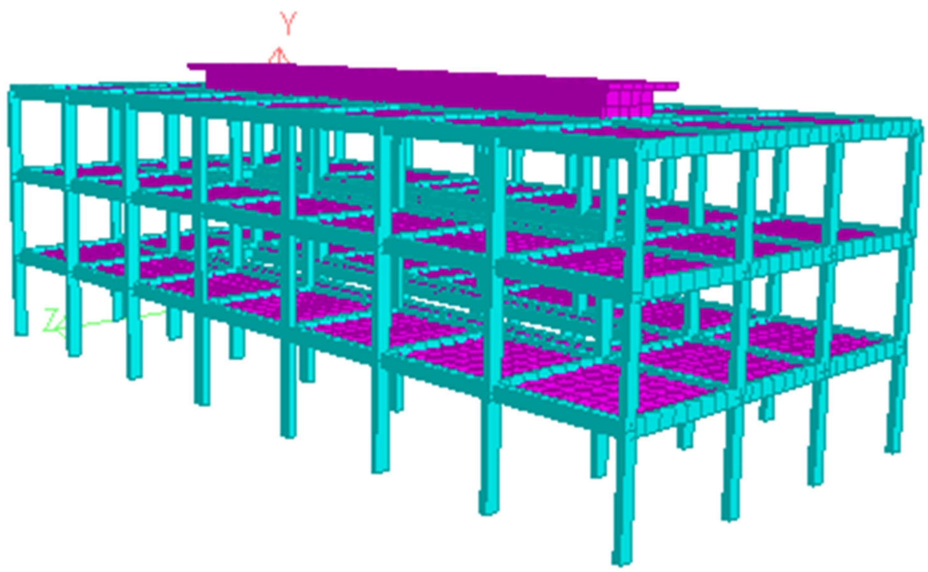
MNU

Design of Gn. Fuvahmulah Campus

Student Accomodation Block

Structural Design Report



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Approved by:	

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00	28/02/2023	First Issue	CJ	MMW	

Contents

1 EXECUTIVE SUMMERY

Riyan Private Limited has been appointed as the Design Consultant to carry out the design of the building complex which comprises of a main classroom building, a student accommodation building and a staff accommodation building for Gn. Fuvahmula Campus of Maldives National University at Fuvahmulah. This report includes the structural design of the 03 storied Staff Accommodation Block.

This report consists of the basis of design for the Structural design of the main building. The design codes of practice, assumed material properties, partial safety factors, concrete section properties such as cover, load calculations and, load combinations will be discussed in detail in this report. Lastly, the finite element analysis and specimen calculation reports will be shown as annextures.

2 PROJECT INFORMATION

The main building consists of 05 story (Ground + 3 + Roof). The intended usage for each level is shown below in table 1. The proposed foundation system is a combination of individual pad foundation and strip foundation system.

Table 1 - Floor arrangement

Floor	Level (m)	Intended use
Ground floor	+0.250	Entrance lobby, office areas, cafeteria, staff rooms, services block
Level 1	+3.250	Class rooms, services block
Level 2	+6.500	Training room, class rooms, service block, open terrace
Roof Level	+9.25	Open terrace, services block
Roof Apex Level	+10.15	Open terrace, services block

Based on prior experience an allowable bearing capacity of 150 kN/m2 was assumed for the foundation design. During construction this will be re-evaluated and confirmed.

A three-dimensional finite element model is used to analysis the building for limit state method of analysis under vertical gravity loads as per BS codes and wind loads as per Australian codes of practice respectively. First three modes of frequencies, other modal parameter of interest, and lateral deflection of the building at top level, story drift, base shear force variations under lateral loading are presented under the relevant topics in the Structural Analytical Report. Overall structural performance of the proposed building is verified based on the relevant codes of practices and other approved references.

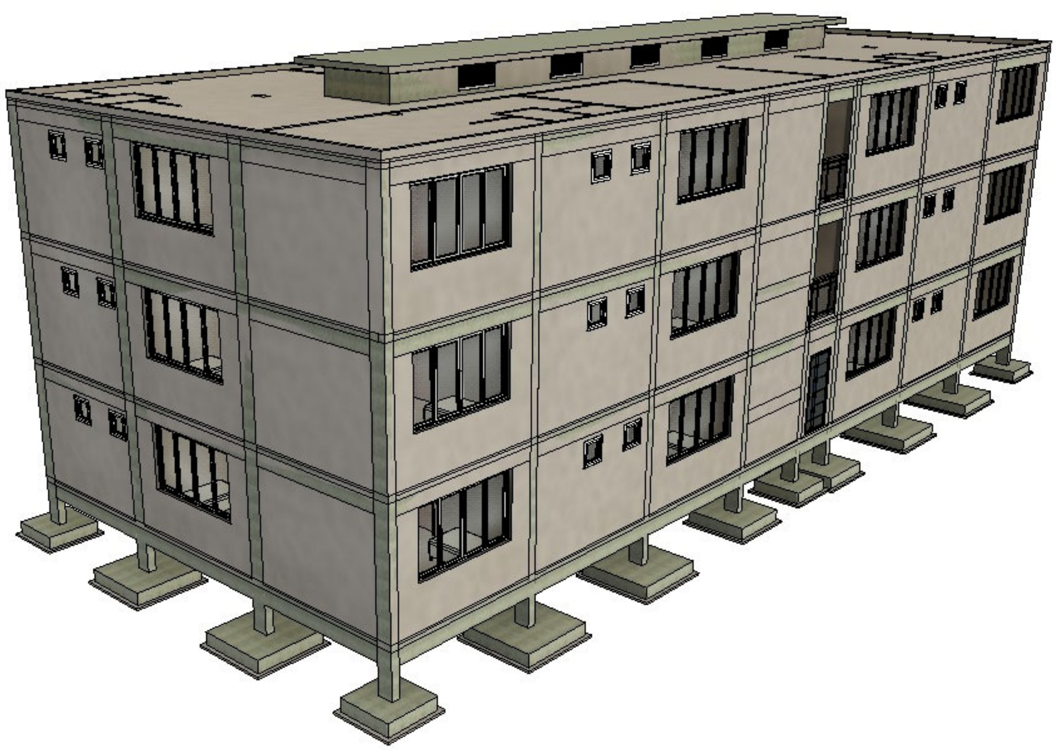


Figure 1 - 3D Revit model form the Architectural concept

The proposed building is modelled in Revit 21 and all structural general arrangements, section at critical locations and details drawings were prepared using that model.

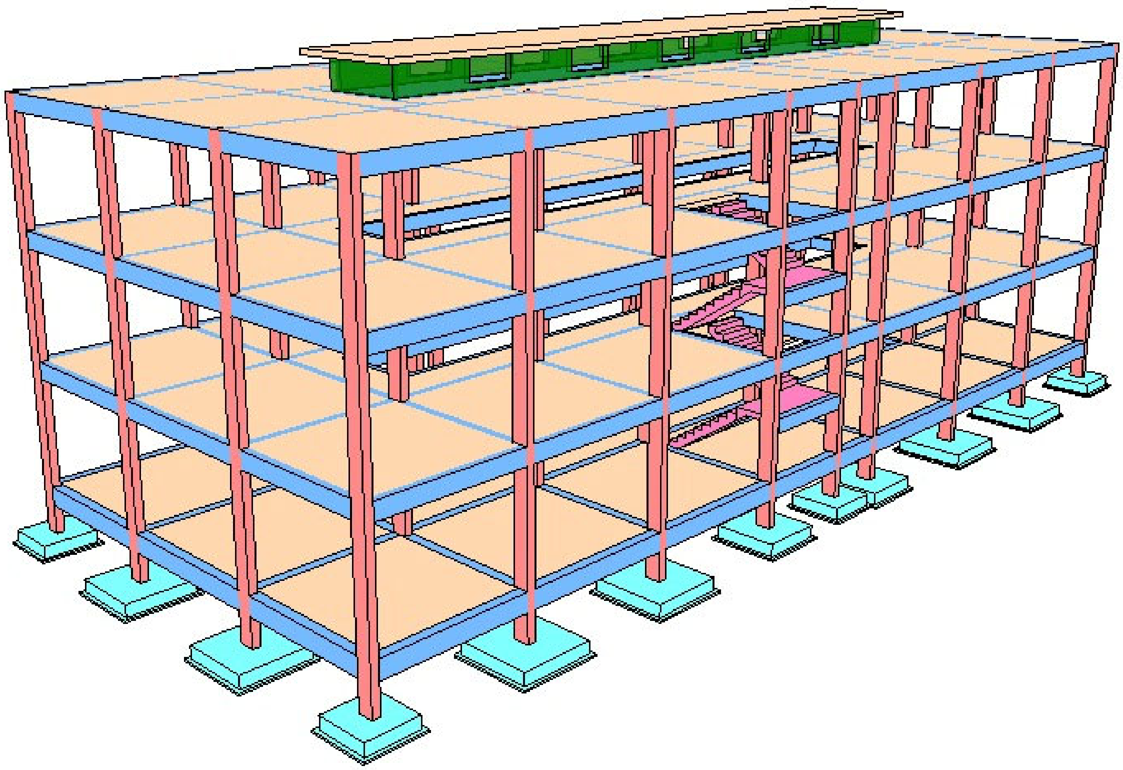


Figure 2 - 3D Revit model from the Structural concept

3 STANDARDS REFERED

3.1 Building Regulations and Codes of Practice

The structure is designed in accordance with the design requirements of the following building regulations and codes of practice:

➢ Structural Use of Concrete	- BS 8110- Part I: 1997
	- BS 8110- Part II: 1997
	- BS 8110- Part III: 1997
➢ Structural steel works in buildings	- BS 5950-Part I: 2000
➢ Design Loading for Buildings	- BS 6399: Part I: 1997 and Part 2:1997
➢ Design of concrete structures for retaining aqueous liquids	- BS 8007: 1987
➢ Code of Practice for Earth retaining Structures	-BS 8002: 1994
➢ Weights of building material	- BS 648
➢ Code of Practice for Foundations	- BS 8004:1986
➢ Wind load calculations	- SAA Loading - Part 2: Wind actions
	- BS 6399- Part 3: 1997 or
	-AS/NZS 1170.2 -2011

Research papers, manuals and hand books referred,

- Manual for Design of Reinforced Concrete Building Structures (IStructE) 2006
- Reinforced Concrete Designer's Hand Book-Charles E. Reynolds

- The Design of Water Retaining Structures by Ian Batty & Roger Westbrook
- Developing a Disaster Risk Profile for Maldives – United Nations Development Program, Maldives, submitted by RMSI

3.2 Material properties

Strength of material used for the structural design are shown below.

Table 2 - Material strength

NOTATION	DESCRIPTION	E (GPa)	V	DENSITY (kg/m3)	a x 10^{-5} (1/^{0}K)
T	Type 02 deformed bars, Characteristic yield strength, fy=500 N/mm2	200	0.3	7.85 x 10^{3}	1.2
R	Plain bars, Characteristic yield strength, fy=250 N/mm2	200	0.3	7.85 x 10^{3}	1.2
C25	Grade 30 Concrete, f cu = 30 N/mm2 characteristic cube strength at 28 Days	25	0.2	2.4 x 10^{3}	1.0
C30	Grade 30 Concrete, f cu = 30 N/mm2 characteristic cube strength at 28 Days	26	0.2	2.4 x 10^{3}	1.0
C35	Grade 30 Concrete, f cu = 35 N/mm2 characteristic cube strength at 28 Days	27	0.2	2.4 x 10^{3}	1.0

3.3 Partial safety factors

The design strength of each structural material was derived from dividing the material characteristic strength by the appropriate material partial safety factor. The material partial safety factors, gm, are shown below in table 3.

Table 3 - Partial safety factors

MATERIAL	g_m FOR ULS DESIGN
Reinforcement	1.15

Concrete in flexure or axial	1.5
Shear strength without shear reinforcement	1.25
Bond strength	1.4
Bearing stress	1.5

3.4 Concrete cover

Table 4 - Specified concrete cover for Grade 30

TYPE OF STRUCTURE	EXPOSURE CONDITION	ELEMENT	LOCATION	FIRE RESISTANCE (hrs)	COVER PROVIDED (mm)
Sub structure	Very severe	All elements	All faces	N/A	50
	Moderate	Walls	All faces	N/A	50
		Columns	All faces	N/A	50
		Ground beams	All faces	N/A	50
Super structure	Mild & moderate	Columns	All faces	1	40
		Walls	All faces	1	30
		Beams	All faces	1	35
		Floor slabs & stairs	All faces	1	30
Water retaining structures / structures in contact with water	Severe	All elements	All faces in contact with water	N/A	50

3.5 Properties of materials (For FEM)

Different characteristic compressive strengths (fcu) of concrete used in the Finite Element Modeling. The relevant properties of concrete were taken from BS 8110-2-1997. Different grades of concrete are used for the structural elements. Concrete grades of each structural elements will be given in the general note of typical structural drawings and in the structural design report (under summary of beams, columns & shear wall design.

Table 5 - Modulus of elasticity of concrete for different grades

$f_{cu,28}$ N/mm2	$E_{c,28}$	
	Mean value kN/mm^2	Typical range kN/mm^2
20	24	18 to 30
25	25	19 to 31
30	26	20 to 32
40	28	22 to 34
50	30	24 to 36
60	32	26 to 38

4 LOAD CALCULATION

4.1 Gravity Loads

Dead, Super-imposed dead and live loads are considered as gravity loads. General floor loading values are tabulated as shown below. Note that loading for special areas will be considered based on BS6399: Part 1 for special loading conditions such as machine rooms, transformer rooms, chiller rooms, etc., and where crowd loading is possible.

Table 6 - General floor gravity loads

Floor usage	Super imposed Dead load (SDL) – kN/m^2)		Live load (LL) – kN/m^2
	Finishes	Services & ceiling	
Bedroom	1.15	0.5	1.5
Kitchen	1.15	0.5	1.5
Toilet	1.5	0.5	2.0
Corridor	1.5	0.5	3.0
Staircases	1.5	0.0	3.0
Roof slabs with solar (inaccessible)	1.5	0.5	1.5

- Solid block work (100 mm Tk) = 2.5 kN/m^2
- Solid block work (200 mm Tk) = 4.5 kN/m^2
- Glass density for façade loading = 25 kN/m^3

4.2 Lateral loads

The lateral loads that can act on a building consist of wind loads and earthquake loads (and incidental wave loads for offshore structures). The report by UNDP-Maldives and RMSI under the topic "Developing a Disaster Risk Profile for Maldives" (May 2006) will be used as the guideline for this purpose.

4.2.1 Wind loads

The magnitude of the wind loads on a building will depend on the basic wind speed used for the calculations. It is the three second (3 sec) gust velocity recommended for records collected over 50 years to determine the probable maximum wind speed that can occur at a height of 10m in open country.

