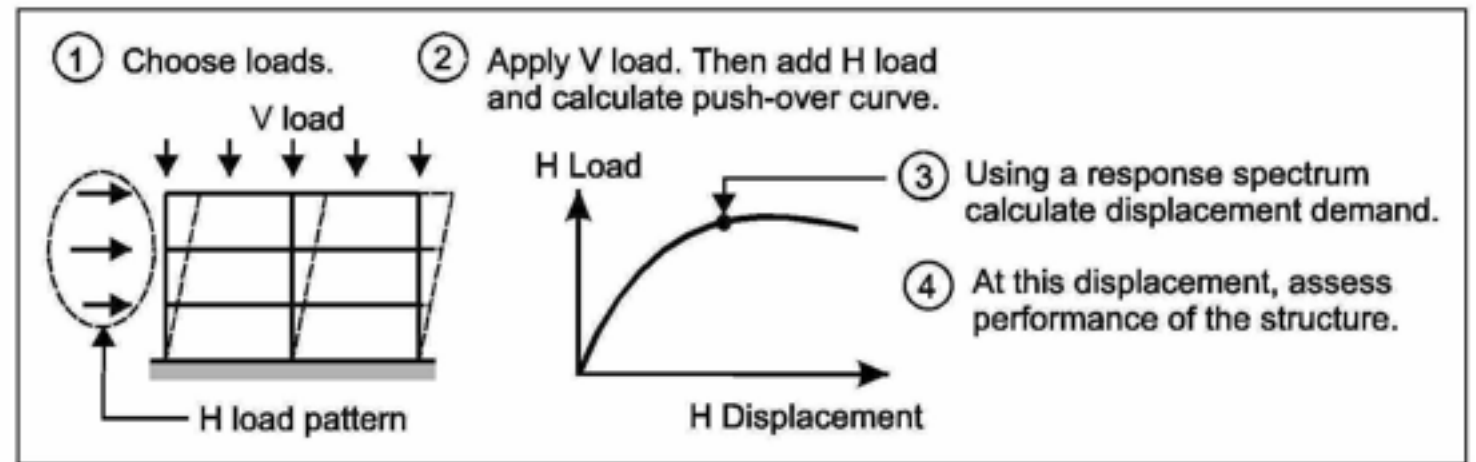
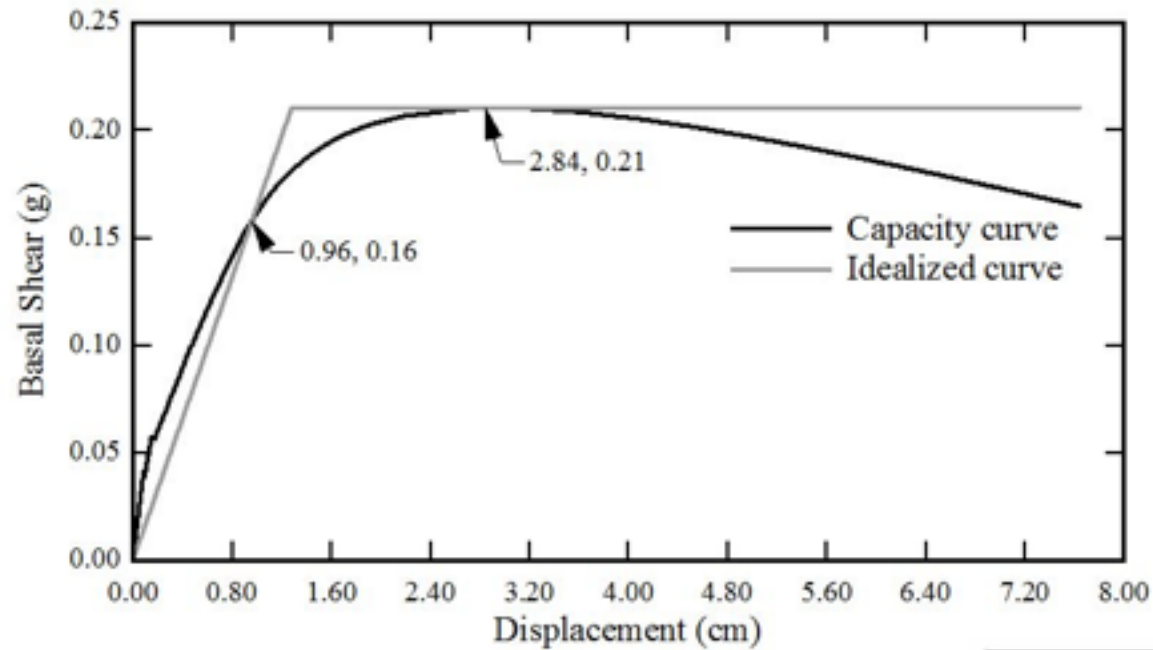
- A mathematical function that expresses the probability that some undesirable event occurs (typically that an asset reaches or exceeds some clearly defined limit state) as a function of some measure of environmental excitation (typically a measure of acceleration, deformation, or force in an earthquake).
- Represents the cumulative distribution function of the capacity of an asset to resist an undesirable limit state

# Fragility and capacity

- Capacity is measured in terms of the degree of environment excitation at which the asset exceeds the undesirable limit state.
- For example, a fragility function could express the uncertain level of shaking that a building can tolerate before it collapses.
- The chance that it collapses at a given level of shaking is the same as the probability that its strength is less than that level of shaking.

