DESIGN OF BEAM-COLUMNS

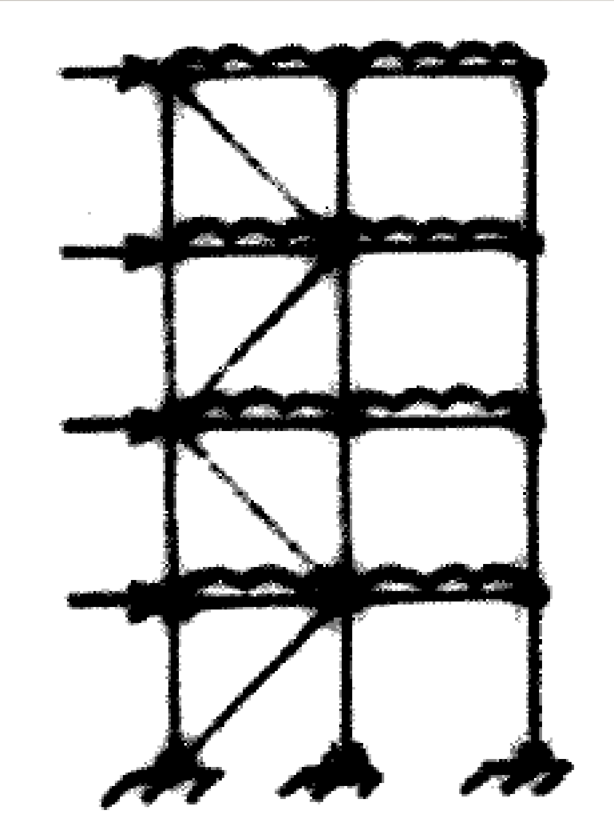
INTRODUCTION

COLUMNS SUBJECT TO AXIAL LOADS ONLY WERE DISCUSSED IN A PREVIOUS LECTURE. WHERE A COLUMN IS ADDITIONALLY SUBJECTED TO MOMENTS THE DESIGN APPROACH IS INTERACTIVE IN CHARACTER AND IS COVERED IN CLAUSES 6.2.1 AND 6.3.3 OF EC3.

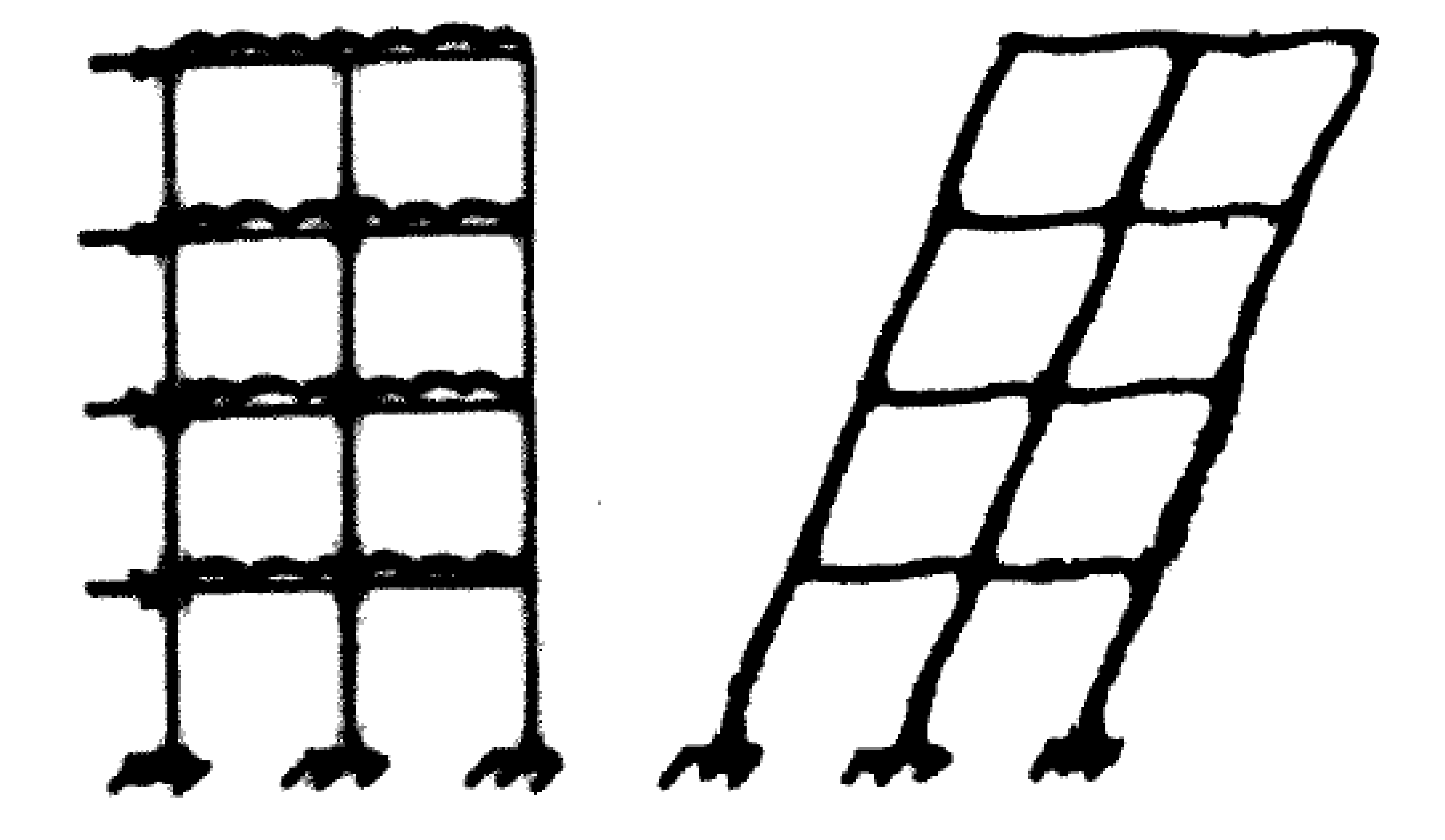
UNDER THIS SYSTEM OF LOADING TWO CHECKS ARE USUALLY NECESSARY: LOCAL CAPACITY AND OVERALL BUCKLING. THESE CHECKS ARE CONDITIONAL UPON SECTION CLASSIFICATION AND THE METHOD OF ANALYSIS/DESIGN OF THE STRUCTURE.

