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Existing Buildings 01
The Basic Concepts

Date: 26 Feb 2022
Session 38

A.S. Moghadam
International Institute of Earthquake Engineering and Seismology (IIEES)
and
S-04 Team Leader, JV of NKY-Protek-Sheltech

S-8A SEng PRP Training Program

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Course Title: Existing Buildings Track 1 The Basic Concepts

- **Course Topics:**

1. Why seismic design codes cannot be used for assessment of existing buildings?
2. Performance objectives for structural and nonstructural elements
3. Force-controlled and deformation-controlled parameters
4. Primary and secondary elements
5. Acceptance criteria
6. Introducing the general flow-chart of assessment of existing buildings

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structural elements, non-structural elements

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বাংলাদেশ গেজেট

অতিরিক্ত সংখ্যা

কর্তৃপক্ষ কর্তৃক প্রকাশিত

বৃহস্পতিবার ফেব্রুয়ারি ১১, ২০২১

Government of the People's Republic of Bangladesh
Ministry of Housing and Public Works

Notification

Date : 05-11-1426/18-02-2020

S.R.O. No.55-Law/2020.—In exercise of the powers conferred under section 18A of the Building Construction Act, 1952 (Act No. II of 1953) the Government is pleased to make the following Code by repealing the Bangladesh National Building Code, 2006, namely :—

PART I
Chapter 1
Title, Purpose, Scope, Etc

1. **Title and commencement.**—(1) This Code may be called the Bangladesh National Building Code (BNBC) 2020.

(2) It shall come into force at once.

2. **Purpose.**—(1) The purpose of this Code is to establish minimum standards for design, construction, quality of materials, use and occupancy, location and maintenance of all buildings within Bangladesh in order to safeguard, within achievable limits, life,

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PART VI
Chapter 2
Loads on Buildings and Structures

2.1 Introduction

2.1.1 Scope

This Chapter specifies the minimum design forces including dead load, live load, wind and earthquake loads, miscellaneous loads and their various combinations. These loads shall be applicable for the design of buildings and structures in conformance with the general design requirements provided in Chapter 1.

2.7 Combinations of Loads

2.7.1 General

Buildings, foundations and structural members shall be investigated for adequate strength to resist the most unfavorable effect resulting from the various combinations of loads provided in this Section. The combination of loads may be selected using the provisions of either Sec 2.7.2 or Sec 2.7.3 whichever is applicable. However, once Sec 2.7.2 or Sec 2.7.3 is selected for a particular construction material, it must be

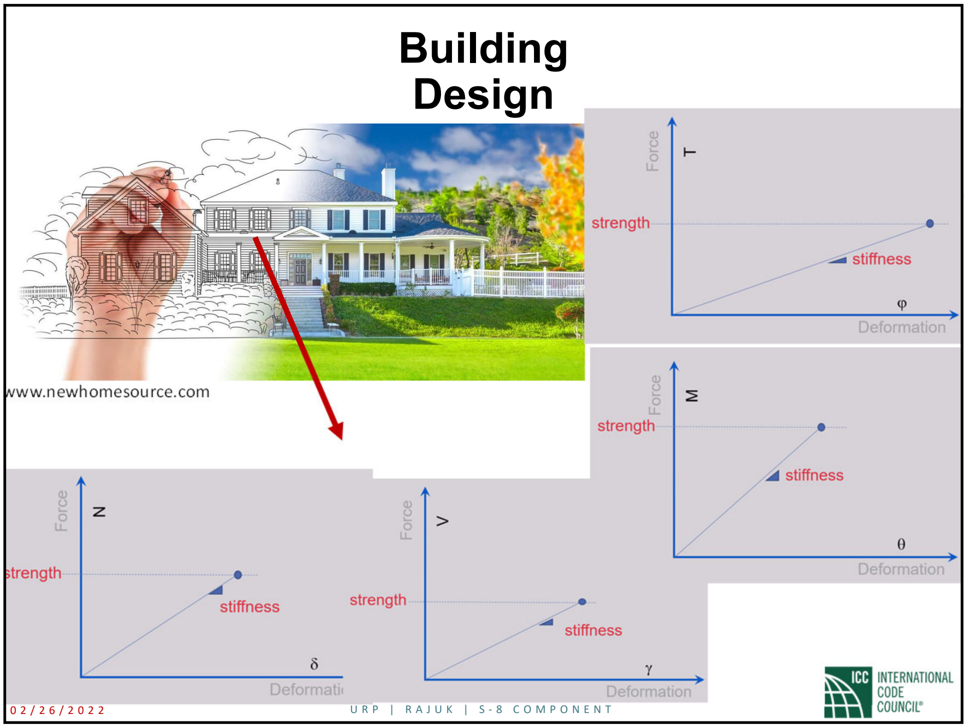
2.7.2 Combinations of Load effects for Allowable Stress/Strength Design Method

2.7.2.1 Basic combinations

Provisions of this Section shall apply to all construction materials permitting their use in proportioning structural members by allowable stress/strength design method. When this method is used in designing structural members, all loads listed herein shall be considered to act in the following combinations. The combination that produces the most unfavorable effect shall be used in design.

