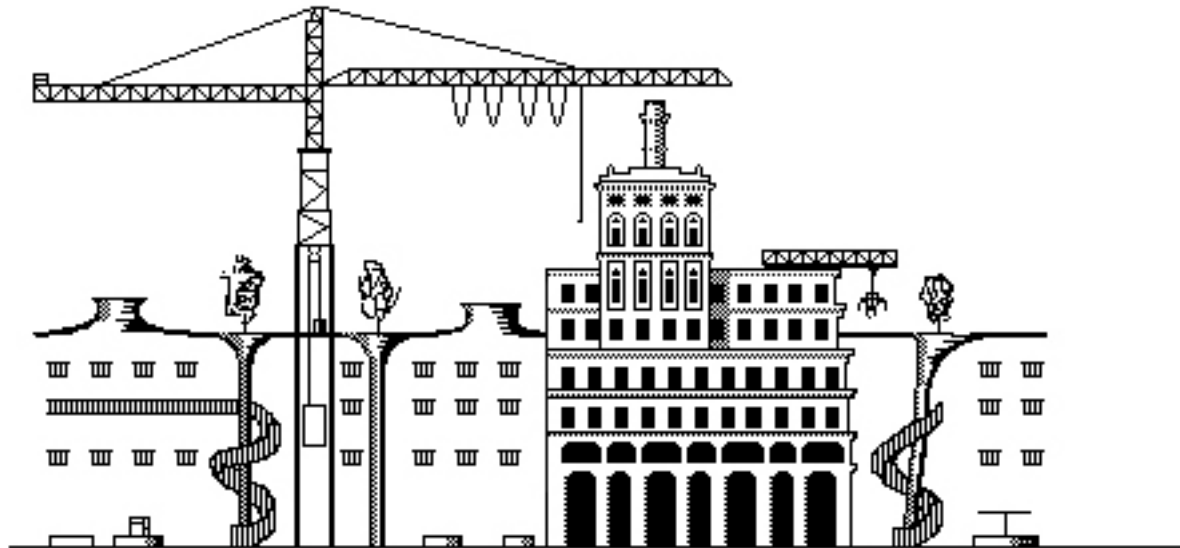


# HENNEBIQUE SILOS

## HYBRID PREFABRICATED SYSTEM FOR FABRIC FORMWORK FOR CONCRETE SHELLS

The renovation of the Hennebique silos building.



P5

Architectural Engineering

Tutors:

Ir. A. Snijders (Architecture)

Dr. -Ir. M. Bilow (Research & Building Technology)