The islands of Maldives are less prone to tropical cyclones. The northern islands of the country were affected by weak cyclones that formed in the southern part of the Bay of Bengal and the Arabian Sea. The number of cyclones directly crossing Maldives is small. Only 11 cyclones crossed the islands over the entire span of 128 years. Most of the cyclones crossed Maldives north of 6.0^{o}N and none of them crossed south of 2.7^{o} N during the period. All the cyclones that affected Maldives were formed during the months of October to January except one, which formed in April. Maldives has not been affected by cyclones after 1993. As cyclones affect an area within a radius of 200-300 kilometers, those coming within certain distance from a location have been included for determining their annual occurrence rates.

Using the wind speeds of 21 cyclonic disturbances, the probabilities and return periods of wind speeds have been calculated. Figure 5 shows the return periods for various categories of cyclones. The return period of a cyclonic storm with a wind speed of 34 knots will be about 23 years. For deep depressions with wind speeds 28-33 knots, the return period varies between 10 -20 years. From the return period analysis, it has also been found that very severe cyclonic storm with surface winds having a speed of 65 knots are expected to recur once in 135 years in Maldives.

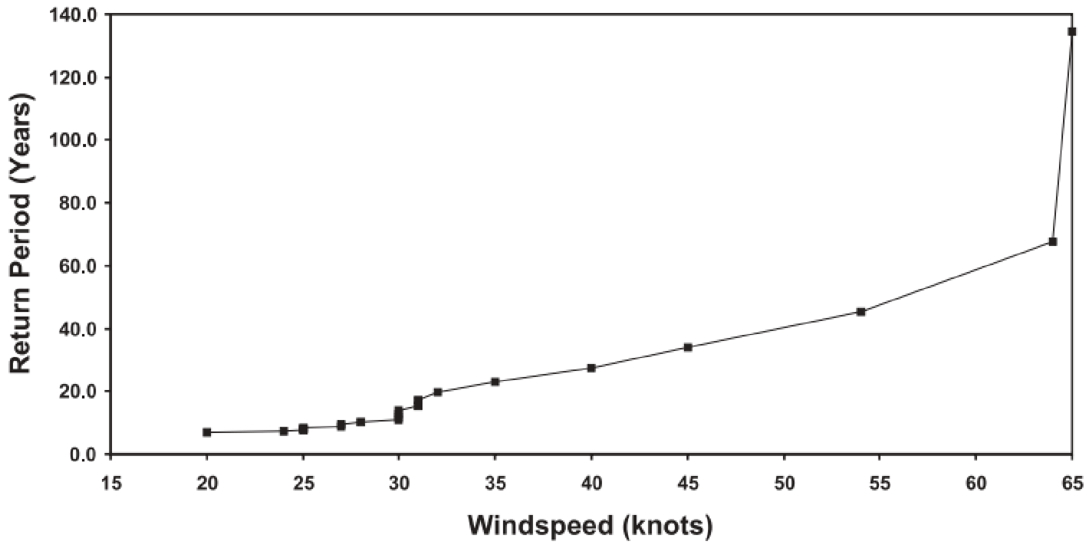


Figure 3 - Return period of Wind speeds associated with cyclones in Maldives

For dividing Maldives into zones with varying scales of cyclone hazards, five regions have been created based on a qualitative judgement of the gradient of the storm tracks from north to south. Figure 6 shows the regions used to compute the highest wind speed of each cyclone captured within the region. Majority of the cyclonic disturbances crossed the northern region. The frequency and wind speed decreases from northern region to southern region. Region 1 is not affected by any storm.

For each hazard zone, probable maximum wind speed has been computed. In this study a 500-year return period has been considered for the probable maximum wind speed estimation. Table 7 shows the probable maximum wind speed for each zone (500-year return period).

The cyclone hazard zones of Maldives have been classified into five regions according to the 500-year return period wind speed of each region. The probable maximum wind speed in Table 8 is the 1-minute average wind speed so as to convert them into Saffir-Simpson hurricane scale. In

Region 5 the probable maximum wind speed comes under Category 3 in the Saffir-Simpson hurricane scale.

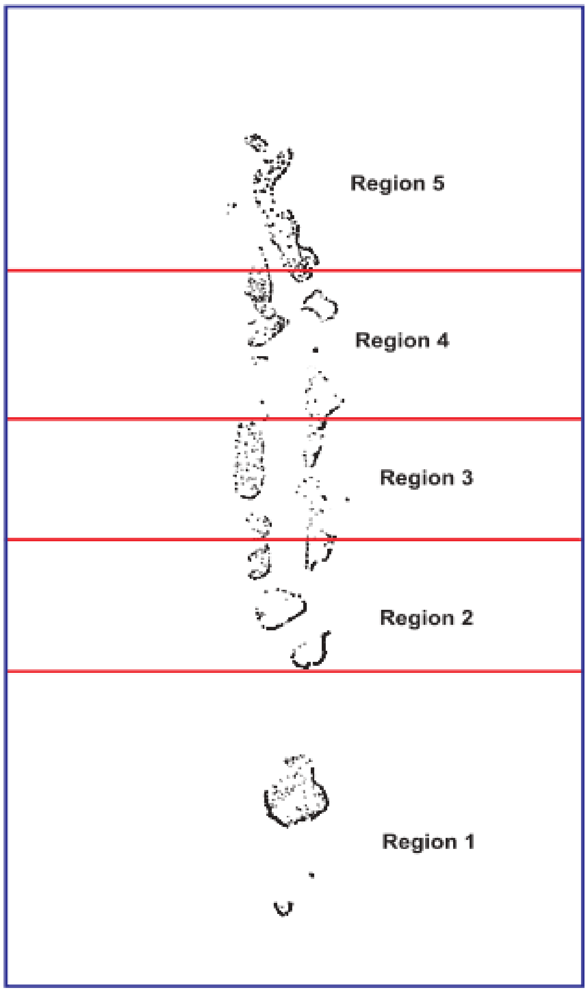


Figure 4 - Hazard zoning regions for Maldives

Table 7 - Probable maximum wind speeds (500 year) and saffir-simpson scale

HAZARD ZONE	WIND SPEED		SAFFIR-SIMPSON SCALE
	knots	m/s	
1	0.0	0.0	0
2	55.9	28.75	0

3	69.6	35.80	1
4	84.2	43.31	2
5	96.8	49.79	3

Table 8 - 1 minute average wind speed based on Saffir-Simpson scale

SAFFIR-SIMPSON CATEGORY	MAX WIND SPEED (m/s)
1	33-42
2	43-49
3	50-58
4	59-69
5	70+

Based on the size (height) of the structure and the availability of other structures around the said building, only a nominal wind load is considered for the purpose of the design.

4.2.2 Earthquake loads

Maldives lays in Indo-Australian Tectonic plate. Maldives is located in the middle of Indian Plate and well away from the plate tectonic boundaries. Therefore, only intra-plate type earthquakes may occur close to Maldives. However, there are few seismic activities recorded during the past and it is safe to conclude that the chances of inter-plate type earthquake affecting Maldives will be remote.

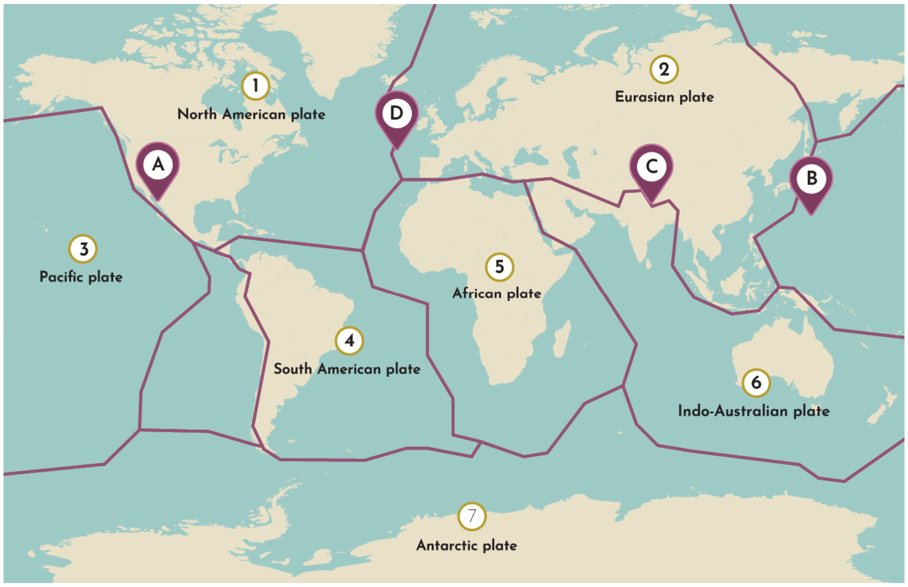


Figure 5 - Major tectonic plates in the world

According to the International Society for Earthquake Technology (ISET), during the period from 1979 to 2004, figure 6 has been derived. It shows that there had been three major events of magnitude above 7.0 had struck the region.

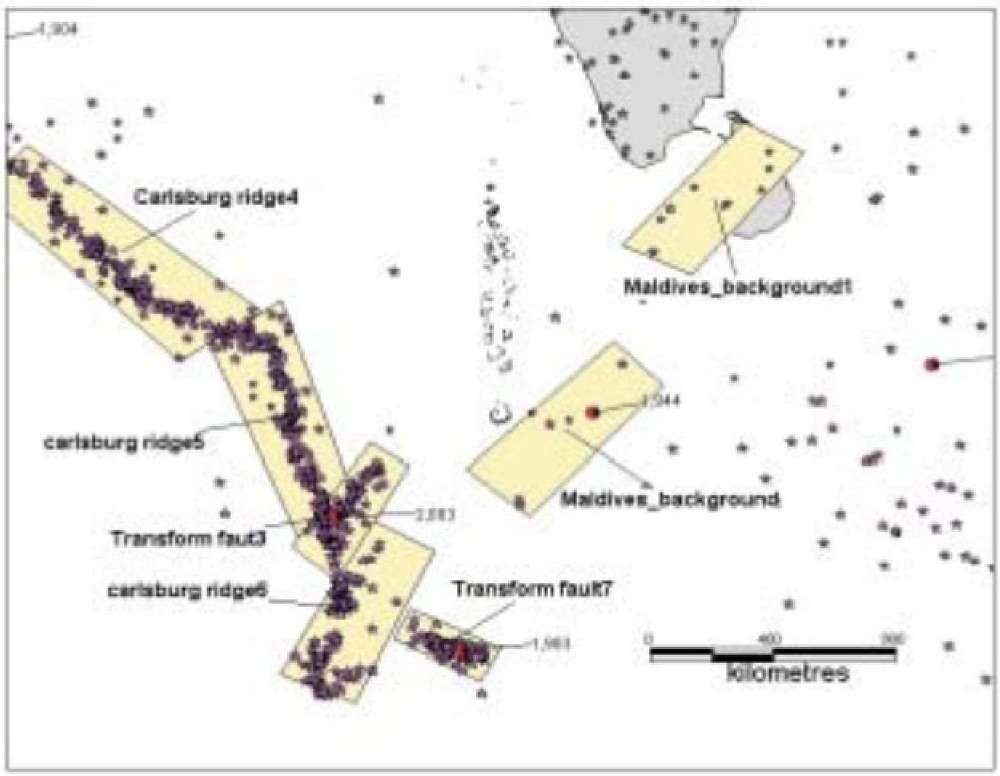


Figure 6 - Earthquake epicenters around Maldives

As main reasons for the poor performance of buildings at an earthquake, the inadequate strength and stiffness of the seismic resisting system, poor distribution of strength and stiffness in successive floors and lack of provision for an adequate load path through the structure, should be considered in the preliminary analysis and design of a building.

A reasonable approach for mitigating the seismic effects by proper reinforcement details at joints and connections, which enhance the ductility at such locations is adopted during the detail design to mitigate seismic effects of the building.

5 LOAD COMBINATIONS

The following load combinations will be used for the structural analysis and design.

SLS Combinations	ULS Combinations
1.0 Gk + 1.0 Qk	1.4 Gk + 1.6 Qk
1.0 Gk + 1.0 Wkx	1.4 Gk + 1.4 Wkx
1.0 Gk - 1.0 Wkx	1.4 Gk - 1.4 Wkx
1.0 Gk + 1.0 Wky	1.4 Gk + 1.4 Wky
1.0 Gk - 1.0 Wky	1.4 Gk - 1.4 Wky
1.0 Gk + 1.0 Qk + 1.0 Wkx	1.2 Gk + 1.2 Qk + 1.2 Wkx
1.0 Gk + 1.0 Qk - 1.0 Wkx	1.2 Gk + 1.2 Qk - 1.2 Wkx
1.0 Gk + 1.0 Qk + 1.0 Wky	1.2 Gk + 1.2 Qk + 1.2 Wky
1.0 Gk + 1.0 Qk - 1.0 Wky	1.2 Gk + 1.2 Qk - 1.2 Wky
	1.0 Gk + 1.4 Wkx
	1.0 Gk - 1.4 Wkx
	1.0 Gk + 1.4 Wky
	1.0 Gk - 1.4 Wky

6 STRUCTURAL ANALYSIS BY FINITE ELEMENT MODELING

The proposed building was modelled in Scia Engineer v.17, a finite element software package. The material properties are assigned to the model and the structural elements are initially selected based on preliminary calculations. Frame type finite elements are used to model the columns and beams whereas shell type of finite elements are used in the modelling of the slabs, pile caps and shear walls. Meshing of the shell elements will be carried out manually in order to have proper connections between nodal points.

The self-weight of the slabs, beams, floor slabs, concrete walls and columns will be calculated using the self-weight option available with Scia Enginer. For this, actual member sizes were used. This is defined as "DEAD" in Scia Engineer model. The dead loads and live loads will be transferred to all the concrete walls and beams that are supporting a slab panel. Additionally, the calculated loads will be assigned to the model. Load cases will be defined for dead loads, live loads & wind loads. This load case will be later scale multiplied to obtain the required load intensity at various load combinations as discussed in the previous chapter. Once the analysis is performed, the initial section sizes will be changed according to the design requirements and structure will be re-analysed until the required design requirements are met.

The three-dimensional forces generated due to lateral loads, eccentricity and asymmetrical frame actions which are considered significant, need to be transferred to the ground without imparting excessive deflection and distress to the structure. The lateral stability against lateral loads will be taken by the shear wall and the frame actions; will be strategically located throughout the structure, and efficient lateral load transfer for the overall structure. The vertical loads generated by the upper floors will be transferred to the foundations via the frames, through concrete walls and columns. These vertical elements will have well spread foundation for efficient force transfer onto the subsoil. The floor slabs at each level will transfer the lateral loads to these stiff elements via diaphragm action, ensuring that the lateral loads are shared proportionately between these vertical elements.

