PRISON BREAK

Drama Oriented Narrative Design: Theatre project in Naumburg city.

Design Strategy

1. HISTORY & MEMORY
The most identical characteristic of the site is that those buildings were prison before. The complex has witnessed many renovations and extensions over the past 100 years.
- continunity of narrative
- exhibition topic

2. MULTI-TASK
Naumburg is a small German city where our potential visitors, audiences and users are limited.
- different size of auditorium is necessary for different needs

3. EDUCATION
Due to the fact that the percentage of popularity of theater is decreasing among young generations, our primary task is exploring its educational ability by:
- revealing unseen part to the public
- proposing experimental stage design for contemporary art

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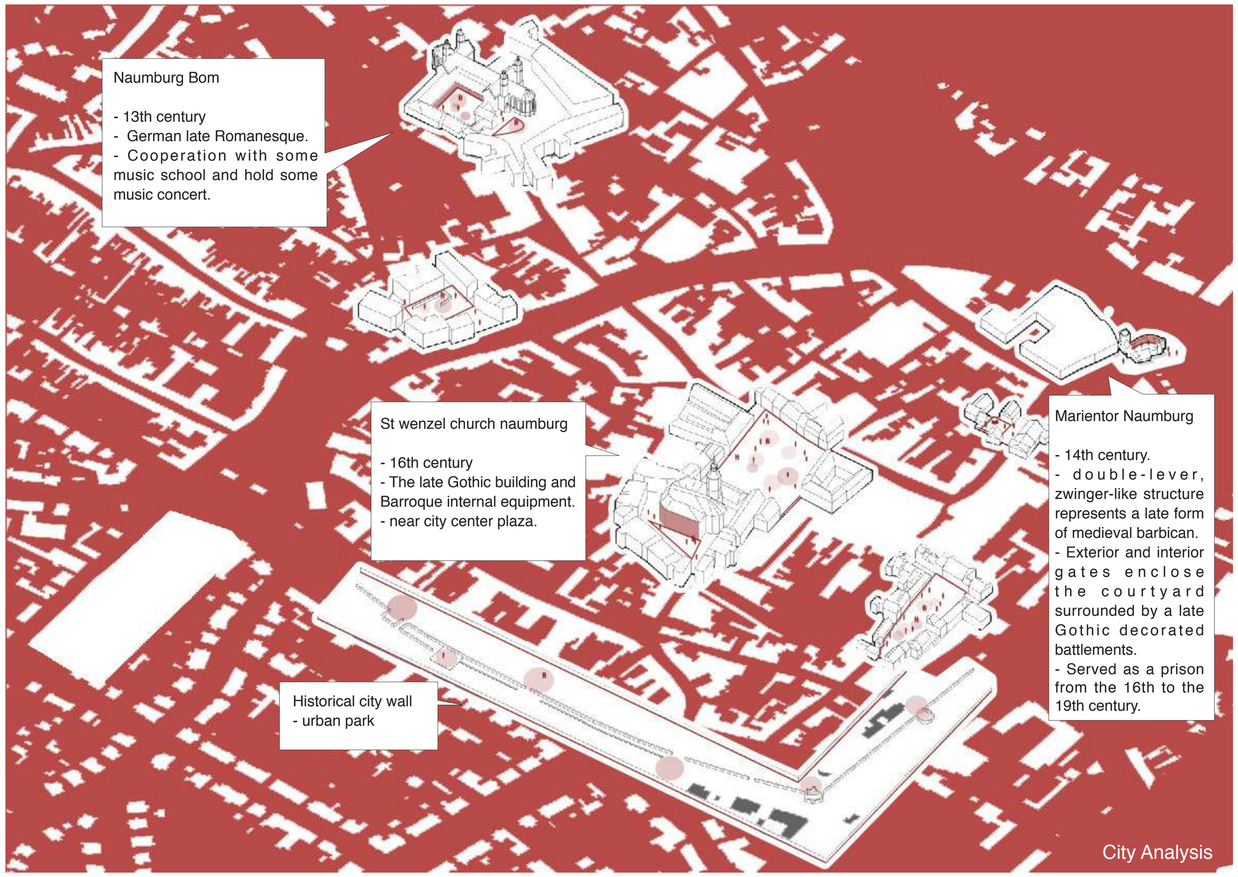
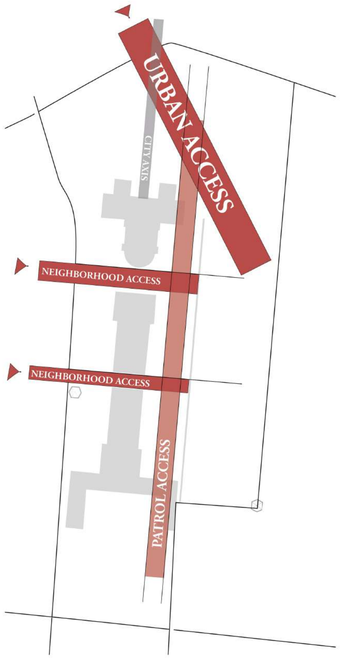
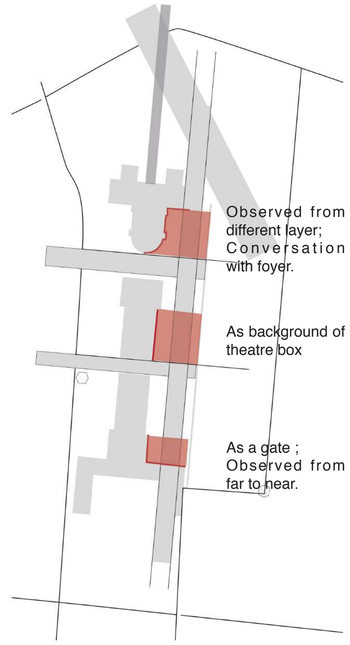


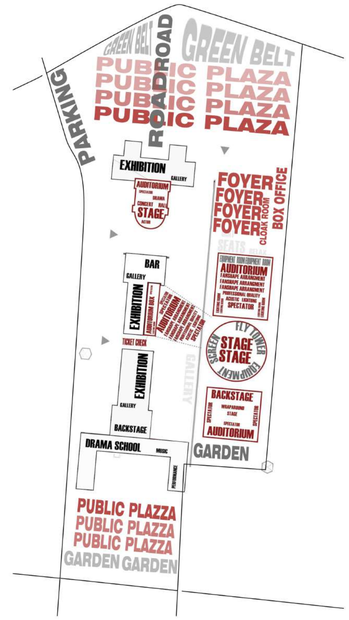
City Analysis



Access On The Site

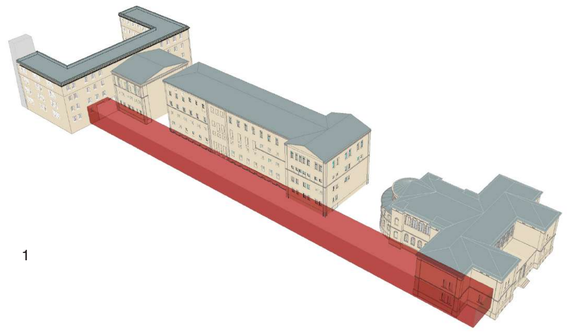


Interaction of Existing Facade



Concept Function Diagram

Design Process



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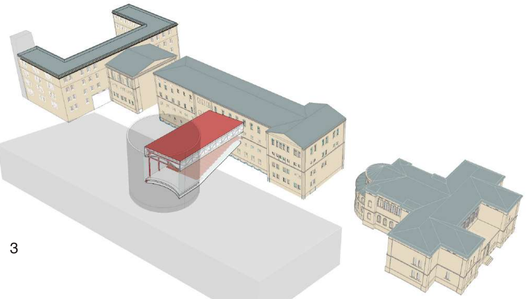

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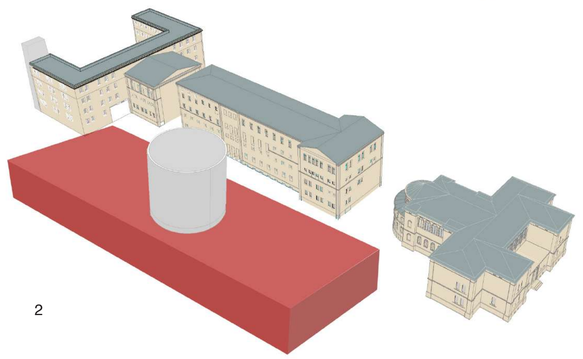

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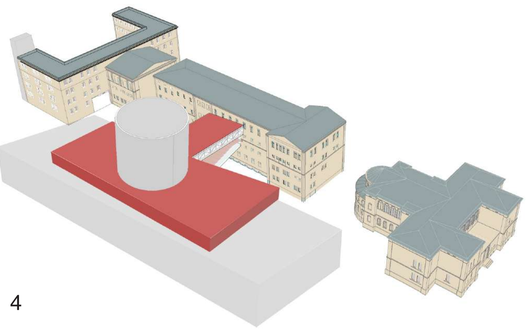


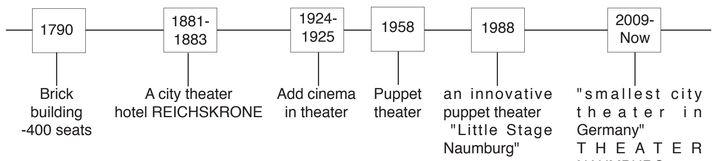
4

1. Define the in between space
- route between history and modern
- limitation and boundary of design

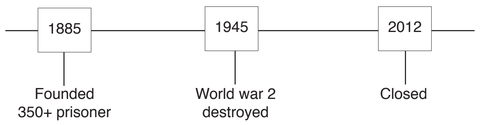
2. Define shape of theater
- Circular flytower : rotatable machine inside

3. Create a new connection
- Second small auditorium between existing building and theater
- Share one flytower

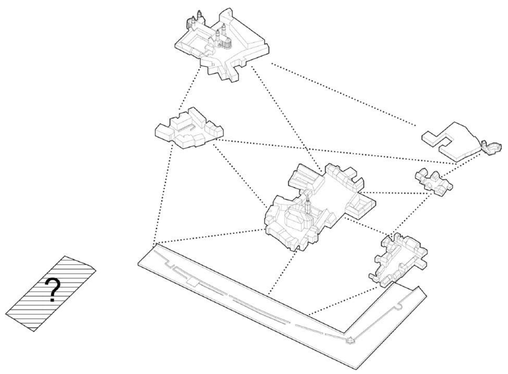
4. Flytower system
- Two auditorium and backstage, workshop controled by one flytower
- Ground level creates lighting atmosphere to respect environment



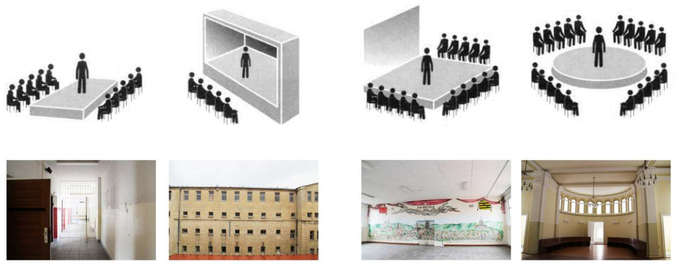
History of Naumburg Theater



History of Naumburg Prison



Study of Stage



Alley Stage | Proscenium Stage | Thrust Stage | Arena Stage

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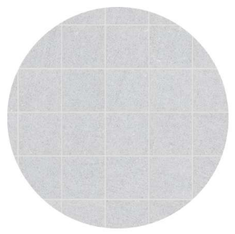
Existing brick
- collected from the demolition of the existing building



Modern grey brick

Grass
- the rain water collect system

Tree with existing brick set

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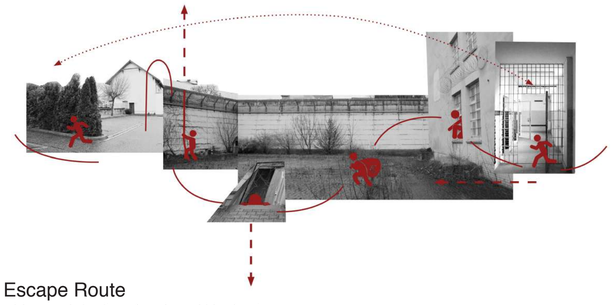
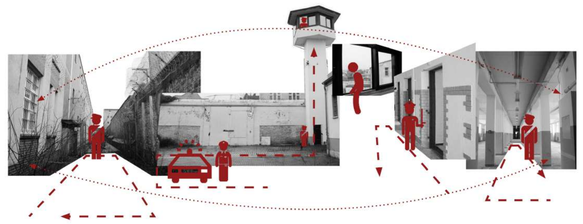


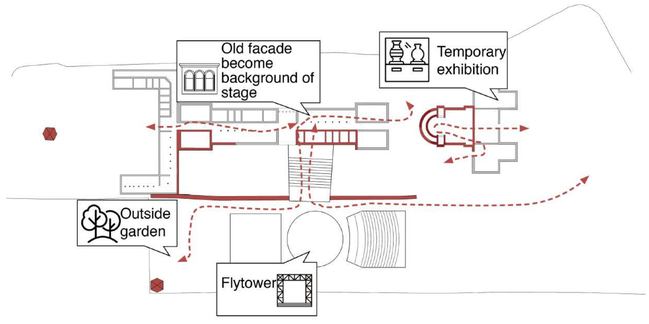
Escape Route

- A long and circuitous (up, down, hide...)route
- Strong feeling and interaction with space itself
- Exploration of space availability

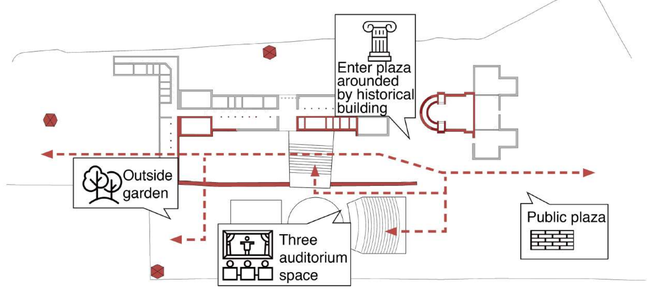


Patrol Route

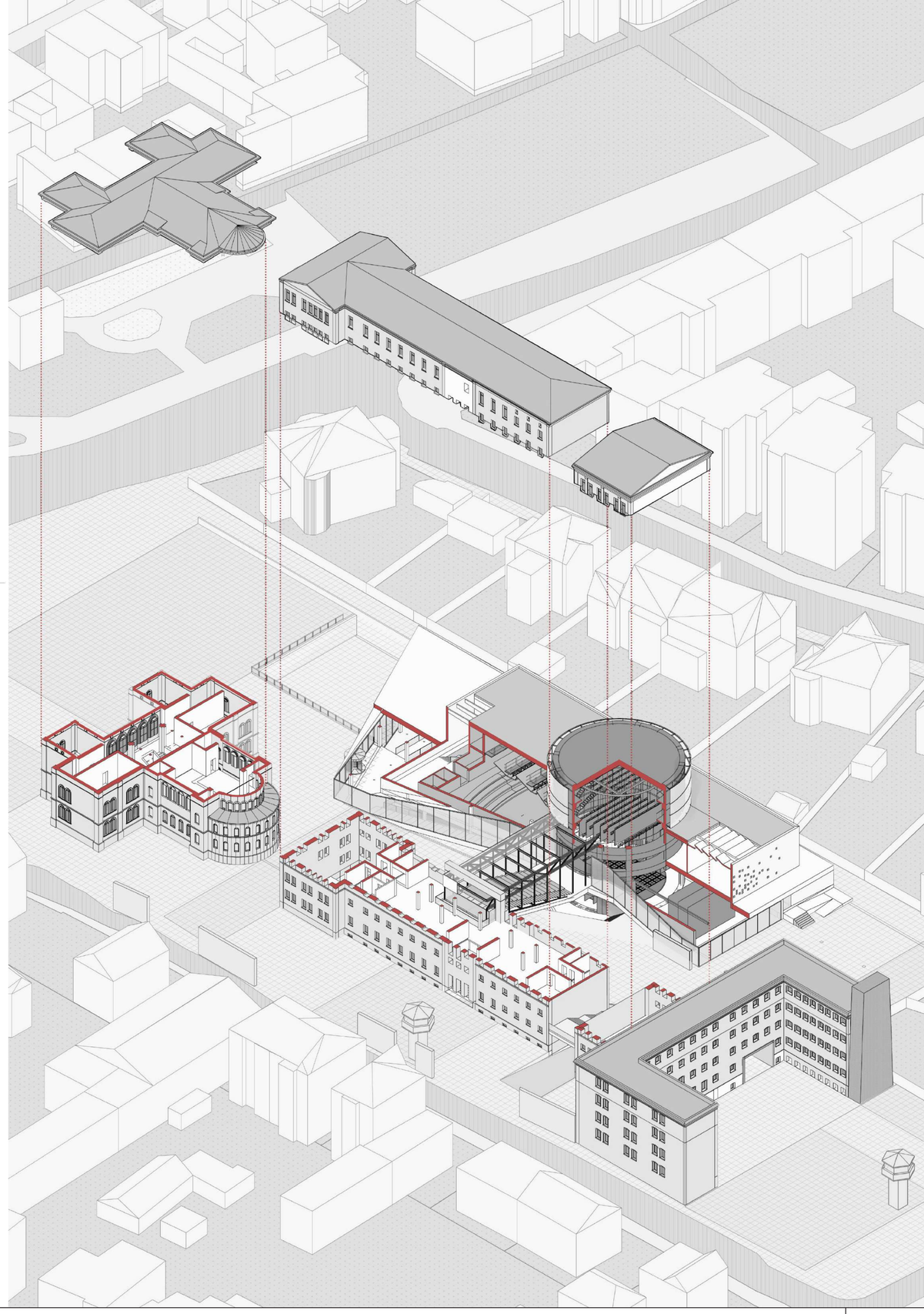
- A recurrent and circular route
- Strong perception of surrounding activities
- Experience of a specific section