METHODS OF DESIGN

- **SIMPLE DESIGN – ALL JOINTS ARE ASSUMED TO BE PINNED. THE STRUCTURE IS INVARIABLY BRACED**
- **CONTINUOUS DESIGN – BEAMS AND COLUMNS ARE CONNECTED SUCH THAT THEY CAN RESIST FORCES AND MOMENTS IN MEMBERS WHICH THEY ATTACH.**
- **SEMI-CONTINUOUS DESIGN – PARTIAL CONTINUITY EXISITS BETWEEN MEMBERS**



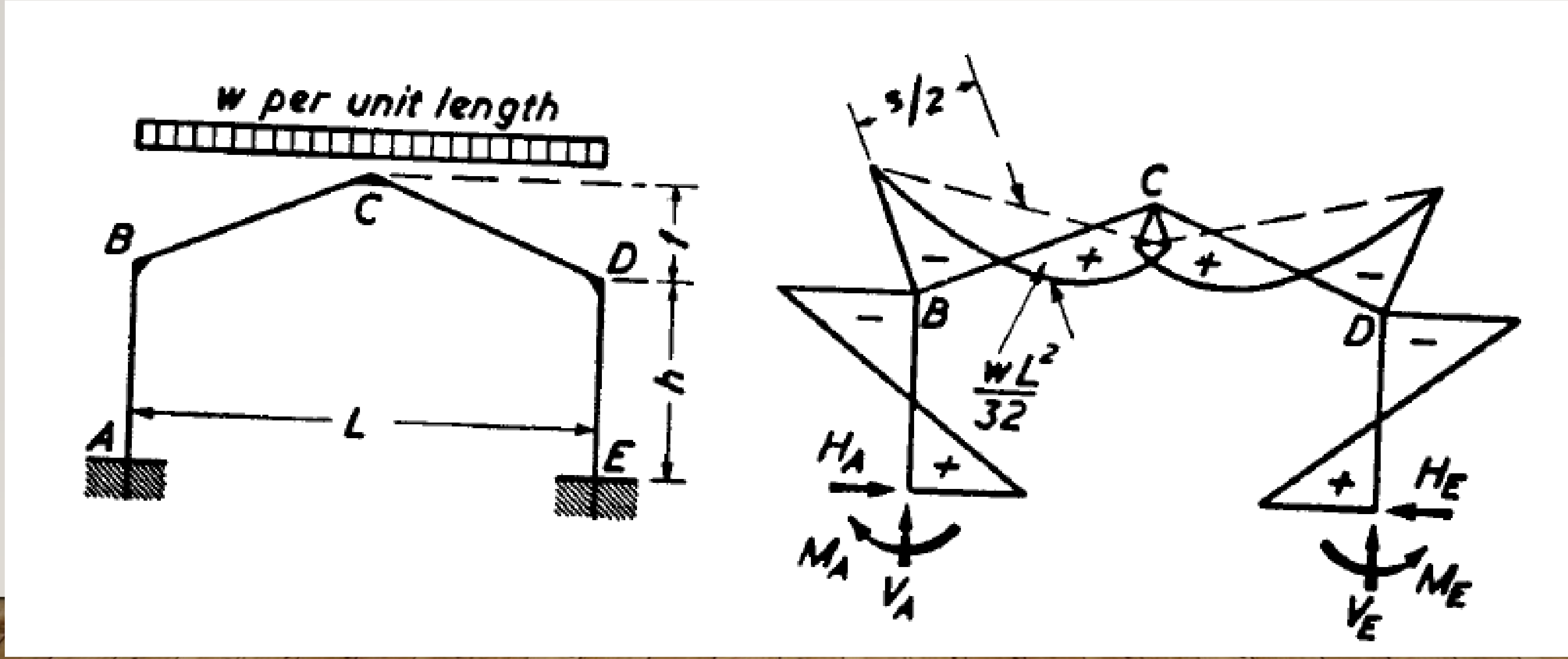
SIMPLE DESIGN



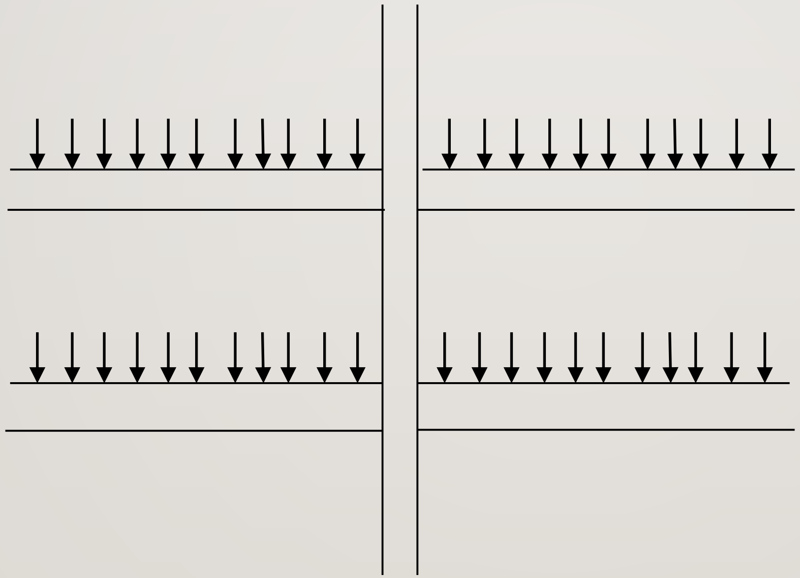
CONTINUOUS DESIGN

RIGID CONSTRUCTION: PORTAL FRAME

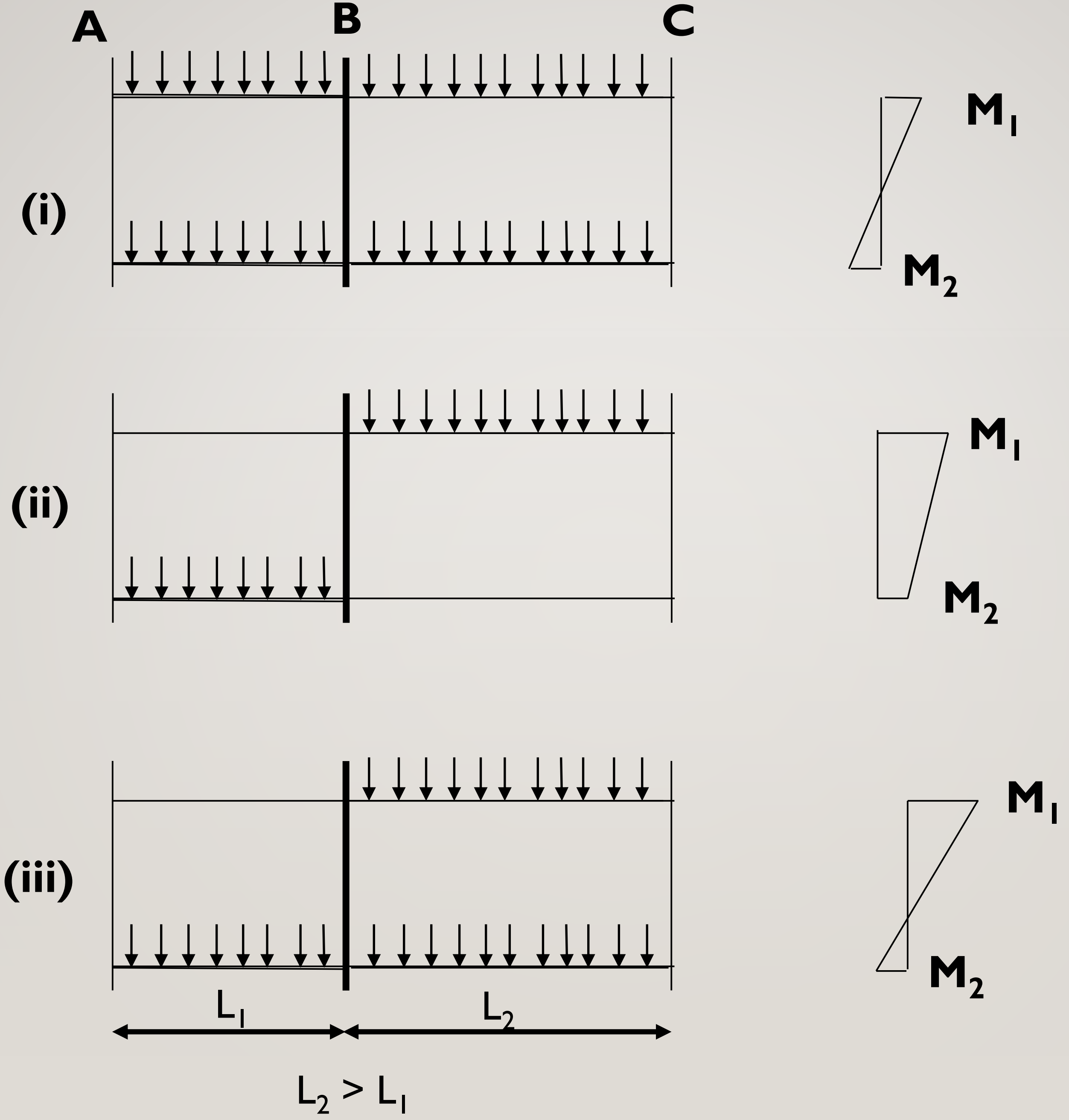
BEAM AND COLUMN CONNECTIONS ARE ASSUMED TO BE FULLY FIXED (RIGID) AND THERE ARE NO ECCENTRICITIES IN THE PLANE OF FIXITY.



