ASIAN DEVELOPMENT BANK

Post-earthquake School Reconstruction Project

Seminar on

Earthquake Resilient Design for School Buildings

Day-1
Session 4

Structural Design Criteria

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Day : 1
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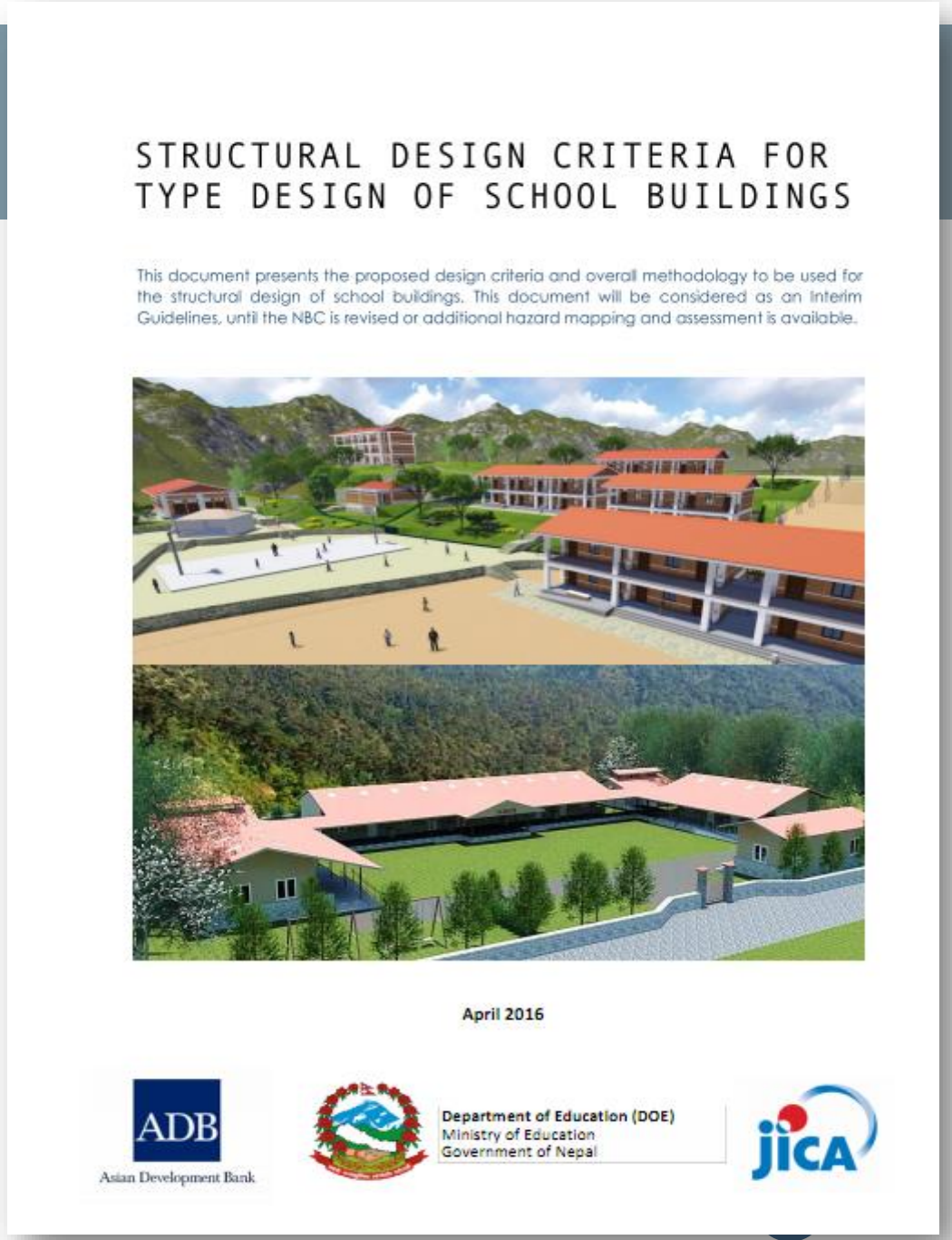

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Introduction

- After Gorkha Earthquake, The Government of Nepal (GON), and several development partners have developed a comprehensive Post Disaster Need Assessment (PDNA) document.

- One of the sector considered in the overall PDNA is Education, which identities the needs for rehabilitation and reconstruction of effected infrastructure for education sector, including the school buildings and facilities.

- As part of the rebuilding strategy, guidelines have been developed for the design of new schools.