Museum Route



Theatre Route



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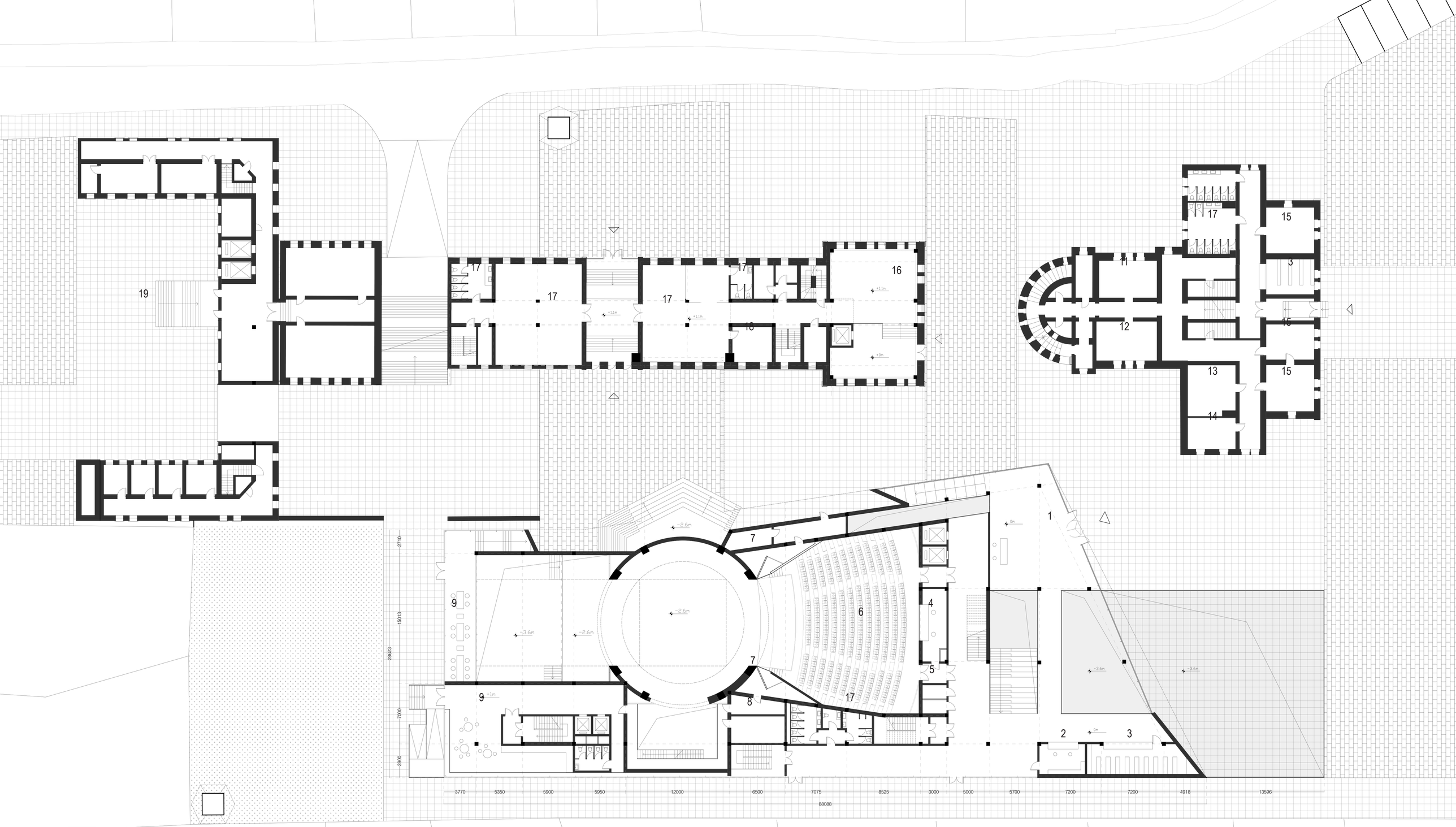

Ground floor plan scale 1:200

1. entrance lobby
2. ticket office
3. cloakroom
4. technical room
5. space for pipe
6. auditorium
7. ear chamber
8. storage
9. lounge
10. workshop for visitor
11. director office
12.procurement manager's office
13. dramatic advisor
14. copy room
15. office
16. exhibition hall
17. toilet

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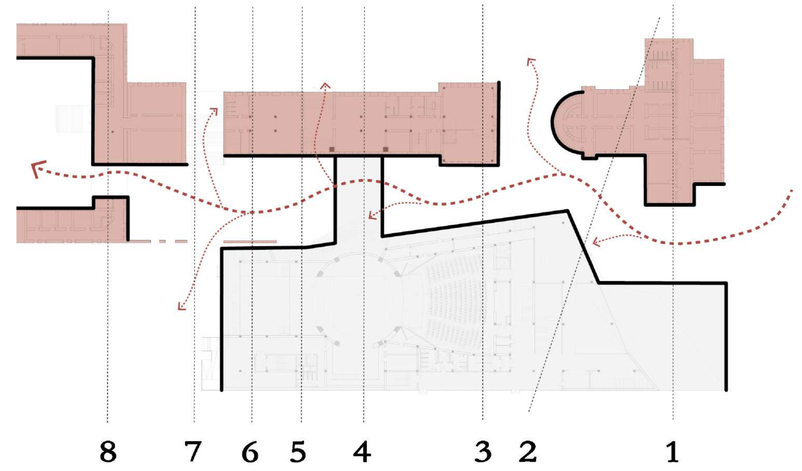
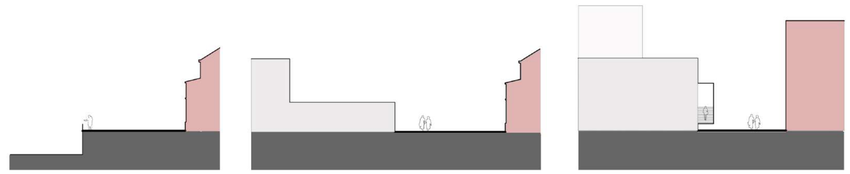
05

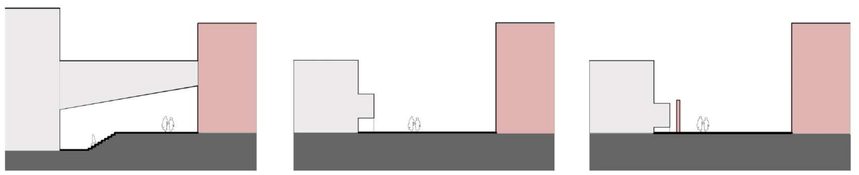




1
Courtyard
with
Circuit court

2
Foyer
with
Circuit court

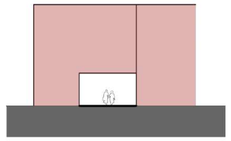
3
Long stairs
with
Museum (Prison)



4
Sunken theatre
Secondary auditorium
Museum (Prison)

5
Corridor
with
Museum (Prison)

6
Historical wall
with
Museum (Prison)



7
Watch tower
Garden
Museum stair entrance

8
End gate
with
Drama school

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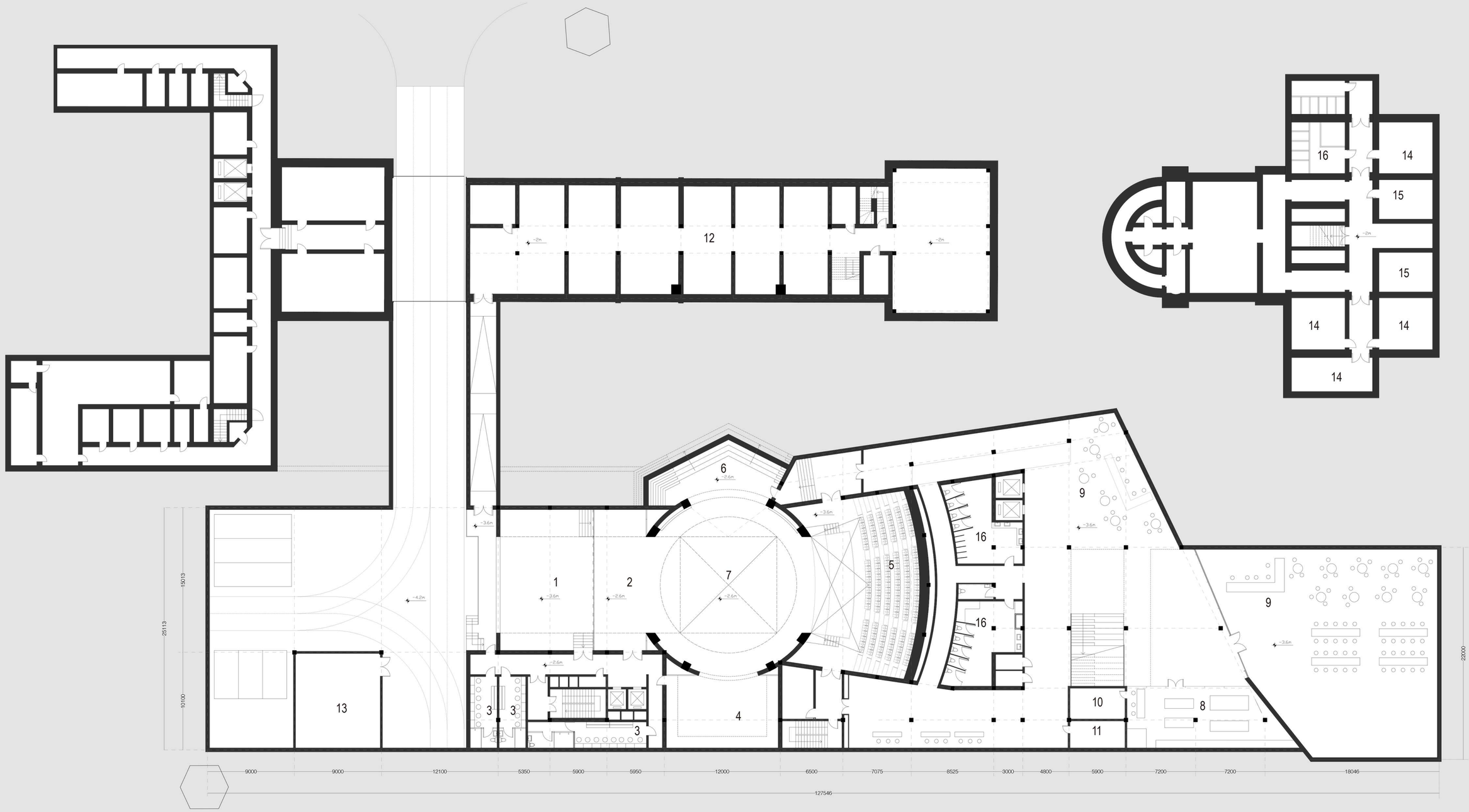

1. workshop for sets
2. backstage
3. dressing room
4.stage wings
5. auditorium
6. terrace
7. stage
8. gift shop
9. cafe
10. storage for shop
11. foyer storage
12. storage(multiple)
13. storage:furniture
14. office(general use)
15. locker's room
16. toilet

-1 floor plan scale 1:200

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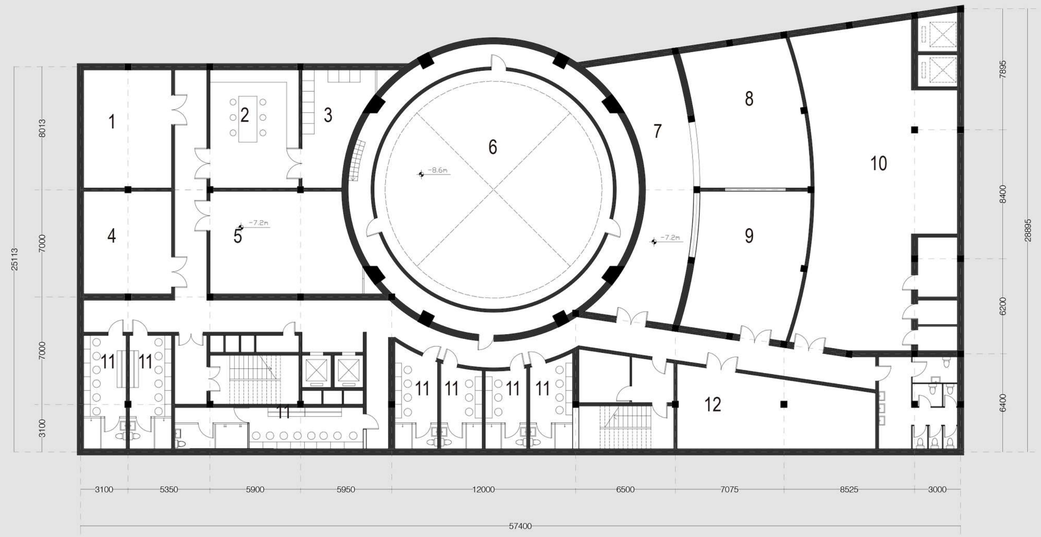

1. material storage
2. tailor shop
3. wash room
4.light/electric dimmer room
5. puppet collection
6. sub-stage
7.orchestra pit
8. musical instrument storage
9. recording room
10. technical room
11. dressing room
12. band room
13.toilet

