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香港工程師學會

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The HKIE Structural Examination – Written Examination 2021

Section 2: Design Questions

(80% of the Written Examination)

Date: 1 December 2021 (Wednesday)
Time: 12:15 pm – 6:15 pm
(Duration: 6 hours)

Question Paper

Seat number:	

Answer ONE question only

Question 1 Commercial Development

Client's Requirements

The following client's requirements must be met:

1. A private commercial development comprises of a high-rise tower is to be built in an urban site in Hong Kong. See Figure Q1.

2. The high-rise tower has 20 office floors and 3 retail floors which situate at the top part of the tower above two MEP/refuge floors. The tower has a floor plate of 36m by 36m on office and retail levels with a central core of 12m by 12m. The bottom part of the tower has the central service core only.

3. The minimum headroom and fire resistance rating of the proposed mixed-use development are listed as follows:

Floor		**Usage**	**Minimum internal clear headroom (m)**	**Fire Resistance rating (hour)**
12/F – 31/F		Office	3.0	1
9/F – 11/F		Retail	3.5	2
8/F (mezzanine)		MEP/Refuge	3.75	2
7/F	General	MEP/Refuge	8	2
	Directly under mezzanine floor		3.75	
G/F (inside core)		Lobby	4.0	2
G/F (outside core)		Plaza with Landscape	N/A	1
Lower Ground Floor		F&B/MEP/Back of House	4.0	4

4. Restrictions on the location of vertical elements are as follows:

Floor	Usage	Restriction
12/F – 31/F	Office	No internal walls or columns permitted.
9/F –11/F	Retail	No restriction of internal columns.
7/F & 8/F	MEP / Refuge	No restriction of internal columns.
1st /F – 6/F	Circulation	No gravity structure is permitted outside the core.
Lower Ground Floor	F&B / MEP / Back of House areas	Minimum spacing of internal columns is 9m centers.

5. The following finishes/services requirements shall apply:

Usage	Finishes	Building Services Zone (including false ceiling if any)
Roof	350mm thick (waterproofing & leveling screed) & 150mm insulation	N/A
Office	150mm raised floor without any screed	0.6m
Retail	100mm thick (screed & floor tiles)	0.6m
MEP/Refuge	25mm screed	0.3m
Back of house areas	25mm Screed	0.3m
Ground Floor	300mm	NA
F&B	100mm thick (screed & floor tiles)	1.0m

6. Other Restrictions:
   a. Maximum 1m structural zone is allowed below 7/F.
   b. Building Height limit is set at +175.0mPD.
   c. Minimum headroom requirement at 7/F & 8/F is not applicable to the localize areas underneath inclined columns or truss diagonals, if any.
   d. Maximum louvre openings shall be required on the exterior surfaces at 7/F & 8/F.

Imposed Loads

7. The imposed loads shall be in accordance with the latest version of the Code of Practice for Dead and Imposed Loads in Hong Kong.

Wind Loads

8. The wind loads shall be in accordance with the Code of Practice on Wind Effects in Hong Kong 2004 or 2019.

Site Conditions

9. The site is located at a sloping ground with levels ranging from about +4.5mPD at the eastern site boundary to about +19.5mPD at the western site boundary.

10. The site is in proximity to the sea. The copeline of the existing seawall is only 10m away from the eastern boundary of the site. The highest possible groundwater table is about the same as seawater level which is around 1m below the lower ground at +4.5m.

11. Abutting the western boundary of the site is an adjoining existing 15-storey R.C. building on piled foundation.

12. Ground conditions are:

+19.5mPD to +14.0mPD	Boulder rich fill, SPT N-value 10-30 [Category 4(c)][Note 1]
+14.0mPD to +11.0mPD	Dense sand, SPT N-value 30-50 [Category 4(b)][Note 1]
+11.0mPD to +3.0mPD	Completely decomposed granite, SPT N-value > 200 [Category 3] [Note 1]
+3.0mPD to -5.0mPD	Moderately decomposed granite with total core recovery greater than 85% [Category 1(c)] [Note 1]
Below -5.0mPD	Slightly decomposed granite with total core recovery greater than 95% [Category 1(b)] [Note 1]

Note 1: Please refer to Code of Practice for Foundation for geological categories.

Omit from Consideration

13. Design of link bridge and staircases.

14. Detailed element design of the floor structures inside the service core.

Section A

a. Prepare a design appraisal with appropriate sketches indicating **two** distinct and viable solutions for the proposed commercial development including **two** viable foundation schemes. For the two superstructure schemes, indicate clearly the functional framing, load transfer and stability aspects of each scheme to meet all client's requirements. For the two foundation schemes, identify the constraints and prepare typical foundation plans. For both superstructure and foundation schemes, identify the solution you recommend and give reasons for your choice.

(40 marks)

Section B

For the solution recommended in Section A:

b. Prepare a detailed wind load calculation and stability (ULS & SLS) checks for the tower. In calculation of the wind loads, considerations on torsional forces and sheltering effects are not required, if Wind Code 2019 version is adopted.

(5 marks)

c. Prepare sufficient design calculations to establish the form and size of all the principal structural elements including the foundation.

   i. Typical Floor elements including beams and slabs;
   ii. Vertical and lateral stability elements including columns, walls and/or bracings etc;
   iii. Transfer elements, if necessary;
   iv. Foundation.

(20 marks)

d. Prepare framing plans, sections and elevations to show the dimensions, layout and disposition of the structural elements and critical details for estimating purposes.

   i. Typical office layout plan;
   ii. Typical retail layout plan;
   iii. Transfer structure layout plan, if necessary;
   iv. Provision of future connection provision for link bridge.
   v. Sufficient sections and/or elevations as necessary;
   vi. Critical details as necessary.

   (Note: Ground floor layout plan is not required.)

(25 marks)

e. Prepare a detailed method statement covering essential activities for the safe construction of the development including foundation works taking account of the site constraints.

(5 marks)

f. Prepare a detailed construction program covering essential activities from commencement of site activities to completion of superstructure works.

(5 marks)