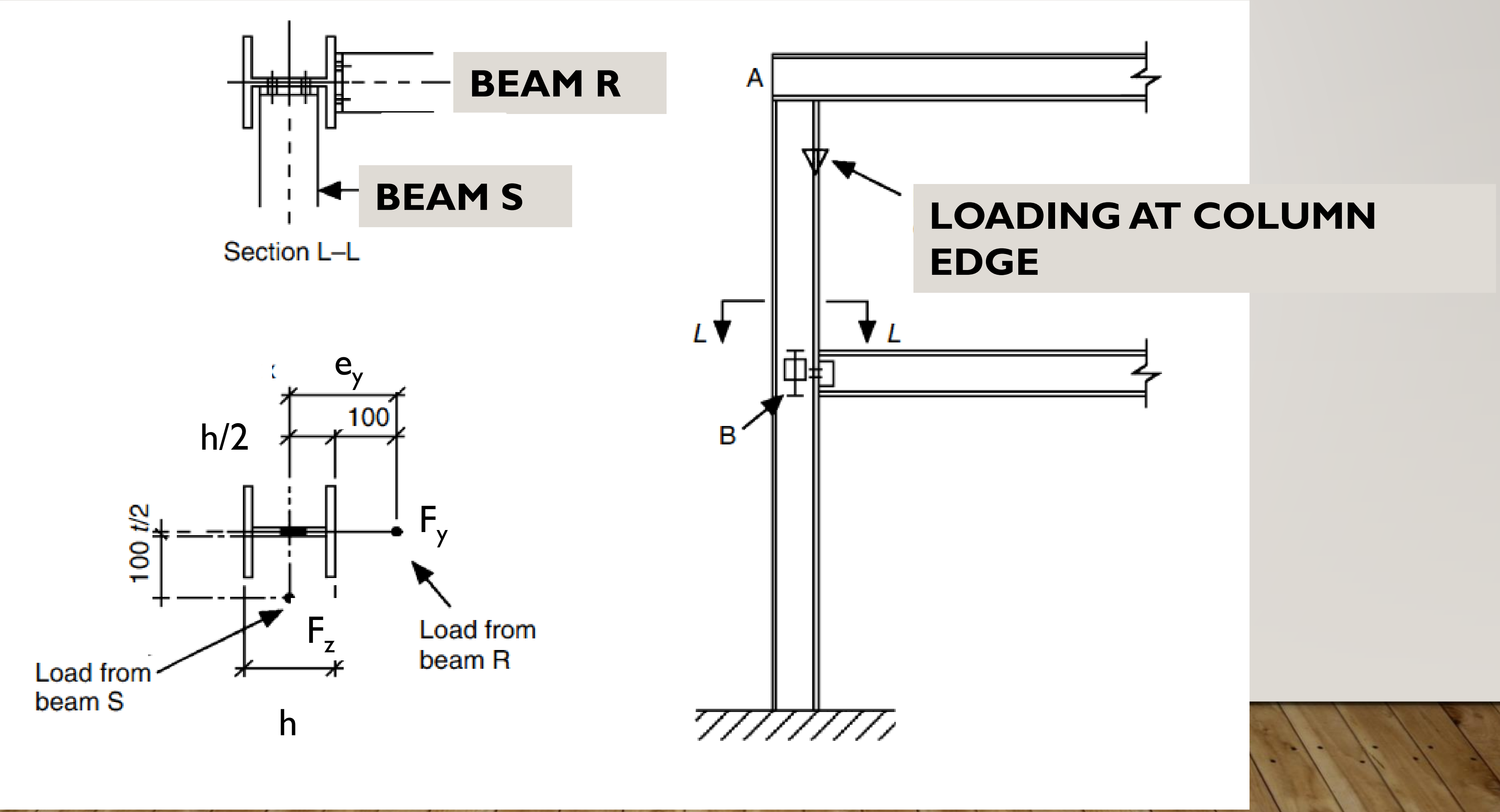
RIGID CONSTRUCTION: BUILDING FRAME



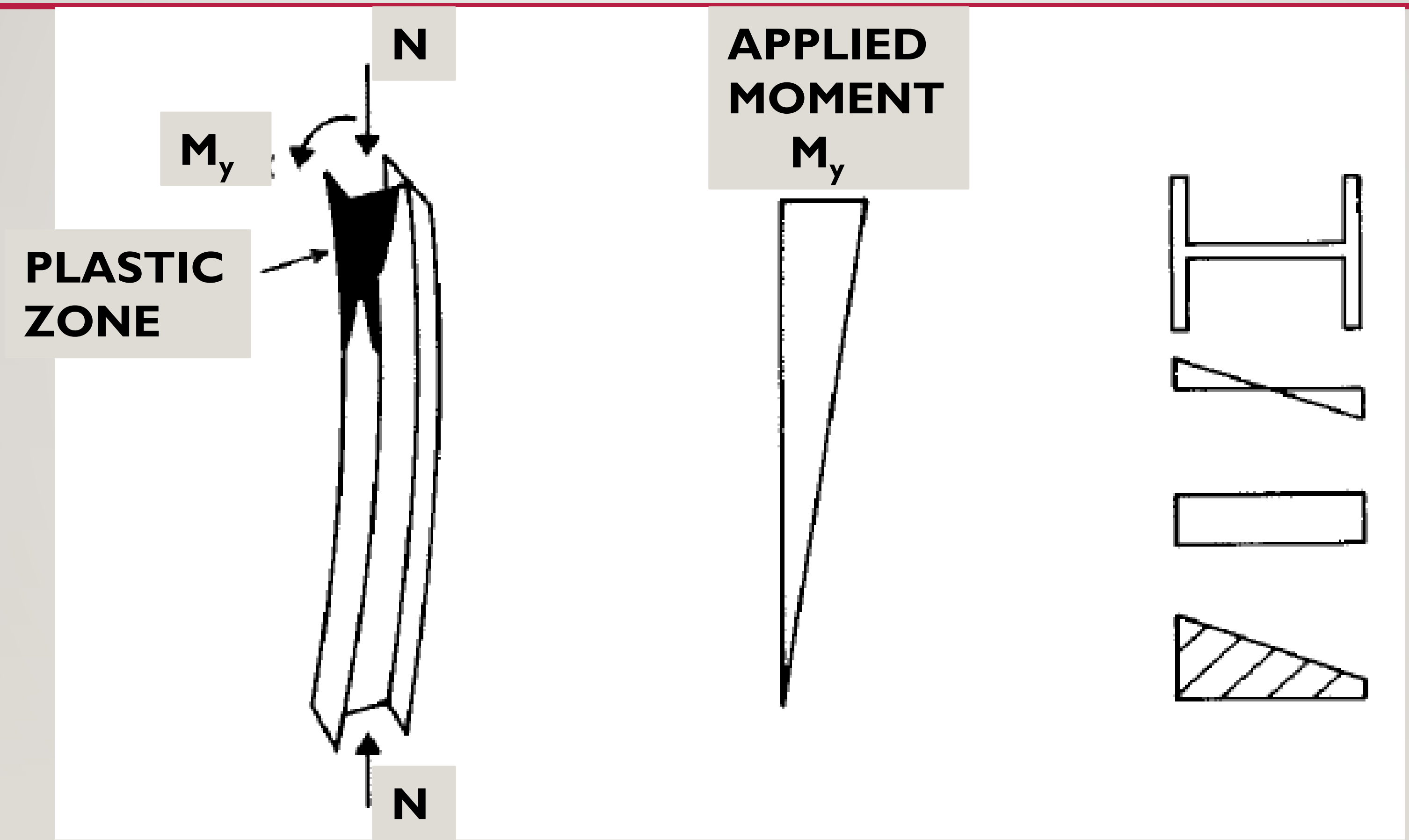
POSSIBLE LOAD CASES



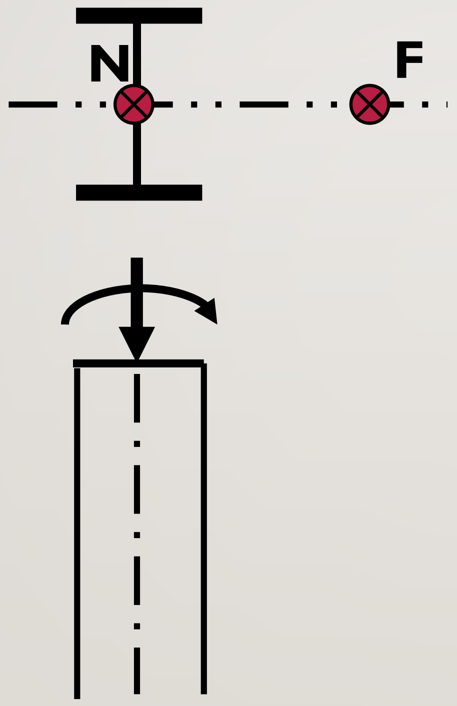
LOAD ECCENTRICITY FOR COLUMNS IN SIMPLE CONSTRUCTION



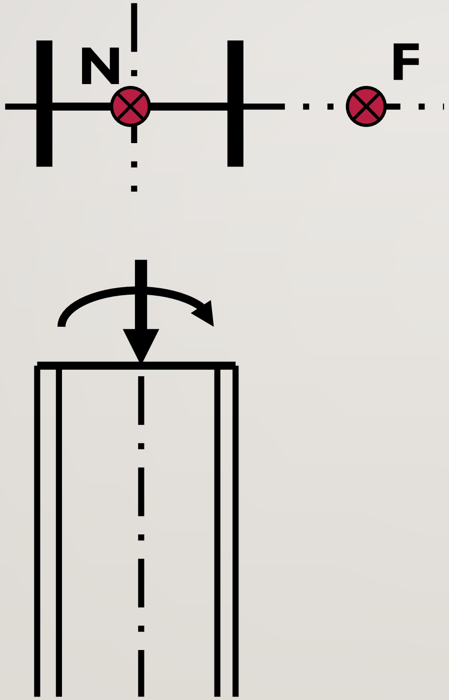
SHORT COLUMN SUBJECT TO AXIAL LOAD AND MAJOR AXIS BENDING



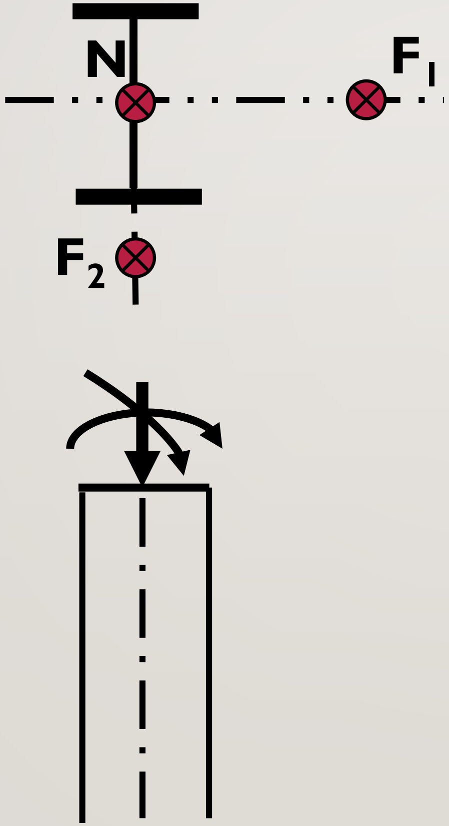
SLENDER COLUMN SUBJECT TO AXIAL LOADING AND MINOR AXIS BENDING



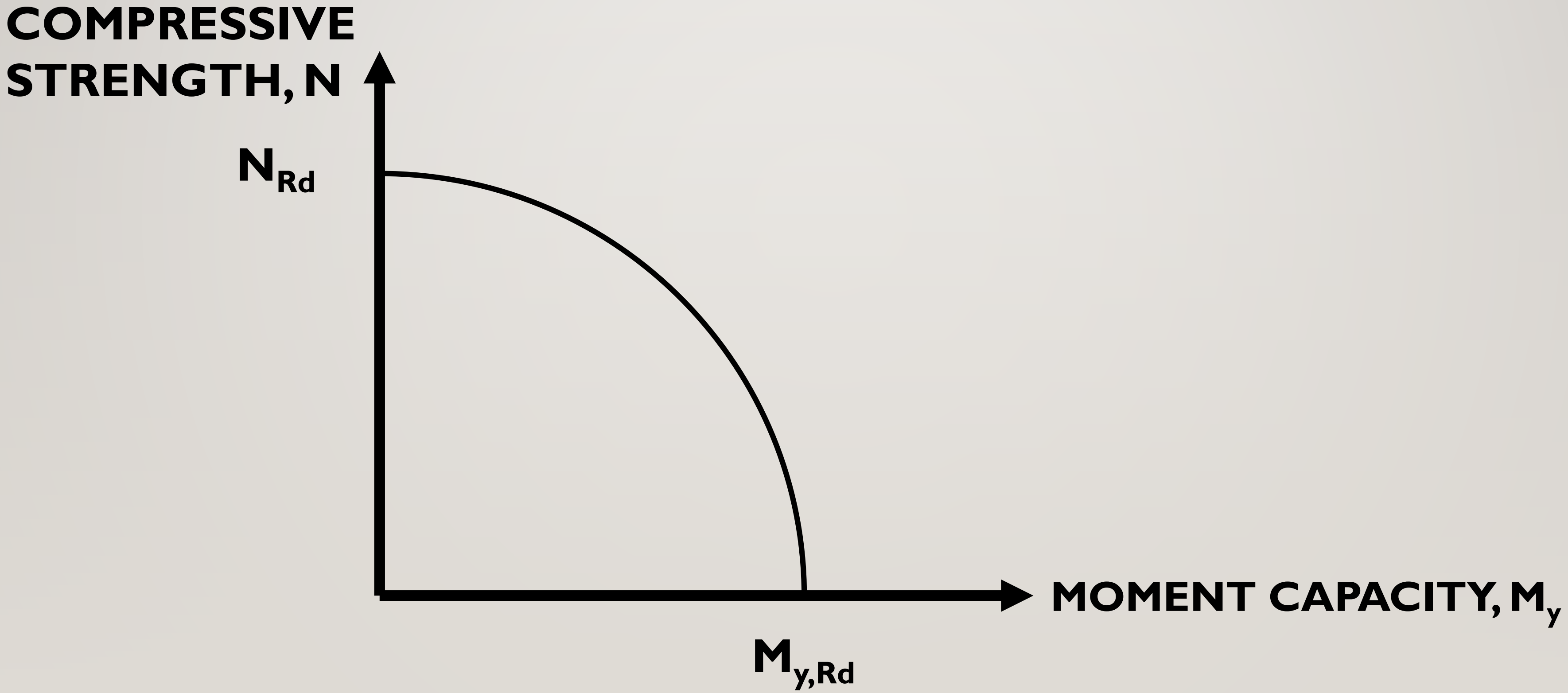