-2 floor plan scale 1:200

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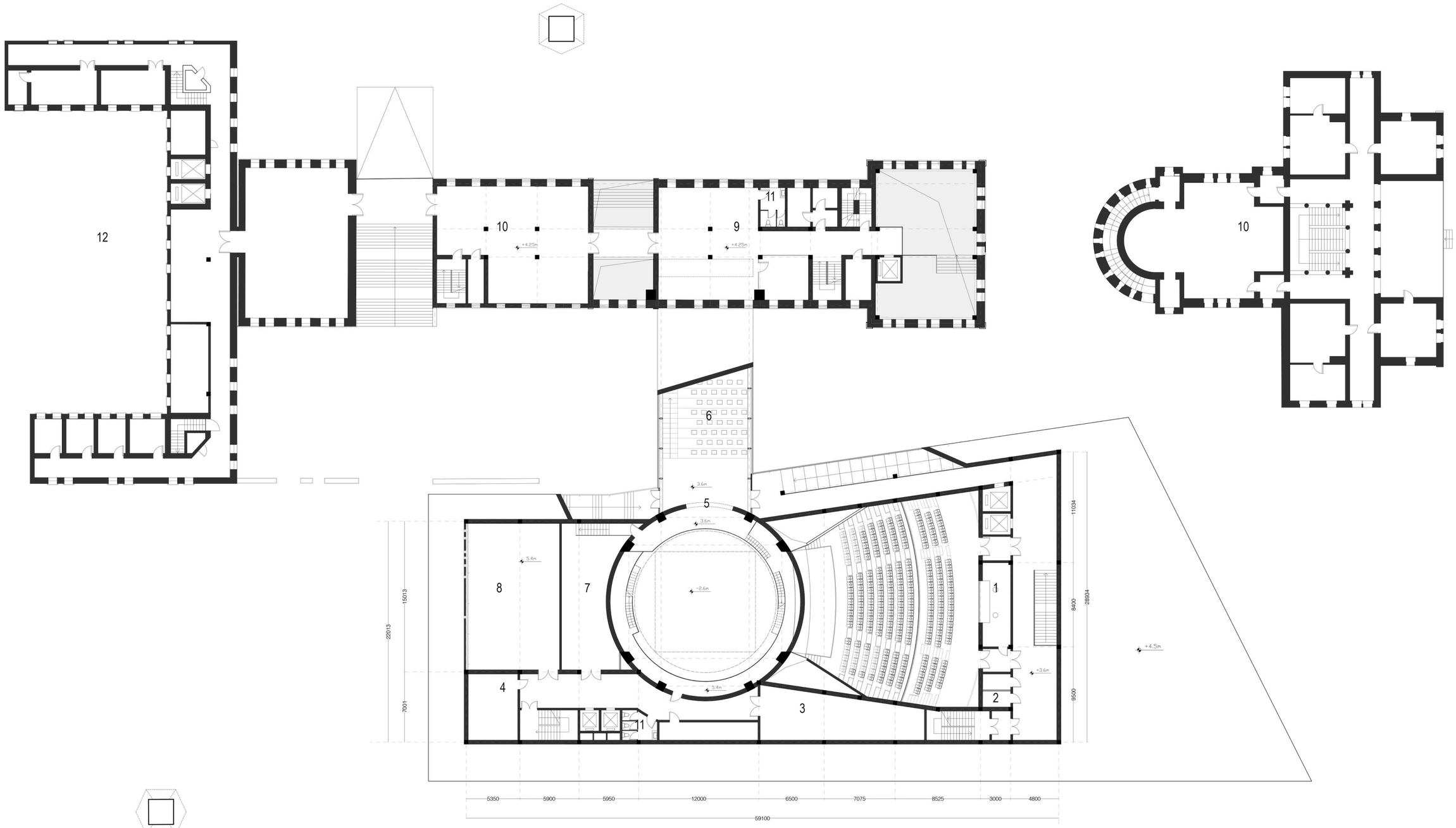

1. technical room
2. space for pipe
3. lighting equipment
4. lounge
5. stage for second auditorium
6. second auditorium
7. backstage for second auditorium
9. exhibition
10. resturant
11. toilet
12. drama school

First floor plan scale 1:200

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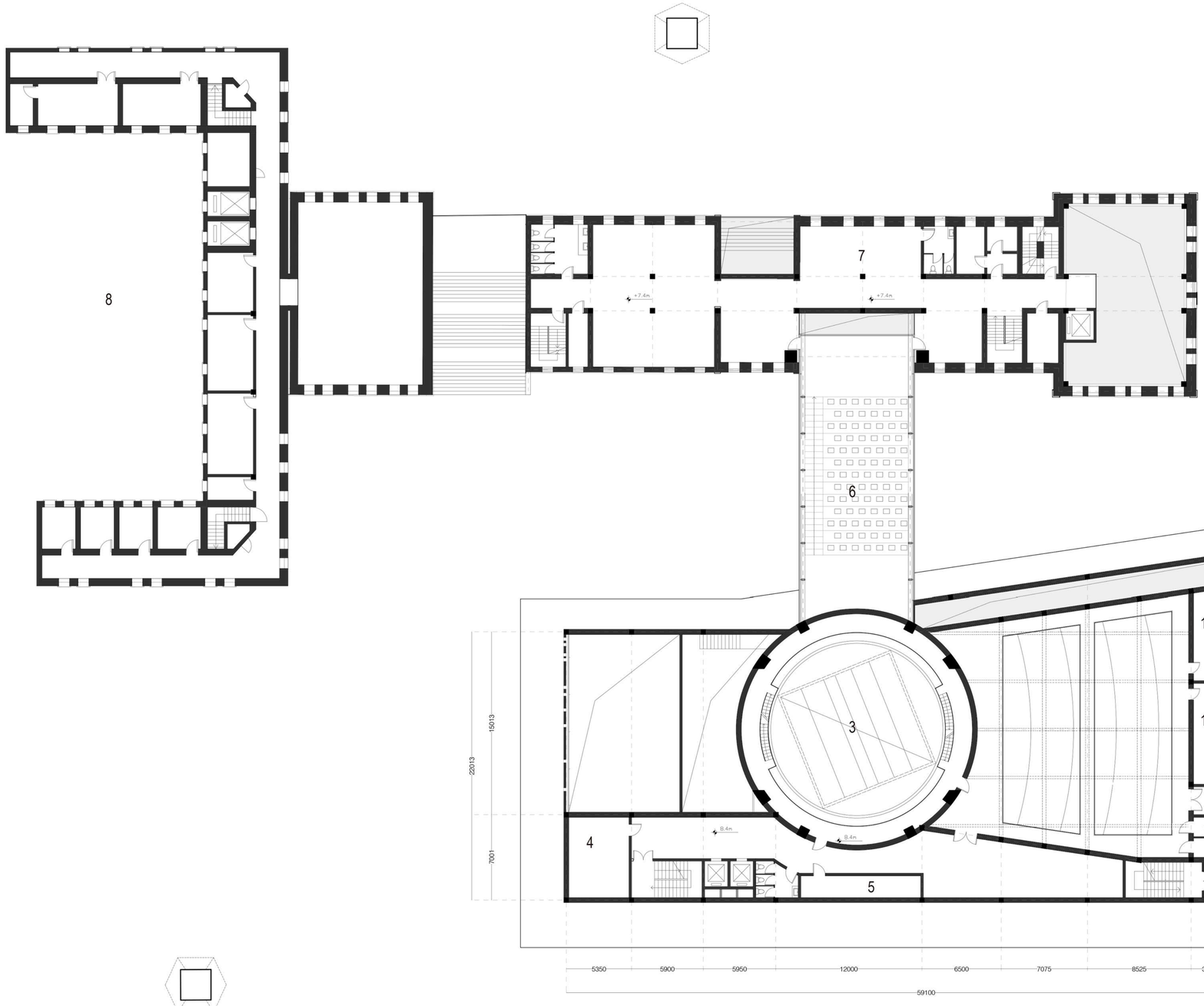

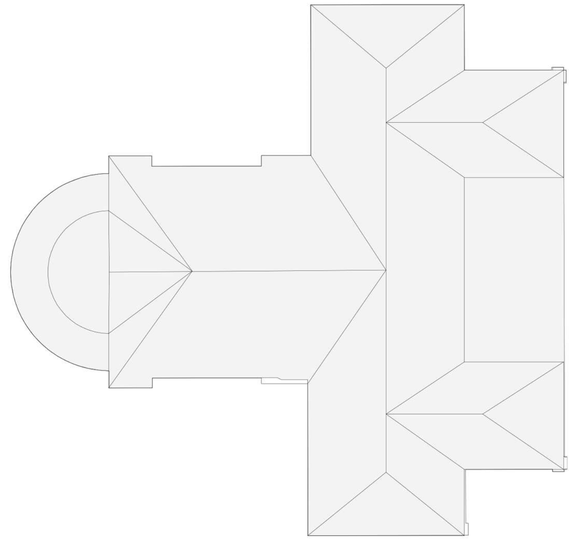

1. storage
2. space for pipe
3. fly tower
4. sound equipment
5. storage
6. second auditorium
7.cafe
8. drama school
9. toilet

Second floor plan scale 1:200

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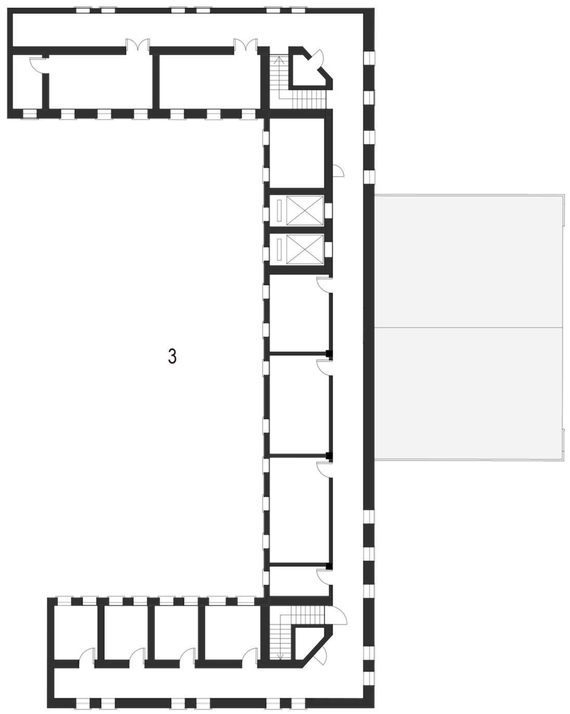

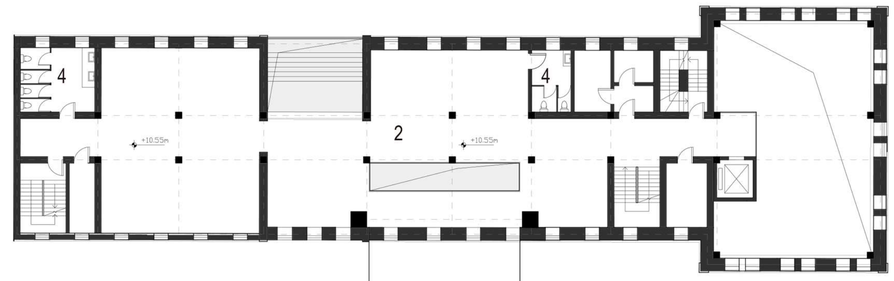

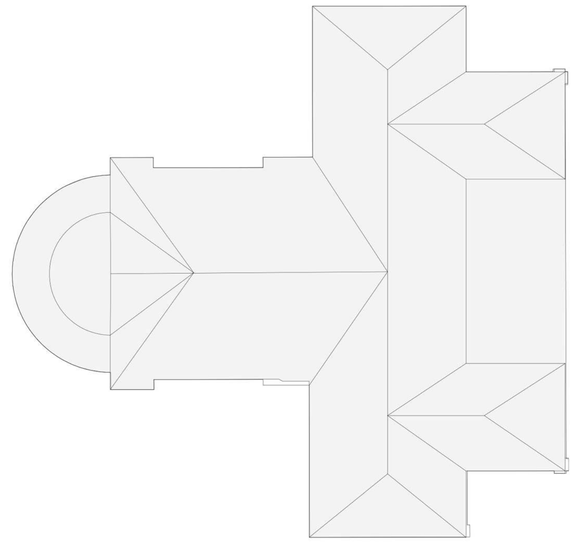

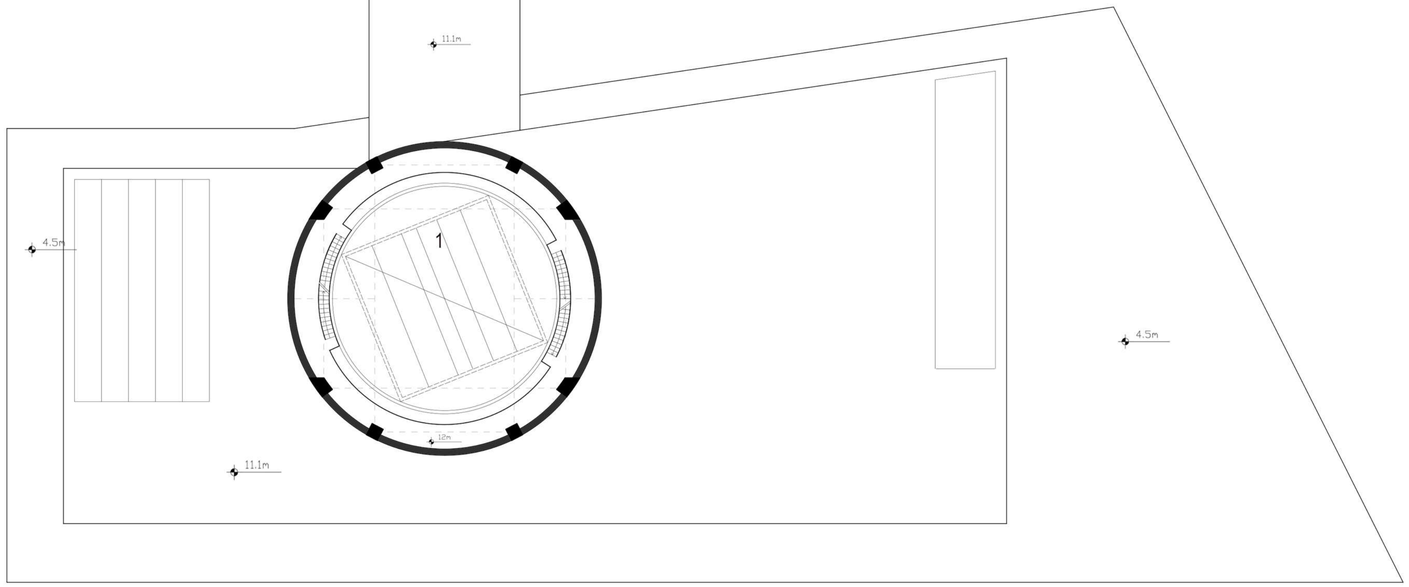

1.fly tower
2. library
3. drama school
4. toilet

Third floor plan scale 1:200

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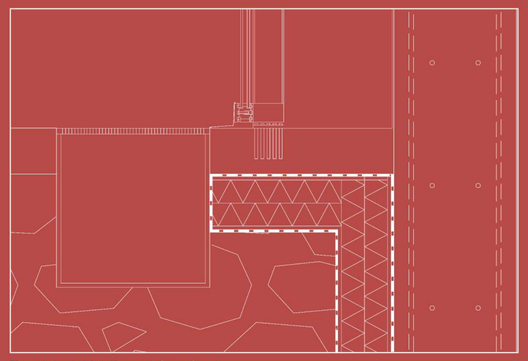
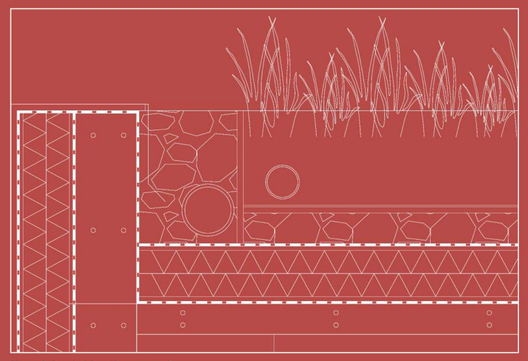
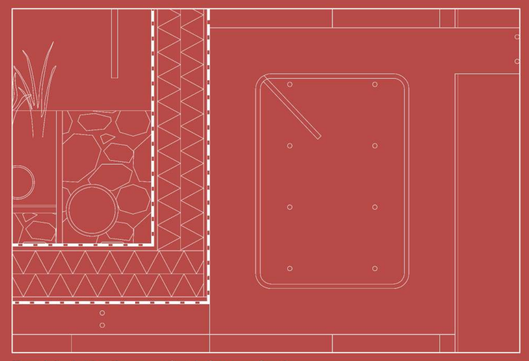