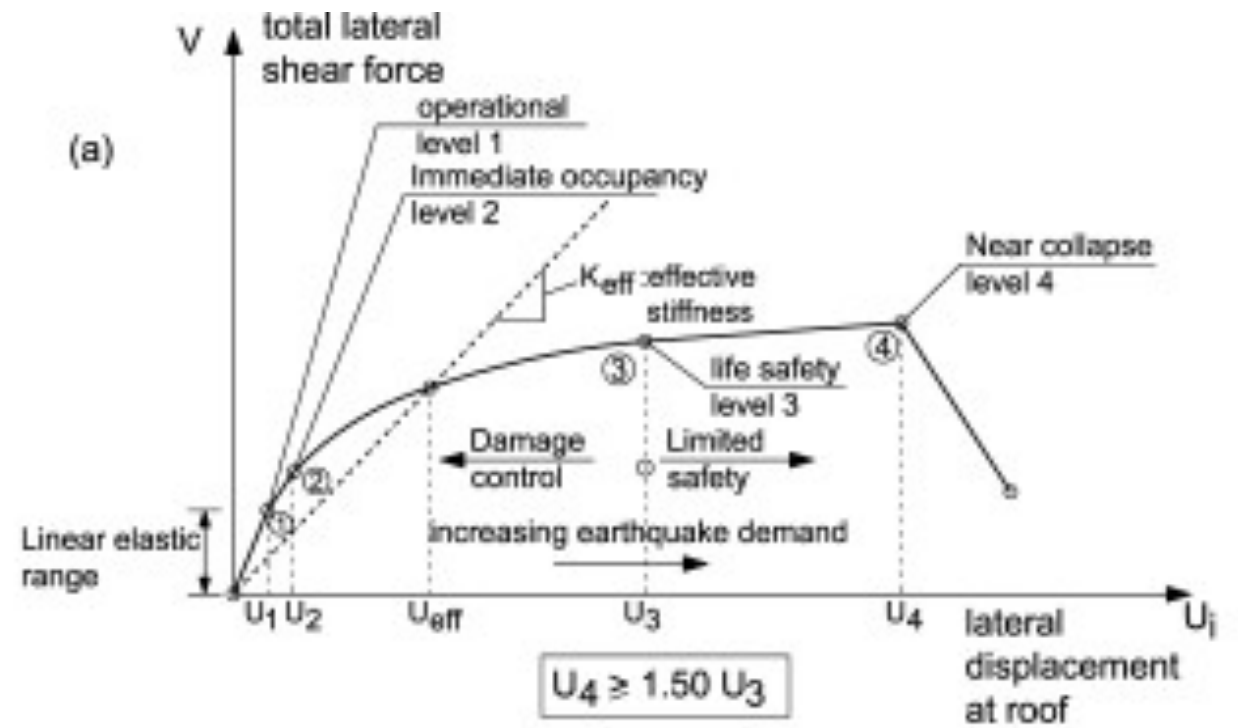
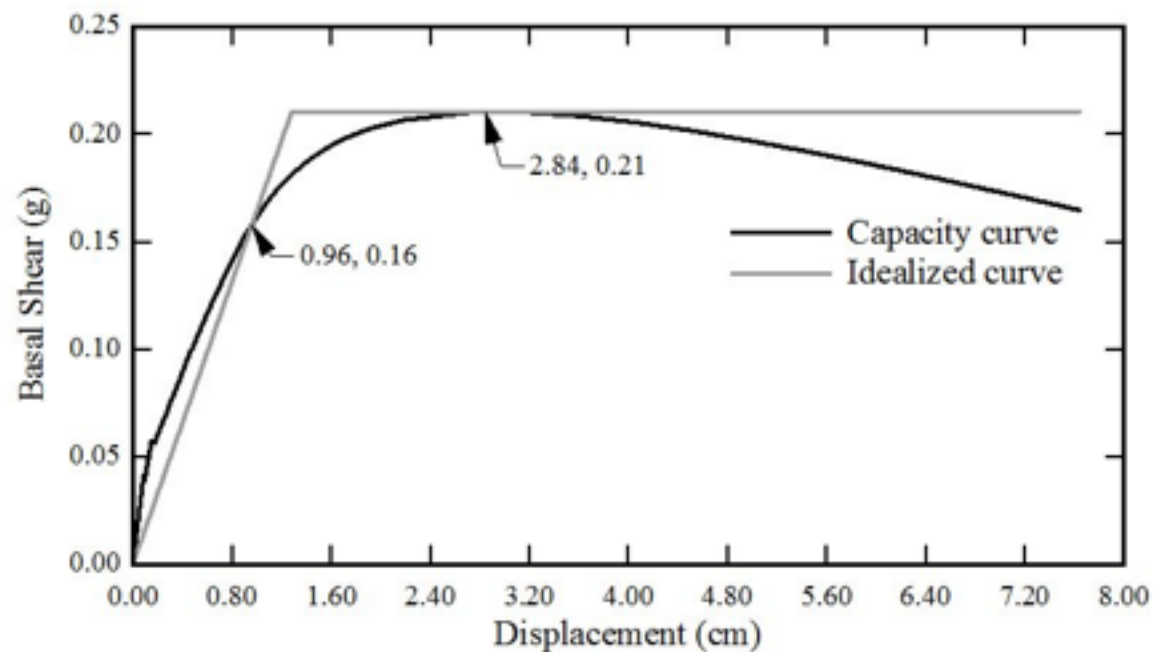