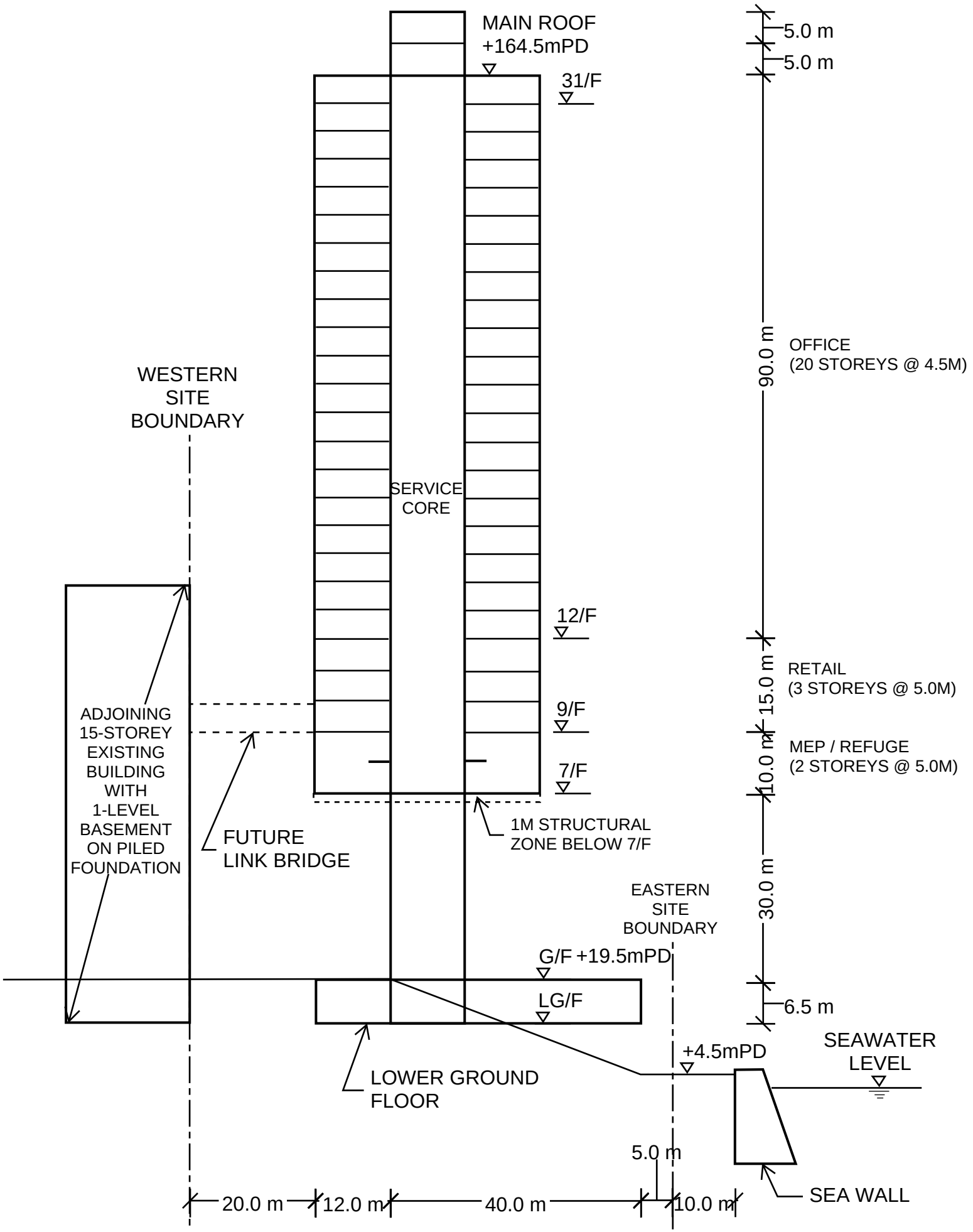
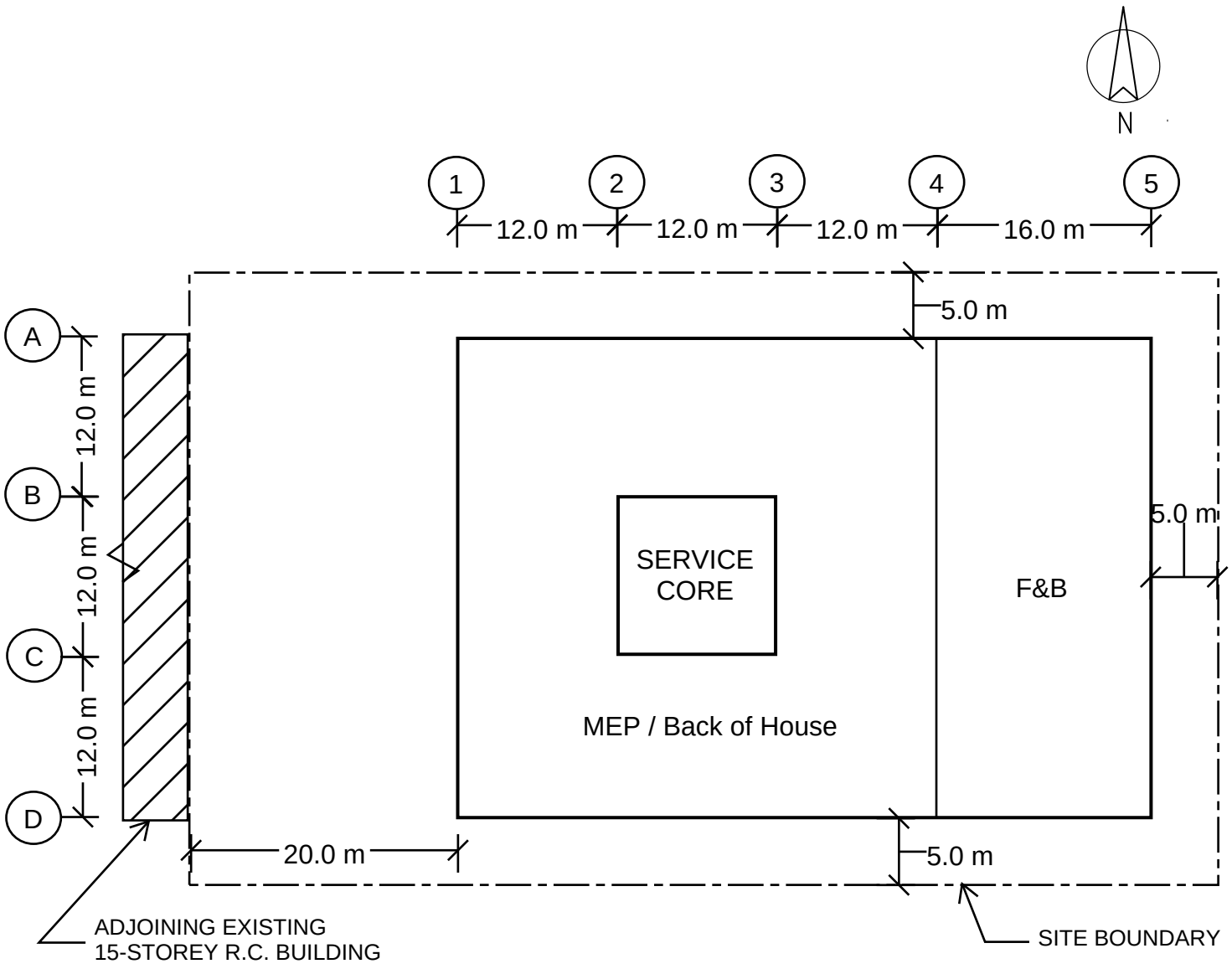
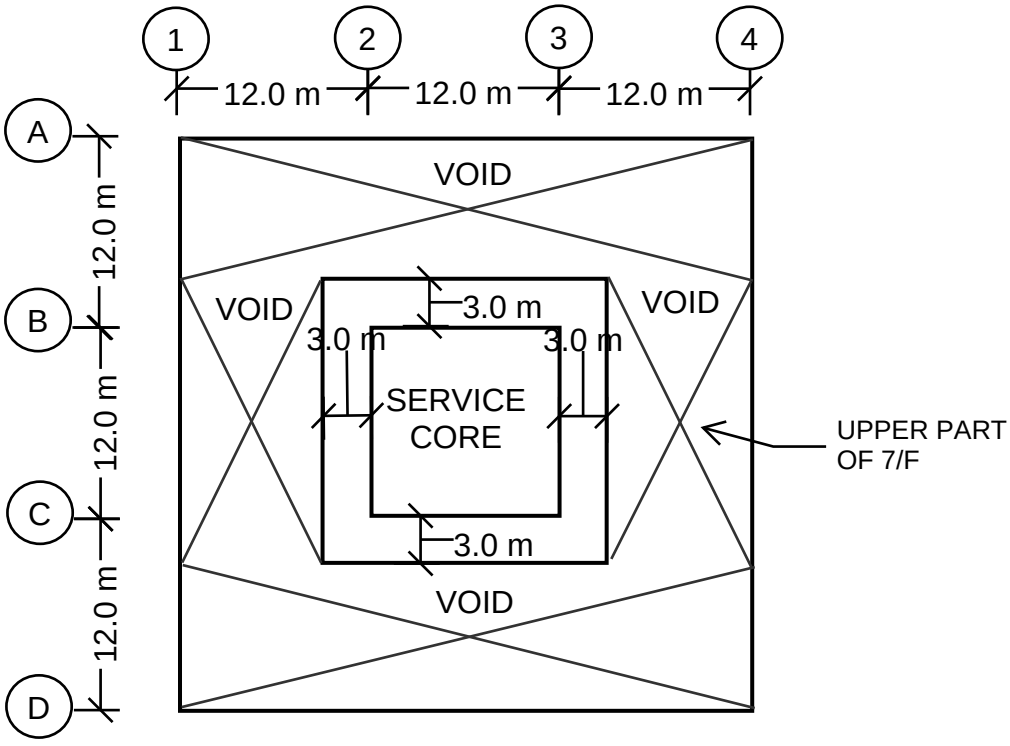

MAIN ROOF
+164.5mPD
31/F
12/F
9/F
7/F
SERVICE
CORE
WESTERN
SITE
BOUNDARY
ADJOINING
15-STOREY
EXISTING
BUILDING
WITH
1-LEVEL
BASEMENT
ON PILED
FOUNDATION
FUTURE
LINK BRIDGE
1M STRUCTURAL
ZONE BELOW 7/F
EASTERN
SITE
BOUNDARY
G/F +19.5mPD
LG/F
LOWER GROUND
FLOOR
+4.5mPD
SEAWATER
LEVEL
SEA WALL
5.0 m
5.0 m
90.0 m
OFFICE
(20 STOREYS @ 4.5M)
15.0 m
RETAIL
(3 STOREYS @ 5.0M)
10.0 m
MEP / REFUGE
(2 STOREYS @ 5.0M)
30.0 m
6.5 m
20.0 m
12.0 m
40.0 m
5.0 m
10.0 m