Architectural Engineering

Giuseppe Campo-Antico

4454847

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1. context

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2. existing situation

| restrictions

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3. concept

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4. research

| construction process

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5. design

| circulation

| material concept

| steel additions

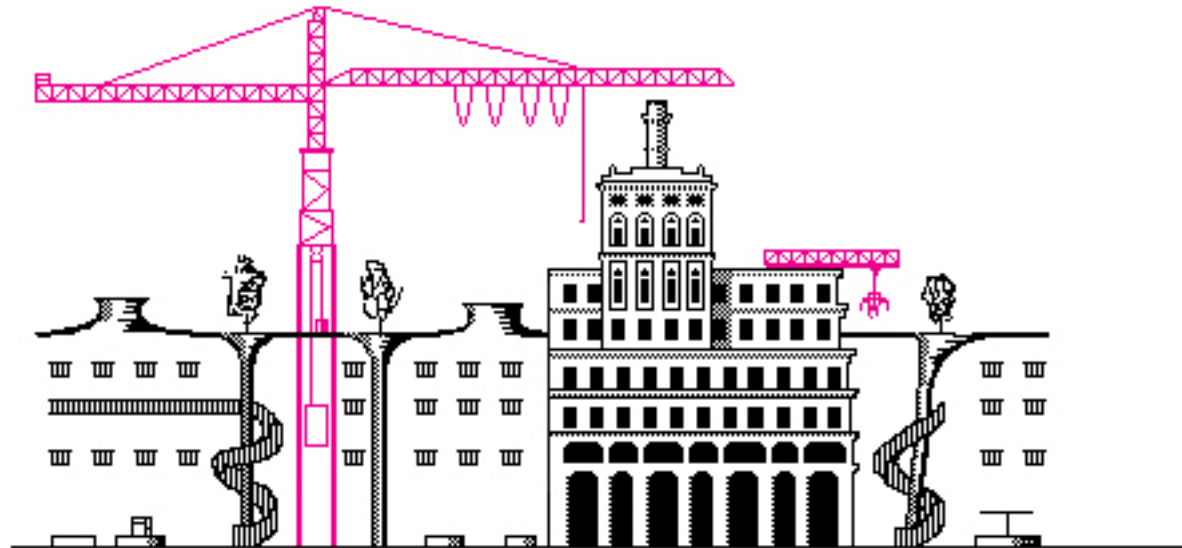
| concrete demolition

| office

| market

| hotel

# 1.CONTEXT





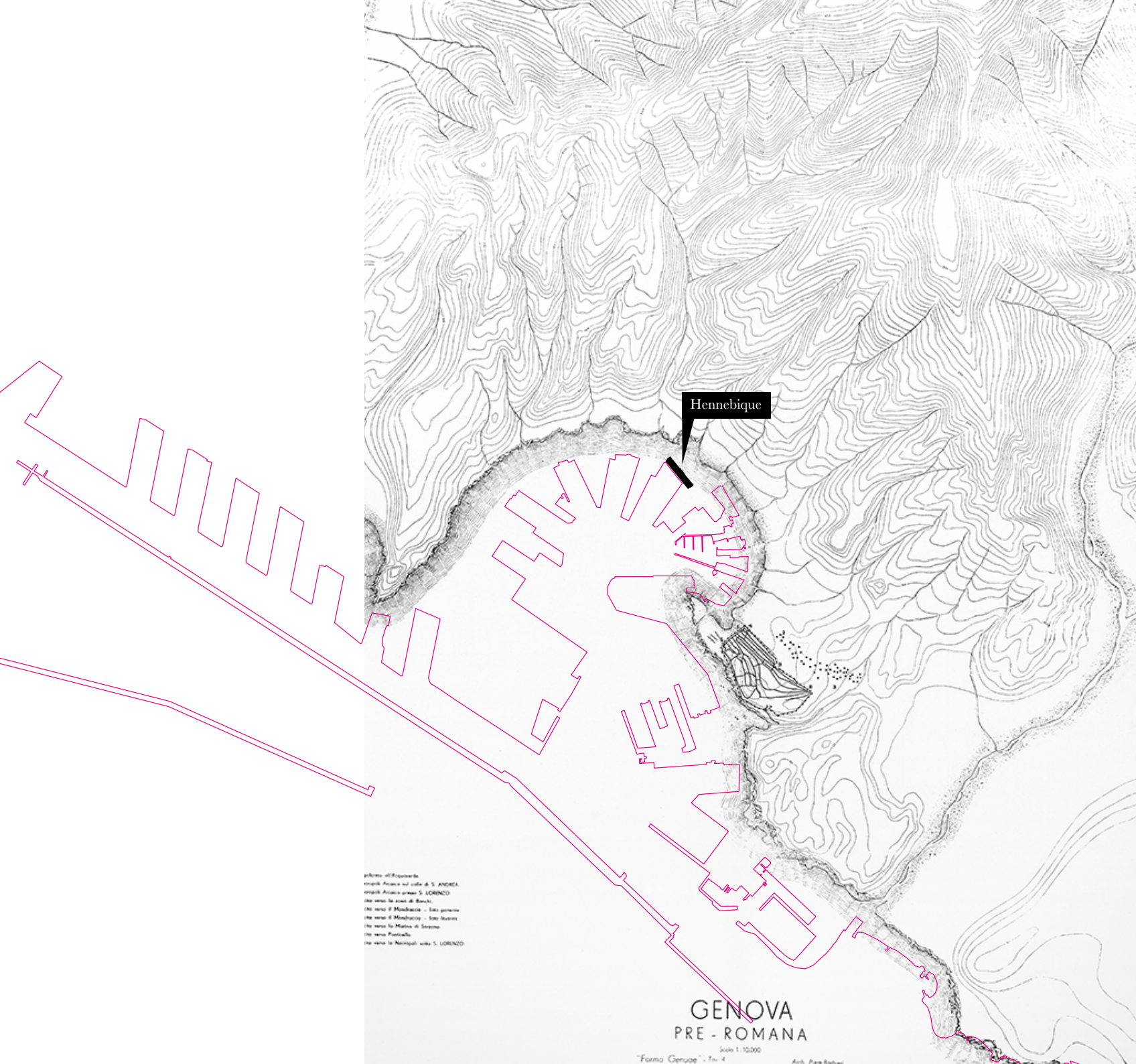
Genova



Hennebique

GENOVA: ZERO

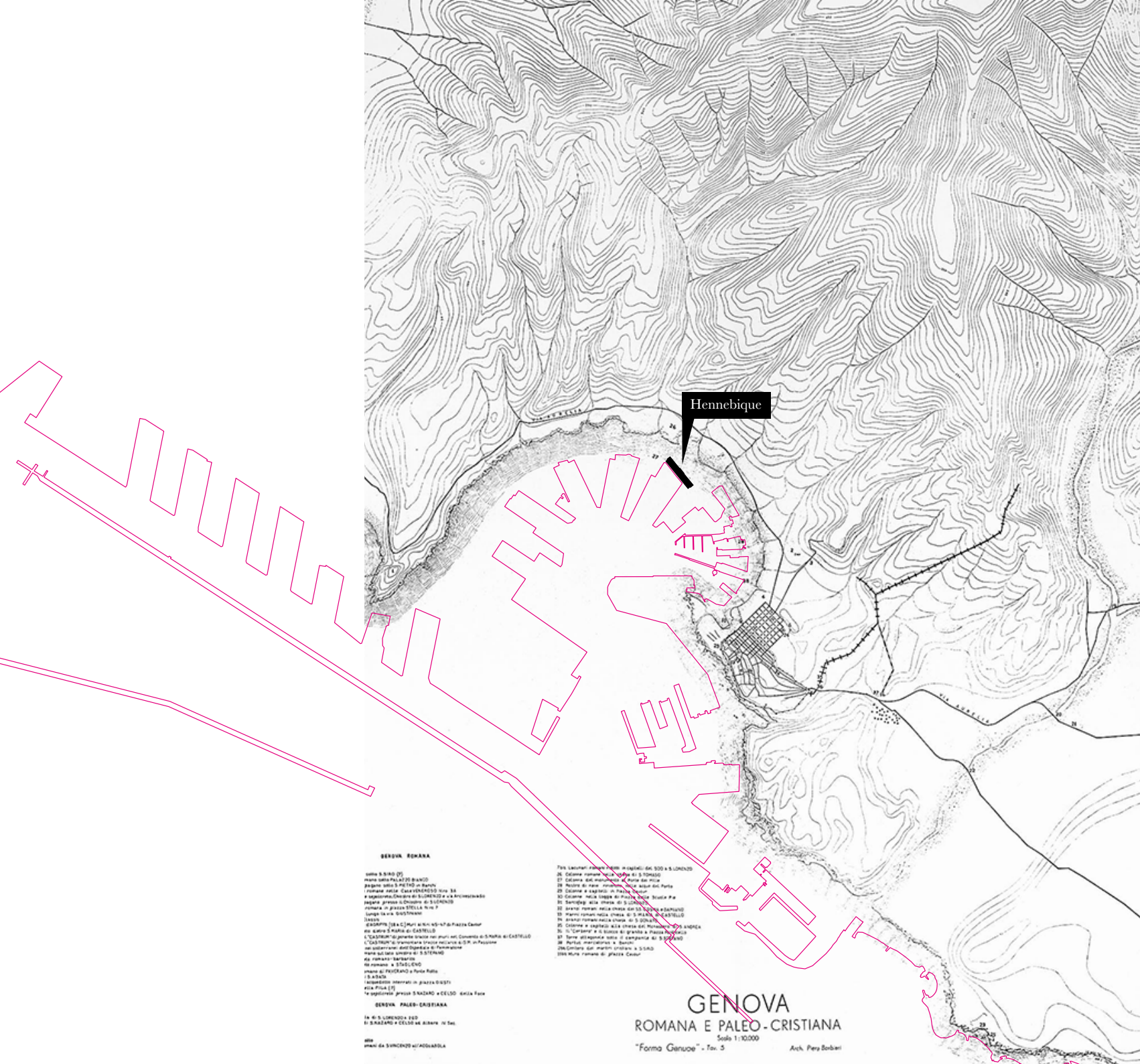
Scala 1:10.000



Hennebique

profilo all'Alqueru  
tempio Arco sul colle di S. ANDREA  
tempio Arco presso S. LORENZO  
che verso la zona di Barchi  
che verso il Mardaccio - lato interno  
che verso il Mardaccio - lato esterno  
che verso la Marina di S. Stefano  
che verso Fontanello  
che verso la Marina di S. LORENZO

# GENOVA PRE-ROMANA



Hennebique

**GENOVA ROMANA**

- 10a S. SIVIO (1)
- 11a S. SIVIO (2)
- 12a S. SIVIO (3)
- 13a S. SIVIO (4)
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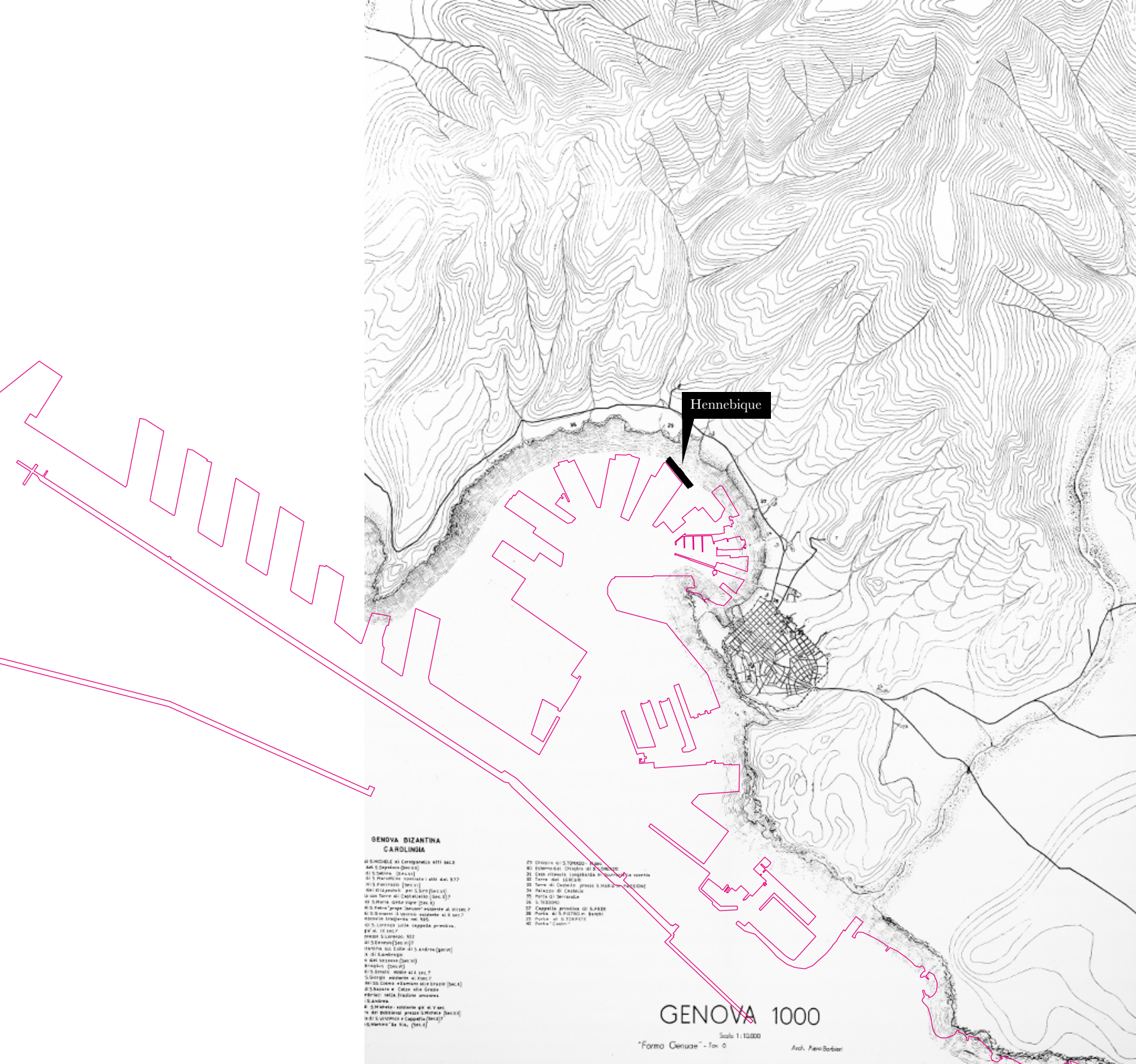
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- 200a S. LORENZO (200)

**GENOVA  
ROMANA E PALEO-CRISTIANA**

Scala 1:10.000  
"Forma Genuae" - Tav. 5  
Arch. Piero Bobbio



Hennebique

### GENOVA BIZANTINA CAROLINGIA

01 BIVOLLE di CANTERALE 1171 SACI  
02 S. SIMEONE (Sec. VI)  
03 S. SIMEONE (Sec. VI)  
04 S. MARCO di S. MARCO (Sec. VI)  
05 S. MARCO di S. MARCO (Sec. VI)  
06 S. MARCO di S. MARCO (Sec. VI)  
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## GENOVA 1000