APPENDIX A

STRUCTURAL ANALYSIS REPORT

Job Information

	Engineer	Checked	Approved
Name:	ZAAR	MMW	
Date:	08-Jan-23		

Structure Type	SPACE FRAME

Number of Nodes	4389	Highest Node	4743
Number of Elements	1549	Highest Beam	6245
Number of Plates	4029	Highest Plate	6257

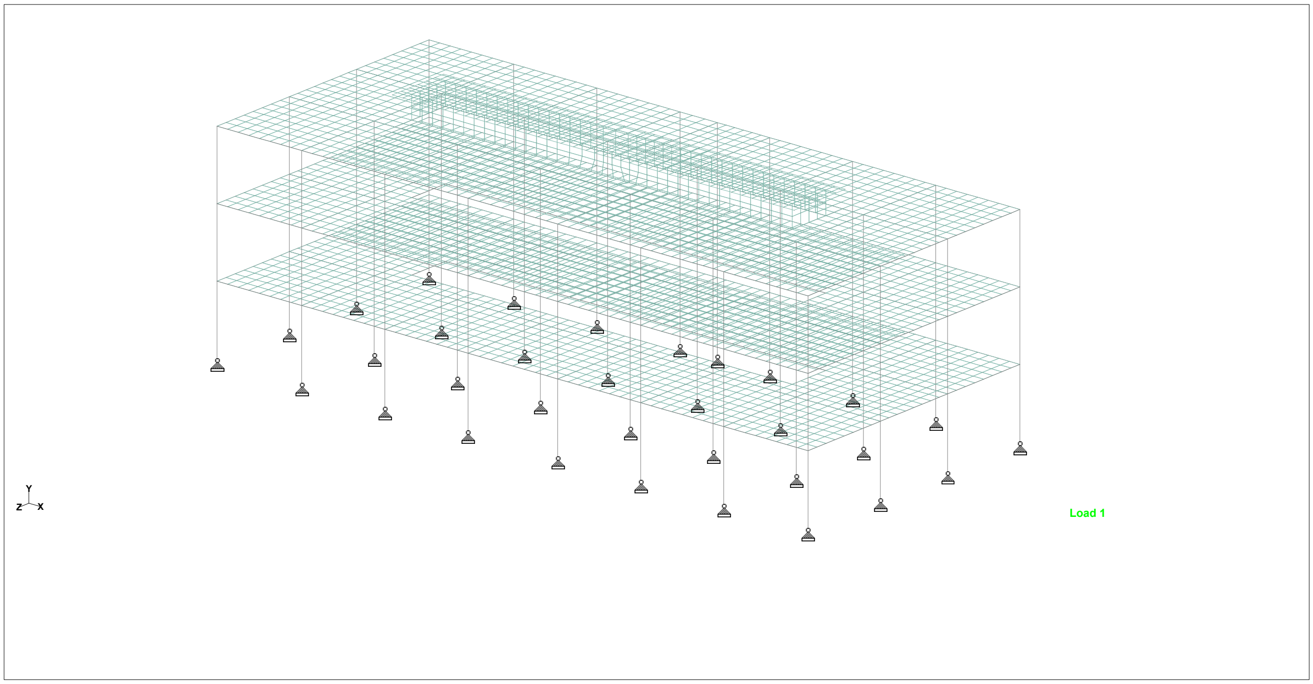
Number of Basic Load Cases	-2
Number of Combination Load Cases	2

Included in this printout are data for:

All	The Whole Structure

Included in this printout are results for load cases:

Type	L/C	Name
Primary	1	DL
Primary	2	LL
Combination	3	SLS
Combination	4	ULS



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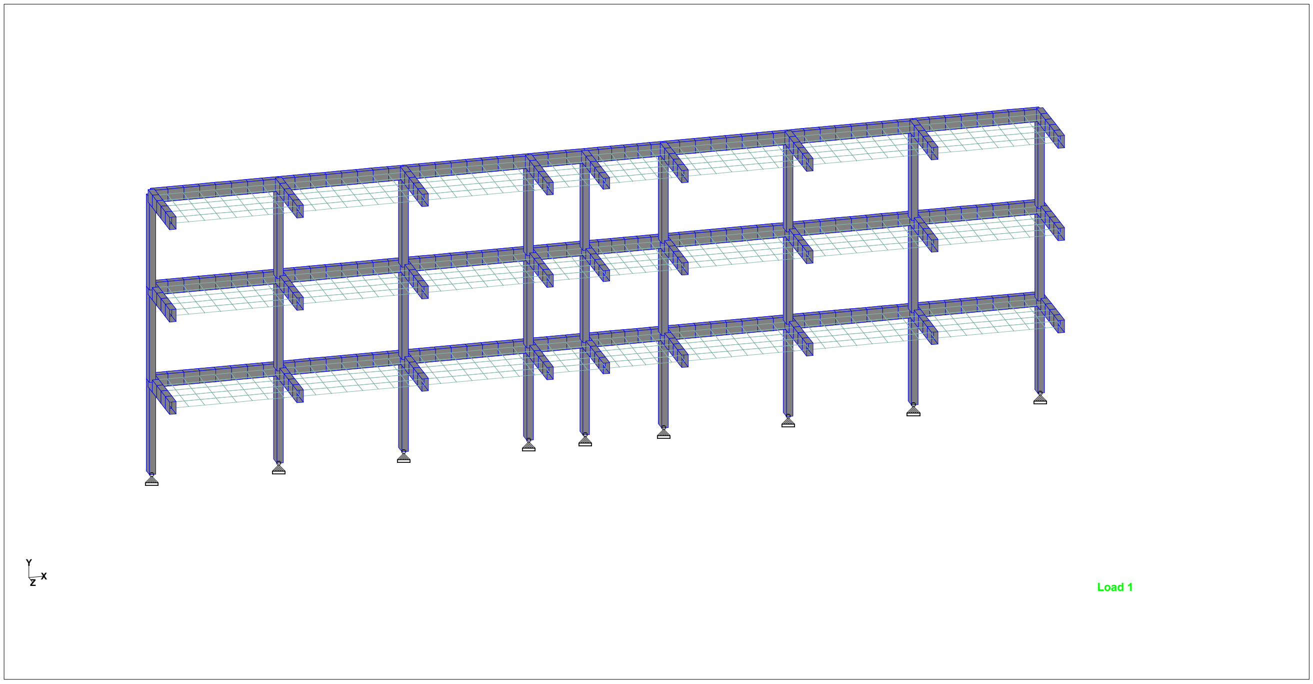

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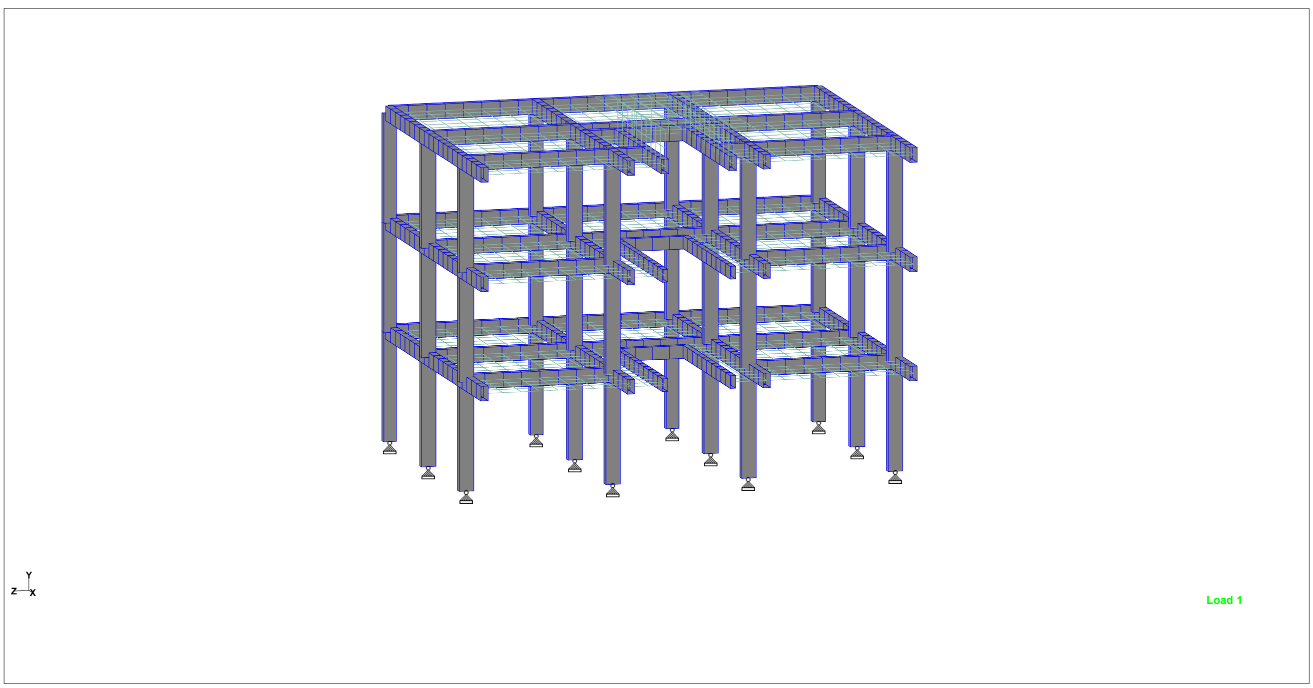

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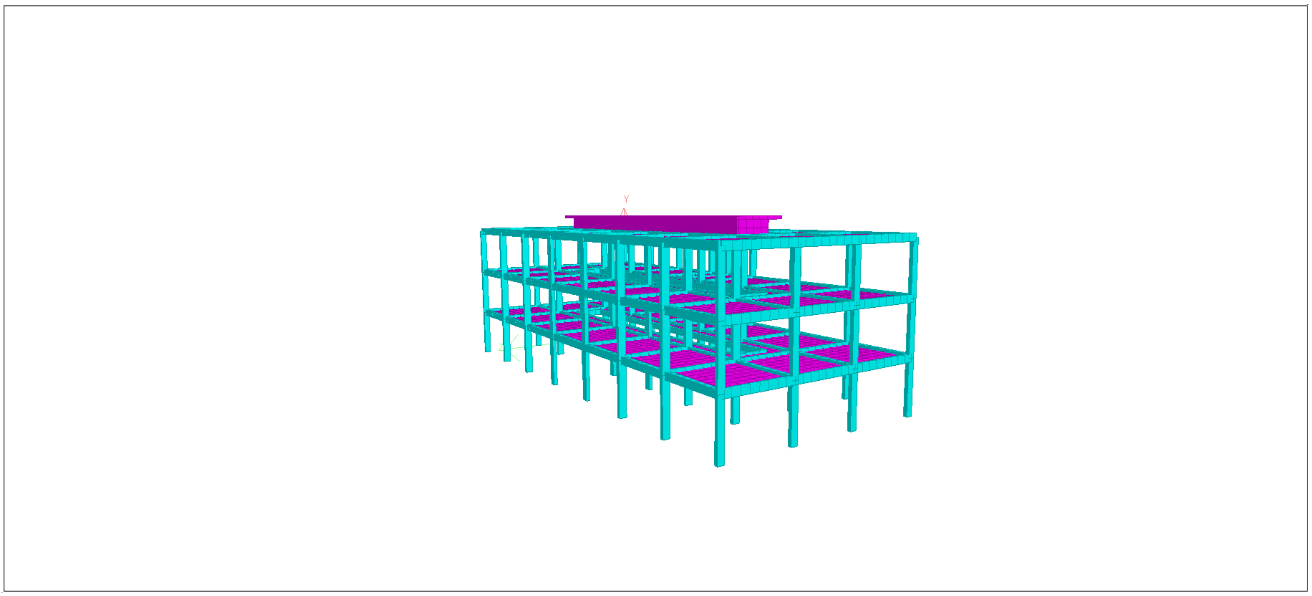

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SUPPORT REATION DL (Input data was modified after picture taken)

SUPPORT REATIONS LL (Input data was modified after picture taken)

SUPPORT REACTIONS SLS (Input data was modified after picture taken)

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	Part		
Job Title STUDENT ACCOMODATION BLOCK	Ref		
	By ZAAR	Date 08-Jan-23	Chd MMW
Client MNU	File mnu student accomodatio	Date/Time 01-Mar-2023 11:28	

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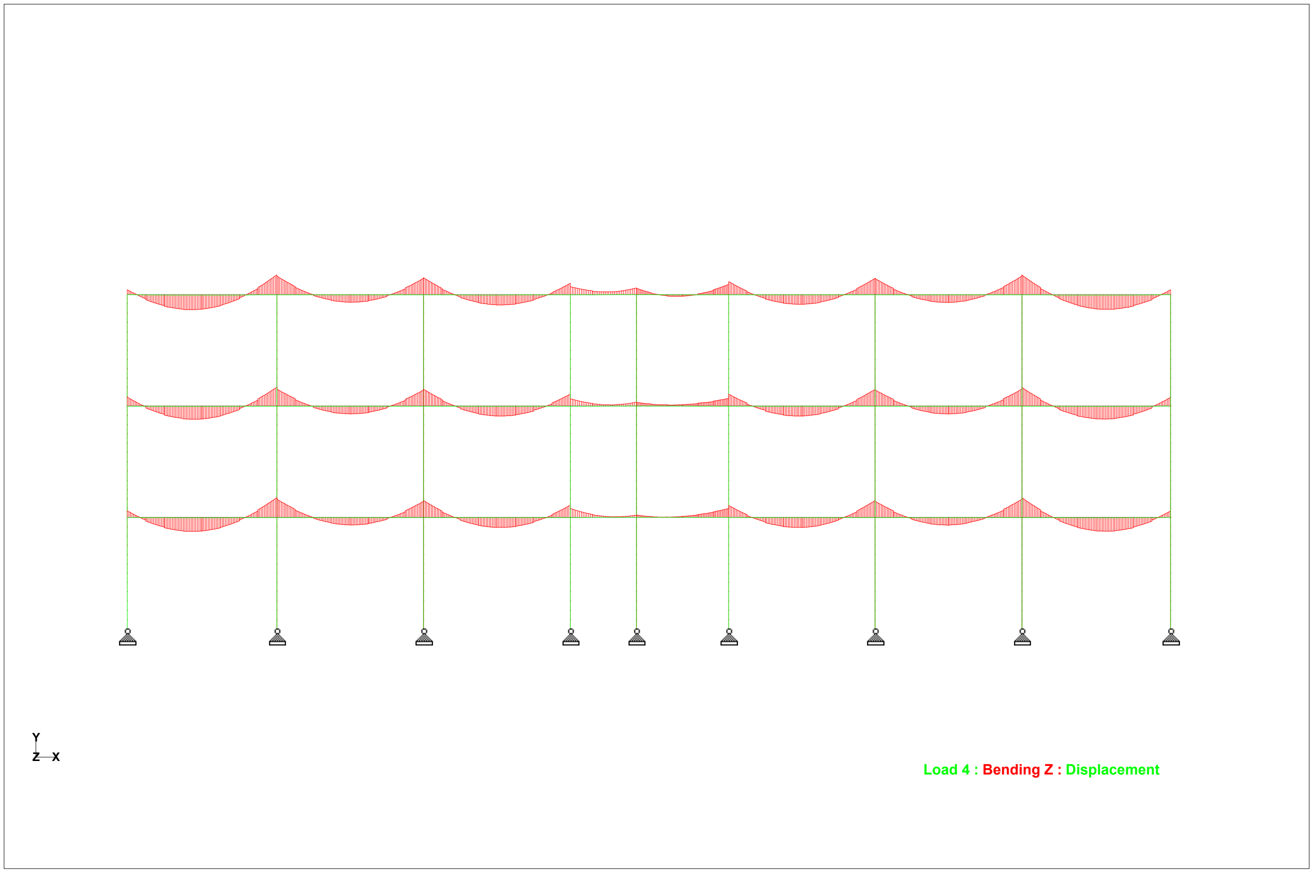