Figure Q1

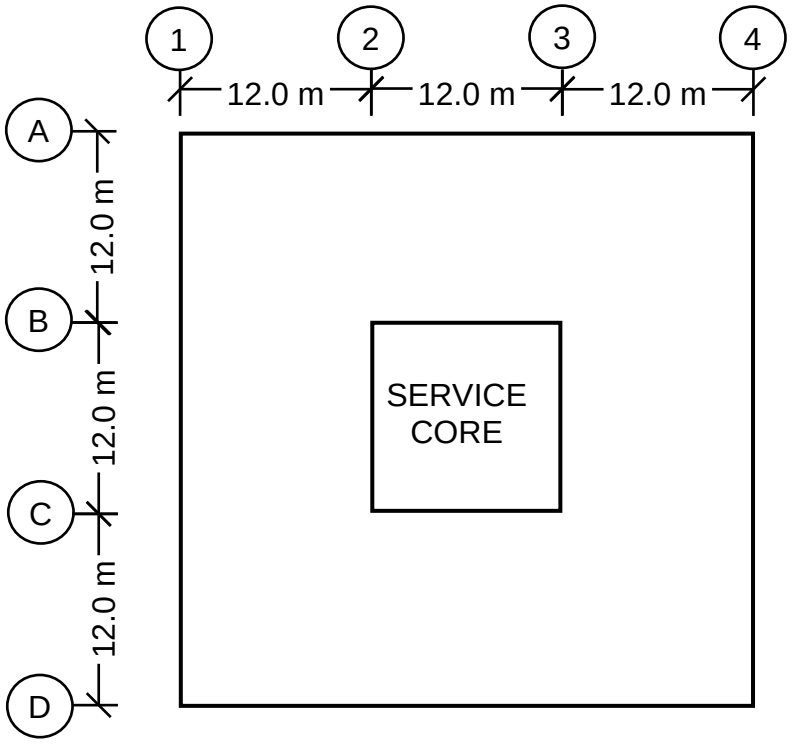


LOWER GROUND FLOOR

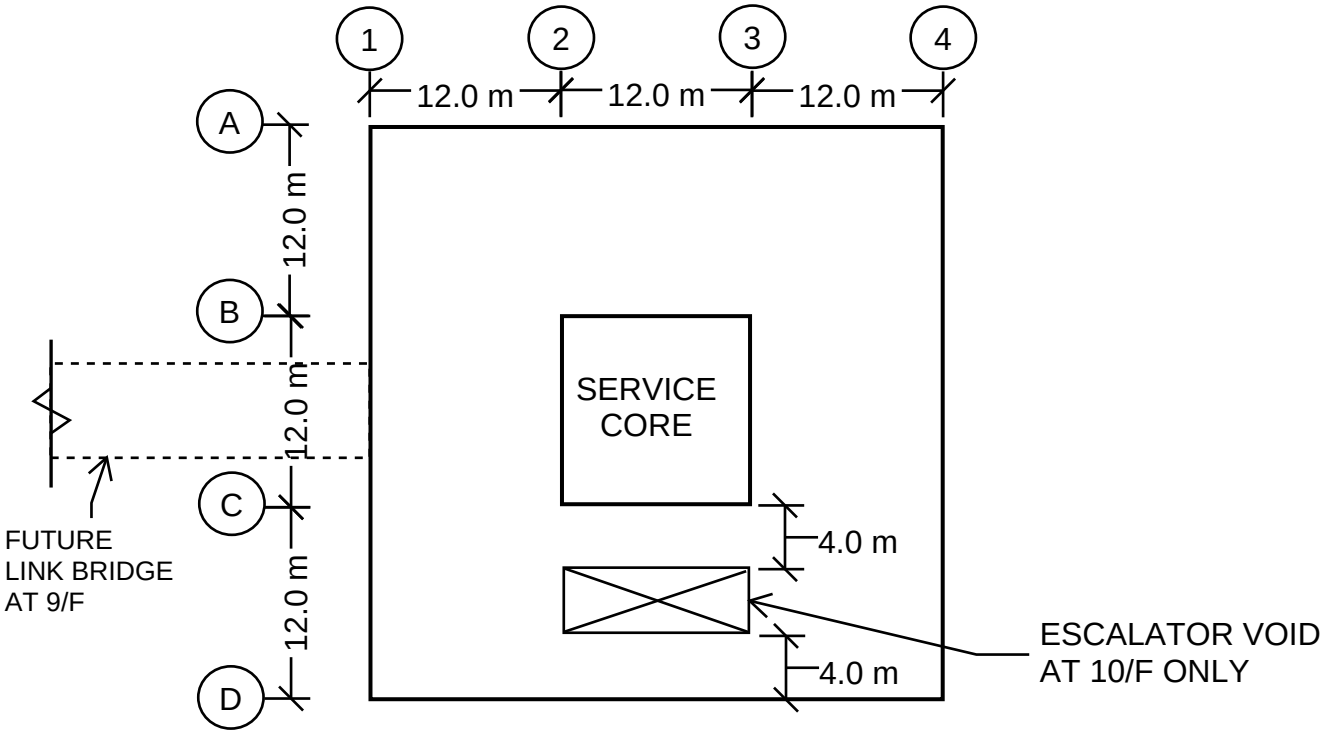


MEP / REFUGE FLOOR (8/F)

Figure Q1

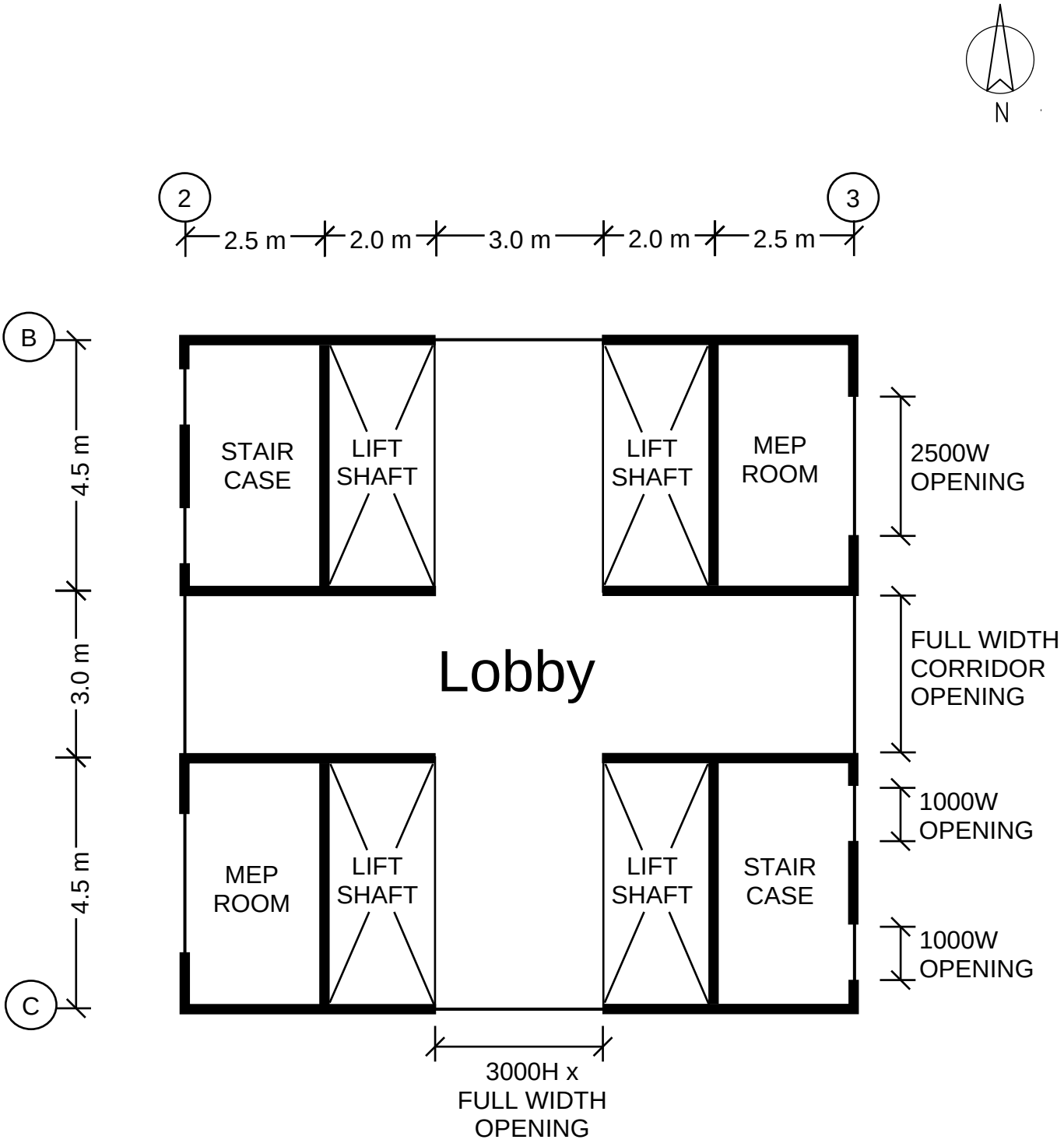


TYPICAL OFFICE FLOOR
(12/F TO 31/F)
(7/F SIMILAR)



TYPICAL RETAIL FLOOR
(9/F TO 11/F)

Figure Q1



TYPICAL SERVICE CORE LAYOUT

NOTES:
(1) ALL OPENINGS SHOULD HAVE A MINIMUM HEIGHT OF 2500mm.
(2) WALL OPENINGS ARE CLOSED AT 2/F TO 6/F.

Figure Q1

Question 2 Sports Center

Client's Requirements

The following client's requirements must be met:

1. A community sports center is to be constructed within the rural area as this is one of the key initiatives to encourage people to exercise healthily and promote the Olympic culture and spirit in Hong Kong sustainably. See Figure Q2.

2. This sports center includes the basement and tower structures. The 2-storey basement includes carpark and training facilities with a maximum area of 63m by 81m. An iconic 6-storey tower includes sports halls, swimming pool, office and restaurant with various dimension at different levels.

3. The building is set back with 2m on three sides and 4m on eastern side at G/F within the site.

4. The main roof structure above tower and flat roof at R/F & 3/F shall not be inverted.

5. For cantilever structure (if any), the maximum cantilever span shall not be greater than 4m from center of support.

6. The proposed use of building with the minimum clear headroom, finishes & E&M services zone and fire resistance rating is listed as follows:

Floor Mark	**Usage**	**Minimum Clear Headroom* (m)**	**Finishes & E&M Services zone (m)**	**Fire Resistance Rating**
4/F – 5/F	Training Center	4.7	0.7	2 hours
3/F	Office Restaurant	4.0	0.5	2 hours
1/F – 2/F	Sports Hall 2 & 3	5.0	0.7	2 hours
G/F	Swimming Pool Sports Hall 1	9.2	1.5	2 hours
B1/F	Lecture room / Library	2.8 5.5	0.7 0.5	4 hours
B2/F	Carpark	2.5	0.5	4 hours

* The minimum clear headroom is the floor height clear of all structures, finishes, and building services.

7. The restrictions on the location of vertical structural elements are as follows:

Floor Mark	Area	Restrictions
4/F – 5/F	Training Center	• Minimum spacing of internal columns/walls is 9m centers.
3/F	Office Restaurant	• Minimum spacing of internal columns/walls is 9m centers at office area. • No restriction of internal columns inside the restaurant area.
1/F – 2/F	Sports Hall 2 & 3	• No internal columns at 9m within the periphery as measured at ceiling levels • Minimum spacing of internal columns/walls is 9m centers. • No internal column inside the void.
G/F	Swimming Pool Sports Hall 1	• No column/wall inside the swimming pool and basketball court, column free area. • No column/wall inside the driveway. • No restriction of column spacing in other area.
B1/F – B2/F	Lecture room Library Carpark	• No column/wall inside the driveway. • Minimum spacing of internal columns is 7.5m centers.

**No restriction on spacing between the internal columns and service core at all levels, if any and reasonable.*

8. The void with 20m X 12m at 2/F is to provide at least 10m full height for rhythmic gymnastics training at sports hall 2.

Imposed Loads

9. The imposed loads shall be in accordance with the latest version of the Code of Practice for Dead and Imposed Loads in Hong Kong, unless stated below.