Scala 1:10.000

"Forma Genuesa" - Tom. 0

Arch. Flavio Barbieri





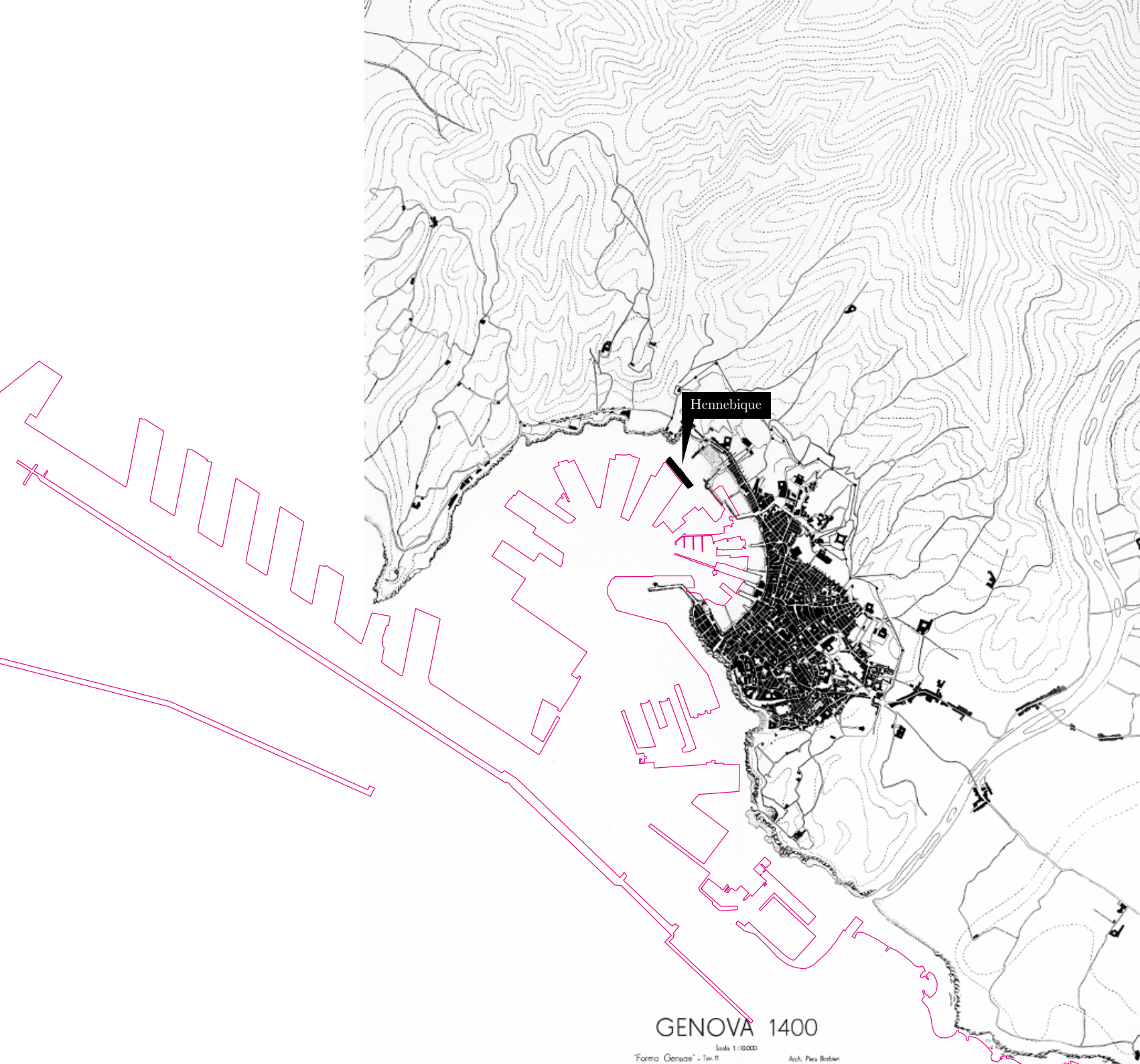
Hennebique

GENOVA 1200

Scala 1:10,000

"Fama Genova" - Tav. 8

Arch. Piero Barbieri



Hennebique

GENOVA 1400

Scala 1:10000

Forma Genova - Tav. II

Arch. Para Bellini



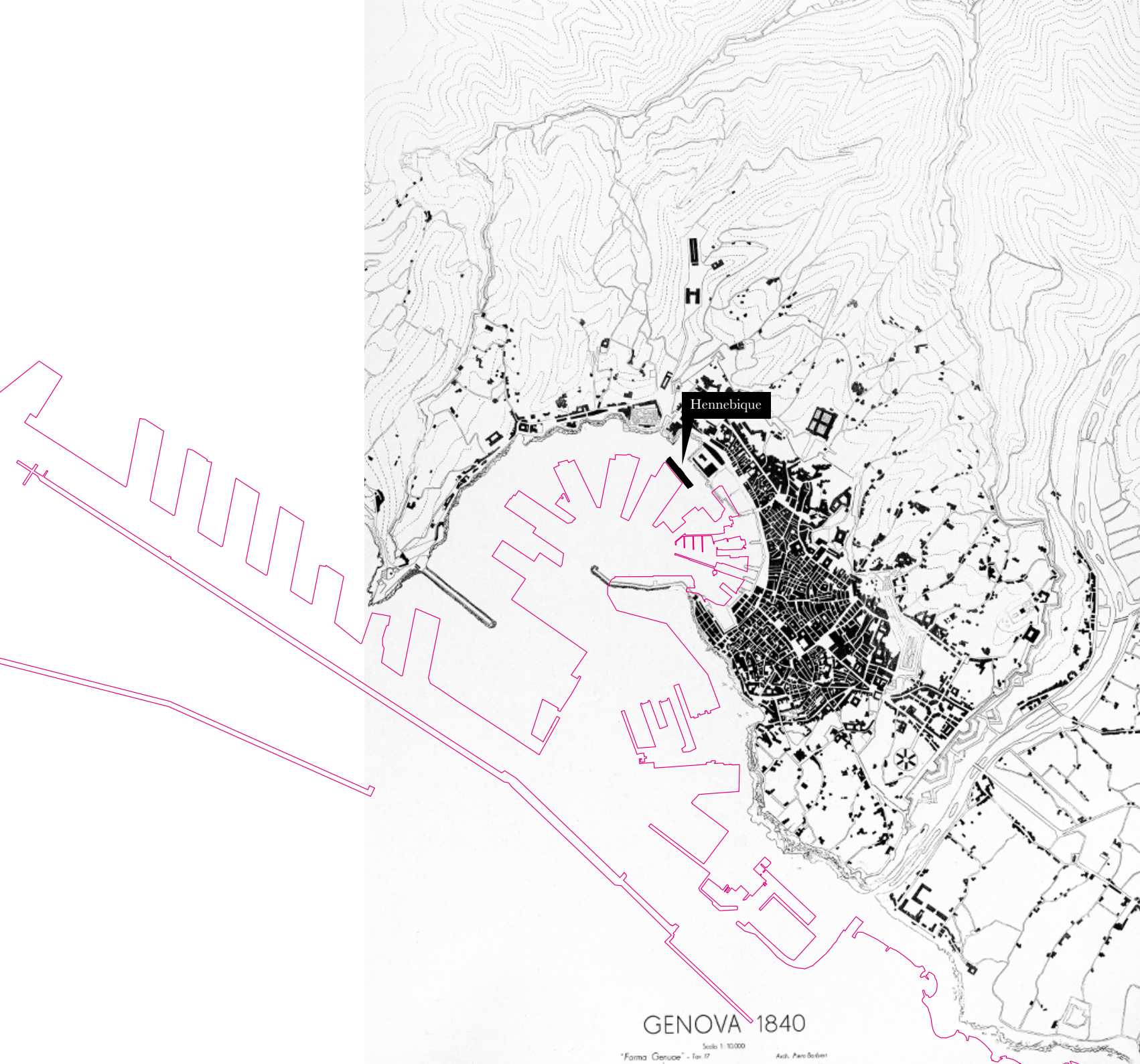
Hennebique

GENOVA 1656

Scala 1:10.000

"Forma Genuae" - Tav. 14

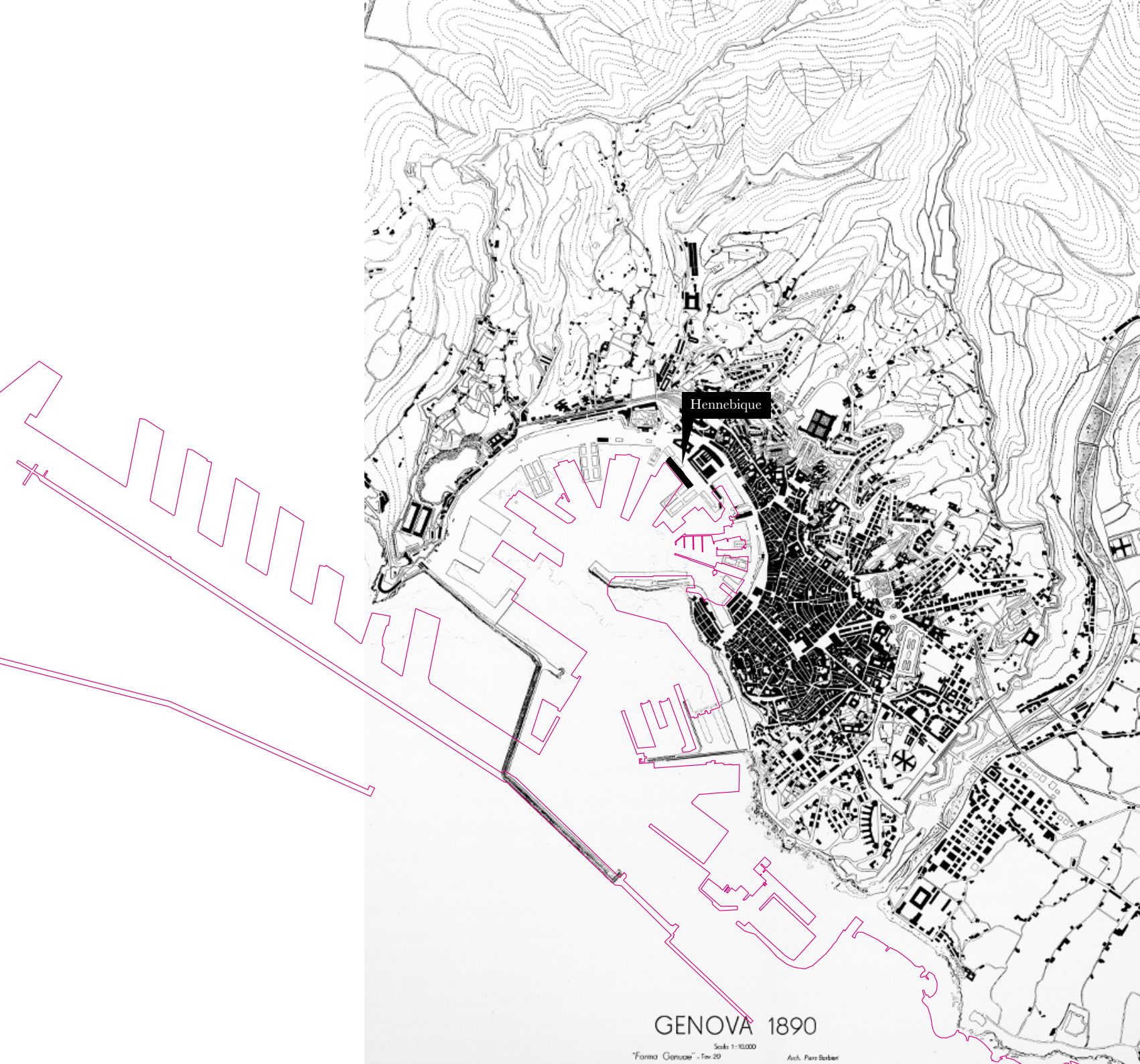
Arch. Pao. Barbieri



Hennebique

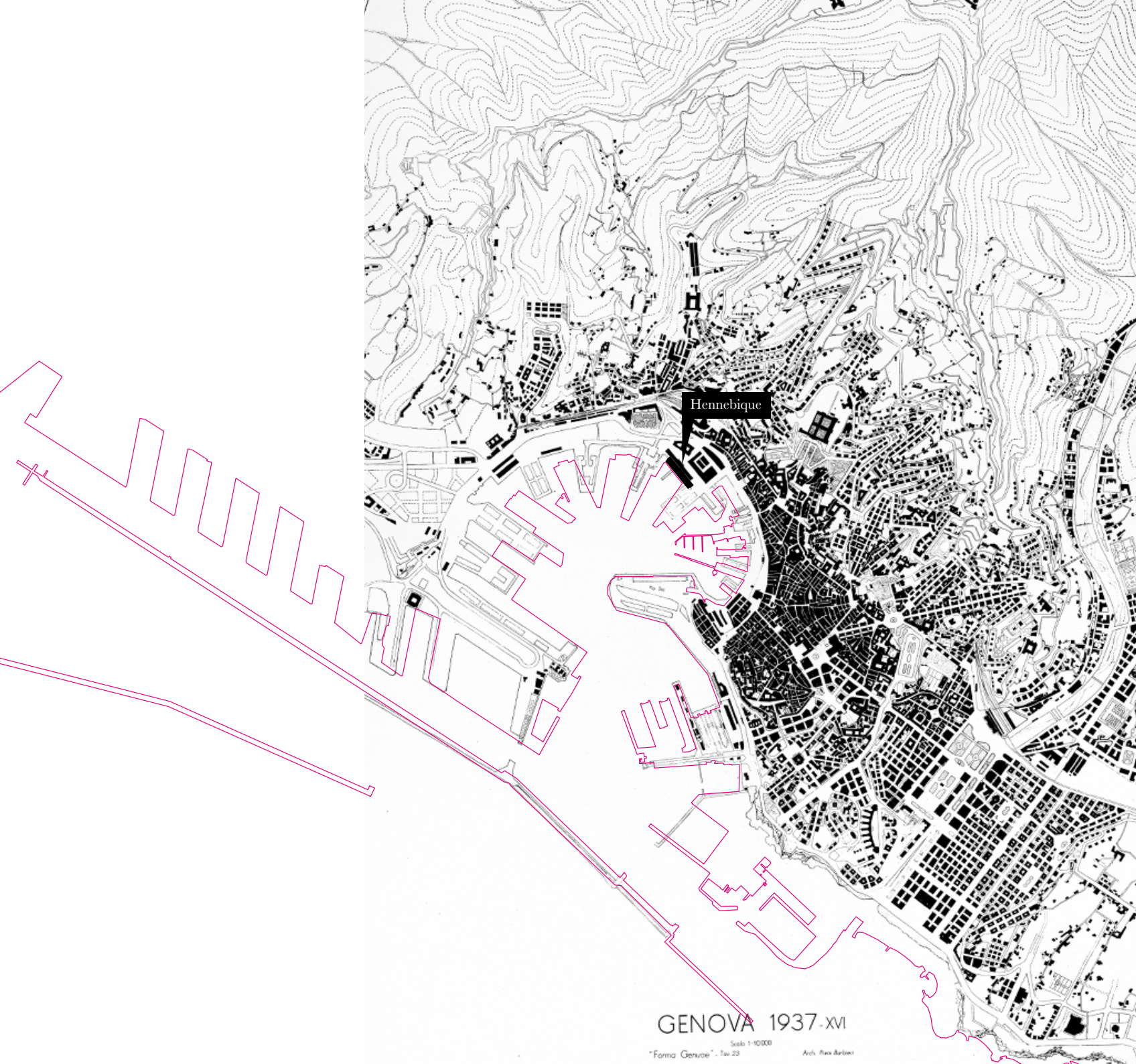
GENOVA 1840

Scale 1:10,000  