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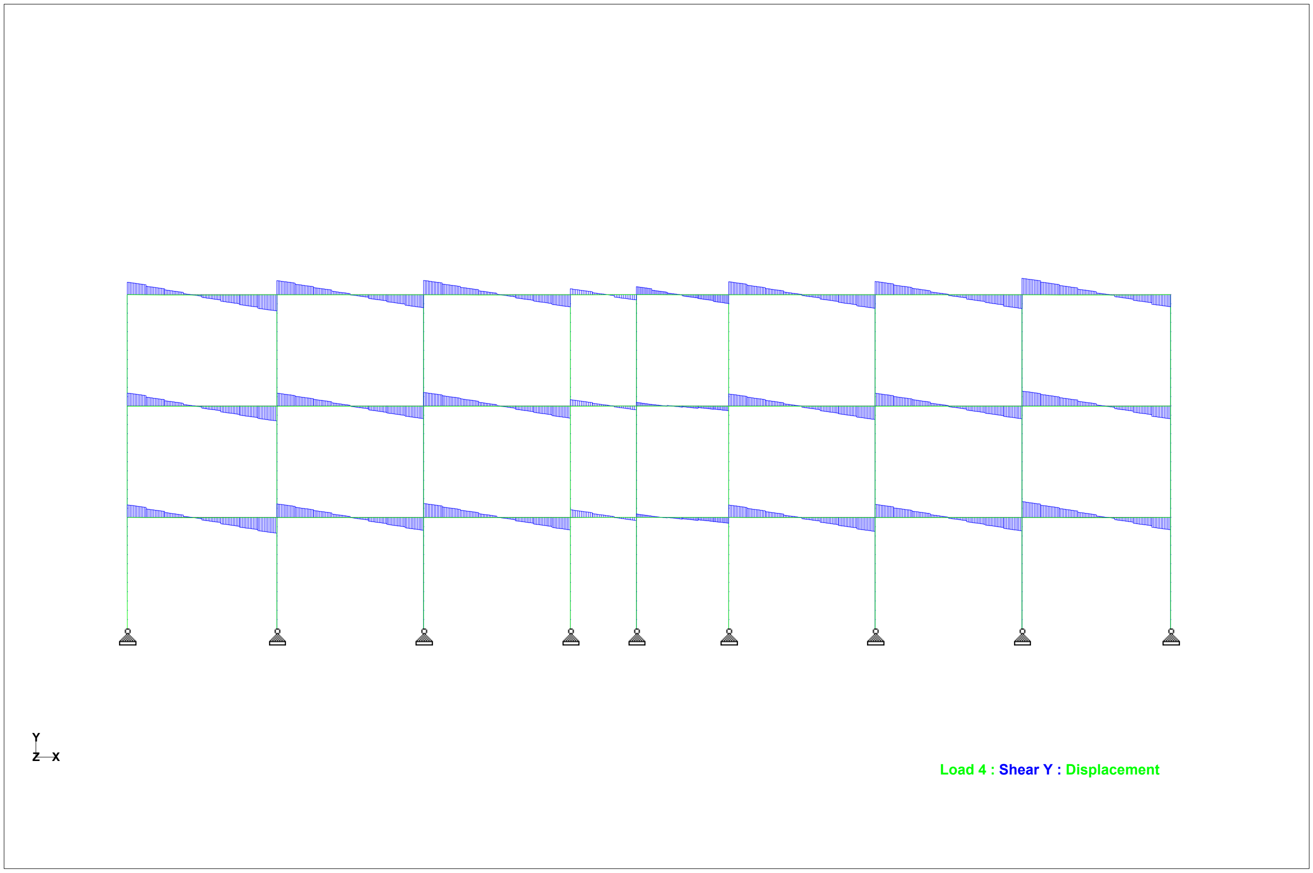

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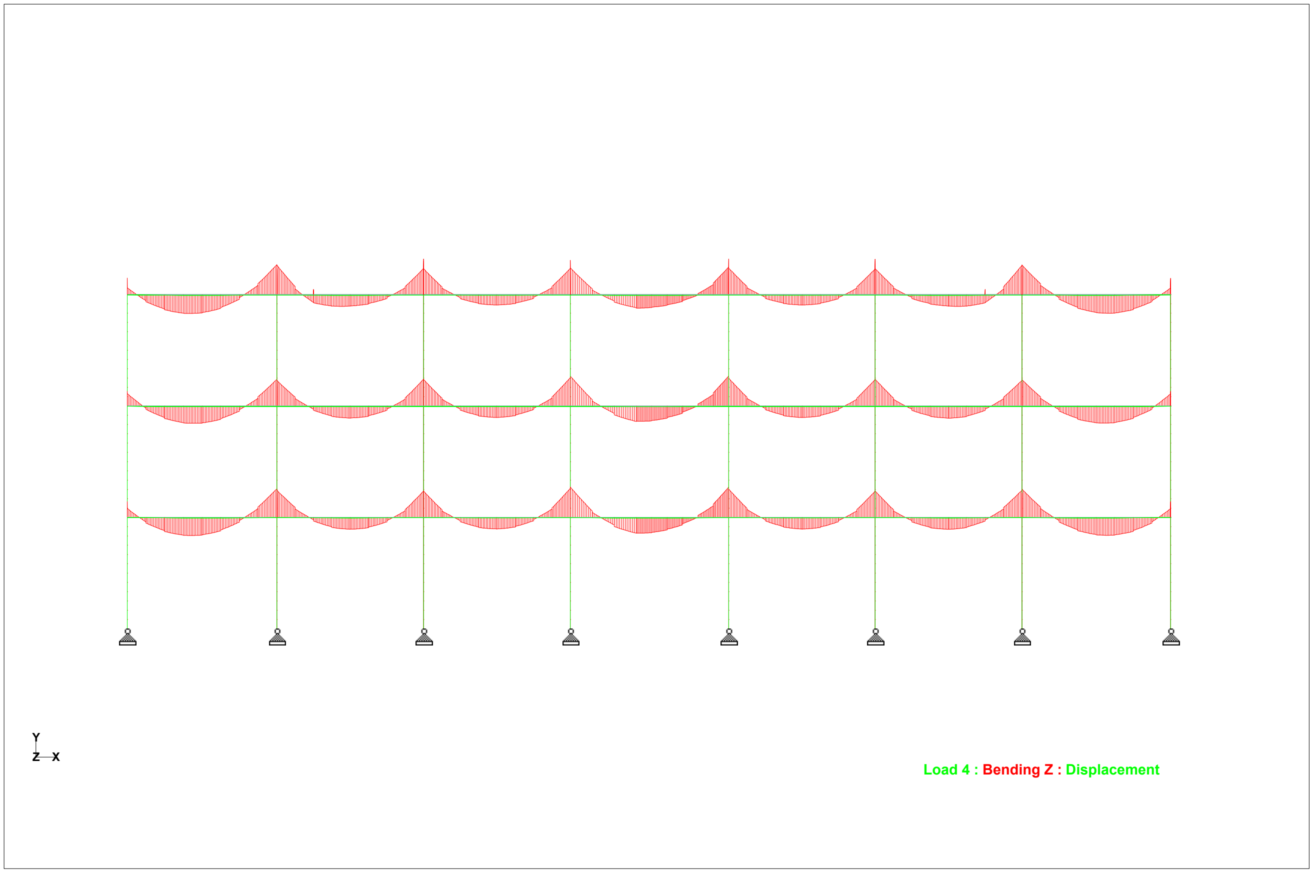

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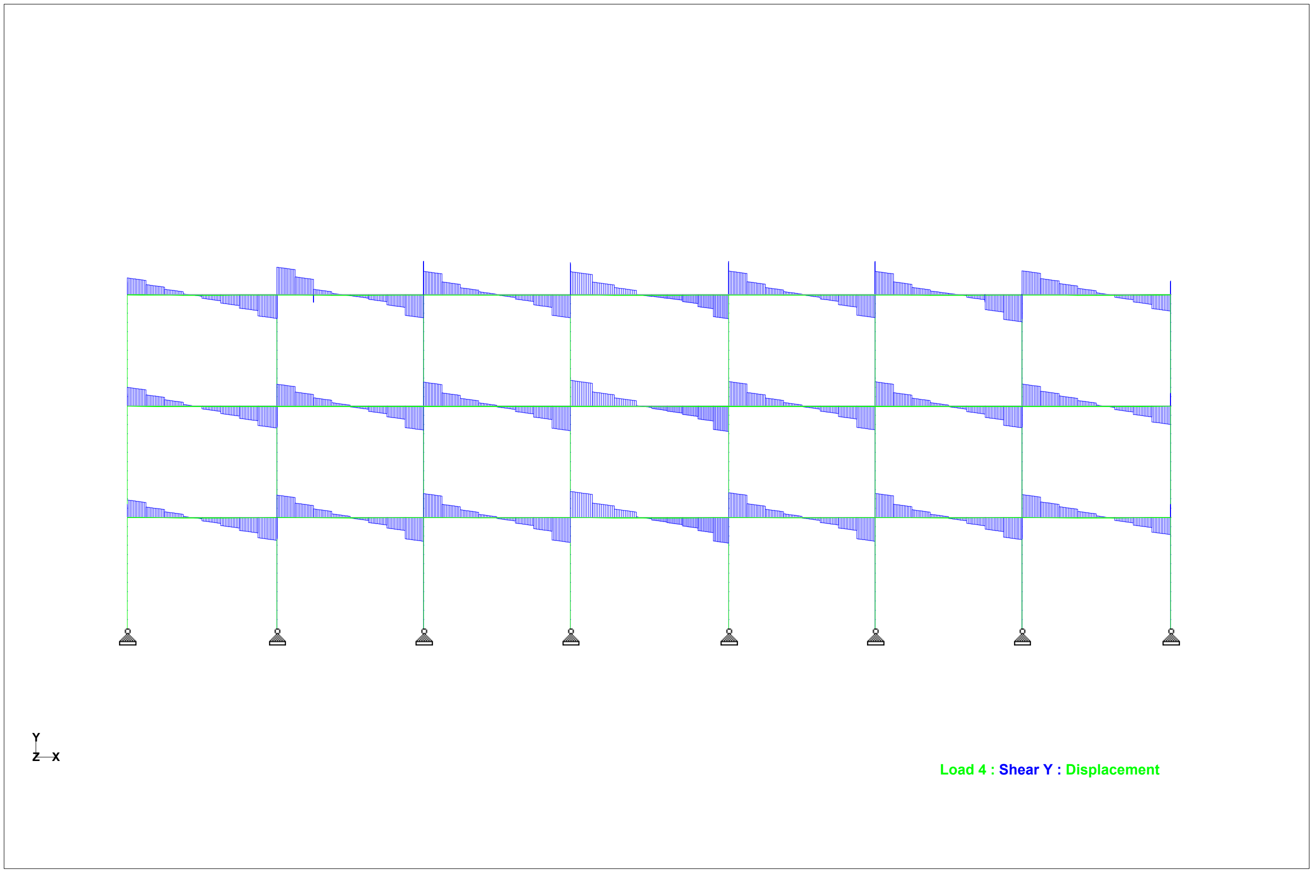

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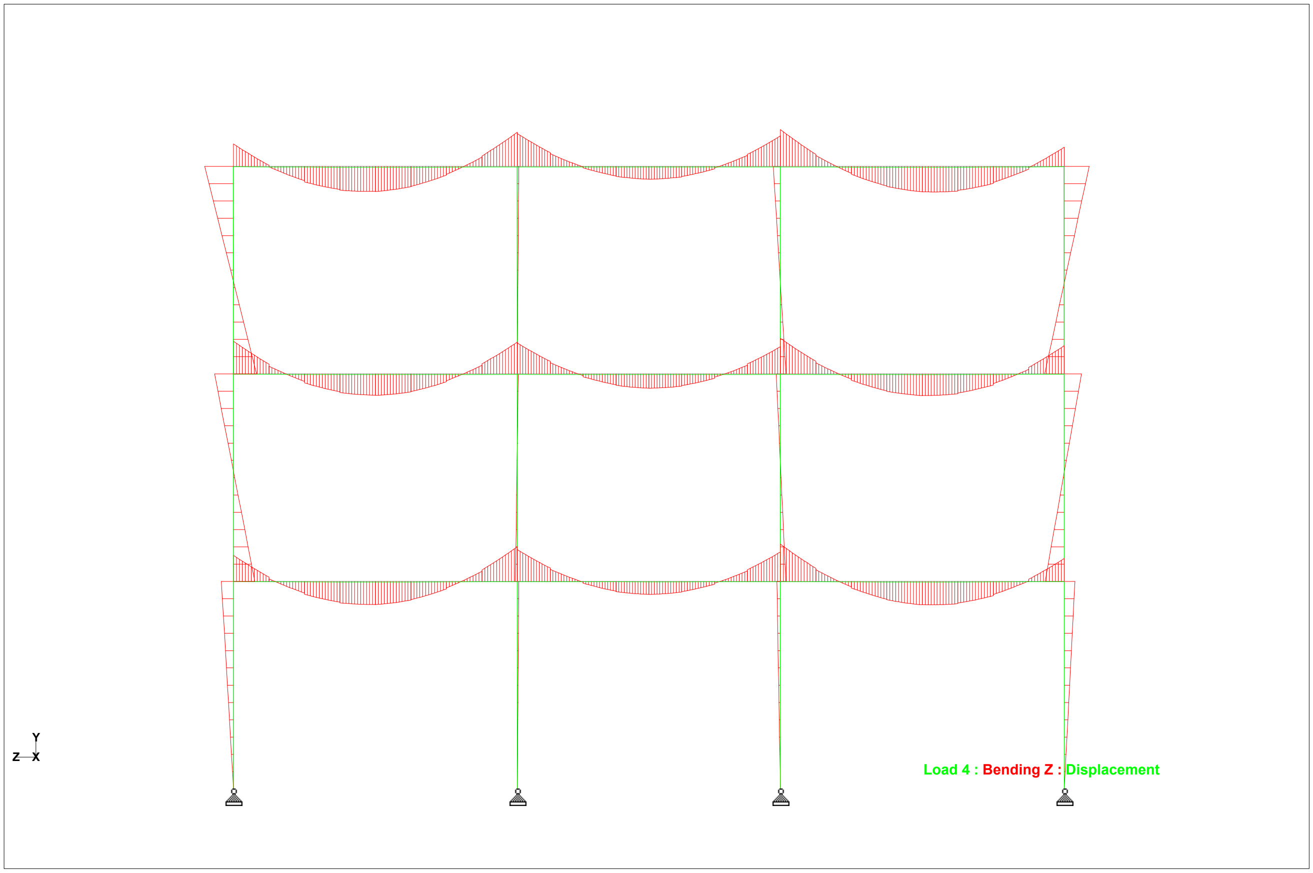