SLENDER COLUMN SUJECT TO AXIAL LOADING AND MAJOR AXIS BENDING



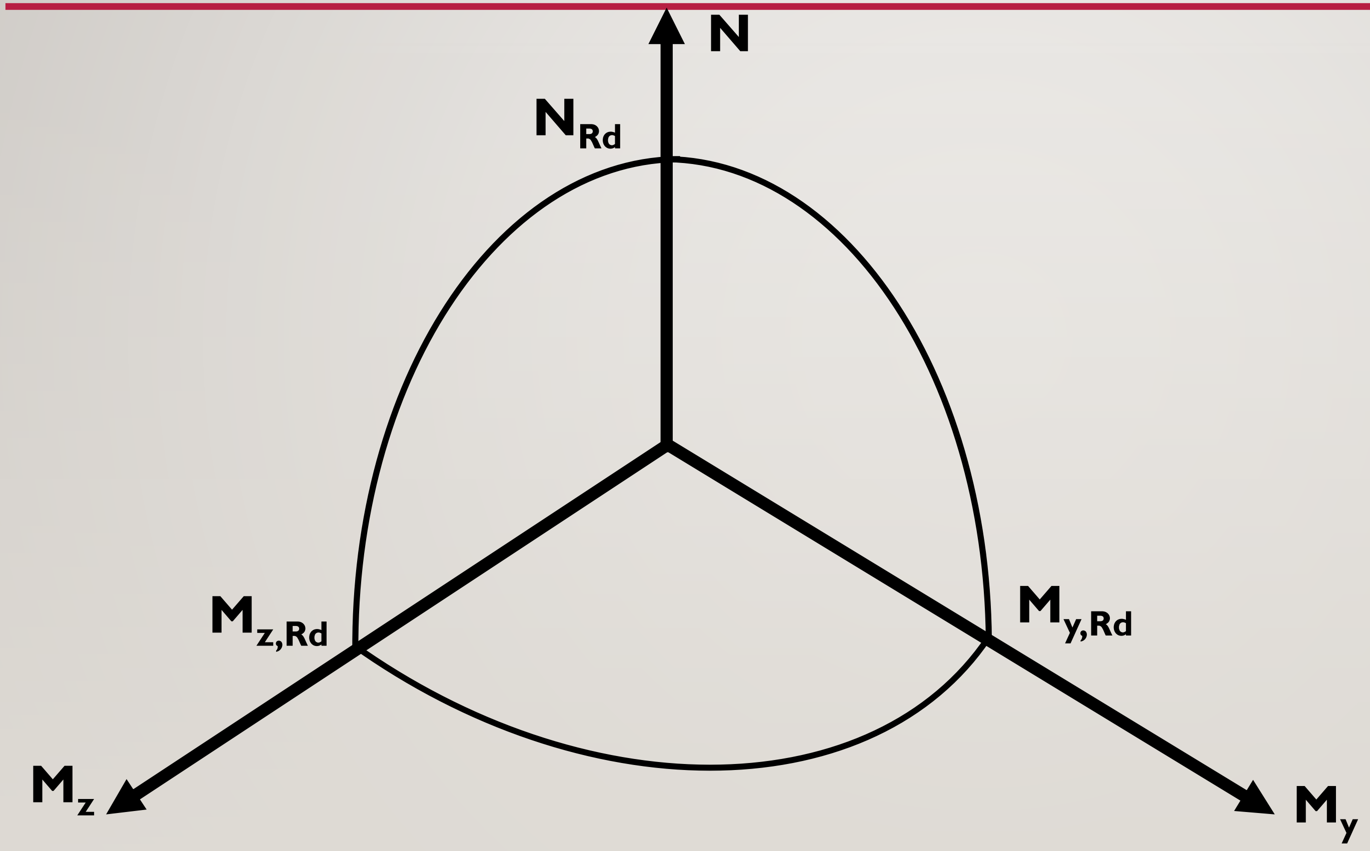
SLENDER COLUMN SUBJECT TO AXIAL LOADING AND BIAXIAL BENDING



LOAD CAPACITY UNDER AXIAL LOAD AND UNI-AXIAL BENDING



LOAD CAPACITY UNDER AXIAL LOAD AND BI-AXIAL BENDING



COLUMN DESIGN: GENERAL PRINCIPLES

A STRUCTURAL MEMBER SUBJECTED TO BOTH AXIAL FORCE AND MOMENTS IS TERMED A BEAM-COLUMN.

WHEN COMBINED CONDITIONS OBTAIN, STRENGTH MAY BE LINKED TO EITHER OF THE FOLLOWING:

- LOCAL CAPACITY