"Forma Genuae" - Tav. 17  
Aut. P.uro. B. d. v. n. 1

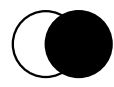


GENOVA 1890

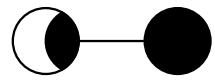
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"Forma Genova" - Tav. 20  
Arch. Piero Barbieri



Origin



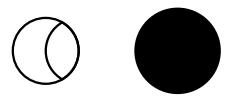
Expansion 1800 - 1850



Old port abandonment 1960 - 1980



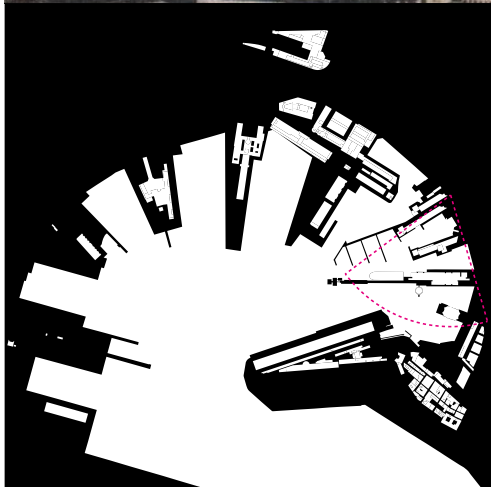
Waterfront refurbishment 1970 - 1990



GENOVA 1937-XVI

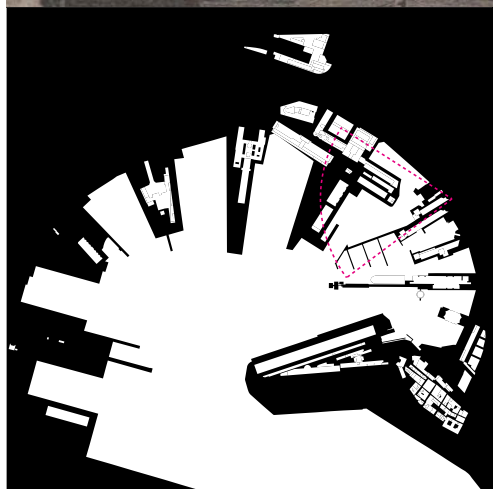
Scala 1:10000  
"Fama Genova" - Tav.25 Arch. Piva Barbieri