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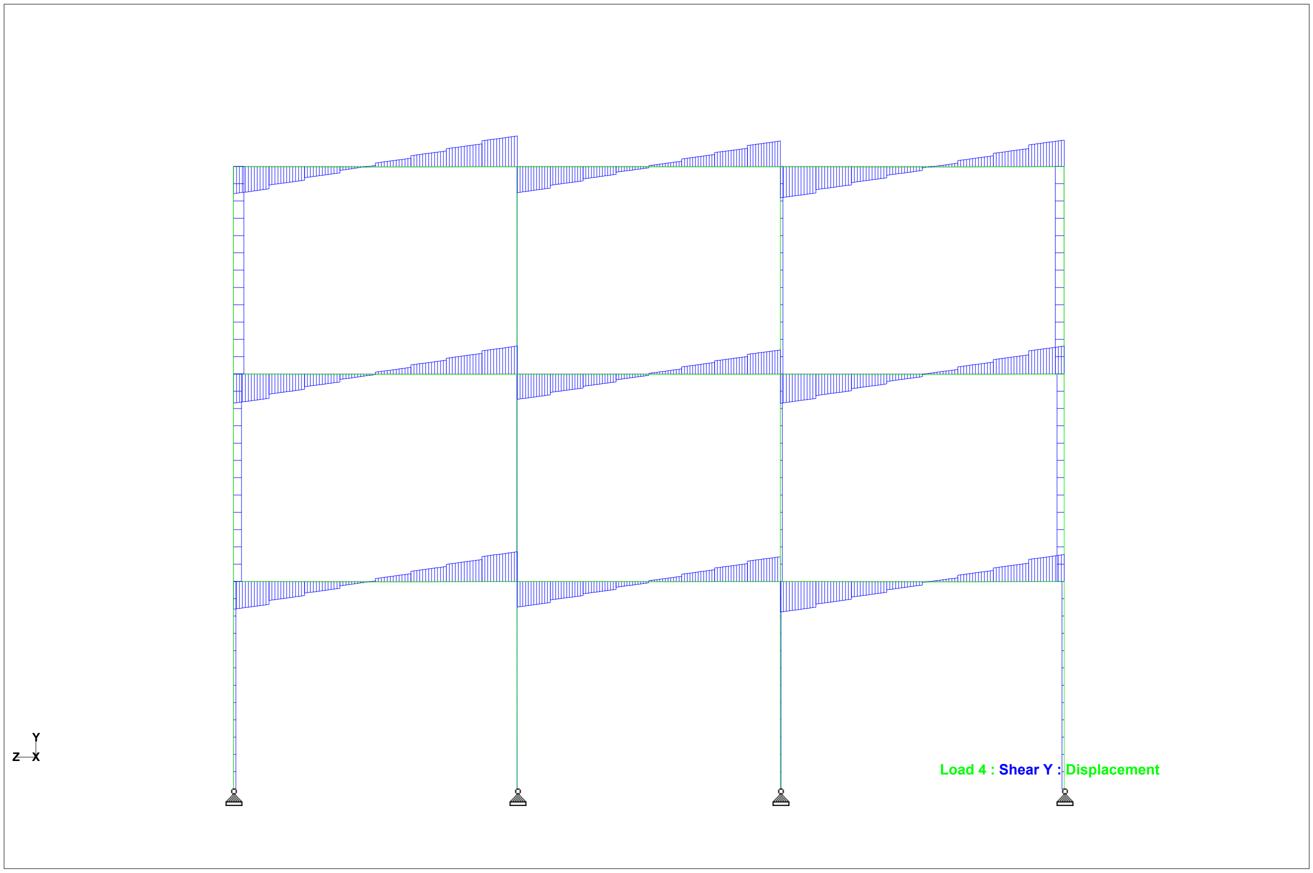

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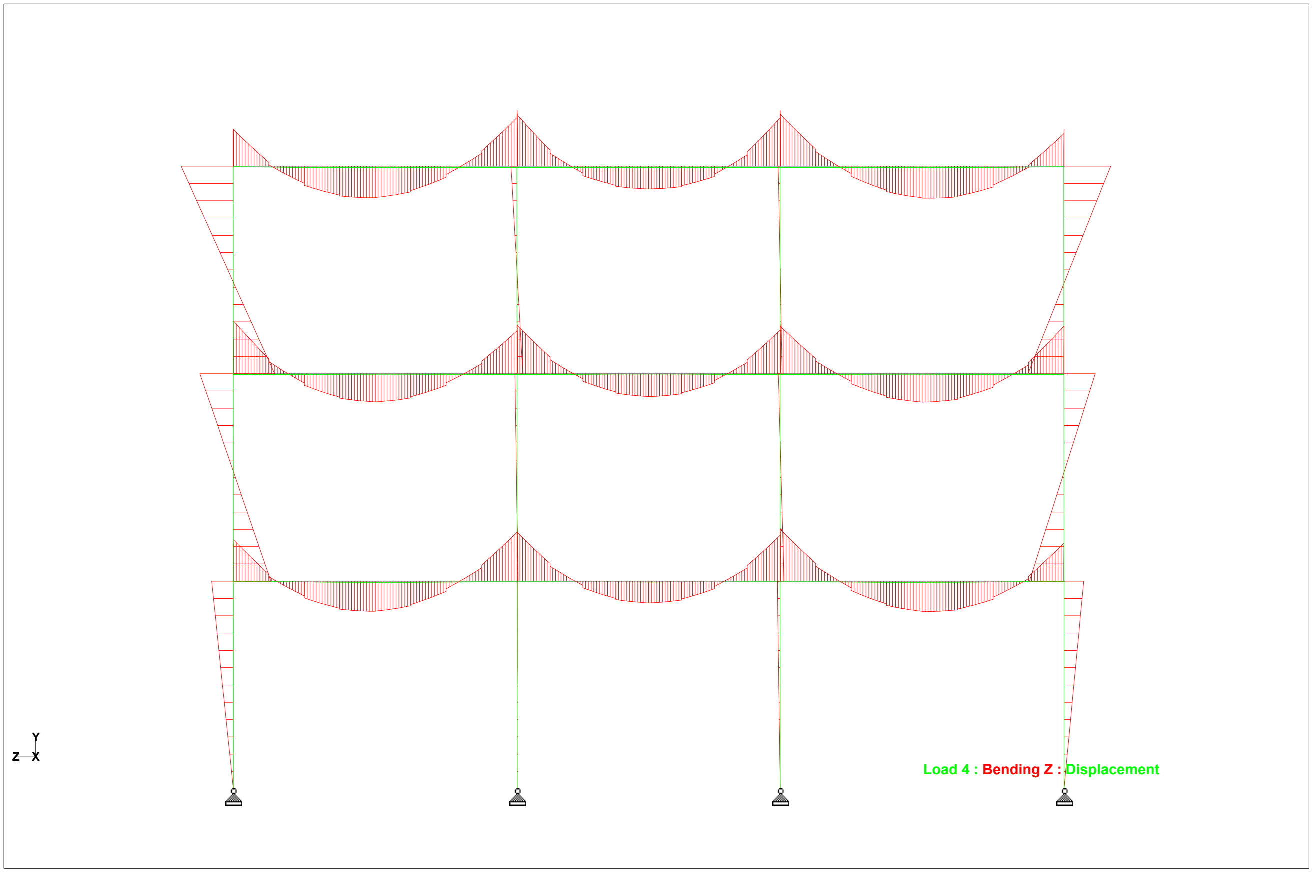

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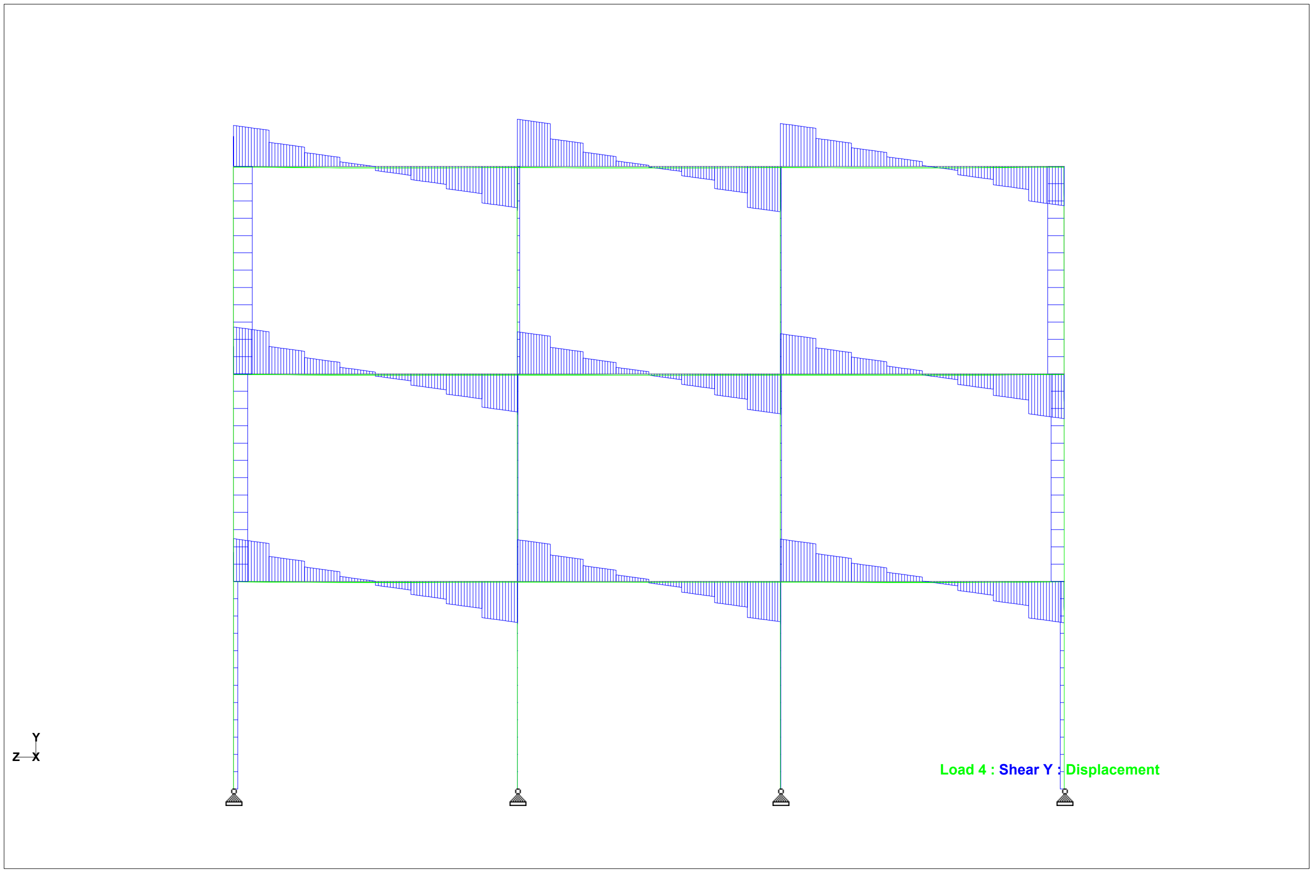

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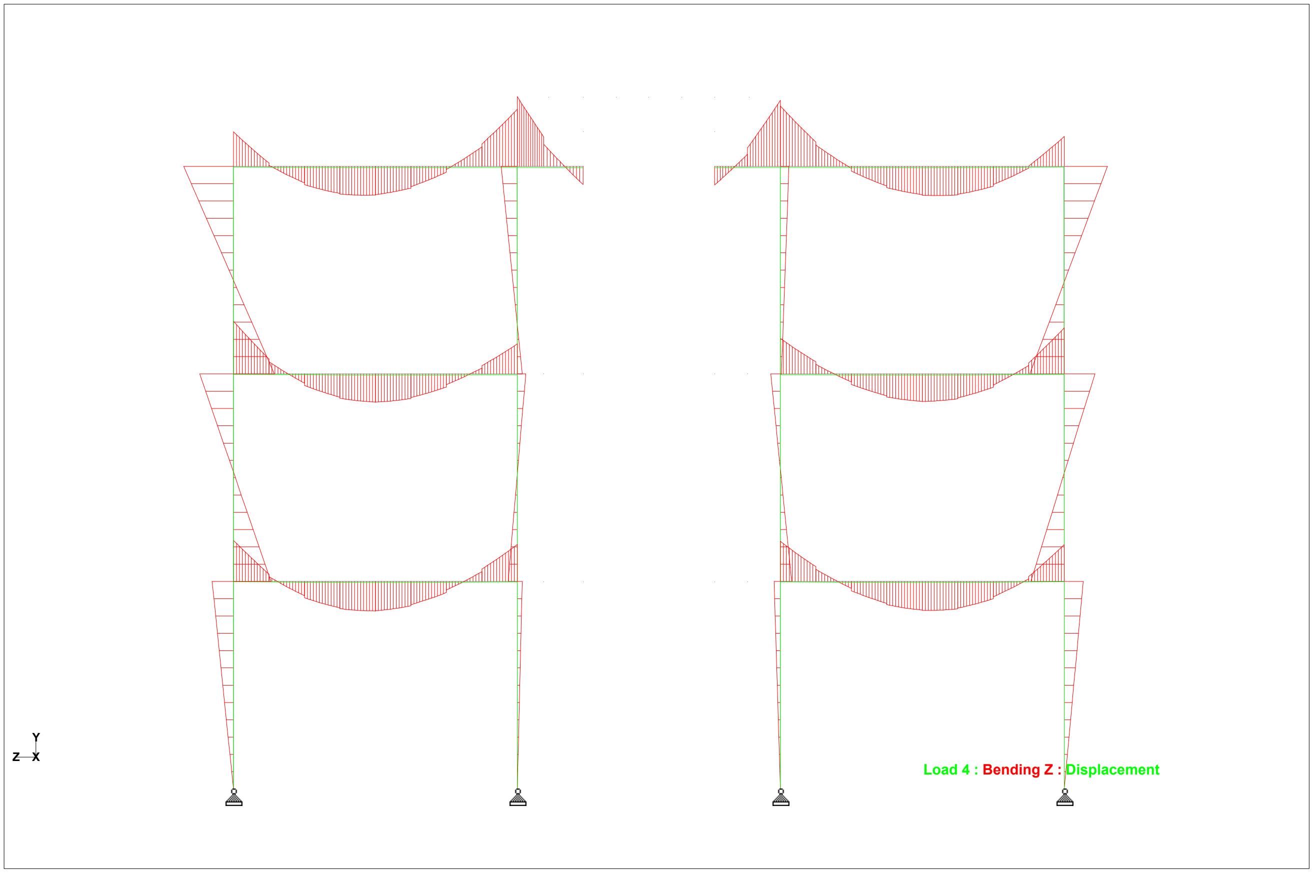