- OVERALL BUCKLING

IT IS NECESSARY TO ASSESS ALL POSSIBLE LOADING REGIMES SINCE SEVERAL FORCE-MOMENT RELATIONSHIPS WILL EXIST. THIS IS IMPORTANT WHEN THE COLUMN FORMS PART OF A RIGID FRAME.

COLUMN DESIGN: SIMPLE STRUCTURES

- IN GENERAL, THE EFFECTIVE LENGTH OF COLUMNS IN BRACED MULTI-STOREY STRUCTURES SHOULD BE TAKEN AS THE STOREY HEIGHT.
- COLUMNS SHOULD BE EFFECTIVELY CONTINUOUS AT THEIR SPLICES
- NOMINAL MOMENTS ARE CALCULATED USING THE FULL VALUE OF THE IMPOSED LOAD, ASSUMING THAT BEAM REACTIONS ACT 100mm FROM THE FACE OF THE COLUMN (WEB/FLANGE).
- PATTERN LOADING MAY BE IGNORED

COLUMN DESIGN: SIMPLE SRUCTURES (CONT'D)

- **THE NET MOMENT APPLIED AT ANY ONE LEVEL SHOULD BE DIVIDED BETWEEN THE COLUMN LENGTHS ABOVE AND BELOW THAT LEVEL IN PROPORTION TO THE STIFFNESS COEFFICIENT I/L OF EACH LENGTH, EXCEPT THAT WHEN THE RATIO OF THE STIFFNESS COEFFICIENTS DOES NOT EXCEED 1.5 THE MOMENT MAY OPTIONALLY BE DIVIDED EQUALLY.**

COLUMN DESIGN: SIMPLE STRUCTURES (CONT'D)