1. $D + F$
2. $D + H + F + L + T$
3. $D + H + F + (L_r \text{ or } R)$
4. $D + H + F + 0.75(L + T) + (L_r \text{ or } R)$
5. $D + H + F + (W \text{ or } 0.7E)$
6. $D + H + F + 0.75(W \text{ or } 0.7E) + 0.75L + 0.75(L_r \text{ or } R)$
7. $0.6D + W + H$
8. $0.6D + 0.7E + H$

4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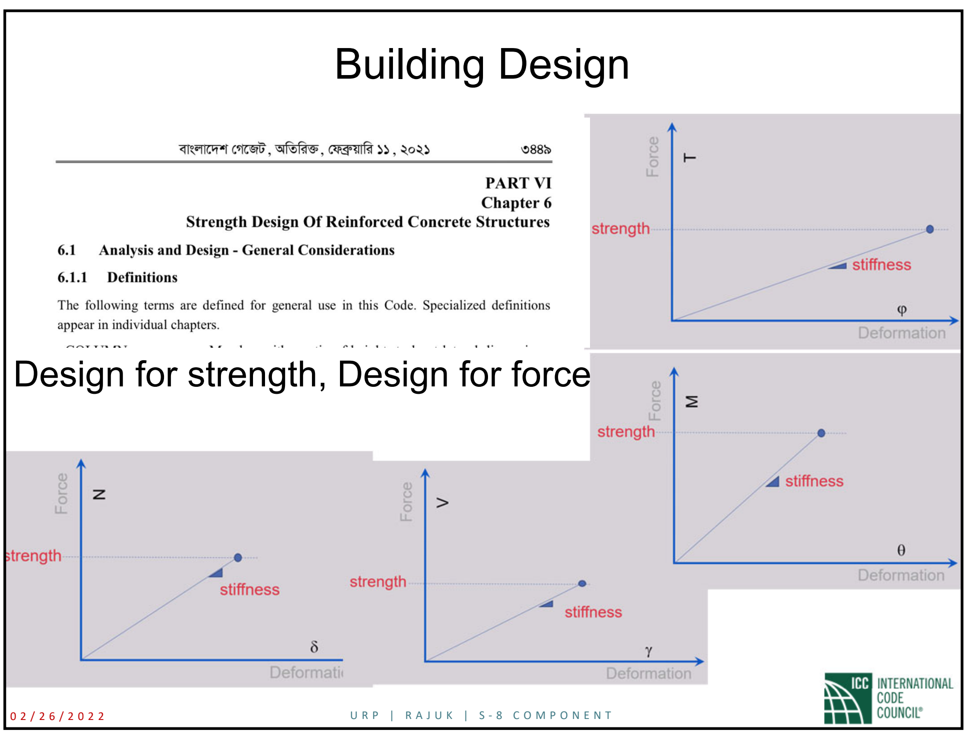
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PART VI
Chapter 6
Strength Design Of Reinforced Concrete Structures
6.1 Analysis and Design - General Considerations
6.1.1 Definitions
The following terms are defined for general use in this Code. Specialized definitions appear in individual chapters.
Design for strength, Design for force
Force
T
strength
stiffness
φ
Deformation
Force
M
strength
stiffness
θ
Deformation
Force
N
strength
stiffness
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Deformati
Force
V
strength
stiffness
γ
Deformation
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6

Building Design

Before

After

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7

Building Seismic Design

Before

After

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8

Building Seismic Design

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PART VI
Chapter 6
Strength Design Of Reinforced Concrete Structures

6.1 Analysis and Design - General Considerations

6.1.1 Definitions

The following terms are defined for general use in this Code. Specialized definitions appear in individual chapters.

6.2 Strength and Serviceability Requirements

6.2.1 General

6.2.1.1 Structures and structural members shall be designed to have desig[n] strengths at all sections at least equal to the required strengths calculated fo[r] the factored loads and forces in such combinations as are stipulated in this Code

6.2.1.2 Members also shall meet all other requirements of this Code to ensur[e] adequate performance at service load levels.

6.2.2 Required Strength

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2.5 Earthquake Loads

2.5.1 General

Minimum design earthquake forces f[...] thereof shall be determined in accorda[...] definitions and symbols relevant for e[...] are provided in Sections 2.1.3 and 2.1.4[...] resistant design concepts. Section [...]

2.5.2 Earthquake Resistant Design – Basic Concepts

2.5.2.1 General principles

The purpose of earthquake resistant design provisions in this Code is to provide guidelines for the design and construction of new structures subject to earthquake ground motions in order to minimize the risk to life for all structures, to increase the expected performance of higher occupancy structures as compared to ordinary structures, and to improve the capability of essential structures to function after an earthquake. It is not economically feasible to design and construct buildings without any damage for a major earthquake event. The intent is therefore to allow inelastic deformation and structural damage at preferred locations in the structure without endangering structural integrity and to prevent structural collapse during a major earthquake.