10. Imposed load of 5kPa should be allowed for the library (without library stack rooms) at B1/F.

11. Imposed load of 5kPa should be allowed for sports hall and training area.

12. Superimposed dead load of 10kPa should be allowed for the Sky Garden at 3/F.

Wind Loads

13. The wind loads shall be in accordance with the Code of Practice on Wind Effects in Hong Kong 2004 or 2019.

Site Conditions

14. The site is located at Fanling with flat ground level at +15.0mPD.

15. At the eastern side of the site, there is a 5m wide drainage reserve zone underneath which there is an existing culvert, see section A-A.

16. The site is not on newly reclaimed land.

17. Ground conditions are:

From +15mPD – +7mPD	Loose Fill, SPT average N-value < 10 [Category 4(d)][Note 1]
From +7mPD – -1mPD	Medium dense sand, SPT average N-value = 50 [Category 4(c)][Note 1]
From -1mPD – -25mPD	Completely decomposed granite, SPT N-value > 200 [Category 3][Note 1]
Below -25mPD	Moderately decomposed granite with total core recovery greater than 85% [Category 1(c) rock][Note 1]

Note 1 : Categories of soil/rock refer to Table 2.1 Code of Practice for Foundation 2017

18. The design highest groundwater level is at +15.0mPD.

Omit from Consideration

19. Design for staircases, cladding, window systems, façade, and protective barrier.

20. Detailed layout and design of the non-structural elements inside the service core.

21. Detailed layout and design of the carpark ramp, swimming pool, and the associated sports halls facilities.

Section A

a. Prepare a design appraisal with appropriate sketches indicating **Two** distinct and viable solutions for the proposed sports center including **Two** viable foundation schemes. For the two superstructural schemes, indicate clearly the functional framing, load transfer and stability aspects of each scheme to meet all client's requirements. For the two foundation schemes, identify the constraints and prepare the typical foundation layout plans. For both superstructure and foundation, identify the solution you recommend and give reasons for your choice.

(40 marks)

Section B

For the solution recommended in Section A:

b. Prepare detailed load calculations and stability checking for the proposed sports center.

(8 marks)

c. Prepare sufficient design calculations to establish the form and size of all the principal structural elements for superstructure for G/F, 1/F, 2/F, 3/F, & 5/F, including transfer (if any) and critical structures.

(14 marks)

d. Prepare dimensional framing plans for G/F, 1/F, 2/F, 3/F, & 5/F, to show the layout and disposition of the structural elements including transfer (if any) and critical structures.

(24 marks)

e. Prepare the structural details for the principal structural elements at B2/F and 3/F including transfer (if any) and critical structures for estimating purposes.

(10 marks)

f. Prepare a detailed construction program covering essential activities from commencement of foundation to completion of structural works.

(4 marks)

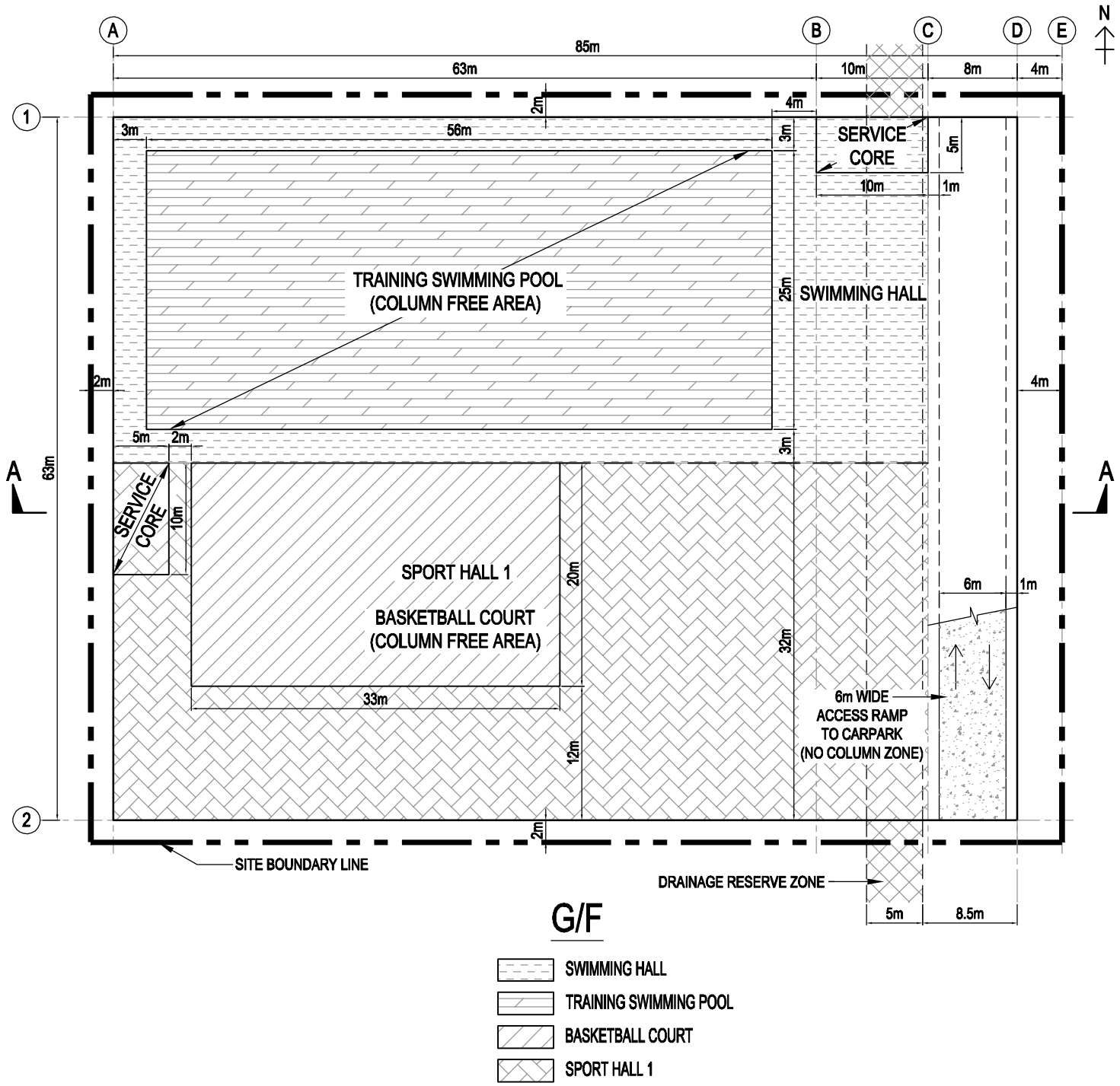
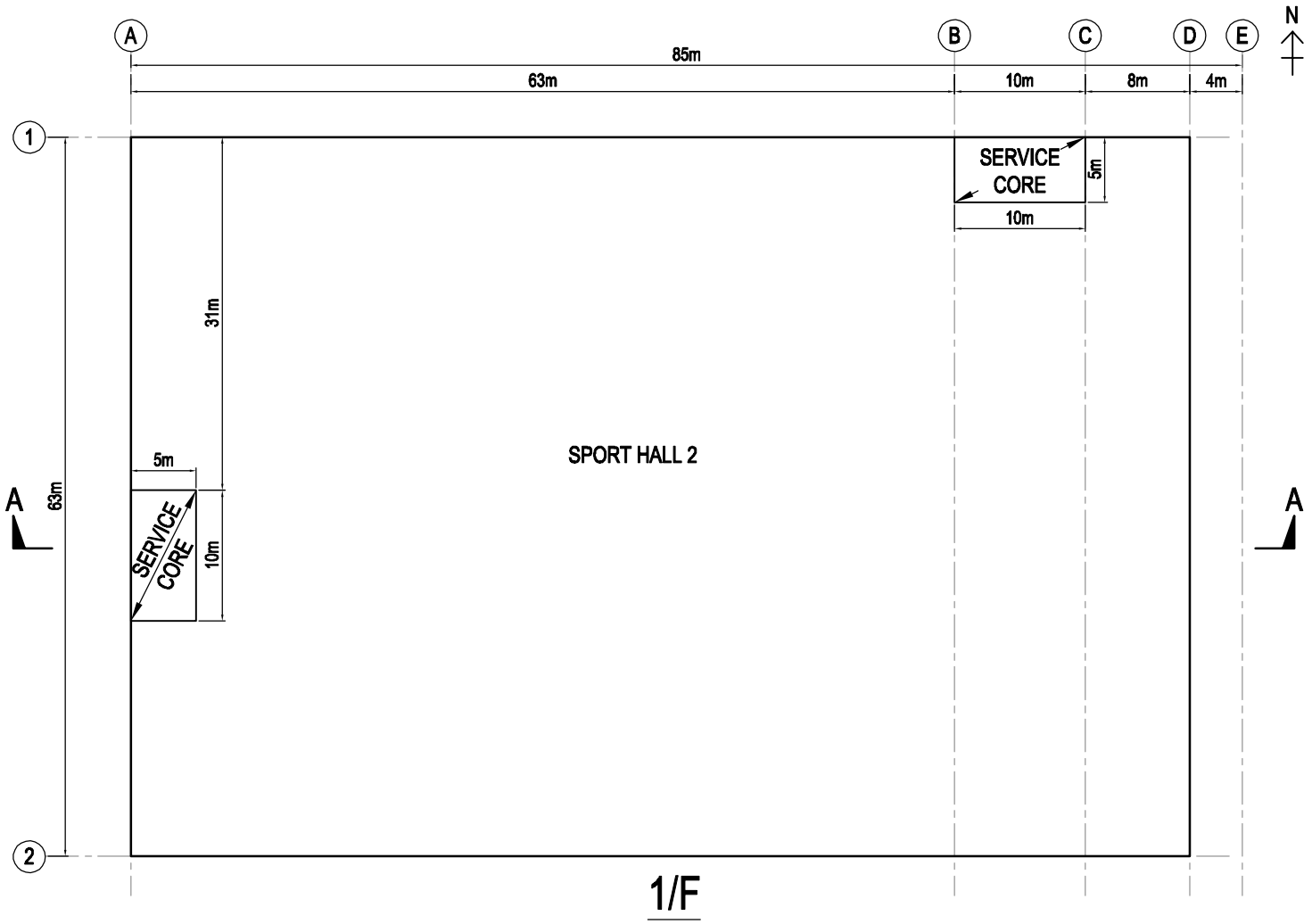
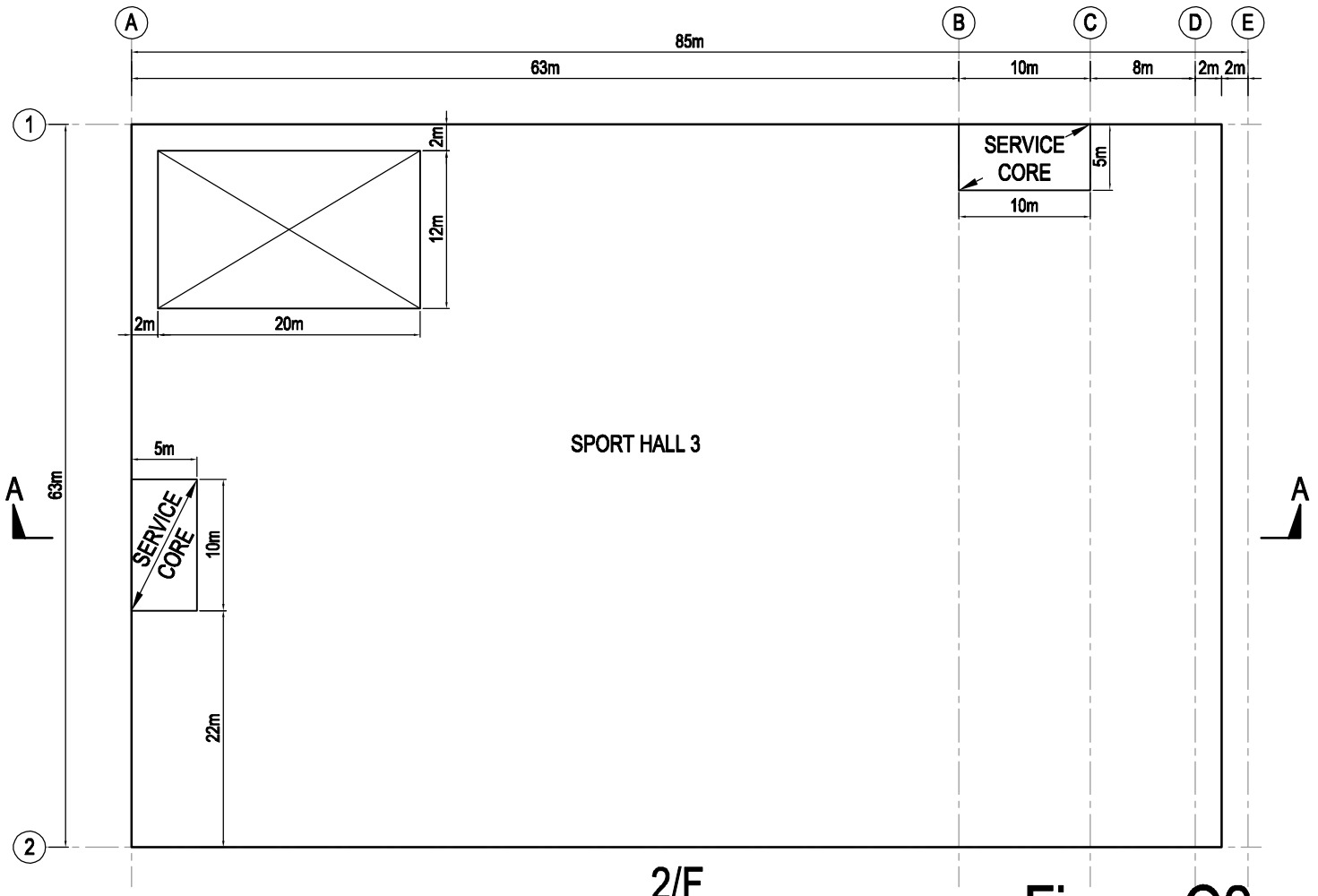