# Pushover curve

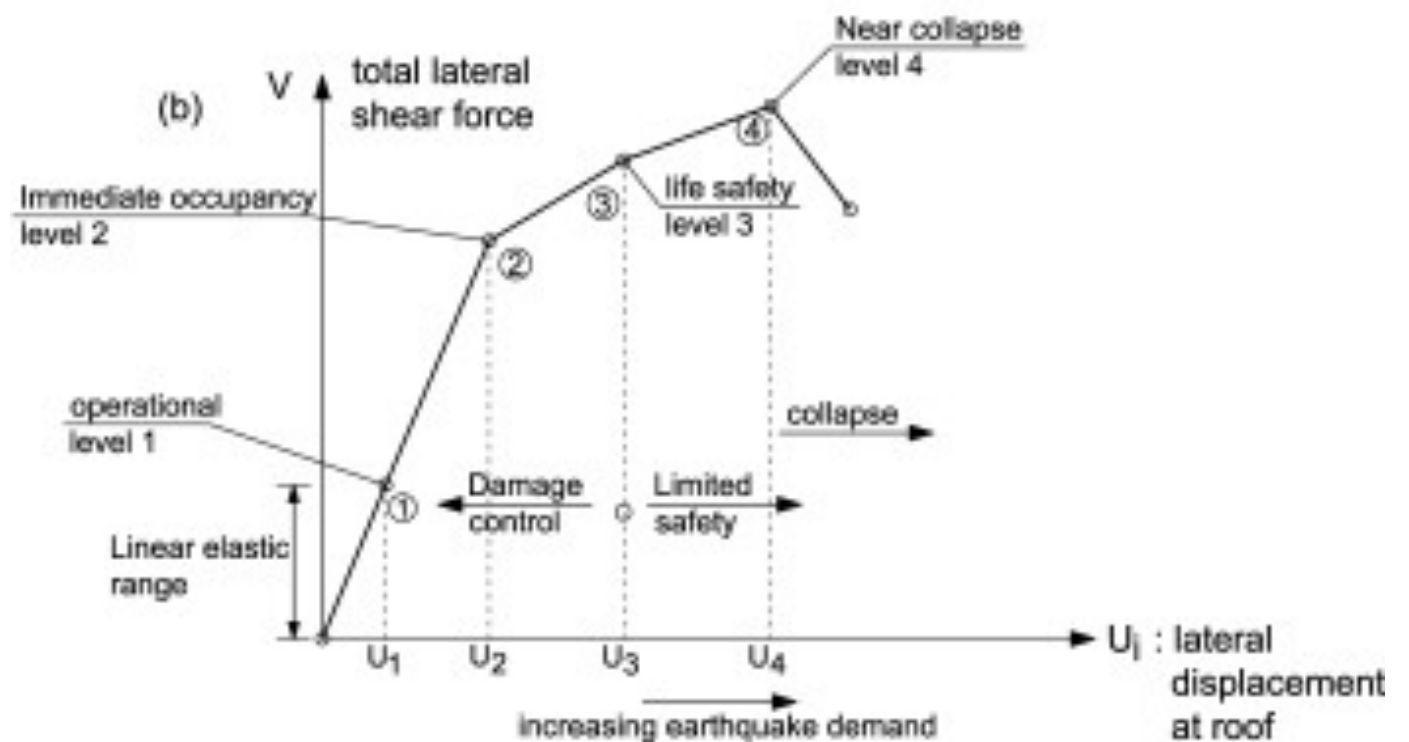
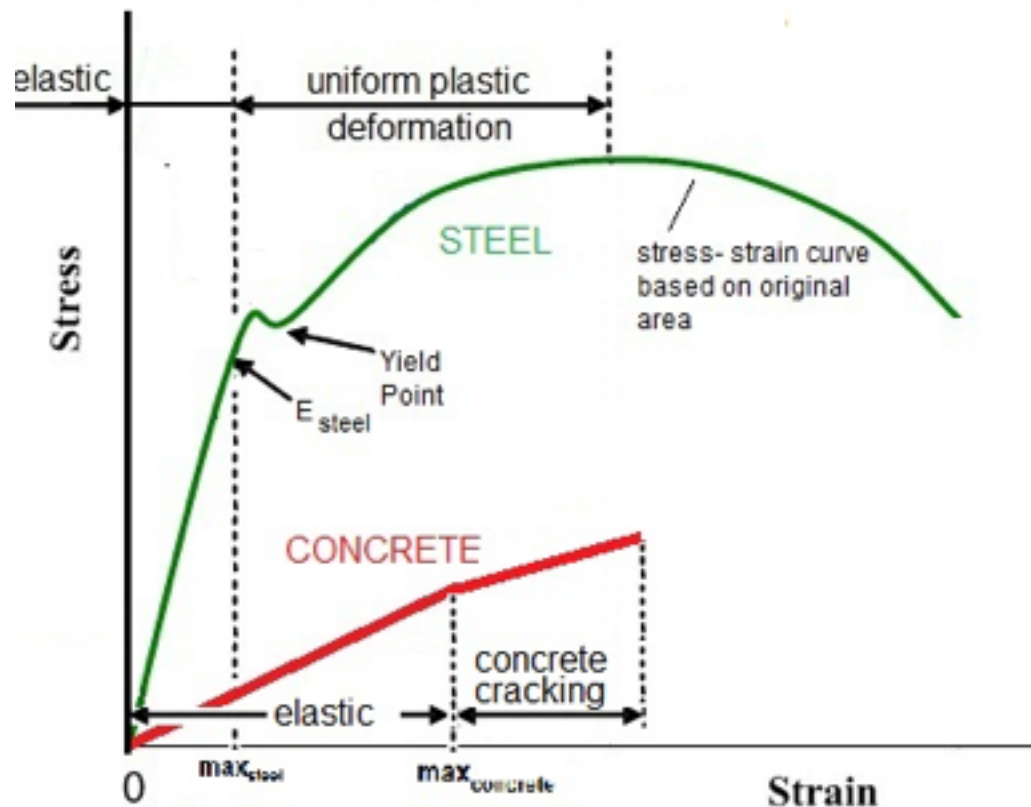