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Building Seismic Design

Seismic Assessment of a 15-Story Building Damaged in the Chile Earthquake of February 27th 2010

15 WCEE
LISBOA 2012

M. Kohrangi
ROSE School, IUSS Pavia, Pavia, Italy

T.J. Sullivan
University of Pavia, Pavia, Italy

G.M. Calvi
IUSS Pavia, Pavia, Italy

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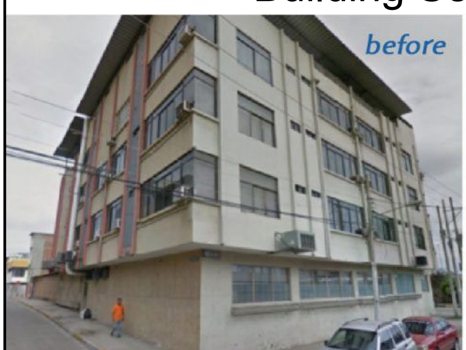

http://temblor.net/earthquake-insights

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Can we use the seismic design approach of NBCC for assessment of an existing building?

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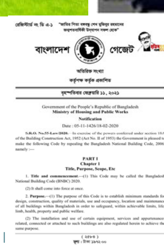
New Building



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Existing Building

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NBCC Seismic design for assessment of a building?

2.5.2 Earthquake Resistant Design – Basic Concepts

2.5.2.1 General principles

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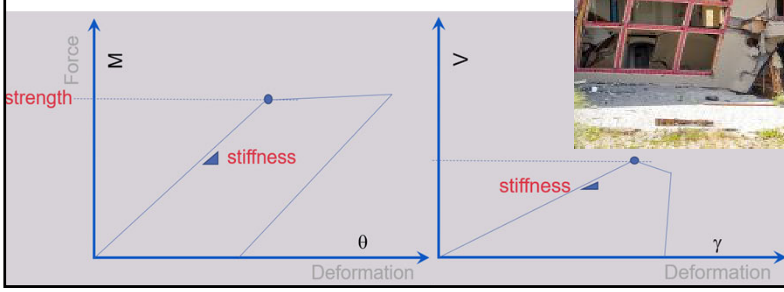
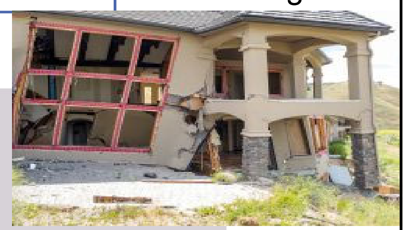
How NBCC performs Seismic design for a new building?





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Seismic **Design** Base Shear

BNBC 2020

$$\boxed{V = S_a W}$$

$$\boxed{S_a = \frac{2}{3}\frac{ZI}{R}C_s}$$

$S_a =$ Design spectral acceleration (in units of g)

$\beta =$ Coefficient used to calculate lower bound for S_a

$Z =$ Seismic zone coefficient

$I =$ Structure importance factor

$R =$ Response reduction factor which depends on structural system

$C_s =$ Normalized acceleration response spectrum

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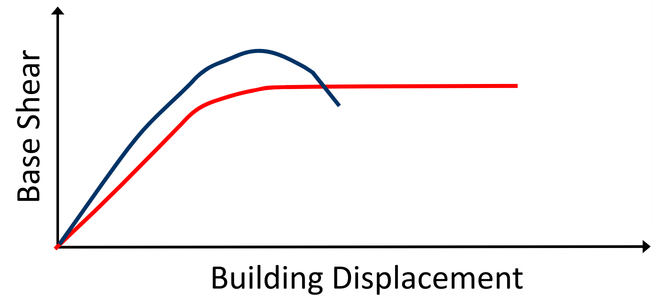
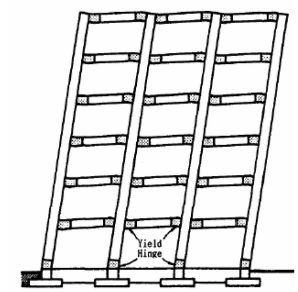
Design based on **Ductility**

R = Response reduction factor which depends on structural system





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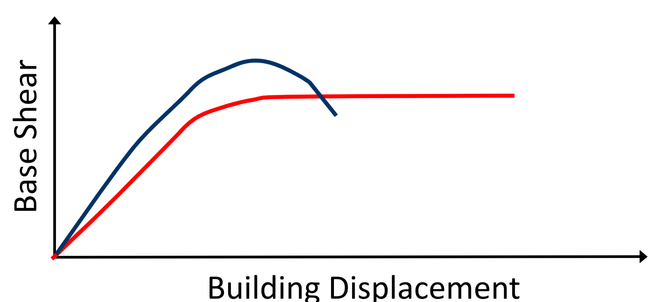
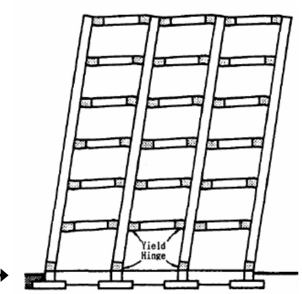
Seismic **Design**