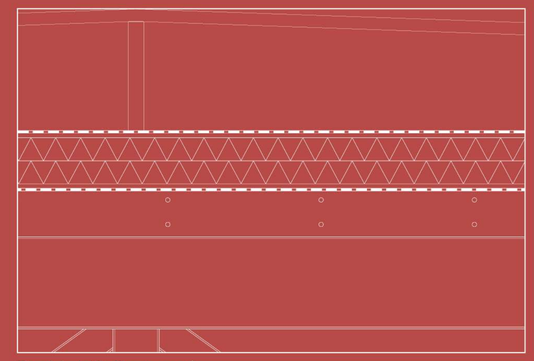
Detail 1 1:10 Ground floor facade



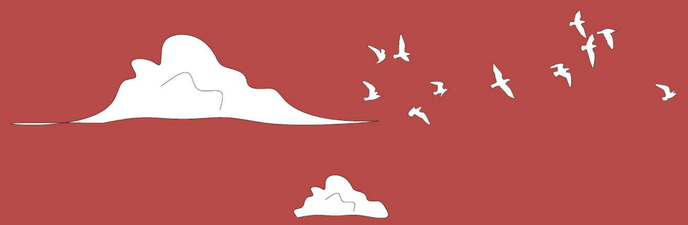
Detail 2 1:10 Green roof

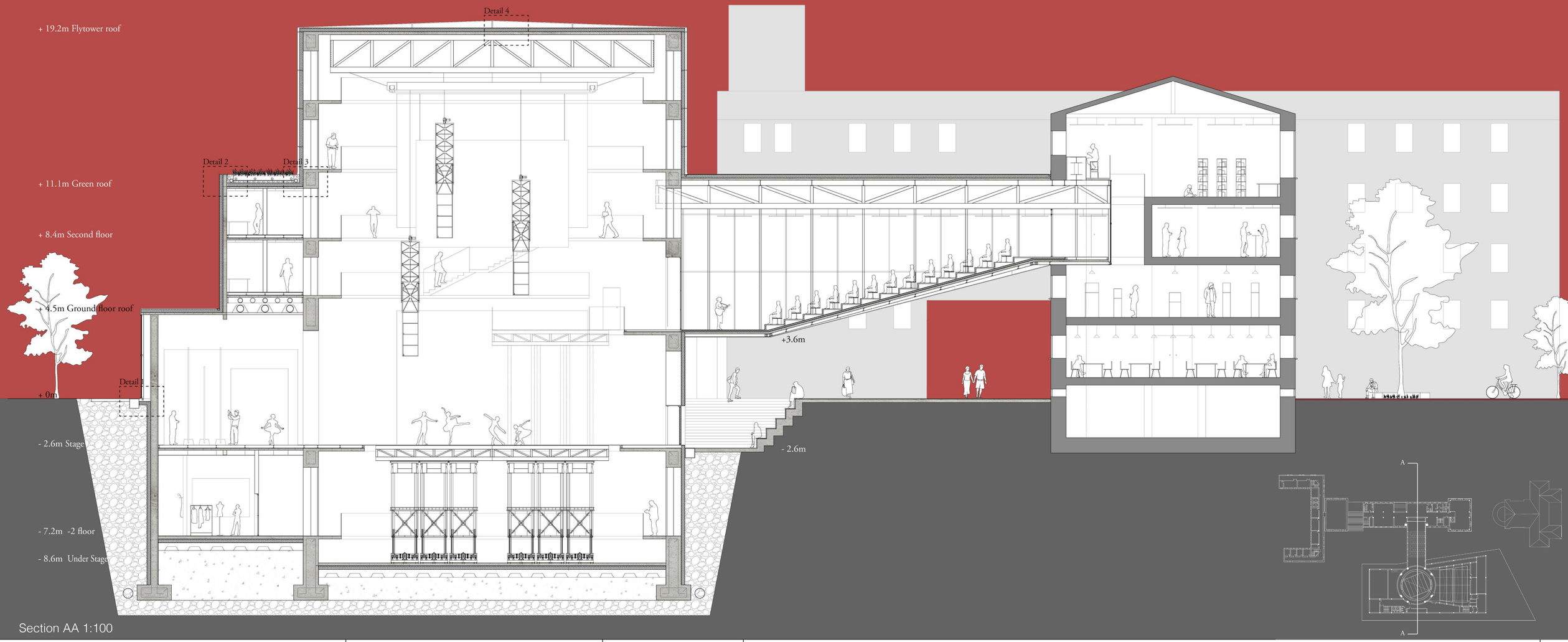


Detail 3 1:10 Green roof with flytower facade



Detail 4 1:10 Flytower roof





Section AA 1:100

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Architettura Urbanistica Ingegneria delle Costruzioni
Architettura - Architettura delle Costruzioni
Architecture - Building Architecture

Academic Year 2018/19
Final Year Design

Supervisor
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Chiara Tagliabue Lavinia

Students
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Nongquan Yang 892033

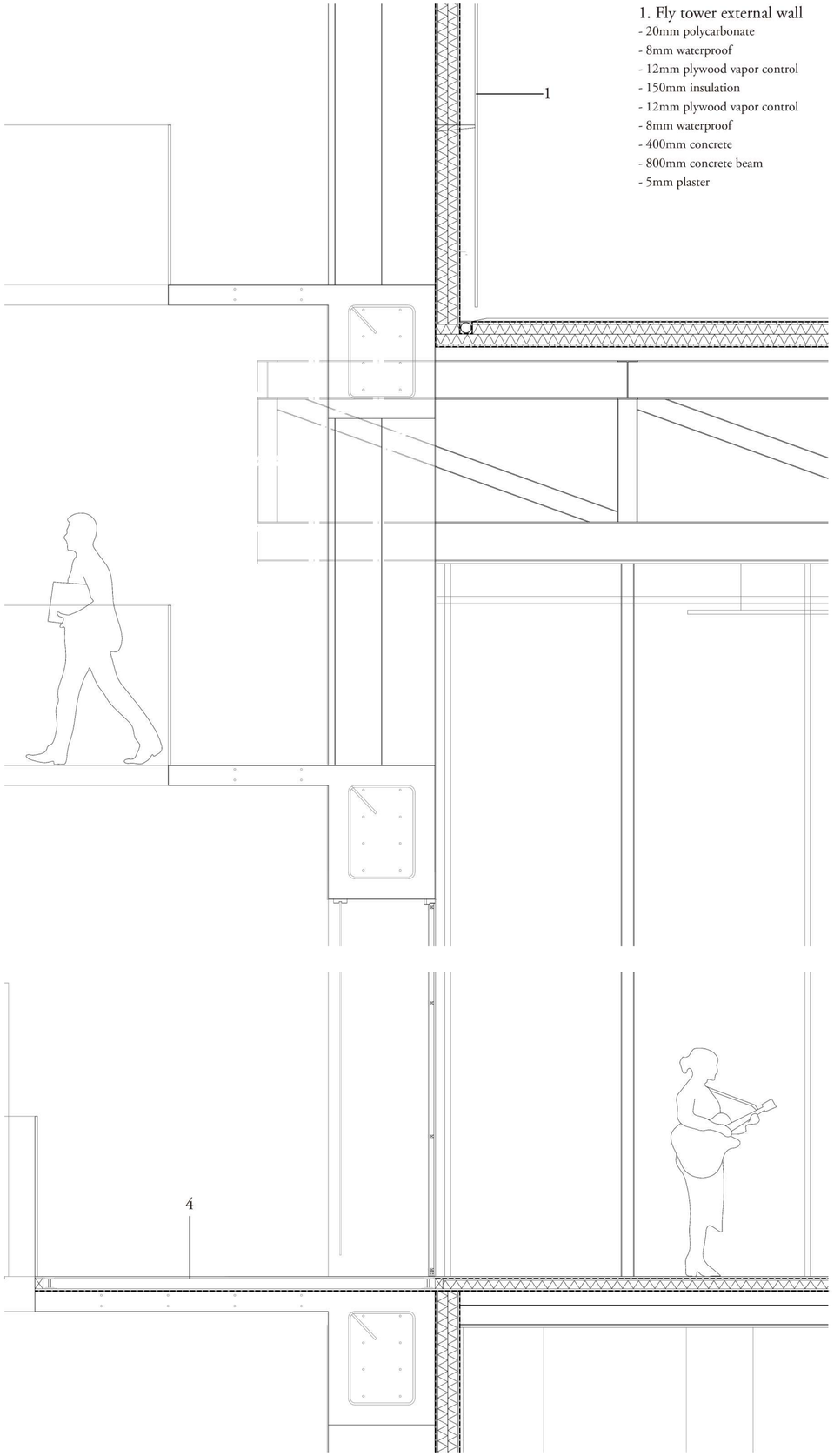
Drama Oriented Narrative Design: Theatre project in Naumburg city

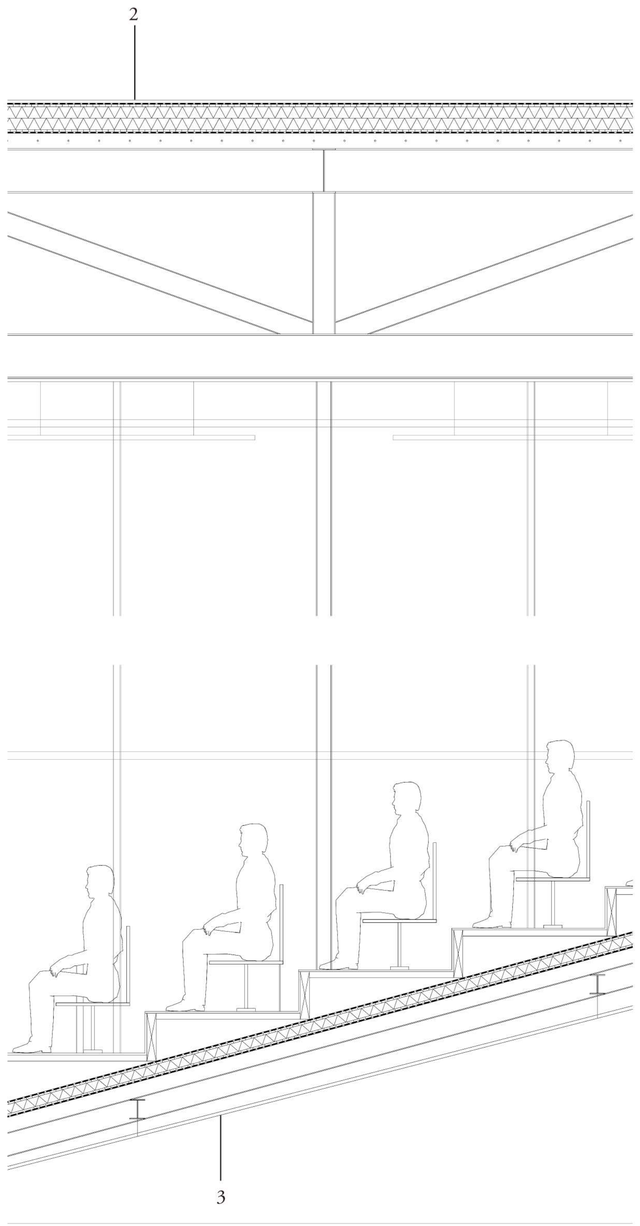
1. Fly tower external wall
- 20mm polycarbonate
- 8mm waterproof
- 12mm plywood vapor control
- 150mm insulation
- 12mm plywood vapor control
- 8mm waterproof
- 400mm concrete
- 800mm concrete beam
- 5mm plaster

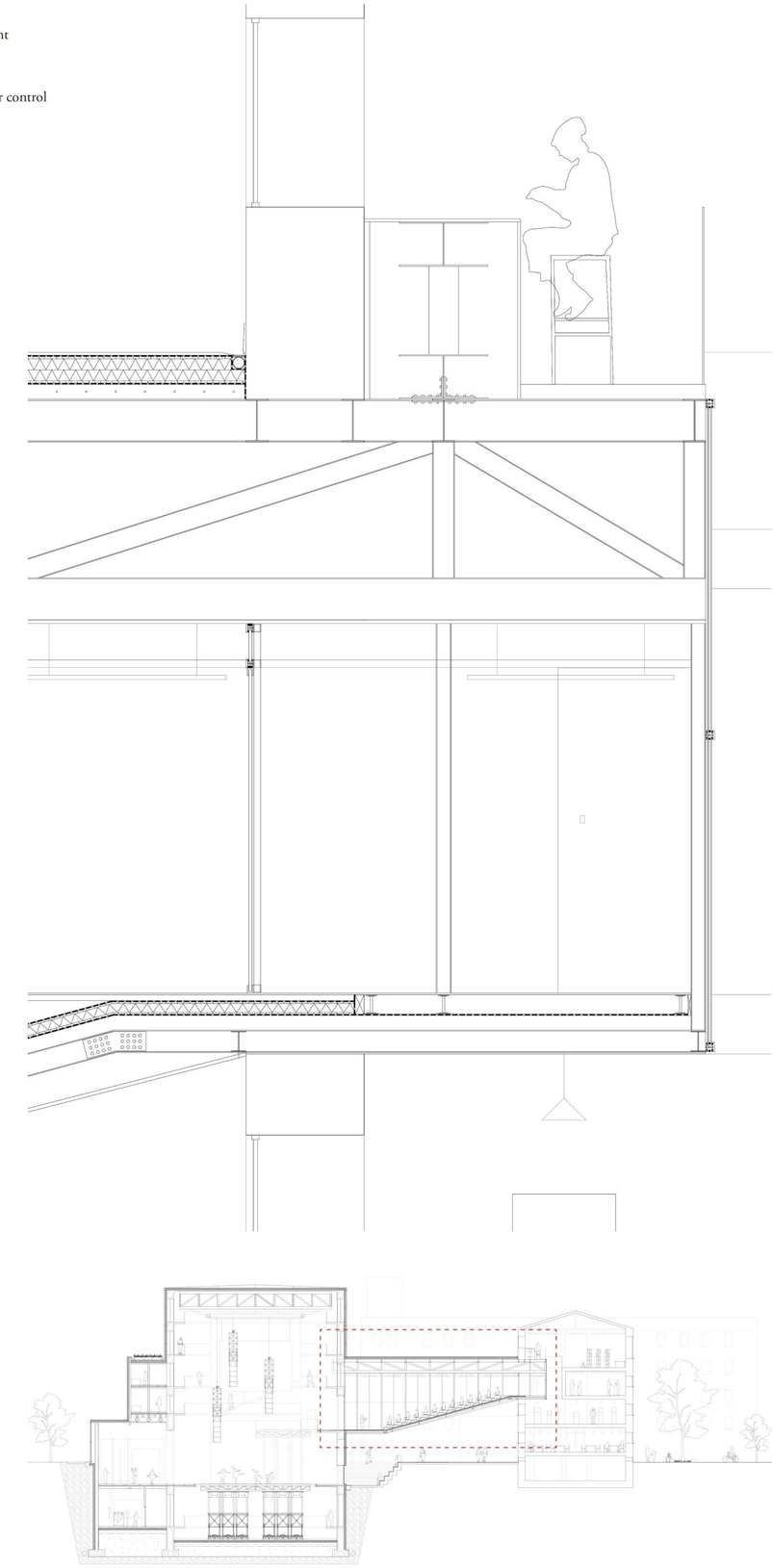
2. Small auditorium roof
- 20mm plaster
- 8mm waterproof
- 12mm plywood vapor control
- 150mm insulation
- 12mm plywood vapor control
- 8mm waterproof
- 100mm concrete
- 1.5m steel truss beam
- 20mm wood pavement

3. Small auditorium floor
- 20mm wood pavement
- 200mm steel beam
- 100mm concrete
- 8mm waterproof
- 12mm plywood vapor control
- 150mm insulation
- 12mm plywood vapor control
- 8mm waterproof
- 20mm wood stair frame
- 20mm wood pavement

4. Interior floor
- 20mm wood pavement
- 300mm suspend area
- 8mm waterproof
- 12mm plywood vapor control
- 150mm concrete
- 20mm plaster