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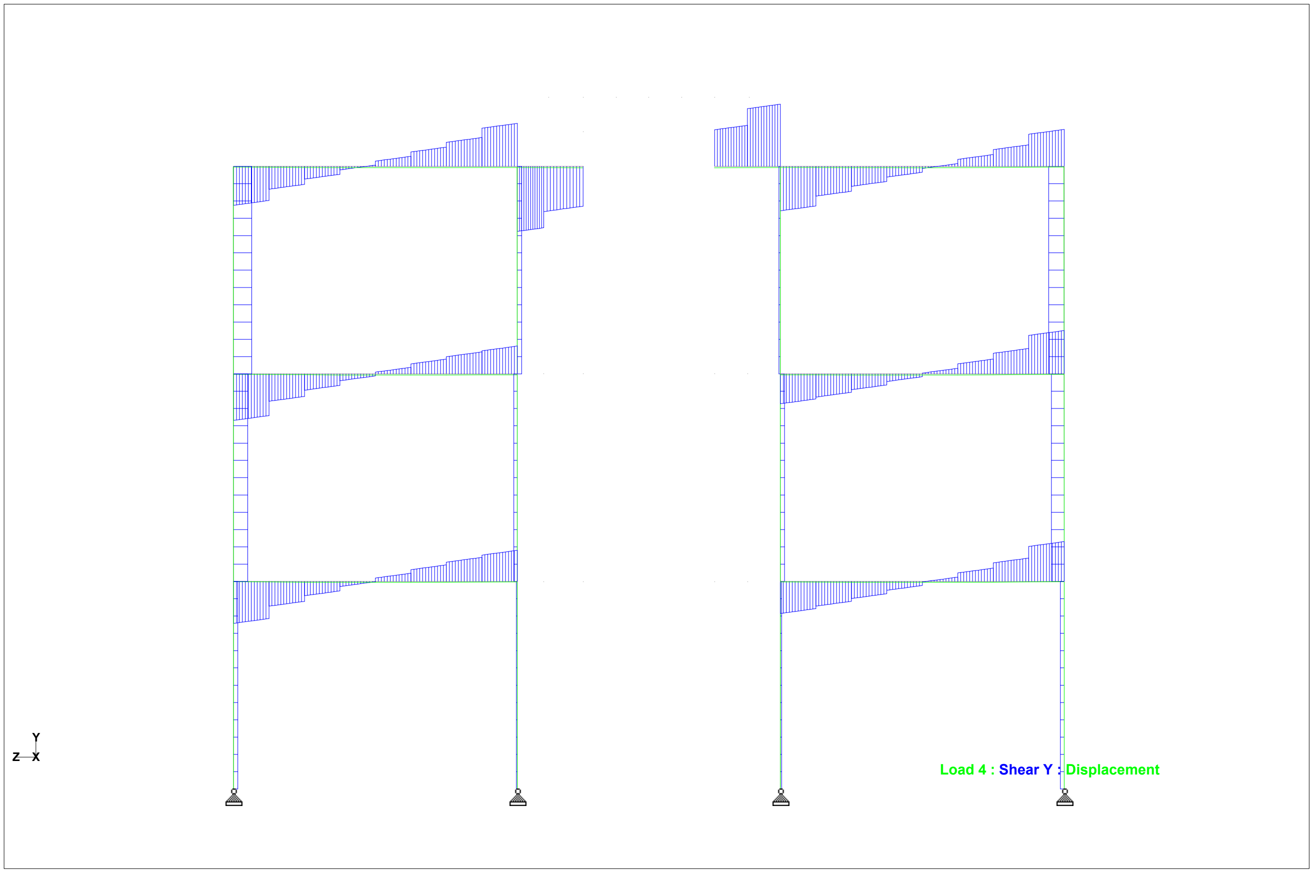

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APPENDIX B

CALCULATIONS

CANTILEVER SLAB

SPAN	1	m		Cover	30	m
Live Load	3	KN/m2		fck	25	Mpa
Floor Finish	2	KN/m2		fy	460	Mpa
Parapet	2.88	KN				
Assumed Thickness	160	mm				
Assume bar size	10	mm				
Eff Depth	125	mm				
Design Loads				**Design Forces**		
Self Weight	3.84	KN/m2		Med	9.37	KNm
Ultimate Load n	12.976	KN/m2		Ved	15.86	KN
Flexural Design				**Deflection**		
K	0.020			ρ	0.004	
No compression reinforcement needed				ρ_o	0.005	
				K	0.4	Cantilevers
z	0.98			L/d	9.572	
	118.75			β_S	2.598	
Reinforcement				L/d,limiting	24.87	
Asreq	197.12	mm2/m		L/d,Actual	8.000	Ok
No of Bars Required	2.510	6				
Bar Spacing Provided	166.7	150		Check For Shear		
Asprov	471.24	mm2/m		τ_v	0.126848	N/mm2
				τ_c	0.8	

TWO WAY SPANING SLAB

BS 8110:1997

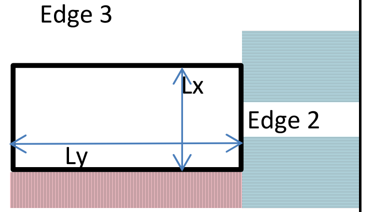
Project Name: FVM Campus Student Accomodation
Client Name: MNU
Location: Bedroom 1/Bedroom 2

Slab Data

Slab Width Lx	4000	mm	fck	25
Slab Length Ly	4100	mm	fy	460
Slab Thickness h	140	mm		
Cover	30	mm	**(1 continuous / 0 discontinuous)**	
Ly/Lx	1.025	Two Way Slab	Edge 1	0
			Edge 2	1
Self Weight	3.36	KN/m2	Edge 3	0
Extra Dead Load Gk	1.75	KN/m2	Edge 4	1
Live Load Qk	2	KN/m2		
Design Load n	10.35	KN/m2		

Edge 3

Edge 1



Edge 2

Edge 4

Moment

Nd	2			
γ	0.238			
Moment in x-direction				
ßx	0.039	Mx	6.49	KN-m
ß3	0.000	M3	0.00	KN-m
ß4	0.052	M4	8.66	KN-m
Moment in y-direction				
ßx	0.034	My	5.63	KN-m
ß1	0	M1	0.00	KN-m
ß2	0.045333	M2	7.51	KN-m

Steel Reinforcement

x-direction	**Bar Size**	**Spacing**	**As Prov**	**As Req**	**dx**	**zx**	**Status**
Bottom	10	150	524	182	105	99.75	**OK**
Edge 3	10	150	524	182	105	99.75	**OK**
Edge 4	10	150	524	217	105	99.75	**OK**

y-direction	**Bar Size**	**Spacing**	**As Prov**	**As Req**	**dy**	**zy**	**Status**
Bottom	10	150	524	182	105	99.75	**OK**
Edge 1	10	150	524	182	105	99.75	**OK**
Edge 2	10	150	524	188	105	99.75	**OK**

Distribution Bars	**0.13%bh**		182	mm2	
Provide	10	150	**524**	mm2	**OK**
Min Steel for Shirinkage/Thermal Cracks 0.25%bh			182	mm2	
Provide	10	150	**524**	mm2	**OK**

Shear

Shear in x-Direction	**Design v**	**v**	**vc**	**Status**
Edge 3	18.54	0.177	0.700	**OK**
Edge 4	22.87	0.218	0.700	**OK**

Deflection

Mx/bdx^2	0.589		
As req	182	mm2	
As prov	524	mm2	
fs	99.93	N/mm2	
Tension Reinforcement Modification factor			2

Lx/dx	26	
Allowable Lx/dx	52.00	
Actual Lx/dx	38.10	**OK**

Cracking Reinforcement

3*dx	315	mm or maximun 750mm
Bar Spacing	150	
	140	**OK**
%100As/bd	0.50	**OK**

RECTANGULAR BEAM

Designed As Per BS 8110

Project: MNU FVM Campus Student accomodation
Floor: FIRST FLOOR
Member ID: B1

Moment	60
Moment Nmm	60000000
Width b	200
Depth h	400
Eff Depth d	331
Fck	25
Fy	415
Cover	35

Bending	
K	0.110
K'	0.156
Singly Reinforced	
z	283.5
0.95d	314.0
Singly Reinforced	
z	283.5
x	104.5
As Required	**536.9**
Doubly Reinforced	
z	
x	
As Required	
As' Required	

Link Dia	6
Bottom Bar dai	16
Top Bar Dia	16
Vertical Bar Spacing	25
Upper Lever arm	310
Lower Lever arm	351
As' Provided	
AS Provided	**804**

Shear	
As (Provided)	804
100As/bd (test)	1.22
100As/bd	1.22
400/d (test)	1.21
400/d	1.21
V	70000
fyv	250
vc	0.88
vc+0.4	1.28
0.8/fck	4.00
v	1.06
v<0.8/fck and 5N/mm2 OK	
No of Legs	2
Bar Dia	6
Asv	**56.55**
Sv	**168**
Sv max	300

Min Reinforcement	**Tension**	**Compression**
Min p	0.18	0.2
P Provided	1.00	

Bar Dia	**bar Areas**	**Bottom Layer**	**Top Layer**
10	79		
12	113		
16	201	2	2
20	314		
25	491		
32	804		
Layer area		402	402

Deflection	
M/bd^2	2.75
fs	161
Mod. Factor Test	1.27
Mod.factor	1.27

Support Type	**Basic l/d Ratio**	**Span**	**l/d Actual**	**l/d Allowed**	**Status**
Cantilever	7	0	0	9	OK
Simply Supported	20	6850	21	25	OK
Continuous	26	6850	21	33	OK

RECTANGULAR BEAM

Designed As Per BS 8110

Project: MNU FVM Campus Student accomodation
Floor: FIRST FLOOR
Member ID: B1

Moment	45
Moment Nmm	45000000
Width b	200
Depth h	400
Eff Depth d	321
Fck	25
Fy	415
Cover	35

Bending	
K	0.087
K'	0.156
Singly Reinforced	
z	286.6
0.95d	305.4
Singly Reinforced	
z	286.6
x	77.5
As Required	**398.3**
Doubly Reinforced	
z	
x	
As Required	
As' Required	

Link Dia	6
Bottom Bar dai	20
Top Bar Dia	16
Vertical Bar Spacing	25
Upper Lever arm	306
Lower Lever arm	349
As' Provided	
AS Provided	**628**

Shear	
As (Provided)	628
100As/bd (test)	0.98
100As/bd	0.98
400/d (test)	1.24
400/d	1.24
V	70000
fyv	250
vc	0.83
vc+0.4	1.23
0.8/fck	4.00
v	1.09
v<0.8/fck and 5N/mm2 OK	
No of Legs	2
Bar Dia	6
Asv	**56.55**
Sv	**168**
Sv max	300

Min Reinforcement	**Tension**	**Compression**
Min p	0.18	0.2
P Provided	0.79	

Bar Dia	**bar Areas**	**Bottom Layer**	**Top Layer**
10	79		
12	113	2	
16	201		2
20	314		
25	491		
32	804		
Layer area		226	402

Deflection	
M/bd^2	2.18
fs	153
Mod. Factor Test	1.43
Mod.factor	1.43

Support Type	**Basic l/d Ratio**	**Span**	**l/d Actual**	**l/d Allowed**	**Status**
Cantilever	7	0	0	10	OK
Simply Supported	20	6850	21	29	OK
Continuous	26	6850	21	37	OK

RECTANGULAR BEAM

Designed As Per BS 8110

Project: MNU FVM Campus Student accomodation
Floor: FIRST FLOOR
Member ID: B1

Moment	35
Moment Nmm	35000000
Width b	200
Depth h	400
Eff Depth d	306
Fck	25
Fy	415
Cover	35

Bending	
K	0.075
K'	0.156
Singly Reinforced	
z	278.0
0.95d	290.7
Singly Reinforced	
z	278.0
x	62.2
As Required	**319.3**
Doubly Reinforced	
z	
x	
As Required	
As' Required	

Link Dia	6
Bottom Bar dai	20
Top Bar Dia	16
Vertical Bar Spacing	25
Upper Lever arm	306
Lower Lever arm	349
As' Provided	
AS Provided	**402**

Shear	
As (Provided)	402
100As/bd (test)	0.66
100As/bd	0.66
400/d (test)	1.31
400/d	1.31
V	70000
fyv	250
vc	0.73
vc+0.4	1.13
0.8/fck	4.00
v	1.14
v<0.8/fck and 5N/mm2 OK	
No of Legs	2
Bar Dia	6
Asv	**56.55**
Sv	**164**
Sv max	300

Min Reinforcement	**Tension**	**Compression**
Min p	0.18	0.2
P Provided	0.50	

Bar Dia	**bar Areas**	**Bottom Layer**	**Top Layer**
10	79		
12	113		
16	201		2
20	314		
25	491		
32	804		
Layer area		0	402

Deflection	
M/bd^2	1.87
fs	191
Mod. Factor Test	1.41
Mod.factor	1.41

Support Type	**Basic l/d Ratio**	**Span**	**l/d Actual**	**l/d Allowed**	**Status**
Cantilever	7	0	0	10	OK
Simply Supported	20	6850	22	28	OK
Continuous	26	6850	22	37	OK

RECTANGULAR BEAM

Designed As Per BS 8110

Project: MNU FVM Campus Student accomodation
Floor: FIRST FLOOR
Member ID: B1

Moment	70
Moment Nmm	70000000
Width b	200
Depth h	400
Eff Depth d	331
Fck	25
Fy	415
Cover	35

Bending	
K	0.128
K'	0.156
Singly Reinforced	
z	273.7
0.95d	314.0
Singly Reinforced	
z	273.7
x	126.3
As Required	**648.8**
Doubly Reinforced	
z	
x	
As Required	
As' Required	

Link Dia	6
Bottom Bar dai	16
Top Bar Dia	16
Vertical Bar Spacing	25
Upper Lever arm	310
Lower Lever arm	351
As' Provided	
AS Provided	**804**