- Ductility
- Damage
- Performance Level

R = Response reduction factor which depends on structural system

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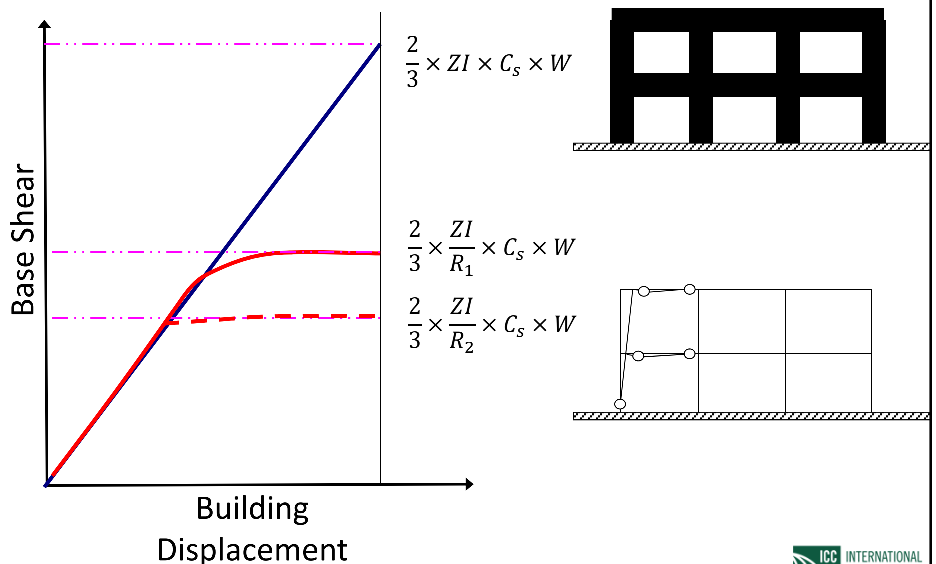
Relationship between **R-values** and **Damage**



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PART VI
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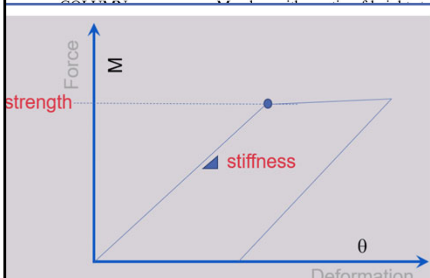

(a) shear-compression failure (b) buckling failure

(c) shear failure

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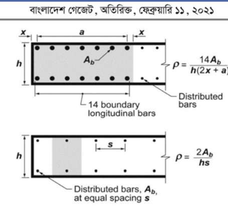

Figure 6.8.12 Longitudinal reinforcement ratios for typical wall boundary conditions

8.3 Earthquake-Resistant Design Provisions

8.3.1 Scope

This section contains special requirements for design and construction of reinforced concrete members of a structure for which the design forces, related to earthquake motions, have been determined on the basis of energy dissipation in the nonlinear range of response.

8.3.2 Provisions

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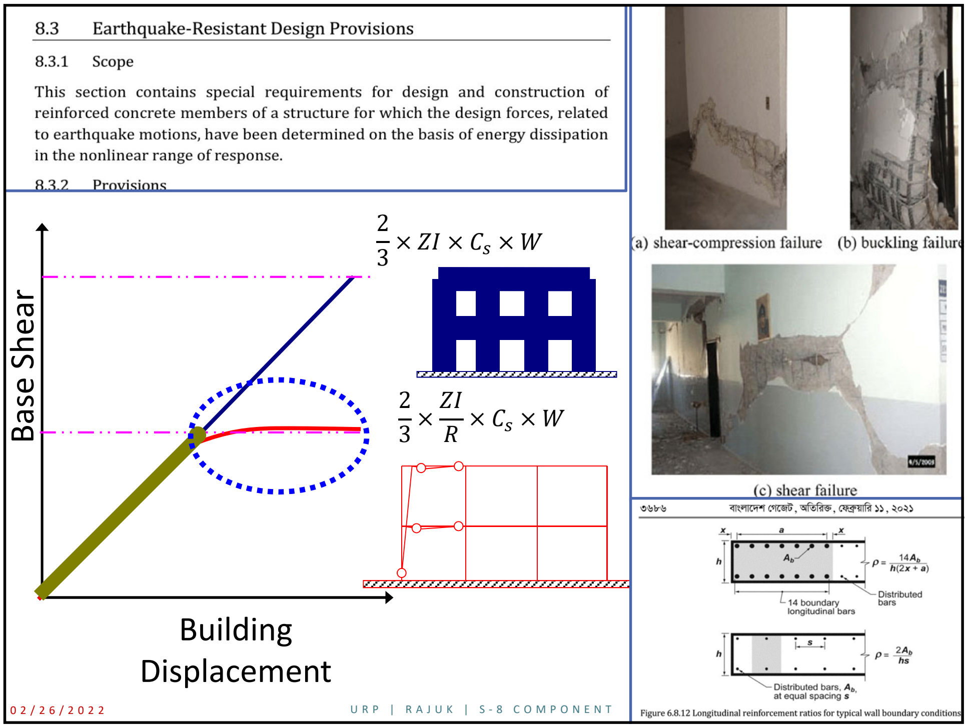

