I.T.U.
STRUCTURAL ANALYSIS GROUP
2016-2017 SPRING SEMESTER
GRADUATION DESIGN PROJECT

DESIGN STORAGE BUILDING WHICH IS MADE OF REINFORCED CONCRETE AND STEEL ELEMENTS

PREPARED BY:

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SERCAN TUTKAÇ

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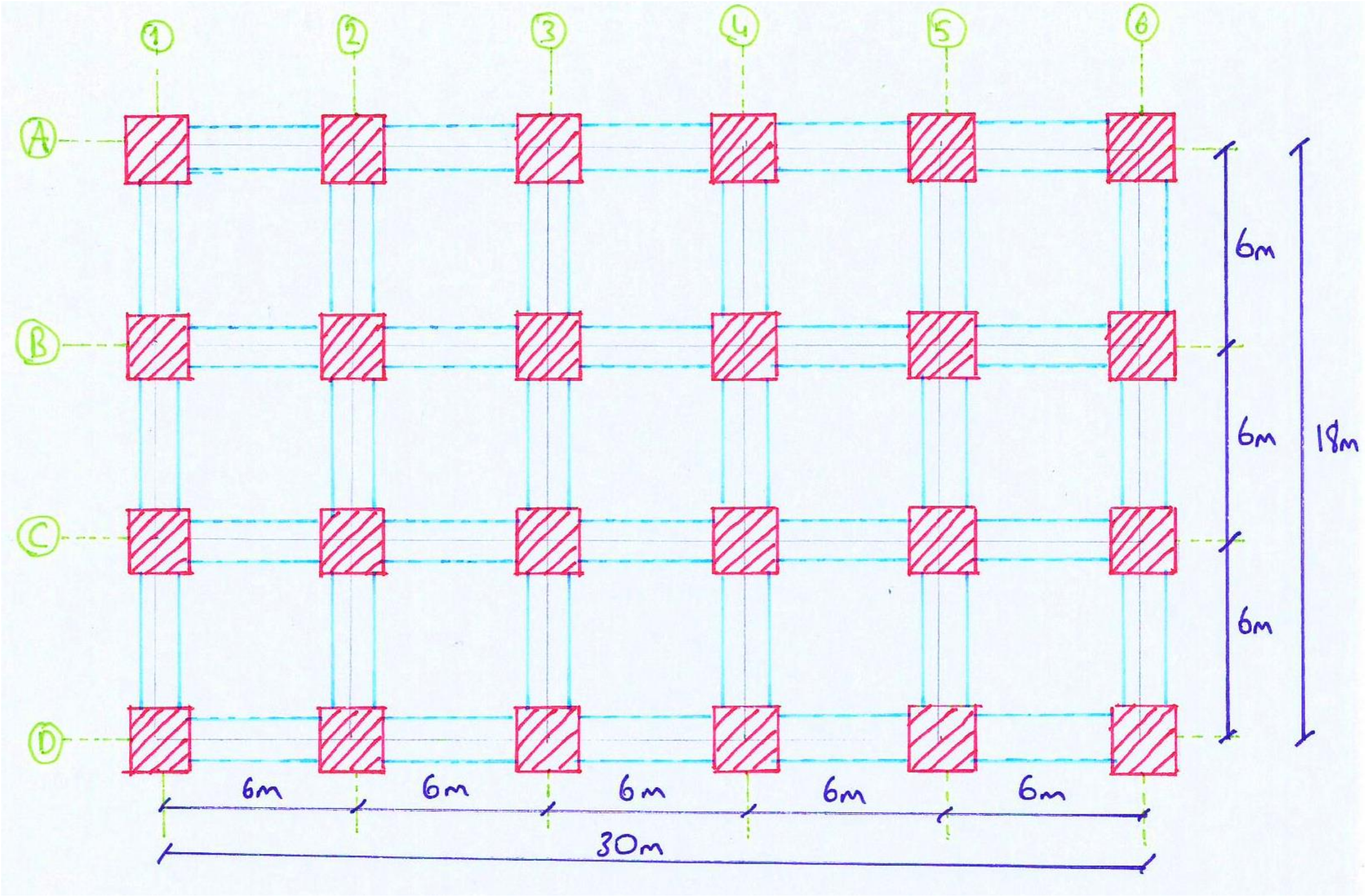
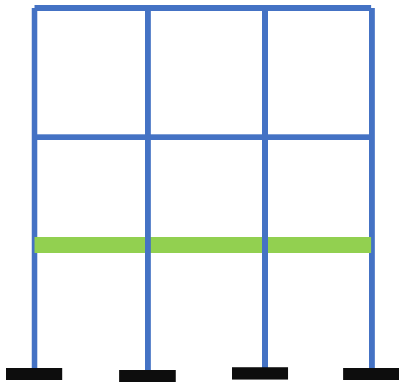
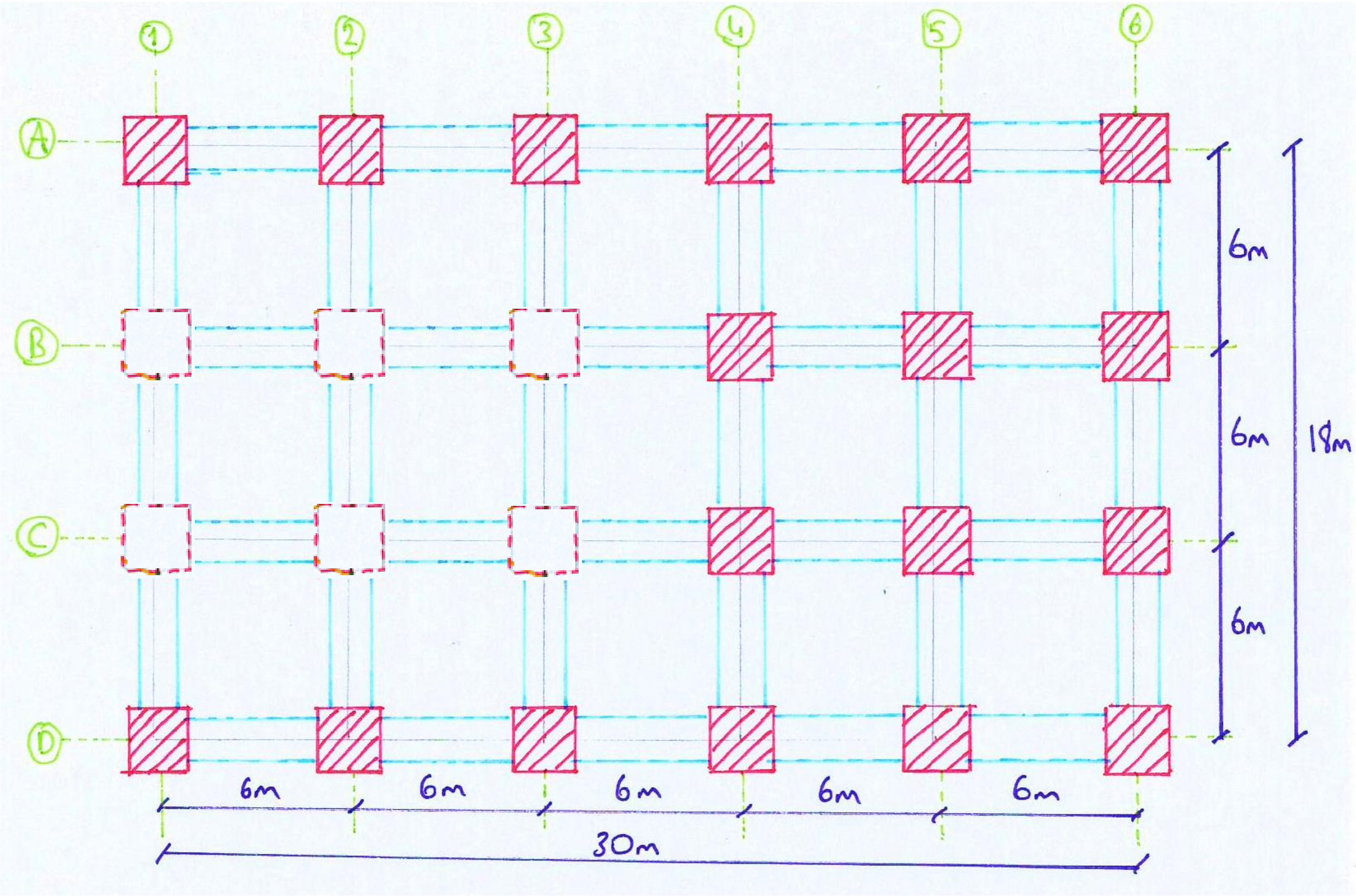
CONTENT

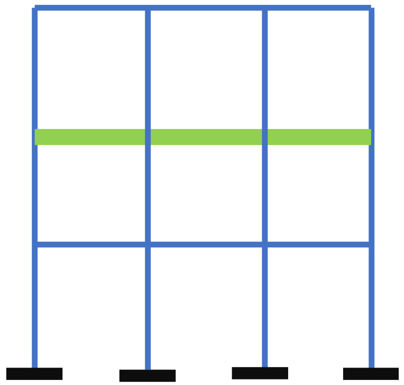
PROJECT DATA	
Building Type	Storage Building
# of Bays (X-Direction)	5
# of Bays (Y-Direction)	3
Plan Dimensions	30x18m
Number of Stories	3
Building Height	14.6m