Shear	
As (Provided)	804
100As/bd (test)	1.22
100As/bd	1.22
400/d (test)	1.21
400/d	1.21
V	91000
fyv	250
vc	0.88
vc+0.4	1.28
0.8/fck	4.00
v	1.38
v<0.8/fck and 5N/mm2 OK	
No of Legs	4
Bar Dia	6
Asv	**113.10**
Sv	**273**
Sv max	300

Min Reinforcement	**Tension**	**Compression**
Min p	0.18	0.2
P Provided	1.00	

Bar Dia	**bar Areas**	**Bottom Layer**	**Top Layer**
10	79		
12	113		
16	201	2	2
20	314		
25	491		
32	804		
Layer area		402	402

Deflection	
M/bd²	3.20
fs	194
Mod. Factor Test	1.12
Mod.factor	1.12

Support Type	**Basic l/d Ratio**	**Span**	**l/d Actual**	**l/d Allowed**	**Status**
Cantilever	7	1200	4	8	OK
Simply Supported	20	6850	21	22	OK
Continuous	26	6850	21	29	OK

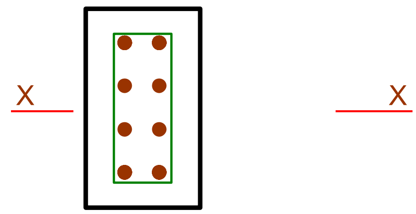
Project	MNU FUVAHMULAH CAMPUS		**The Concrete Centre**		
Client	MNU FUVAHMULAH CAMPUS		Made by	Date	Page
Location	C1 STUDENT ACCOMODATION		MMW	1-Mar-23	
	SYMMETRICALLY REINFORCED RECTANGULAR COLUMN DESIGN, BENT ABOUT TWO AXES TO BS 8110:2005		Checked	Revision	Job No
	Originated from **RCC53.xls** v3.2 on CD	© 2006 TCC		-	

MATERIALS

fcu	25	N/mm²	γm, steel	1.15	Cover to link	40	mm
fy	415	N/mm²	γm, conc	1.5	h agg	20	mm
steel class	A						

SECTION

h	400	mm
b	200	mm
with	2	bars per 200 face
and	4	bars per 400 face



RESTRAINTS

	Lo (mm)	Top Condition	Btm Condition	Braced ?	ß	Le (mm)	Slenderness	Status
X-AXIS	3300	2	1	N	1.3	4290	Lex/h = 10.73	Column is
Y-AXIS	3300	2	1	N	1.3	4290	Ley/b = 21.45	SLENDER

LOADCASES

	AXIAL N (kN)	TOP MOMENTS (kNm) M ix	TOP MOMENTS (kNm) M iy	BTM MOMENTS (kNm) M ix	BTM MOMENTS (kNm) M iy
HIGHEST AXIAL	800	1.0	4.0	1.0	4.0
HIGHEST My	59	16.0	13.0	16.0	13.0
HIGHEST Mx	239	1.0	28.0	1.0	28.0
COMBINED My + Mx				0.0	0.0
				0.0	0.0
				0.0	0.0

BAR ARRANGEMENTS

Bar Ø	Asc %	Link Ø	BAR CENTRES (mm) 200 Face	BAR CENTRES (mm) 400 Face	Nuz (kN)	Checks
R 40	12.57	10	60	87	0	Asc > 6 % (3.12.6.2)
R 32	8.04	8	72	91	0	Asc > 6 % (3.12.6.2)
R 25	4.91	8	79	93	2267	ok
R 20	3.14	6	88	96	1772	ok
R 16	2.01	6	92	97	1456	ok
R 12	1.13	6	96	99	1210	ok

DESIGN MOMENTS (kN

	K	X AXIS M add	X AXIS Mx	Y AXIS M add	Y AXIS My	COMBINED Axis	COMBINED M '	REBAR	max V *
HEST AXIAL	0.641	11.8	12.8	23.6	27.6	Y	30.5	8 R16	49.1
HIGHEST My	1.000	1.4	17.4	2.7	15.7	Y	22.8	8 R12	40.7
HIGHEST Mx	1.000	5.5	6.5	11.0	39.0	Y	41.4	8 R16	48.9
NED My + Mx									#DIV/0!
0									#DIV/0!
0									#DIV/0!

SEE CHARTS ON NEXT SHEET

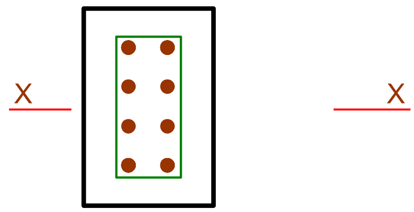
Project	MNU FUVAHMULAH CAMPUS		**The Concrete Centre**
Client	MNU FUVAHMULAH CAMPUS	The Concrete Centre™	Made by: MMW · Date: 1-Mar-23 · Page
Location	C2 STUDENT ACCOMODATION		
	SYMMETRICALLY REINFORCED RECTANGULAR COLUMN DESIGN, BENT ABOUT TWO AXES TO BS 8110:2005		Checked · Revision: - · Job No
	Originated from **RCC53.xls** v3.2 on CD	© 2006 TCC	

MATERIALS

fcu	25	N/mm²	γm, steel	1.15	Cover to link	40	mm
fy	415	N/mm²	γm, conc	1.5	h agg	20	mm
steel class	A						

SECTION

h	350	mm
b	200	mm
with	2	bars per 200 face
and	4	bars per 350 face



RESTRAINTS

	Lo (mm)	Top Condition	Btm Condition	Braced ?	ß	Le (mm)	Slenderness	Status
X-AXIS	3300	2	1	N	1.3	4290	Lex/h = 12.26	Column is
Y-AXIS	3300	2	1	N	1.3	4290	Ley/b = 21.45	SLENDER

LOADCASES

	AXIAL N (kN)	TOP MOMENTS (kNm) M ix	TOP MOMENTS (kNm) M iy	BTM MOMENTS (kNm) M ix	BTM MOMENTS (kNm) M iy
HIGHEST AXIAL	526	1.0	14.0	1.0	14.0
HIGHEST My	165	14.0	4.0	14.0	4.0
HIGHEST Mx	60	8.0	25.0	8.0	25.0
COMBINED My + Mx				0.0	0.0
				0.0	0.0
				0.0	0.0

BAR ARRANGEMENTS

Bar Ø	Asc %	Link Ø	BAR CENTRES (mm) 200 Face	BAR CENTRES (mm) 350 Face	Nuz (kN)	Checks
R 40	14.36	10	60	70	0	Asc > 6 % (3.12.6.2)
R 32	9.19	8	72	74	0	Asc > 6 % (3.12.6.2)
R 25	5.61	8	79	76	2155	ok
R 20	3.59	6	88	79	1661	ok
R 16	2.30	6	92	81	1344	ok
R 12	1.29	6	96	82	1098	ok

DESIGN MOMENTS (kN

	K	X AXIS M add	X AXIS Mx	Y AXIS M add	Y AXIS My	COMBINED Axis	COMBINED M '	REBAR	max V *
HEST AXIAL	0.840	11.6	12.6	20.3	34.3	Y	38.4	8 R16	44.8
HIGHEST My	1.000	4.3	18.3	7.6	11.6	Y	19.7	8 R12	37.3
HIGHEST Mx	1.000	1.6	9.6	2.8	27.8	Y	32.3	8 R16	44.7
NED My + Mx									#DIV/0!
0									#DIV/0!
0									#DIV/0!

SEE CHARTS ON NEXT SHEET

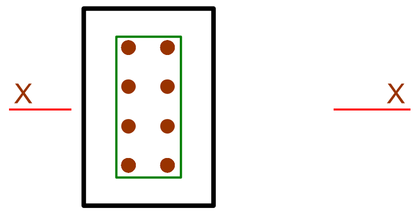
Project	MNU FUVAHMULAH CAMPUS	The Concrete Centre	
Client	MNU FUVAHMULAH CAMPUS	Made by: MMW	Date: 1-Mar-23
Location	C3 STUDENT ACCOMODATION	Page:	
	SYMMETRICALLY REINFORCED RECTANGULAR COLUMN DESIGN, BENT ABOUT TWO AXES TO BS 8110:2005	Checked:	Revision: -
	Originated from RCC53.xls v3.2 on CD © 2006 TCC	Job No:	

MATERIALS

fcu	25	N/mm²	γm, steel	1.15	Cover to link	40	mm
fy	415	N/mm²	γm, conc	1.5	h agg	20	mm
steel class	A						

SECTION

h	350	mm
b	200	mm
with	2	bars per 200 face
and	4	bars per 350 face



RESTRAINTS

	Lo (mm)	Top Condition	Btm Condition	Braced ?	ß	Le (mm)	Slenderness	Status
X-AXIS	3300	2	1	N	1.3	4290	Lex/h = 12.26	Column is
Y-AXIS	3300	2	1	N	1.3	4290	Ley/b = 21.45	SLENDER

LOADCASES

	AXIAL N (kN)	TOP MOMENTS (kNm) M ix	TOP MOMENTS (kNm) M iy	BTM MOMENTS (kNm) M ix	BTM MOMENTS (kNm) M iy
HIGHEST AXIAL	306	4.0	7.0	4.0	7.0
HIGHEST My	135	11.0	14.0	11.0	14.0
HIGHEST Mx	132	11.0	14.0	11.0	14.0
COMBINED My + Mx				0.0	0.0
				0.0	0.0
				0.0	0.0

BAR ARRANGEMENTS

Bar Ø	Asc %	Link Ø	BAR CENTRES (mm) 200 Face	BAR CENTRES (mm) 350 Face	Nuz (kN)	Checks
R 40	14.36	10	60	70	0	Asc > 6 % (3.12.6.2)
R 32	9.19	8	72	74	0	Asc > 6 % (3.12.6.2)
R 25	5.61	8	79	76	2155	ok
R 20	3.59	6	88	79	1661	ok
R 16	2.30	6	92	81	1344	ok
R 12	1.29	6	96	82	1098	ok

DESIGN MOMENTS (kN

	K	X AXIS M add	X AXIS Mx	Y AXIS M add	Y AXIS My	COMBINED Axis	COMBINED M '	REBAR	max V *
HEST AXIAL	1.000	8.0	12.0	14.1	21.1	Y	25.8	8 R12	37.3
HIGHEST My	1.000	3.5	14.5	6.2	20.2	Y	26.8	8 R12	37.3
HIGHEST Mx	1.000	3.5	14.5	6.1	20.1	Y	26.6	8 R12	37.3
NED My + Mx									#DIV/0!
0									#DIV/0!
0									#DIV/0!

SEE CHARTS ON NEXT SHEET

Project	MNU FUVAHMULAH CAMPUS Student Accom	The Concrete Centre			
Client	MNU	Made by	Date	Page	
Location	F1	RMW	1-Mar-23	147	
	PAD FOUNDATION DESIGN to BS 8110:2005	Checked	Revision	Job No	
	Originated from RCC81.xls v4.1 on CD	chg	-	R68	

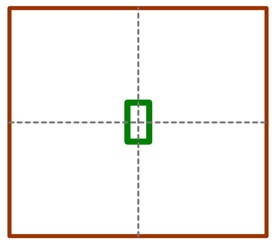
The Concrete Centre
Single column base

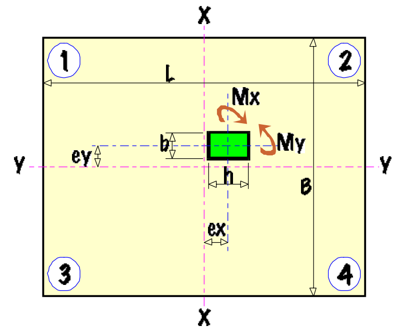
MATERIALS

fcu	25	N/mm²	h agg	20	mm	γc	1.5	concrete
fy	415	N/mm²	cover	50	mm	γs	1.15	steel
Densities - Concrete	24	kN/m³	Soil	18	kN/m³	steel class	A	
Bearing pressure	150	kN/m² (net allowable increase)						

DIMENSIONS mm

BASE		COLUMN	
L =	2350	h =	200
B =	2350	b =	400
depth H =	350		
ex =	0	ey =	0


Plot (to scale)



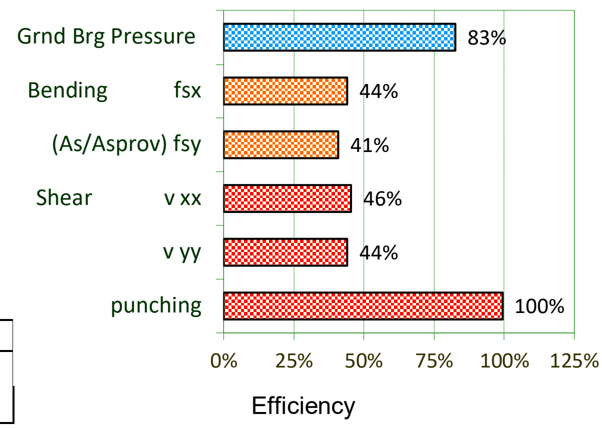
Key

COLUMN REACTIONS kN, kNm *characteristic*

	DEAD	IMPOSED	WIND
Axial (kN)	597.0	76.0	
Mx (kNm)			
My (kNm)			
Hx (kN)			
Hy (kN)			

Overturning FOS = Large
Uplift FOS = infinite

STATUS VALID DESIGN



BEARING PRESSURES kN/m² *characteristic*

CORNER	1	2	3	4
no wind	124.0	124.0	124.0	124.0
with wind	124.0	124.0	124.0	124.0

REINFORCEMENT

Detail to 3.11.3.2			Detail to 3.11.3.2		
Mxx =	235.4	kNm	Myy =	193.6	kNm
b =	2350	mm	b =	2350	mm
d =	287.5	mm	d =	262.5	mm
As =	2406	mm²	As =	2166	mm²
PROVIDE	12 R25 @ 150 & 250 B1		PROVIDE	10 R25 @ 125 & 400 B2	
As prov =	5890	mm²	As prov =	4909	mm²
	Asx increased 143% for shear			Asy increased 122% for shear	

BEAM SHEAR

Vxx =	319.8	kN at d from col face	Vyy =	287.2	kN at d from col face
v =	0.473	N/mm²	v =	0.466	N/mm²
or Vxx =	201.7	kN at 2d from col face	or Vyy =	177.2	kN at 2d from col face
v =	0.298	N/mm²	v =	0.287	N/mm²
vc =	0.656	N/mm²	vc =	0.651	N/mm²

PUNCHING SHEAR

d ave =	275	mm	u crit =	4500	mm
As prov =	0.834	%	v max =	3.056	N/mm² at col face
v =	0.650	N/mm²	vc =	0.653	N/mm²

Project	MNU FUVAHMULAH CAMPUS Student Accom	The Concrete Centre		
Client	MNU	Made by	Date	Page
Location	F2	RMW	1-Mar-23	147
	PAD FOUNDATION DESIGN to BS 8110:2005	Checked	Revision	Job No
	Originated from RCC81.xls v4.1 on CD © 2006-9 TCC	chg	-	R68