A
B
C
D
E
N
85m
63m
10m
8m
4m
1
2
2m
4m
3m
56m
SERVICE CORE
5m
10m
1m
TRAINING SWIMMING POOL
(COLUMN FREE AREA)
25m
SWIMMING HALL
2m
4m
5m
2m
3m
63m
A
A
SERVICE CORE
10m
SPORT HALL 1
BASKETBALL COURT
(COLUMN FREE AREA)
20m
6m
1m
32m
33m
6m WIDE
ACCESS RAMP
TO CARPARK
(NO COLUMN ZONE)
12m
2m
SITE BOUNDARY LINE
DRAINAGE RESERVE ZONE
5m
8.5m
G/F
SWIMMING HALL
TRAINING SWIMMING POOL
BASKETBALL COURT
SPORT HALL 1

Figure Q2

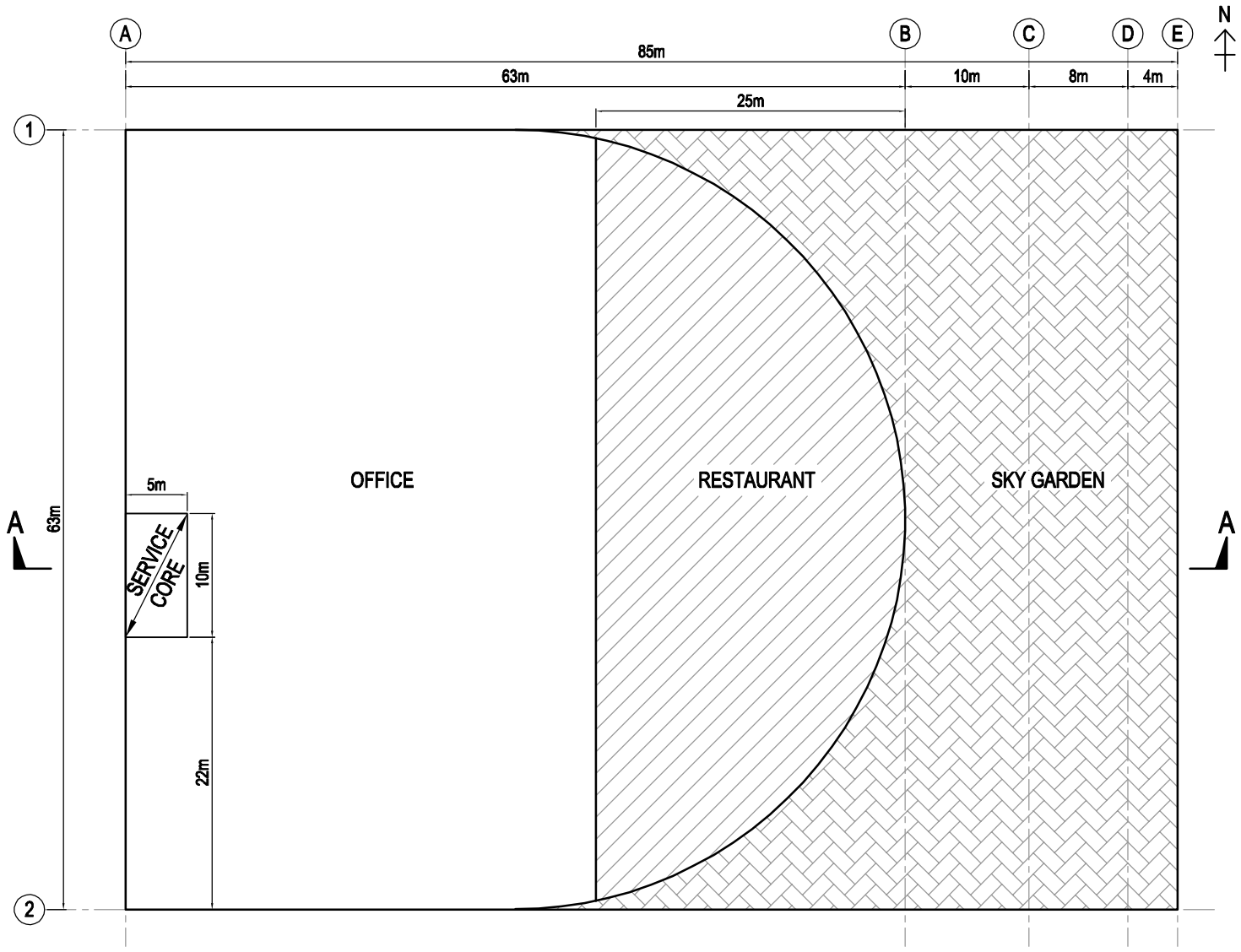


1/F



2/F

Figure Q2



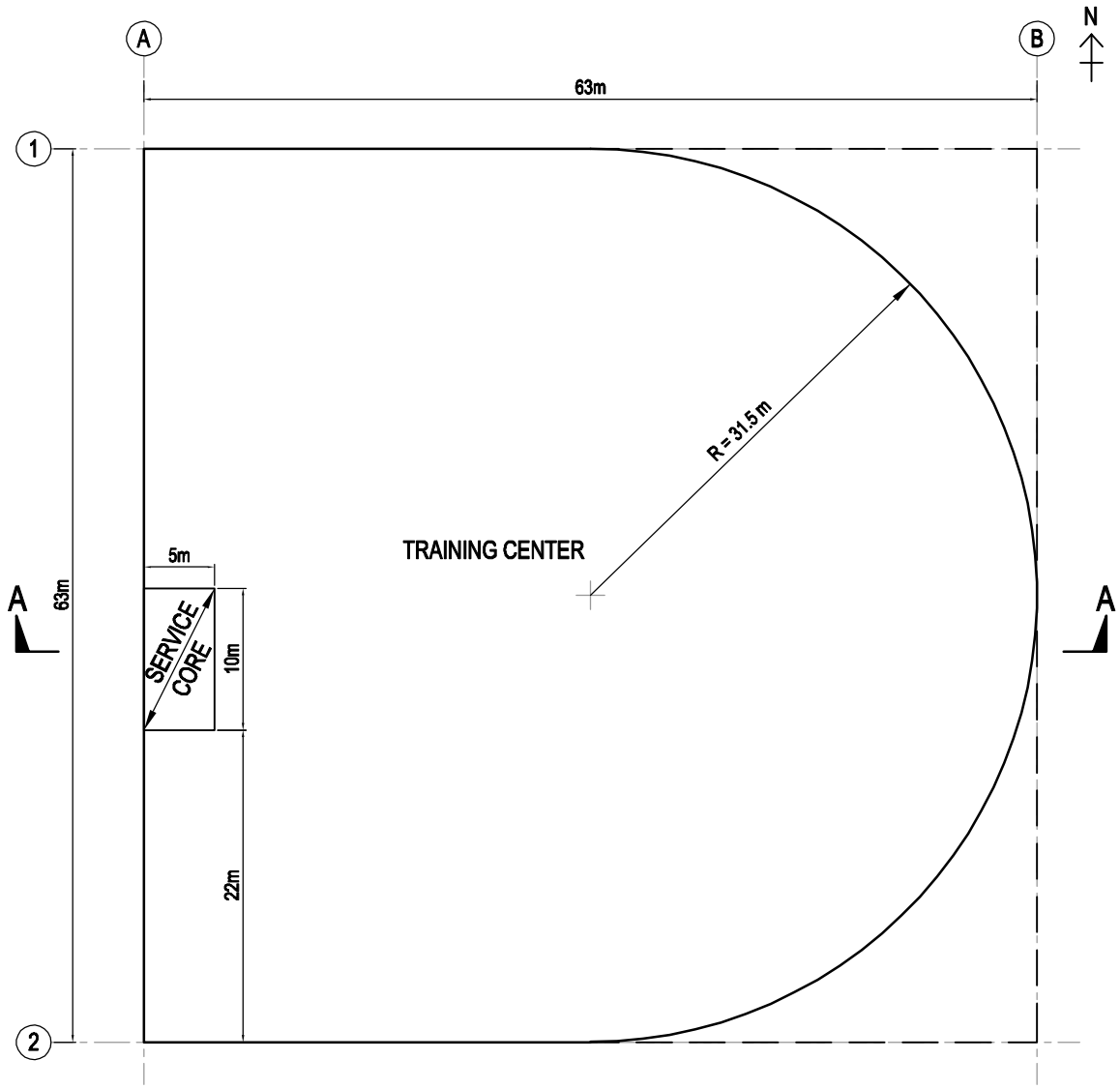
3/F

OFFICE

RESTAURANT

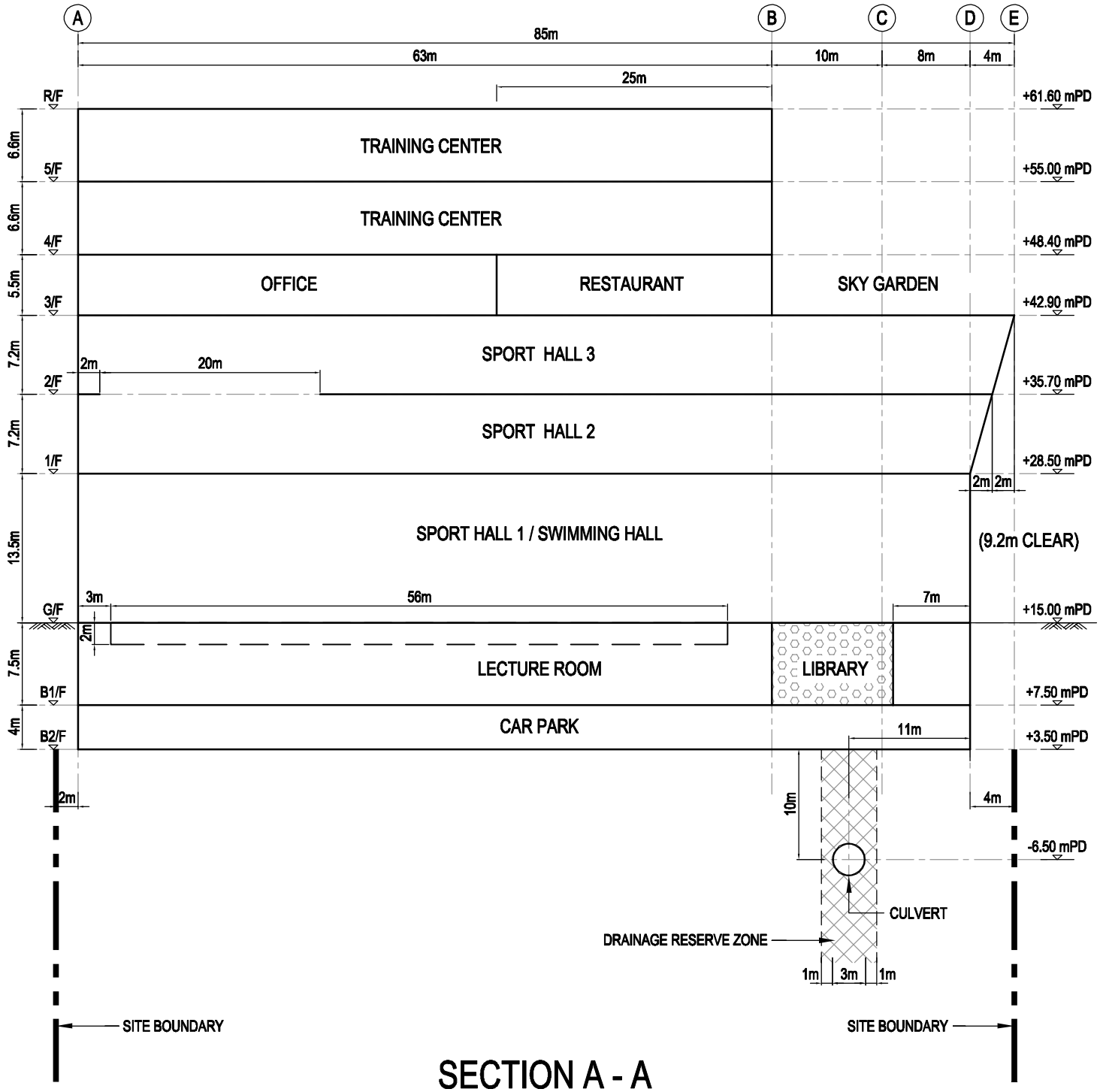
SKYGARDEN

Figure Q2



4/F - 5/F

Figure Q2



SECTION A - A

Figure Q2

Question 3 Art Gallery

Client's Requirements

The following client's requirements must be met:

1. A new art gallery with large span glass roof over an atrium is proposed to be constructed near the seaside.

2. The footprint of the art gallery is 140m by 140m. An atrium of plan dimensions of 60m by 60m is located at the centre of the building covered by a glass roof. The glass roof should have a plan dimensions not exceeding 72m by 72m and with maximum height of 6m (entirely for structures of the glass roof) above the R/F. The layout of the building is shown in Figure Q3.

3. All structures including foundations/pile caps should be within the footprint of the art gallery. No structures are allowed within the atrium from G/F to R/F.

4. The ground level is at +5mPD. Except the columns or cables supporting the glass roof, no structures of the building should be above +53mPD (i.e. 48m above ground level). Although the columns or cables supporting the glass roof are allowed to be extended above +53mPD, the numbers and extent of the protruding structures should be kept as minimal and neat in order to deliver an aesthetic appearance of the building. There is no height restriction during construction of the building.