# Pushover curve



## Stress-strain diagram for steel and concrete



# Capacity spectrum

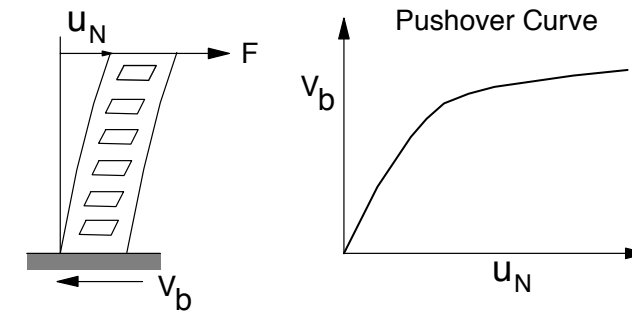
Capacity spectrum method:

(a) development of pushover curve

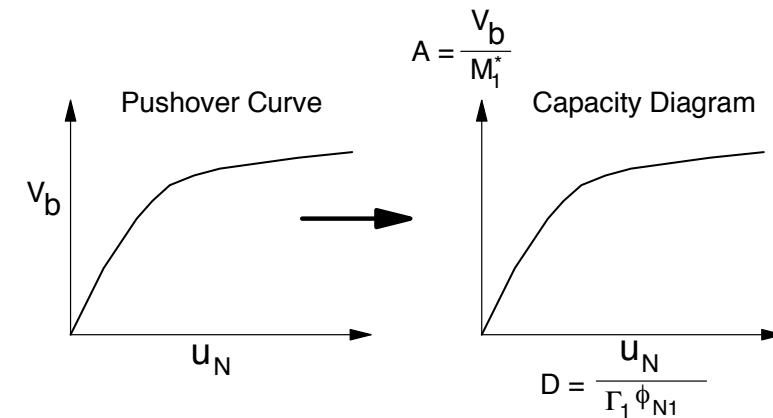
(b) conversion of pushover curve to capacity diagram