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This section contains special requirements for design and construction of reinforced concrete members of a structure for which the design forces, related to earthquake motions, have been determined on the basis of energy dissipation in the nonlinear range of response.

8.3.2 Provisions

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Design Base Shear verses **Assessment** Base Shear

BNBC 2020

$$\boxed{V = S_a W}$$

$$\boxed{S_a = \frac{2}{3}\frac{ZI}{R}C_s}$$

ASCE 41-17

$$\boxed{V = C_1 C_2 C_m S_a W}$$

$S_a =$ Design spectral acceleration (in units of g)

$\beta =$ Coefficient used to calculate lower bound for S_a

$Z =$ Seismic zone coefficient

$I =$ Structure importance factor

$R =$ Response reduction factor which depends on structural system

$C_s =$ Normalized acceleration response spectrum

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To perform **Seismic Evaluation** and **Assessment** of an **Existing Building**

- Fragility Curves and Vulnerability functions
- Visual Screening

- Rapid Vulnerability Assessment (RVA)
- Preliminary Engineering Assessment (PEA)
- Detailed Engineering Assessment (DEA)

ASCE 41-17
- TIER 1 Screening
- TIER 2 Deficiency-Based Evaluation and Retrofit
- TIER 3 **Systematic** Evaluation and Retrofit

And many more methods …

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Earthquake considerations for Buildings

- New Buildings → **BNBC**
- Existing Buildings
- Post earthquake Damaged Buildings

Seismic Vulnerability Assessment

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To perform **Seismic Evaluation** and **Assessment** of an **Existing Building**

- Detailed Engineering Assessment (DEA)

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- TIER 3 **Systematic** Evaluation and Retrofit

Different Performance levels
For
Different seismic hazard levels

Performance Objective

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Performance Objective

Probability of Exceedance	Mean Return Period (years)
50%/30 years	43
50%/50 years	72
20%/50 years	225
10%/50 years	475
5%/50 years	975
2%/50 years	2,475

Earthquake Hazard Level	Target Building Performance Levels: Operational Level (1-A)	Immediate Occupancy Performance Level (1-B)	Life Safety Performance Level (3-C)	Collapse Prevention Performance Level (5-E)
50%/50 year	a	b		d
20%/50 year	e	f		h
BSE-1 (~10%/50 year)				l
BSE-2 (~2%/50 year)	m	n	o	p

Life Safety Level (3-C)
Moderate
Some residual strength and stiffness left in all stories. Gravity-load-bearing elements function. No out-of-plane failure of walls. Some permanent drift. Damage to partitions. Continued occupancy might not be likely before repair. Building might not be economical to repair.
Falling hazards, such as parapets, mitigated, but many architectural, mechanical, and electrical systems are damaged.
Somewhat more damage and slightly higher life-safety risk.

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Table C2-2. Performance Objectives

Seismic Hazard Level	Target Building Performance Levels: Operational Performance Level (1-A)	Immediate Occupancy Performance Level (1-B)	Life Safety Performance Level (3-C)	Collapse Prevention Performance Level (5-D)
50%/50 years	a	b	c	d
BSE-1E(20%/50 years)	e	f	g	h
BSE-2E(5%/50 years)	i	j	k	l
BSE-2 N(ASCE 7 MCE_R)	m	n	o	p

Nonstructural Performance Levels	Structural Performance Levels: Immediate Occupancy (S-1)	Damage Control (S-2)	Life Safety (S-3)	Limited Safety (S-4)	Collapse Prevention (S-5)	Not Considered (S-6)
Operational (N-A)	Operational 1-A	2-A	NR[a]	NR[a]	NR[a]	NR[a]
Position Retention (N-B)	Immediate Occupancy 1-B	2-B	3-B	4-B	NR[a]	NR[a]
Life Safety (N-C)	1-C	2-C	Life Safety 3-C	4-C	5-C	6-C
Hazards Reduced (N-D)	NR[a]	NR[a]	3-D	4-D	Collapse Prevention 5-D	6-D
Not Considered (N-E)	NR[a]	NR[a]	3-E	4-E	5-E	No evaluation or retrofit