5. The G/F area of the atrium serves as garden area, while other area on G/F of the building serves as exhibition hall (refer to Section A-A). The exhibition hall on G/F should be supported by suspended floor, i.e. on-grade floor is NOT allowed. The supporting structure for the garden area on G/F may be on-grade or suspended.

6. Building services zone of 500mm depth should be allowed for each floor. To maintain adequate headroom for exhibition, the minimum clear headroom of G/F, 1/F, 2/F and 3/F are 10m, 8m, 8m and 8m respectively. The height of each floor is shown in Section A-A in Figure Q3. No building services zone is required in the glass roof and its supporting structure.

7. The external walls of the building are curtain wall. To maintain the transparency of the building, all columns should be located with minimum clearance of 3m from the external surface of the curtain wall.

8. No structural walls is allowed except the staircase and lift cores near the four corners of the building.

9. Except the floor slabs, walls and foundations, all structural elements of the building should be constructed of steel and glass materials.

10. The minimum centre-to-centre column spacing on each floor is 15m.

11. The top of the foundations/pile caps should be at least 2m below the ground surface to give enough room for utility services to pass into the site. No bulk excavation apart from pile caps and ground beams is permitted.

12. A minimum 2-hour fire resistance rating is required for all elements of construction for the art gallery, except the glass roof.

Imposed Loads

13.

UR/F and R/F	3 kN/m2 (including lifting of display items)
1/F, 2/F and 3/F	5 kPa
G/F	5kPa (exhibition area / garden area)

Wind Loads

14. The site is located by the sea. The structure shall be checked against wind loads in accordance with the Code of Practice on Wind Effects in Hong Kong 2004 or 2019.