(c) conversion of elastic response spectrum from standard format to A-D format

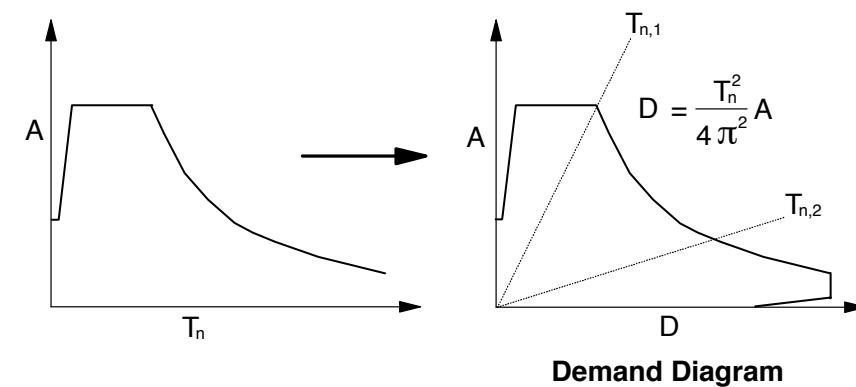
(d) determination of displacement demand.



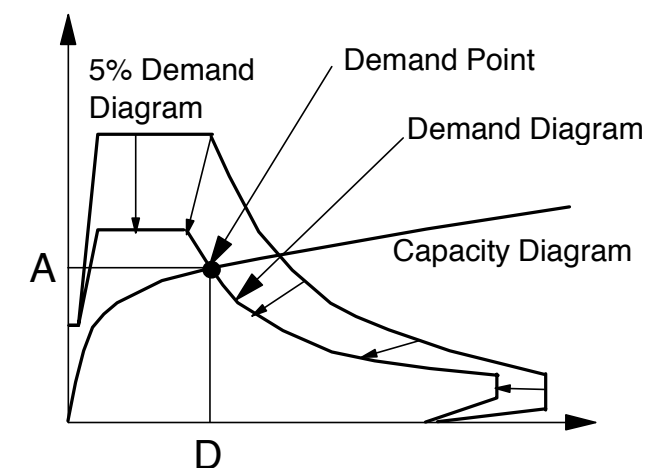
(a)



(b)