Genova - Panorama e Porto



Porto Antico, 1950

GENOVA - Darsena e antico Bacino

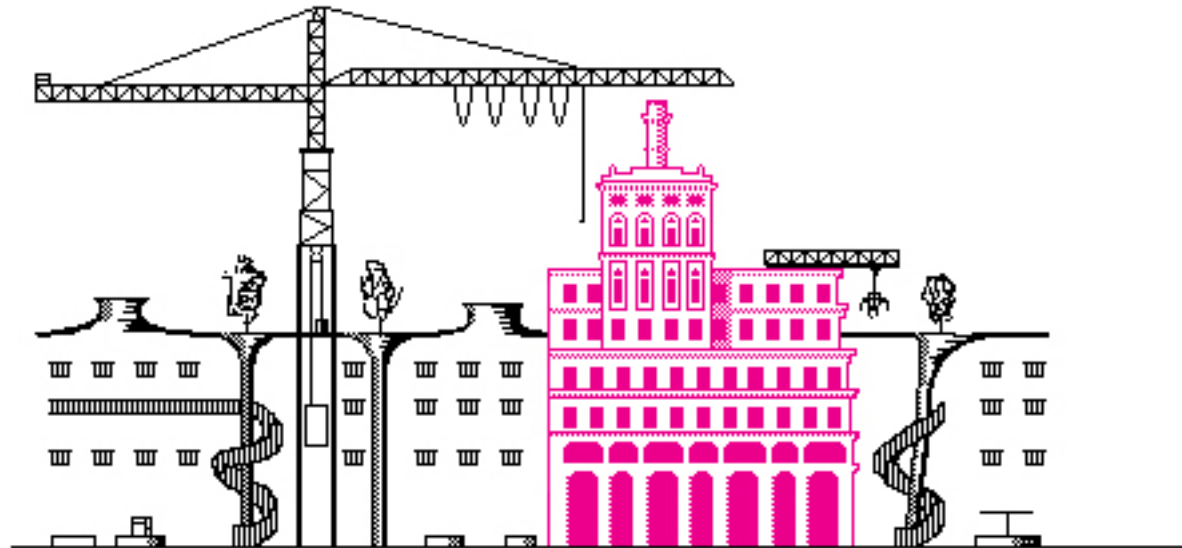


Ponte Parodi, 1910





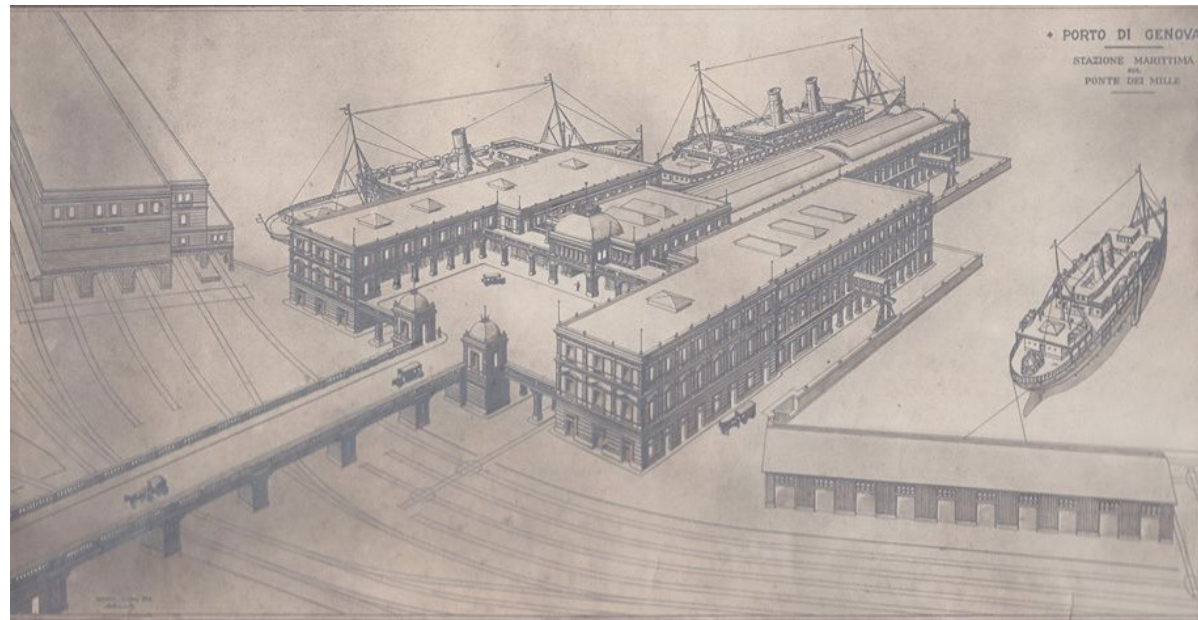
## 2.EXISTING SITUATION



LANDMARK

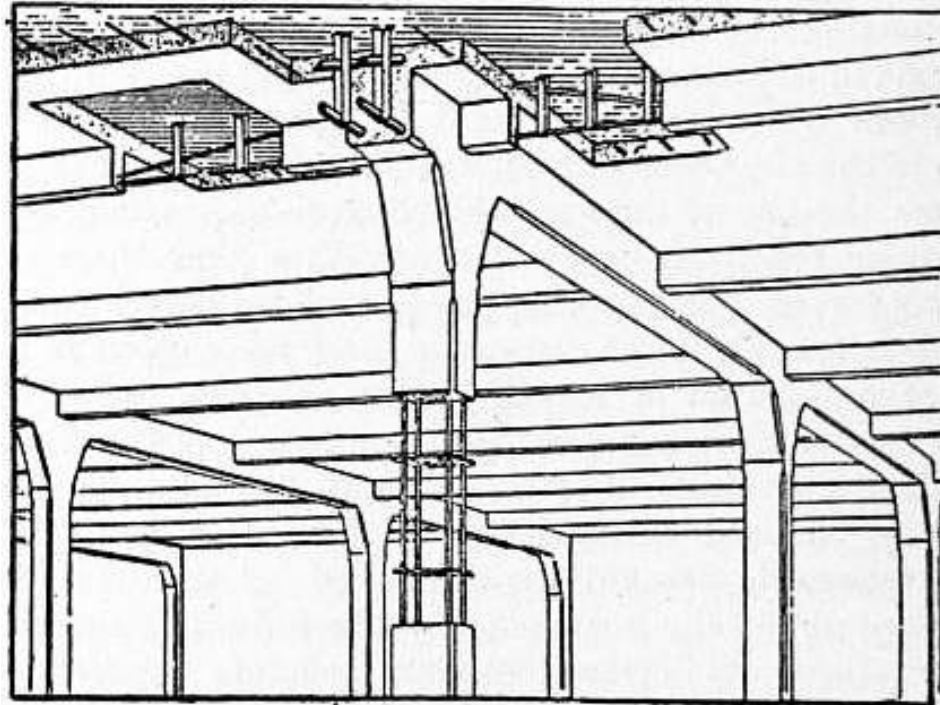


Postcard, 1918



Maritime Station project

INNOVATIVE CONSTRUCTION

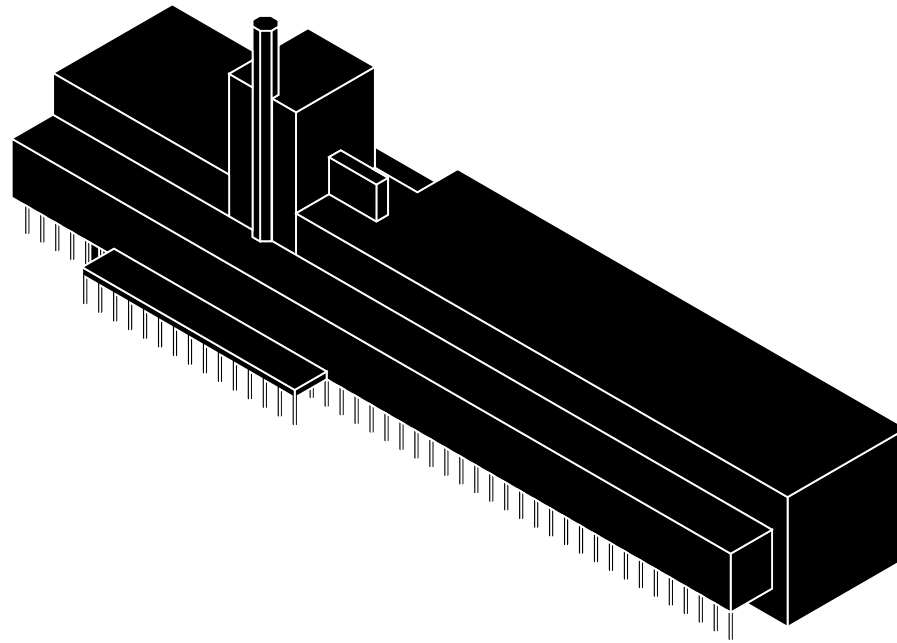


Hennebique construction method



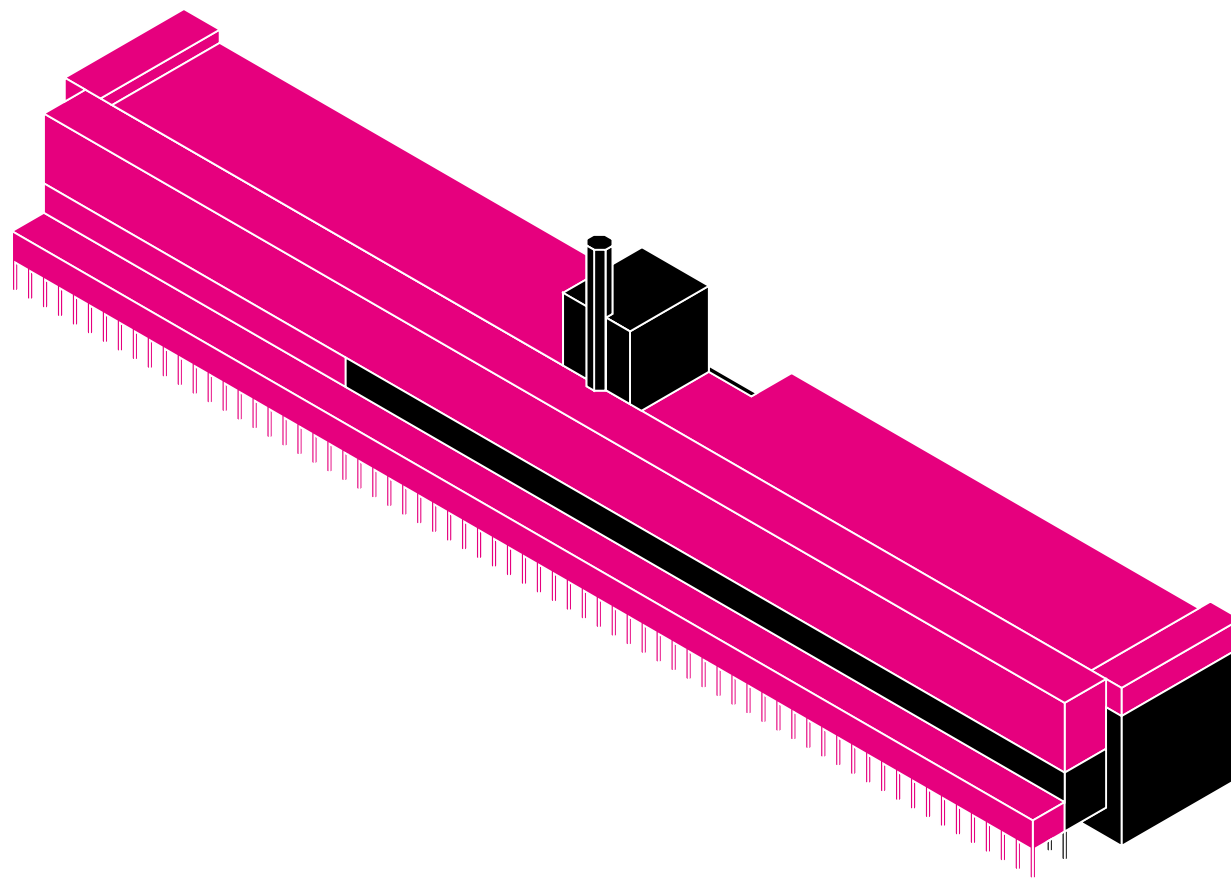
View from the first floor next to the sea