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Nonstructural Performance Levels	Structural Performance Levels: Immediate Occupancy (S-1)	Damage Control (S-2)	Life Safety (S-3)	Limited Safety (S-4)	Collapse Prevention (S-5)	Not Considered (S-6)
Operational (N-A)	Operational 1-A	2-A	NR[a]	NR[a]	NR[a]	NR[a]
Position Retention (N-B)	Immediate Occupancy 1-B	2-B	3-B	4-B	NR[a]	NR[a]
Life Safety (N-C)	1-C	2-C	Life Safety 3-C	4-C	5-C	6-C
Hazards Reduced (N-D)	NR[a]	NR[a]	3-D	4-D	Collapse Prevention 5-D	6-D
Not Considered (N-E)	NR[a]	NR[a]	3-E	4-E	5-E	No evaluation or retrofit

Seismic-Force-Resisting System	Type	Structural Performance Levels: Collapse Prevention (S-5)	Life Safety (S-3)	Immediate Occupancy (S-1)
Concrete frames	Primary elements	Extensive cracking and hinge formation in ductile elements. Limited cracking or splice failure in some nonductile columns. Severe damage in short columns.	Extensive damage to beams. Spalling of cover and shear cracking in ductile columns. Minor spalling in nonductile columns. Joint cracks.	Minor cracking. Limited yielding possible at a few locations. Minor spalling of concrete cover.
	Secondary elements	Extensive spalling in columns and beams. Limited column shortening. Severe joint damage. Some reinforcing buckled.	Major cracking and hinge formation in ductile elements. Limited cracking or splice failure in some nonductile columns. Severe damage in short columns.	Minor spalling in a few places in ductile columns and beams. Flexural cracking in beams and columns. Shear cracking in joints.
	Drift	Transient drift sufficient to cause extensive nonstructural damage. Extensive permanent drift.	Transient drift sufficient to cause nonstructural damage. Noticeable permanent drift.	Transient drift that causes minor or no nonstructural damage. Negligible permanent drift.

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Nonstructural Performance Levels	Structural Performance Levels					
	Immediate Occupancy (S-1)	Damage Control (S-2)	Life Safety (S-3)	Limited Safety (S-4)	Collapse Prevention (S-5)	Not Considered (S-6)
Operational (N-A)	Operational 1-A	2-A	NR[a]	NR[a]	NR[a]	NR[a]
Position Retention (N-B)	Immediate Occupancy 1-B	2-B	3-B	4-B	NR[a]	NR[a]
Life Safety (N-C)	1-C	2-C	Life Safety 3-C	4-C	5-C	6-C
Hazards Reduced (N-D)	NR[a]	NR[a]	3-D	4-D	Collapse Prevention 5-D	6-D
Not Considered (N-E)	NR[a]	NR[a]	3-E	4-E	5-E	No evaluation or retrofit

Component Group	Nonstructural Performance Levels		
	Life Safety (N-C)	Position Retention (N-B)	Operational (N-A)
Cladding Panels	Distortion in connections and damage to cladding components, including loss of weather-tightness and security. Overhead panels do not fall.	Distortion in connections and damage to cladding components, including loss of weather-tightness and security. Overhead panels do not fall.	Negligible damage to panels and connections. No loss of function or weather-tightness.
Glazing	Some cracked panes; none broken. Limited loss of weather-tightness.	Some cracked panes; none broken. Limited loss of weather-tightness.	No cracked or broken panes. No loss of function or weather-tightness.
Heavy partitions (masonry and hollow clay tile or stud walls with tile or masonry veneer)	Distributed damage; cracking, crushing, and dislodging of veneer or parge coat in some areas. Damage to adjacent ceiling, but no wall failure.	Distributed damage; cracking, crushing, and dislodging of veneer or parge coat in some areas.	Minor crushing and cracking at corners. Limited dislodging of veneer or parge coat.
Light partitions (plaster and gypsum)	Distributed damage; some severe cracking of sheathing and racking in some areas.	Cracking at openings. Minor cracking of sheathing.	Minor cracking.
Ceilings	Extensive damage to suspended acoustical ceilings and grids. Plaster ceilings cracked and spalled but do not drop as a unit. Tiles in grid ceilings dislodged and falling; grids distorted and pulled apart. Plaster and gypsum board ceilings cracked and spalled but did not drop as a unit.	Limited damage. Plaster ceilings cracked and spalled but did not drop as a unit. Suspended ceiling grids largely undamaged, though individual tiles falling.	Generally negligible damage with no impact on reoccupancy or functionality.
Parapets and ornamentation	Minor damage; some falling of unreinforced elements in unoccupied areas.	Minor damage.	Negligible damage.
Canopies and marquees	Some damage to the elements, but essentially in place.	Some damage to the elements, but essentially in place.	Minor damage to the elements.
Chimneys and stacks	Minor damage. No collapse.	Minor damage. No collapse.	Negligible damage.

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To perform **Seismic Evaluation** and **Assessment** of an **Existing Building**

- Detailed Engineering Assessment (DEA)

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- TIER 3 **Systematic** Evaluation and Retrofit

Simple or Complex?