1. Floor Plan



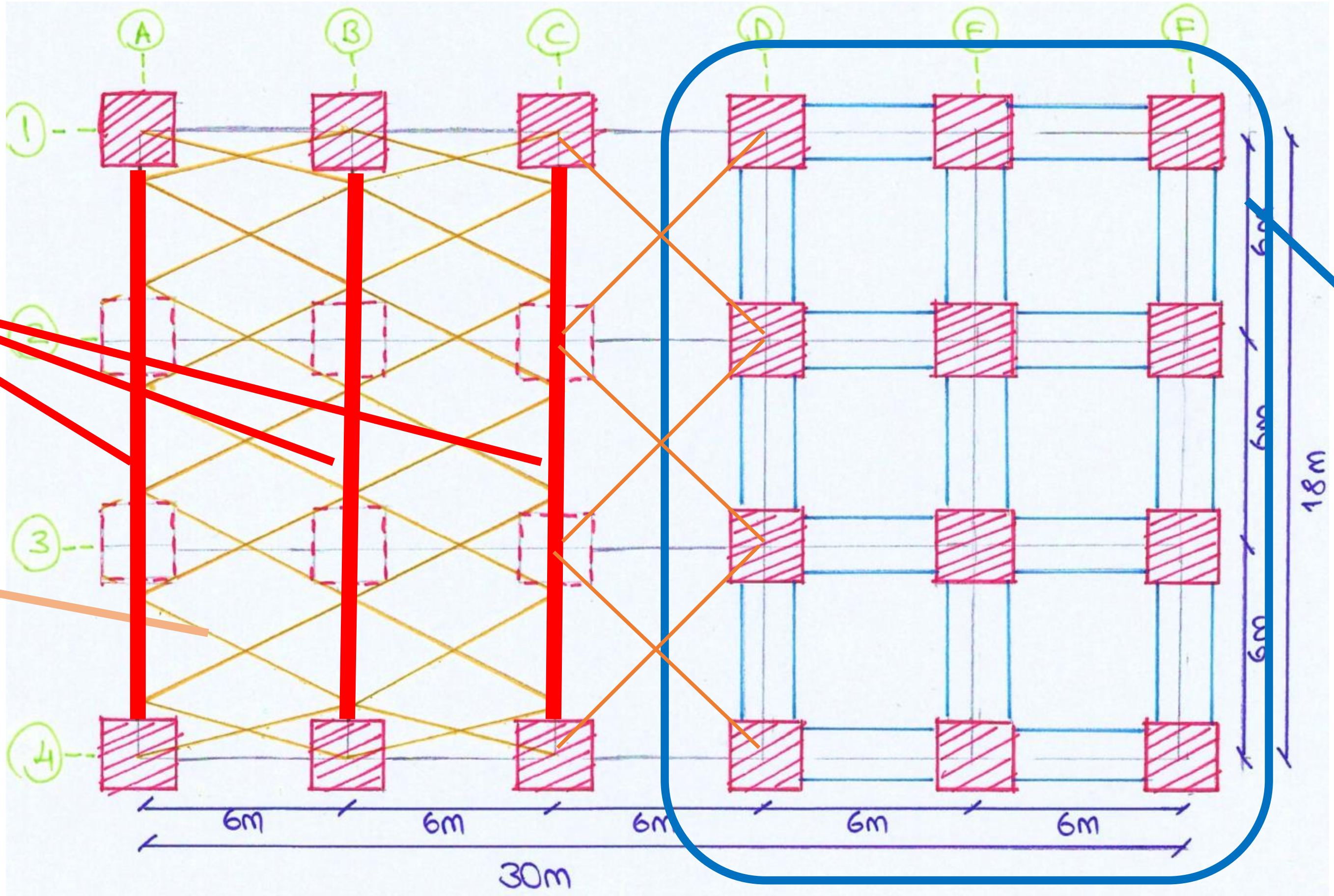


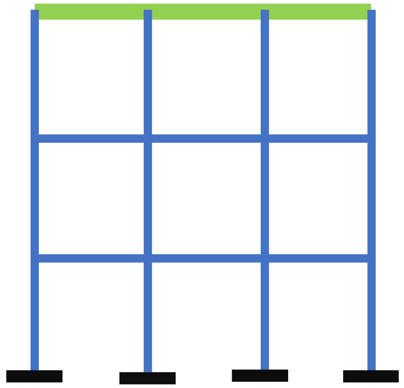
2. Floor Plan

3. Story Plan View

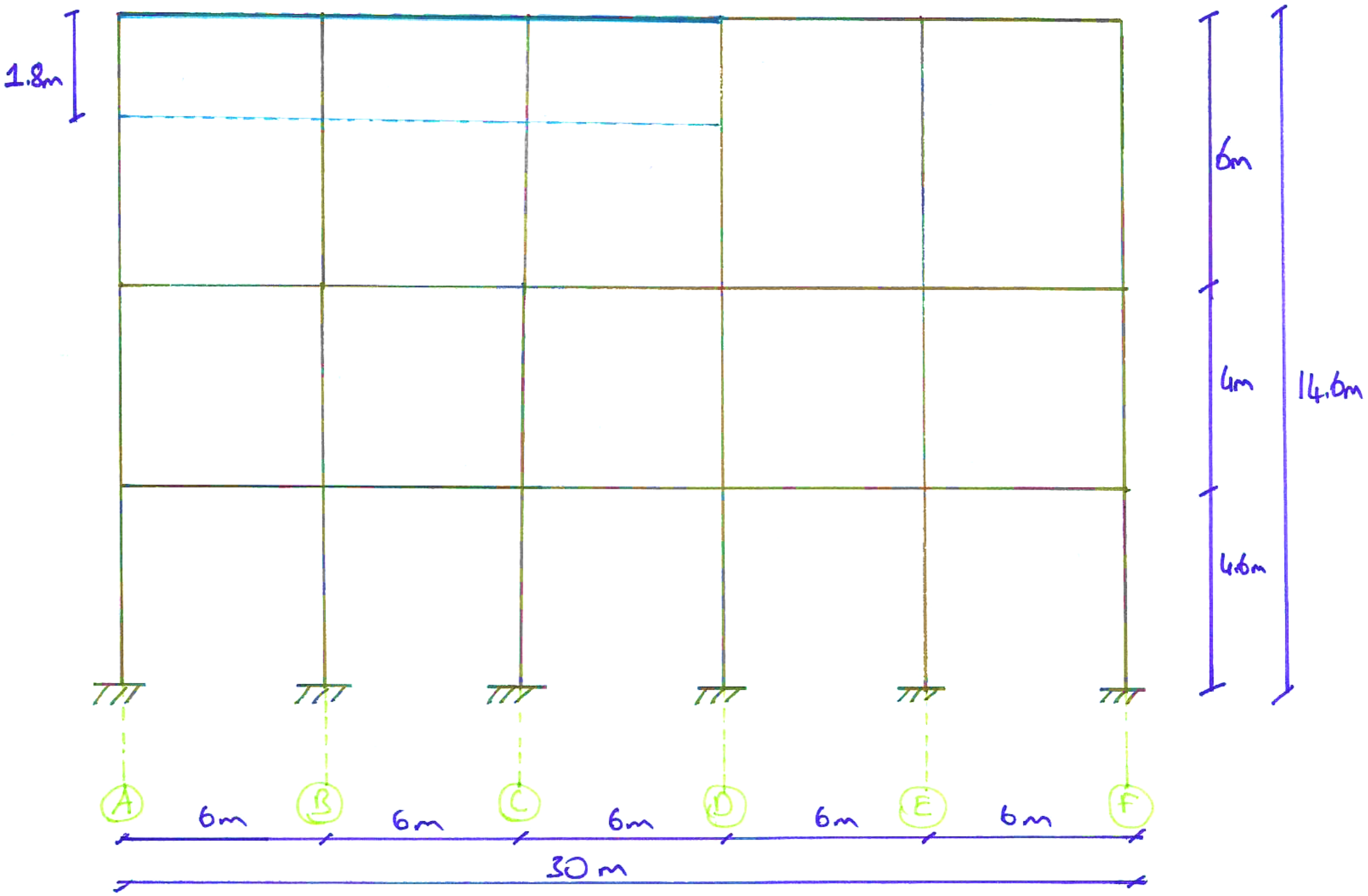
STEEL TRUSS

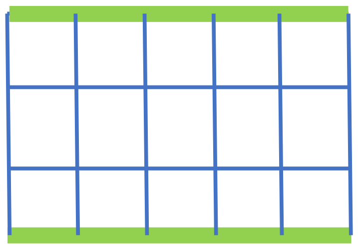
HORIZONTAL STABILITY MEMBERS



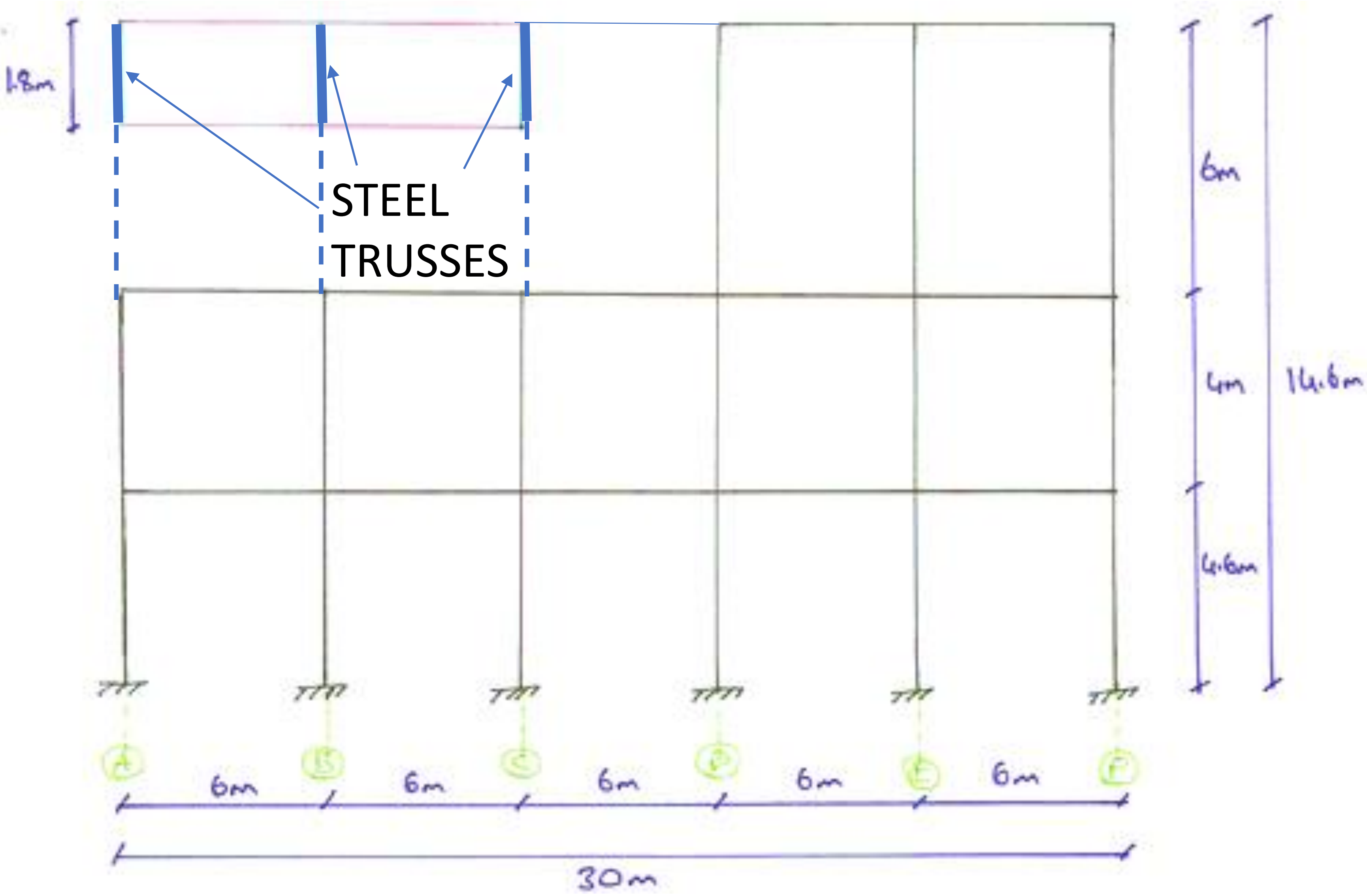


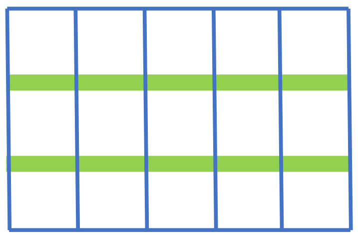
RC FRAME





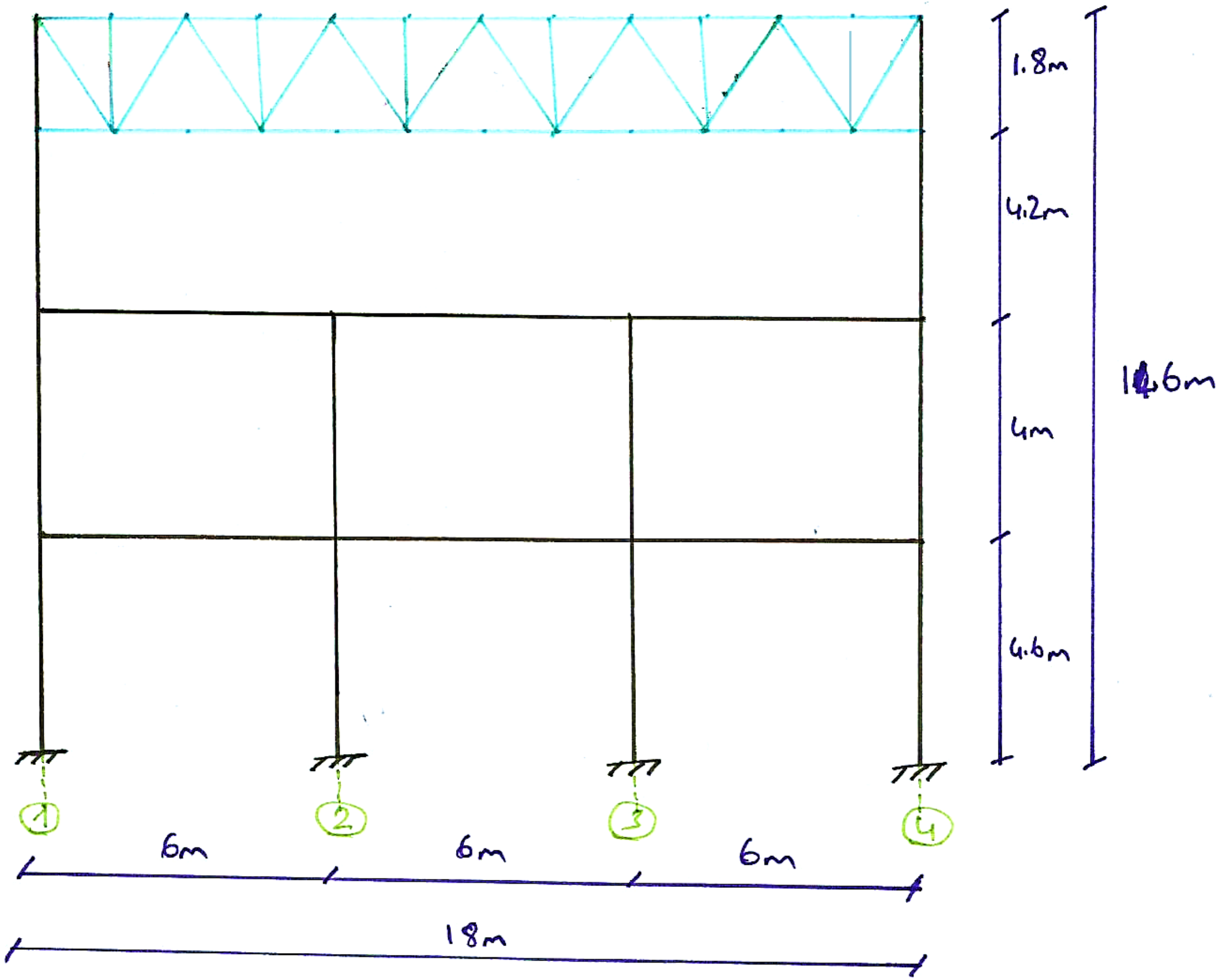
1-1 and 4-4 Axis

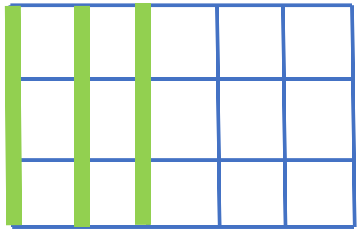




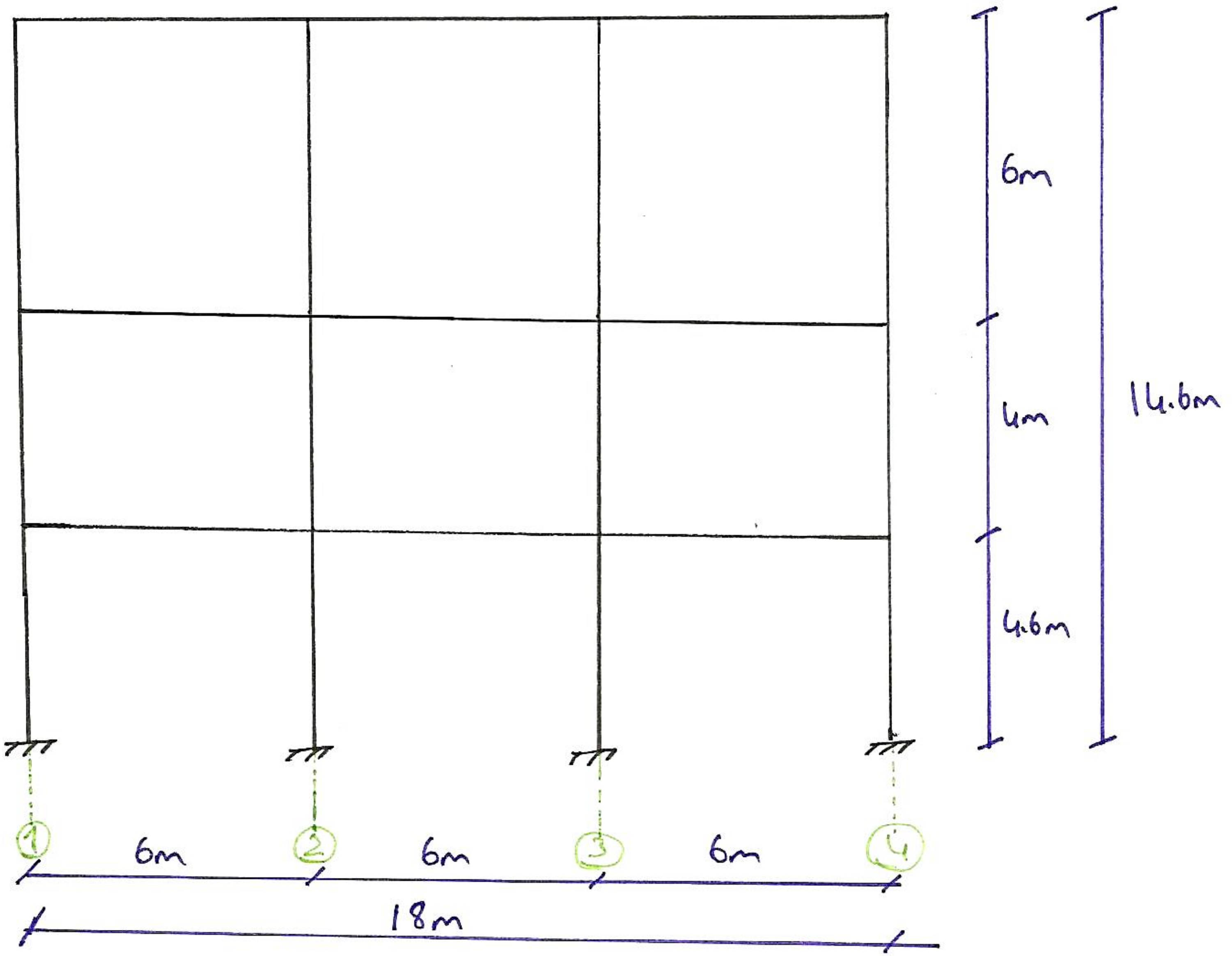
2-2 and 3-3 Axis

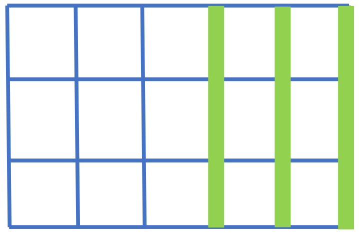
INTRODUCTION: ELEVATIONS





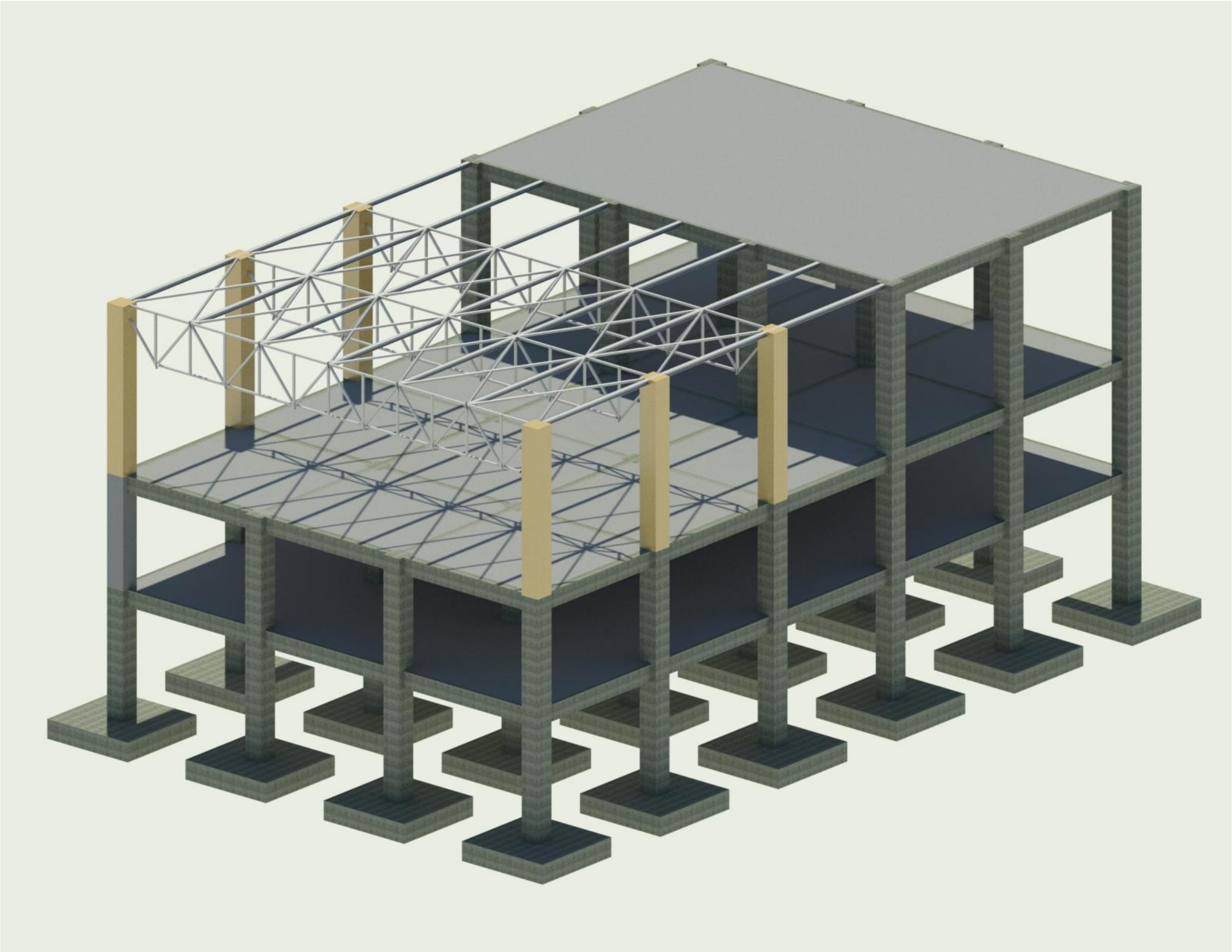
A-A,B-B and C-C Axis





D-D, E-E and F-F Axis

INTRODUCTION: 3D VIEWS



WHY THIS STRUCTURE

- ✓ MOMENT FRAME STRUCTURE
- ✓ WITHOUT SHEAR WALL
- ✓ CANTILEVER COLUMN
- ✓ PROGRAMMING
- ✓ COMBINATION OF STEEL AND RC

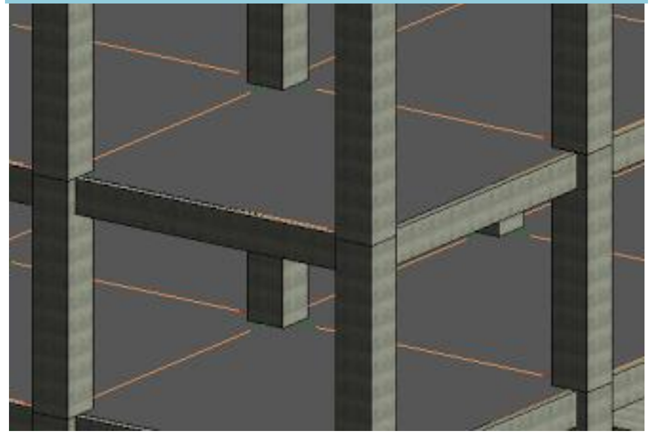
GRAVITY SYSTEM

LATERAL SYSTEM

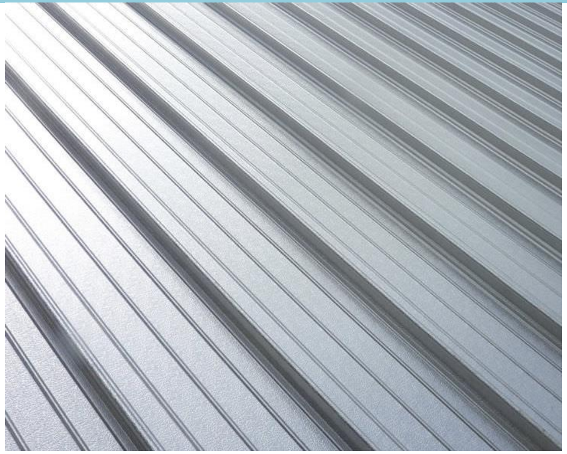
FOUNDATION SYSTEM

DESIGN BASIS: GRAVITY SYSTEM

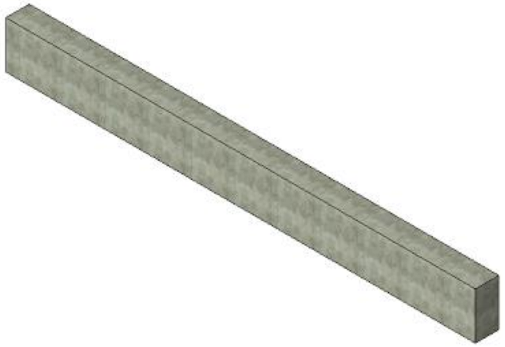
RC SLAB



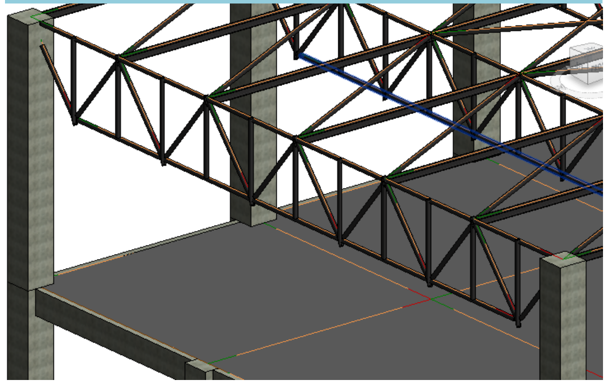
ALIMINIUM MEMBER



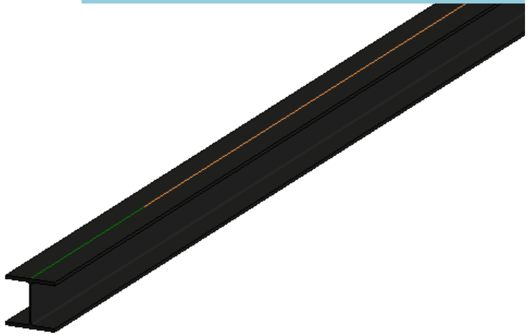
BEAM



TRUSS

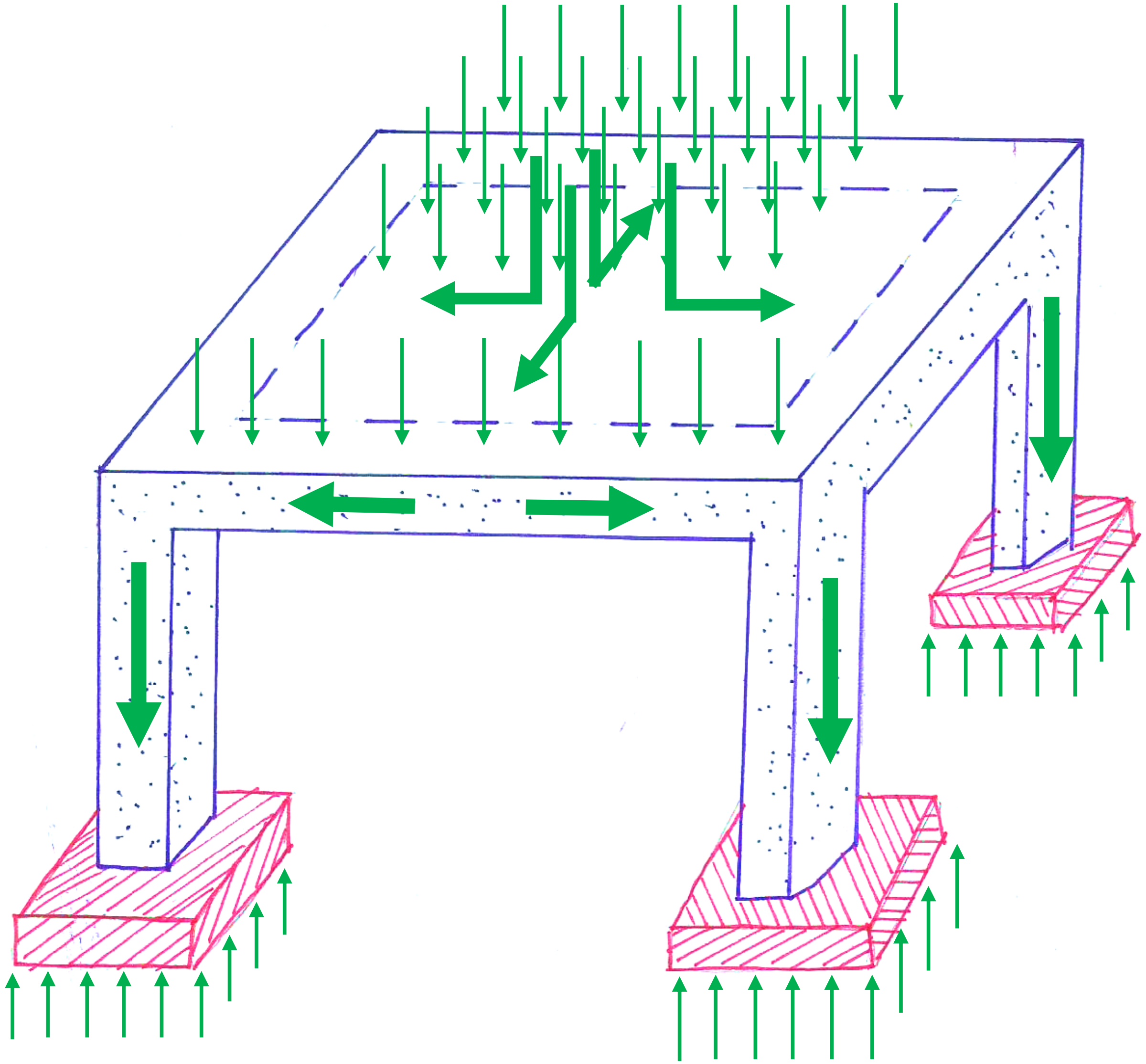


PURLIN



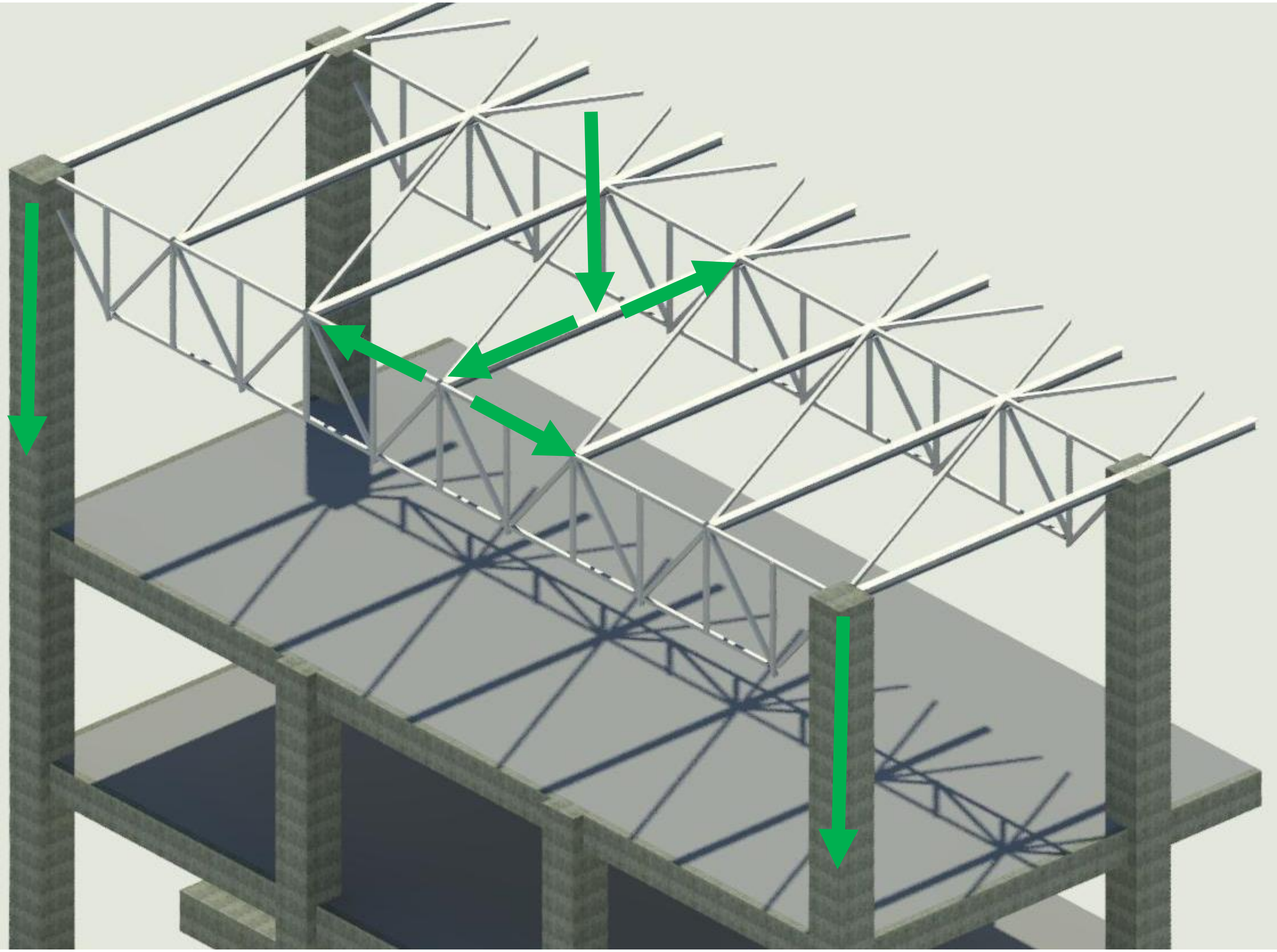
COLUMN

RC SLAB

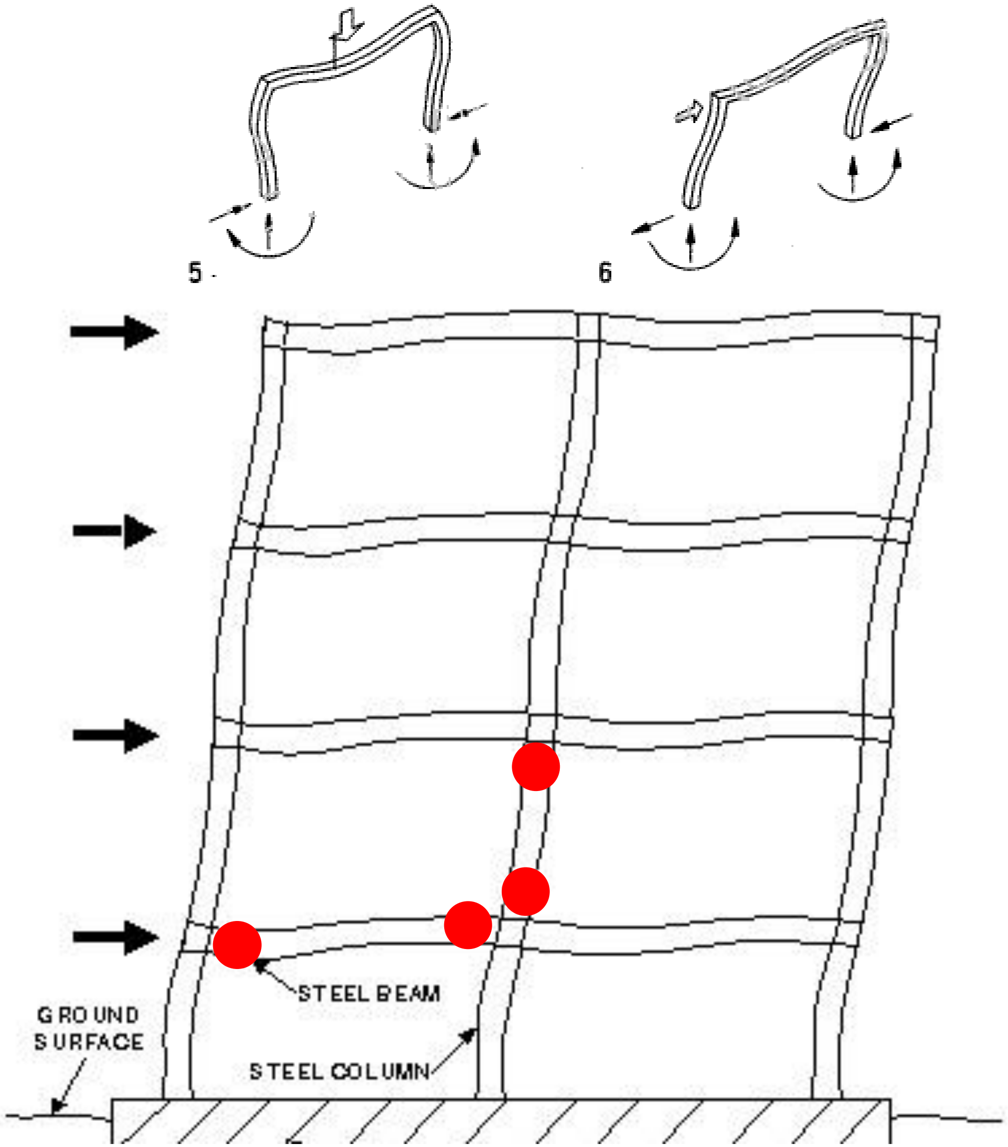


DESIGN BASIS GRAVITY SYSTEM LOAD PATH

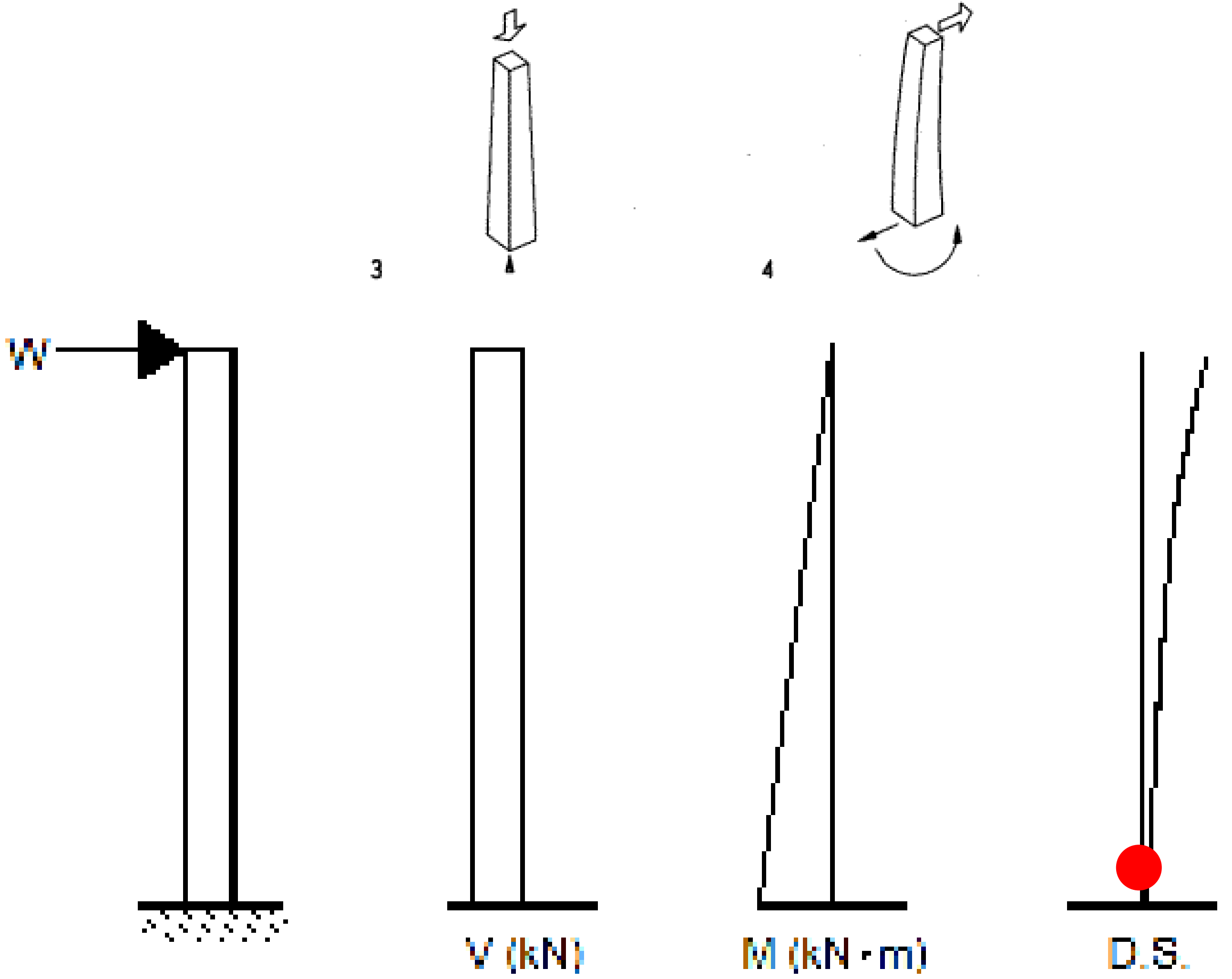
STEEL ROOF



SPECIAL MOMENT RESISTING FRAME

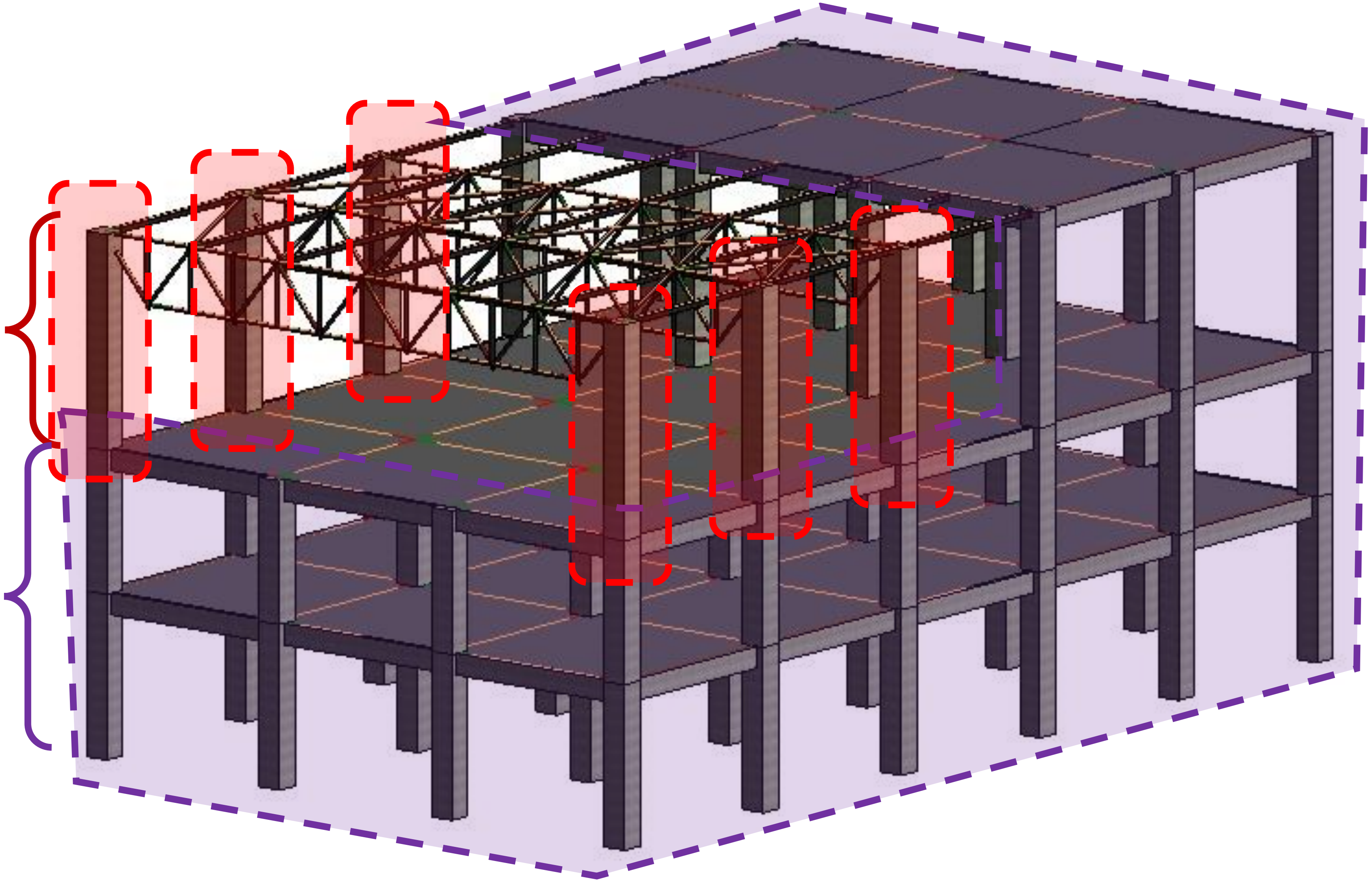


SPECIAL R. C. CANTILEVER COLUMN



SPECIAL R.C.
CANTILEVER COLUMN

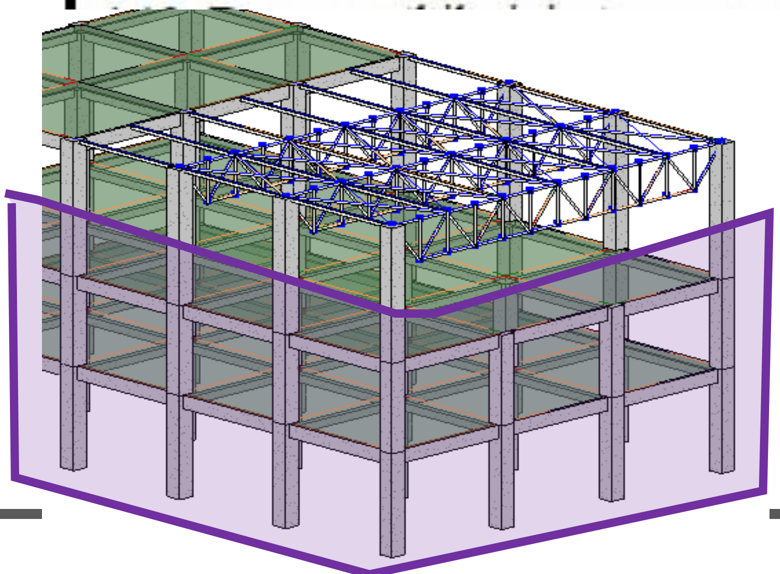
SPECIAL MOMENT
RESISTING FRAME



DESIGN BASIS : SPECIAL MOMENT RESISTING FRAME

TSC-DRAFT 2017

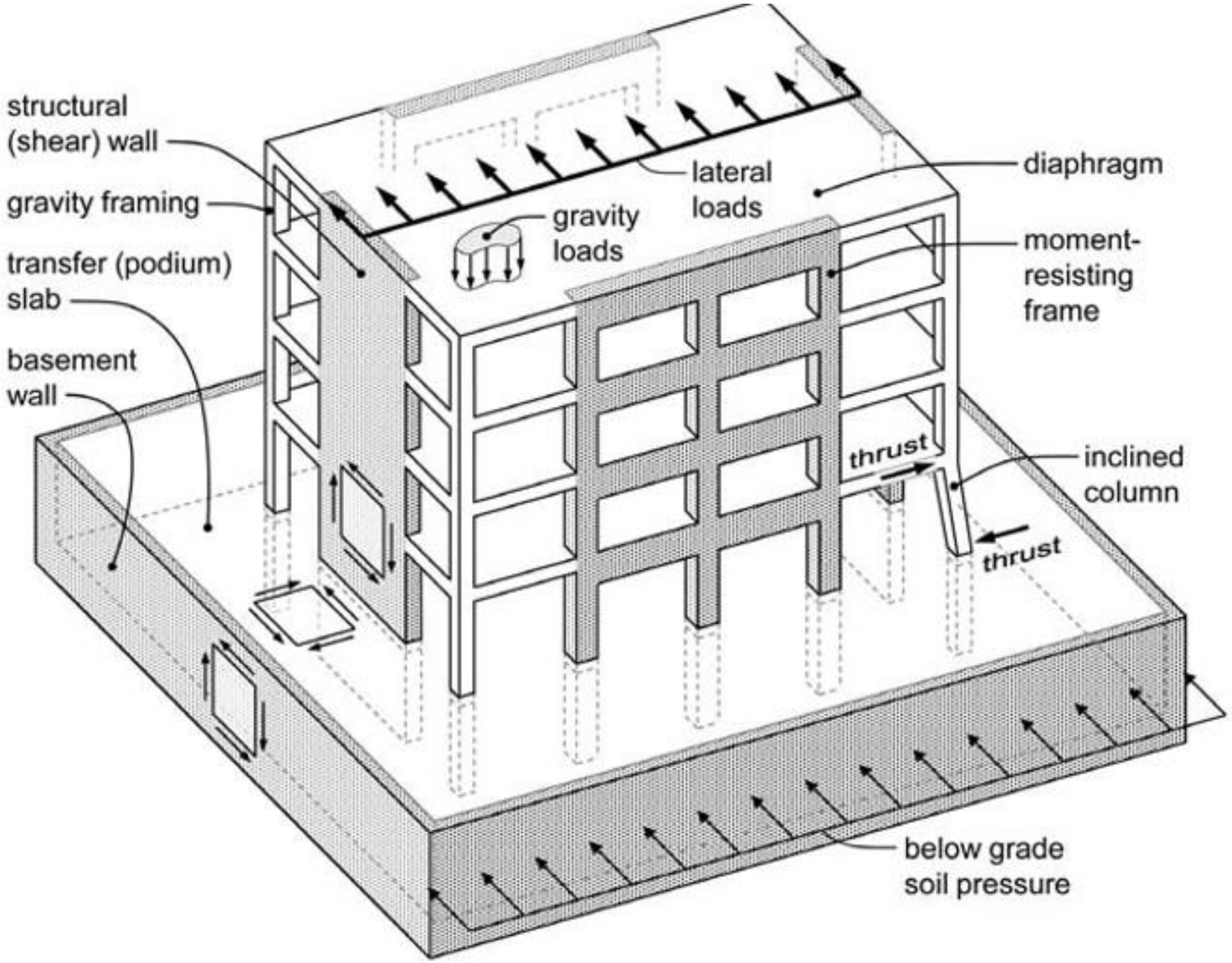
Bina Taşıyıcı Sistemi	Taşıyıcı Sistem Davranış Katsayısı *R*	Dayanım Fazlalığı Katsayısı *D*	İzin Verilen Bina Yükseklik Sınıfları BYS
A. YERİNDE DÖKME BETONARME BİNA TAŞIYICI SİSTEMLERİ			
A1. Süneklik Düzeyi Yüksek Taşıyıcı Sistemler			
A11. Deprem etkilerinin tamamının moment aktaran *süneklik düzeyi yüksek* betonarme çerçevelerle karşılandığı binalar	8	3	BYS ≥ 3

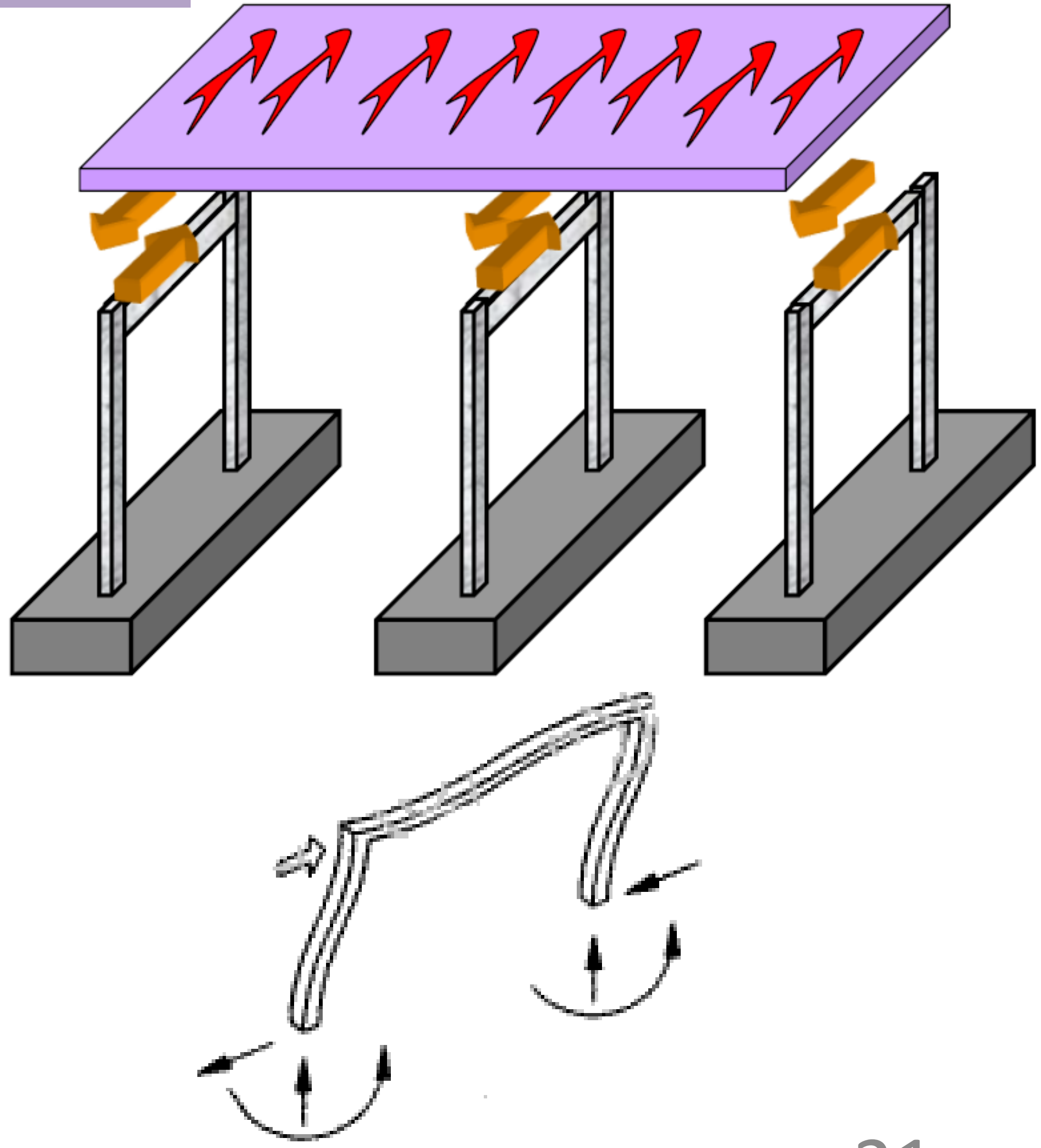


SMRF

ASCE 7-10	
R	8
C_d	5,5
Ω_d	3

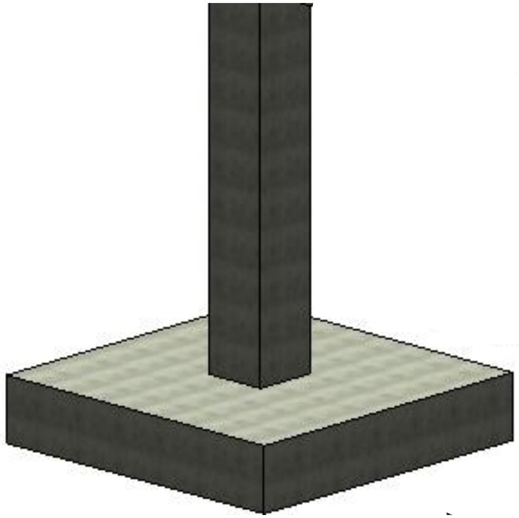
DESIGN BASIS : SMRF – LOAD PATH





İTÜ

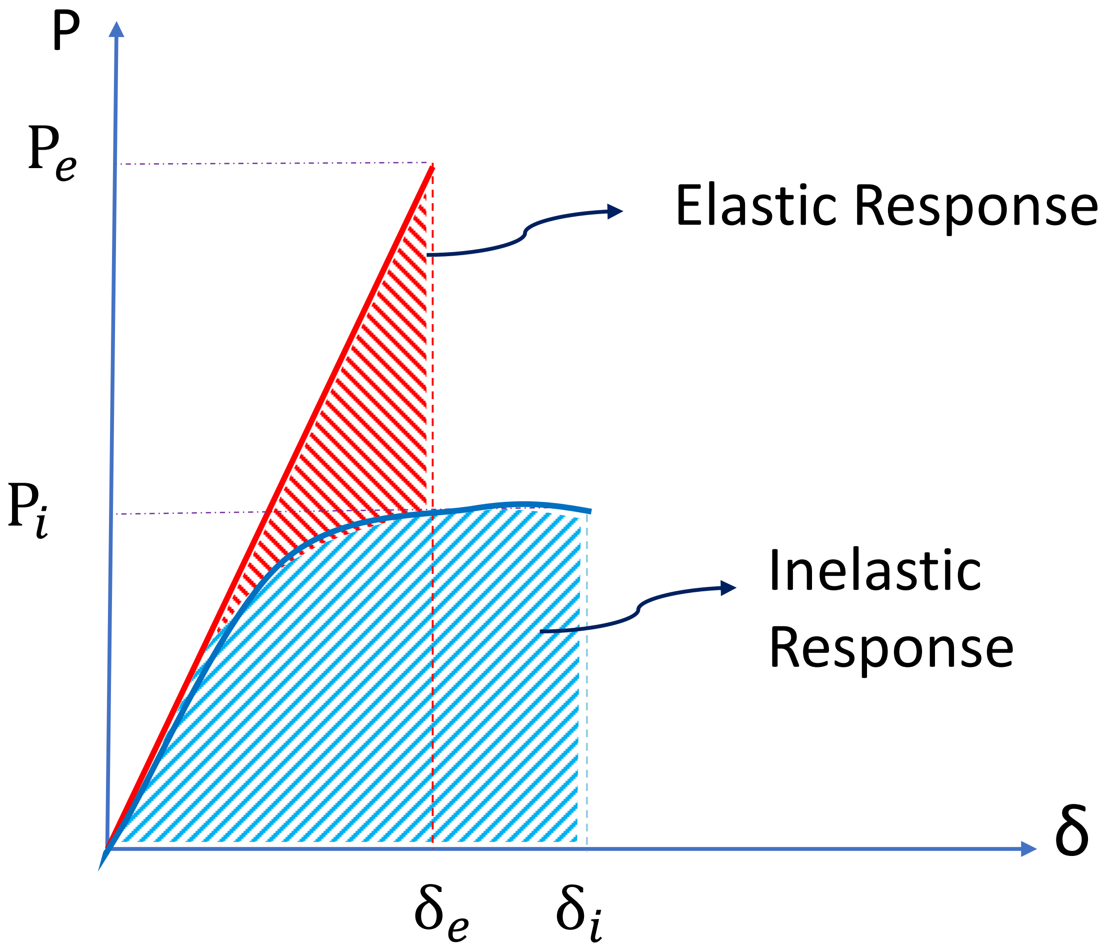
Bina Taşıyıcı Sistemi **TSC-DRAFT 2017**	Taşıyıcı Sistem Davranış Katsayısı *R*	Dayanım Fazlalığı Katsayısı *D*	İzin Verilen Bina Yükseklik Sınıfları BYS
A16. Deprem etkilerinin tamamının çatı düzeyindeki bağlantıları mafsallı olan ve yüksekliği 12 m'yi geçmeyen *süneklik düzeyi yüksek* betonarme kolonlar tarafından karşılandığı tek katlı binalar	3	2	–