Site Conditions

15. Ground conditions as revealed by the ground investigation boreholes are:

From existing ground level to 2m	Loose Fill, SPT N-value range from 5 to 10 [Category 4(d) soil][Note 1]
2m to 10m	Medium dense sand with SPT N-values range from 11 to 30 [Category 4(c) soil][Note 1]
10m to 40m	Dense to very dense completely decomposed granite with SPT N-values 50-200 [Category 4(b) to Category 4(a) soil][Note 1]
Below 40m	Slightly to moderately decomposed (grade III or better) moderately strong granite with total core recovery greater than 85% [Category 1(c) rock][Note 1]

Note 1: Categories of soil/rock refer to Table 2.1 of Code of Practice for Foundations 2017

16. Groundwater table is found at 1m below the existing ground level.

Omit from Consideration

17. Design of curtain walls and glass panel of glass roof.

18. Design of lift shafts and stair wells.

19. Design of significant resonant dynamic effect.

Section A

a. Prepare a design appraisal with appropriate sketches and calculations indicating **two distinct and viable solutions** for the proposed art gallery structure. Indicate clearly the functional framing, load transfer and stability aspects of each scheme to meet all client's requirements. Identify the solution you recommend and give reasons for your choice.

(35 marks)

b. Identify the site constraints and propose **one viable scheme for the foundation**. Prepare typical foundation layout plan.

(5 marks)

Section B

For the solution recommended in Section A:

c. Prepare sufficient design calculations to establish the form and size of all the principal structural elements, including the foundation.

(20 marks)

d. Prepare framing plans, sections and elevations to show the dimensions, layout and disposition of the structural elements and critical details including foundation for estimating purposes.

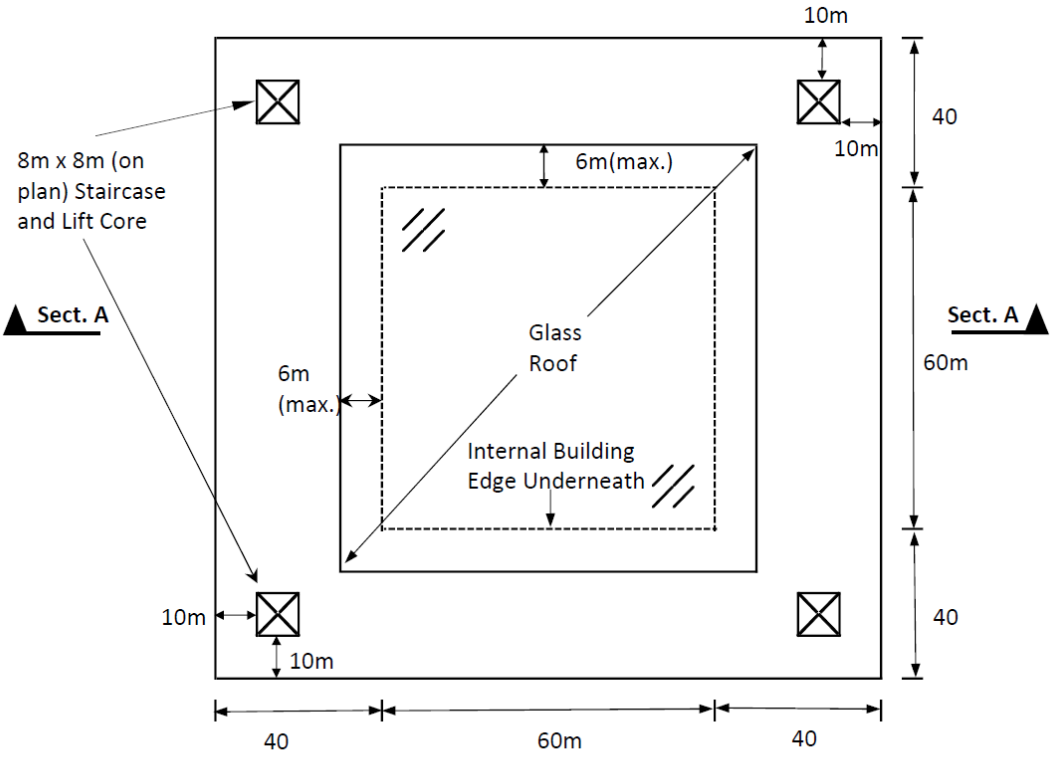
(20 marks)

e. Prepare a detailed method statement covering essential activities for the safe construction of the structure including foundation works and erection of roof.

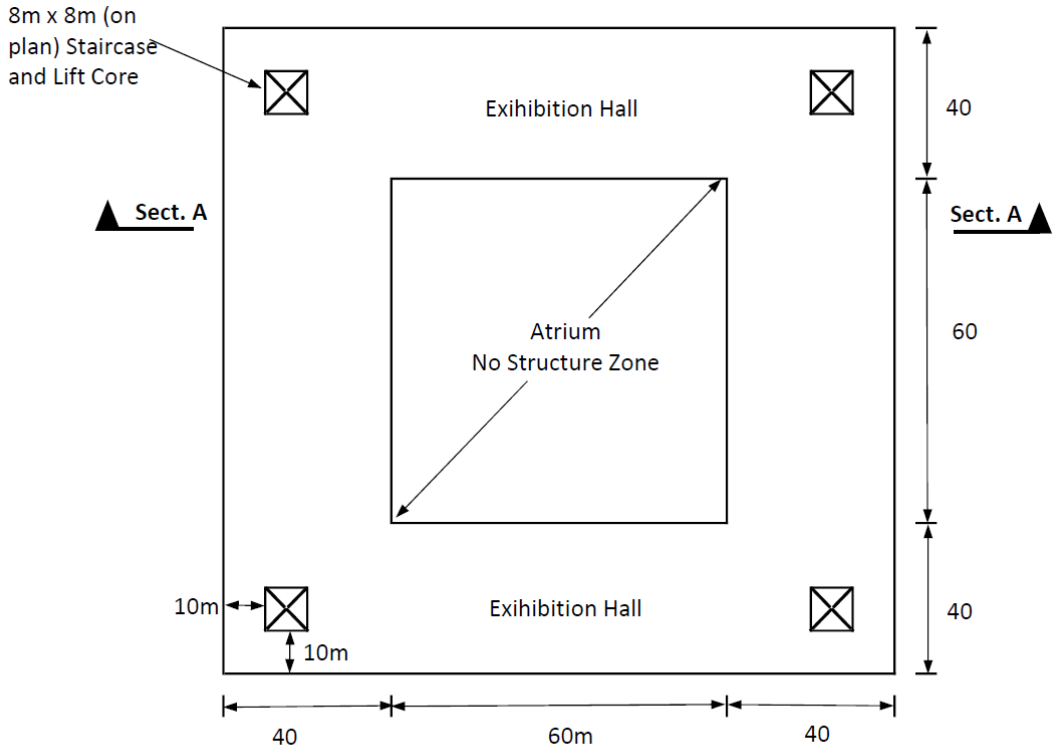
(10 marks)

f. Prepare a detailed construction program covering essential activities from commencement of foundation to completion of structural works.

(10 marks)



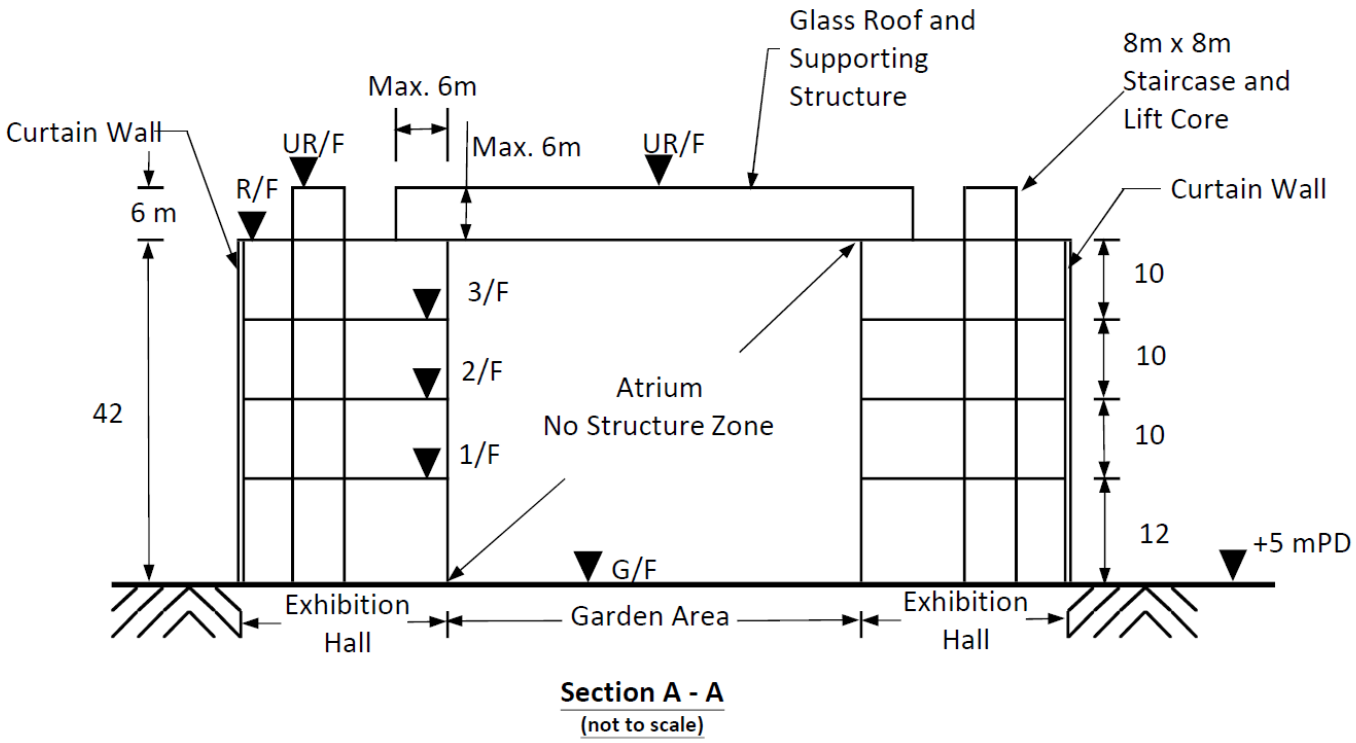
R/F and UR/F Plan (not to scale)



1/F, 2/F and 3/F Plan (not to scale)

PLAN VIEWS

Figure Q3



Section A-A (not to scale)

Figure Q3

Question 4 Footbridge

Client's Requirements

The following client's requirements must be met:

1. A new footbridge is proposed to cross a major highway to provide access to an existing commercial building. See Figure Q4.