Detail 5 1:20 Small auditorium

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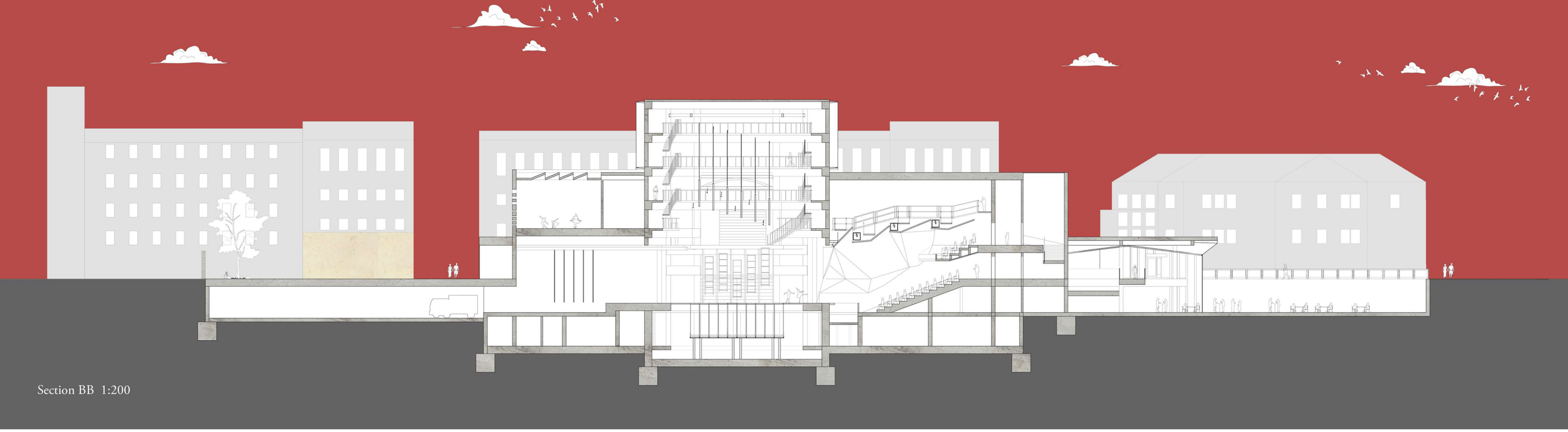

Section BB 1:200

Elevation CC 1:200

Elevation DD 1:200

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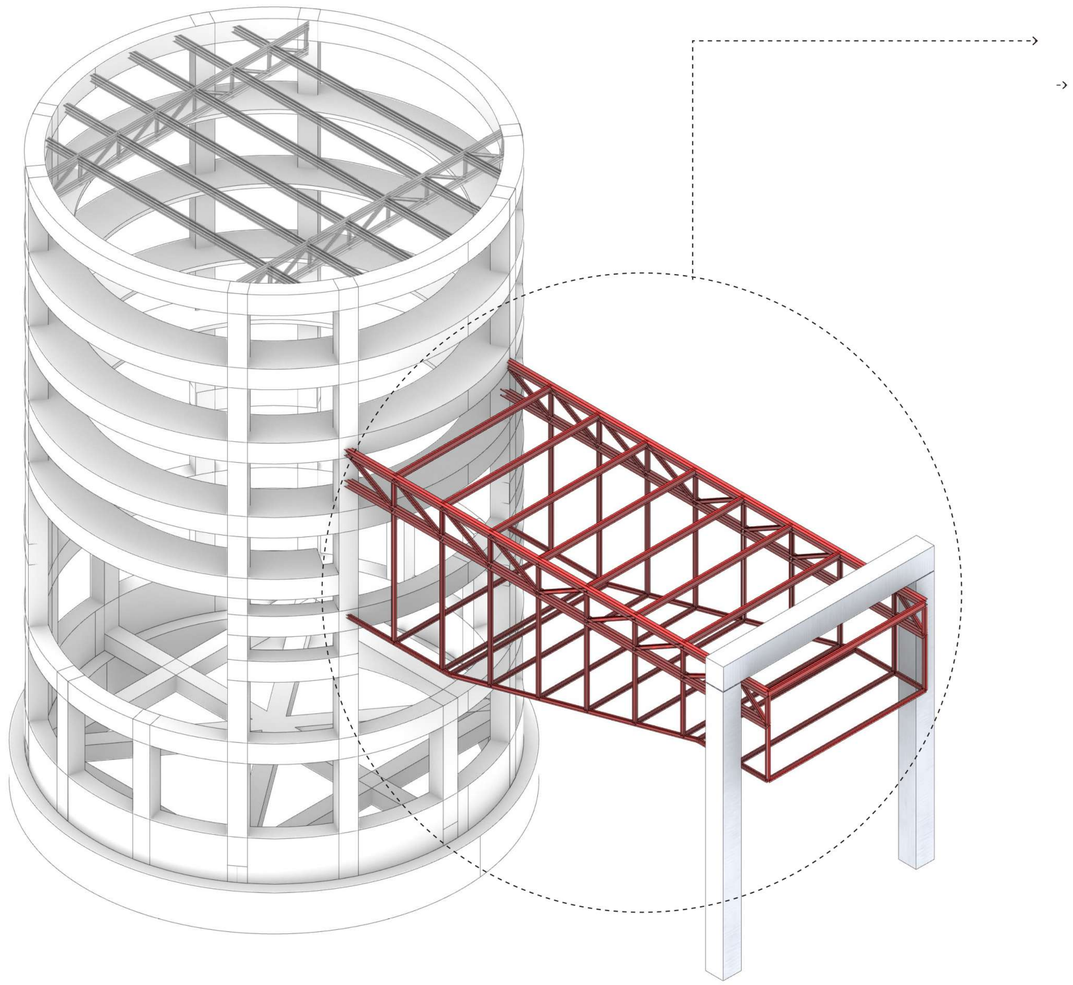
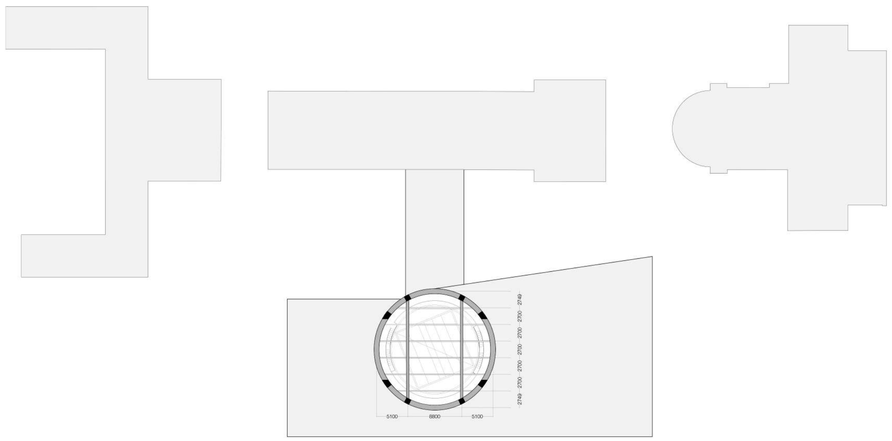
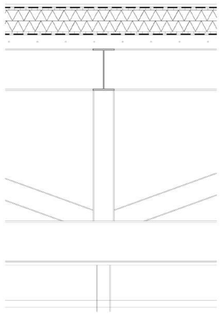
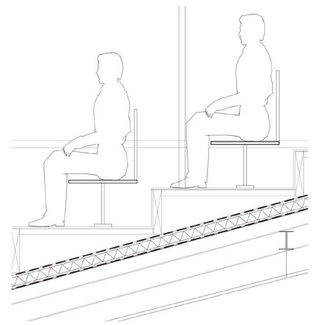




Typical section





1. Roof
   plaster finishing 20mm
   waterproof-high density polyethylene sheet 8mm
   vapor barrier membrane polythylene sheet 15mm
   glass wool insulation 150mm
   vapor barrier membrane polythylene sheet 15mm
   waterproof-high density polyethylene sheet 8mm
   timber finishing 20mm
   existing wall 1300mm*8800mm

2. Floor
   plaster finishing 20mm
   waterproof-high density polyethylene sheet 8mm
   vapor barrier membrane polythylene sheet 12mm
   glass wool insulation 60mm
   vapor barrier membrane polythylene sheet 12mm
   waterproof-high density polyethylene sheet 8mm
   timber stub
   timber finishing 20mm

Material form

Roof Load	Bulk density(kg/m³)	Thickness(mm)	Weight per unit area(KN/m²)
Dead load from slab(structural)	2300	100	**2.3**
Dead load from slab(no structural)			0.481
Timber finishing	600	20	0.12
Waterproof-high density polyethylene	950	8	0.076
Vapor barrier membrane polyethylene shee	500	15	0.075
Glass wool insulation	32	150	0.048
Vapor barrier membrane polyethylene shee	500	15	0.075
Waterproof-high density polyethylene	950	8	0.076
Plaster finishing	55	20	0.011
Snow load			**1.5**
Roof service load			**0.5**

Floor load	Bulk density(kg/m³)	Thickness(mm)	Weight per unit area(KN/m²)
Dead load from slab(structural)	2300	100	**2.3**
Dead load from slab(no structural)			**0.4112**
Timber finishing	600	12	0.072
Timber stub	600		0.037
Waterproof-high density polyethylene	950	8	0.076
Vapor barrier membrane polyethylene shee	500	12	0.06
Glass wool insulation	32	60	0.0192
Vapor barrier membrane polyethylene shee	500	12	0.06
Waterproof-high density polyethylene	950	8	0.076
Plaster finishing	55	20	0.011
Live load			**4**

Load calculation

Secondary beam:
q1=1.3dl+1.5+0.5=5.6KN/m², Q=Q1+Qw=18.5KN/m
M=Ql²/8=179KNm
Beam IPE360 S275, Wpl×=1090cm³=109000mm³
M/fyd=M/(fyk/1.05)=46901.90mm³<Wpl×
Primary Truss:
q=1.3dl+1.5dl+1.5+0.5=15.53KN/m
Q=68.32KN/m, Qsecondary=23*72.73*10^-4=0.16
Qt=Q+Qsecondary+Qw=80.98KN/m

Truss calculation

M=QtL²/8=4889.58KNm
As for steel S275,fy=275N/mm²
M=f*A*h
When using HEA300A, 1.5m height of truss can be used

Calculation the Force in the Truss

As ΣF=0 and ΣM=0
P=184KN
Fa=Fb=4p,
ΣFy=0, so N2=0.5p/sinα
ΣM=0,so N1=-7.5Pa/b
ΣFy=0,so N3=-0.5pcosα/sinα+7.5pa/b
N2=43.81KN, N1=2548.4KN, N3=2382.8KN

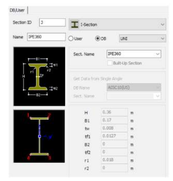
Check the buckling
Ncr=π2 EI/(Ka)2=20710822.68N, λ=(Afy/Ncr)-1=0.39,
Φ=0.5[1+α(λ-0.2)+λ2]=0.61, X=1/(Φ+(Φ2-λ2)-1)=0.93
NbED=2728KN
Ned/NbED=0.87<1, It is OK

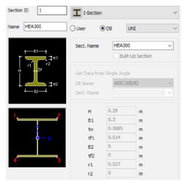
Structure in Midas

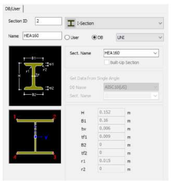
Beam information:

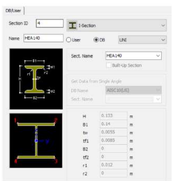
--Secondary beam
  IPE360

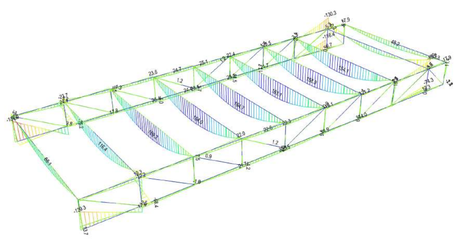
--Primary turss
  HEA300
  HEA160
  HEA140

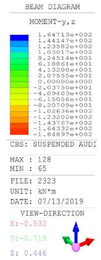


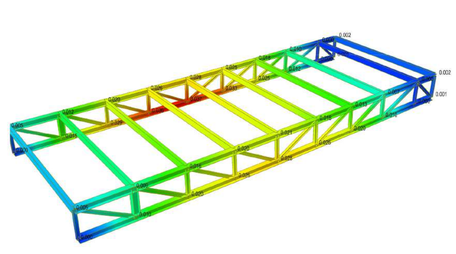


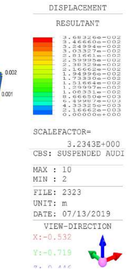












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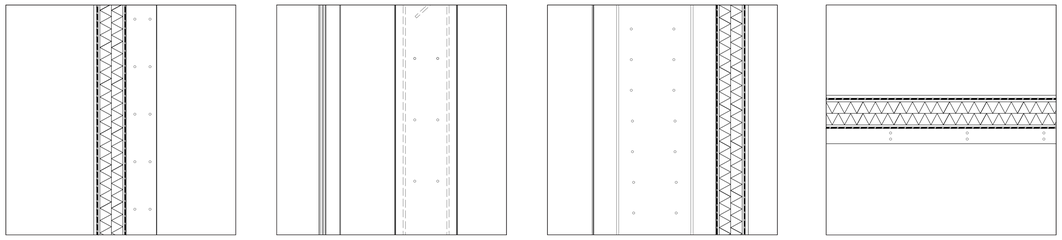
Building Services Design

Part 1 U value

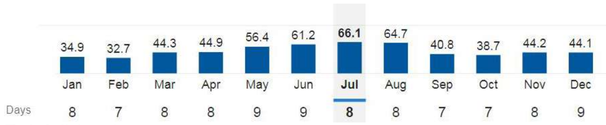


Wall 1 | Wall 2 | Wall 3 | Roof

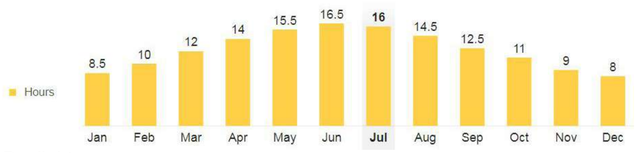
U Value= 1/ (ΣR + Ri + Ro)
R = Material tickness (m)/Thermal Conductivity (m*k/w)

U value							
material			thickness (m)	thermal conductivity k (w/m.k)	R value=d/k	R total (m2.k/w)	U value (w/m2.k)
eastern facade	wall 1	plaster	0.02	0.4	0.05	4.9405	0.202408042
		vapor control layer	0.024	0.33	0.072727273		
		waterproof	0.016	0.25	0.064		
		glass wool insulation	0.15	0.033	4.545454545		
		reinforced concrete	0.15	1.2	0.125		
		internal pavement wood	0.01	0.12	0.083333333		
	wall 2	reinforced concrete	0.15	1.2	0.125	0.3950	2.53164557
		double glass	0.01	0.04	0.27		
north facade	wall 1	plaster	0.02	0.4	0.05	4.9405	0.202408042
		vapor control layer	0.024	0.33	0.072727273		
		waterproof	0.016	0.25	0.064		
		glass wool insulation	0.15	0.033	4.545454545		
		reinforced concrete	0.15	1.2	0.125		
		internal pavement wood	0.01	0.12	0.083333333		
western facade	wall 3	plaster	0.02	0.4	0.05	5.3155	0.18812852
		vapor control layer	0.024	0.33	0.072727273		
		waterproof	0.016	0.25	0.064		
		glass wool insulation	0.15	0.033	4.545454545		
		reinforced concrete	0.6	1.2	0.5		
		internal pavement wood	0.01	0.12	0.083333333		
south facade	wall 1	plaster	0.02	0.4	0.05	4.9405	0.202408042
		vapor control layer	0.024	0.33	0.072727273		
		waterproof	0.016	0.25	0.064		
		glass wool insulation	0.15	0.033	4.545454545		
		reinforced concrete	0.15	1.2	0.125		
		internal pavement wood	0.01	0.12	0.083333333		
Typical Roof	Roof	plaster	0.02	0.4	0.05	5.0856	0.19663457
		vapor control layer	0.024	0.33	0.072727273		
		waterproof	0.016	0.25	0.064		
		glass wool insulation	0.15	0.033	4.545454545		
		vapor control layer	0.024	0.33	0.072727273		
		waterproof	0.016	0.25	0.064		
		reinforced concrete	0.2	1.2	0.166666667		
		plaster	0.02	0.4	0.05		

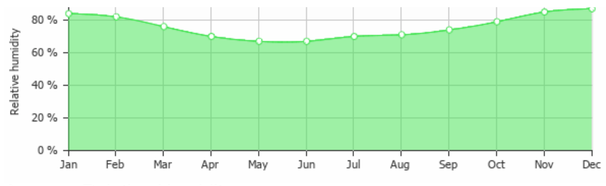
Average Temperatures



Rainfall (mm)