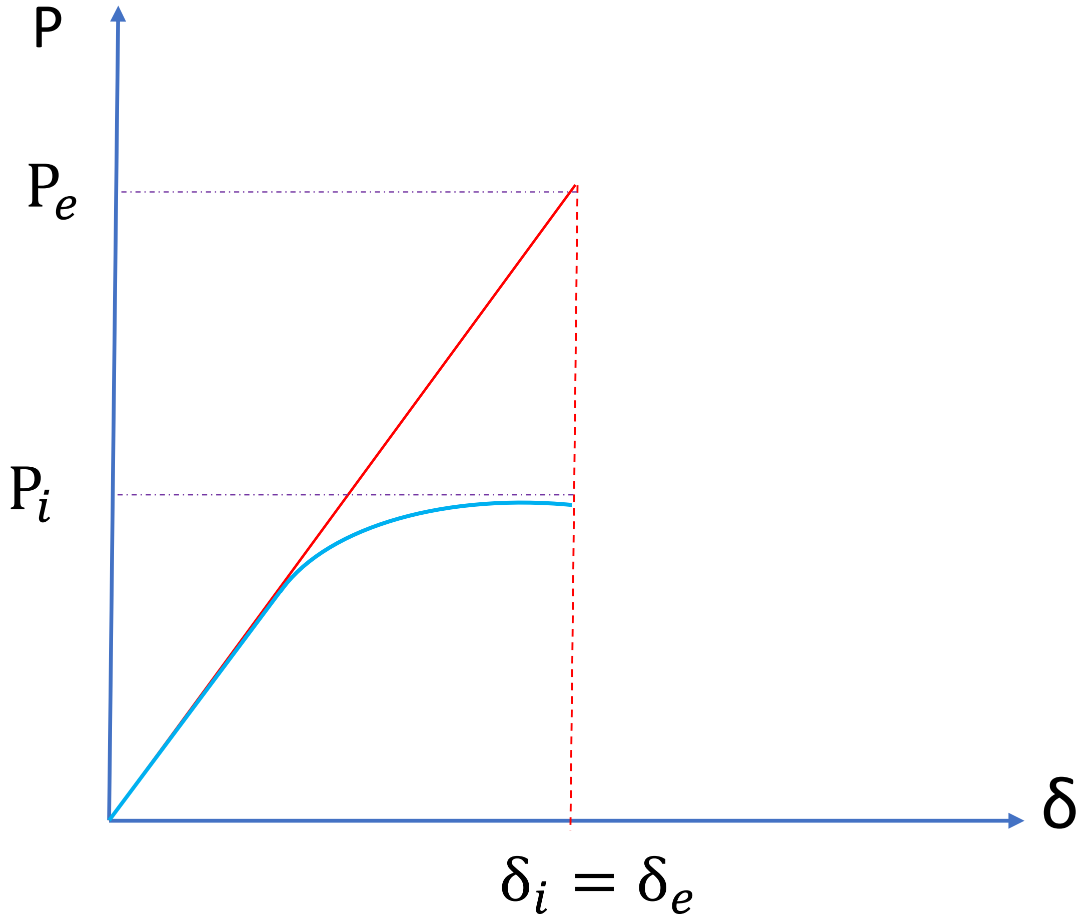
S. R. C.
CANTILEVER

ASCE 7-10	
R	2,5
C_d	2,5
Ω_d	1,25

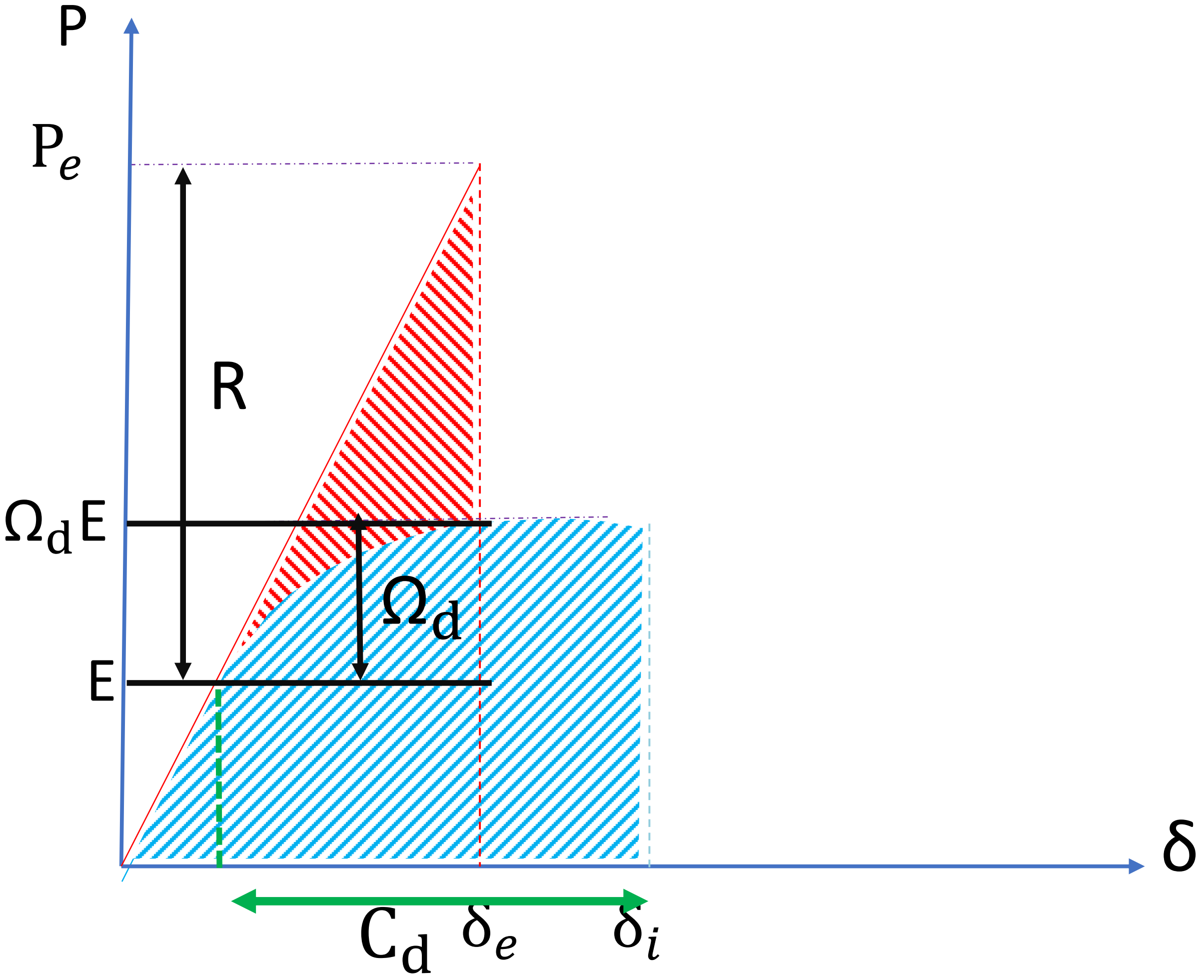
EQUIVALENT ENERGY



EQUIVALENT DISPLACEMENT

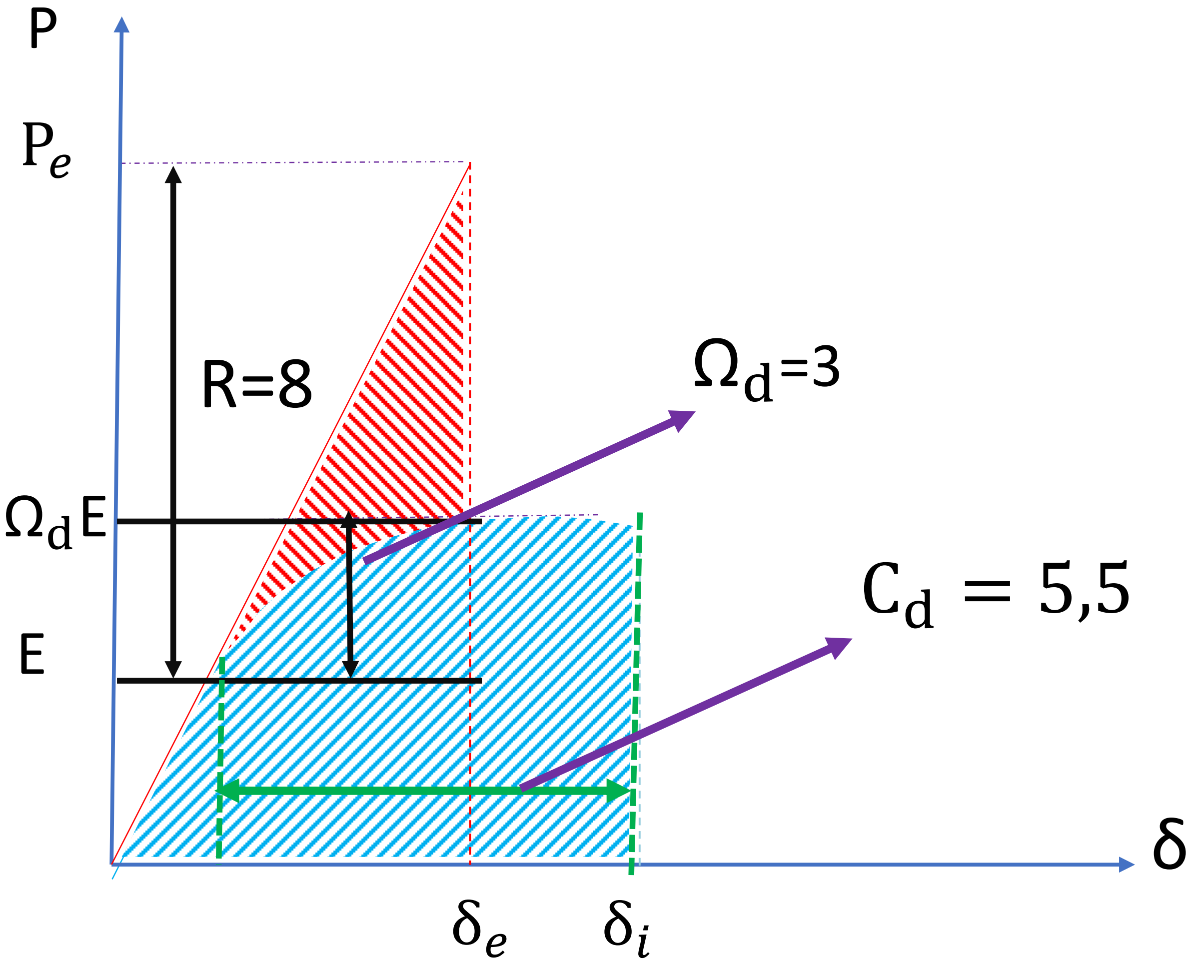


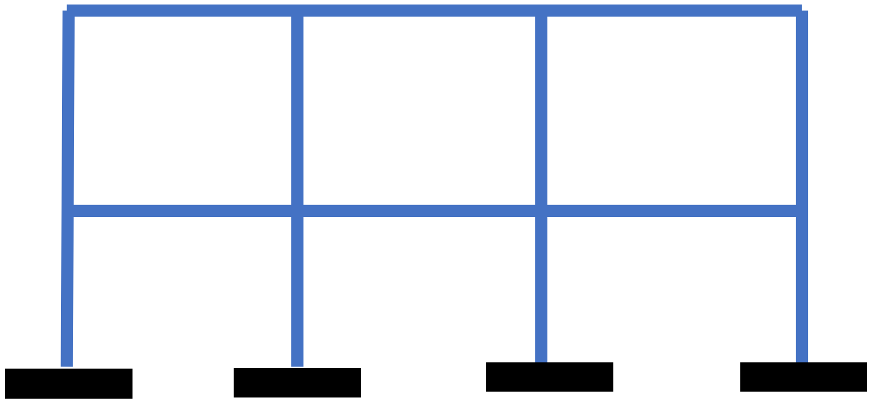
EQUIVALENT ENERGY



$$E = \frac{S_a}{R}$$

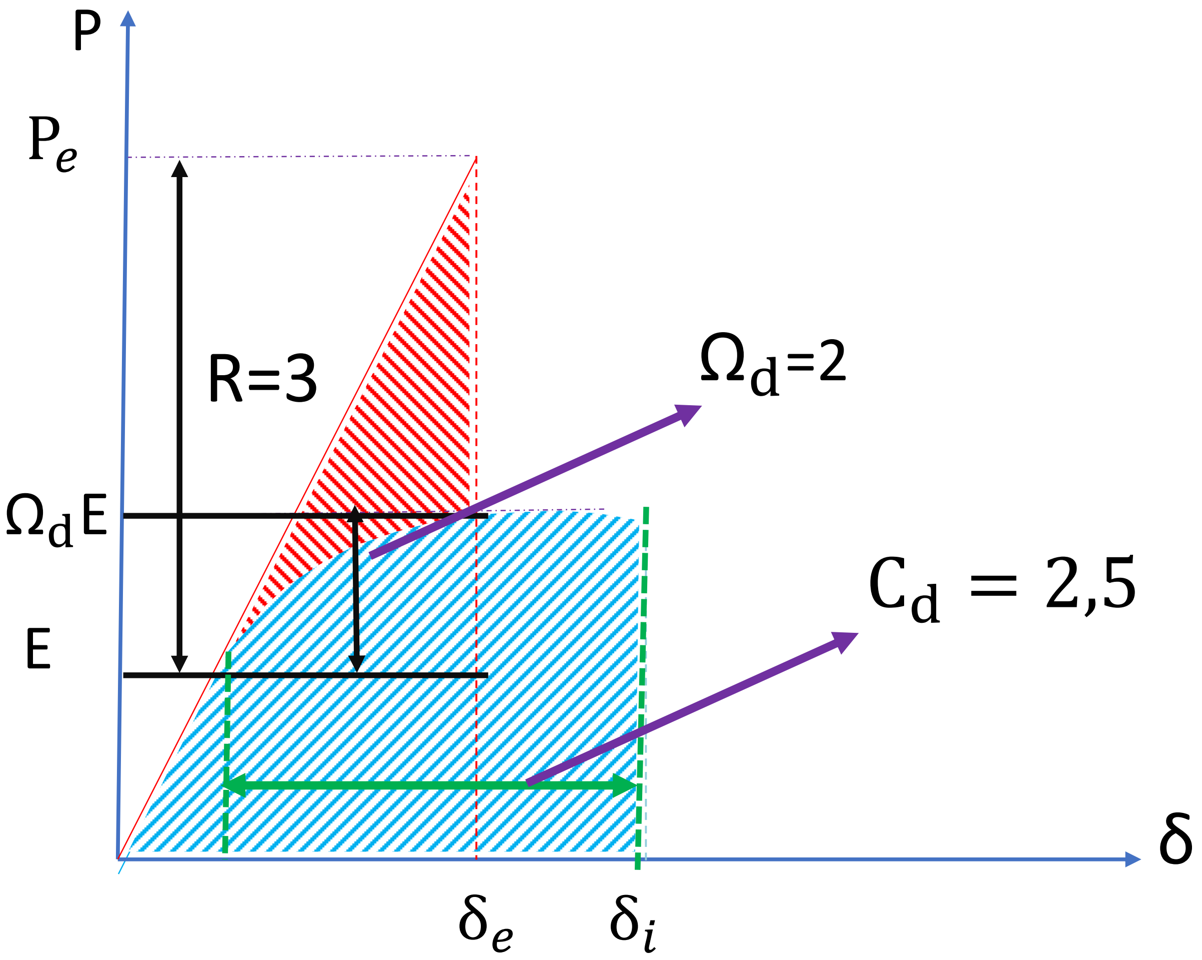
SIMILAR APPLIES TO EQUIVALENT DISPLACEMENT





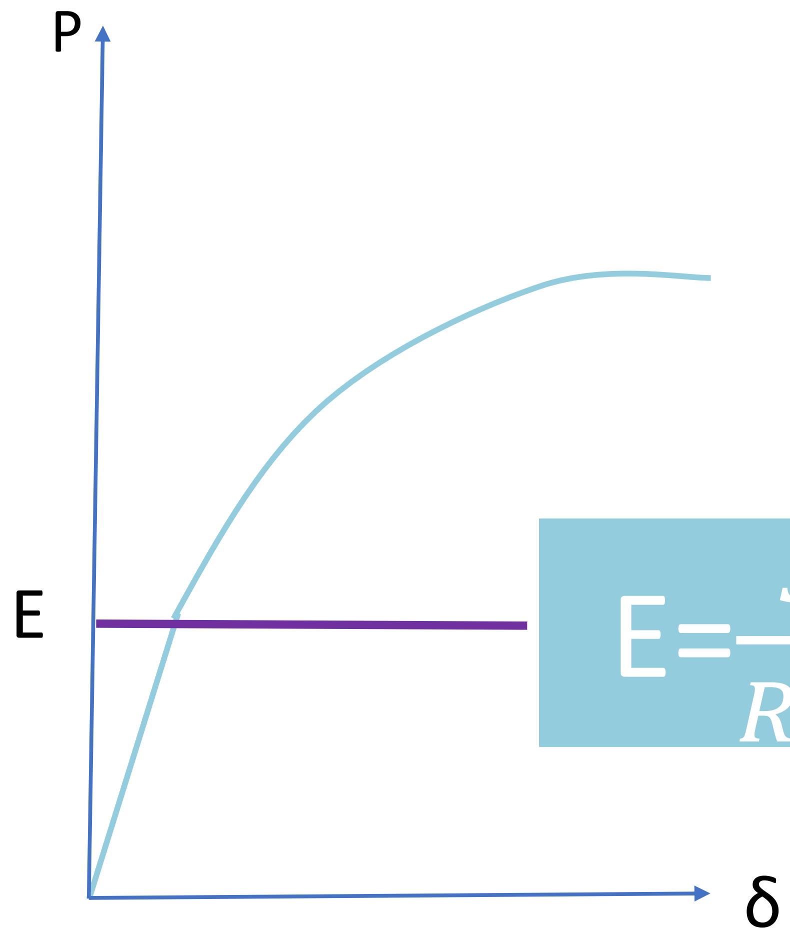
BENDING → E
SHEAR → $\Omega_e E$

[ASIDE] CODE PARAMETERS – CANTILEVER COLUMN

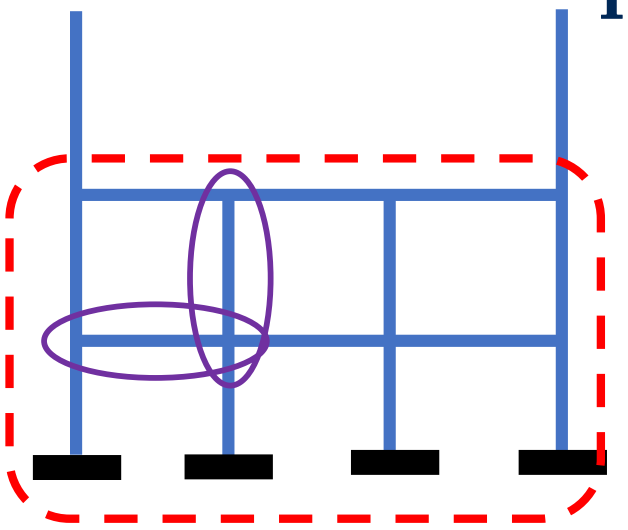


BENDING → E

SHEAR → Ω_eE



$$E = \frac{S_a}{R=8}$$

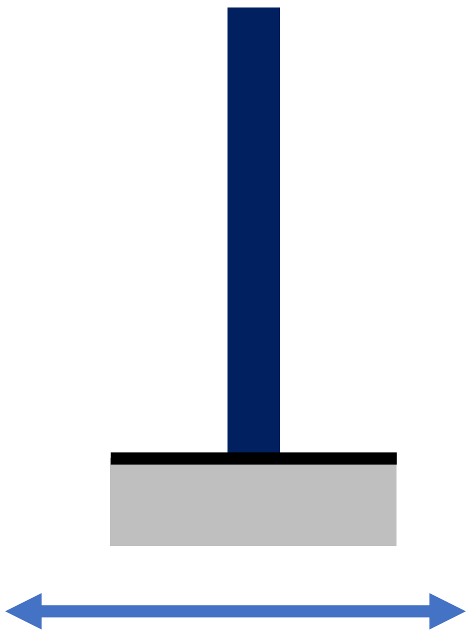


Bending (M) → **E**

Shear (V) → Ω_e **E**

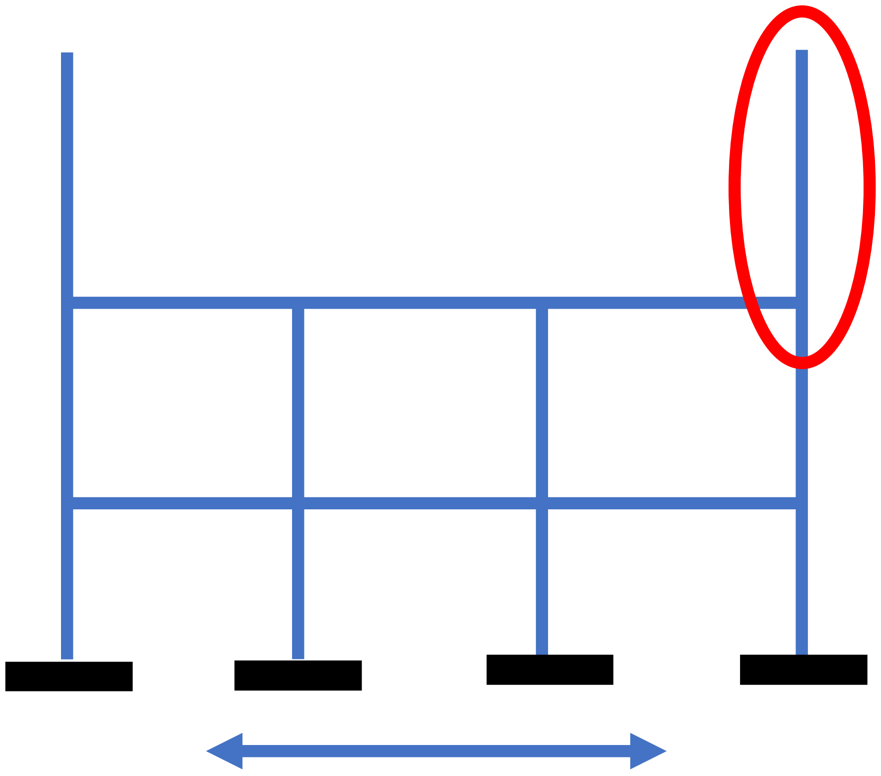
SPECIAL CASE (!)

CODE PARAMETERS



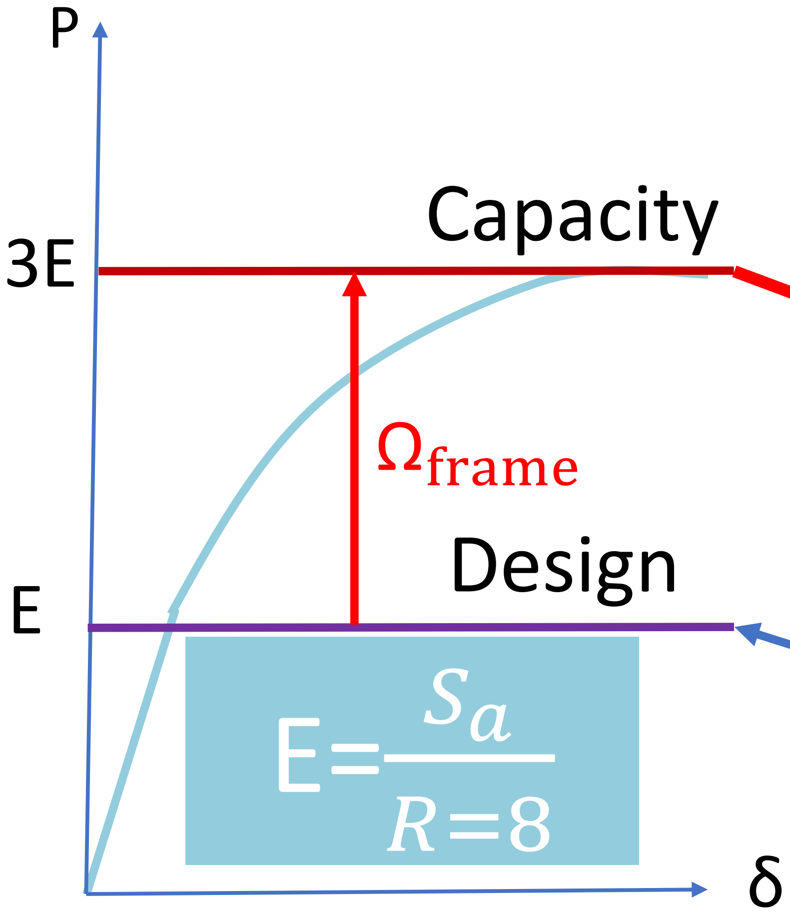
Ground Acceleration

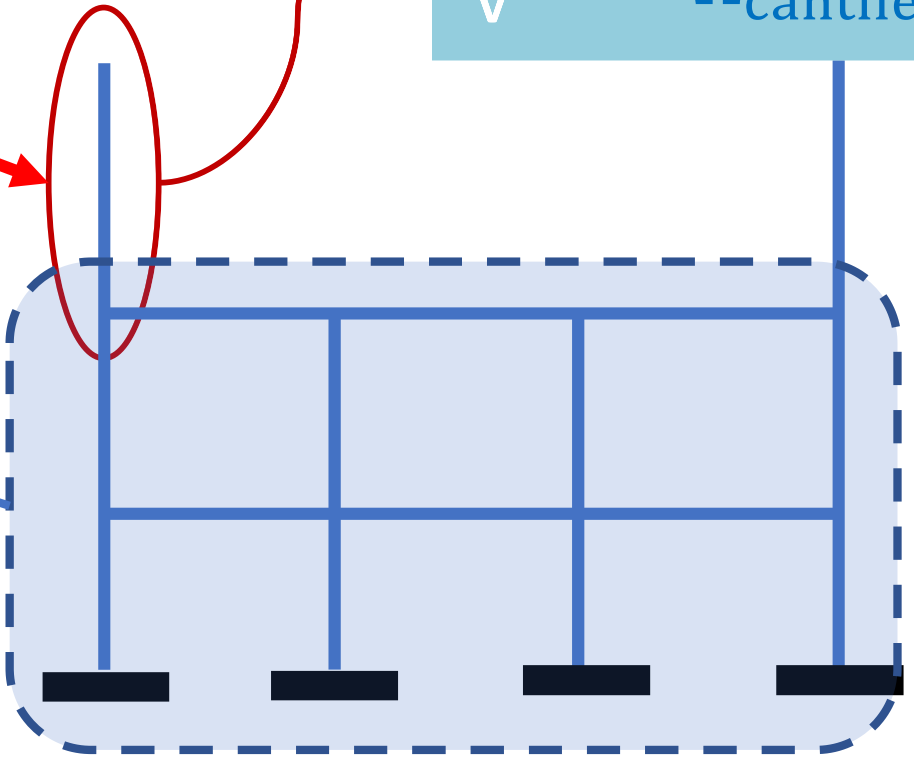
OUR PROJECT



Ground Acceleration

SPECIAL CASE (!)



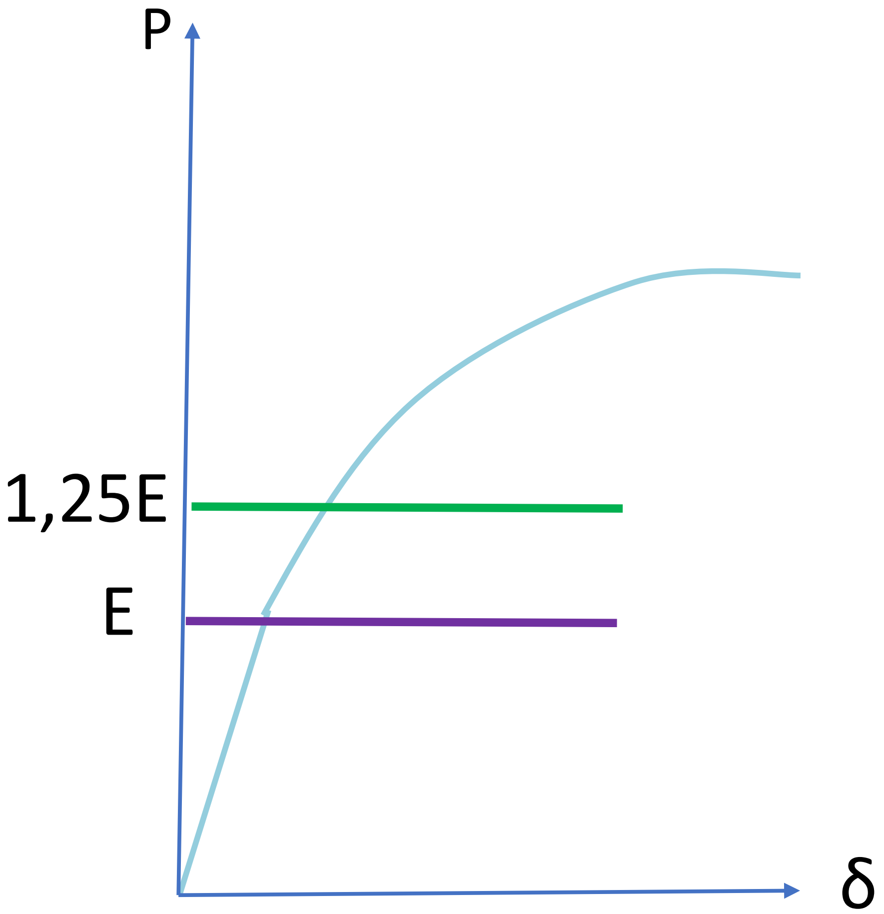


CANTILEVER COLUMN STAYS LINEAR

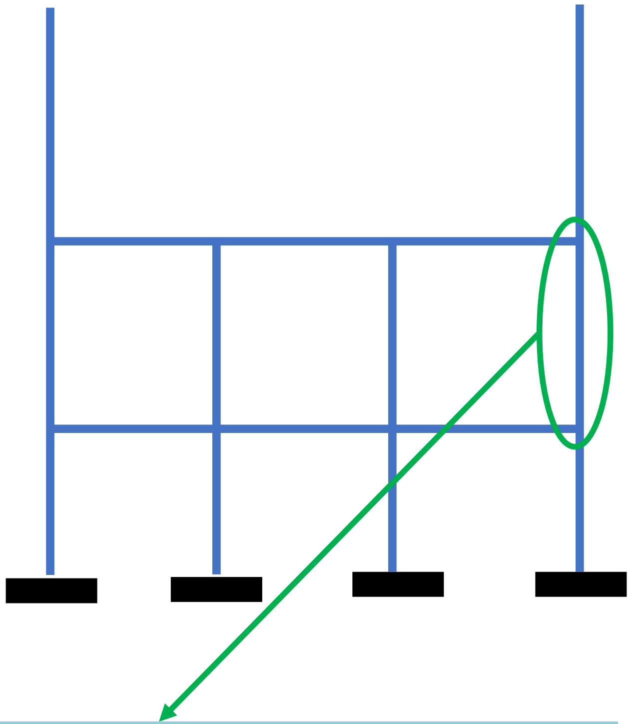
M ⟶ Ω_{frame} E

V ⟶ $\Omega_{cantilever}$ Ω_{frame} E

SPECIAL CASE (!)