# HISTORICAL PHASES



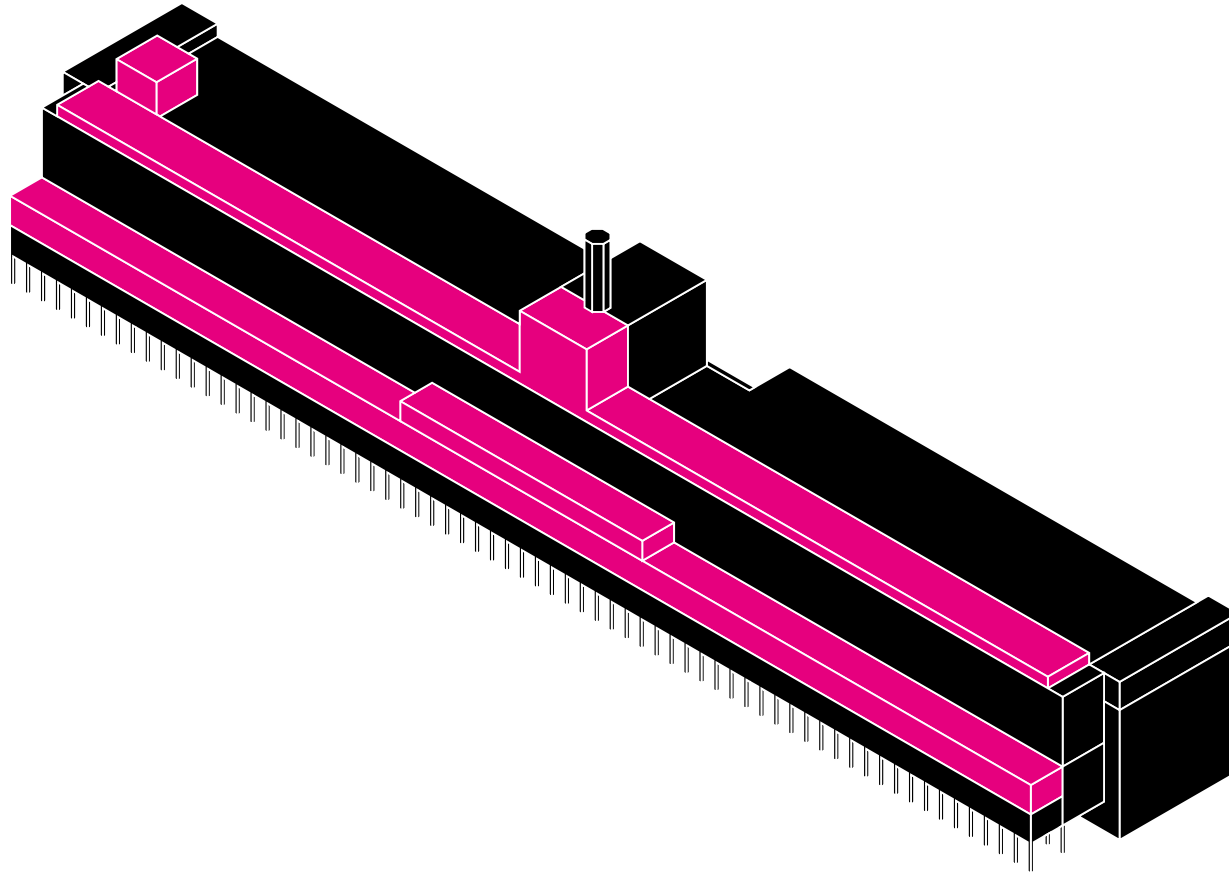
1901

HISTORICAL PHASES



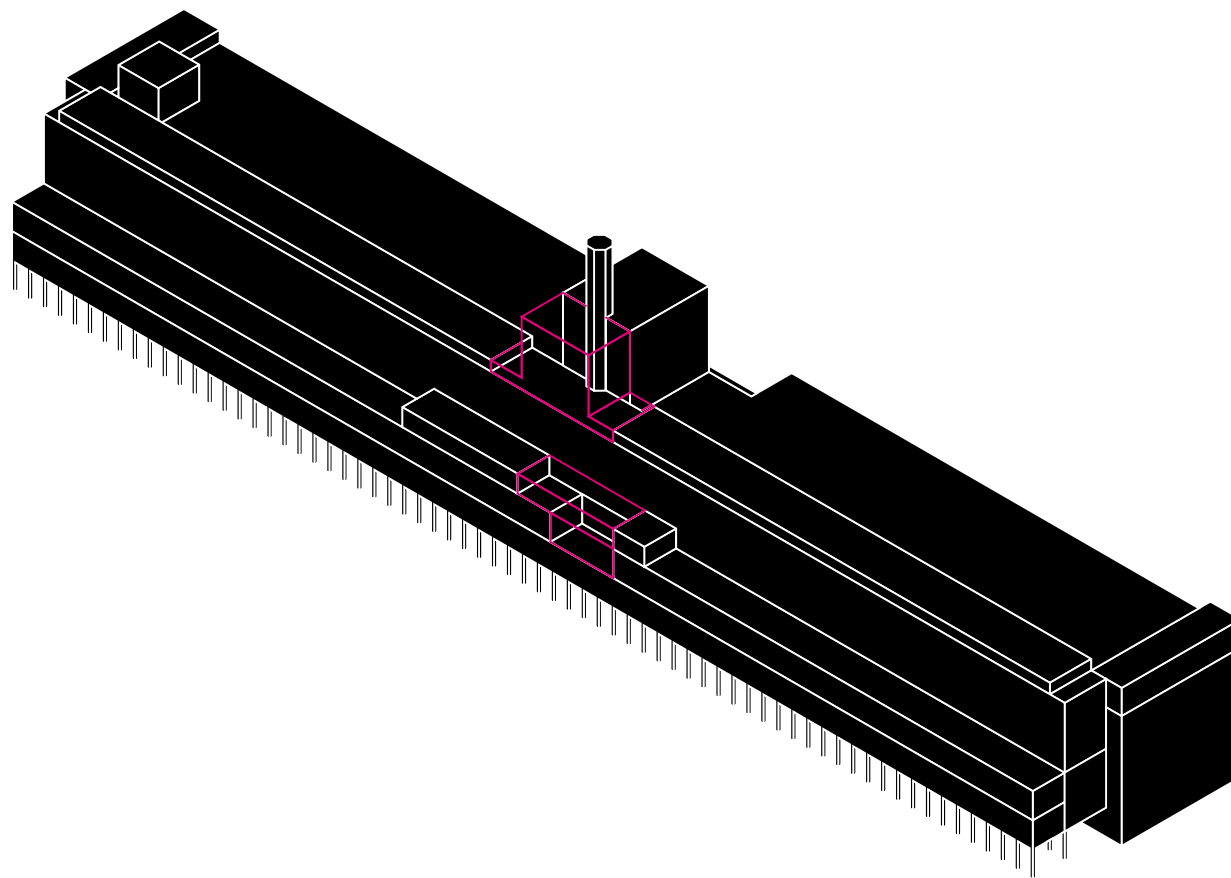
1906

HISTORICAL PHASES



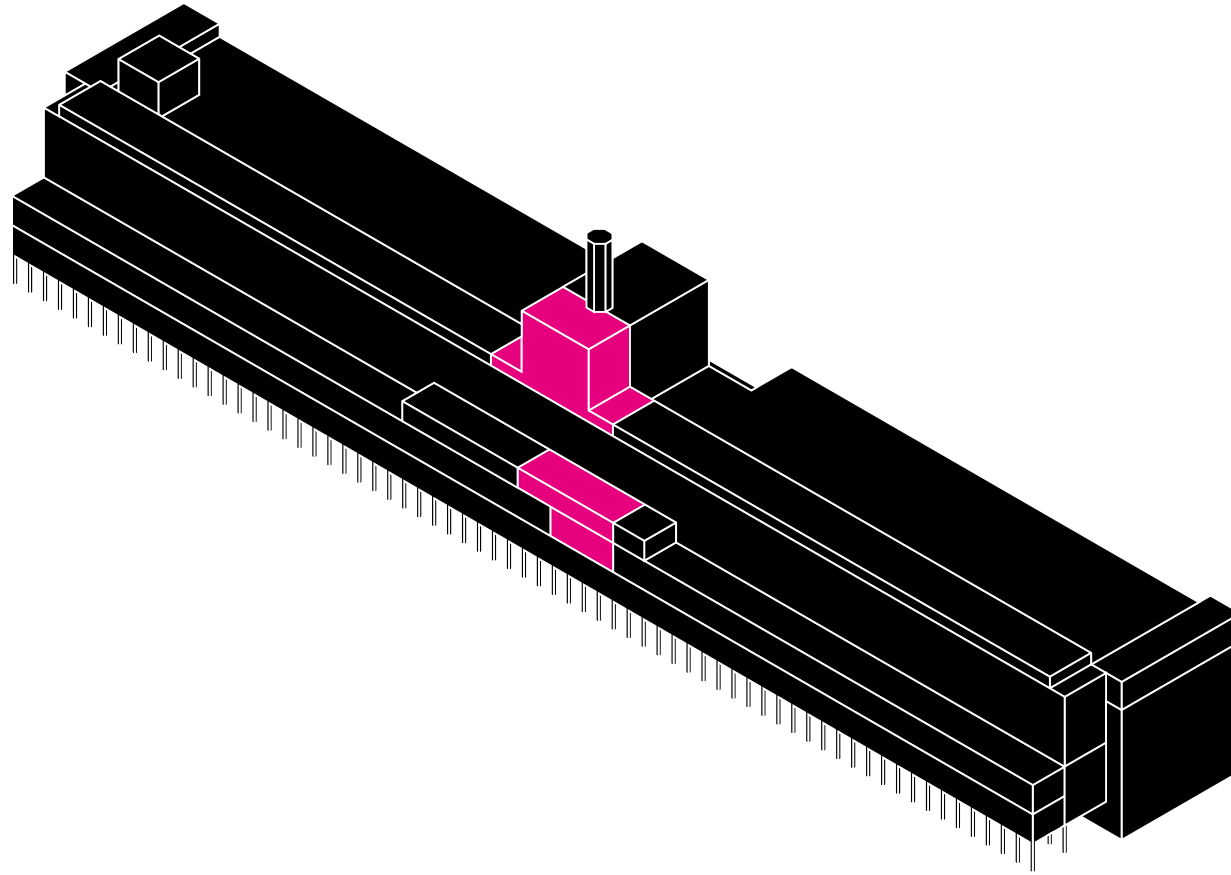
1924

HISTORICAL PHASES

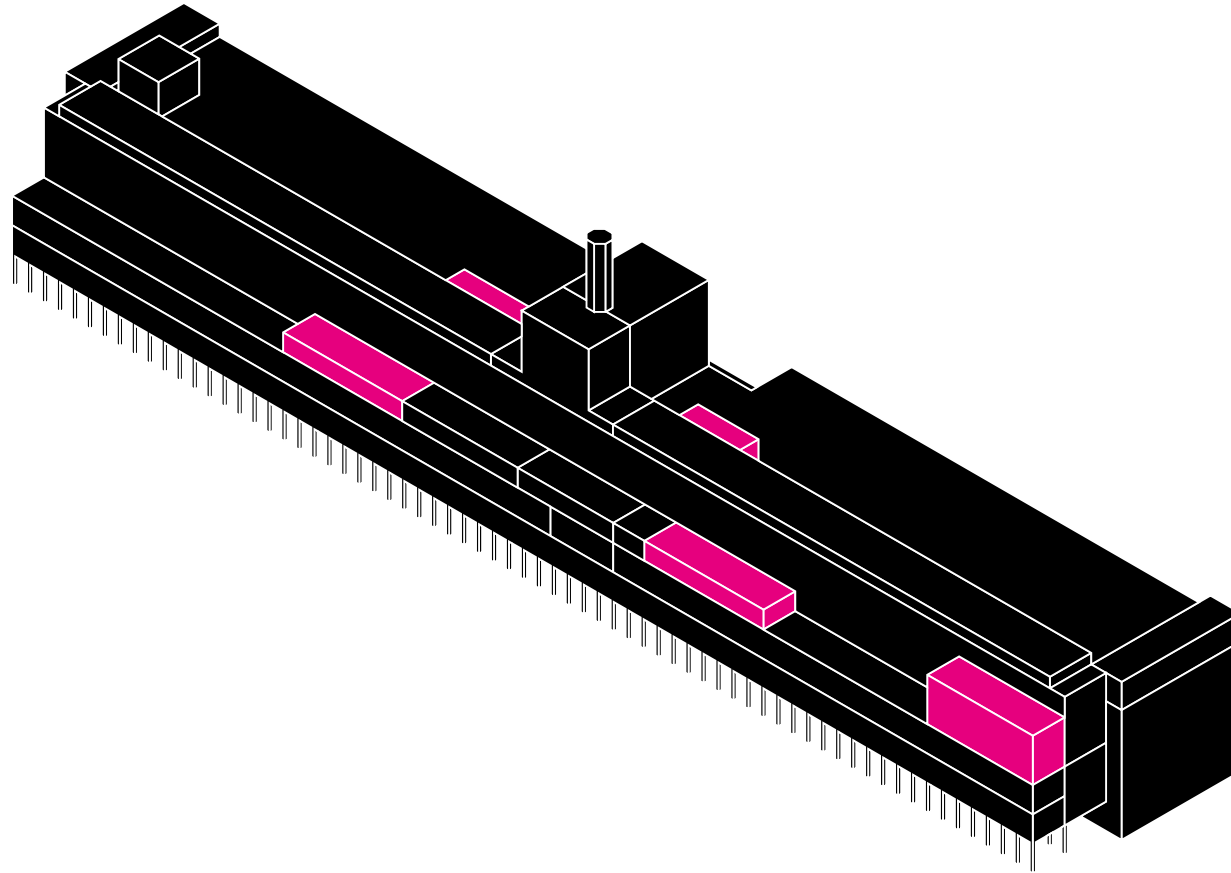




HISTORICAL PHASES