Introduction

- This document presents the proposed design criteria and overall methodology to be used for the structural design of school buildings.

- This document has been prepared by the Asian Development Bank (ADB) and Japan International Cooperation Agency (JICA).

- The document is intended to be the official guidelines to the Department of Education (DOE), for structural aspects of planning and design of new schools consistent with the Design Guidelines for Type Design of School Buildings which sets out architectural and planning requirements.

Scope and Purpose

- This document is intended to provide a unified and consistent criterion for carrying out detailed structural design of school buildings in Nepal, for resistance to the effects of earthquakes and other natural hazards.

- The document is particularly applicable to the Type Design of new school buildings for the post-earthquake reconstruction in the 14 most effected districts.

- The document may also be used for structural design of school buildings in general for all districts in Nepal, either in mountains, hills or plains.

Contents

- Introduction
- Design Philosophy and Approach
- Basic Materials
- Loads
- Structural Systems
- Code-based Design
- Seismic Performance-based Evaluation

Structural Systems

Sys-1: Ordinary reinforced concrete moment frame with unreinforced masonry infill walls
Sys-2: Special steel moment resisting frame
Sys-3: Reinforced interlocking block bearing wall system (for example, Habitech system)
Sys-4: Special reinforced concrete moment frame
Sys-5: Cold-formed steel ordinary moment frame
Sys-6: Hold-rolled steel ordinary moment frame
Sys-7: Timber structure

Two Design Approaches

Approach 1:
Code based and Performance Based

Approach 2:
Code based and optional verification

Difference Between CBD and PBD

- Code Based
  - Create an elastic model, ignore nonlinearly
  - Reduce elastic seismic demand to get design demand (By R or K)
  - Increase design force by load factors (1.4 to 1.8)
  - Hope the combined factors provide adequate performance

- Performance Based
  - Use nonlinear model
  - Use defined hazard level without scaling
  - Compare capacity with demand, without load factors
  - Confirm the expected performance explicitly

Why Two Approaches

- The basis of Hazard levels in the Code are not clearly
- There are arbitrary factors in Codes (K and R) used to scale the elastic response
- The capacity and response of specific structural systems can be verified/confirmed using the code approach only
- Schools are for the future, and codes will be revised, greater reliability is required
- This criteria is for “Type Designs” to be used for large number of replications

Table 4-3 : Parameters for Seismic Loading

Parameter	Value
Zone factor, Z (NBC 105-1994) Zone factor, Z (IS 1893-2002)	1 0.36
Importance factor	1.5
Soil type	II (Needs to be determined based on building location)
Structural performance factor, K	• System 1 = 2 • System 2 = 1 • System 3 = 4 • System 4 = 1 • System 5 = 4
Response reduction factor, R	• System 1 = 1.5** • System 2 = 5 • System 3 = 3 • System 4 = 5 • System 5 = 3
C_a*	• 500-yr = 0.36 • 1000-yr = 0.46 • 2000-yr = 0.58
C_v*	• 500-yr = 0.45 • 1000-yr = 0.58 • 2000-yr = 0.73