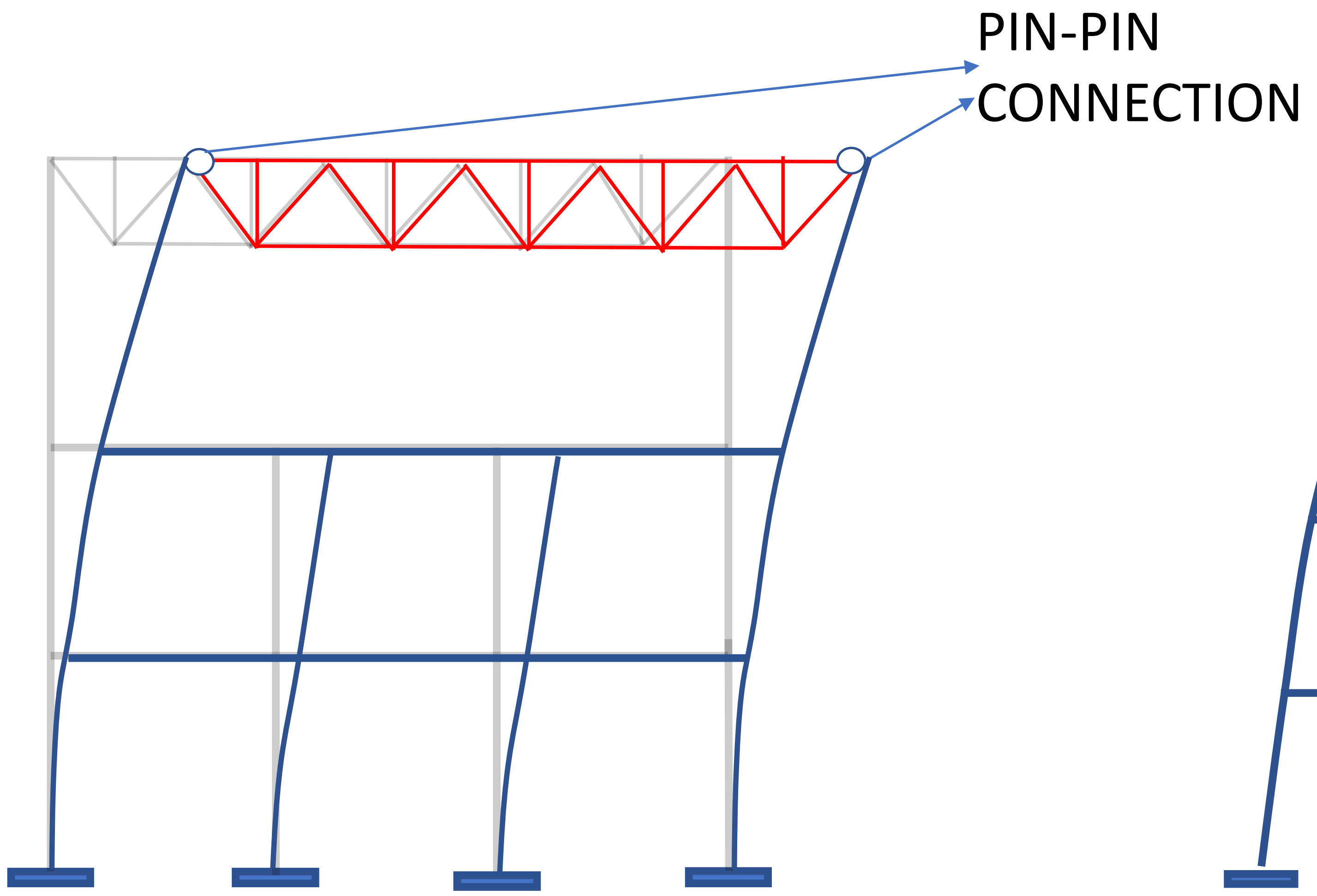
$$E = \frac{S_a}{R=8}$$

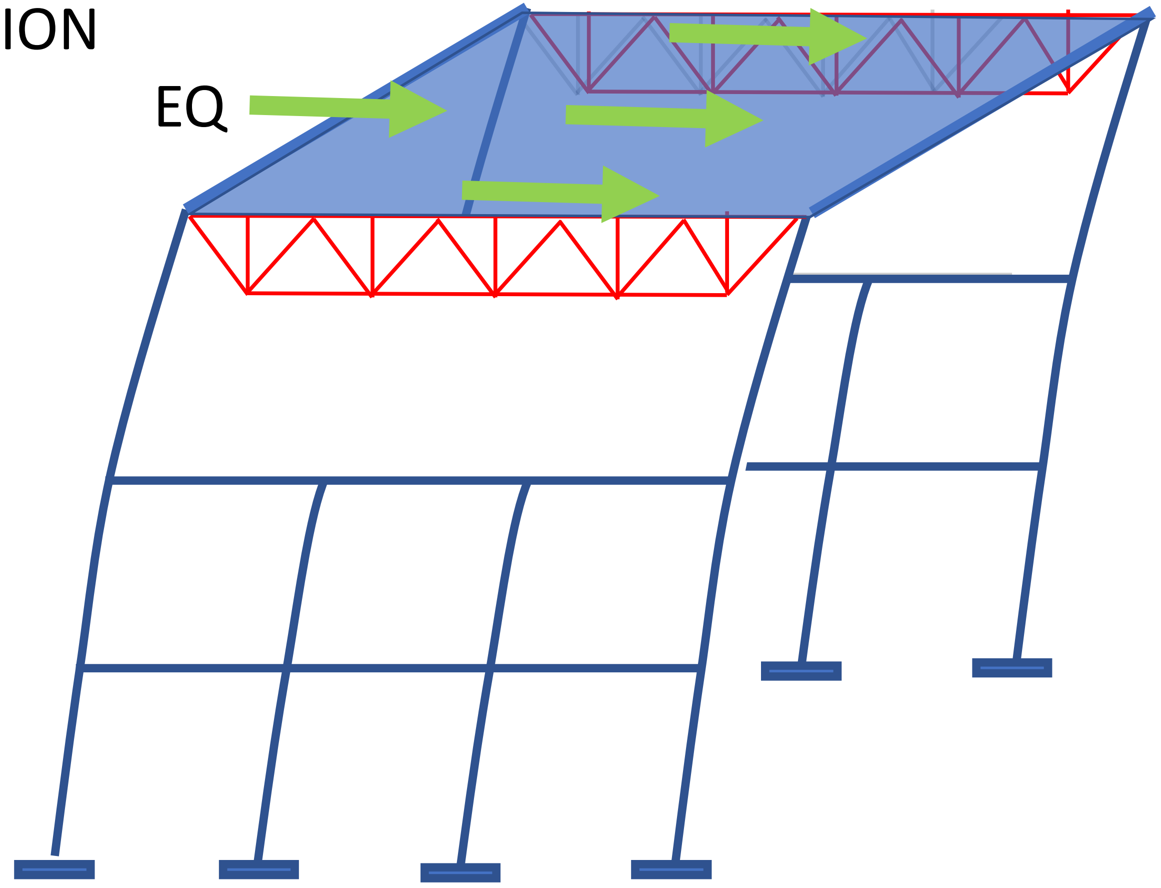


M → 1,25E

V → Ω_{frame} 1,25E

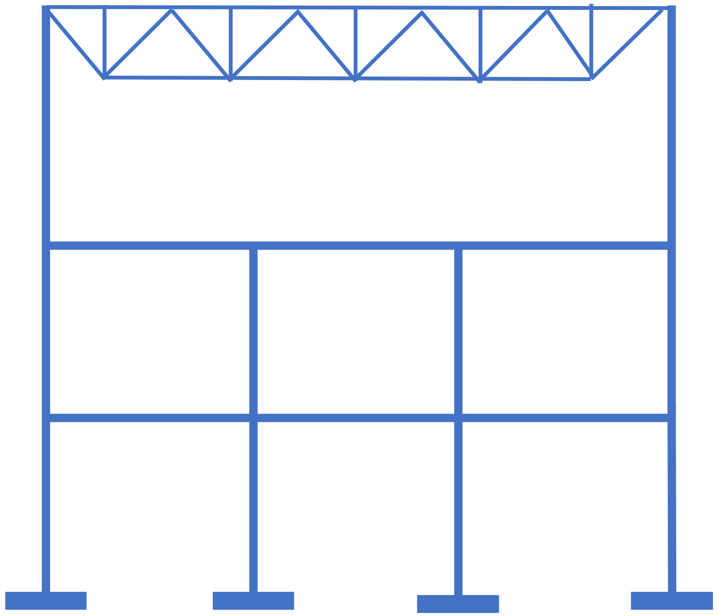
ASCE 7-10





NOT PART OF MAIN LATERAL SYSTEM

DIAPHRAM FORCES



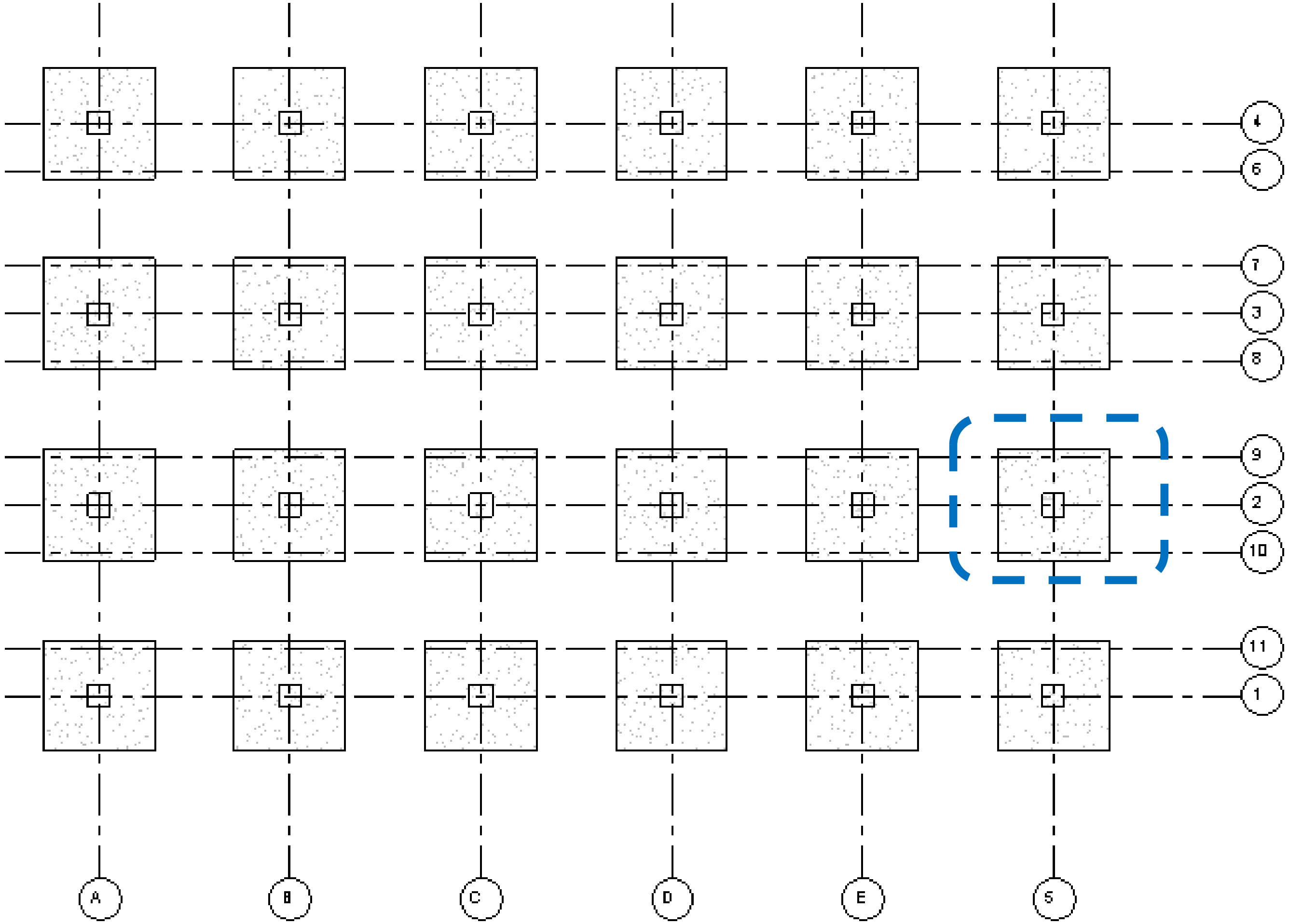
DIAPHRAM DESING LOADS

$$F_{px} = \frac{\sum_{i=x}^{n} F_i}{\sum_{i=x}^{n} W_i} \times W_{px}$$

$$0.2S_{DS}Iw_{px} < F_{px} < 0.4S_{DS}Iw_{px}$$

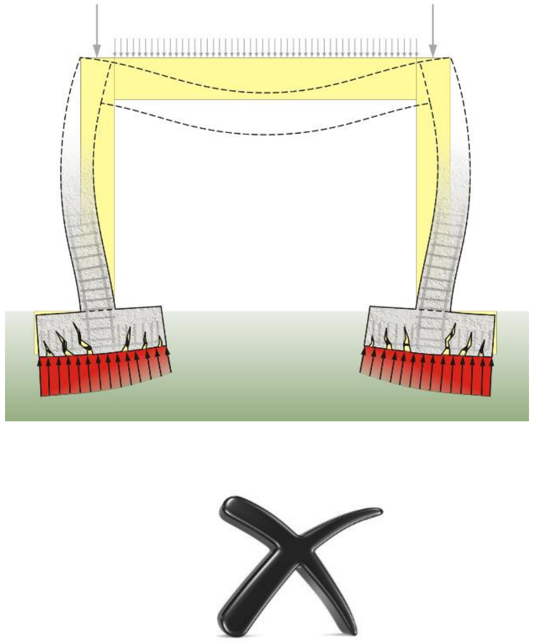
1.4G+1.6Q

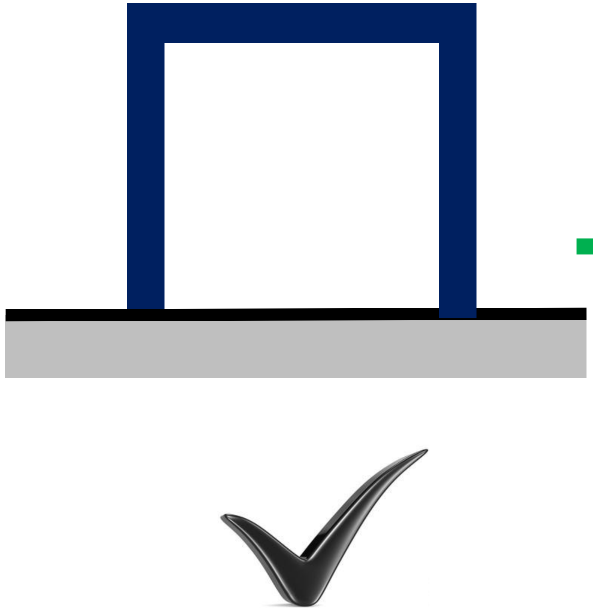
TSC DRAFT 2017/ASCE 7-10

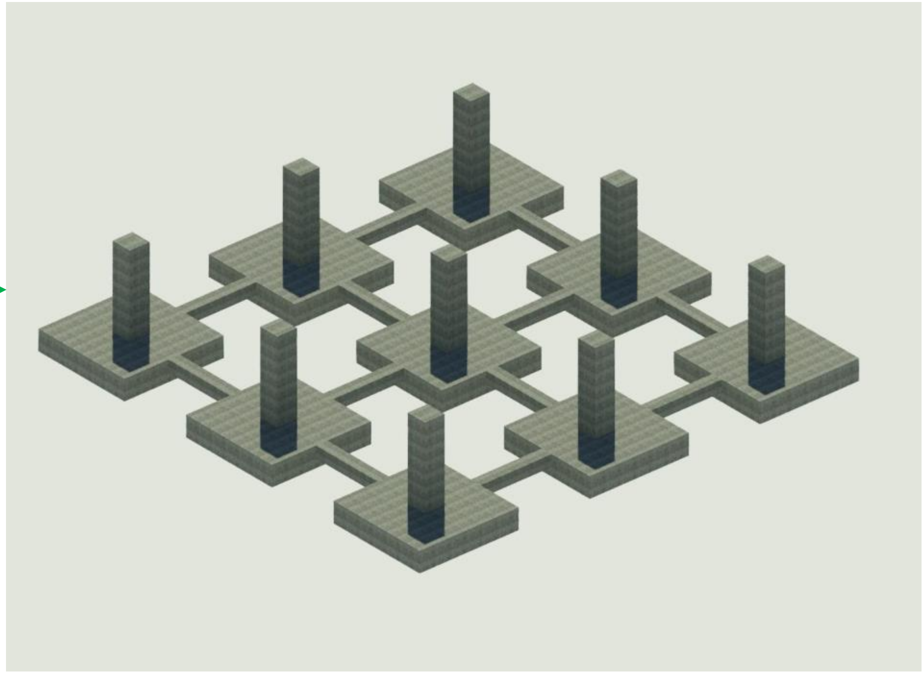


SOIL CLASS: Z2
ALLOWABLE SOIL STRESS: 180 kN/m^2

→ SPREAD FOOTING

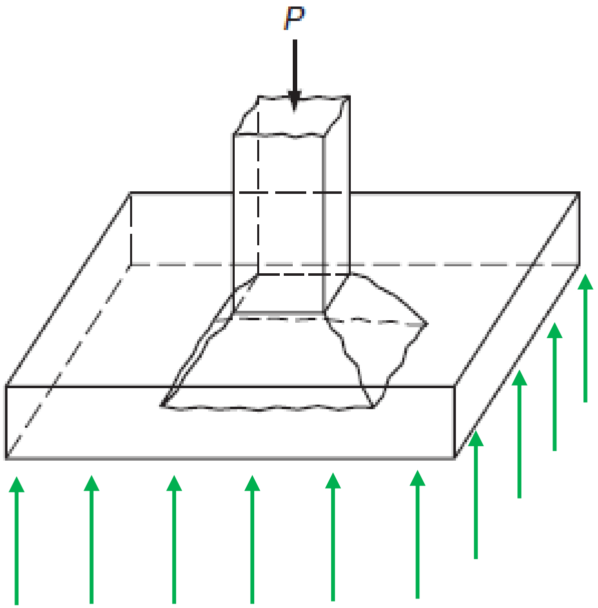


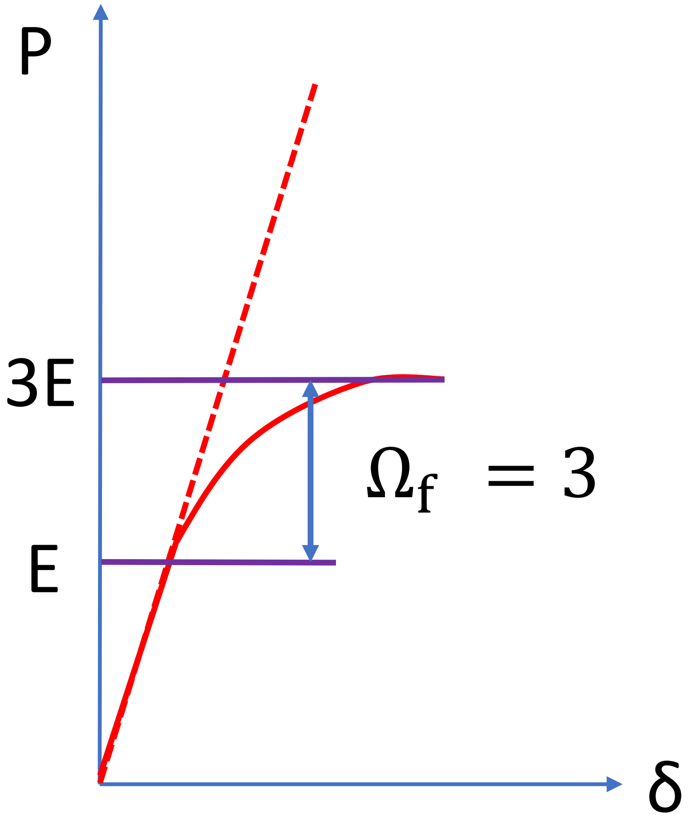




ASSUME NO SOIL FOUNDATION INTERACTION ASSUMPTION

LINK BEAMS

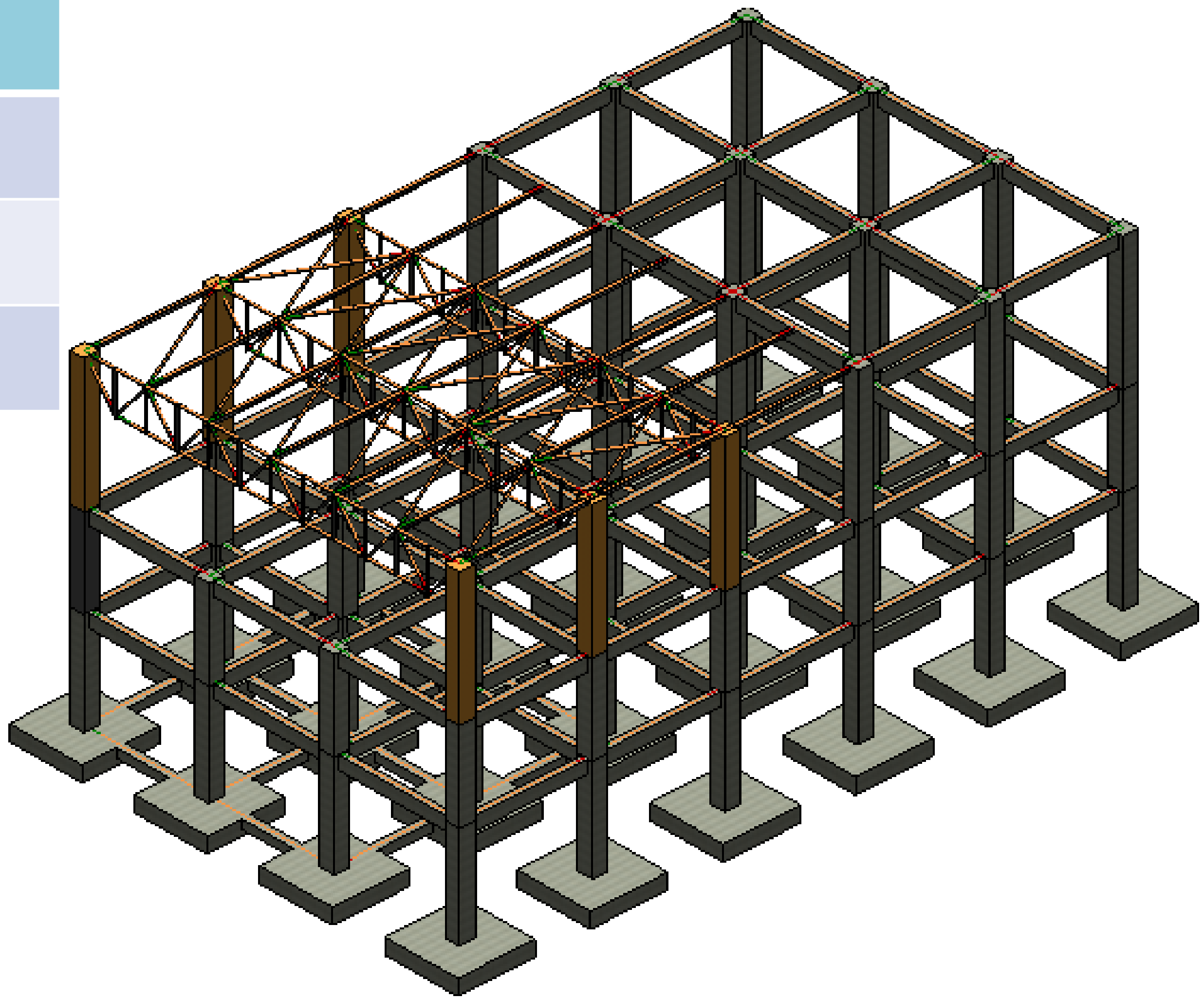




M → E

V → 3E

MODELS USED	IN-PLANE RIGIDITY	OUT-PLANE RIGIDITY
REGULAR SLAB	%100	%100
FLEXIBLE SLAB	%1	%1
EFFECTIVE SLAB	%25	%25

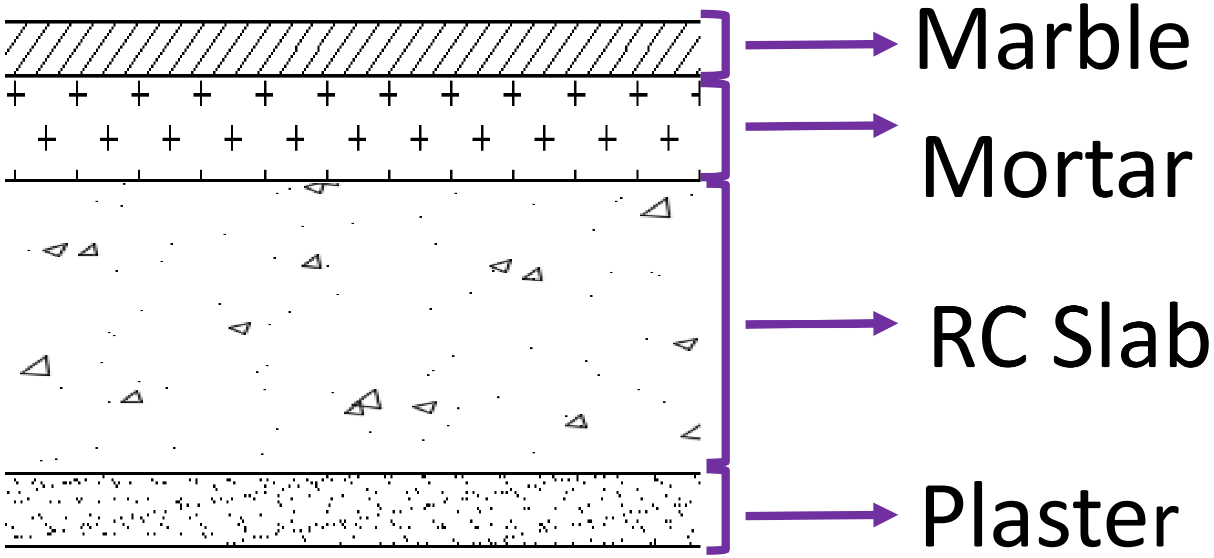


MATERIAL	UNIT WEIGHT	ELASTICITY MODULUS	POISSON RATIO
CONCRETE	25 kN/m^3	32×10^6 N/m^2	0,2
STEEL	79 kN/m^3	210×10^6 N/m^2	0,265
ALIMINIUM	27 kN/m^3	69×10^9 N/m^2	0,334
PLASTER	20 kN/m^3		
MORTAR	20 kN/m^3		
E.PARTITION WALL	4,5 kN/m		
I.PARTITION WALL	2,5 kN/m		

DESIGN BASIS: STRUCTURAL LOADS

Material	Load
Concrete	25 kN/m³
Steel	79 kN/m³
Aluminium	27 kN/m³
E.Wall	4,5 kN/m
I.Wall	2,5 kN/m
Floor	5,92 kN/m²

Material	Unit Weight
RC Slab	25 kN/m³
Plaster	20 kN/m³
Marble	26 kN/m³
Mortar	21 kN/m³



LIVE LOADS

Live Load: 5 kN/m^2

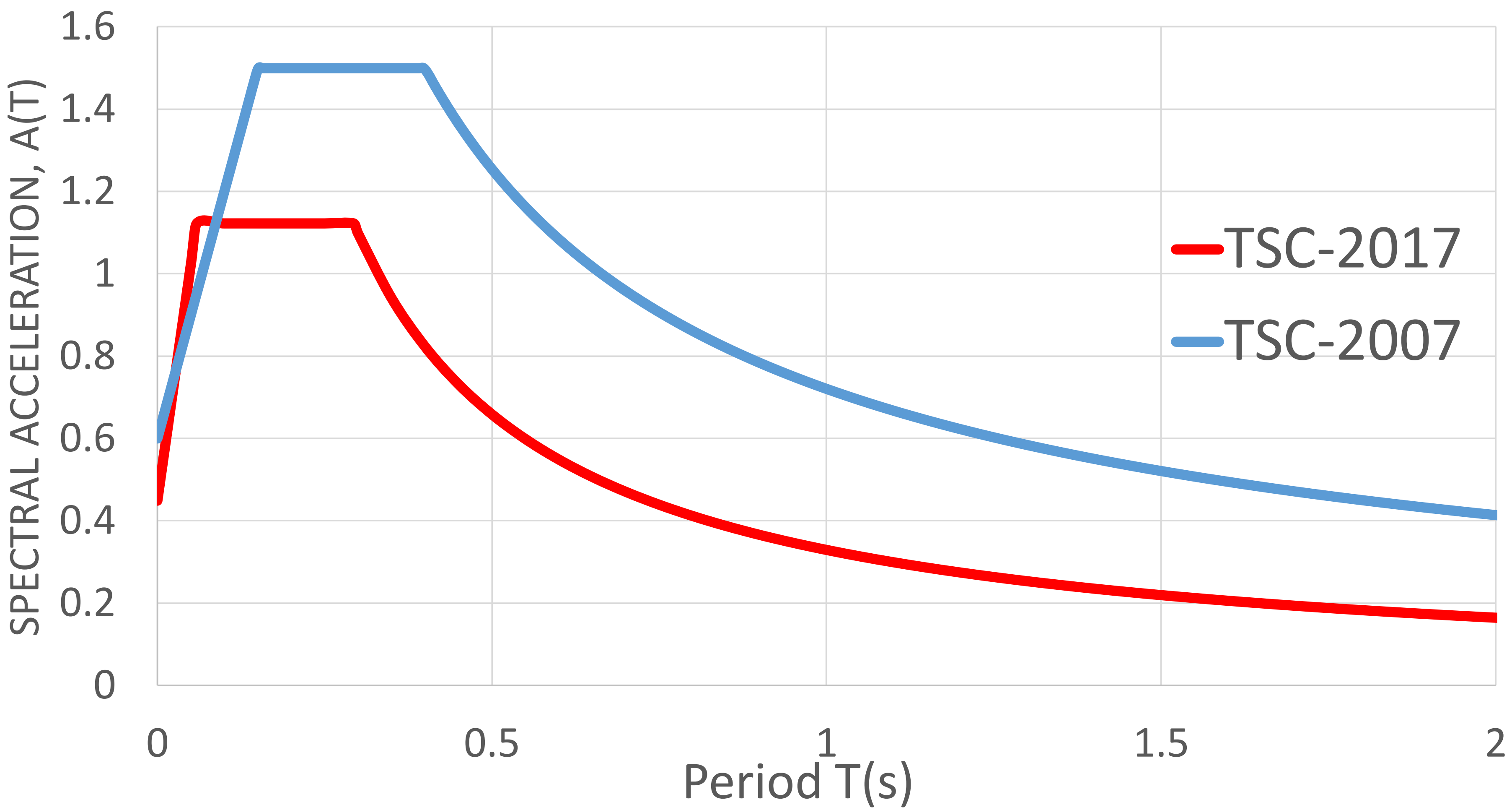
SNOW LOADS

Snow Load: 0,75 kN/m^2

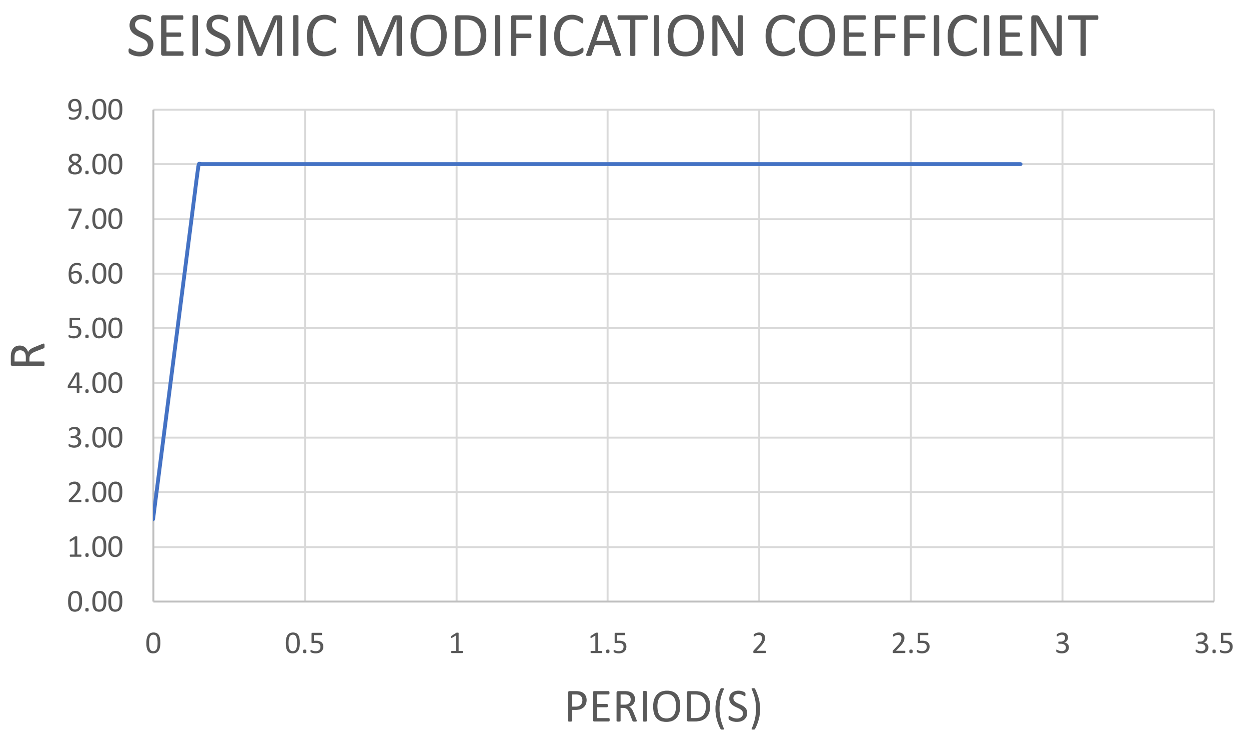
SEISMIC WEIGHT

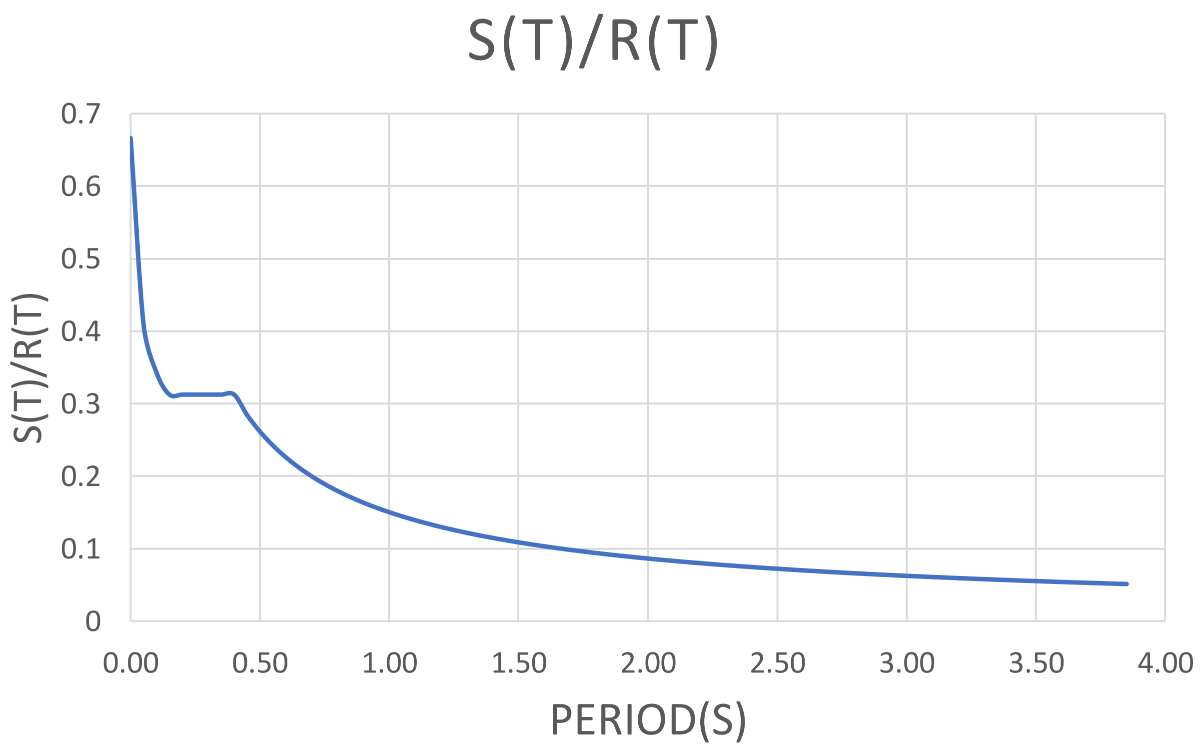
$$W = D + 0.3L + 0.3S$$

DESIGN SPECTRUM



DESIGN SPECTRUM

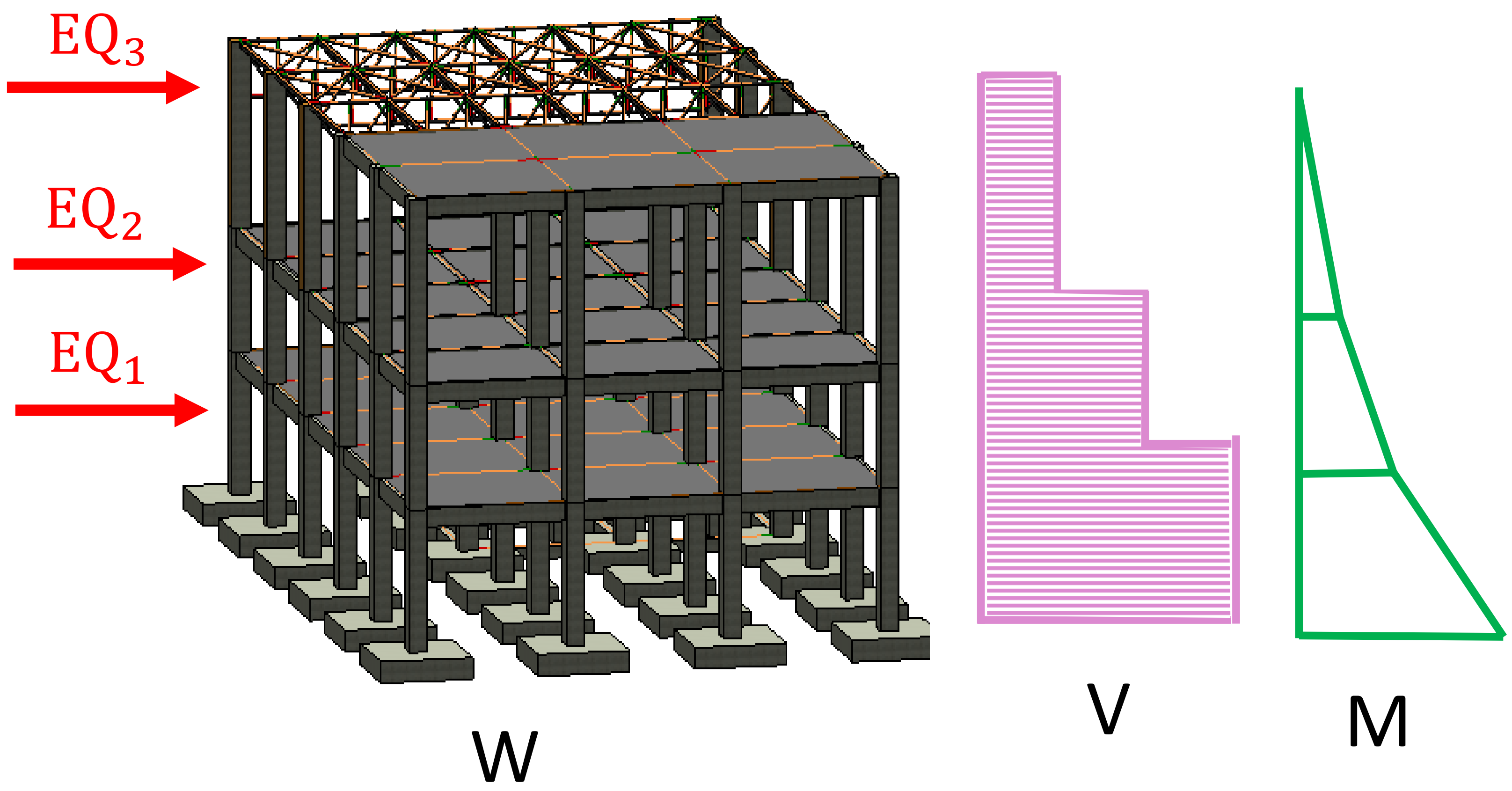


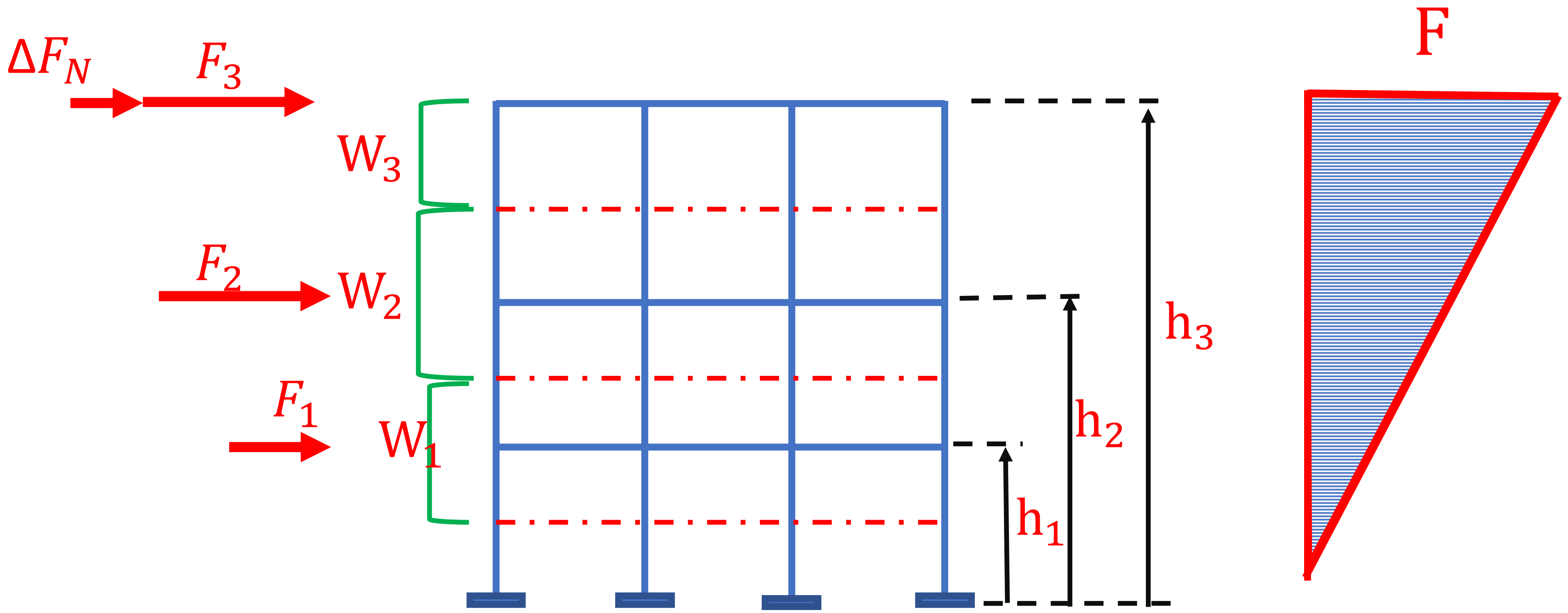


EQUIVALENT STATIC FORCE PROCEDURE

BASE SHEAR

$$Vt = \frac{\sum W \times A(T)}{R}$$





$$\Delta F_N = 0{,}0075 N V_t$$

$$F_i = (V_t - \Delta F_N) \times \frac{W_i \times h_i}{\sum (W_i \times h_i)}$$

LOAD COMBINATIONS
$1.4G+1.6Q$
$G+Q\pm Ex\pm 0,3Ey$
$G+Q\pm Ey\pm 0.3Ex$

SAP2000 v18

python v3.6.1

INTRODUCTION: OUT OF STUDIES

VERTICAL SEISMIC EFFECT

SUPER OPTIMIZATION

TEMPERATURE EFFECT

LONG TERM DEFLECTION EFFECT

SOIL SUPPORT INTERACTION (ELASTIC SUPPORT)

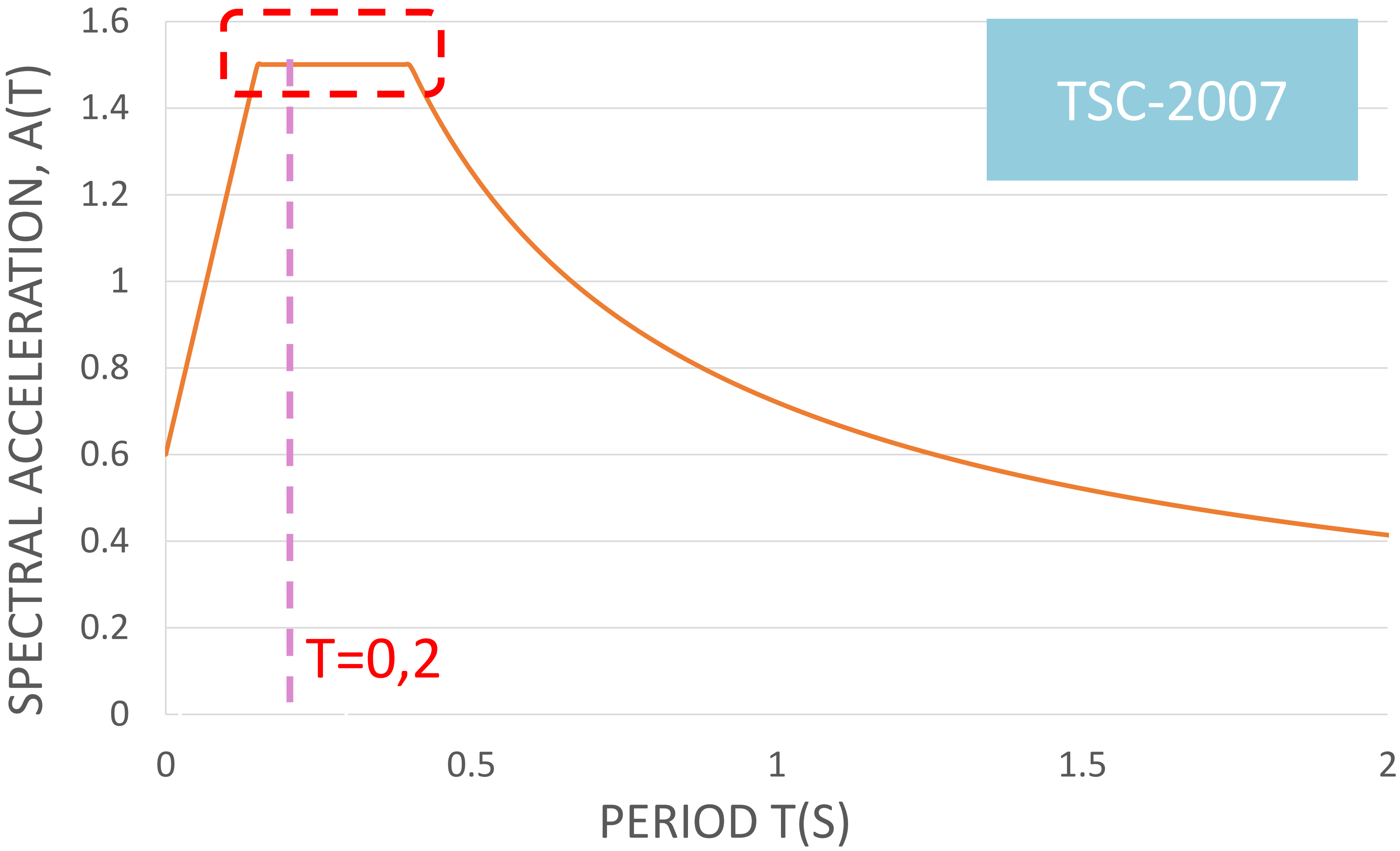
RESPONSE SPECTRUM METHOD

DIAPHRAGM DESIGN

CONTENT

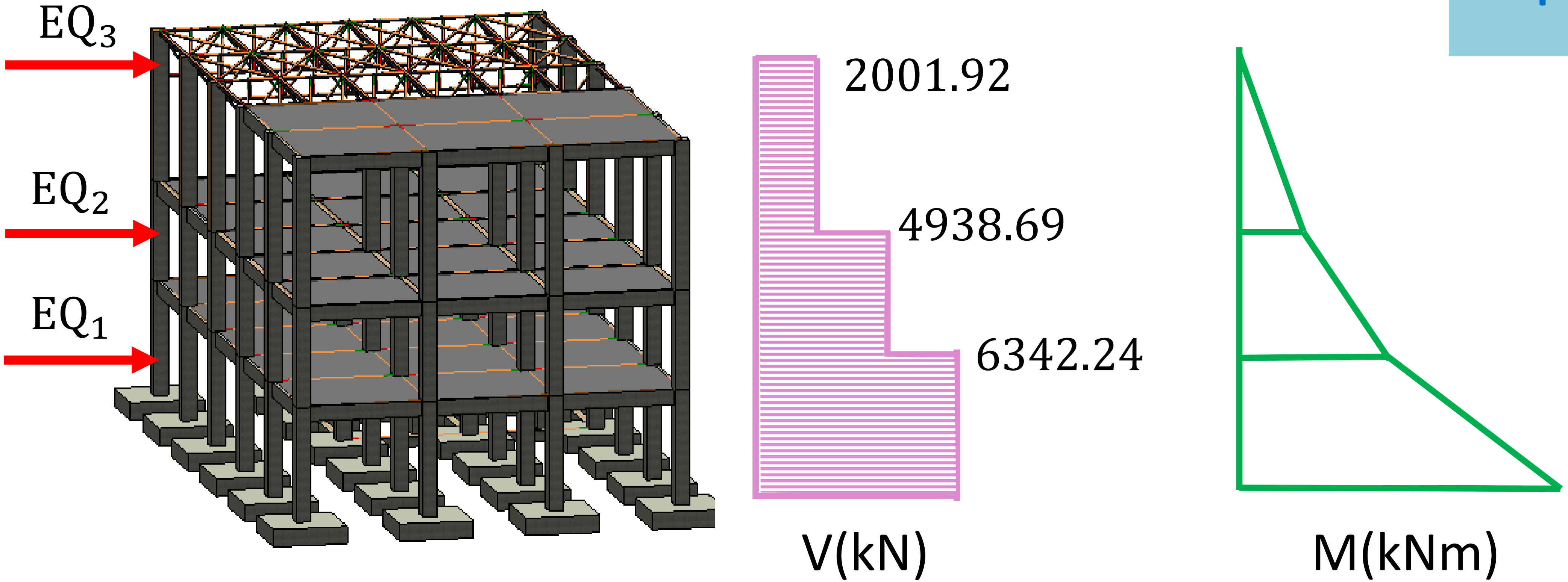
MEMBERS	LOAD COMBINATION	CAPACITY
COLUMN	1.4G+1.6Q	• %30 Axial D/C Ratio $\rightarrow (0,3A_c f_{ck})$ • 1.8 Coefficient
BEAM	1.4G+1.6Q	Structural Code
SLAB	1.4G+1.6Q	Structural Code
FOUNDATION	1.4G+1.6Q	$V_{cr} = 0,65 \times f_{ctd} \times b_w \times d$
STEEL	1.4G+1.6Q	$1\ \mathrm{kN/m^2}$

MEMBER	DIMENSIONS
COLUMN	70x70 cm
BEAM	60x30 cm
SLAB	Thick. = 18 cm
FOUNDATION	Thick. = 70cm Max. 3.25x3.25m Min. 2.10x2.10m
STEEL ROOF	Detailed Design


1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
SPECTRAL ACCELERATION, A(T)
TSC-2007
T=0,2
0
0.5
1
1.5
2
PERIOD T(S)