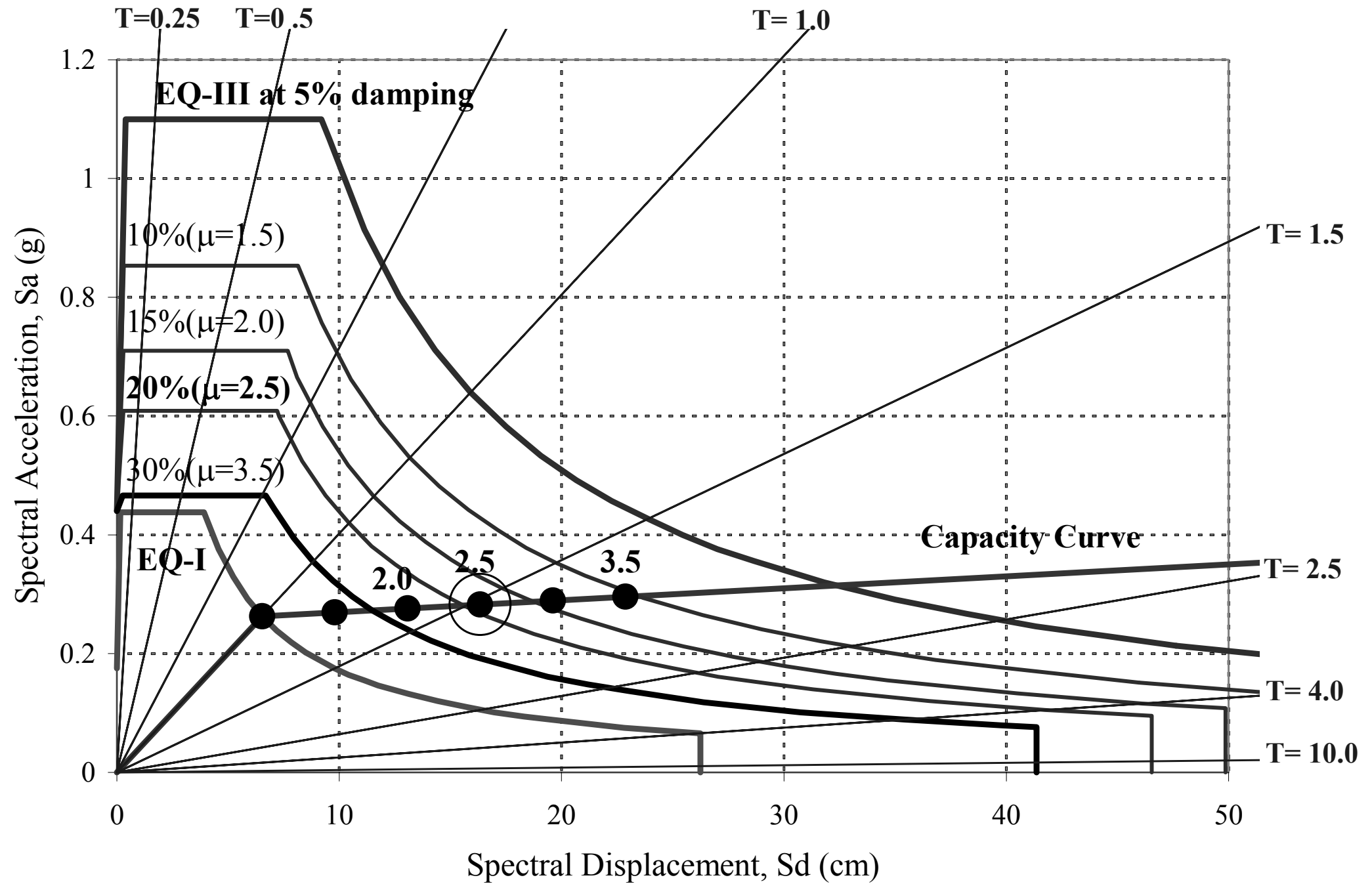


(c)



(d)