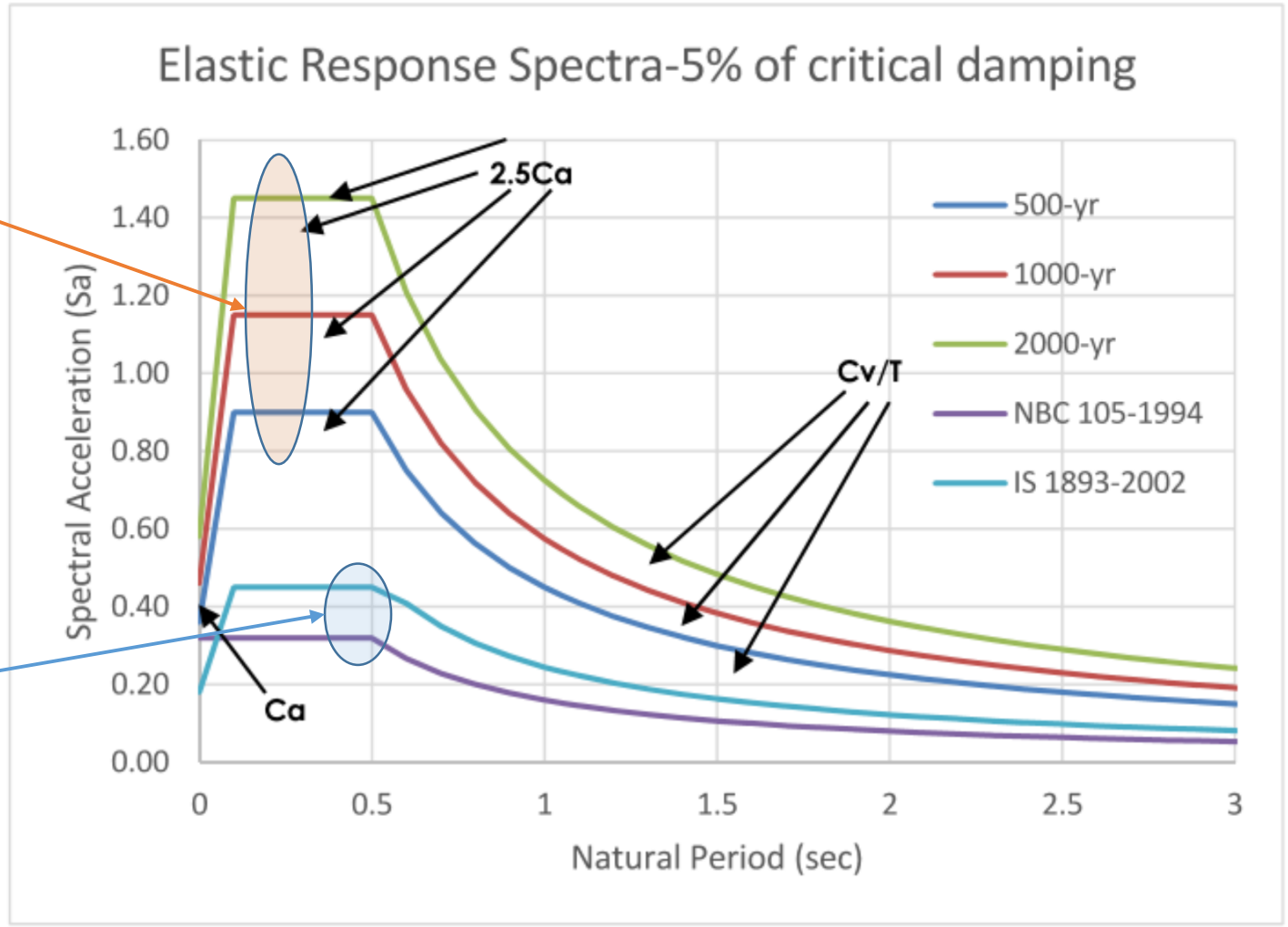
* Used in design procedure 1.