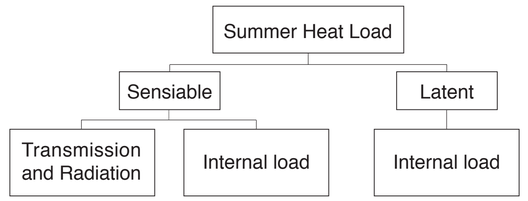


Daylight



Average Relative Humidity

Part 2 Summer Heat Load



			U value	surface (m2)	T outside	T inside	ΔT	heat flow
Wall Transmission	eastern facade	wall 1	0.202	430.2	30	25	5	434.502
		wall 2	2.53	261				3301.65
	north facade	wall 1	0.202	471				475.71
	western facade	wall 3	0.1881	570.8				536.8374
	south facade	wall 1	0.202	240				242.4
	roof	roof	0.196	2681				2627.38
	total							7618.4794

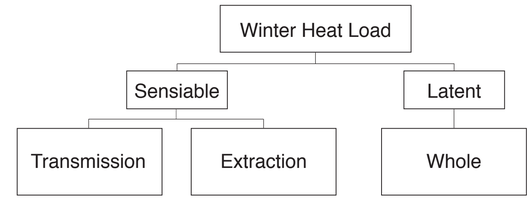
Window radiation	window heat load	surface (m2)	shading coefficient	solar cooling load factor	heat load	
	window	3086.8	0.8	16	39511.04	

		number	Qint.s.pp (w)	sensiable internal load	Qint.v.pp (w)	latent internal load
latent internal load	people	1206	65	78490	45	54270
	equipment	2 auditorium	300	600	–	650
		8 office	20	160		
		11 storage	20	220		
		10 toilte	30	300		
		1 workshop	30	30		
		1 shop	30	30		
		2 foryer	60	120		
		1 backstge	100	100		
		1 rehearsal room	30	30		
		1 orchestre	30	30		
		others	100	100		
	total (W)			80210		54920

Qs = 7618.48 + 39511.04 = 47129.52 W
Ql = 5492 W
Qtot = Qs + Ql = 102049.52 W

Summer heat load = 102049.52 W

Part 3 Winter Heat Load



			U value	surface (m2)	T outside	T inside	ΔT	heat flow
Wall Transmission	eastern facade	wall 1	0.202	430.2	0	25	25	2172.51
		wall 2	2.53	261				16508.25
	north facade	wall 1	0.202	471				2378.55
	western facade	wall 3	0.1881	570.8				2684.187
	south facade	wall 1	0.202	240				1212
	roof	roof	0.196	2681				13136.9
	total							38092.397

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Building Services Design

Part 3 Winter Heat Load

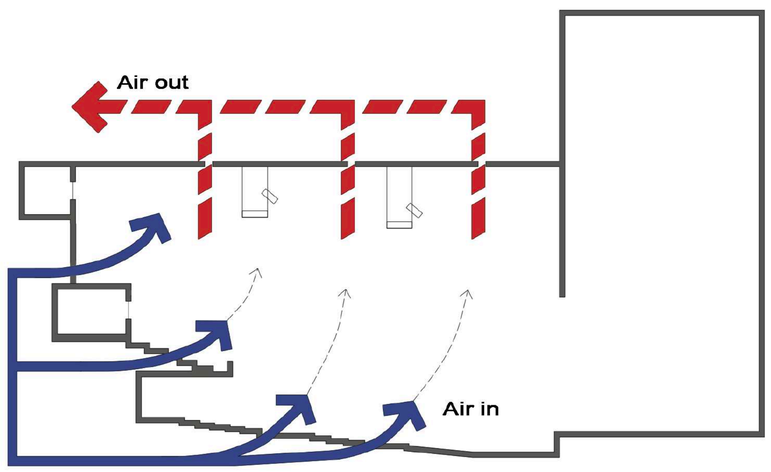
Window transmittance	window heat load	surface (m2)	U value	heat flow
	window	3086.8	3.7	11421.16

additional heating power	heat space surface m2	specific heating up	total
	2258	84 w/m2	189672

Thermal dispersion	heat flow
transmission towards the ground	139745
transmission towards heated spaces	15241.5
transmission towards external	38092.397
Window transmittance	11421.16
additional heating power	189672
winter total heat load (W)	394172.057

Qs = 38092.397 + 11421.16 + 139745 + 15241.5 = 204500 W
Ql = 189672 W
Qtot = Qs + Ql = 394172 W

Winter heat load = 394172 W



HVAC System - All Air System

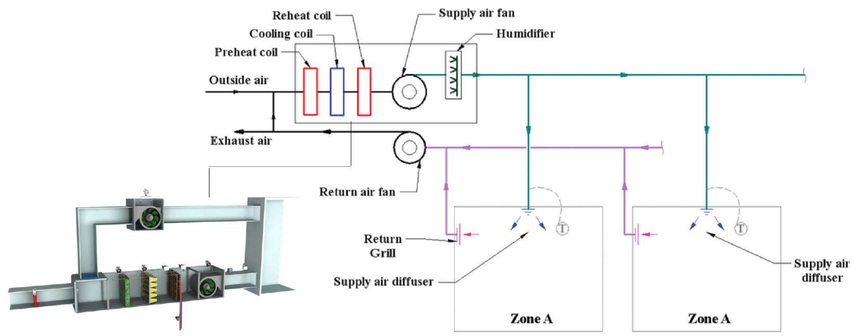
Advantages of all air system in theatre design
1. Maintenance is performed in unoccupied areas, for example on the roof.

2. No drain piping or power wiring or compressors.

3. Systems can include options such as air-side economizer, heat recovery, winter humidification, and large outside air volumes where required.

4. Good for temperature and humidity control.

5. Simple seasonal changeover.



Part 4 Air Ducts

Unit conversion :
1W = 3.412 Btu/h
Bruh = CFM x 1.08 x (EAT - LAT)
1 CFM = 1.7 m3/h

Summer
Btu = 102049.5194 x 3.412 = 348192.894
CFM = 348192.894 / 1.08 x (86 - 77) = 35822
35822 x 1.7 = 60897 m3/h

Winter
Btu = 394172.057 x 3.412 = 1344915.058
CFM = 1344915.058 / 1.08 x (77 - 32) = 27673
27673 x 1.7 = 47044 m3/h

If the maximum required ventilation is 6100 m3/h :

Ventilation pipe flow rate	main supply (m/s)	main return (m/s)	secondary pipe (m/s)	branch pipe (m/s)	tertiary pipe (m/s)
	4	6.5-10	5-6.5	3-4.5	3-3.5
select flow rate	4	8	6	4	4
	14400m/h	28800m/h	21600m/h	14400m/h	14400m/h

heat flow m3/h	61000 m3/h				
pipe area (m2)	main supply : 4.2	main return :2.11	secondary pipec : 2.8	branch pipe : 4.2	tertiary pipe : 4.2
pipe select d(mm)	1000	1000	600	450	300
number	6	3	10	26	60

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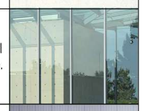
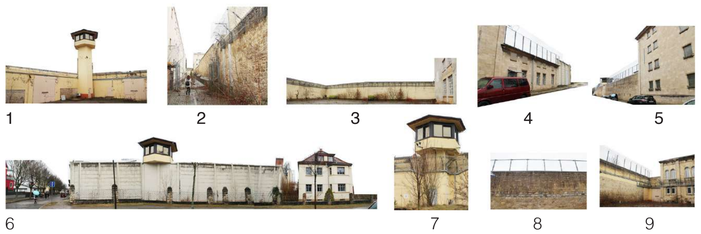
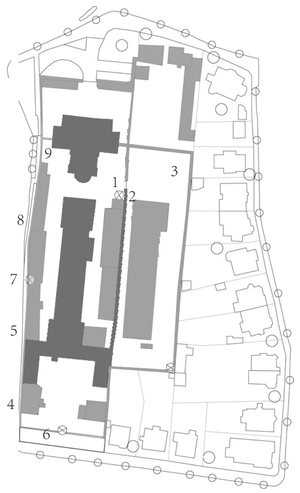
Innovative Material For Architecture

Main Materials

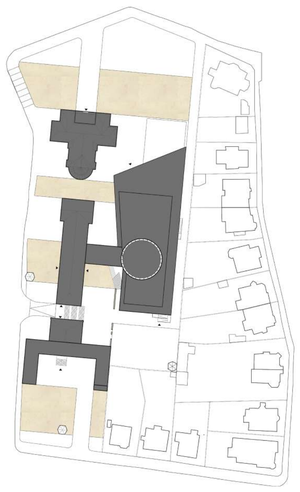
Materials		Thickness	Thermal Conductivity	U value	Reason	Texture
Facade	white concrete	0.15 m	1.5 m.k/w	0.1 w/m2.k	Pure facade has a contrast with existing buidling.	
	double glass	0.01 m	0.04 m.k/w	0.27 w/m2.k	Provide more natural light for public space.	
	polycarbonate	0.1 m	0.2 m.k/w	0.5 w/m2.k	1.It cover the fly tower to reduce strong volume's atmosphere. 2. Hightlight theatre at night.	
Interior	timber	0.02 m	0.13 m.k/w	0.15 w/m2.k	Create harmonious and soft interior atmosphere.	
	marble	0.02 m	2.07 m.k/w	0.009 w/m2.k	Pavement of floor.	
landscape	brick (reuse)	0.05 m	0.8 m.k/w	0.0625 w/m2.k	Reuse brick from demolition pision to keep memories.	
	gray concrete	0.1 m	1.4 m.k/w	0.071 w/m2.k	For road and plaza.	

Recycling Brick From Demolition Prison





Demolition Part

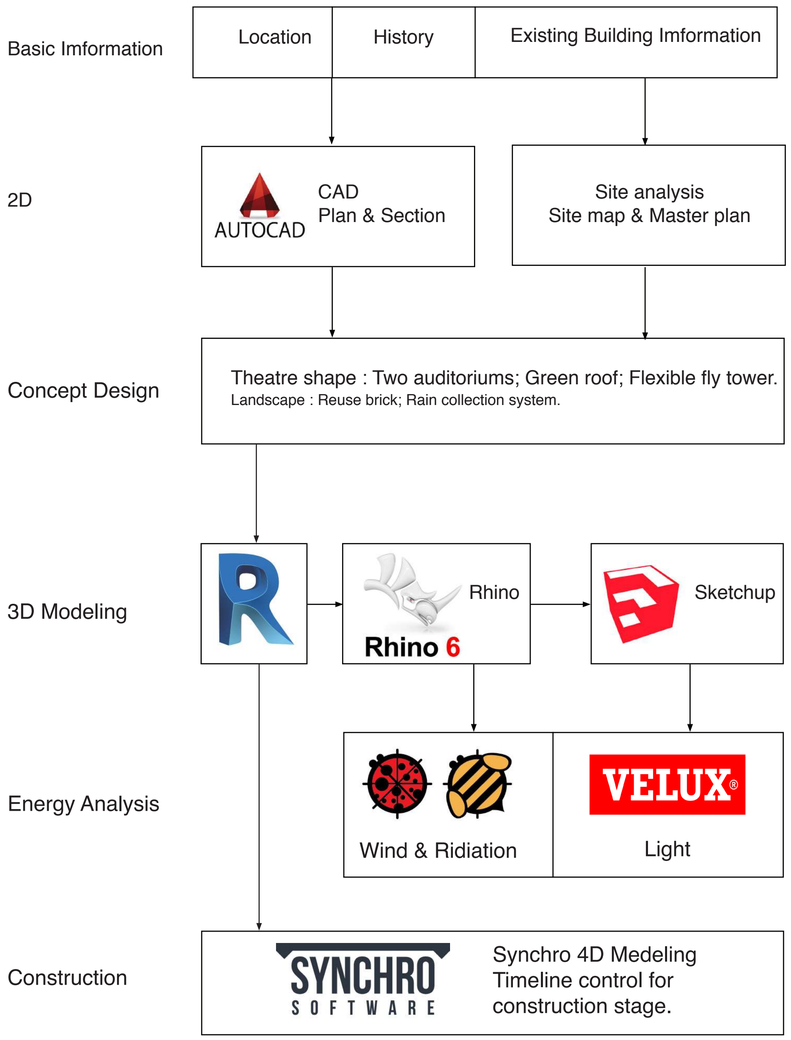


New Landscape

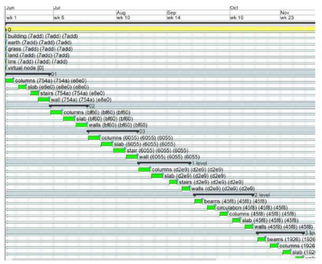
Technology And Design In BIM Environment

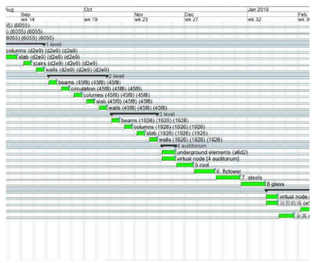
Workflows

BIM analysis aim :
- Energy analysis and sustainability design for theatre.
- Revit imformation model



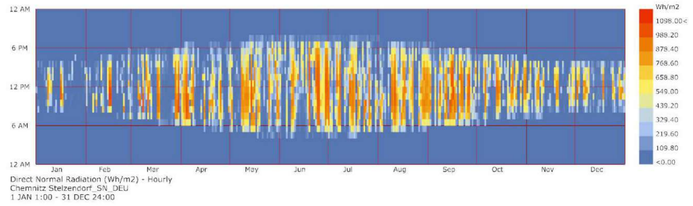
Synchro 4D



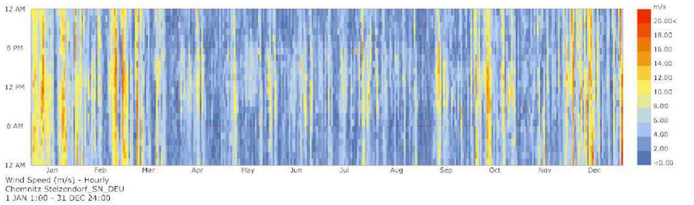


Honeybee

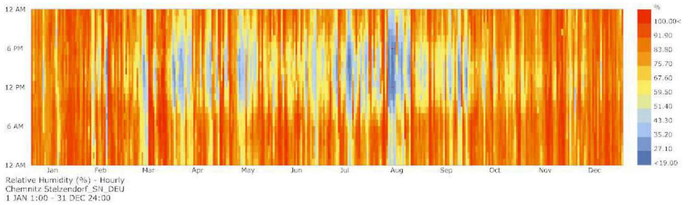
Radiation



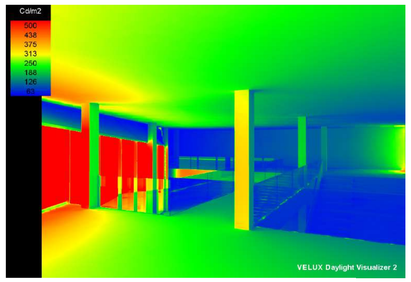
Wind Speed



Relative Humidity

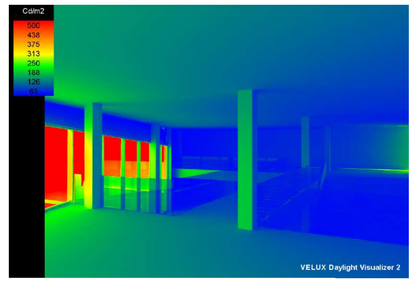


Velux Analysis : Foyer Daylight



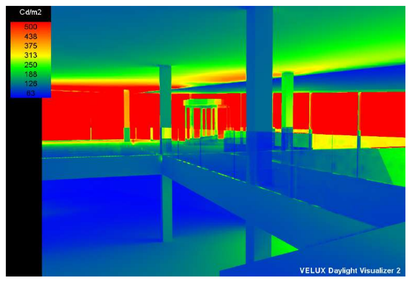
Location	Berlin, latitude 52.3 N, longitude 13.2 E
Time	June at 12:00
Orientation	85.0 CW
Sky condition	Clear (12)

June 12AM



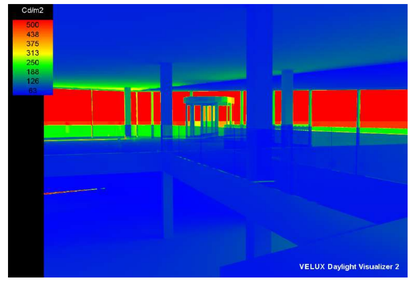
Location	Berlin, latitude 52.3 N, longitude 13.2 E
Time	November at 12:00
Orientation	85.0 CW
Sky condition	Clear (12)