# Capacity Spectrum Method



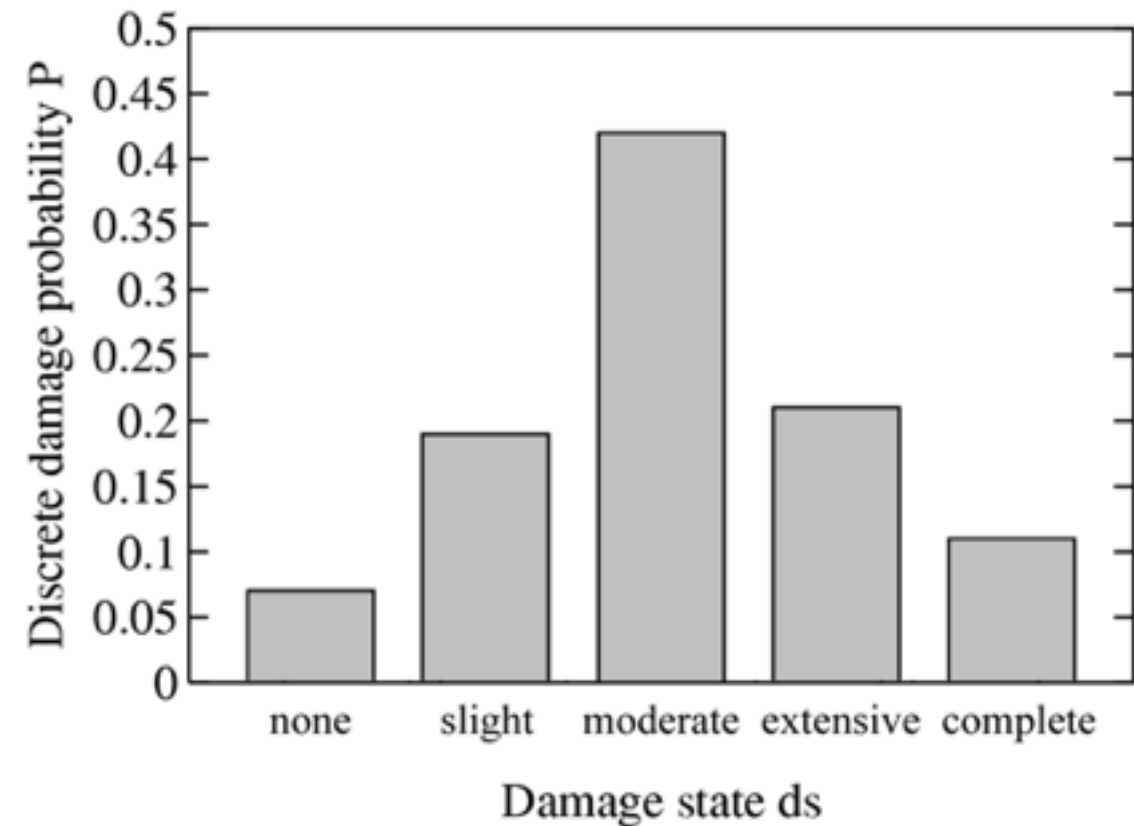
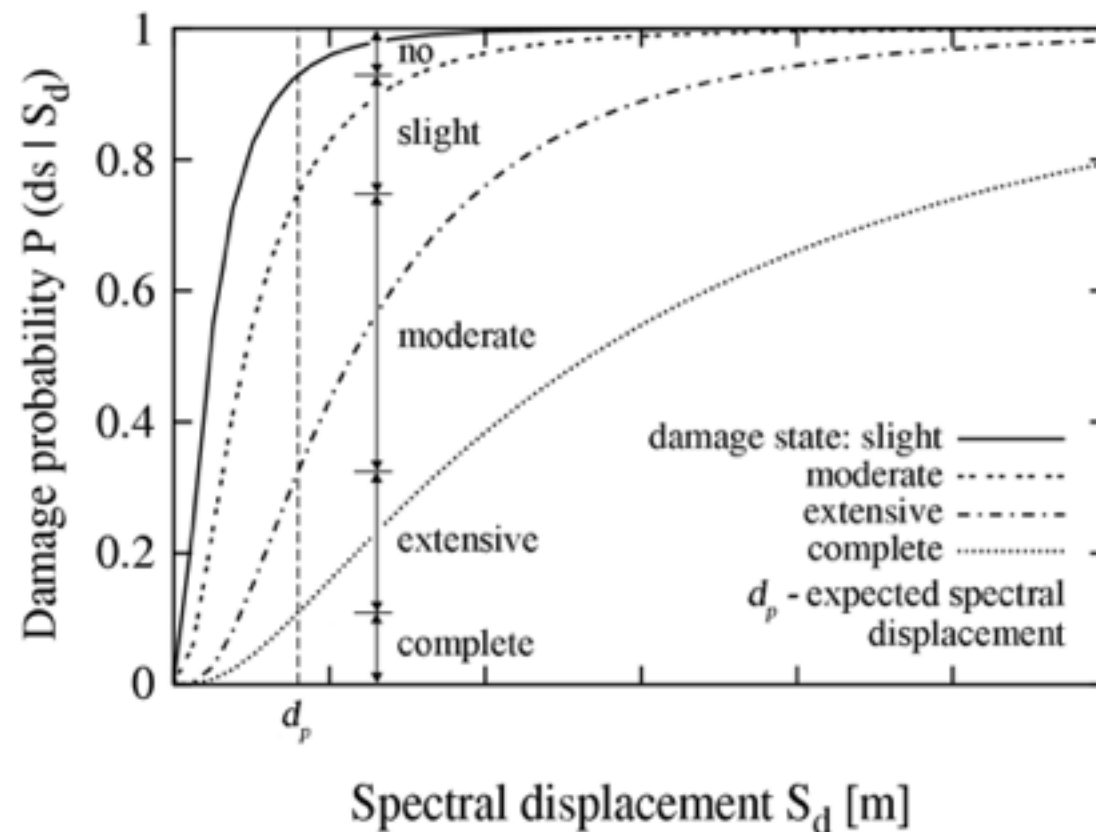
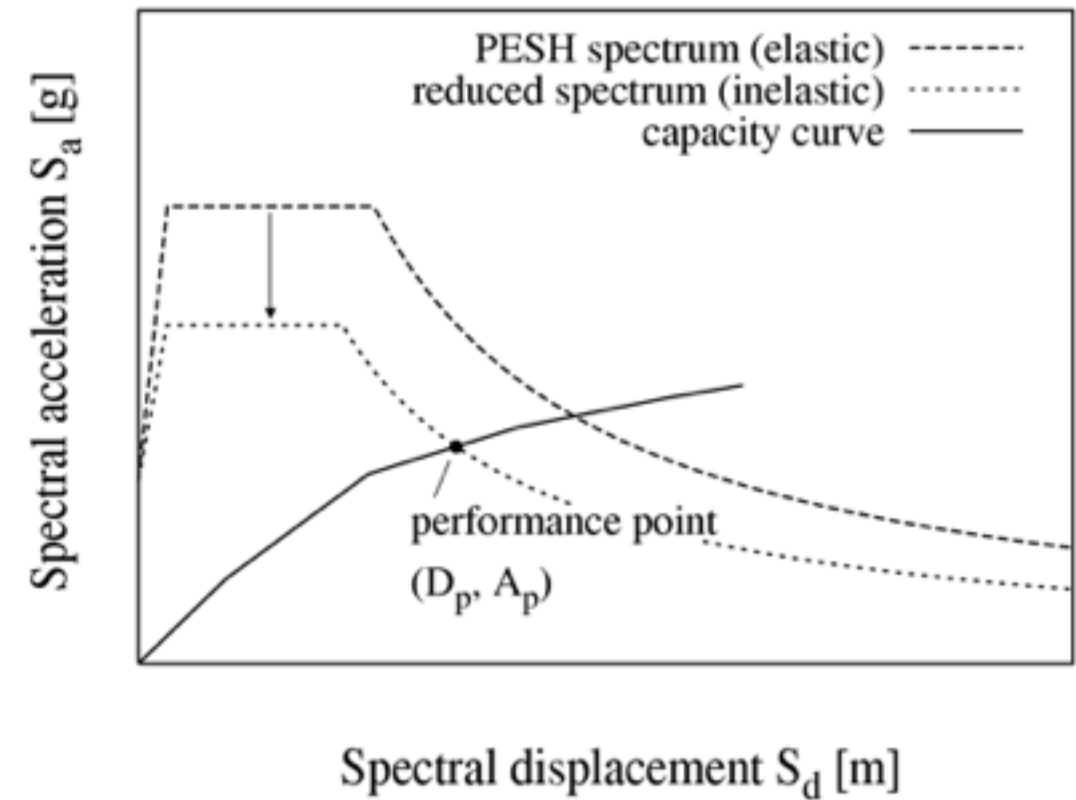
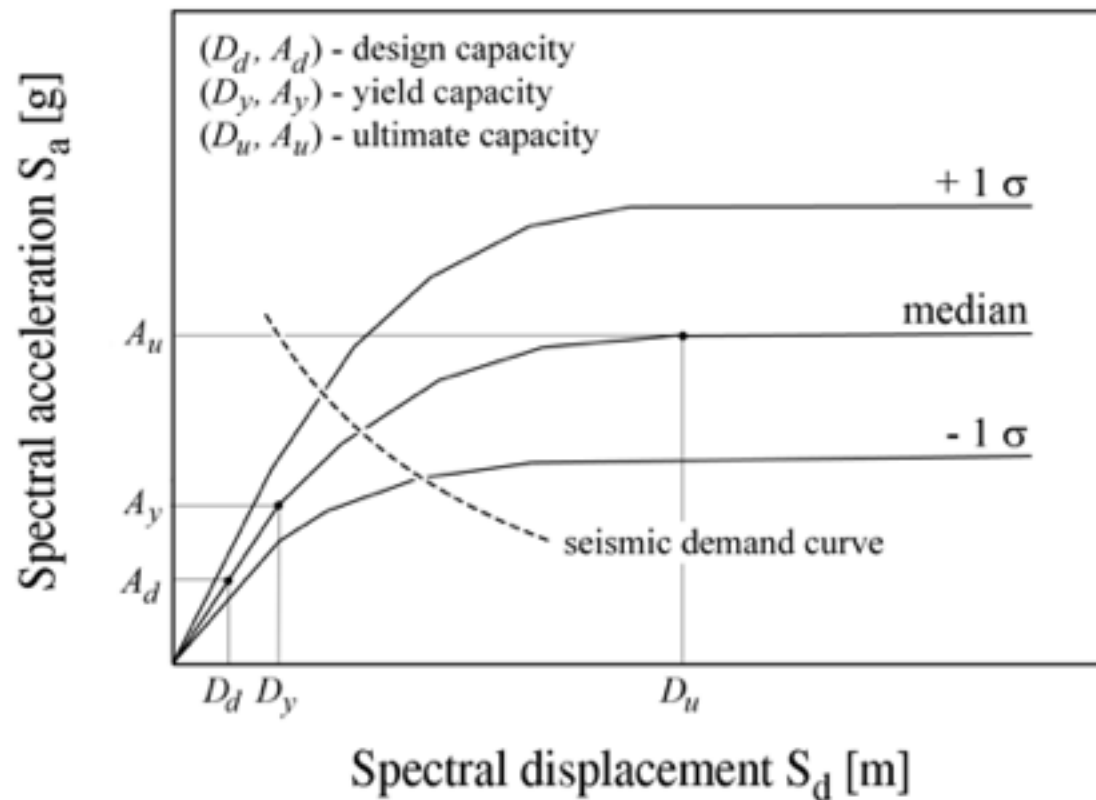
# Damageability

- Damageability is also measured in terms of the degree of the undesirable outcome, called loss, in terms of repair costs, life-safety impacts, and loss of functionality (dollars, deaths, and downtime), or in terms of environmental degradation, quality of life, historical value, and other measures.
- When loss is depicted as a function of environmental excitation, the function can be called a vulnerability function.

# Vulnerability

- A seismic vulnerability function relates uncertain loss to a measure of seismic excitation, such as spectral acceleration response at some damping ratio and period. A seismic vulnerability function usually applies to a particular asset class.
- Vulnerability is not fragility. Vulnerability measures loss, fragility measures probability.
- Vulnerability functions are referred to many ways: damage functions, loss functions, vulnerability curves, and probably others.

# Demand and Capacity





# Cost