** Assumed R value since the values are not available in IS1893-2002.

Elastic Response and Code Response Spectrum Curves

Approach 1: No K or R or load factors

Approach 2: Code based K, R and load factors



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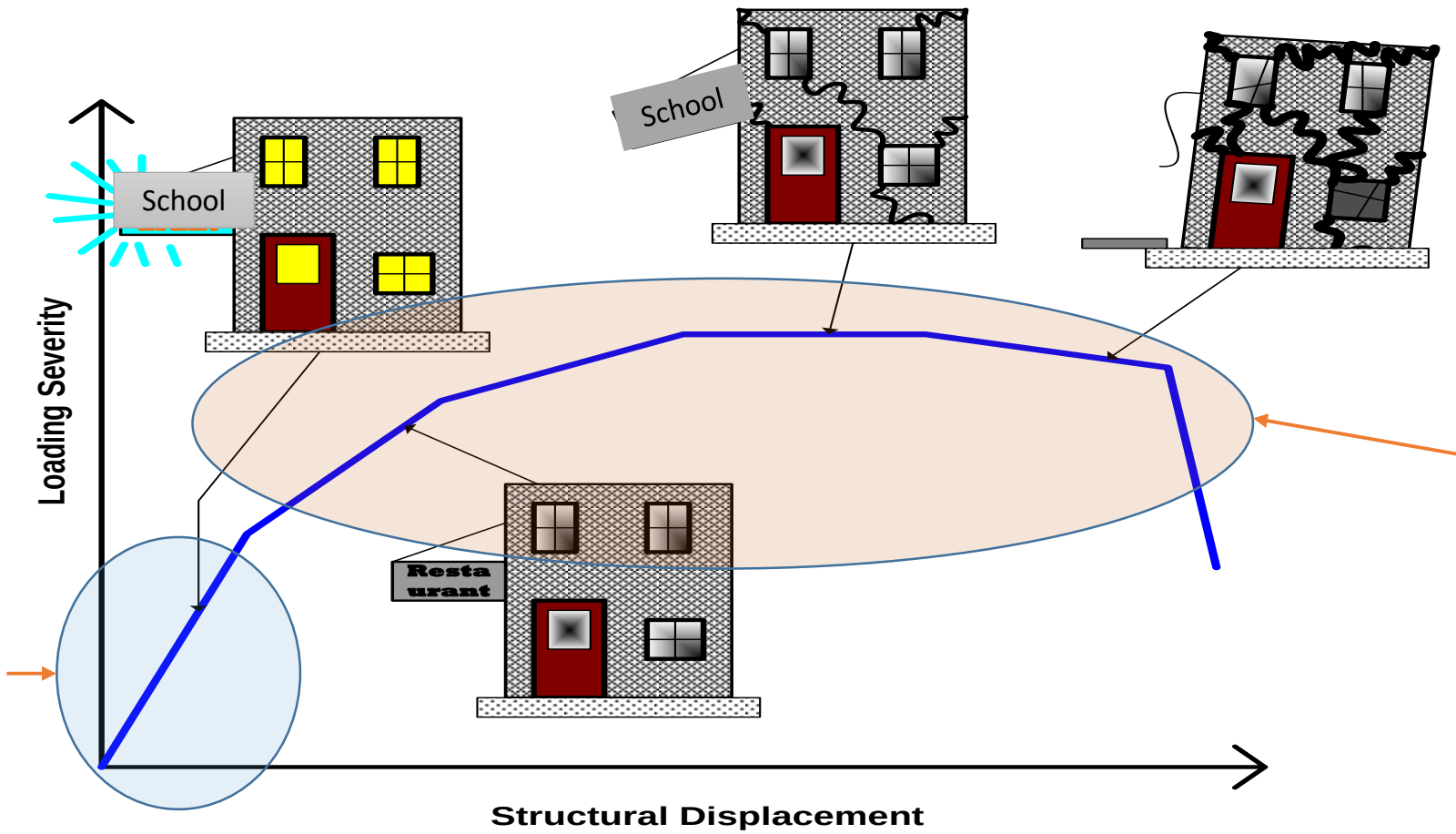
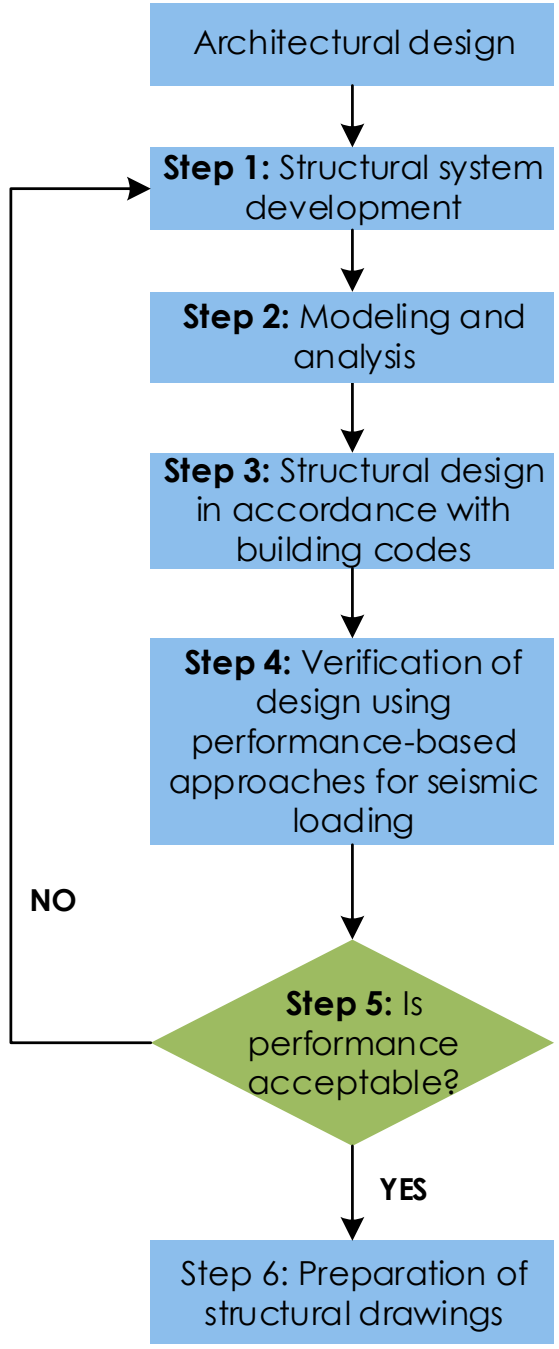
The Two Design Approaches