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Components that affect the lateral stiffness or distribution of forces in a structure, or are loaded as a result of lateral deformation of the structure are classified as:

Primary or **Secondary Components**

A structural component that is required to resist seismic forces and accommodate deformations for the structure to achieve the selected Performance Level shall be classified as primary.

A structural component that accommodates seismic deformations and is not required to resist seismic forces for the structure to achieve the selected Performance Level shall be permitted to be classified as secondary.

Table 10-10b. Numerical Acceptance Criteria for Linear Procedures—Reinforced Concrete Circular Columns with Spiral Reinforcement or Seismic Hoops as Defined in ACI 318

			m-Factors[a]				
			Performance Level				
				Component Type			
				Primary		Secondary	
$\left(\frac{N_{UD}}{A_g f'_{cE}}\right)$	ρ_t	V_{yE}/V_{ColOE}	IO	LS	CP	LS	CP
Columns not controlled by inadequate development or splicing along the clear height[b]							

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Difference between response parameters (**Deformation-Controlled** actions and **force-controlled** actions) and difference in estimation of their capacity and demand

Primary component actions exhibiting this behavior shall be classified as deformation controlled if the plastic range is such that $d \geq 2g$; otherwise, they shall be classified as force controlled. Secondary component actions exhibiting this behavior shall be classified as deformation controlled for any d/g ratio.

Primary component actions exhibiting this behavior shall be classified as deformation controlled if the plastic range is such that $e \geq 2g$; otherwise, they shall be classified as force controlled. Secondary component actions exhibiting this behavior shall be classified as deformation controlled if $f \geq 2g$; otherwise, they shall be classified as force controlled.

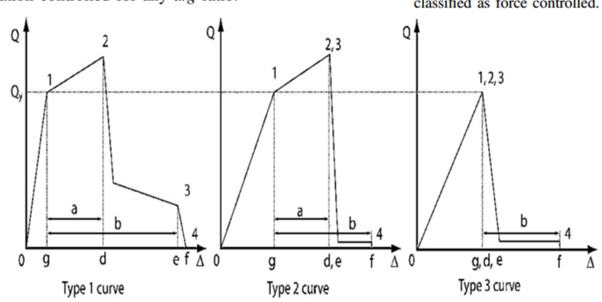

Figure 7-4. Component Force Versus Deformation Curves

Notes:

1. Only secondary component actions permitted between points 2 and 4.
2. The force, *Q*, after point 3 diminishes to approximately zero.

Primary component actions exhibiting this behavior shall be classified as force controlled. Secondary component actions exhibiting this behavior shall be classified as deformation controlled if $f \geq 2g$; otherwise, they shall be classified as force controlled.

For nonlinear procedures, force-controlled components defined in Chapters 8 through 12 may be reclassified as Type 3 deformation-controlled components, provided the following criteria are met:

1. The component action being reclassified exhibits the Type 3 deformation-controlled performance defined in this section;
2. The gravity-load-resisting load path is not altered, or if it is altered, an alternate load path is provided to ensure that local stability is maintained in accordance with the load combinations of Section 7.2.2 at the anticipated maximum displacements predicted by the analysis;
3. The total gravity load supported by all components that are reclassified from force controlled to deformation controlled does not exceed 5% of the total gravity load being supported at that story; and
4. All remaining deformation-controlled components meet the acceptance criteria to achieve the target performance level and all remaining force-controlled components are not overstressed.

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Difference between response parameters (**Deformation-Controlled** actions and **force-controlled** actions) and difference in estimation of their **capacity** and demand

Q_{CE} = Expected strength of component deformation-controlled action

Q_{CL} = Lower-bound strength of a force-controlled action

7.5.1.4 Material Properties. Expected material properties shall be based on mean values of tested material properties. Lower-bound material properties shall be based on mean values of tested material properties minus one standard deviation, σ.

Nominal material properties, or properties specified in construction documents, shall be taken as lower-bound material properties unless otherwise specified…

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Difference between **Deformation-Controlled** based on their **Demand**

Table 10-6. Component Ductility Demand Classification

Maximum Value of DCR or Displacement Ductility	Descriptor
<2	Low ductility demand
2 to 4	Moderate ductility demand
>4	High ductility demand

Example:

columns, lap-spliced transverse reinforcement shall be assumed to be not more than 50% effective in regions of moderate ductility demand and ineffective in regions of high ductility demand, and

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Difference between **Force-Controlled** based on their **Criticality**

Table 7-8. Load Factor for Force-Controlled Behaviors

Action Type	γ
Critical	1.3
Ordinary	1.0
Noncritical	1.0

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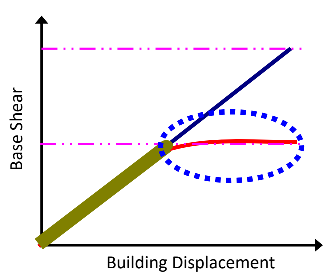
Summary 1/5

- The main two categories of Design requirements of a building in earthquake prone regions.