November 12AM



Time	June at 12:00
Orientation	85.0 CW
Sky condition	Clear (12)

June12AM



Time	December at 12:00
Orientation	85.0 CW
Sky condition	Clear (12)

December 12AM

POLITECNICO MILANO 1863

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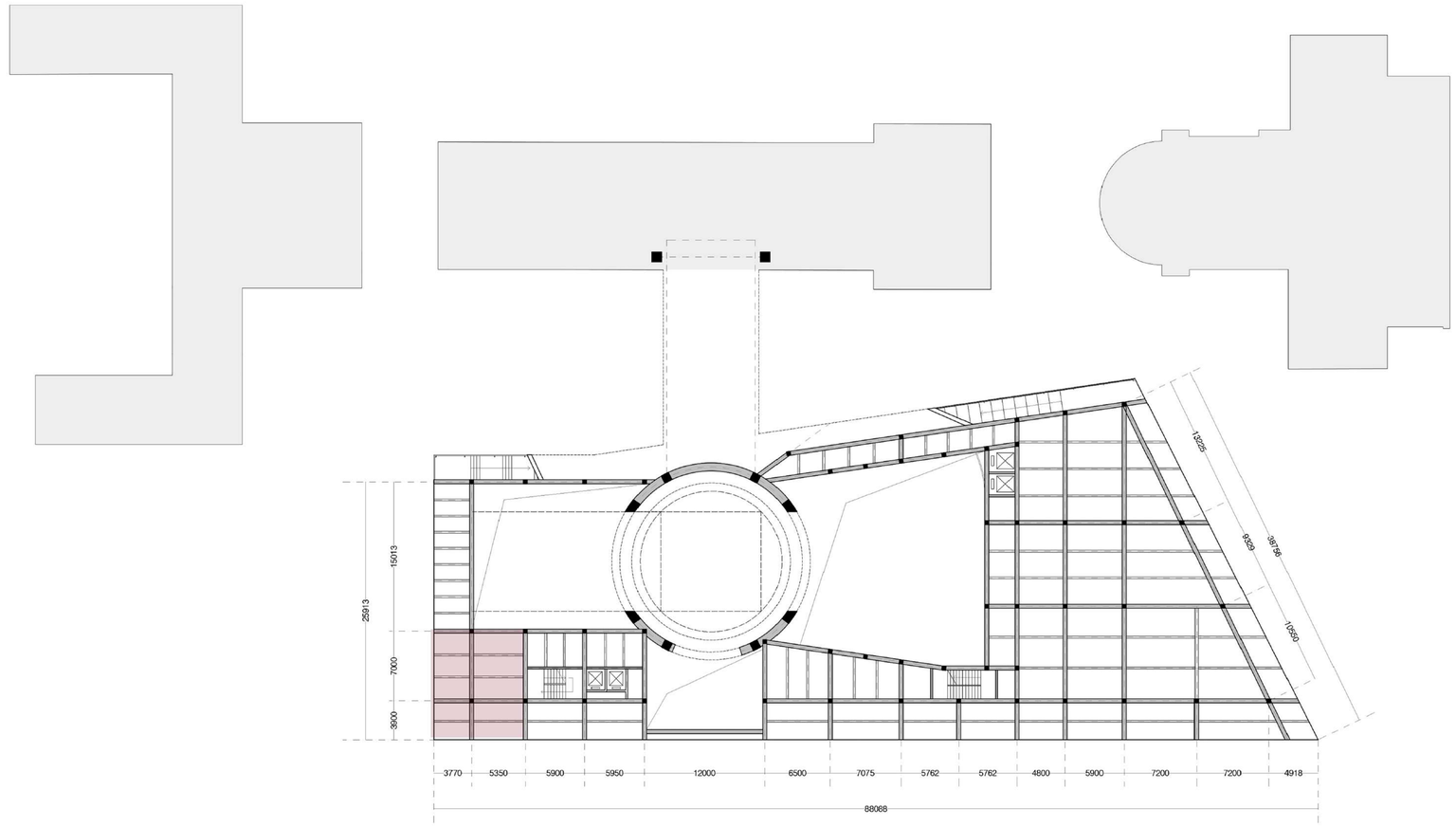
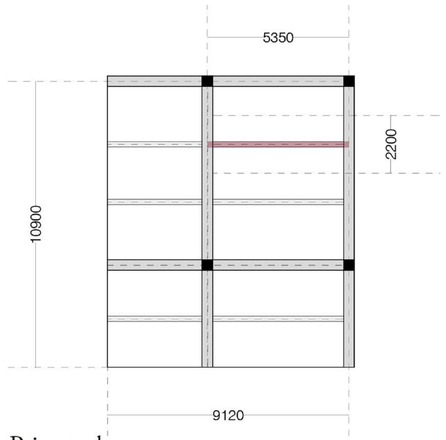
Drama Oriented Narrative Design: Theatre project in Naumburg city

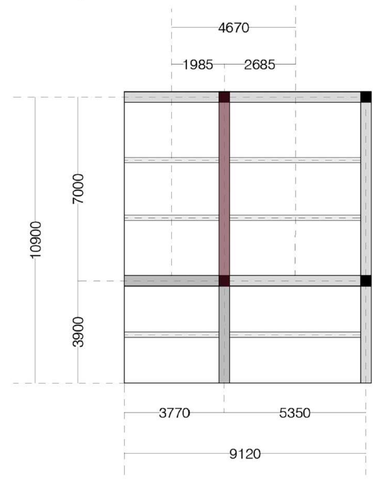
Structural plan of ground floor scale 1:500



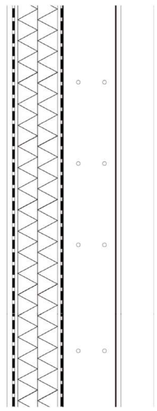
Secondary beam



Primary beam

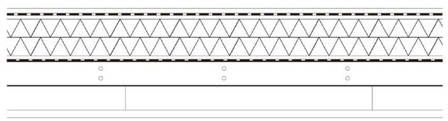


Typical section



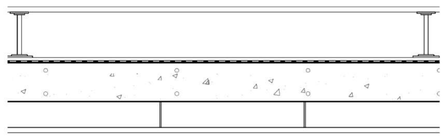
1. Wall typical section

plaster finishing 20mm
waterproof 8mm
vapor barrier sheet 15mm
glass wool insulation 150mm
vapor brrier sheet 15mm
waterproof 8mm
plaster finishing 20mm



2. Roof typical section

plaster finishing 20mm
waterproof 8mm
vapor barrier sheet 15mm
polyurethane foam 150mm
vapor brrier sheet 15mm
waterproof 8mm
plaster finishing 20mm



3. Roof typical section

plaster finishing 20mm
waterproof 8mm
vapor barrier sheet 12mm
plaster finishing 20mm

Material form

Wall load	Bulk density(kg/m³)	Thickness(mm)	Weight per unit area(KN/m²)
Dead load from wall(structural)	2300.00	200.00	**4.60**
Dead load from slab(no structural)			**0.29**
Plaster finishing	55.00	20.00	0.01
Waterproof-high density polyethylene	950.00	8.00	0.08
Vapor barrier membrane polyethylene shee	500.00	15.00	0.08
Glass wool insulation	32.00	150.00	0.05
Vapor barrier membrane polyethylene shee	500.00	15.00	0.08
Waterproof-high density polyethylene	950.00	8.00	0.08
Plaster finishing	55.00	20.00	0.01

Roof Load(green roof)	Bulk density(kg/m³)	Thickness(mm)	Weight per unit area(KN/m²)
Dead load from slab(structural)	2300	100	**2.3**
Dead load from slab(no structural)			**0.354**
Plaster finishing	55	20	0.011
Waterproof-high density polyethylene	950	8	0.076
Vapor barrier membrane polyethylene shee	500	15	0.075
polyurethane foam	20	150	0.03
Vapor barrier membrane polyethylene shee	500	15	0.075
Waterproof-high density polyethylene	950	8	0.076
Plaster finishing	55	20	0.011
Snow load			**1.5**
Roof service load			**0.5**

Floor load	Bulk density(kg/m³)	Thickness(mm)	Weight per unit area(KN/m²)
Dead load from slab(structural)	2300	100	**2.3**
Dead load from slab(no structural)			**0.458**
Plaster finishing	55	20	0.011
Mental spacer	7750	96	0.3
Waterproof-high density polyethylene	950	8	0.076
Vapor barrier membrane polyethylene sheet	500	12	0.06
Plaster finishing	55	20	0.011
Live load			**4**

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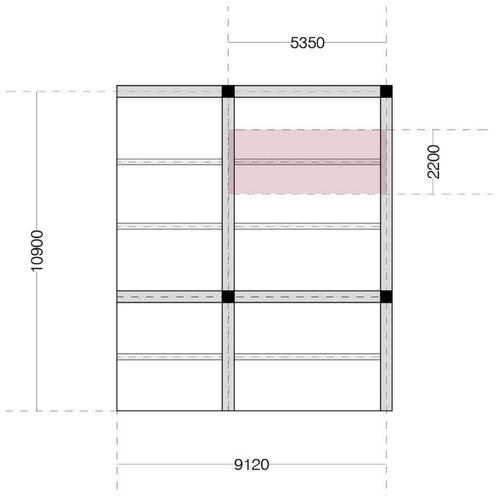
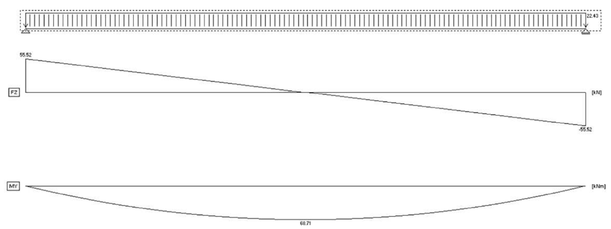
Secondary beam of floor



Load calculation

Secondary beam information	number	unit
Floor		
L3: interval of beam	2.2	m
L4:Length of beam	5.35	m
H2：height of beam	0.3	m
B2：width of beam	0.15	m
A1: area of beam	0.05	m²



Floor Q1=(G4+G5+G6)1.3+1.5Q	formula	number	unit
G4: Self load of beam	H2*B2*23KN/m³	1.035	KN/m
G5: Dead load from slab(structural)	L3*2.3KN/m²	5.06	KN/m
G6: Dead load from slab(non-structural)	L3*0.458KN/m²	1.008	KN/m
Q: live load	L3*4KN/m²	8.8	KN/m
Q2: factored total load on secondary	Q2=(G4+G5+G6)1.3+1.5Q	22.433	KN/m

Roof Q3=(G7+G8+G9)1.3+Qs+Qr	formula	number	unit
G7: Self load of beam	H2*B2*23KN/m³	1.035	KN/m
G8: Dead load from slab(structural)	L3*2.3KN/m²	5.06	KN/m
G9: Dead load from slab(non-structura	L3*6.713KN/m²	0.779	KN/m
Qs: Snow load	L3*1.5KN/m²	3.3	KN/m
Qrs: Roof service load	L3*0.5KN/m²	1.1	KN/m
Q3: factored total load on secondary	Q1=(G7+G8+G9)1.3+Qs+Q	13.336	KN/m

Check the main reinforcement

Chose Grade C45/50, so the concrete Grades less than C50, Maximum x/d=0.45

TABLE Values of limiting design parameters for concrete Grades less than or equal to C50.

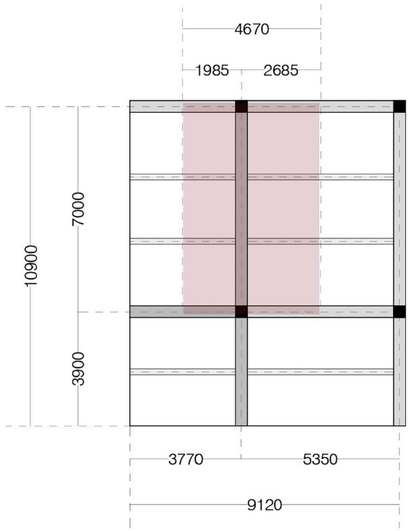
α_{cc}	x_{max}/d	$A_{s,max}f_{yk}/bdf_{ck}$	$M_{Sd,max}/bd^2f_{ck}$
0.85	$(\delta-0.44)/1.25$ for $\delta=1$	$0.417\delta-0.184$	$0.535\delta-0.21-0.133\delta^2$
	0.45	0.233	0.168
	Plastic		
	0.25	0.13	0.117
1.00	$(\delta-0.44)/1.25$ for $\delta=1$	$0.491\delta-0.216$	$0.63\delta-0.246-0.157\delta^2$
	0.45	0.275	0.227
	Plastic		
	0.25	0.153	0.138

Check the Moment				
Med max	Max applied moment	Med max=Q2*L4²/8	80.26	KNm
Mrd max	Max moment without compression steel	Mrd max=0.168*bd²fck	90.76	KNm
				Mrd max>Med max

Check the shear

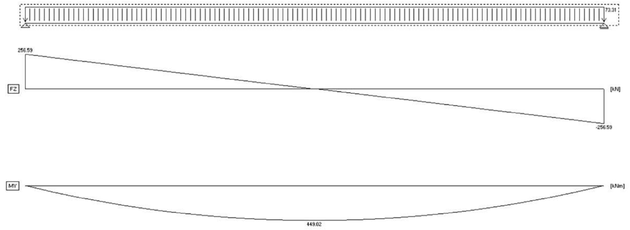
Check the shear			
L1: interval of beam	L4/2	2.675	m
d1	B2/2	0.08	
Vmax1		55.52	KN
Ved1	Ved=(L-d)/L*Vmax	53.84	KN
Vn=Vc+Vs			
	Vc=2*fck^-2bwd	49.30	Vc<Ved
Vs	Vs=Vrd1-Vc	4.54	KN
Av	6mm*2	12.00	mm²
fy		6000.00	psi
S	Av*fy*d/Vs	26.66	cm

Primary beam of floor



Load calculation

Primary beam information	number	unit
Floor		
L3: interval of beam	5.35	m
L4:Length of beam	7.00	m
L5:length of cantilever beam	3.90	m
H2：height of beam	0.50	m
B2：width of beam	0.40	m
A1: area of beam	0.20	m²



Floor Q1=(G4+G5+G6+G7+G8)1.3+1.5Q	formula	number	unit
G4: Self load of beam	H2*B2*23KN/m³	4.60	KN/m
G5：load ofsecondary beam		1.04	KN/m
G6:Load from wall	Qw*L4/2	17.10	KN/m
G6: Dead load from slab(structural)	L3/2*2.3KN/m²	6.15	KN/m
G7: Dead load from slab(non-structural)	L3/2*0.458KN/m²	1.23	KN/m
Q: live load	L3/2*4KN/m²	10.70	KN/m
Q2: factored total load on secondary	Q2=(G4+G5+G6+G7)1.3+1.5Q	55.19	KN/m

Roof Q3=(G7+G8+G9+G10)1.3+Qs+Qr	formula	number	unit
G7: Self load of beam	H2*B2*23KN/m³	4.60	KN/m
G8: load of secondary beam		1.04	KN/m
G9: Dead load from slab(structural)	1.98*2.3KN/m²	4.55	KN/m
G10: Dead load from slab(non-structura	1.98*0.354KN/m²	0.70	KN/m
Qs: Snow load	1.98*1.5KN/m²	2.97	KN/m
Qrs: Roof service load	1.98*0.5KN/m²	0.99	KN/m
Q3: factored total load on secondary	Q1=(G7+G8+G9+G10)1.3+Qs+Q	18.12	KN/m

Check the main reinforcement

Chose Grade C45/50, so the concrete Grades less than C50, Maximum x/d=0.45

TABLE Values of limiting design parameters for concrete Grades less than or equal to C50.