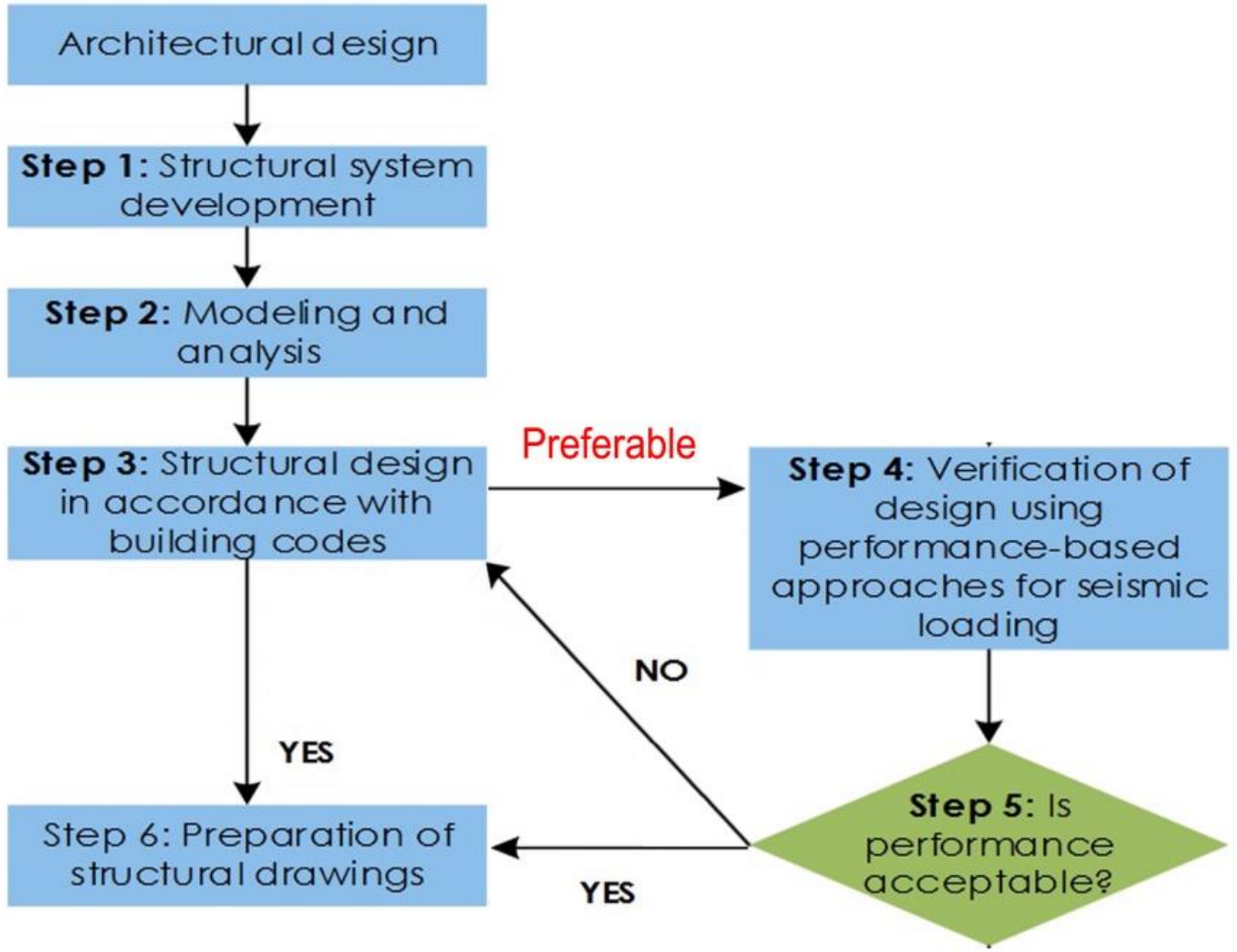
Approach 1: Directly confirm this response, after code based design