STRUCTURAL ANALYSIS: DESIGN SPECTRUM

T=0,2s



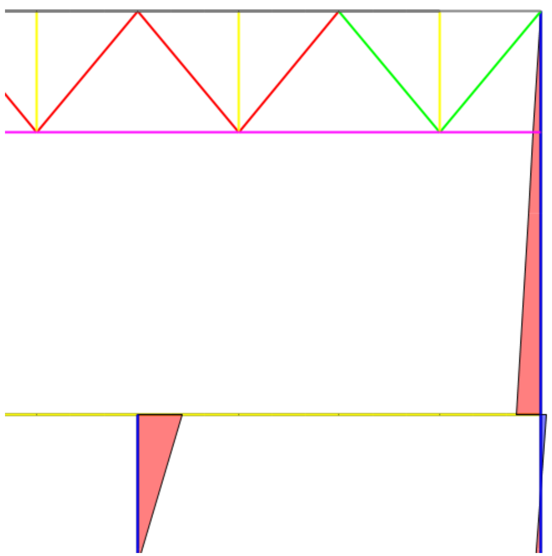
W=25368.95kN

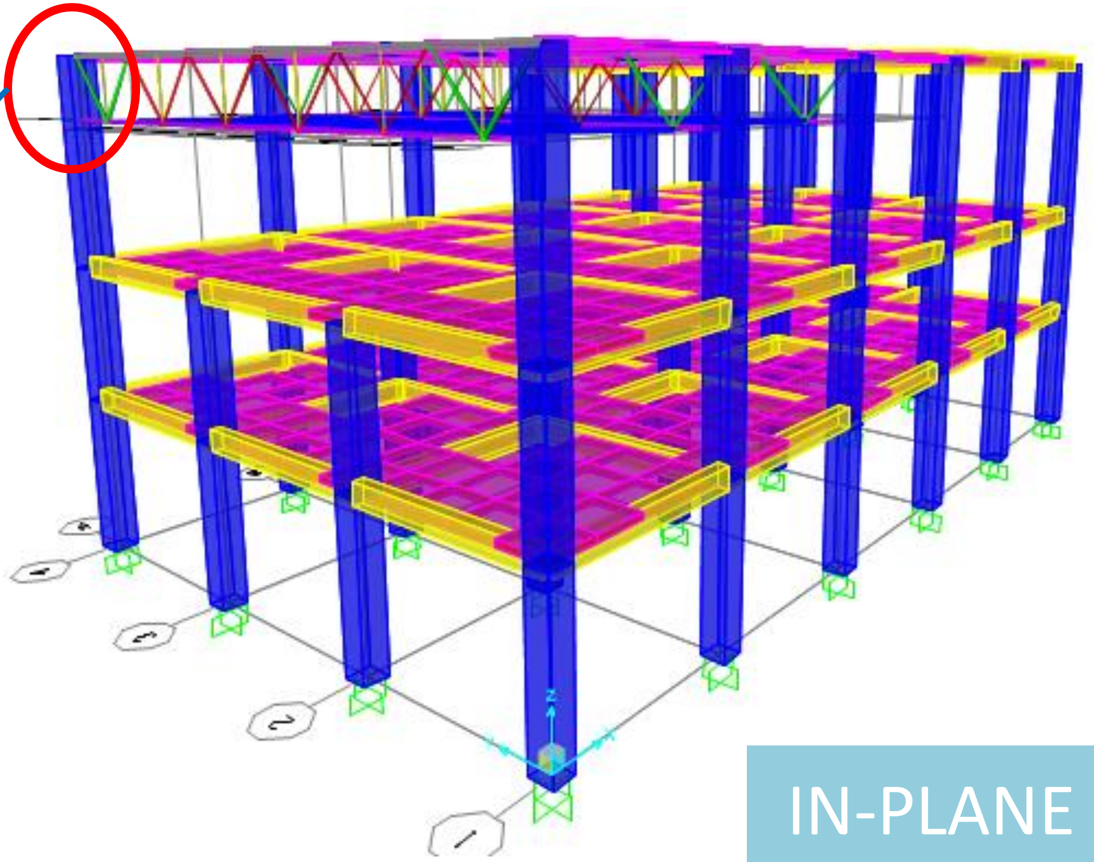
$$Vt = \frac{\sum W \times A(T)}{R}$$

3D SAP2000 MODELS
REGULAR SLAB
FLEXIBLE SLAB
WITHOUT SLAB
EFFECTIVE RIGIDITY

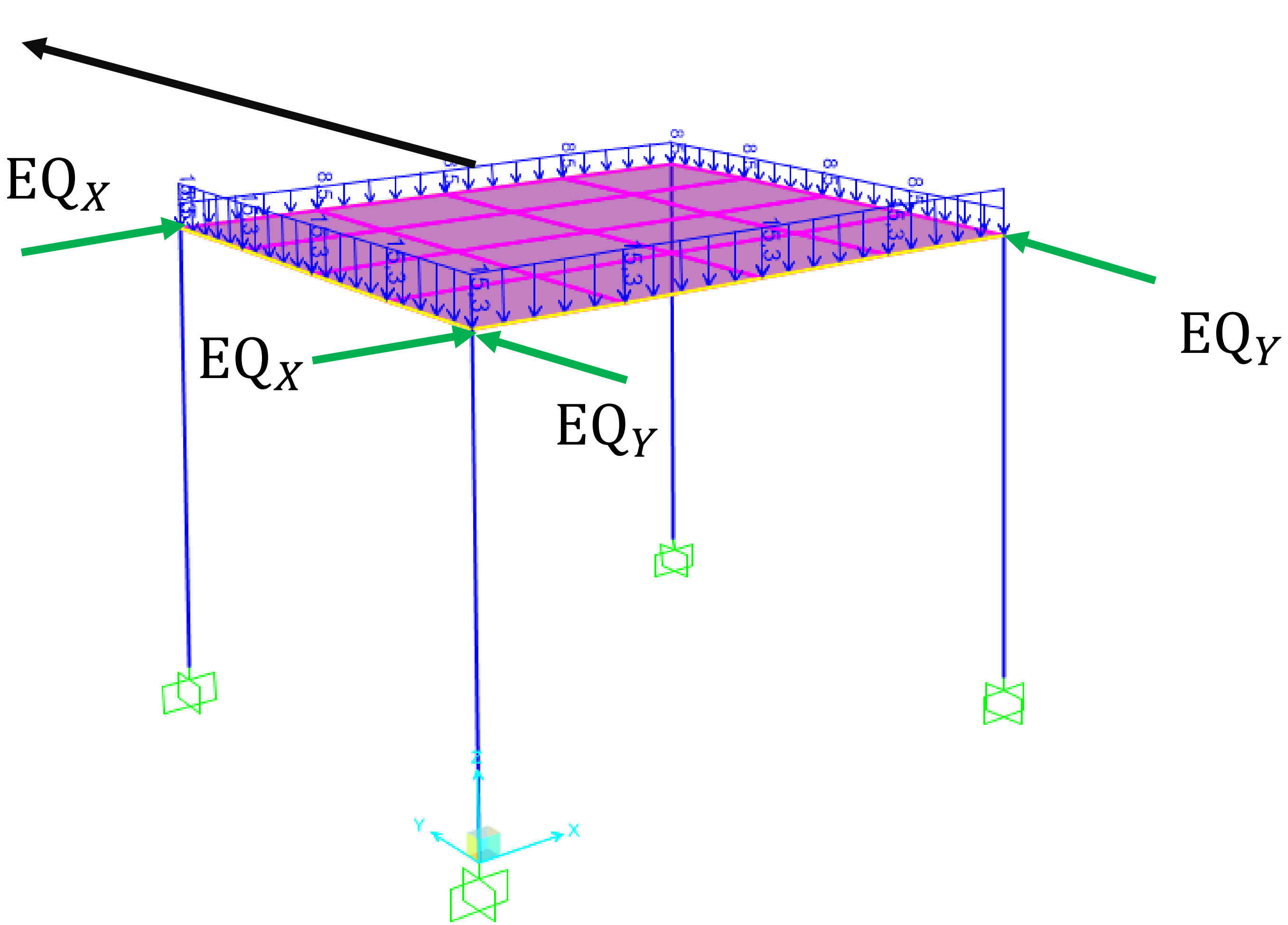
2D MODELS
RECTANGULAR BEAM
T-SHAPE BEAM
PYTHON-RECTANGULAR
PYTHON-T SHAPE

STRUCTURAL ANALYSIS: 3D **REGULAR SLAB** SAP2000 MODEL





IN-PLANE SLAB RIGIDITY: %100

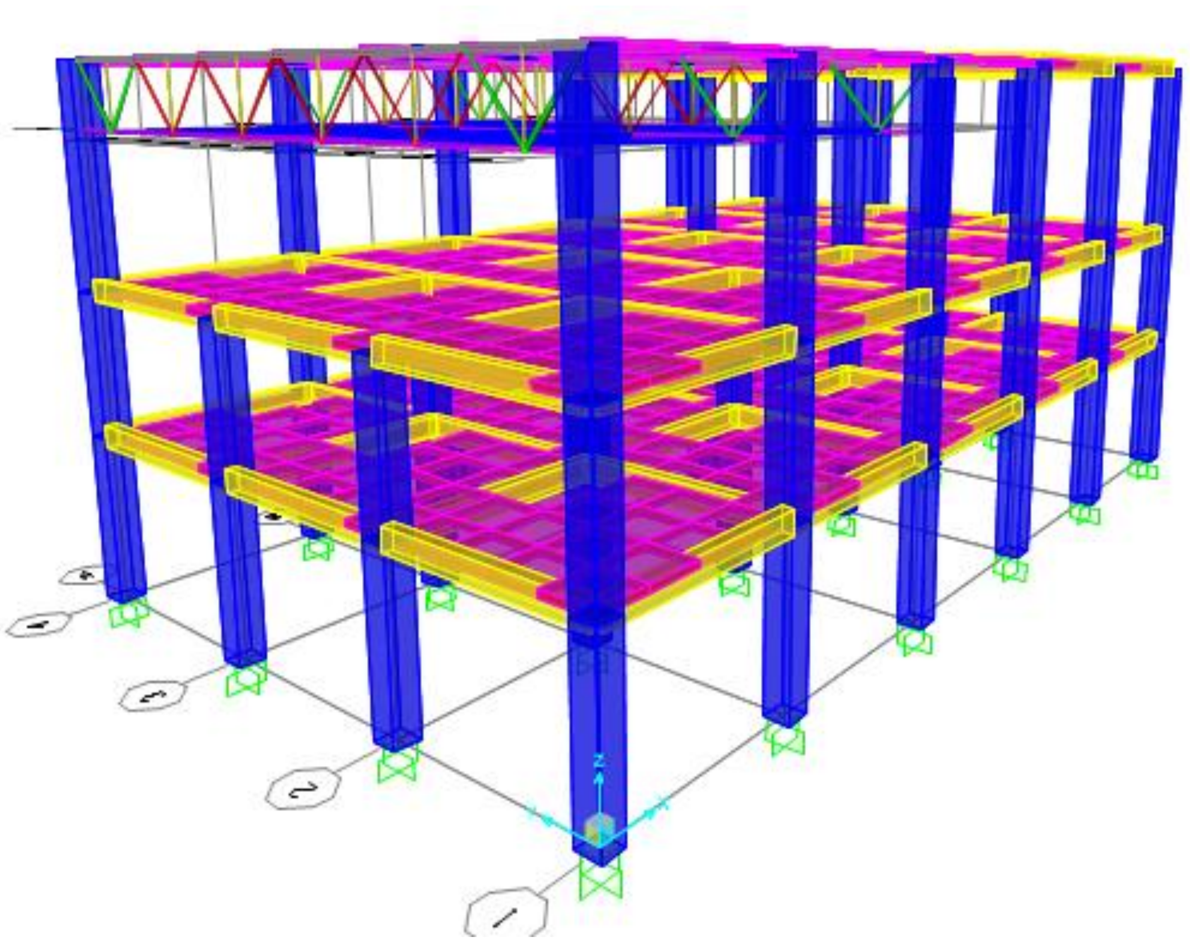


SNOW LOAD

LIVE LOAD

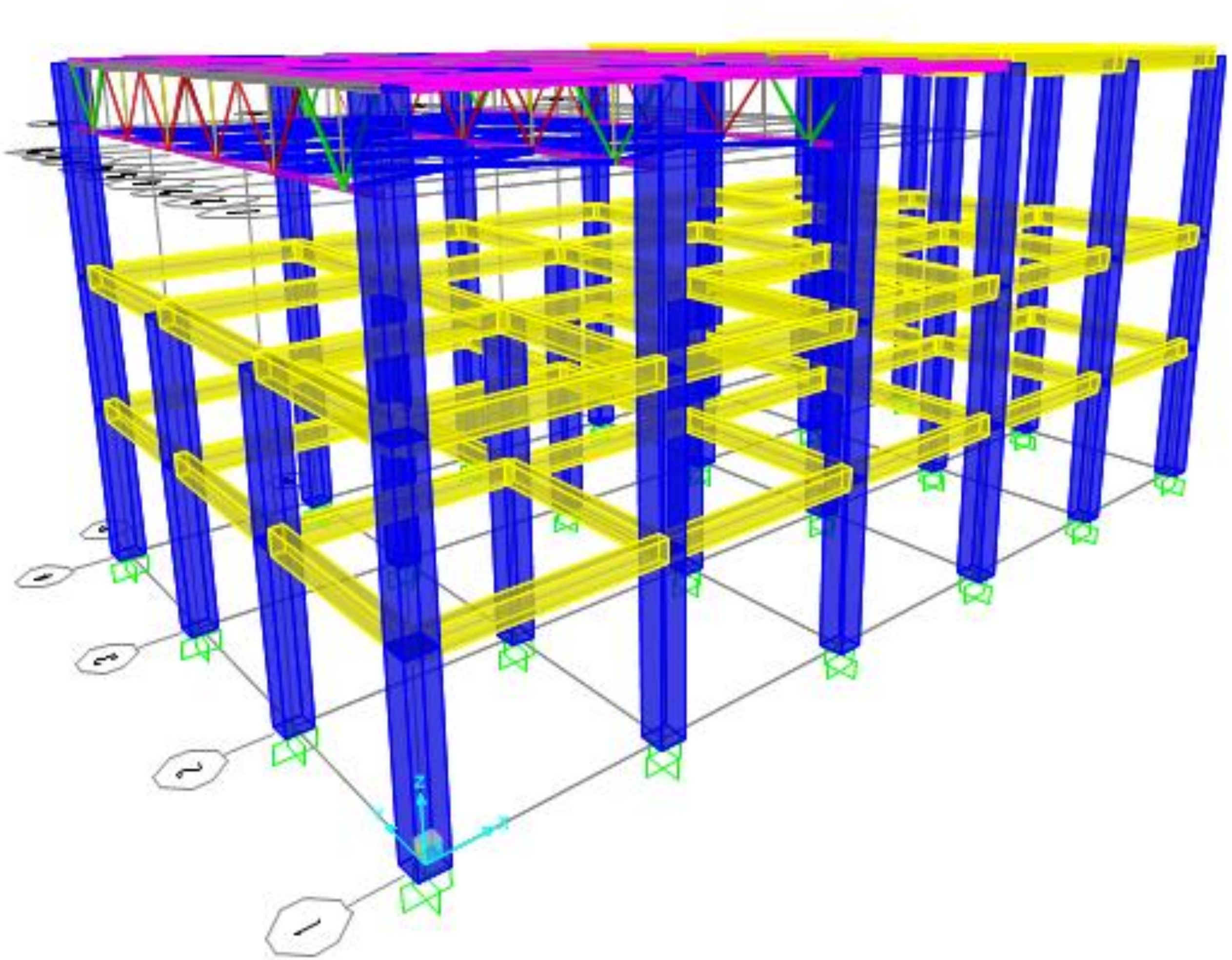
DEAD LOAD

STRUCTURAL ANALYSIS: 3D **FLEXIBLE SLAB** SAP2000 MODEL



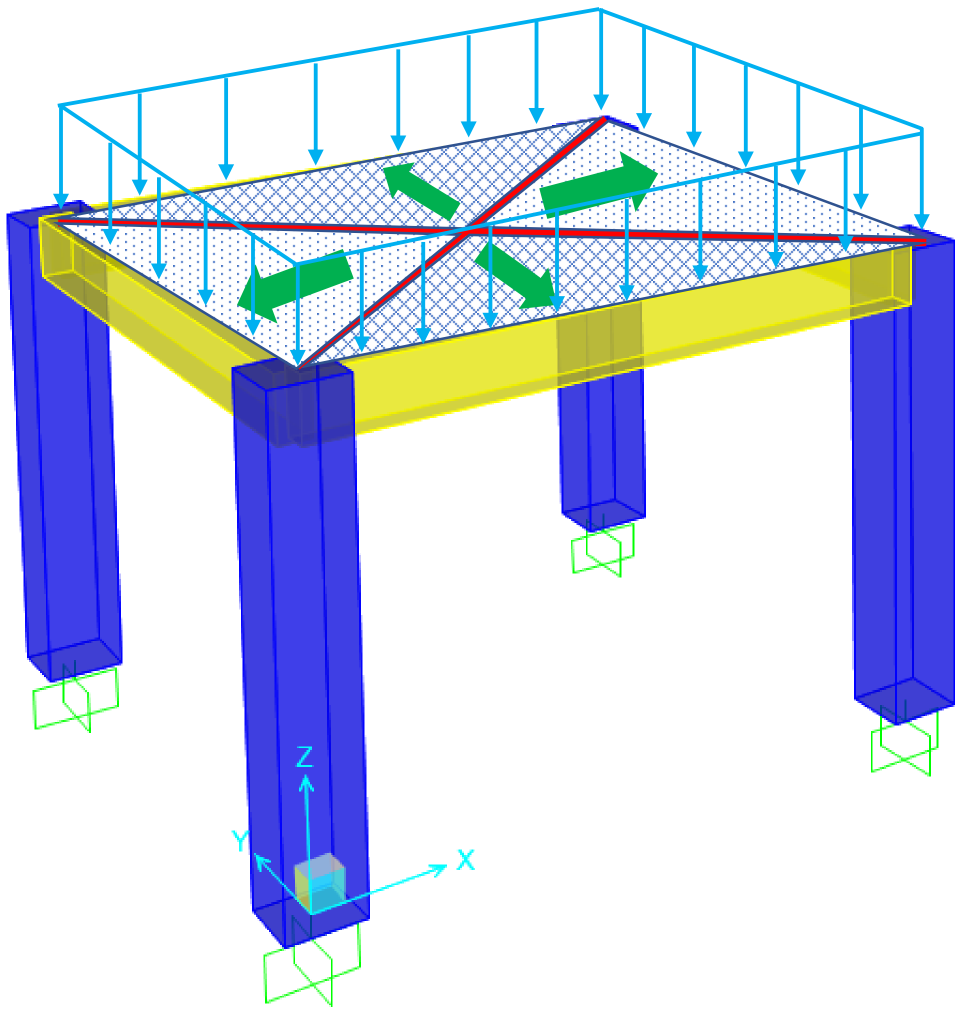
IN-PLANE & OUT-PLANE SLAB RIGIDITY: %1

STRUCTURAL ANALYSIS: 3D **WITHOUT SLAB** SAP2000 MODEL

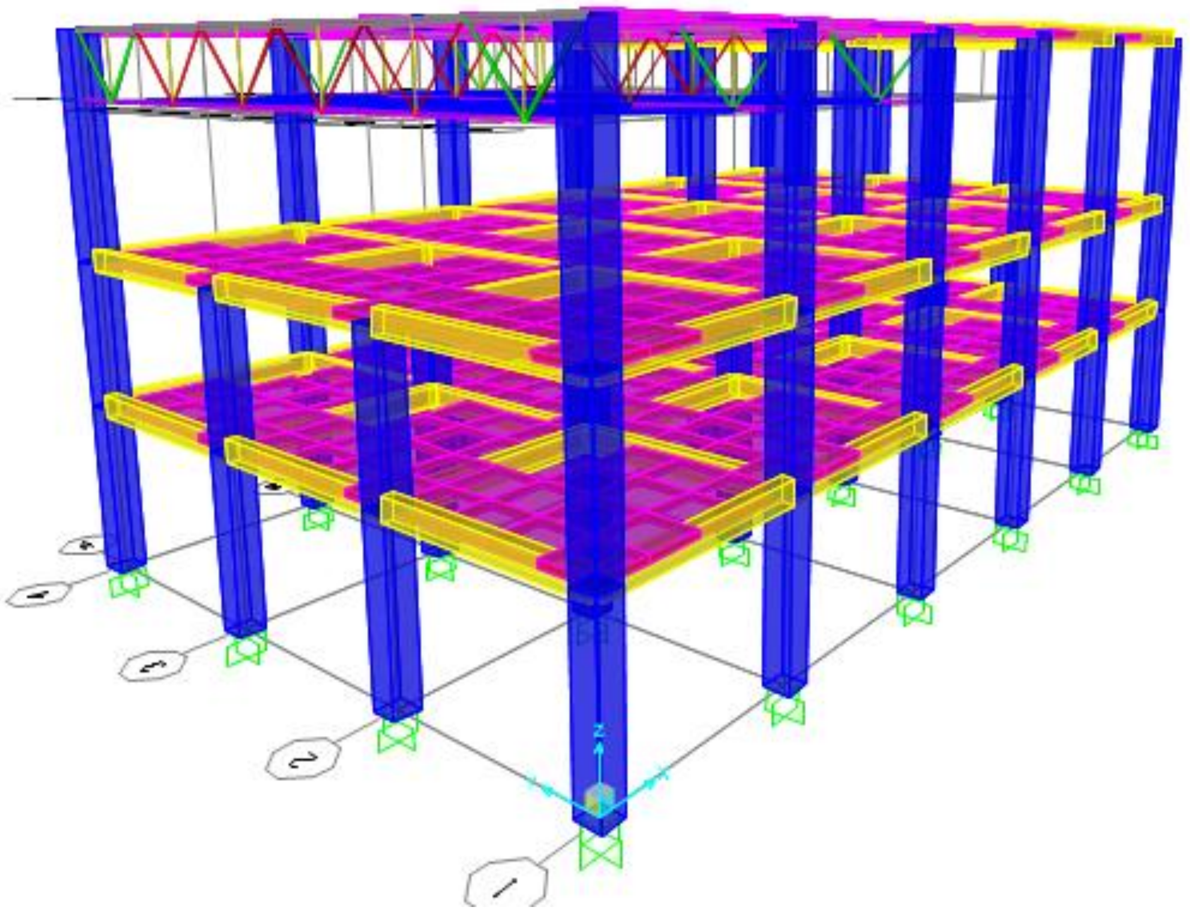


WITHOUT SLAB

STRUCTURAL ANALYSIS: 3D **WITHOUT SLAB** SAP2000 MODEL-LOADS

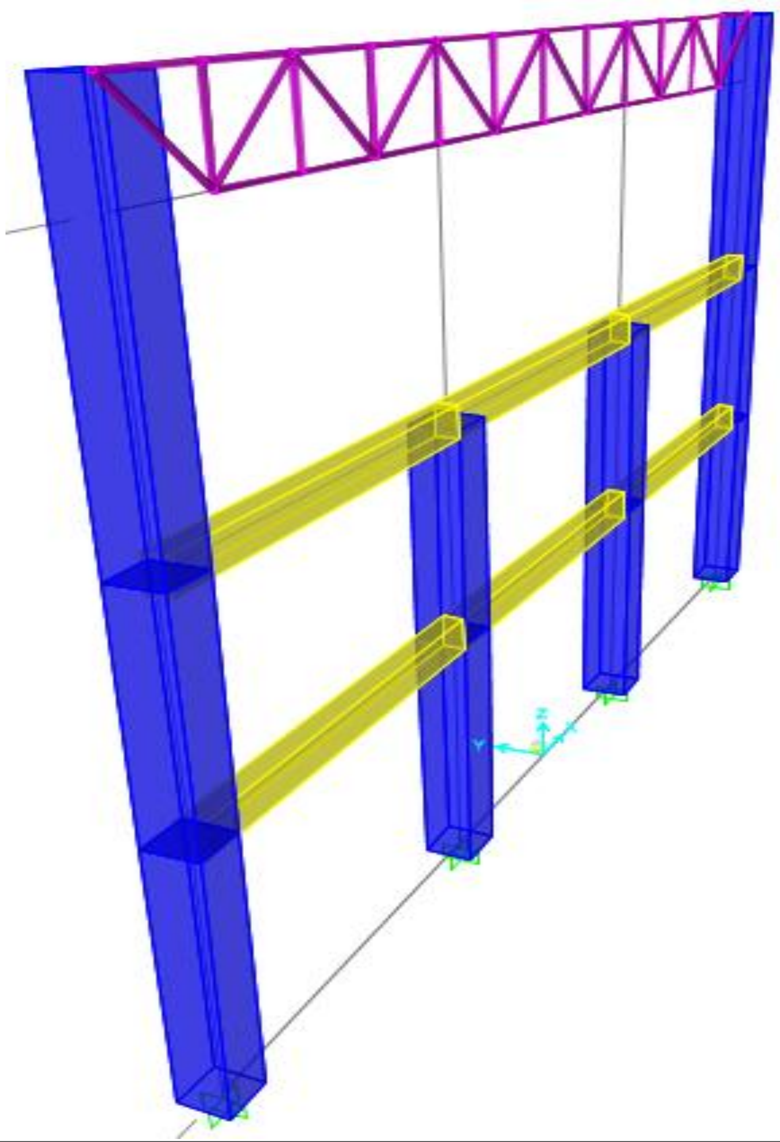


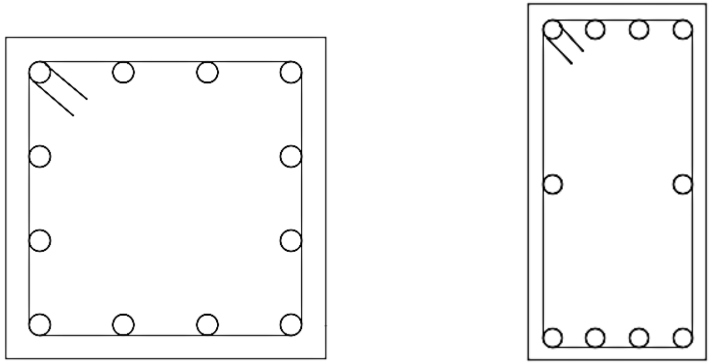
STRUCTURAL ANALYSIS: 3D **EFFECTIVE RIGIDITY** SAP2000 MODEL



TSC-2017 4.5.8.1

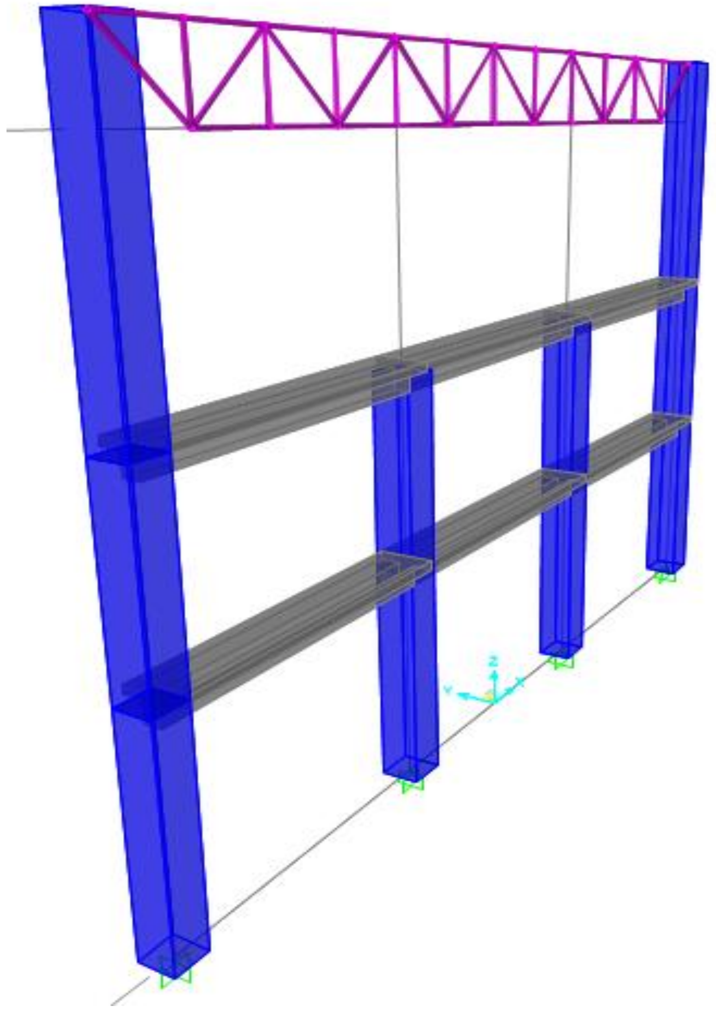
IN-PLANE SLAB RIGIDITY: %25
COLUMN: %70
BEAM: %35

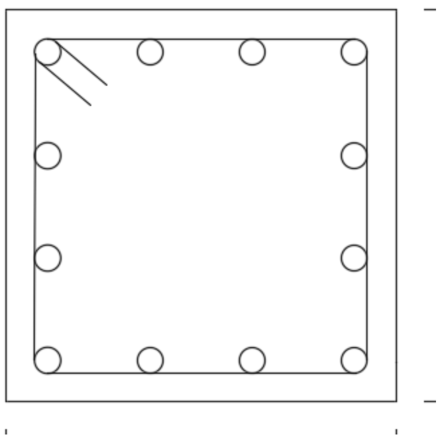


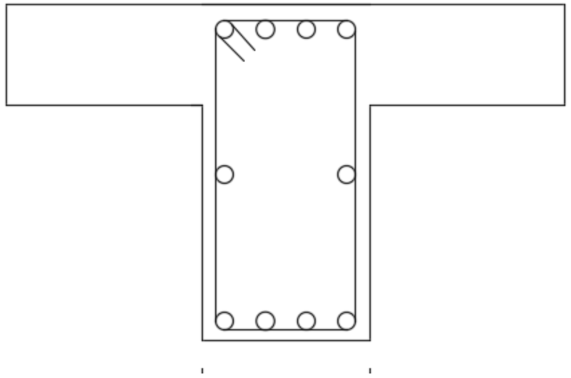


COLUMN & BEAM
RIGIDITY: %100

STRUCTURAL ANALYSIS: 2D T-SHAPE BEAM SAP2000 MODEL

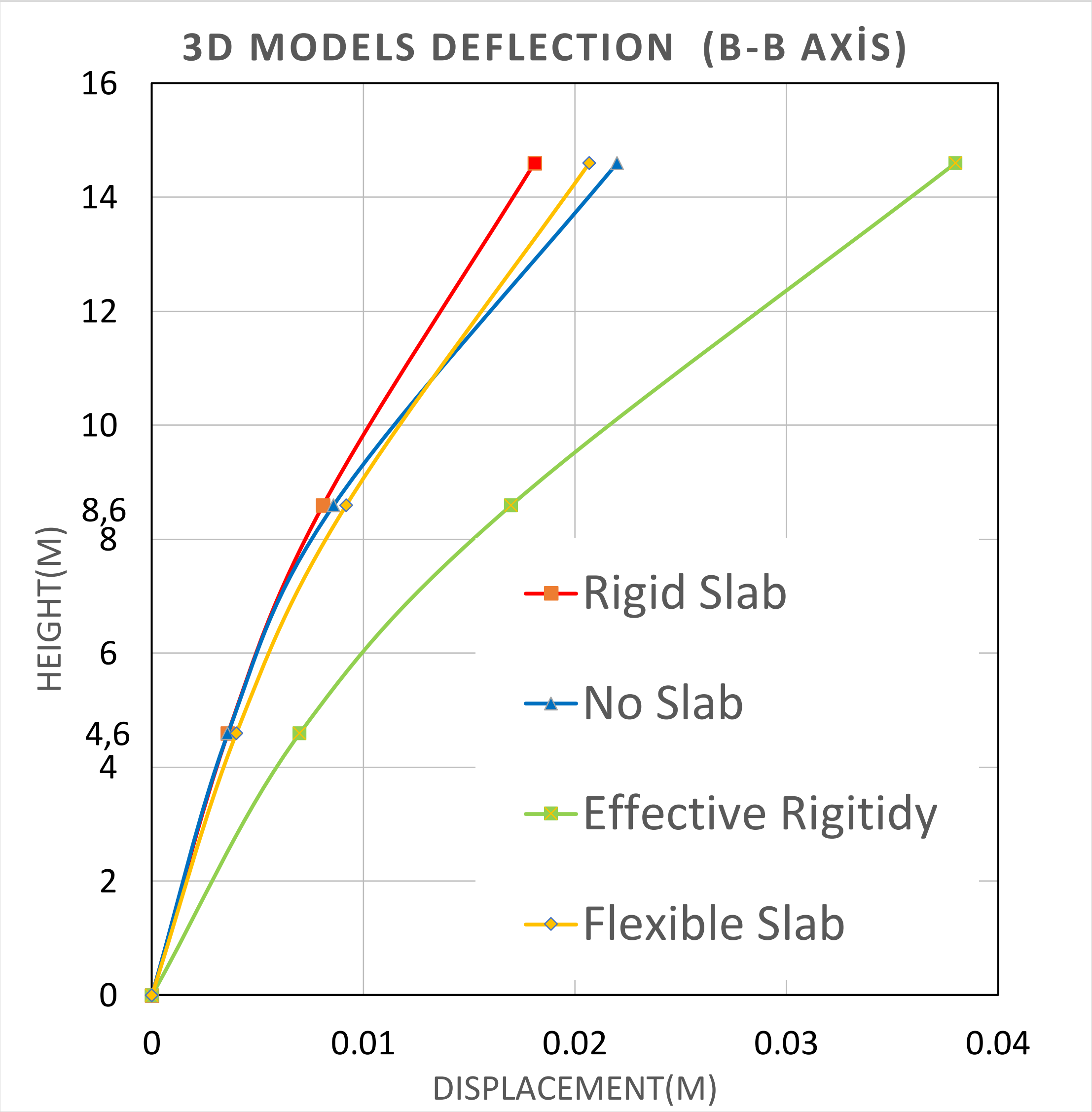


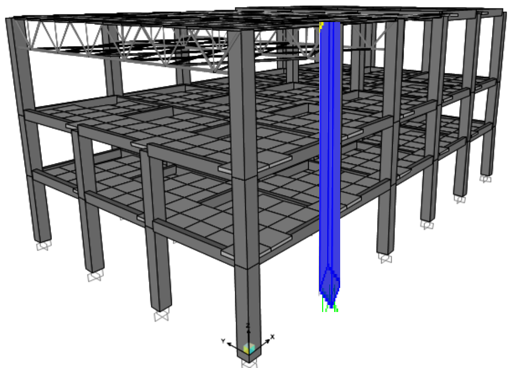




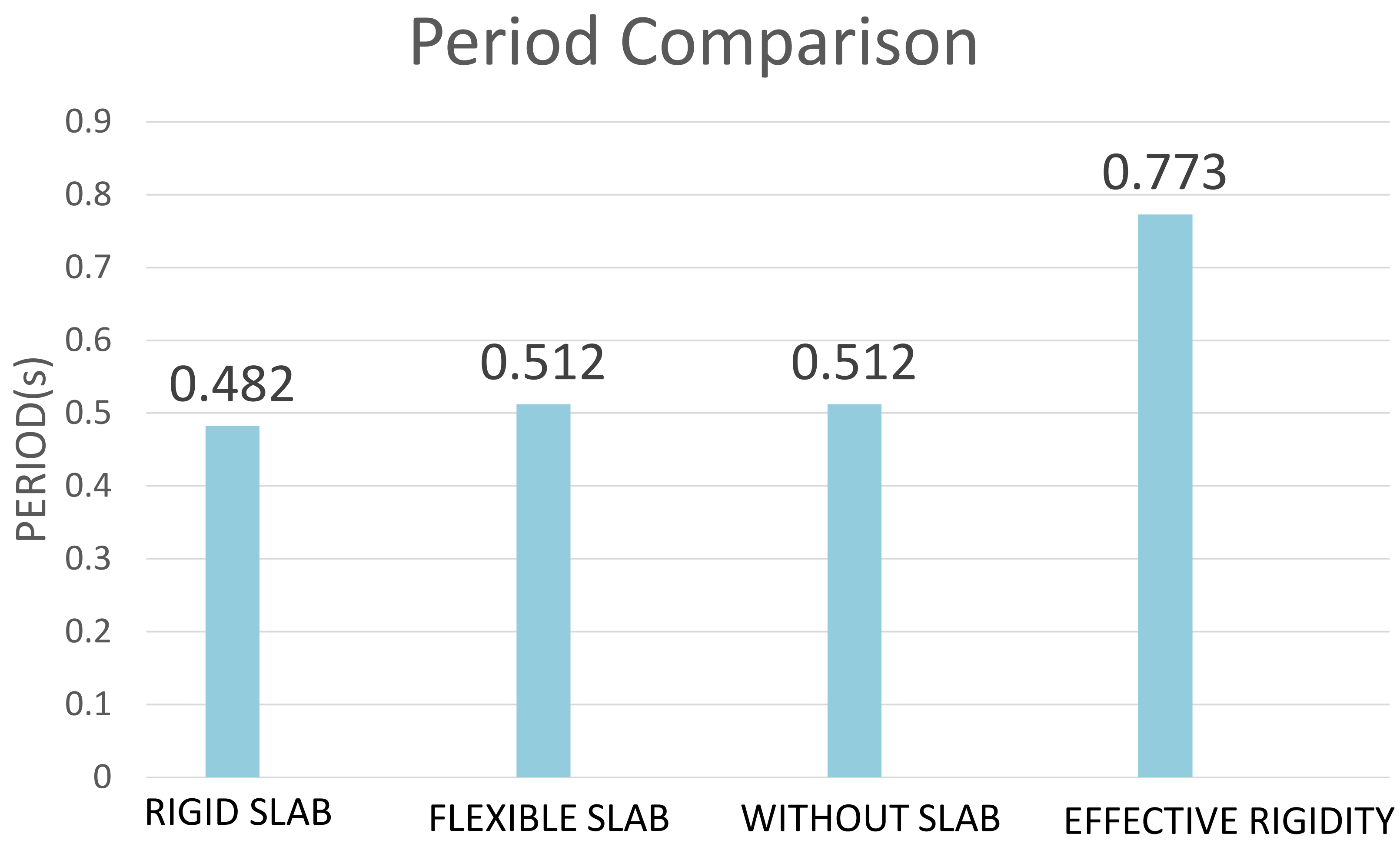
İTÜ

$EQ_Y \rightarrow T=0{,}773s$



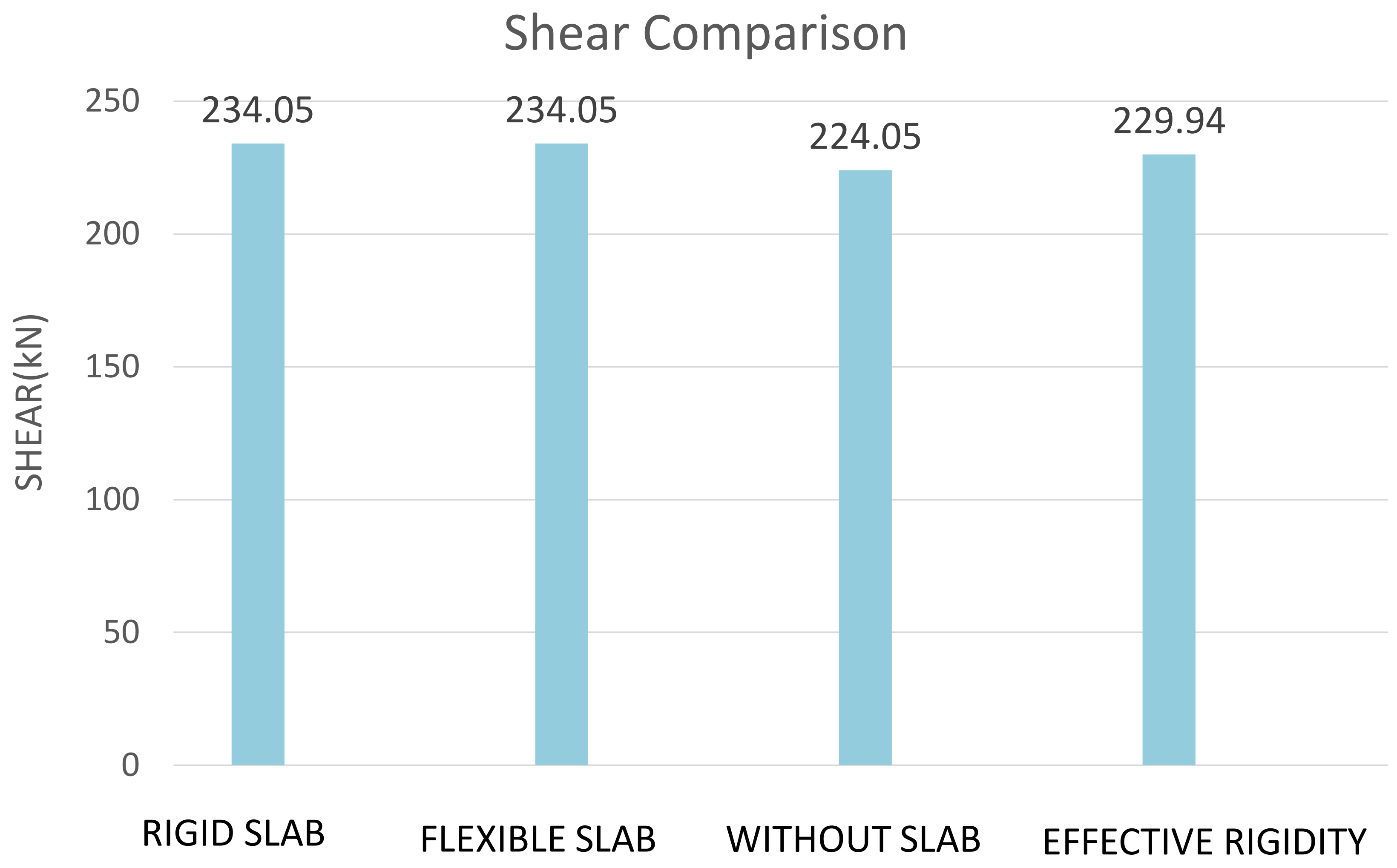


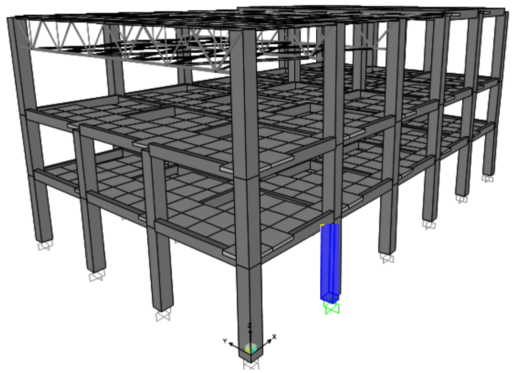
TYPE	MODEL	TOP DEFL.
3D	Flexible Slab	0,0207 m
3D	Rigid Slab	0,0181 m
3D	No Slab	0,0220 m
3D	Effective Slab	0,0380 m
2D	Rect. Beam	0,0191 m
2D	T-Beam	0,0152 m