- Seismic design codes cannot be used for assessment of existing buildings.

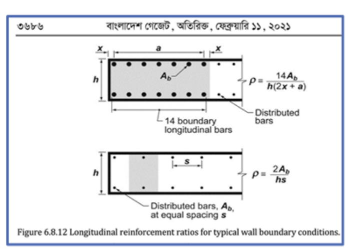


Figure 6.8.12 Longitudinal reinforcement ratios for typical wall boundary conditions.

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Summary 2/5

- The main characteristic of "Systematic" Evaluation.

Probability of Exceedance	Mean Return Period (years)
50%/30 years	43
50%/50 years	72
20%/50 years	225
10%/50 years	475
5%/50 years	975
2%/50 years	2,475

Earthquake Hazard Level	Target Building Performance Levels: Operational Performance Level (1-A)	Immediate Occupancy Performance Level (1-B)	Life Safety Performance Level (3-C)	Collapse Prevention Performance Level (5-E)
50%/50 year	a	b		d
20%/50 year	e	f		h
BSE-1 (~10%/50 year)				i
BSE-2 (~2%/50 year)	m	n	o	p

~~Life Safety Level (3-C)~~

~~Moderate~~

~~Some residual strength and stiffness left in all stories. Gravity-load-bearing elements function. No out-of-plane failure of walls. Some permanent drift. Damage to partitions. Continued occupancy might not be likely before repair. Building might not be economical to repair.~~

~~Falling hazards, such as parapets, mitigated, but many architectural, mechanical, and electrical systems are damaged.~~

~~Somewhat more damage and slightly higher life safety risk.~~

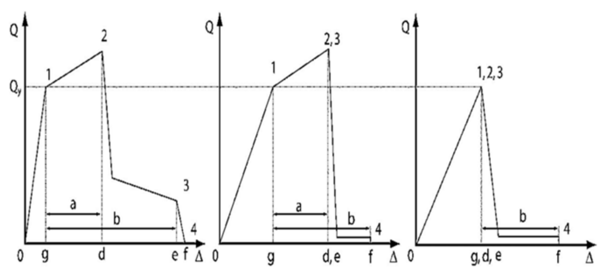
Different Performance levels For Different seismic hazard levels

- "Primary Component".

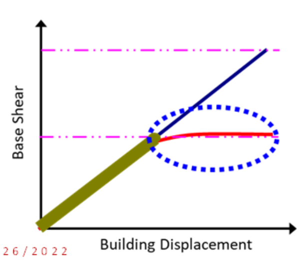
A structural component that is required to resist seismic forces and accommodate deformations

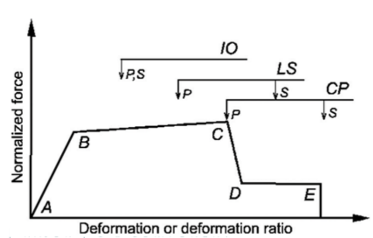
Summary 3/5

- "Deformation-Controlled actions" and "force-controlled actions".



- Satisfy a performance level such as "Life Safety (LS)".





Summary 4/5

- Factor in the Seismic Design Base Shear formula of BNBC-2020 that is not applicable to existing buildings.

$$\boxed{V = S_a W} \qquad \boxed{S_a = \frac{2}{3}\frac{ZI}{R}C_s}$$

- Calculations of capacities for "Deformation-Controlled actions" and "force-controlled actions".

Q_{CE} = Expected strength of component deformation-controlled action

Q_{CL} = Lower-bound strength of a force-controlled action

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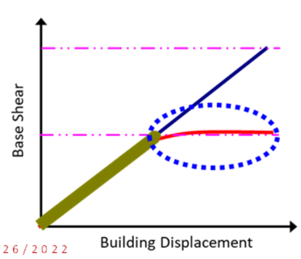
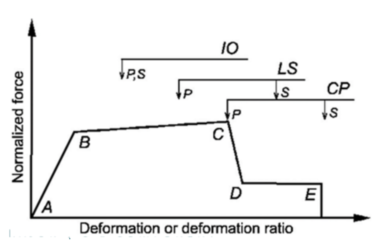
Summary 5/5

- Systematic Assessment are often complicated and complex.

$$\boxed{V = S_a W} \qquad \boxed{S_a = \frac{2}{3}\frac{ZI}{R}C_s}$$

- Meaning of the "Performance Level" of a structural member.





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Course Title: Existing Buildings Track 1 The Basic Concepts

- **Course Outcomes:**

1. Understand the main concepts in systematic retrofitting of the existing buildings.
2. Have a clear view on differences between seismic design of a new building and seismic assessment of an existing building.
3. Differentiate between different response parameters and the way they are treated in estimation of capacity and demand.
4. Relate the concept of performance of a building to accept levels of damages.
5. Understand why modelling is the main issue in systematic assessment, and how it is different with ordinary design procedures.

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Questions? Thank you

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