Approach 2: Use Code Based and hope it will satisfy other zones

Overall Design Procedure – Approach 1



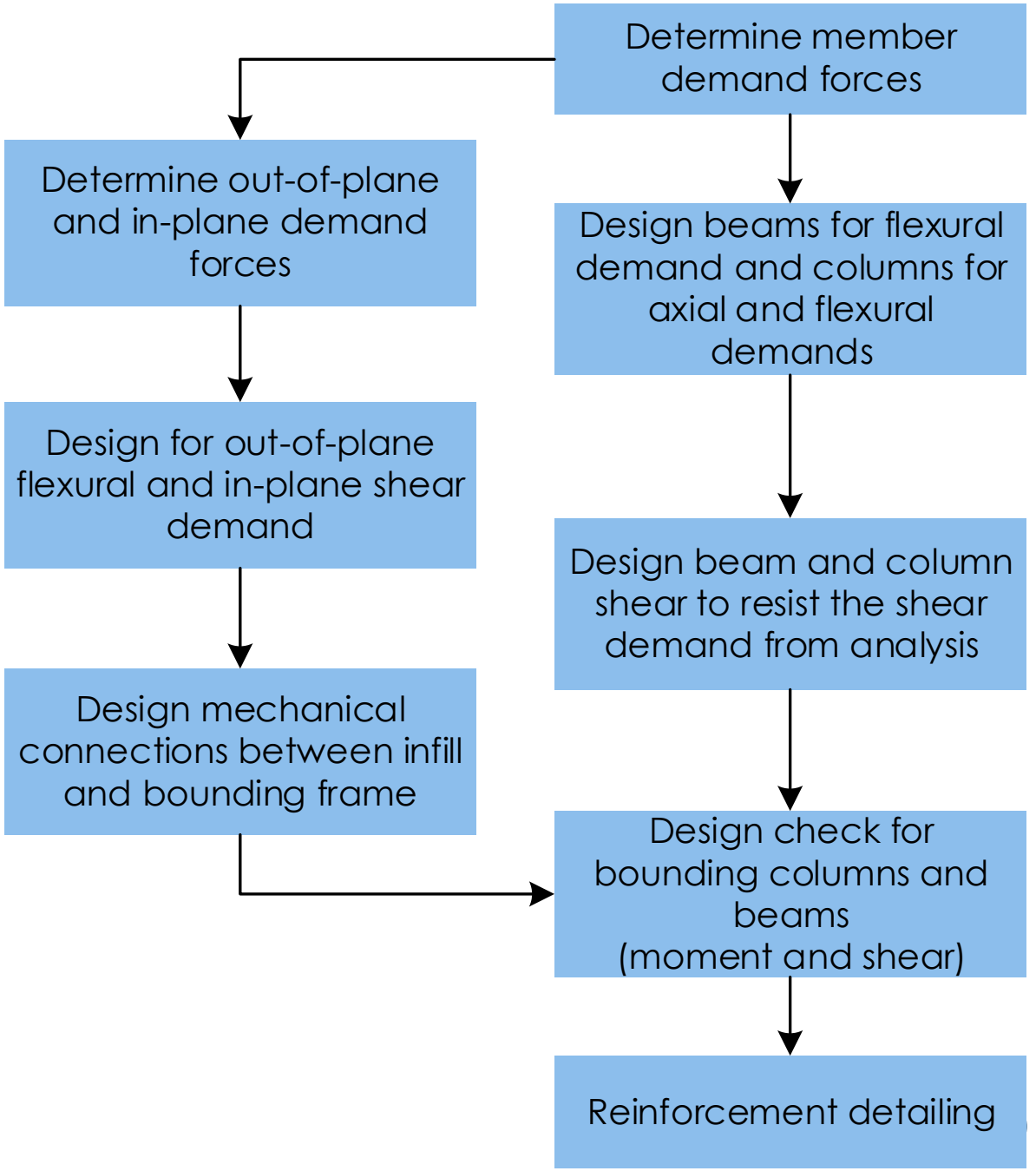
Overall Design Procedure – Approach 2



Typical Structural Member and Components

Structural System	Element	Typical Component Types
Sys-1: Ordinary RC moment frame with masonry infill walls	Foundation	RC isolated footing for column or RC strip footing for column and wall
	Column	RC column
	Beam	RC beam
	Slab on grade	Generally not required
	Plinth beams	RC beam
	Lintels	RC beam
	Intermediate floors	RC slab
	Walls	Unreinforced masonry walls full contact with bounding frames
	Roof system	Steel truss or RC slab