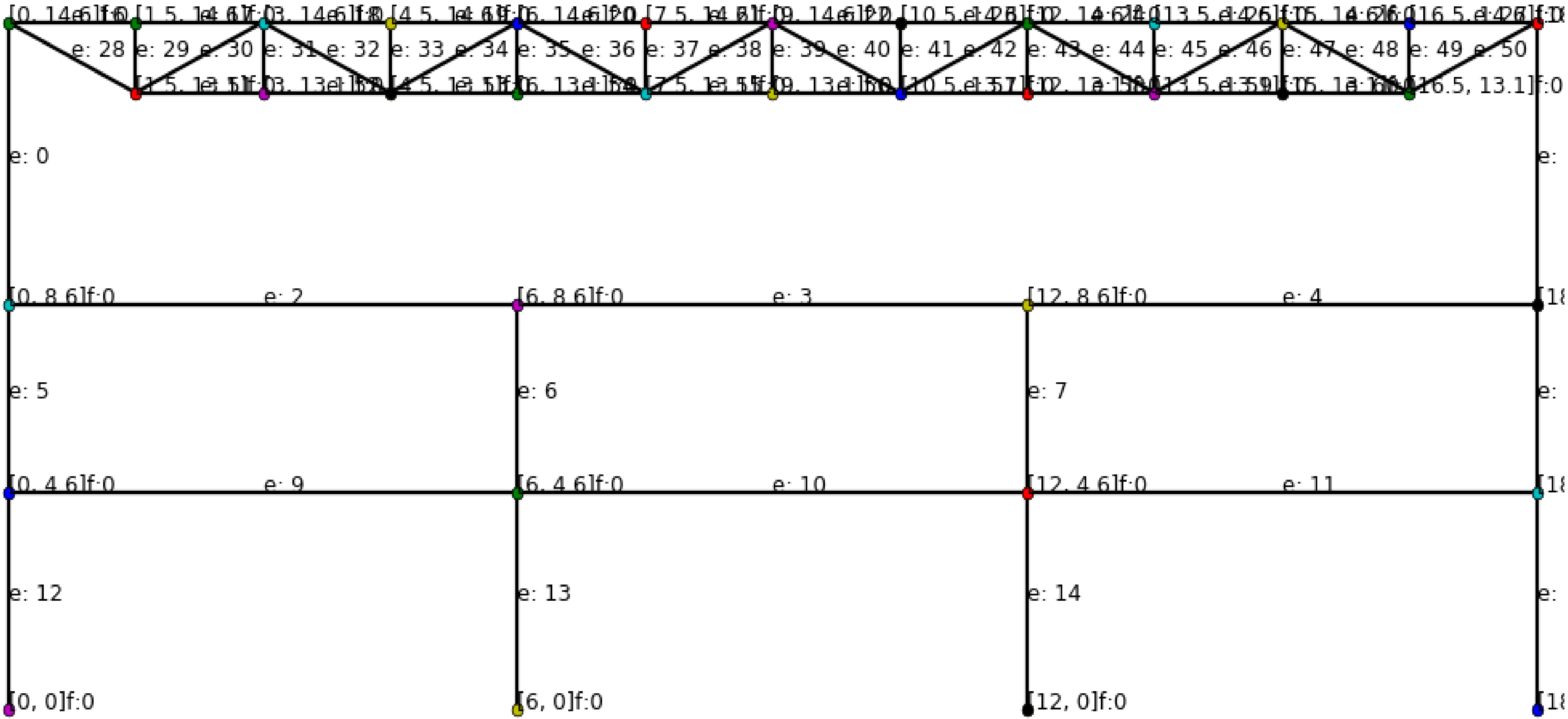

Period Comparison
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
PERIOD(s)
0.482
0.512
0.512
0.773
RIGID SLAB
FLEXIBLE SLAB
WITHOUT SLAB
EFFECTIVE RIGIDITY

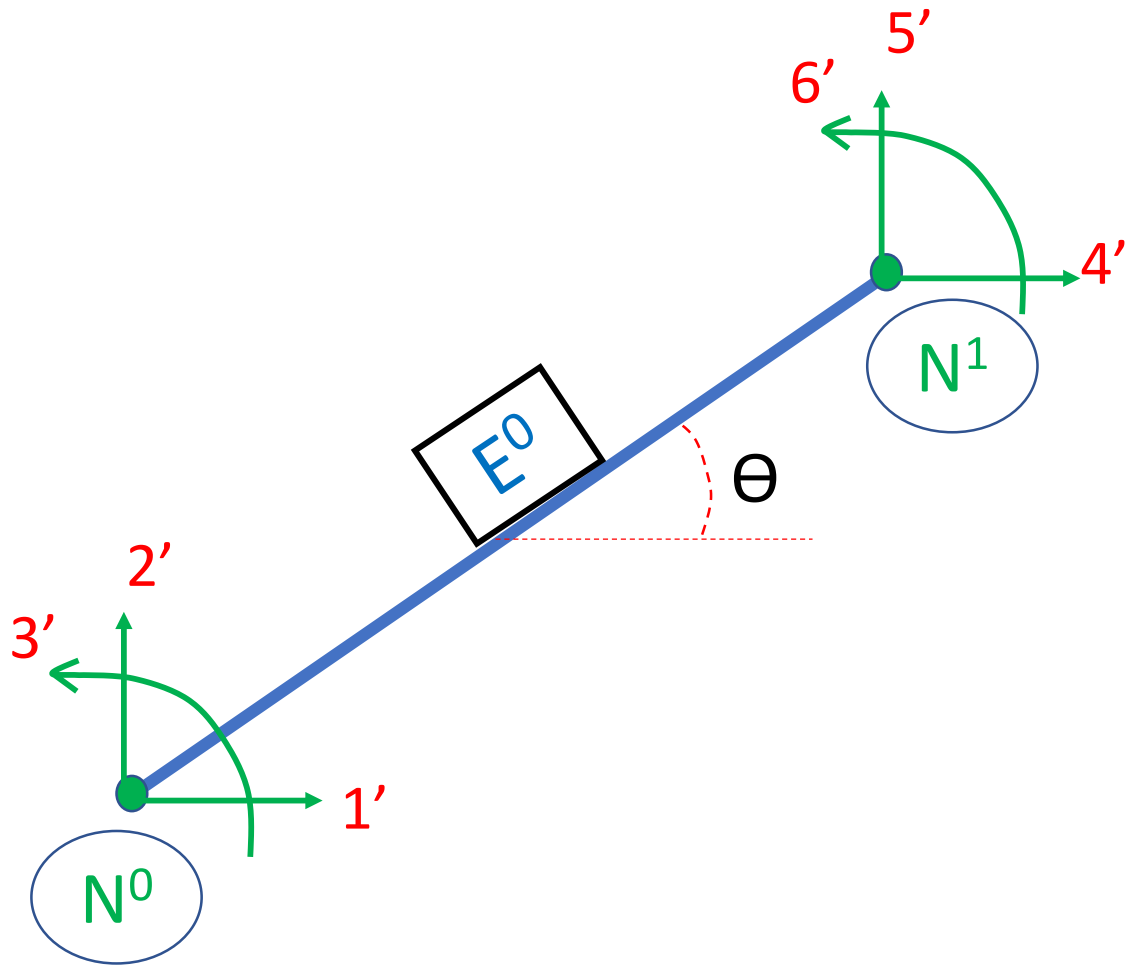
STRUCTURAL ANALYSIS: 3D SAP 2000 MODELS COMPARASION

$EQ_Y \rightarrow T=0,773s$

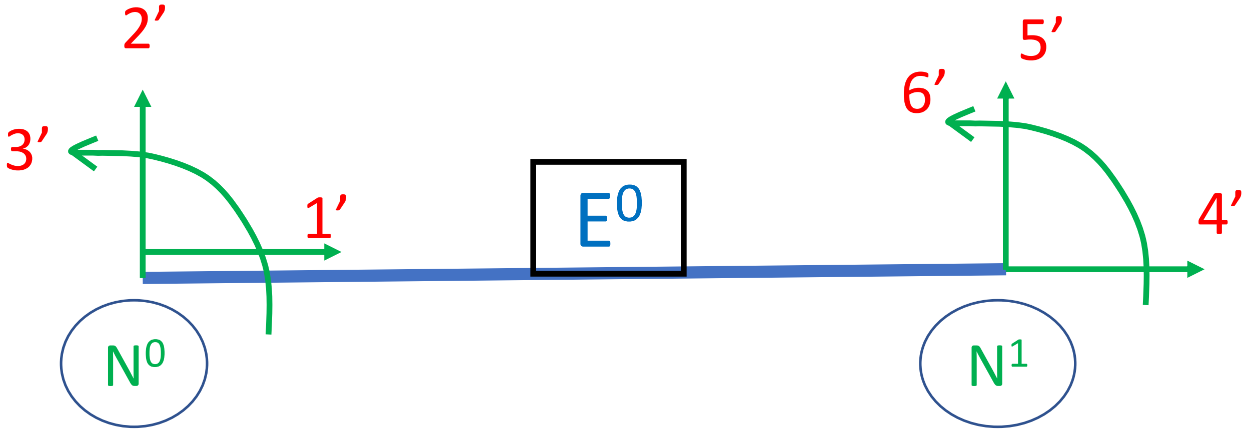




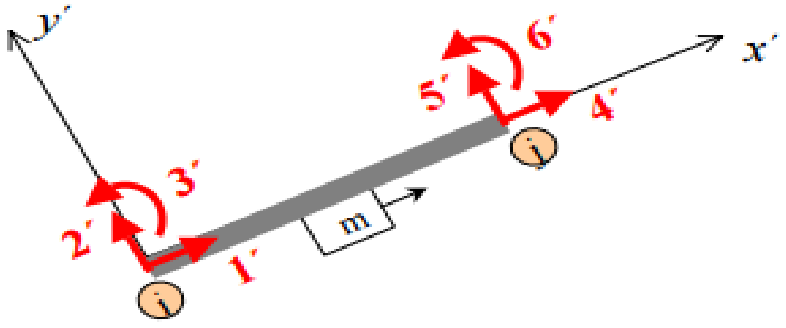

e: 28
e: 29
e: 30
e: 31
e: 32
e: 33
e: 34
e: 35
e: 36
e: 37
e: 38
e: 39
e: 40
e: 41
e: 42
e: 43
e: 44
e: 45
e: 46
e: 47
e: 48
e: 49
e: 50
[16.5, 13.1]f:0
e: 0
[0, 8.6]f:0
e: 2
[6, 8.6]f:0
e: 3
[12, 8.6]f:0
e: 4
e: 5
e: 6
e: 7
[0, 4.6]f:0
e: 9
[6, 4.6]f:0
e: 10
[12, 4.6]f:0
e: 11
e: 12
e: 13
e: 14
[0, 0]f:0
[6, 0]f:0
[12, 0]f:0



LOCAL DEGREE OF FREEDOM



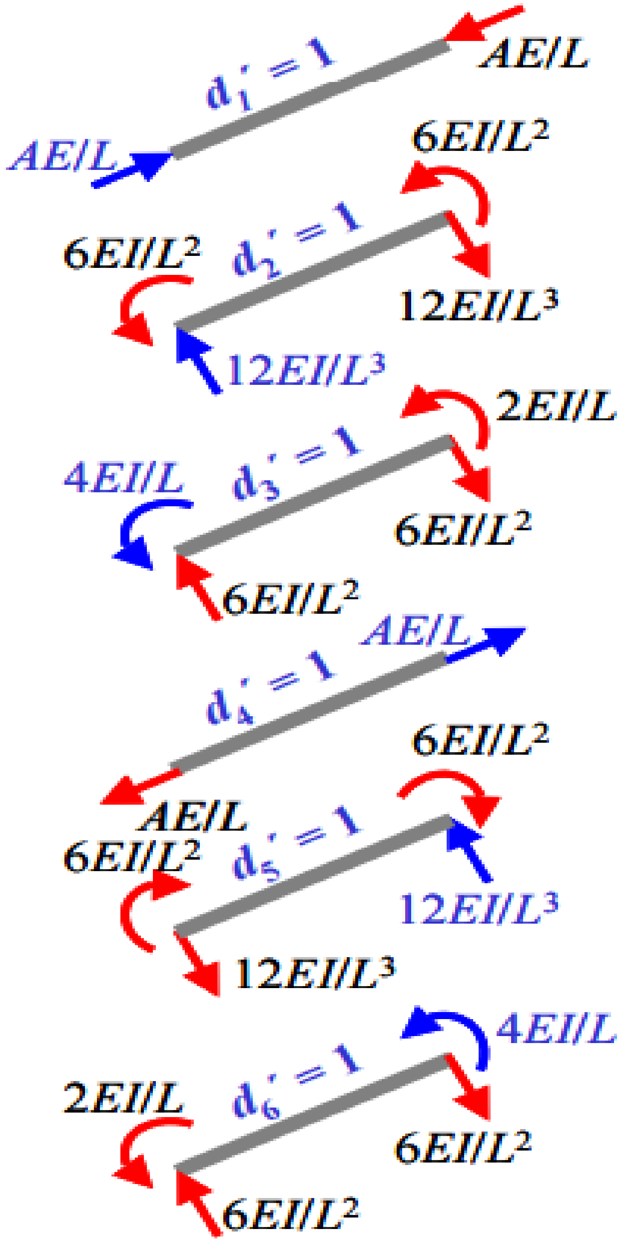
GLOBAL DEGREE OF FREEDOM

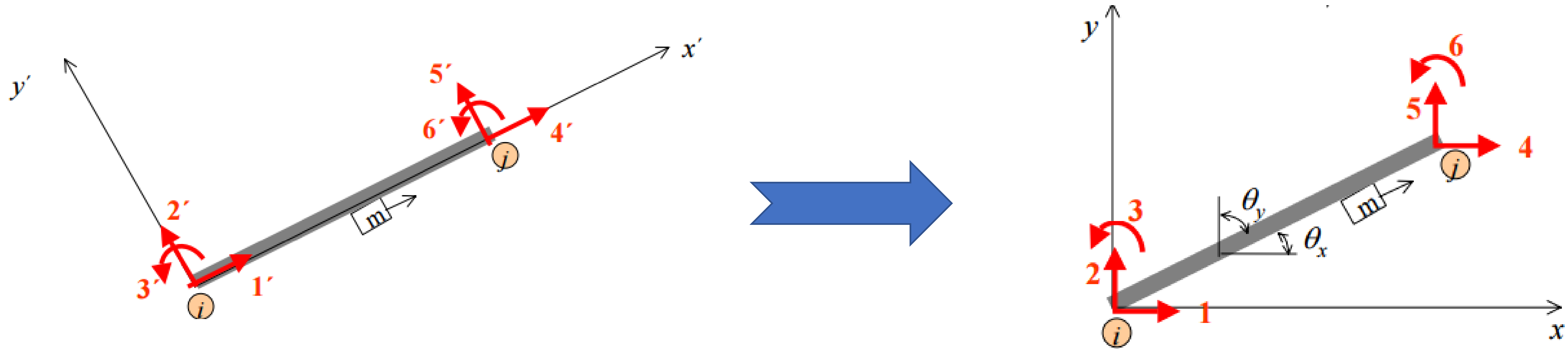


[k′]

$$
\begin{array}{cc}
 & \begin{array}{cccccc} 1' & 2' & 3' & 4' & 5' & 6' \end{array} \\
\begin{array}{c} 1' \\ 2' \\ 3' \\ 4' \\ 5' \\ 6' \end{array} &
\begin{pmatrix}
AE/L & 0 & 0 & -AE/L & 0 & 0 \\
0 & 12EI/L^3 & 6EI/L^2 & 0 & -12EI/L^3 & 6EI/L^2 \\
0 & 6EI/L^2 & 4EI/L & 0 & -6EI/L^2 & 2EI/L \\
-AE/L & 0 & 0 & AE/L & 0 & 0 \\
0 & -12EI/L^3 & -6EI/L^2 & 0 & 12EI/L^3 & -6EI/L^2 \\
0 & 6EI/L^2 & 2EI/L & 0 & -6EI/L^2 & 4EI/L
\end{pmatrix}
\end{array}
$$

STIFFNESS MATRIX





$$\mathbf{T}^e = \begin{bmatrix} \cos x & \sin x & 0 & 0 & 0 & 0 \\ -\sin x & \cos x & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & \cos x & \sin x & 0 \\ 0 & 0 & 0 & -\sin x & \cos x & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\boxed{[q] = [T]^{\mathrm{T}}[q']}$$

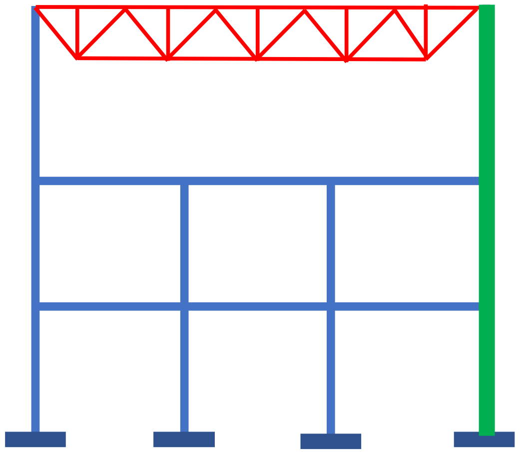
$$\boxed{[d'] = [T][d]}$$

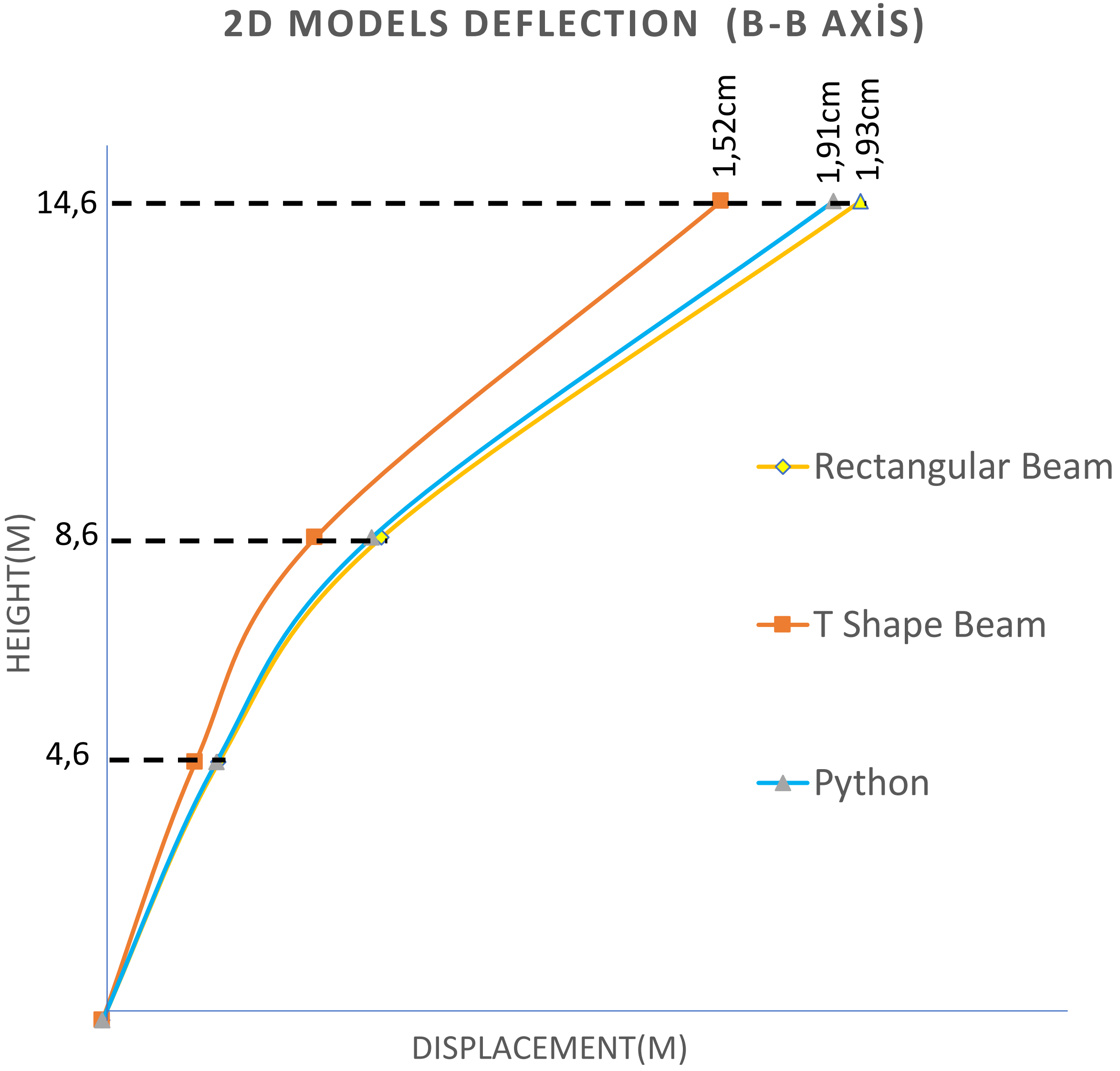
$$\boxed{[\boldsymbol{k}] = [\boldsymbol{T}]^{\mathrm{T}}[\boldsymbol{k}'][\boldsymbol{T}]}$$

$$[Q] = [K][D] + [Q^{\mathrm{F}}]$$

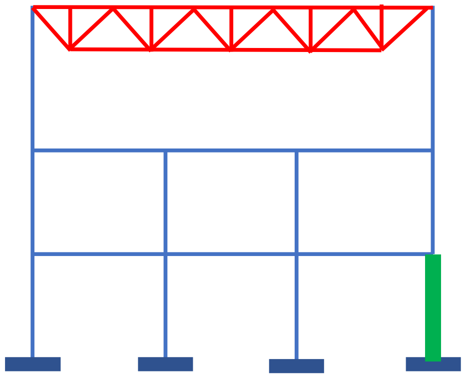
STRUCTURAL ANALYSIS: **2D SAP2000 & PYTHON MODELS**

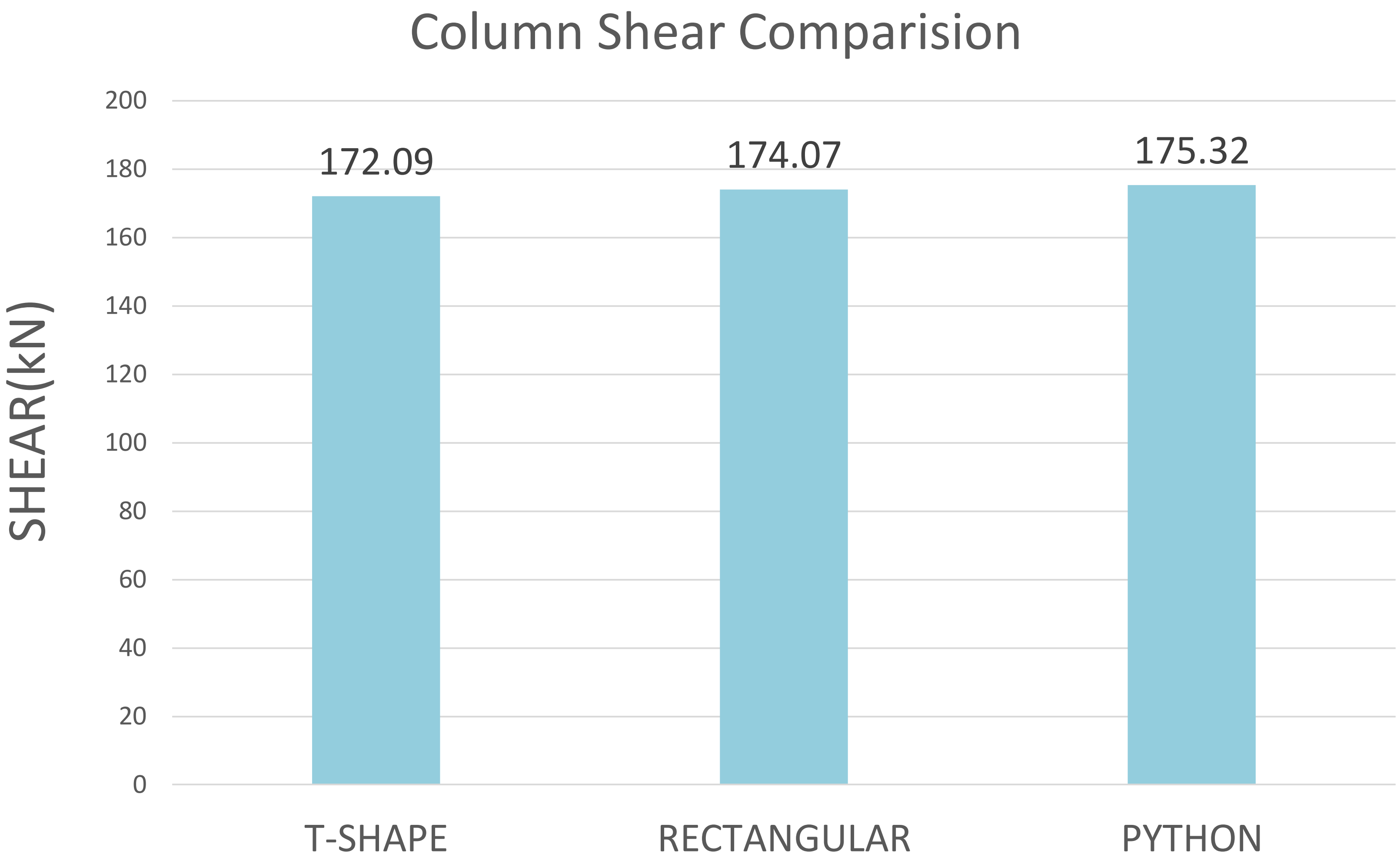
EQ$_Y$ → T=0,773s



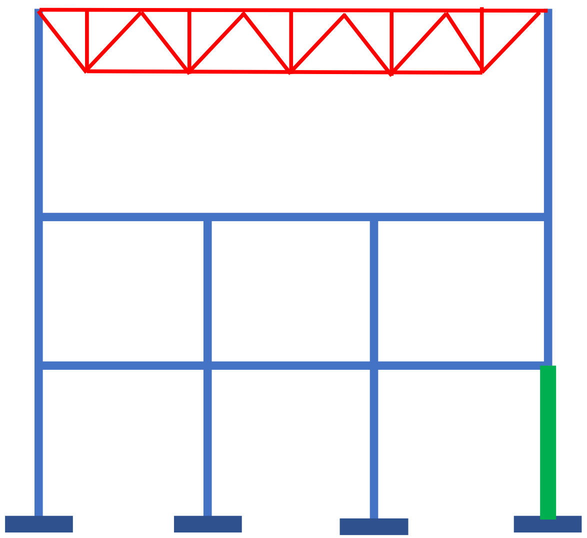


STRUCTURAL ANALYSIS: **2D SAP2000 & PYTHON MODELS**



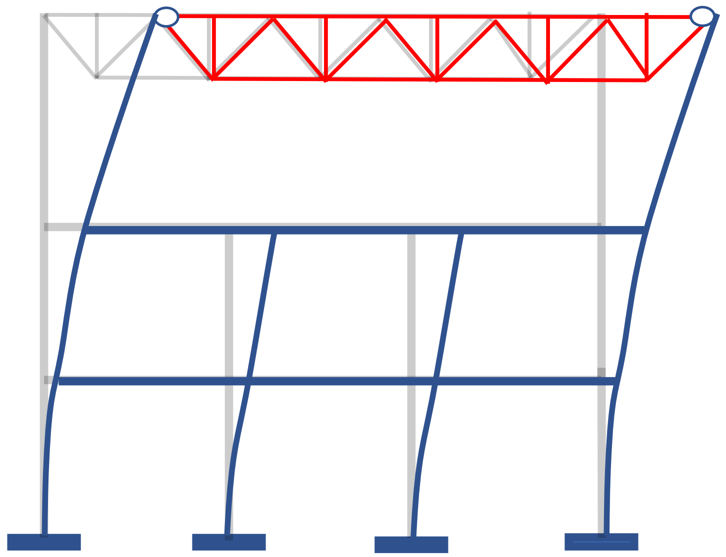


STRUCTURAL ANALYSIS: 2D SAP 2000 MODELS COMPARASION

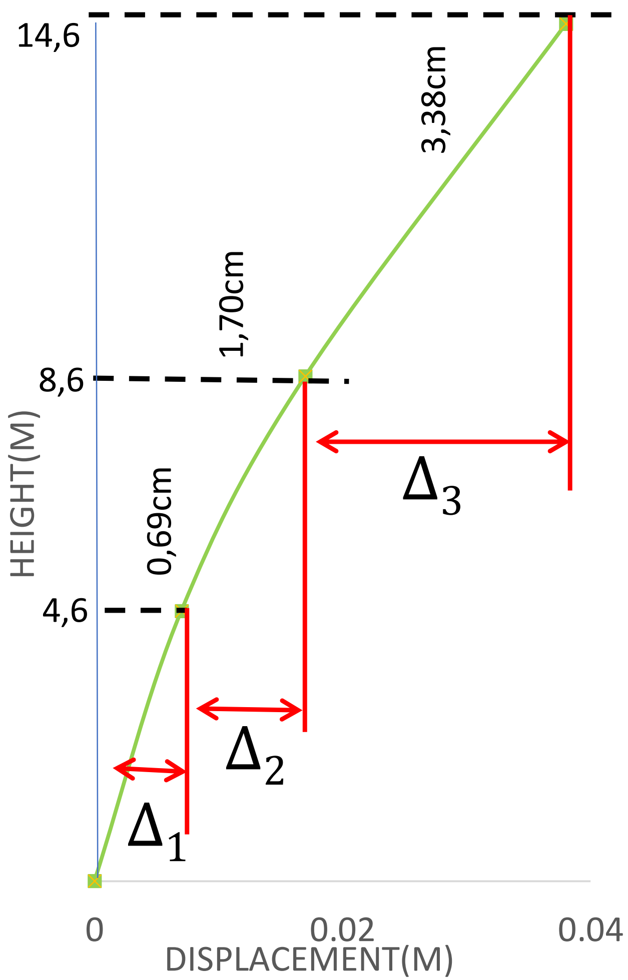


COMPARISON	2D RECT. SAP2000	2D RECT. PYTHON	ACC (%)
COLUMN AXIAL / 1,4G+1,6Q	1460,47 kN	1460,92 kN	99,97
COLUMN SHEAR / G+Q-E	-202,87 kN	-204,06kN	99,42
COLUMN MOMENT / 0,9G+E	677,79 kNm	674,32kNm	99,49
CANTILEVER DEFLECTION / E	1,91 cm	1,93 cm	98,96
TRUSS DEFL. / 1,4G+1,6Q	4,52cm	4,56cm	99,12

$EQ_Y \rightarrow T=0,773s$



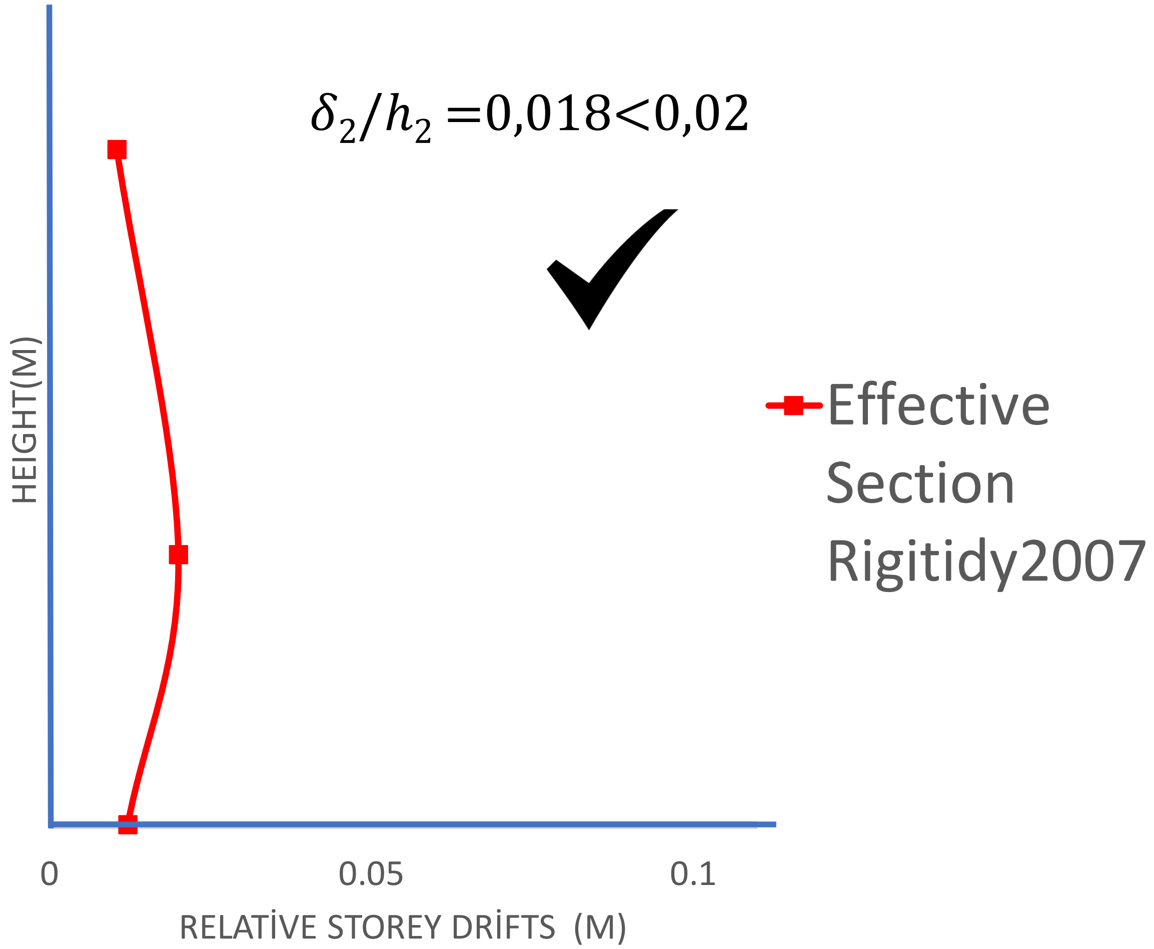
3D MODELS DEFLECTION (B-B AXİS)