LOCAL CAPACITY CHECK IS UNNECESSARY

MEMBER STABILITY CAN BE CHECKED USING THE FOLLOWING RELATIONSHIP

$$\frac{N_{Ed}}{N_{b,z,Rd}} + \frac{M_{y,Ed}}{M_{b,Rd}} + 1.5\frac{M_{z,Ed}}{M_{z,Rd}} \leq 1$$

where

$M_{b,Rd} = \chi_{LT} W_y f_y / \gamma_{M1}$

$M_{z,Rd} = W_{pl,z} f_y / \gamma_{M1}$

$$N_{b,z,Rd} = \frac{\chi_z A f_y}{\gamma_{M1}}$$

CONTINUOUS STRUCTURES

- **BEAM AND COLUMN CONNECTIONS ARE ASSUMED TO BE FIXED AND THERE ARE NO ECCENTRICITIES IN THE PLANE OF FIXITY.**
- **LOAD REGIMES WILL GIVE RISE TO SEVERAL DESIGN CASES AND IT IS IMPORTANT THAT ALL POSSIBLE COMBINATIONS ARE CONSIDERED DURING MEMBER SIZING.**
- **COLUMN MEMBERS SHOULD BE CHECKED FOR BOTH LOCAL CAPACITY AND OVERALL BUCKLING**

CONTINUOUS STRUCTURES: LOCAL CAPACITY CHECK

MAY BE VERIFIED BY MEANS OF THE FOLLOWING EXPRESSION;

ENSURES THAT THE YIELD STRESS HAS NOT BEEN EXCEEDED.

$$\frac{N_{Ed}}{N_{Rd}} + \frac{M_{y,Ed}}{M_{y,Rd}} + \frac{M_{z,Ed}}{M_{z,Rd}} \leq 1$$

CLASSES 1- 3 ONLY

WHERE

N_{Ed} – AXIAL LOAD

$M_{y,Ed}$ – APPLIED MOMENT ABOUT MAJOR AXIS

$M_{z,Ed}$ – APPLIED MOMENT ABOUT THE MINOR AXIS

N_{Rd} – AXIAL LOAD CAPACITY OF SECTION = Af_y/γ_{M0}

$M_{y,Rd}$ – MOMENT CAPACITY ABOUT MAJOR AXIS = $W_{el,y}f_y/\gamma_{M0}$

$M_{z,Rd}$ – MOMENT CAPACITY ABOUT MINOR AXIS = $W_{el,z}f_y/\gamma_{M0}$

CONTINUOUS STRUCTURES: LOCAL CAPACITY CHECK (CONT'D)

ALTERNATIVE EXPRESSION FOR CLASS 1 AND 2 SECTIONS

$$\left(\frac{M_{y,Ed}}{M_{N,y,Rd}}\right)^{\alpha} + \left(\frac{M_{z,Ed}}{M_{N,z,Rd}}\right)^{\beta} \leq 1.0$$

WHERE

$M_{N,y,Rd}$ DESIGN PLASTIC MOMENT OF RESISTANCE ABOUT y-y REDUCED DUE TO THE AXIAL FORCE N_{Ed}

$M_{N,z,Rd}$ DESIGN PLASTIC MOMENT OF RESISTANCE ABOUT z-z REDUCED DUE TO THE AXIAL FORCE N_{Ed}

α = 2 (FOR I AND H SECTIONS)

$\beta = 5n \geq 1$ (FOR I AND H SECTIONS, WHERE $n = N_{Ed}/N_{pl,Rd}$)

CONTINUOUS STRUCTURES: OVERALL BUCKLING CHECK

VERIFIED BY CHECKING THAT BOTH THE FOLLOWING RELATIONSHIPS ARE SATISFIED

$$\frac{N_{Ed}}{\chi_y N_{Rk}/\gamma_{M1}} + k_{yy}\frac{M_{y,Ed}}{\chi_{LT} M_{y,Rk}/\gamma_{M1}} + k_{yz}\frac{M_{z,Ed}}{M_{z,Rk}/\gamma_{M1}} \leq 1$$

$$\frac{N_{Ed}}{\chi_z N_{Rk}/\gamma_{M1}} + k_{zy}\frac{M_{y,Ed}}{\chi_{LT} M_{y,Rk}/\gamma_{M1}} + k_{zz}\frac{M_{z,Ed}}{M_{z,Rk}/\gamma_{M1}} \leq 1$$

CONTINUOUS STRUCTURES: OVERALL BUCKLING CHECK (CONT'D)

WHERE

N_{Ed}, M_{yEd} and $M_{z,Ed}$	**DESIGN AXIAL LOAD AND MOMENTS**
χ_y AND χ_z	**REDUCTION FACTORS FOR FLEXURAL BUCKLING**
χ_{LT}	**REDUCTION FACTOR FOR L.T.B.**
k_{yy}, k_{yz}, k_{zy} and k_{zz}	**INTERACTION FACTORS**
N_{Rk}	$= Af_y$ **(CLASS 1)**
$M_{y,Rk}$, $M_{z,Rk}$	**RESPECTIVELY,** $W_{pl,y}f_y$, $W_{pl,z}f_y$ **(CLASS 1 AND 2)**

INTERACTION FACTORS

TWO ALTERNATIVE METHODS FOR CALCULATING VALUES OF THE INTERACTION FACTORS ARE PRESENTED IN EC3. METHOD 2, CONTAINED WITHIN ANNEX B, IS SOMEWHAT SIMPLER AND MORE AMENABLE TO HAND CALCULATIONS.