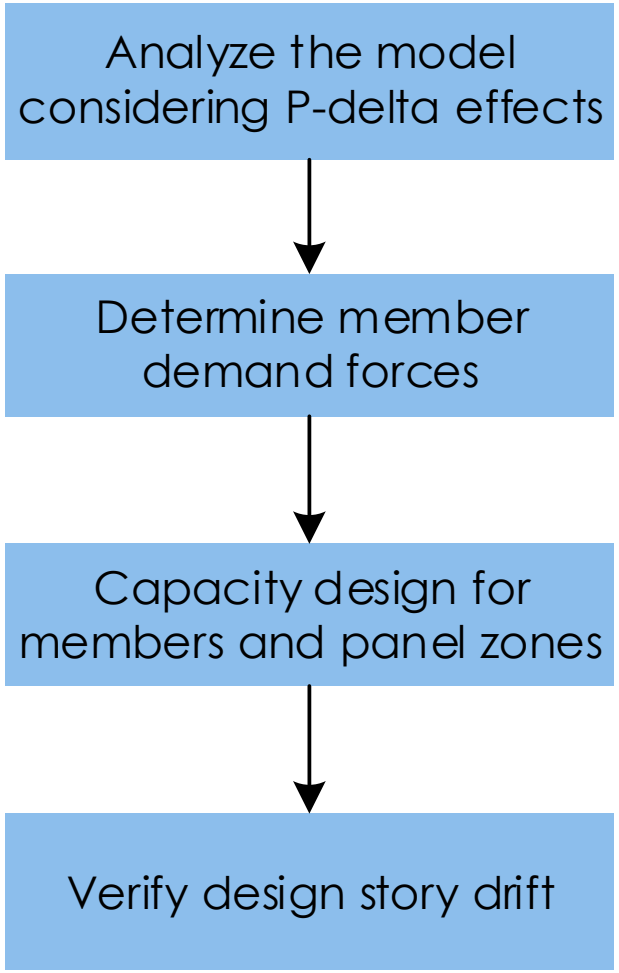
Design Procedure for Ordinary Reinforced Concrete Moment Resisting Frames with Masonry Infill Walls



Typical Structural Member and Components

Structural System	Element	Typical Component Types
Sys-2: Special steel moment resisting frame	Foundation	RC isolated footing for column RC strip footing for column
	Column	Steel hollow box or H, I or W shapes, or built up sections
	Beam	Steel hollow box or I sections, or built up sections
	Slab on grade	Generally not required
	Plinth beams	RC beam
	Lintels	RC beam
	Intermediate floors	Composite slab
	Walls	Unreinforced masonry walls, Light weight partitions (non-load bearing walls)
	Roof system	Steel truss or composite slab

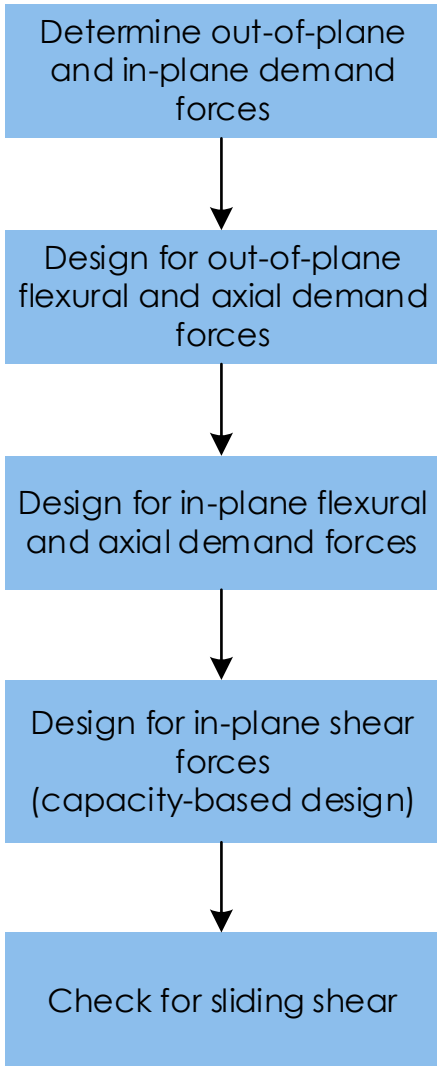
Special Steel Moment Resisting Frames



Typical Structural Member and Components

Structural System	Element	Typical Component Types
Sys-3: Reinforced interlocking bearing wall (Habitech system)	Foundation	Brick or stone RC strip footing for wall reinforced stone masonry in C/C mortar
	Bearing wall	Compressed interlocking blocks, reinforced with rebars
	Slab on grade	Generally not required
	Plinth beams	RC beam, blocks reinforced with rebars
	Lintels	RC beam, blocks reinforced with rebars
	Intermediate floors	RC slab, Habitech waist slab or similar
	Roof system	Steel truss or RC slab