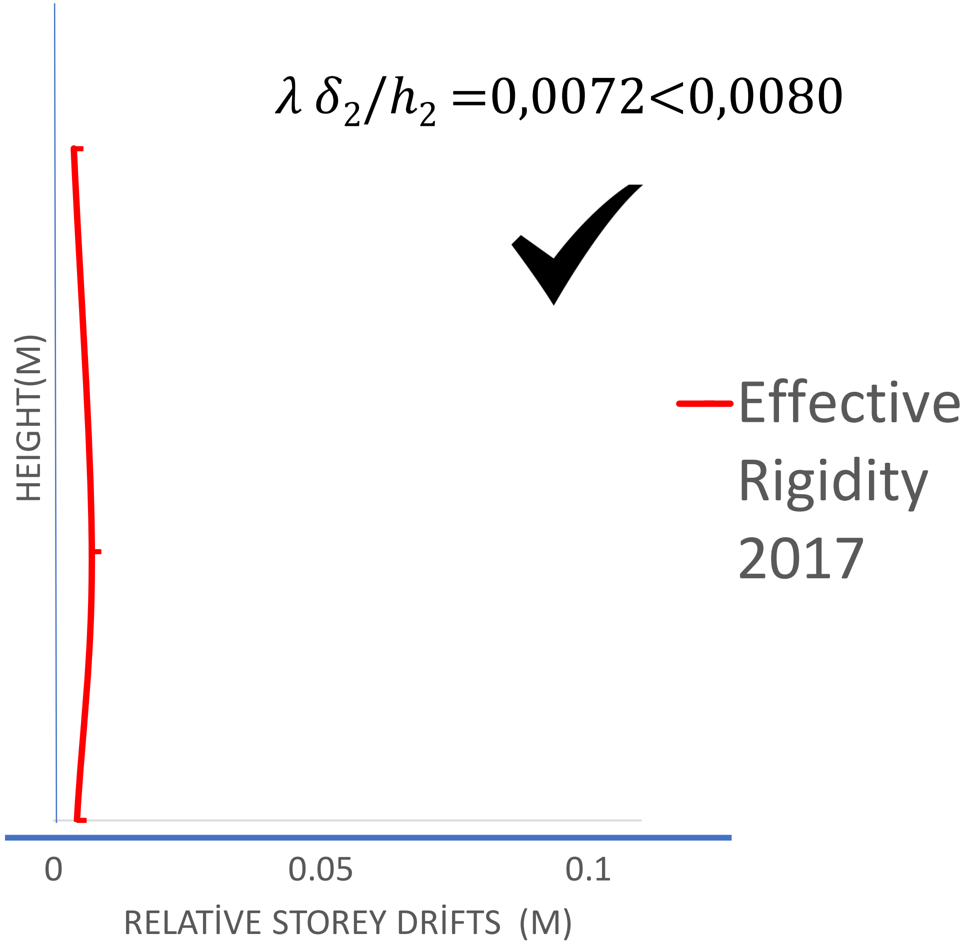
Model with
Effective Rigidity

EFFECTIVE RELATIVE STOREY DRIFTS CHECK

3D MODELS EFFECTİVE RELATİVE STOREY DRIFTS (B-B AXİS) TSC-2007

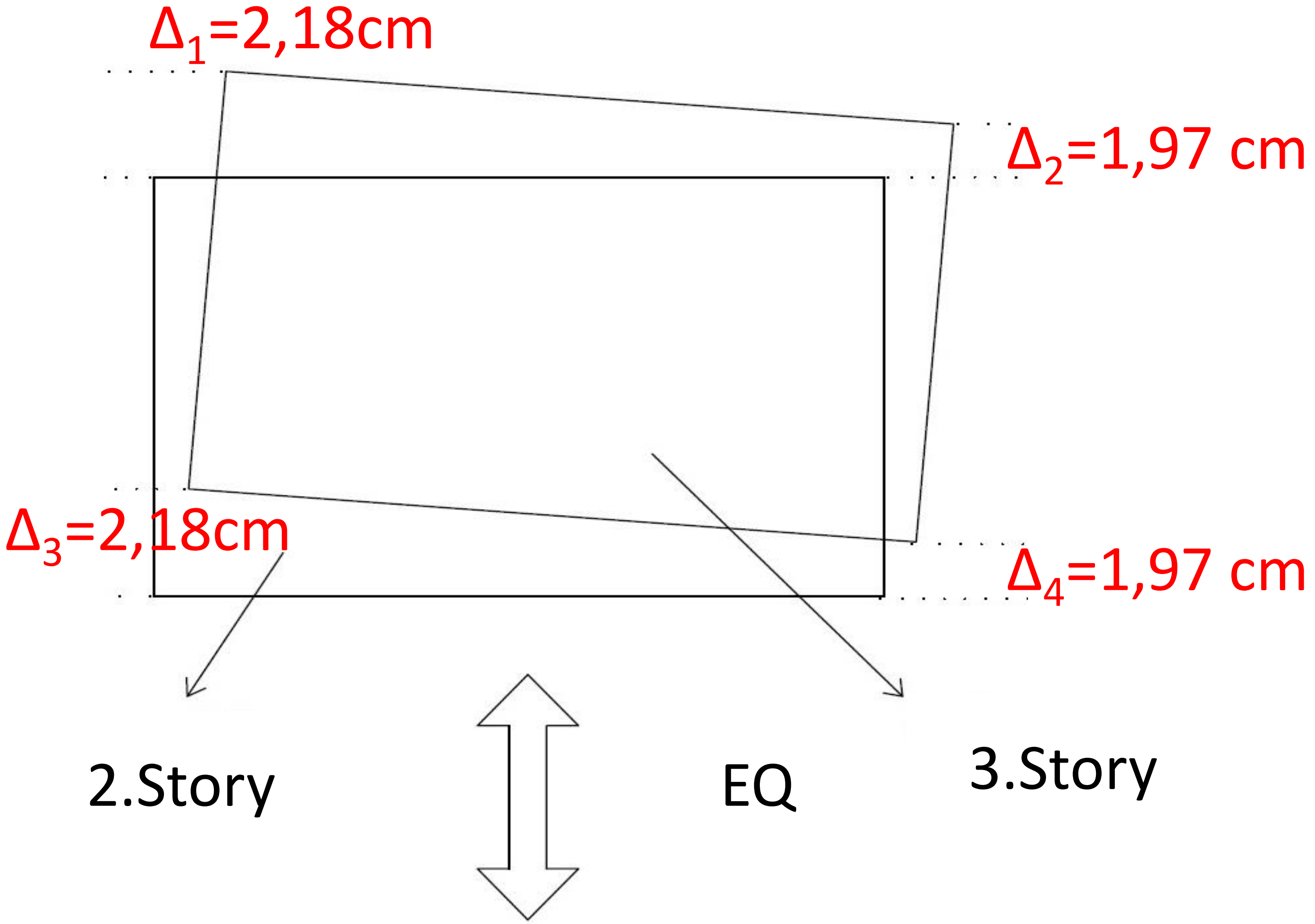


3D MODELS EFFECTİVE RELATİVE STOREY DRİFTS (B-B AXİS) TSC-2017



IRREGULARITIES IN PLANE	
TORSIONAL IRREGULARITY	✓
FLOOR DISCONTUNITIES	✓
PROJECTIONS IN PLANE	✓
IRREGULARITIES IN ELEVATION	
INTERSTORY STRENGTH IRREGULARITY	✓
INTERSTORY STIFFNESS IRREGULARITY	✓
DISCONTUNITIES OF VERTICAL STRUCTURAL ELEMENTS	✓

STRUCTURAL ANALYSIS: TORSIONAL IRREGULARITIES CHECK

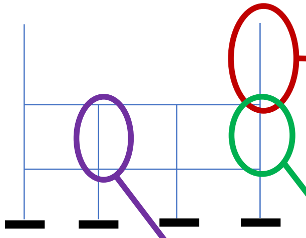


$$\eta 23 = \frac{2.18}{2.075} = 1.05 < 1.20$$

✔

CONTENT

1. INTRODUCTION
2. PRELIMINARY DESIGN
3. STRUCTURAL ANALYSIS
4. DETAILED DESIGN
5. BIM STRUCTURAL INTEGRATION
6. CONCLUSION



M → Ω_{frame} E

V → $\Omega_{cantilever}\ \Omega_{frame}$ E

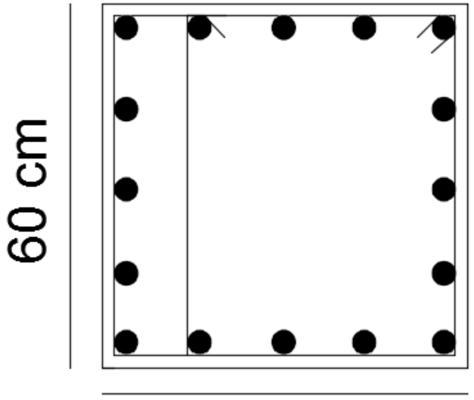
M → 1,25E

V → Ω_{frame} 1,25E

M → E

V → Ω_{frame} E

$$S/_{(R\,=\,8)} = E$$

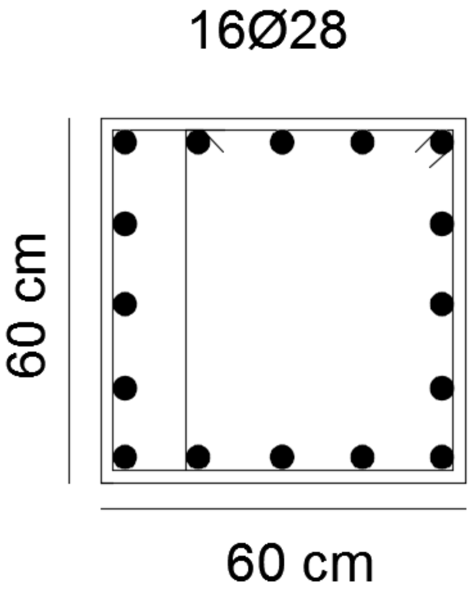


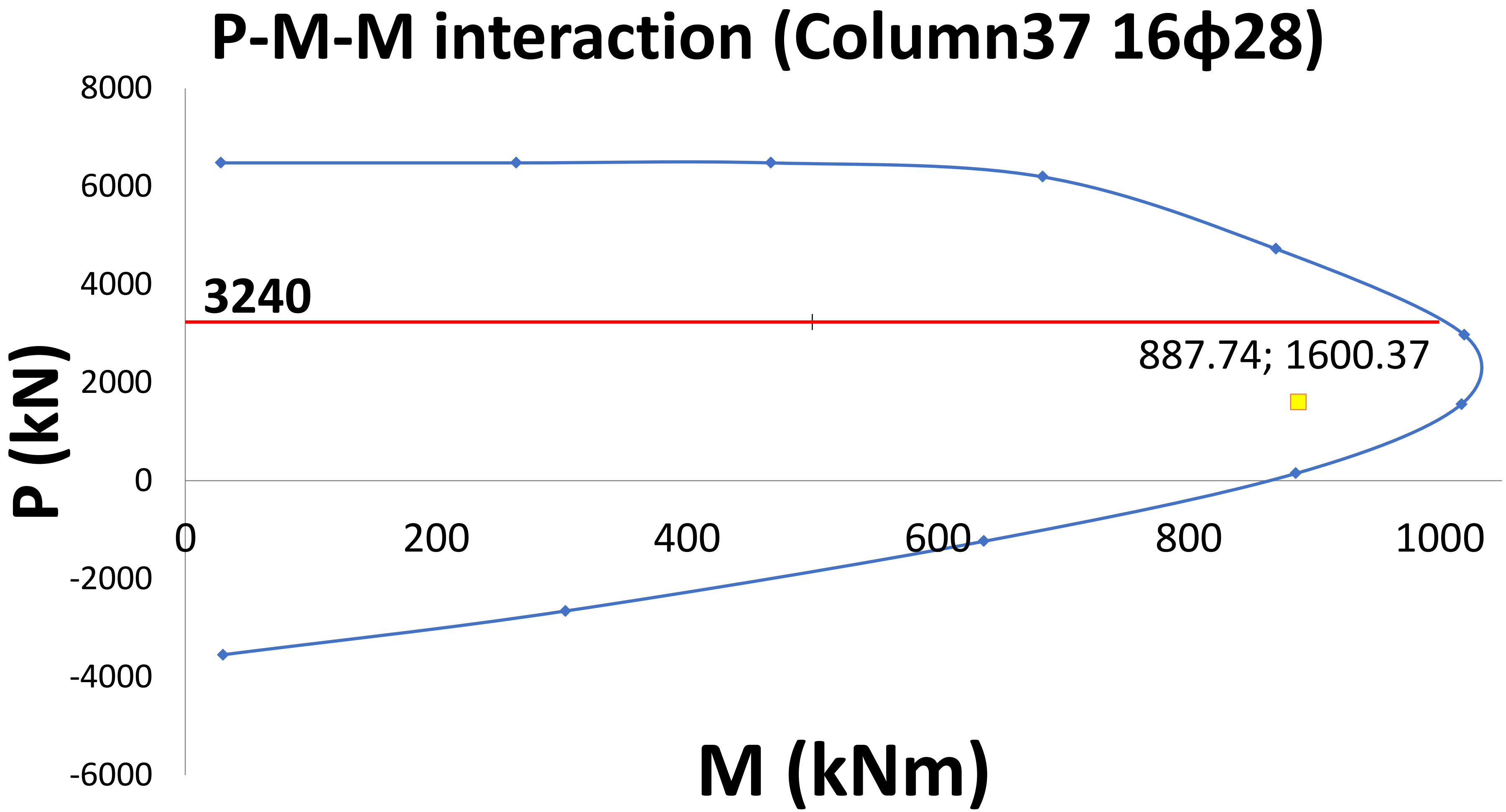
70x70 Column	
Axial Capacity	14700 kN
$0{,}3f_{ck}A_c$	4410 kN

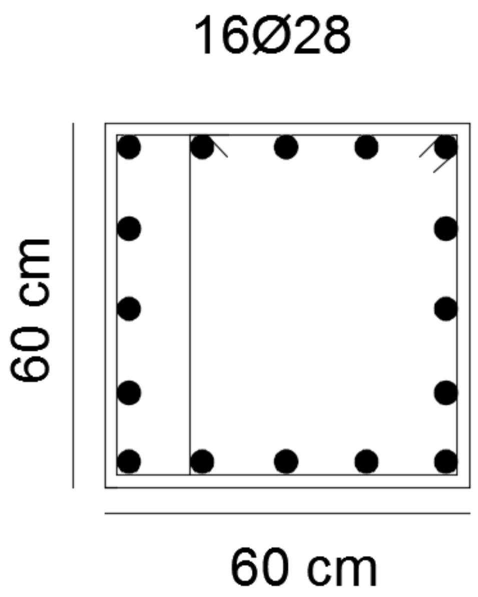
60x60 Column	
Axial Capacity	10800 kN
$0{,}3.f_{ck}.A_c$	3240 kN

4410 kN >2353.48 kN

Max Axial (1,4G+1,6Q)


16Ø28
60 cm
60 cm

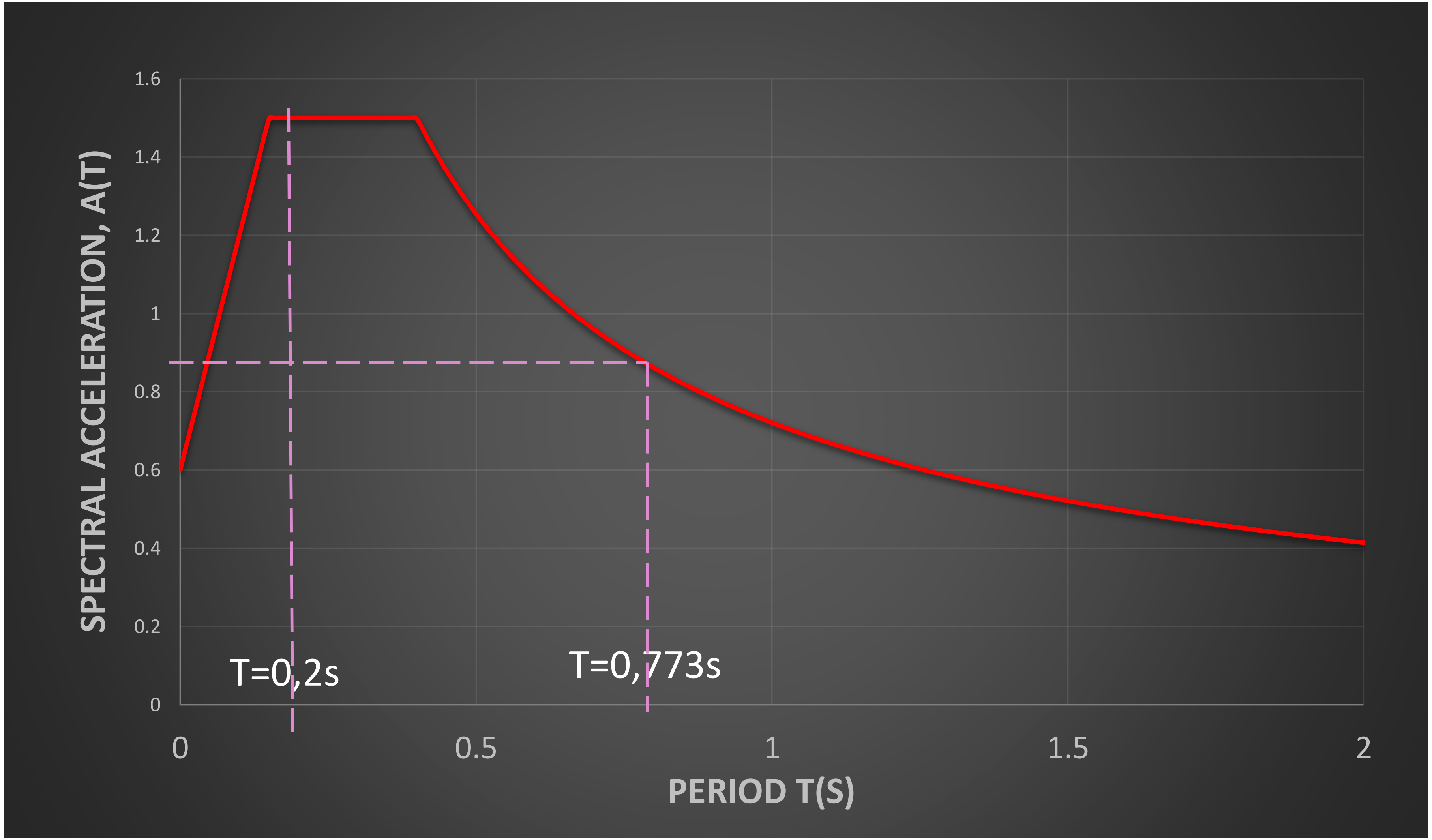

P-M-M interaction (Column37 16ϕ28)
8000
6000
4000
2000
0
-2000
-4000
-6000
3240
887.74; 1600.37
0
200
400
600
800
1000
P (kN)
M (kNm)



ρ =0,0274

1)0,01≤ρ≤0,04(TSC 2007)

2)Is this constructable?

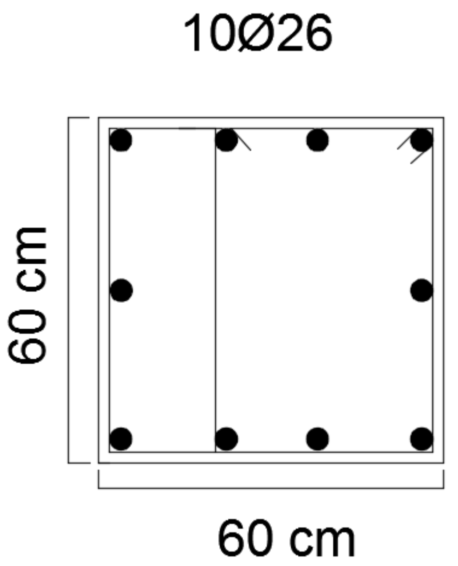


For T=0,2 s

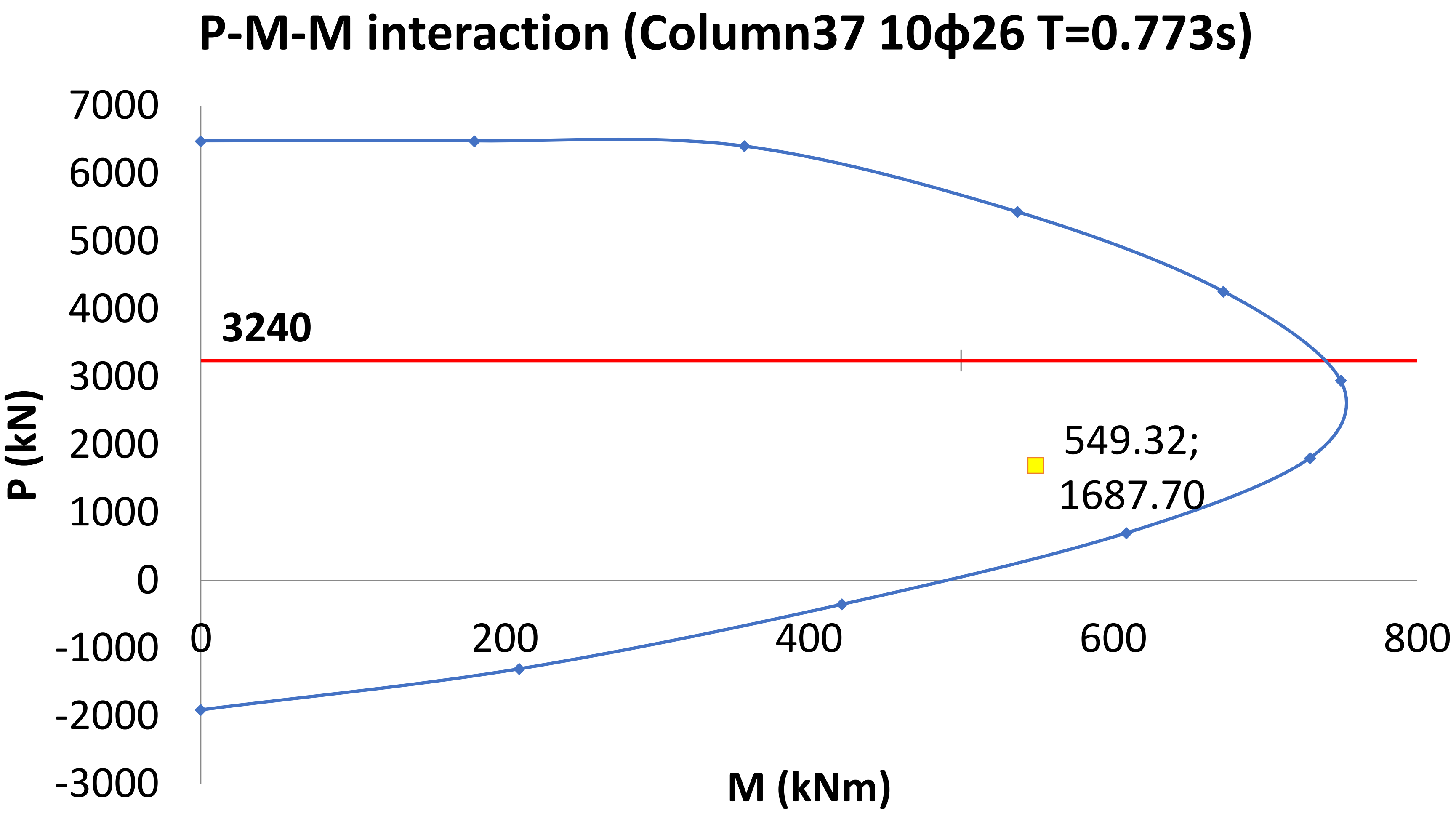
$$\sum Vt = 6342{,}24\ kN$$

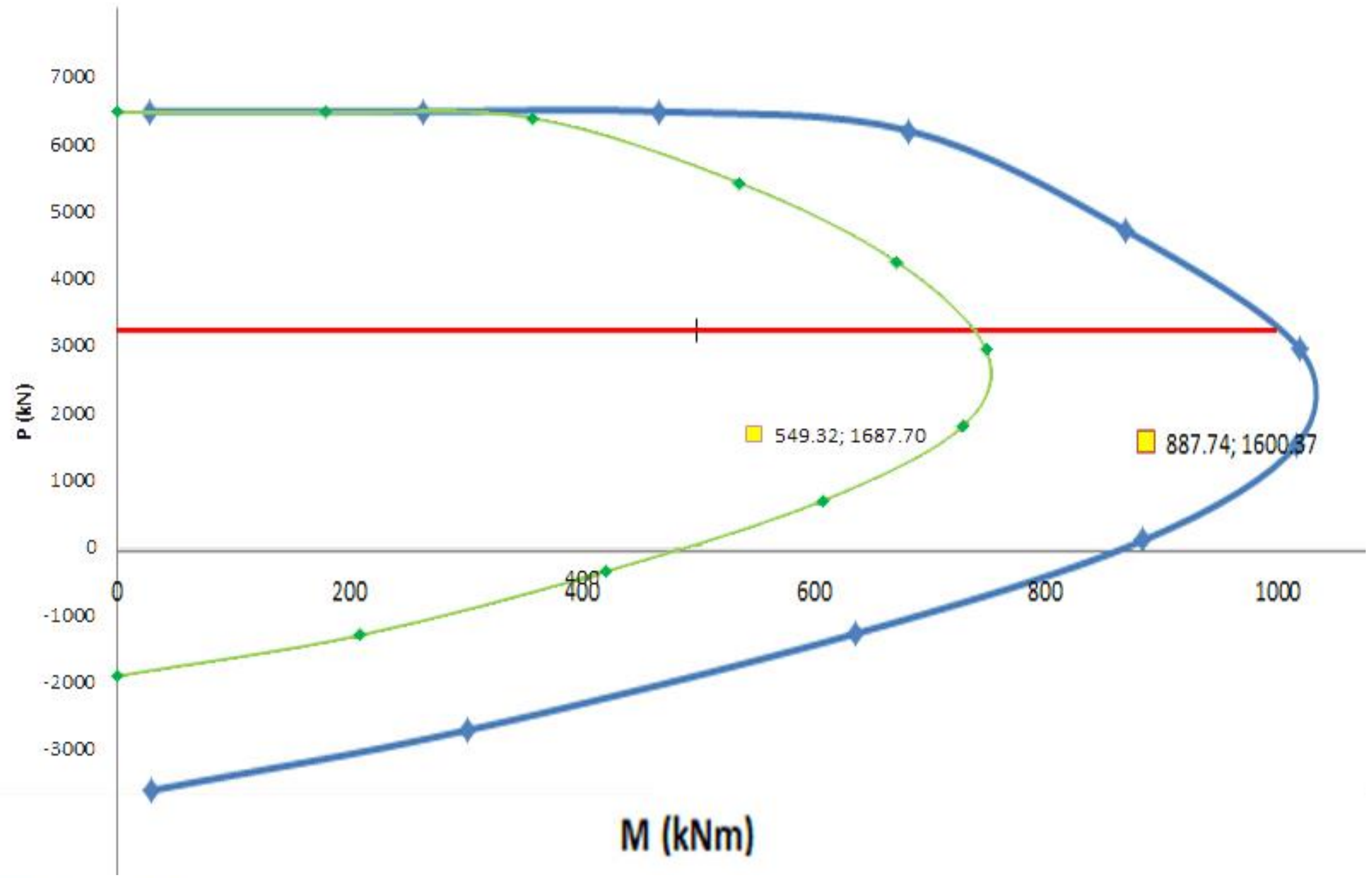
For T=0,773 s

$$\sum Vt = 3744{,}02\ kN$$


10Ø26
60 cm
60 cm

ρ =0,0147

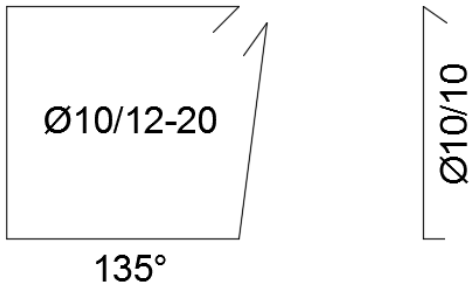

P-M-M interaction (Column37 10ϕ26 T=0.773s)
7000
6000
5000
4000
3000
2000
1000
0
-1000
-2000
-3000
P (kN)
3240
549.32;
1687.70
0
200
400
600
800
M (kNm)



P-M-M interaction (Column37 16ϕ26 T=0. 2 s)

P-M-M interaction (Column37 10ϕ26 T=0.773s)

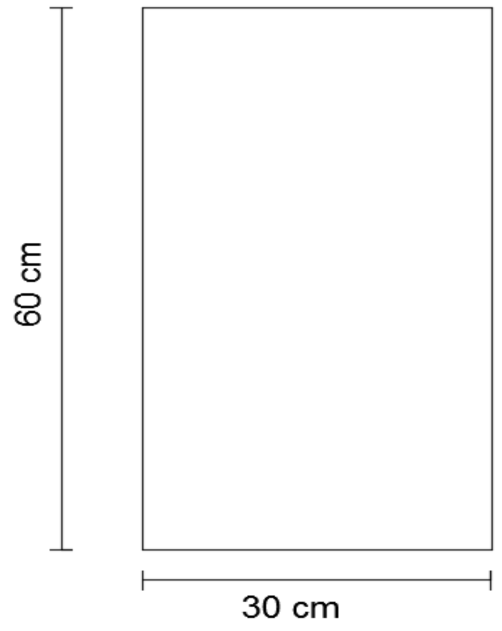
MOMENT CURVATURE

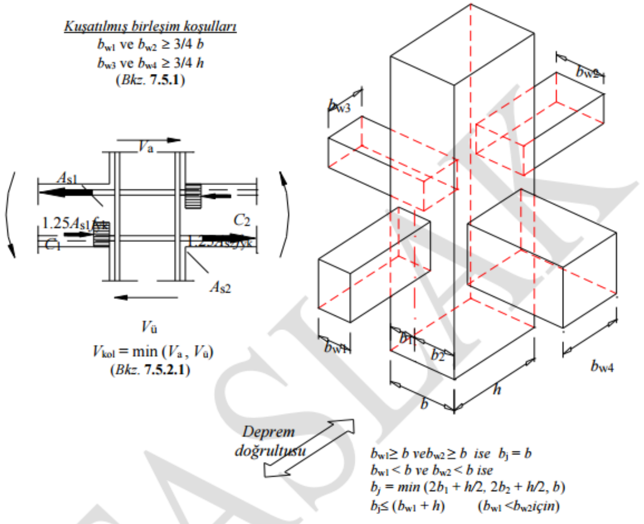


1.43

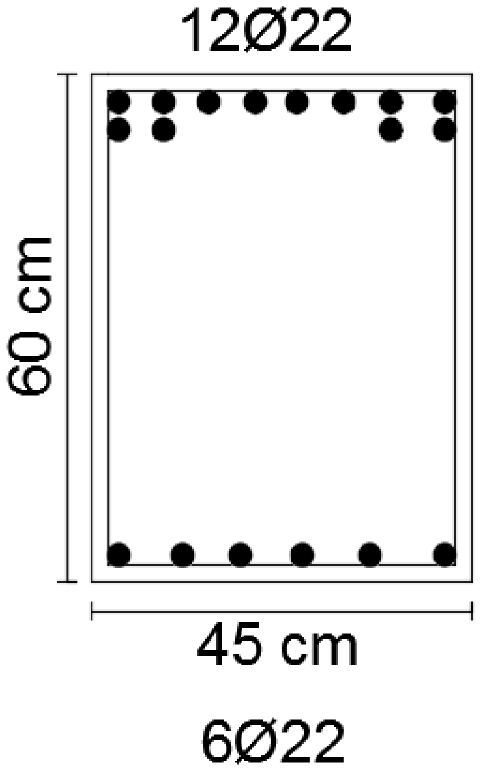
$$\sum M_{Pİ} \approx 1.4 M_{rİ}$$

DETAILED DESIGN: BEAM DESIGN

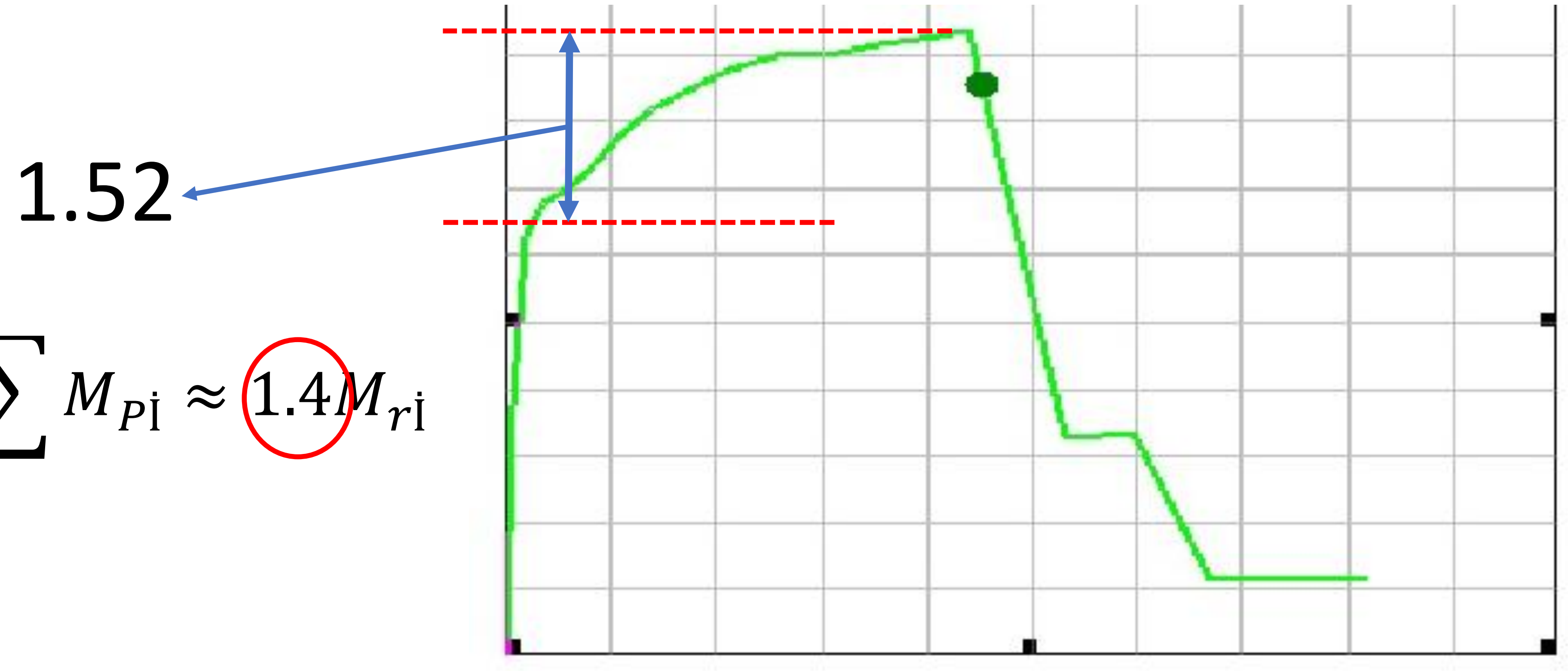




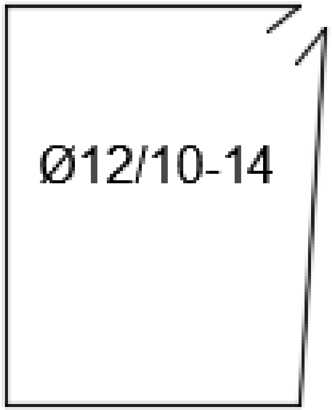
Şekil 7.10



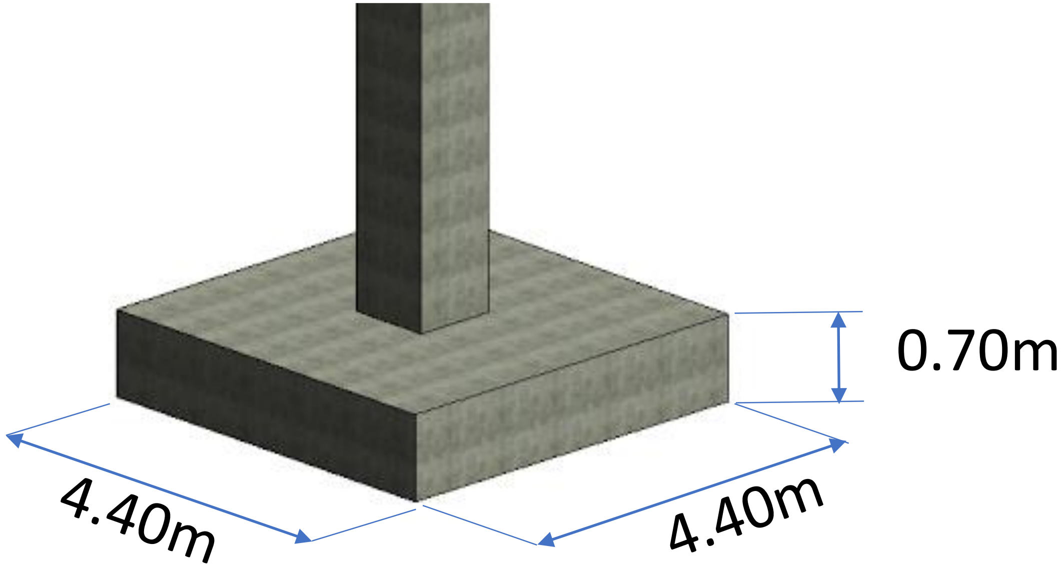
MOMENT CURVATURE

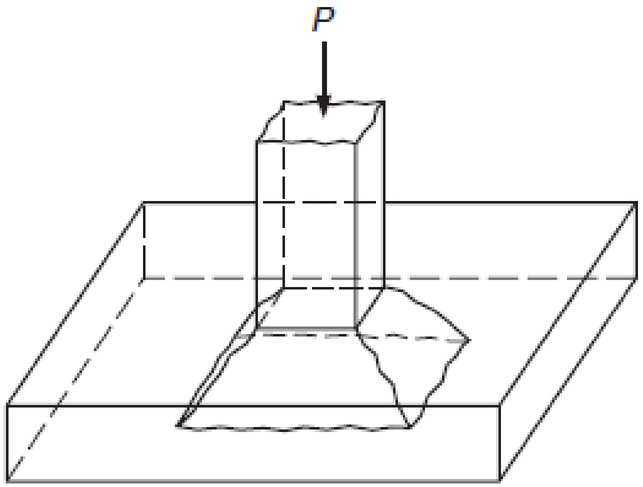


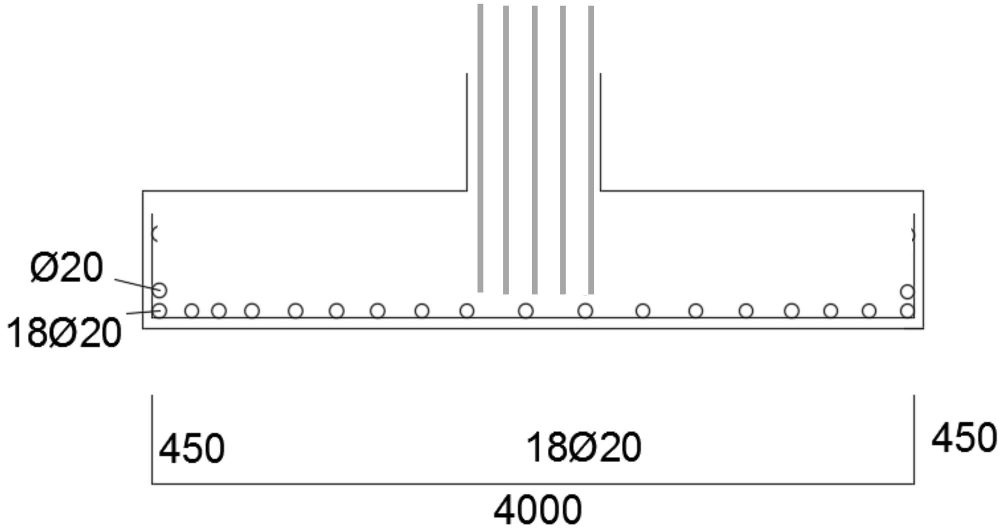
$$\sum M_{Pi} \approx 1.4 M_{ri}$$



PUNCHING & SHEAR CHECK

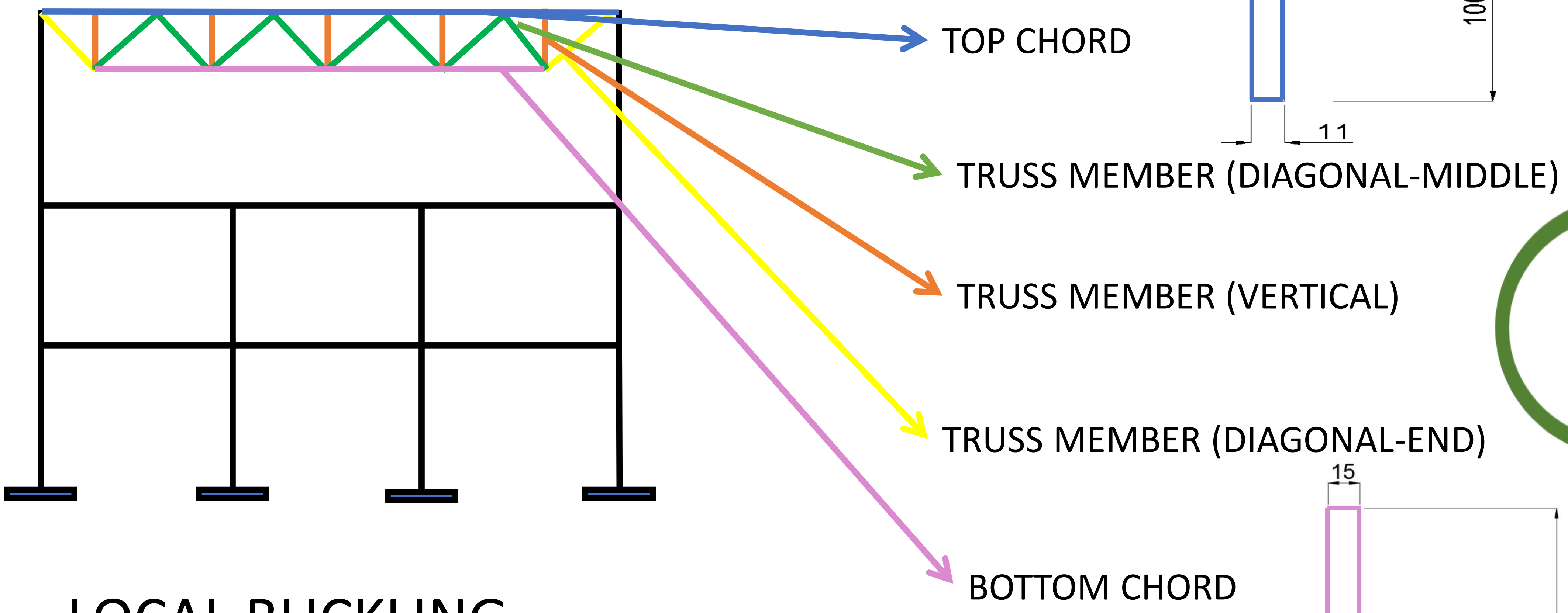


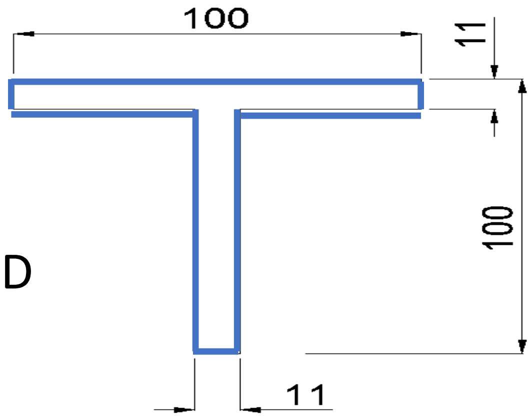


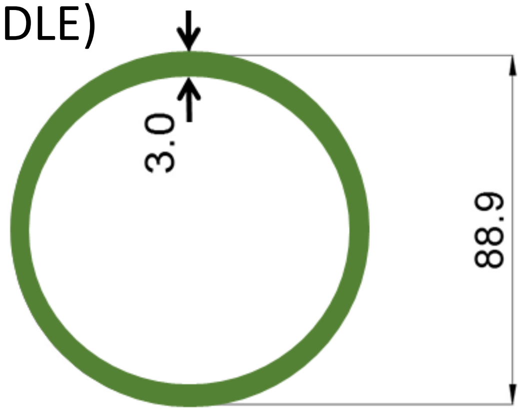


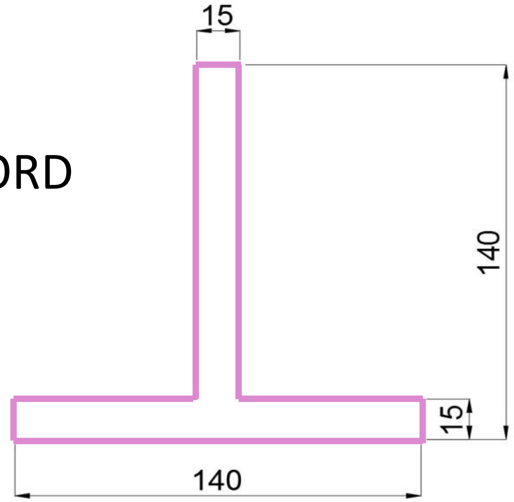
$$V_{pr} = \gamma \times f_{ctd} \times U_p \times d_{mean}$$