2. The footbridge is to cross the highway at an angle of 15 degrees. At the east end of the bridge a ramp is required to descend to ground. Provision is to be made for a future extension of the bridge further to the east.

3. No loading is allowed to transfer from the footbridge to the commercial building and an expansion joint is required at the interface. Column supports to the footbridge are permitted only within the highway amenity area and at the central divider. No columns are permitted under the east end of the bridge.

4. Maximum permitted gradient of the ramp is 1:12. Horizontal landings are required in the ramp at vertical intervals of not more than 3.5m and the length of each landing must not be less than 2m. The footbridge is to be fully enclosed for air-conditioning with a clear width of 6m and 4m for the ramp and a 1m high railing on both sides with an overall height of 3.5m.

5. The minimum requirements on clear headroom and horizontal clearance for the highway zone to edge of structures as follows:

Location	**Min. Clear Headroom (m)**	**Min. Horizontal Clearance (m)**
Existing Highway	5.1	0.8

6. Closure of only one lane of highway for construction is allowed each night between mid-night and 6.00am.

Design Requirements

7. The structural design shall be in accordance with the latest version of the Structures Design Manual for Highways and Railways published by the Highways Department of the HKSAR Government.

Imposed Loads

8. The loading from the enclosure on the footbridge to be 6 kN/m each side.

Wind Loads

9. The wind loads shall be in accordance with the requirements in the latest version of the Structures Design Manual for Highways and Railways.

Site Conditions

10. The site is located at open area with Degree 3 of exposure to wind.

11. Ground conditions as revealed by the ground investigation boreholes are:

From 0m to 3m	Loose Fill, SPT N-value = 0 – 10 [Category 4(d)] Note 1
From 3m to 15m	Medium dense soil, SPT N-value = 10 – 40 [Category 4(c)] Note 1
From 15m to 25m	Very dense soil, SPT N-value >50 [Category 4(d)] Note 1
25m and below	Moderately decomposed granite with total core recovery >85% [Category 1(c)] Note 1
Groundwater is encountered at 4.0m below ground level.	

Note 1: Categories of soil/rock refer to Table 2.1 of Code of Practice for Foundation 2017.

Omit from Consideration

12. Design calculations for enclosure, railing and the ramp for footbridge.

Section A

a. Prepare a design appraisal with appropriate sketches indicating **Two** distinct and viable solutions for the spans of the proposed footbridge including **Two** viable foundation schemes. For the footbridge, indicate clearly the functional framing, load transfer and stability/live load vibration aspects of each scheme to meet all client's requirements. For the foundation schemes, identify the site constraints and prepare typical foundation layout plans. For both schemes, identify the solution you recommend and give reasons for your choice.

(40 marks)

Section B

For the solution recommended in Section A:

b. Explain how the structure will resist wind load including detailed description of the wind loads and design assumptions. Prepare detailed wind load calculations for the proposed footbridge.

(10 marks)

c. Prepare sufficient design calculations to establish the form and size of all the principal structural elements including the foundation.

(18 marks)

d. Prepare framing plans, sections and elevations to show the dimensions, layout and disposition of the structural elements and critical details for cost estimating purposes.

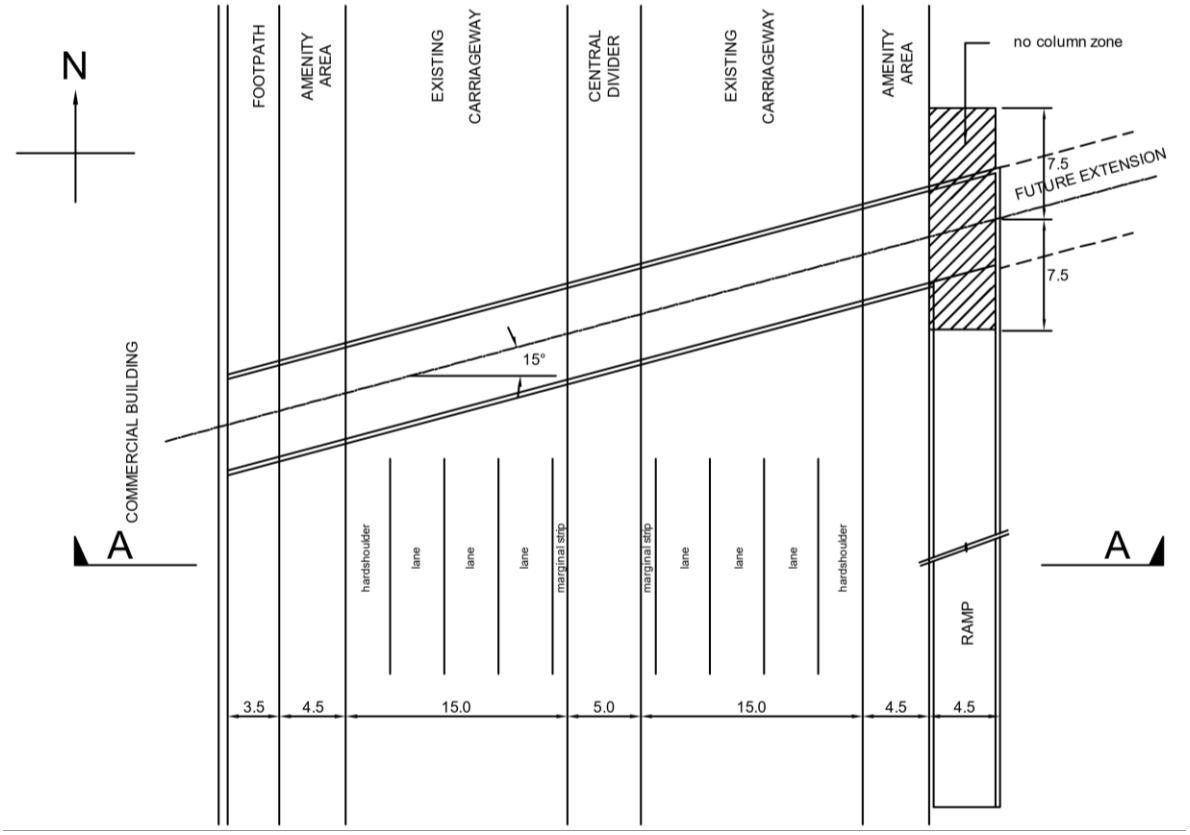
(18 marks)

e. Prepare a detailed method statement covering essential activities for the safe construction of the footbridge and ramps including foundation works.

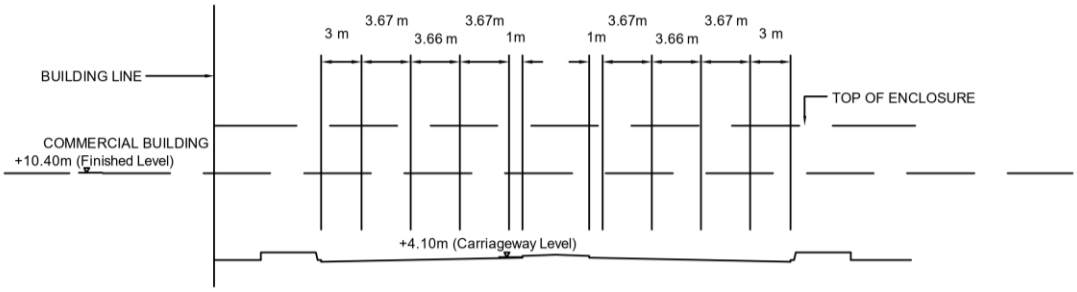
(8 marks)

f. Prepare a detailed construction program covering essential activities from commencement of foundation to completion of structural works.

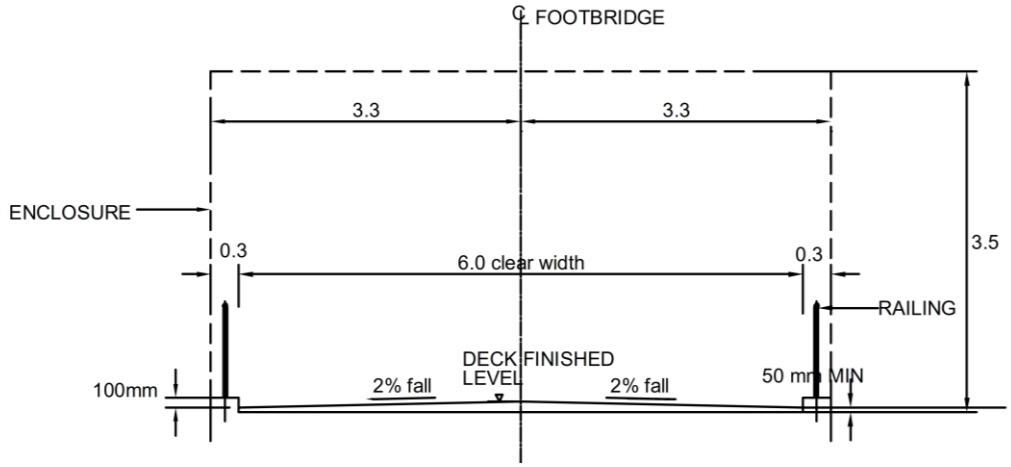
(6 marks)



PLAN



SECTION A-A



TYPICAL FOOTBRIDGE CROSS SECTION

NOTE: All dimensions are in metres

Figure Q4