α_{cc}	x_{max}/d	$A_{s,max}f_{yk}/bdf_{ck}$	$M_{Sd,max}/bd^2f_{ck}$
0.85	$(\delta-0.44)/1.25$ for $\delta=1$	$0.417\delta-0.184$	$0.535\delta-0.21-0.133\delta^2$
	0.45	0.233	0.168
	Plastic		
	0.25	0.13	0.117
1.00	$(\delta-0.44)/1.25$ for $\delta=1$	$0.491\delta-0.216$	$0.63\delta-0.246-0.157\delta^2$
	0.45	0.275	0.227
	Plastic		
	0.25	0.153	0.138

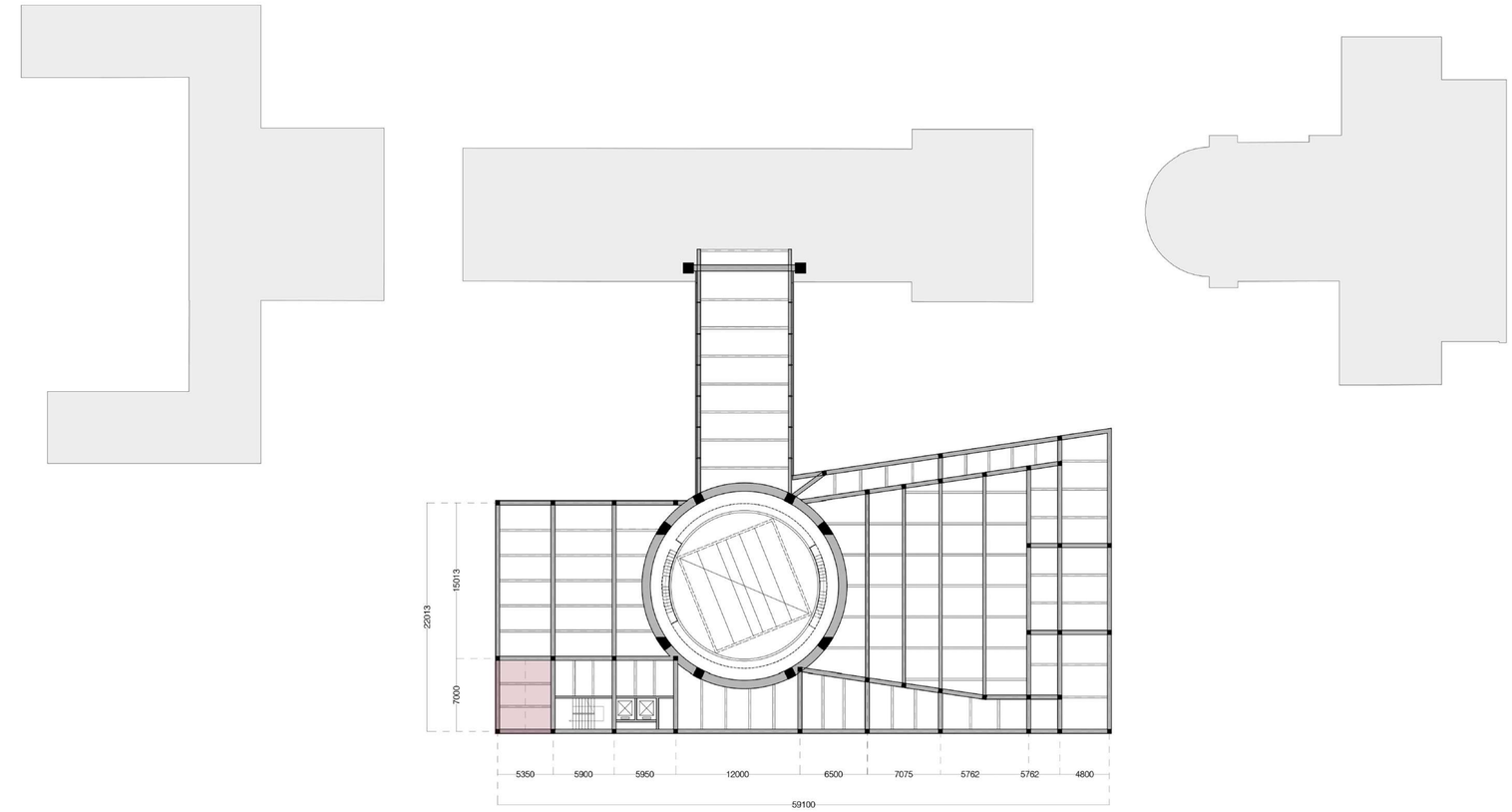
Check the Moment				
Med max	Max applied moment	Med max=(Q2+Q3)*L4²/8	449.02	KNm
Mrd max	Max moment without compression ste	Mrd max=0.168*bd²fck	572.22	KNm
				Mrd max>Med max

Check the shear

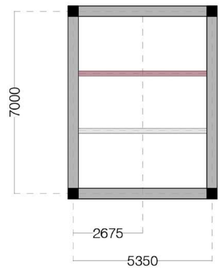
Check the shear			
L1: interval of beam	L4/2	3.50	m
d1	B2/2	0.20	
Vmax1		256.59	KN
Ved1	Ved=(L-d)/L*Vmax	241.93	KN
Vn=Vc+Vs			
	Vc=2*fck^-2bwd	233.45	Vc<Ved
Vs	Vs=Vrd1-Vc	8.48	KN
Av	6mm*2	12.00	mm²
fy		6000.00	psi
S	Av*fy*d/Vs	20.55	cm

Structure

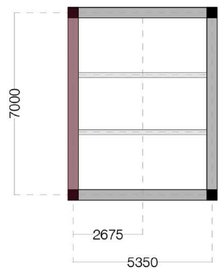
Structural plan of Third floor scale 1:500

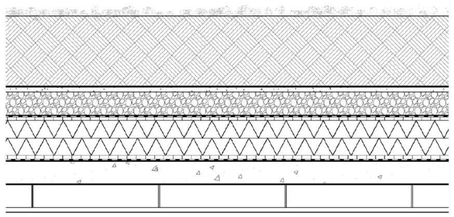


Secondary beam



Primary beam

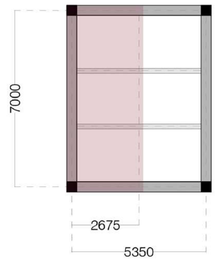




1. Green roof
   - soil 300mm
   - filter
   - sandtone
   - gravel 100mm
   - waterproof 8mm
   - vapor barrier sheet 15mm
   - glass wool insulation 150mm
   - vapor brrier sheet 15mm
   - waterproof 8mm
   - plaster finishing 20mm

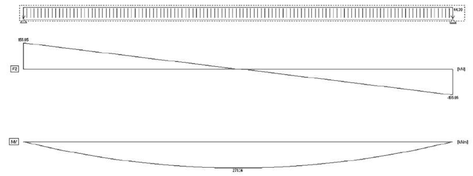
Roof Load(green roof)	Bulk density(kg/m³)	Thickness(mm)	Weight per unit area(KN/m²)
Dead load from slab(structural)	2300	100	**2.3**
Dead load from slab(no structural)			**6.713**
green roof		425	6.37
Waterproof-high density polyethylene	950	8	0.076
Vapor barrier membrane polyethylene sheet	500	15	0.075
polyurethane foam	20	150	0.03
Vapor barrier membrane polyethylene sheet	500	15	0.075
Waterproof-high density polyethylene	950	8	0.076
Plaster finishing	55	20	0.011
Snow load			**1.5**
Roof service load			**0.5**

Primary beam of roof



Load calculation

Primary beam informatic	number	unit
Roof		
L1: interval of beam	5.35	m
L2:Length of beam	7.00	m
H1: height of beam	0.50	m
B1: width of beam	0.40	m
A1: area of beam	0.20	m²



Green Roof Q1=(G1+G2+G3+G4)1.3+Qs+Qr	formula	number	unit
G1: Self load of beam	H1*B1*23KN/m³	4.60	KN/m
G2: load ofsecondary beam		1.04	KN/m
G3: Dead load from slab(str	L1/2*2.3KN/m²	6.15	KN/m
G4: Dead load from slab(no	L1/2*6.713KN/m²	17.96	KN/m
Qs: Snow load	L1/2*1.5KN/m²	4.01	KN/m
Qrs: Roof service load	L1/2*0.5KN/m²	1.34	KN/m
Q1: factored total load on se	Q1=(G1+G2+G3+G4)1.3+Qs+Qr	44.03	KN/m

Check the main reinforcement

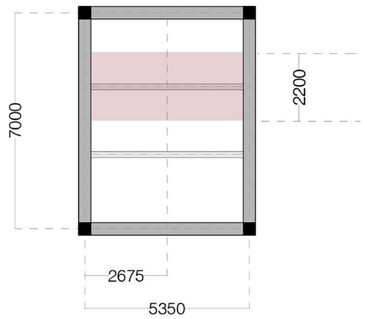
Chose Grade C45/50, so the concrete Grades less than C50, Maximum x/

Check the Moment				
Med max	Max applied moment	Med max=Q1*L²/8	269.65	KNm
Mrd max	Max moment without compression steel	Mrd max=0.168*bd²fck	572.22	KNm
				Mrd max>Med max

Check the shear

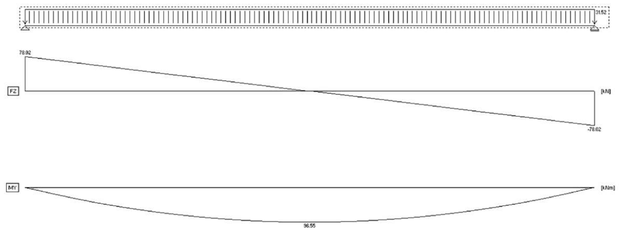
Check the shear			
l	L2/2	3.50	m
d	B1/2	0.20	
Vmax		155.05	KN
Ved	Ved=(L-d)/L*Vmax	146.19	KN
Vn=Vc+Vs			
	Vc=2*fck^-2bwd	233.45	
			Vc>Ved

Secondary beam of roof



Load calculation

Secondary beam information	number	unit
Roof		
L1: interval of beam	2.2	m
L2:Length of beam	5.35 4.95	m
H1：height of beam	0.3	m
B1：width of beam	0.15	m
A1: area of beam	0.045	m²



Green Roof Q1=(G1+G2+G3)1.3+Qs+Qr	formula	number	unit
G1: Self load of beam	H1*B1*23KN/m³	1.035	KN/m
G2: Dead load from slab(structural)	L1*2.3KN/m²	5.06	KN/m
G3: Dead load from slab(non-structural)	L1*6.713KN/m²	14.769	KN/m
Qs: Snow load	L1*1.5KN/m²	3.3	KN/m
Qrs: Roof service load	L1*0.5KN/m²	1.1	KN/m
Q1: factored total load on secondary	Q1=(G1+G2+G3)1.3+Qs+Q	31.523	KN/m

Check the main reinforcement

Chose Grade C45/50, so the concrete Grades less than C50, Maximum x/d=0.45

Check the Moment				
Med max	Max applied moment	Med max=Q1*L²/8	112.782	KNm
Mrd max	Max moment without compression ste	Mrd max=0.168*bd²fck	90.758	KNm
				Mrd max<Med max

Therefore, the compression steel is required

Compressed steel yield		
fyk		500
Xlim		0.45
d'/d	d'/d=(1-fyk/805)Xlim/d	d'/d=0.17
		d'>0.17d=41.65mm
		d'=45mm

Table A: Sectional areas of groups of bars (mm²)

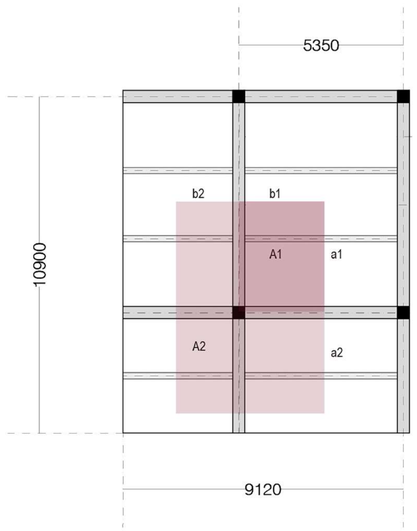
Bar size (mm)	Number of bars 1	2	3	4	5	6	7	8	9	10
6	28.3	56.6	84.8	113	141	170	198	226	255	283
8	50.3	101	151	201	251	302	352	402	452	503
10	78.6	157	236	314	393	471	550	628	707	786
12	113	226	339	452	566	679	792	905	1018	1131
16	201	402	603	804	1005	1207	1408	1609	1810	2011
20	314	628	943	1257	1571	1885	2199	2514	2828	3142
25	491	982	1473	1964	2455	2946	3437	3928	4418	4909
32	804	1609	2413	3217	4022	4826	5630	6435	7239	8044
40	1257	2514	3770	5027	6284	7541	8798	10054	11311	12568

compression bar	3D6	84.800	mm²
fs'	fs'=700(1-(d'/d)(d/Xlim))	414.286	Mpa
As'	As'/bdfck=(Mrd add/bd²fck)/(1-d'/d)	73.560	mm²
tension bar	5D16	1005.000	mm²
As add	As add=As'fs'/(fyk/1.15)	80.802	mm²
As lim	0.233*bdfck/fyk	885	mm²
As total		965.8022857	mm²

Check the shear

Check the shear			
l	L2/2	2.675	m
d	B1/2	0.075	
Vmax		78.02	KN
Ved	Ved=(L-d)/L*Vmax	75.833	KN
Vn=Vc+Vs			
	Vc=2*fck^-2bwd	49.3	Vc<Ved
Vs	Vs=Vrd1-Vc	26.533	KN
Av	6mm*2	12	mm²
fy		6000	psi
S	Av*fy*d/Vs	19.17	cm

Column caculation



a1	3.50
a2	2.05
b1	2.70
b2	1.96
A1	9.45
A2	16.41

Green Roof Q1=(W1+W2+W3+W4)1.3+Ws+Wrs	formula	number	unit
W1:primary beam	H1*B1*b2*23KN/m³+H1*B1*a1*23KN/m	25.12	KN
W2 secondary beam		2.79	KN
W3: Dead load from slab(structural)	A1*2.3KN/m²	21.74	KN
W4: Dead load from slab(non-structural	A1*6.713KN/m²	63.46	KN
Ws: Snow load	A1*1.5KN/m²	14.18	KN
Wrs: Roof service load	A1*0.5KN/m²	4.73	KN
Q1: factored total load on column	Q1=(W1+W2+W3+W4)1.3+Ws+Wrs	165.93	KN

Floor（1,2） Q2=(W4+W5+W6+W7)1.3+1.5Wl	formula	number	unit
W4: primary of beam	H2*B2*23KN/m³*b2+H1*B1*a1*23KN/m	25.12	KN
W5：Secondary beam		2.79	KN
W6: Dead load from slab(structural)	A1*2.3KN/m²	21.74	KN
W7: Dead load from slab(non-structural	A1*0.458KN/m²	4.33	KN
Wl: live load	A1*4KN/m²	37.80	KN
Q2: factored total load on column	Q2=(W4+W5+W6+W7)1.3+1.5Wl	126.87	KN

Roof Q3=(G7+G8+G9+G10)1.3+Qs+Qr	formula	number	unit
W7: primary beam	H2*B2*a2*23KN/m³+H2*B2*b2*23KN/m	18.45	KN
W8: load of secondary beam		6.85	KN
W9: Dead load from slab(structural)	A2*2.3KN/m²	37.75	KN
W10: Dead load from slab(non-structura	A2*0.354KN/m²	5.81	KN
Ws: Snow load	A2*1.5KN/m²	24.62	KN
Wrs: Roof service load	A2*0.5KN/m²	8.21	KN
Q3: factored total load on column	Q1=(W7+W8+W9+W10)1.3+Ws+Wrs	122.34	KN

Total	Q1+2Q2+Q3	542.01	KN

SW=d*v=d*A*h	density(KN/m³)	A(m²)	h(m)	SW(KN)
	23.00	0.16	11.00	40.48

Ned=Q+SW	Q(KN)	SW(KN)	Ned(KN)
	542.00	40.48	582.48

Nrd

Nrd=A*fcd*0.8	A	fcd=fcu(C45/50)/rm	Nrd(KN)
	0.16	30.00	3840.00
			Ned<Nrd

Check the blucking of column

λ=L0/i	i=(j/A)	L0=L0.8	λ
	c/12^-2=0.11	3.60	32.73

Conclusion

Primary beam	0.4*0.5	C45/50
Secondary beam	0.15*0.3	C45/50
Column	0.4*0.4	C45/50

POLITECNICO MILANO 1863

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