$$V_{cr} = 0{,}65 \times f_{ctd} \times b_w \times d$$









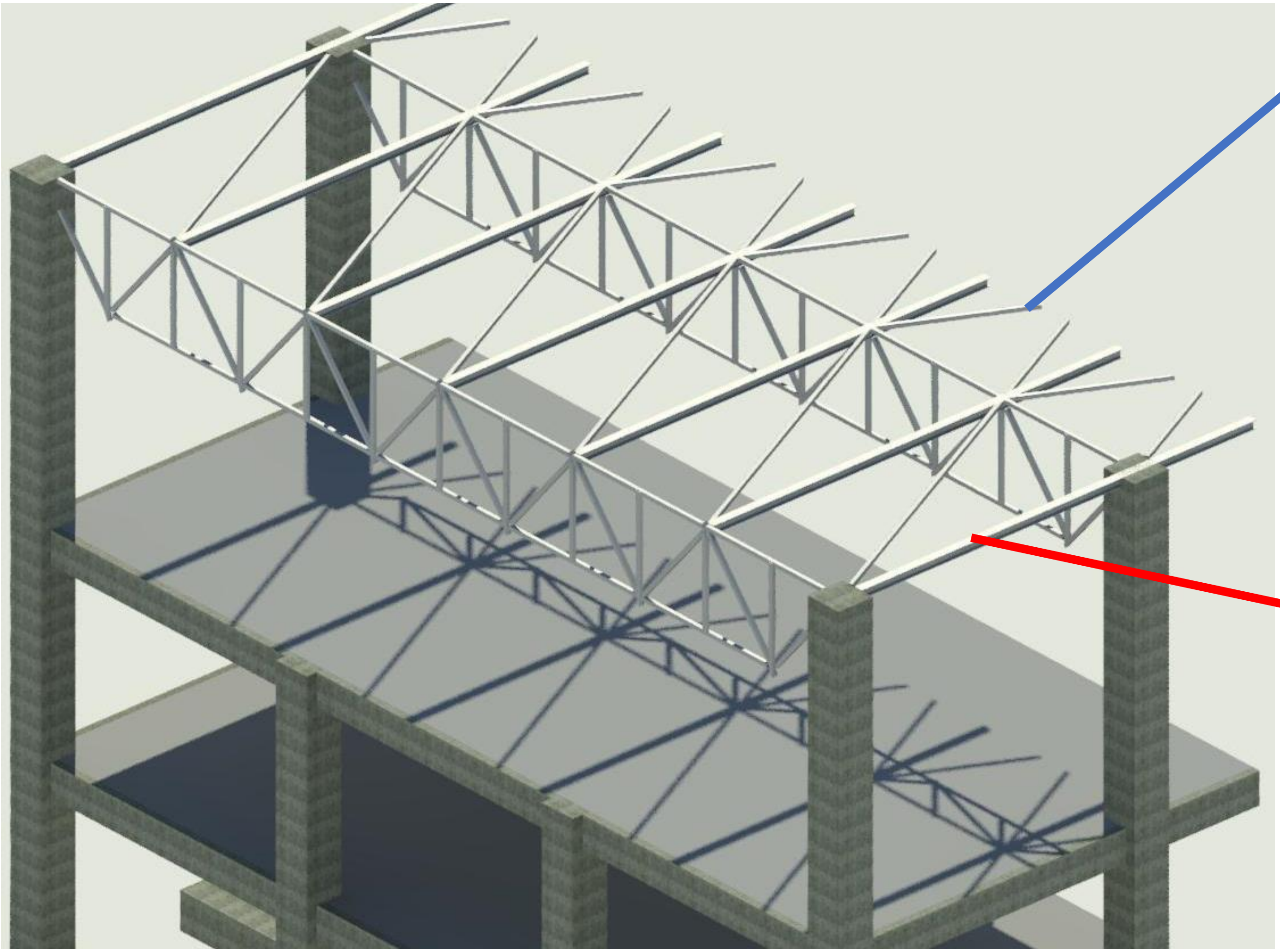
LOCAL BUCKLING

GLOBAL BUCKLING

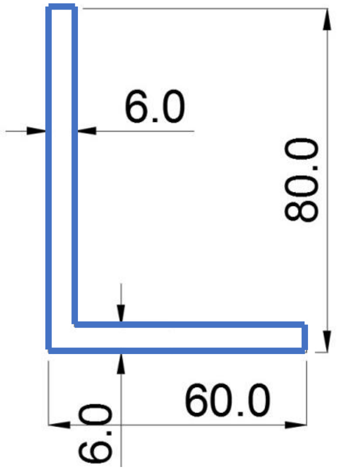
BEARING STRENGTH

İTÜ

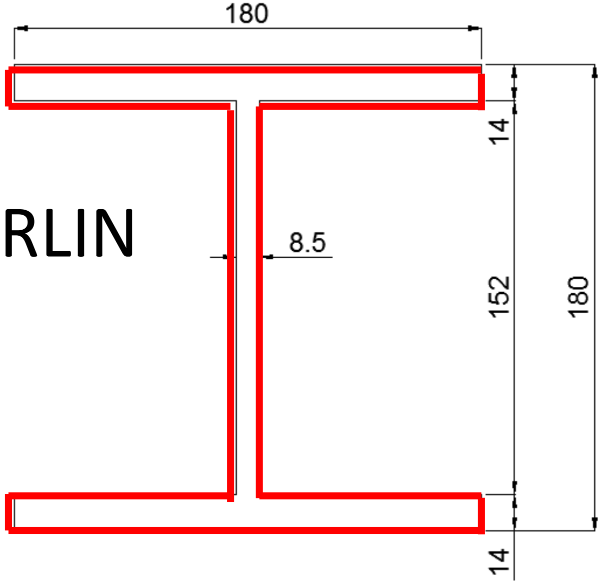
STEEL ROOF

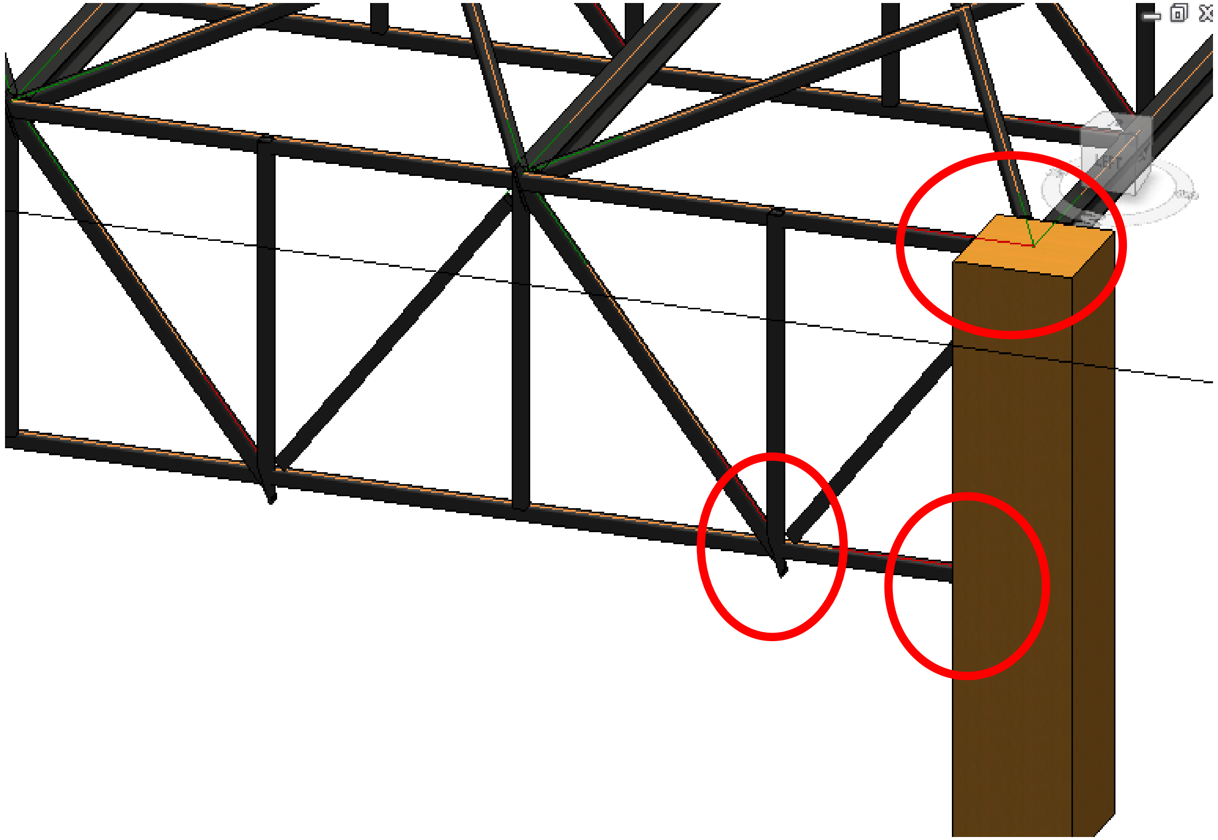


HORIZANTAL STABILITY MEMBER

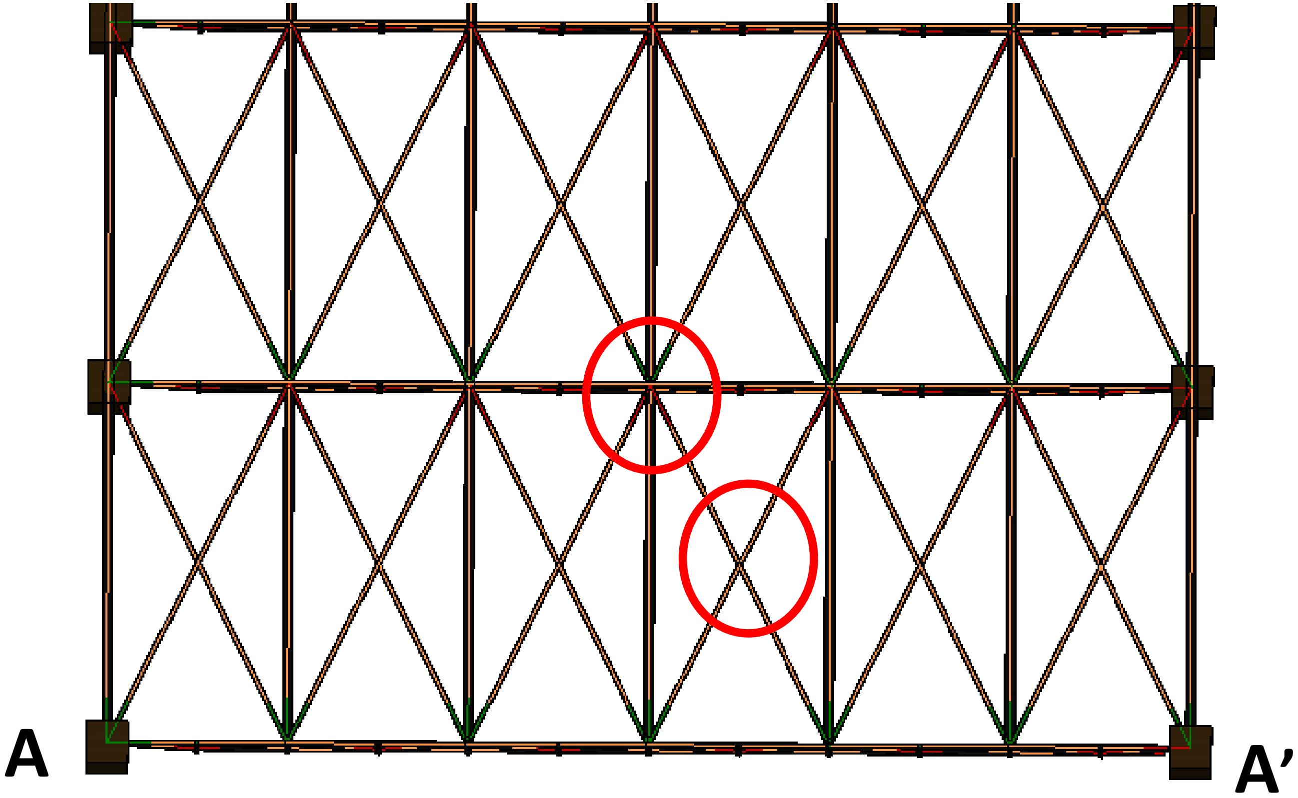


PURLIN

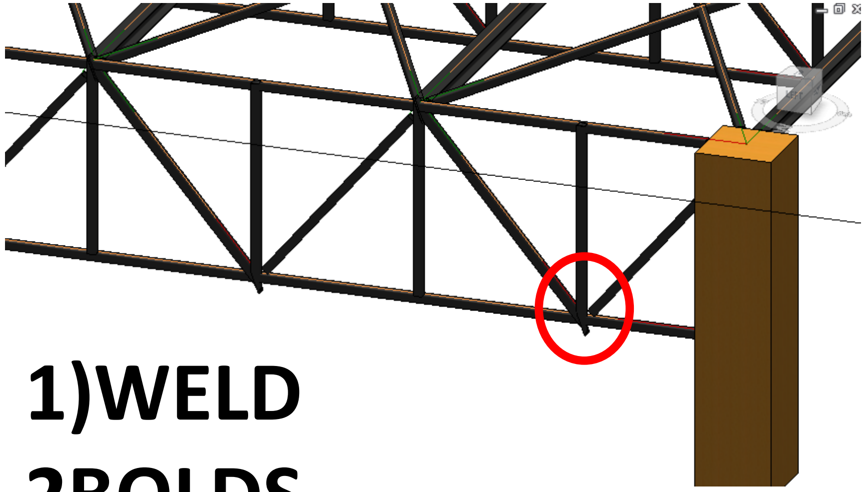


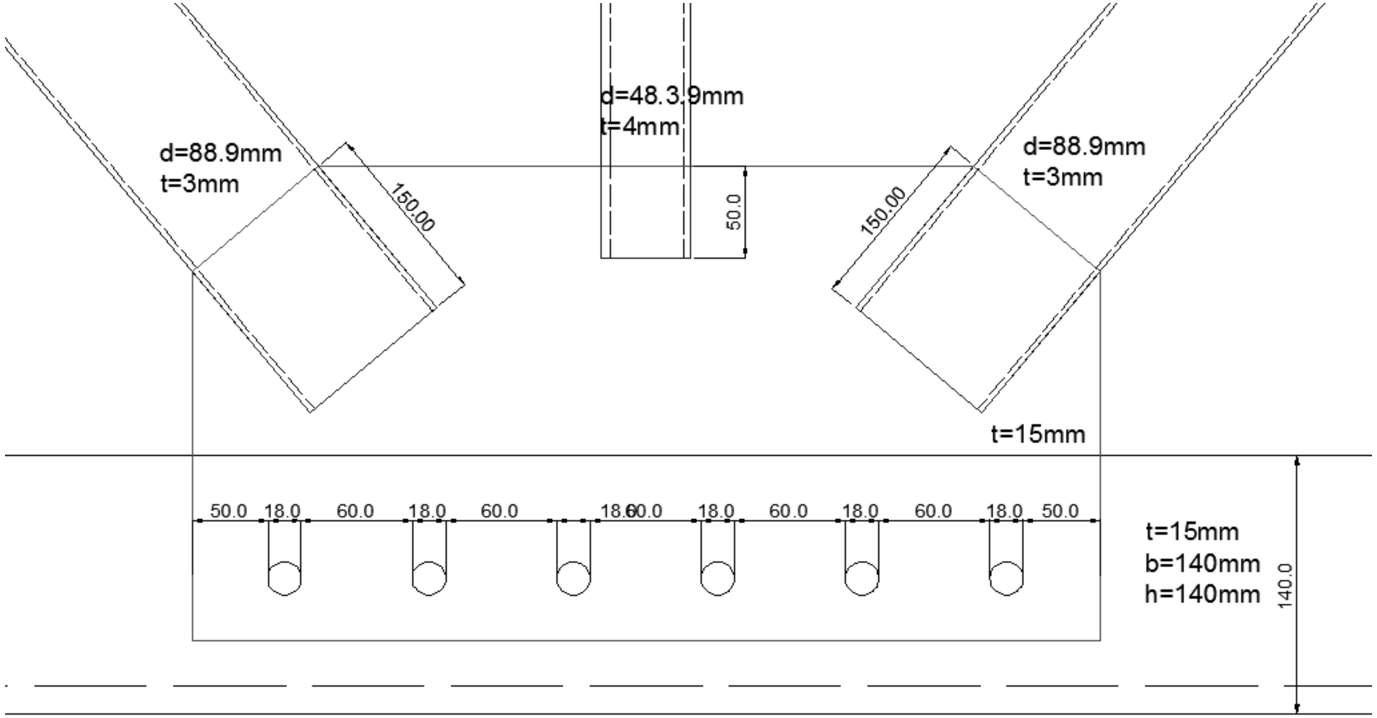


A-A’ SECTION



PLAN





1)WELD

2BOLDS

<u>Checks</u>

--Bearing Strength of Bolds

--Shear Strength of Bolds

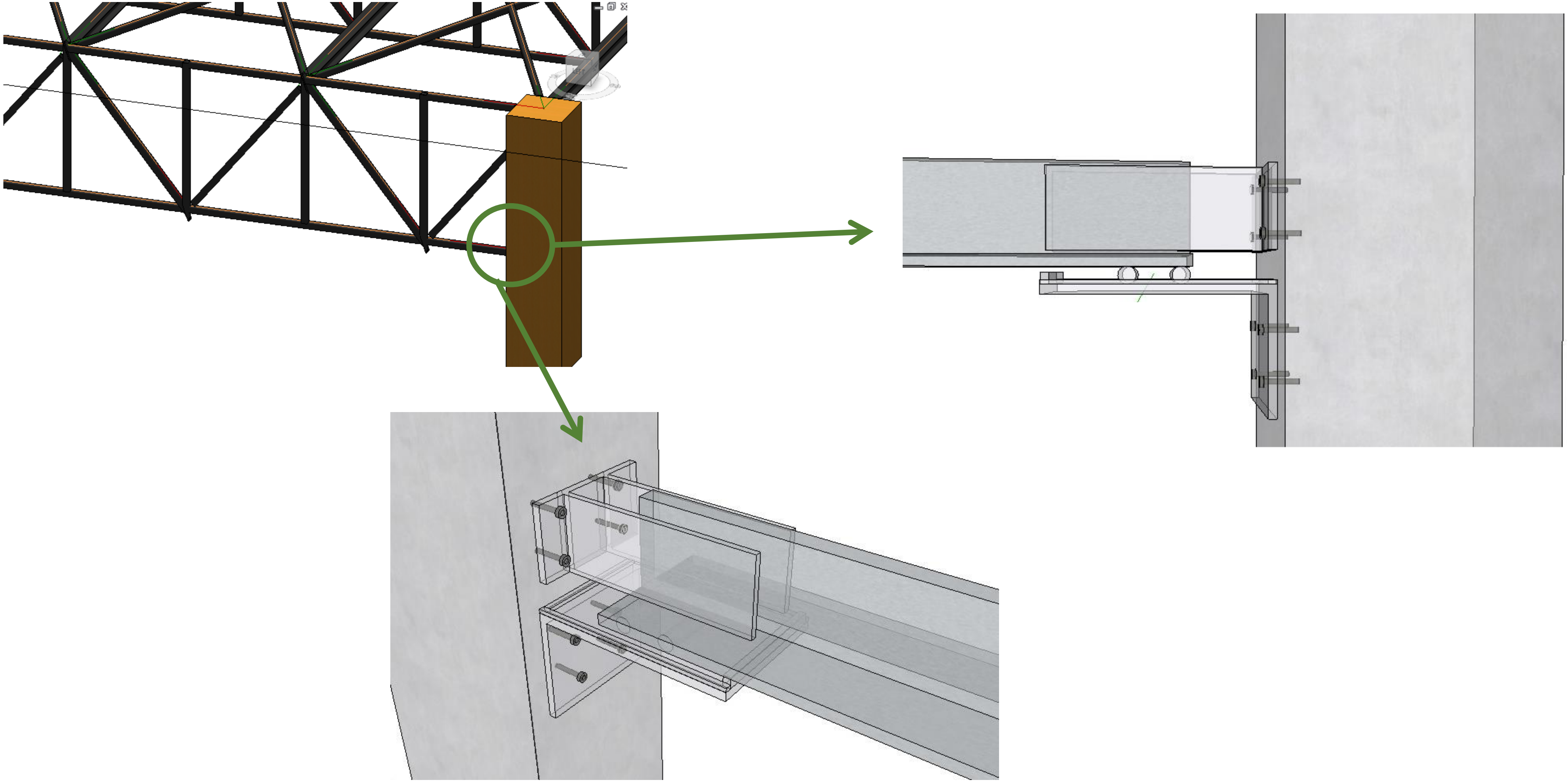
--Block Shear

--Bearing Strength o Tension Member

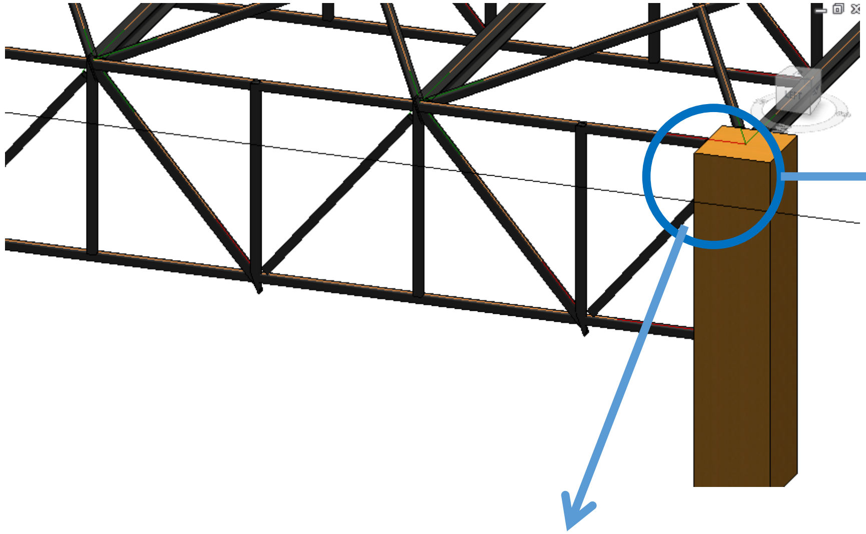
a)Rapture Strenght

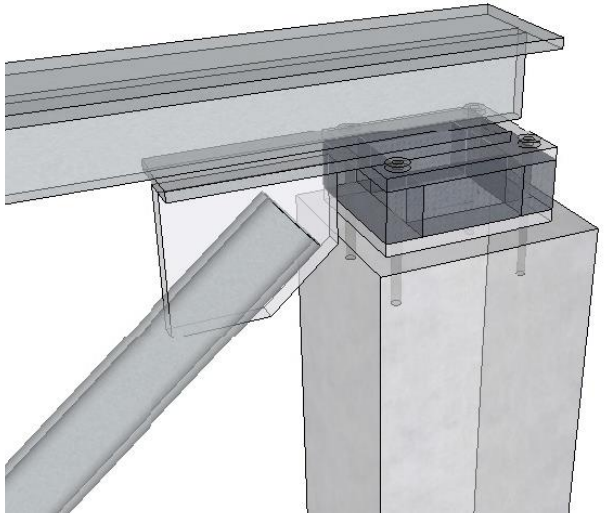
b)Yielding Strength

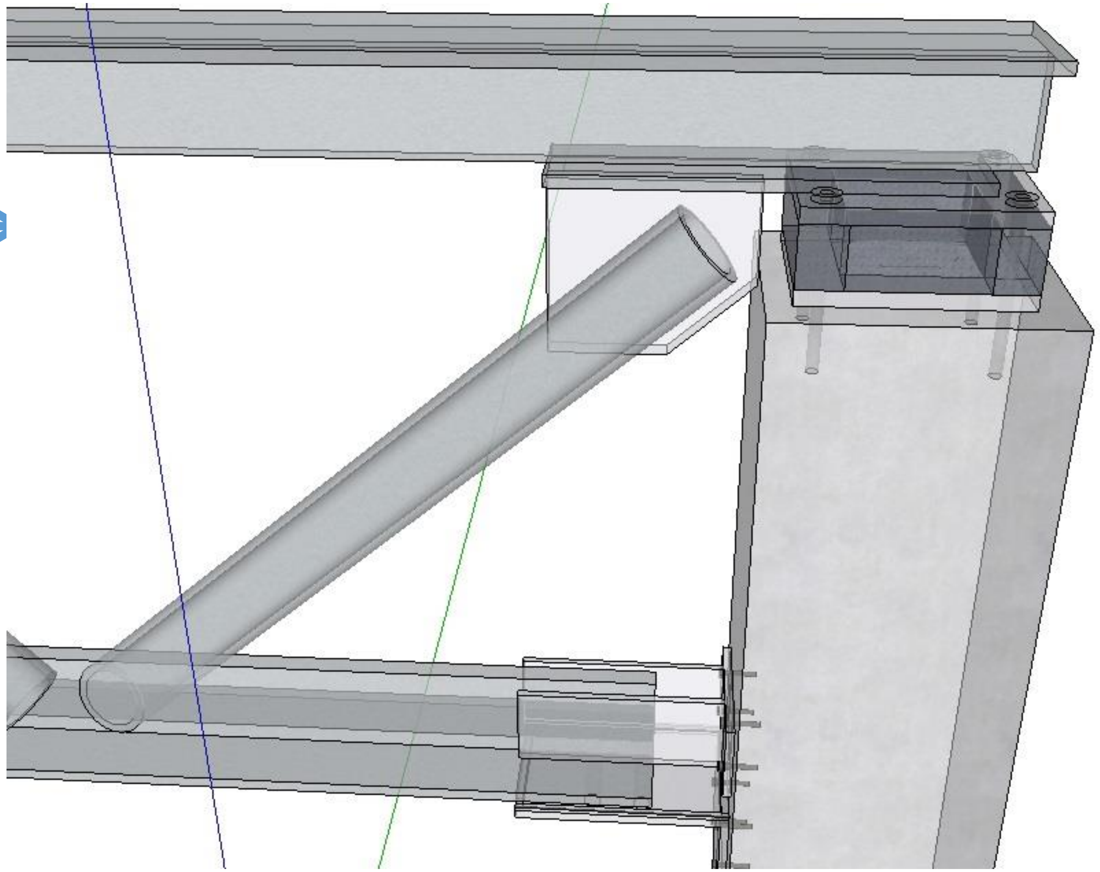
DETAILED DESIGN: STEEL DESIGN-CONNECTION DESIGN



DETAILED DESIGN: STEEL DESIGN-CONNECTION DESIGN







CONTENT

Dynamo

File Edit View Packages Settings Help

Library

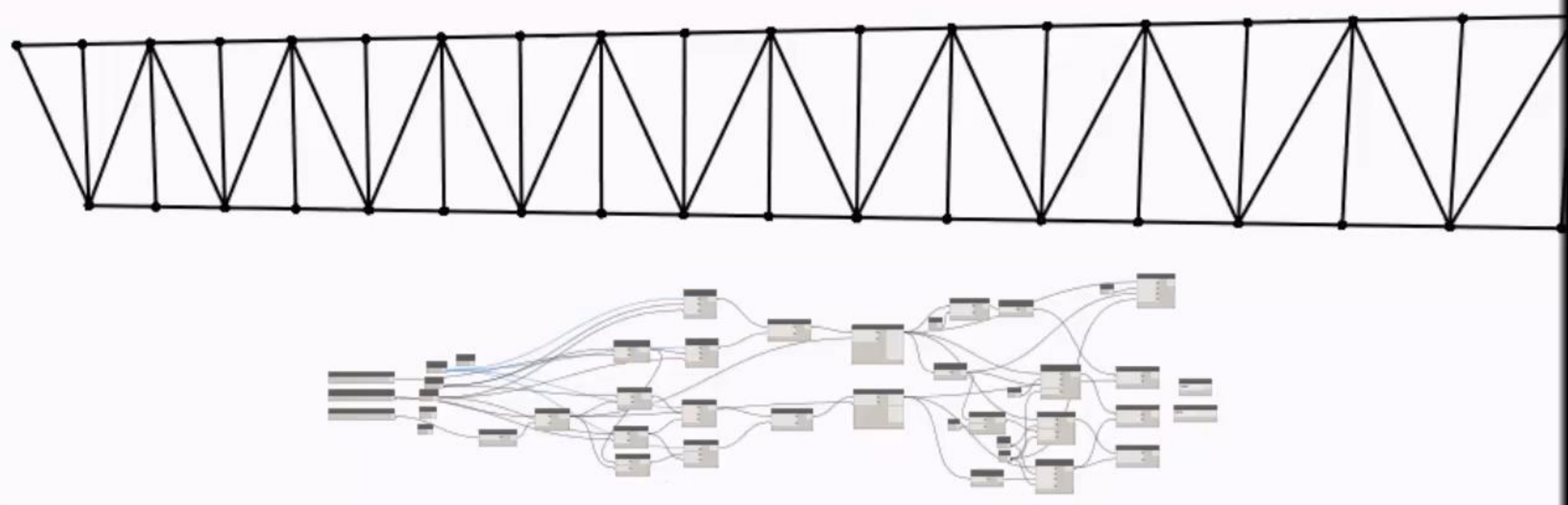
SLİDER

Number Slider
A slider that produces numeric values.
Input Core

Integer Slider
A slider that produces integer values.
Input Core

Rhythm.IntegerSlider
Provides an integer slider for the dynamo player. Has min, max and description.
Input Rhythm

STEEL ROOF SLAYT.dyn*



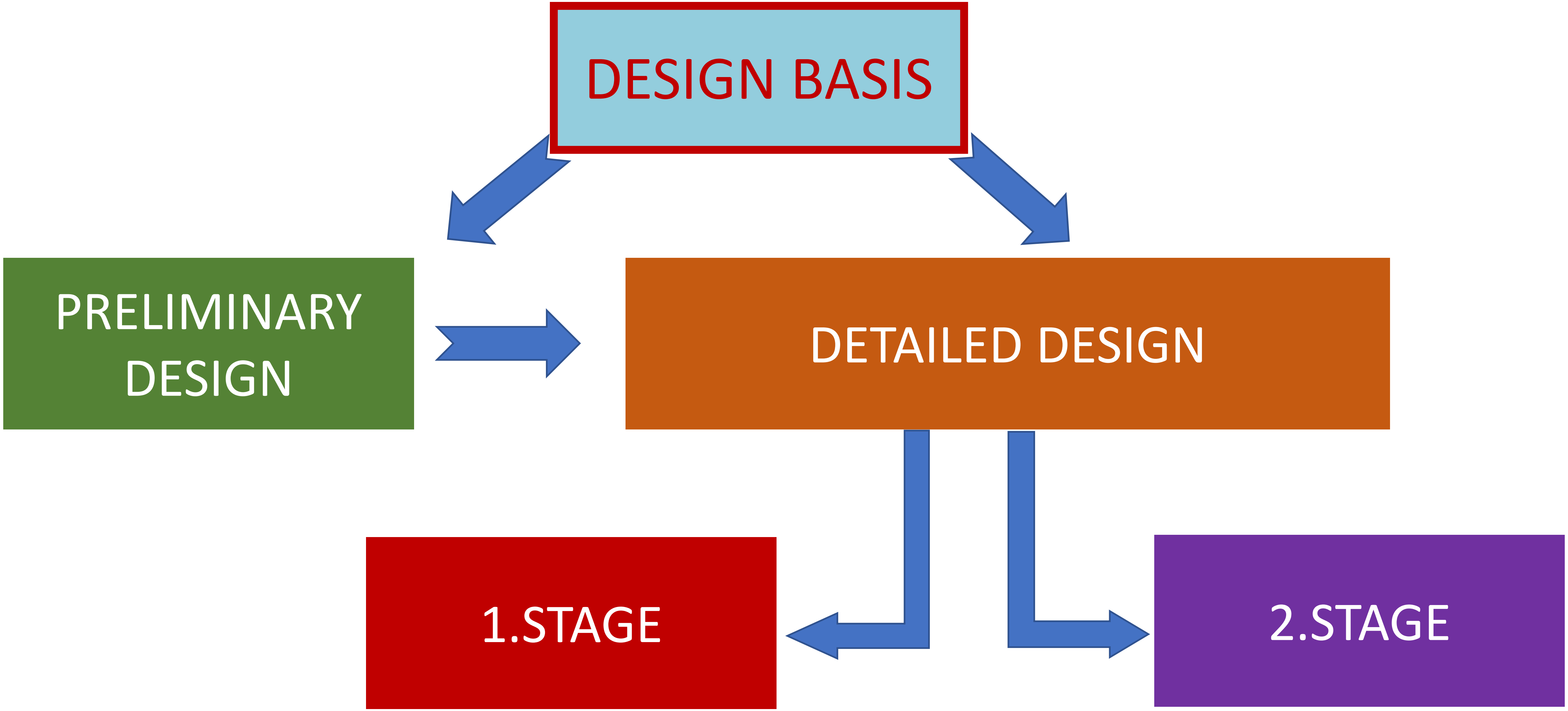
Automatic

Run completed.

Video kayıt - Başlat REC

TUR 00:25 14.6.2017

CONCLUSION



DESIGN BASIS
PRELIMINARY DESIGN
DETAILED DESIGN
1.STAGE
2.STAGE

THANK YOU
FOR YOUR ATTENTION

QUESTIONS?

STRUCTURAL ANALYSIS: 2D PYTHON MODEL