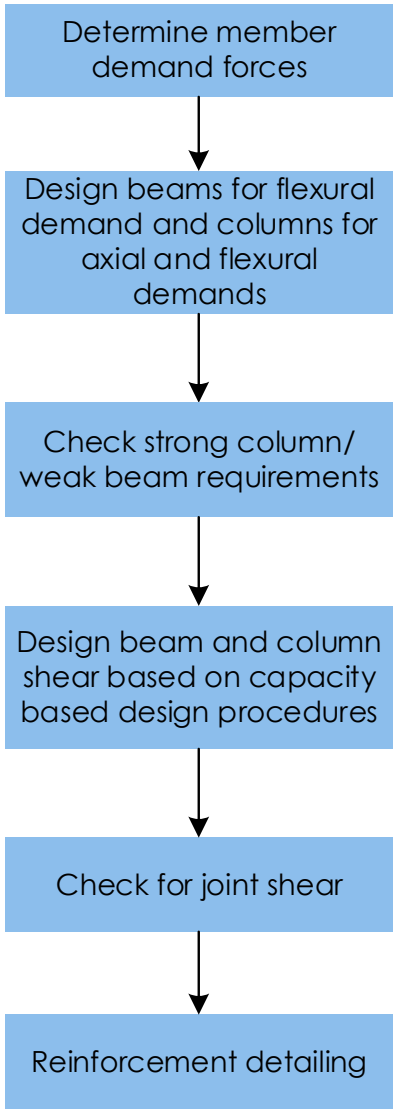
Reinforced Interlocking Bearing Walls



Typical Structural Member and Components

Structural System	Element	Typical Component Types
Sys-4: Special reinforced concrete moment frame	Foundation	RC isolated footing for column RC strip footing for column
	Column	RC column
	Beam	RC beam
	Slab on grade	Generally not required
	Plinth beams	RC beam
	Lintels	RC beam
	Intermediate floors	RC slab
	Walls	Unreinforced masonry walls, Light weight partitions (non-load bearing walls)
	Roof system	Steel truss or RC slab

Reinforced Concrete Special Moment Resisting Frame



Typical Structural Member and Components

Structural System	Element	Typical Component Types
Sys-5: Cold-formed steel ordinary moment frame	Foundation	RC isolated footing for column RC strip footing for column
	Column	Cold-formed channel sections
	Beam	Cold-formed channel sections
	Slab on grade	Generally not required
	Plinth beams	RC beam
	Lintels	RC beam
	Intermediate floors	Not permitted.
	Walls	Unreinforced masonry walls, Light weight partitions (non-load bearing walls)
	Roof system	Cold-formed steel channel truss

Cold-formed steel ordinary moment resisting frames

- Cold-formed steel ordinary moment resisting frames shall be proportioned and detailed in such a way that the frame will remain essentially elastic or design the higher strength to reduce the high ductility demands under earthquakes.

- As the mass of structural system is small, the design will be primarily governed by wind loading.

Typical Structural Member and Components

Structural System	Element	Typical Component Types
Sys-6: Hot-rolled steel ordinary moment frame	Foundation	RC isolated footing for column RC strip footing for column
	Column	Steel hollow box or H, I or W shapes sections
	Beam	Steel hollow box or I sections
	Slab on grade	Generally not required
	Plinth beams	RC beam
	Lintels	RC beam
	Intermediate floors	Composite slab
	Walls	Unreinforced masonry walls, Light weight partitions (non-load bearing walls)
	Roof system	Steel truss or composite slab

Hot-rolled steel ordinary moment resisting frames

- Hot-rolled steel ordinary moment resisting frames shall be designed and detailed for higher strength to reduce the high ductility demands.

Typical Structural Member and Components

Structural System	Element	Typical Component Types
Sys-7: Timber structure	Foundation	RC isolated footing for column RC strip footing for column
	Column	Timber column
	Beam	Timber beam
	Slab on grade	Generally not required
	Plinth beams	RC beam
	Intermediate floors	Timber floor
	Roof system	Timber truss

Timber structure

- Wood-frame shear walls sheathed with shear panels of particle board, structural fiber board, and gypsum wall board are used to resist the seismic forces.
- Bearing wall system category would be applicable because shear walls used for seismic force resistance also function to support gravity loads of a building.

- Materials, loading and load combination should be according to code based provisions.

- Typical modeling, analysis and design procedure of structural systems are also explained in document.

- Seismic performance-based evaluation of structural systems are also explained in document.

References

- Structural design criteria for type design of school buildings, DOE, Nepal

Any Questions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Thank You