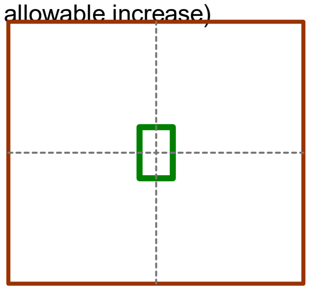
The Concrete Centre
Single column base

MATERIALS

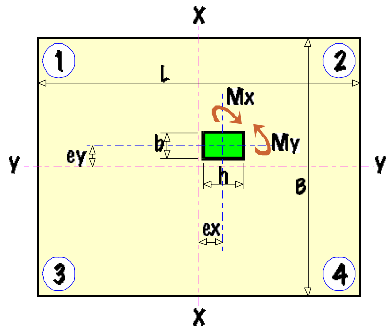
fcu	25	N/mm²	h agg	20	mm	γ_c	1.5	concrete
fy	415	N/mm²	cover	50	mm	γ_s	1.15	steel
Densities - Concrete	24	kN/m³	Soil	18	kN/m³	steel class	A	
Bearing pressure	150	kN/m² (net allowable increase)						

DIMENSIONS mm

BASE		COLUMN	
L =	1800	h =	200
B =	1800	b =	350
depth H =	300		
ex =	0	ey =	0



Plot (to scale)

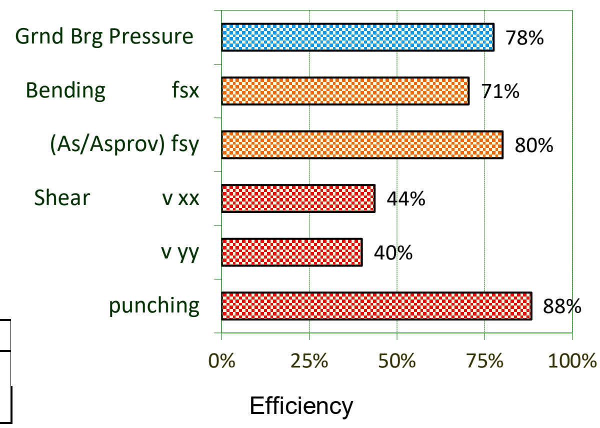


Key

COLUMN REACTIONS kN, kNm *characteristic*

	DEAD	IMPOSED	WIND
Axial (kN)	334.0	37.0	
Mx (kNm)			
My (kNm)			
Hx (kN)			
Hy (kN)			

STATUS VALID DESIGN



Overturning FOS = Large
Uplift FOS = infinite

BEARING PRESSURES kN/m² *characteristic*

CORNER	1	2	3	4
no wind	116.3	116.3	116.3	116.3
with wind	116.3	116.3	116.3	116.3

REINFORCEMENT

Detail to 3.11.3.2			Detail to 3.11.3.2		
Mxx =	93.7	kNm	Myy =	76.9	kNm
b =	1800	mm	b =	1800	mm
d =	242	mm	d =	226	mm
As =	1129	mm²	As =	993	mm²
PROVIDE 7 R16 @ 225 & 300 B1			PROVIDE 7 R16 @ 175 & 375 B2		
As prov =	1407	mm²	As prov =	1407	mm²

BEAM SHEAR

Vxx =	163.9	kN at d from col face	Vyy =	147.8	kN at d from col face
v =	0.376	N/mm²	v =	0.363	N/mm²
or Vxx =	93.7	kN at 2d from col face	or Vyy =	83.4	kN at 2d from col face
v =	0.215	N/mm²	v =	0.205	N/mm²
vc =	0.492	N/mm²	vc =	0.512	N/mm²

PUNCHING SHEAR

d ave =	234	mm	u crit =	3908	mm
As prov =	0.335	%	v max =	2.129	N/mm² at col face
v =	0.443	N/mm²	vc =	0.502	N/mm²

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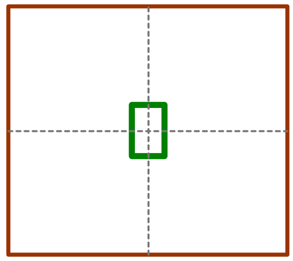
MATERIALS

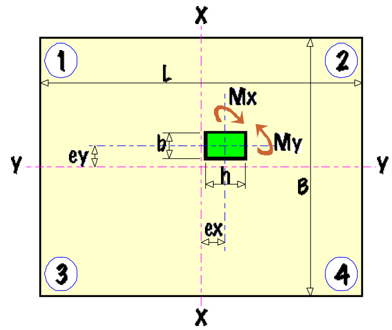
fcu	25	N/mm²	h agg	20	mm	γ_c	1.5	concrete
fy	415	N/mm²	cover	50	mm	γ_s	1.15	steel
Densities - Concrete	24	kN/m³	Soil	18	kN/m³	steel class	A	
Bearing pressure	150	kN/m² (net allowable increase)						

DIMENSIONS mm

BASE		COLUMN	
L =	1700	h =	200
B =	1700	b =	350
depth H =	300		
ex =	0	ey =	0



Plot (to scale)



Key

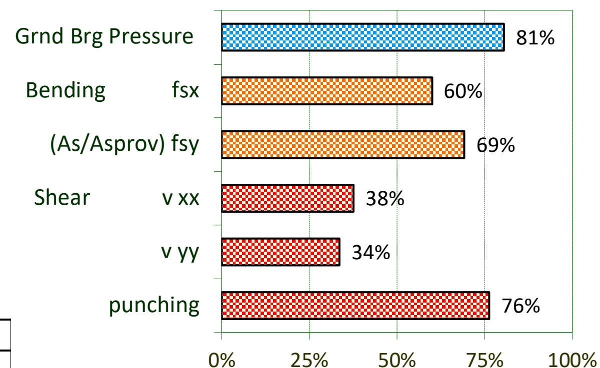
COLUMN REACTIONS kN, kNm *characteristic*

	DEAD	IMPOSED	WIND
Axial (kN)	309.0	35.0	
Mx (kNm)			
My (kNm)			
Hx (kN)			
Hy (kN)			

Overturning FOS = Large

Uplift FOS = infinite

STATUS VALID DESIGN



Efficiency

BEARING PRESSURES kN/m² *characteristic*

CORNER	1	2	3	4
no wind	120.8	120.8	120.8	120.8
with wind	120.8	120.8	120.8	120.8

REINFORCEMENT

Detail to 3.11.3.2			Detail to 3.11.3.2		
Mxx =	80.8	kNm	Myy =	65.5	kNm
b =	1700	mm	b =	1700	mm
d =	242	mm	d =	226	mm
As =	974	mm²	As =	845	mm²
PROVIDE 7 R16 @ 225 & 250 B1			PROVIDE 7 R16 @ 175 & 350 B2		
As prov =	1407	mm²	As prov =	1407	mm²

BEAM SHEAR

Vxx =	146.6	kN at d from col face	Vyy =	130.8	kN at d from col face
v =	0.356	N/mm²	v =	0.340	N/mm²
or Vxx =	77.6	kN at 2d from col face	or Vyy =	67.5	kN at 2d from col face
v =	0.189	N/mm²	v =	0.176	N/mm²
vc =	0.501	N/mm²	vc =	0.522	N/mm²

PUNCHING SHEAR

d ave =	234	mm	u crit =	3908	mm
As prov =	0.354	%	v max =	1.965	N/mm² at col face
v =	0.391	N/mm²	vc =	0.511	N/mm²

Project	MNU FUVAHMULAH CAMPUS Student Accom	The Concrete Centre		
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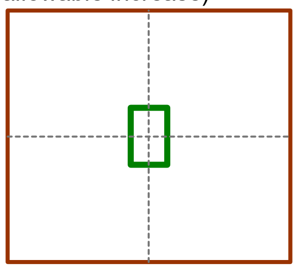
MATERIALS

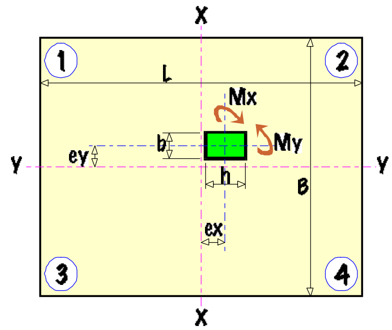
fcu	25	N/mm²	h agg	20	mm	γ_c	1.5	concrete
fy	415	N/mm²	cover	50	mm	γ_s	1.15	steel
Densities - Concrete	24	kN/m³	Soil	18	kN/m³	steel class	A	
Bearing pressure	150	kN/m² (net allowable increase)						

DIMENSIONS mm

BASE		COLUMN	
L =	1550	h =	200
B =	1550	b =	350
depth H =	300		
ex =	0	ey =	0



Plot (to scale)



Key

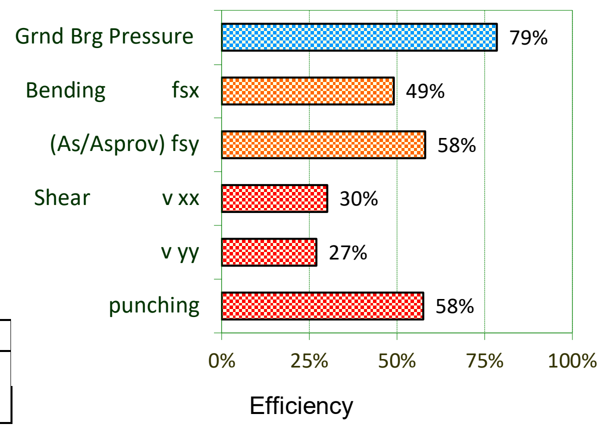
COLUMN REACTIONS kN, kNm *characteristic*

	DEAD	IMPOSED	WIND
Axial (kN)	253.0	26.0	
Mx (kNm)			
My (kNm)			
Hx (kN)			
Hy (kN)			

Overturning FOS = Large

Uplift FOS = infinite

STATUS VALID DESIGN



BEARING PRESSURES kN/m² *characteristic*

CORNER	1	2	3	4
no wind	117.9	117.9	117.9	117.9
with wind	117.9	117.9	117.9	117.9

REINFORCEMENT

Detail to 3.11.3.2

Mxx =	58.2	kNm	Myy =	46.0	kNm
b =	1550	mm	b =	1550	mm
d =	242	mm	d =	226	mm
As =	701	mm²	As =	593	mm²
PROVIDE 6 R16 @ 300 B1			PROVIDE 6 R16 @ 200 & 325 B2		
As prov =	1206	mm²	As prov =	1206	mm²

BEAM SHEAR

Vxx =	111.1	kN at d from col face	Vyy =	97.0	kN at d from col face
v =	0.296	N/mm²	v =	0.277	N/mm²
or Vxx =	49.8	kN at 2d from col face	or Vyy =	40.9	kN at 2d from col face
v =	0.133	N/mm²	v =	0.117	N/mm²
vc =	0.491	N/mm²	vc =	0.511	N/mm²

PUNCHING SHEAR

d ave =	234	mm	u crit =	3908	mm
As prov =	0.333	%	v max =	1.587	N/mm² at col face
v =	0.288	N/mm²	vc =	0.501	N/mm²

Project	MNU FUVAHMULAH CAMPUS Student Accom	The Concrete Centre		
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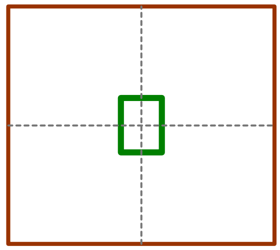
The Concrete Centre
Single column base

MATERIALS

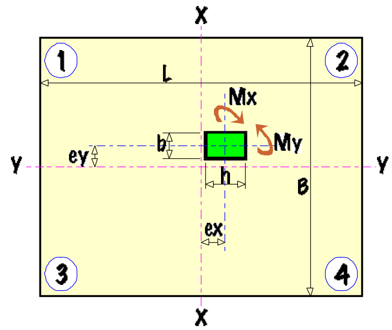
fcu	25	N/mm²	h agg	20	mm	γc	1.5	concrete
fy	415	N/mm²	cover	50	mm	γs	1.15	steel
Densities - Concrete	24	kN/m³	Soil	18	kN/m³	steel class	A	
Bearing pressure	150	kN/m² (net allowable increase)						

DIMENSIONS mm

BASE		COLUMN	
L =	1300	h =	200
B =	1300	b =	300
depth H =	300		
ex =	0	ey =	0



Plot (to scale)



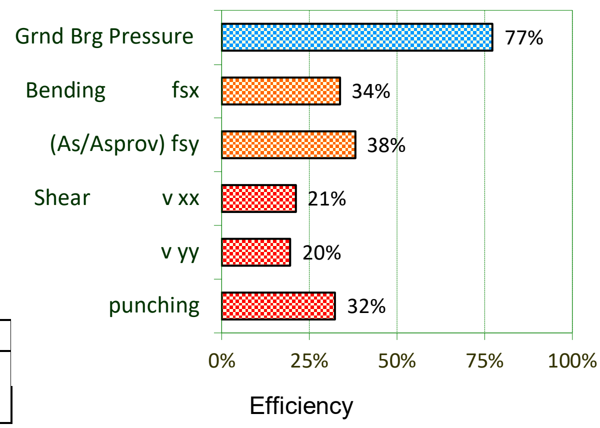
Key

COLUMN REACTIONS kN, kNm *characteristic*

	DEAD	IMPOSED	WIND
Axial (kN)	178.0	15.0	
Mx (kNm)			
My (kNm)			
Hx (kN)			
Hy (kN)			

Overturning FOS = Large
Uplift FOS = infinite

STATUS VALID DESIGN



BEARING PRESSURES kN/m² *characteristic*

CORNER	1	2	3	4
no wind	116.0	116.0	116.0	116.0
with wind	116.0	116.0	116.0	116.0

REINFORCEMENT

Mxx =	31.8	kNm	Myy =	26.3	kNm
b =	1300	mm	b =	1300	mm
d =	242	mm	d =	226	mm
As =	383	mm²	As =	339	mm²
PROVIDE	5 R16 @ 300 B1		PROVIDE	5 R16 @ 300 B2	
As prov =	1005	mm²	As prov =	1005	mm²

BEAM SHEAR

Vxx =	65.1	kN at d from col face	Vyy =	58.8	kN at d from col face
v =	0.207	N/mm²	v =	0.200	N/mm²
or Vxx =	14.7	kN at 2d from col face	or Vyy =	12.6	kN at 2d from col face
v =	0.047	N/mm²	v =	0.043	N/mm²
vc =	0.490	N/mm²	vc =	0.510	N/mm²

PUNCHING SHEAR

d ave =	234	mm	u crit =	3808	mm
As prov =	0.331	%	v max =	1.199	N/mm² at col face
v =	0.162	N/mm²	vc =	0.500	N/mm²