HISTORICAL PHASES



after 1945



Hennebique silos building

SITE | UNEXPRESSED POTENTIAL



SITE | BUFFER ZONE



SITE | VACANT BUILDINGS





The two maritime stations, 1967



Demolished silos building, 2002





UN Studio, 2001  
Winning proposal



MVRDV, 2001



Hennebique silos building

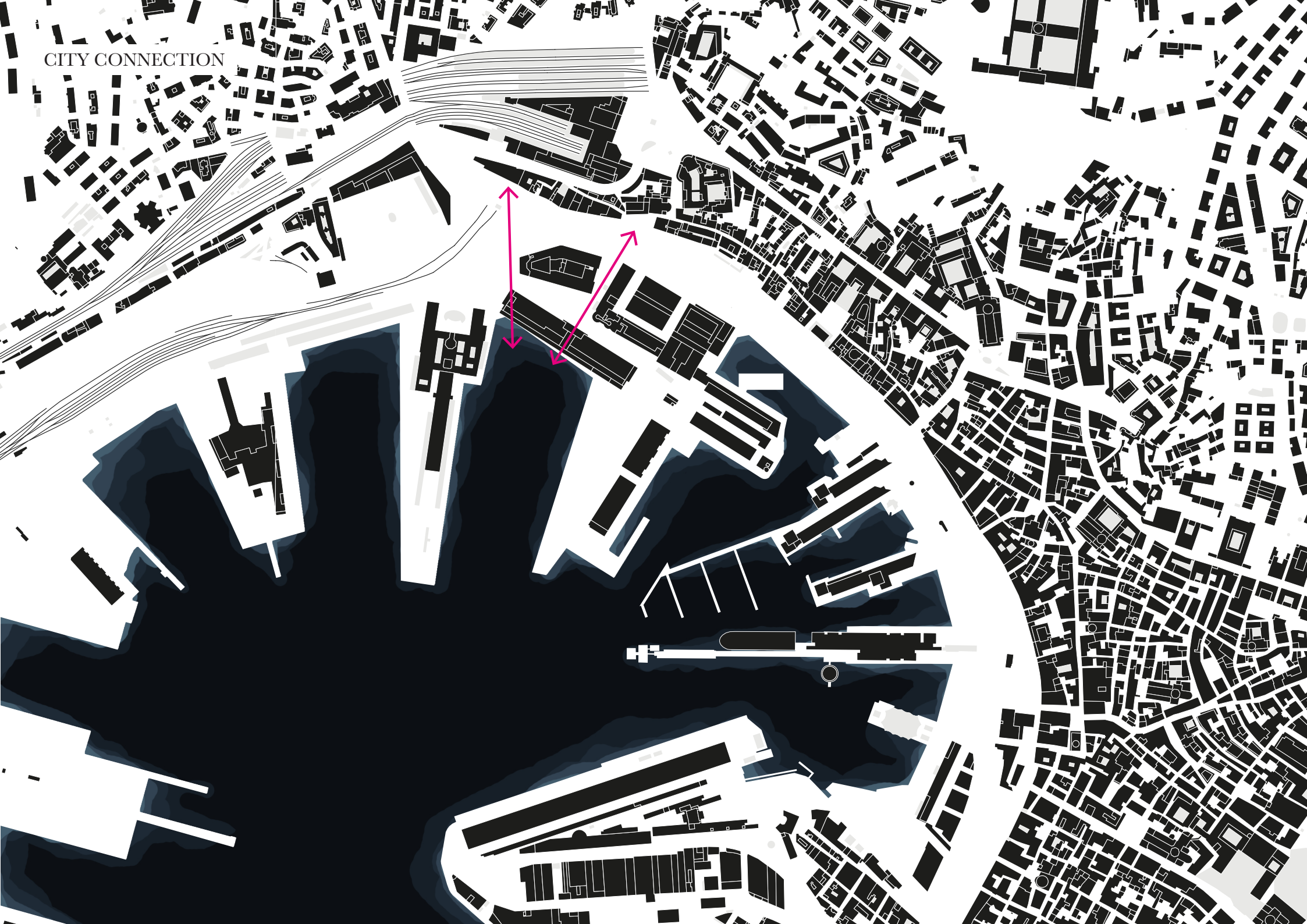


Hennebique silos building

WATERFRONT CONNECTION



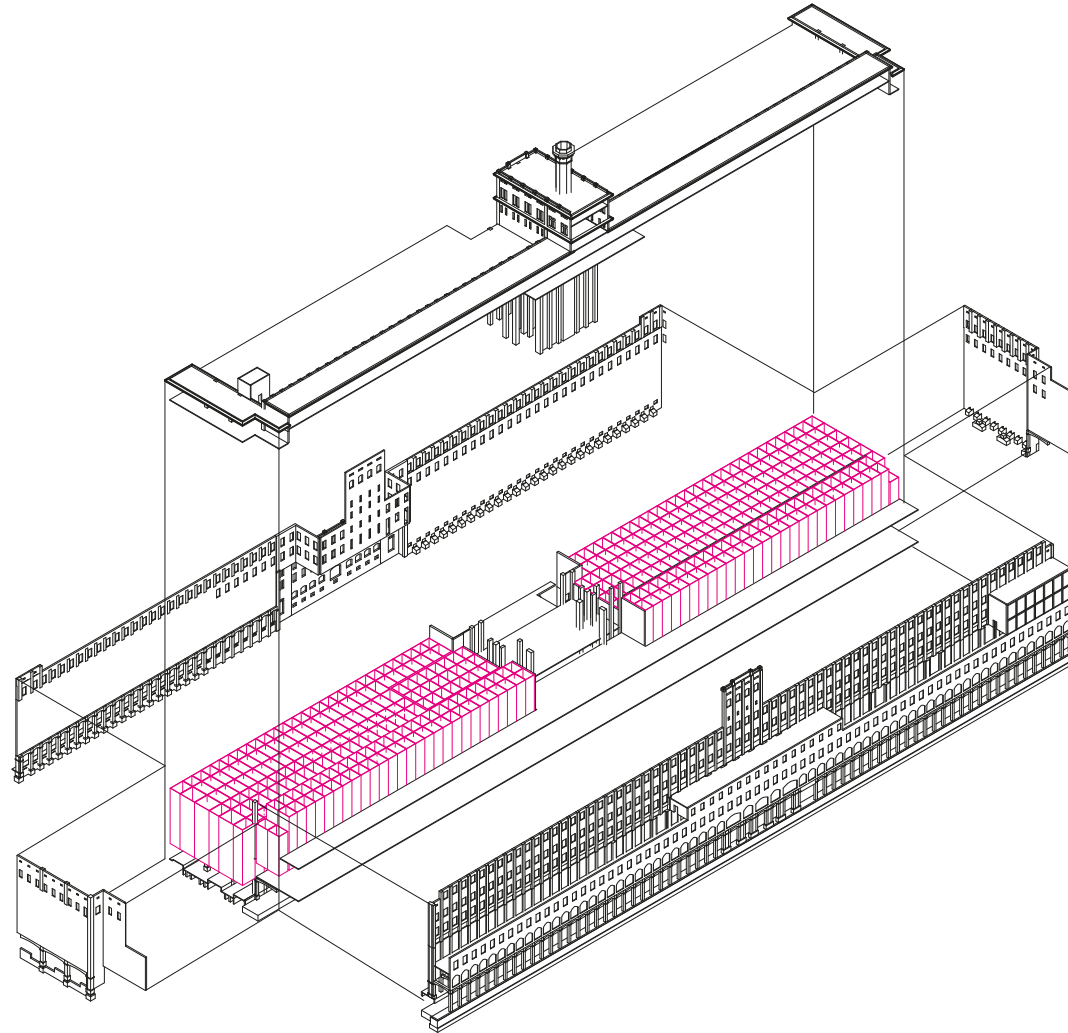
CITY CONNECTION



# RESTRICTIONS

## BUILDING HERITAGE COMMISSION

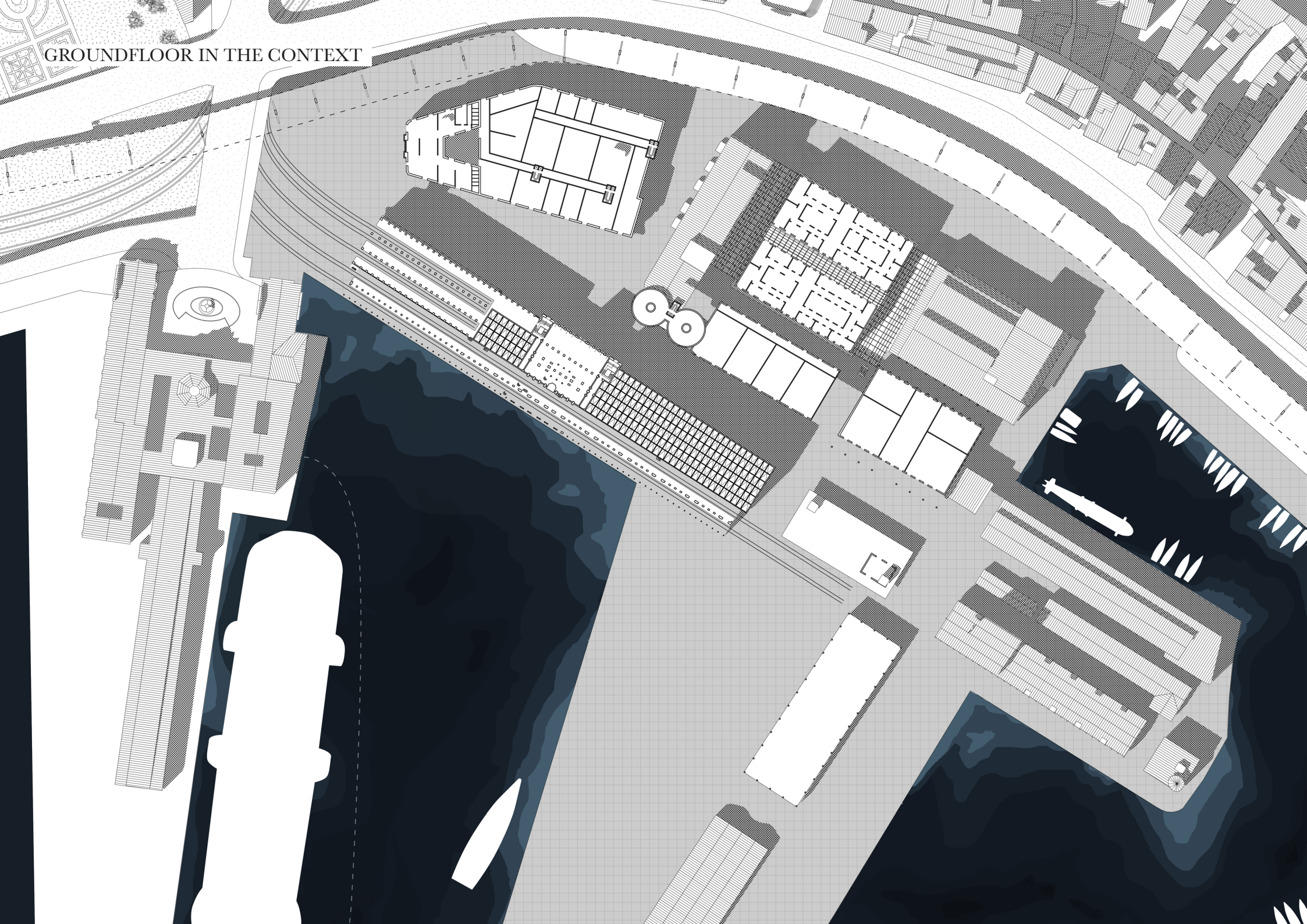
- maintain the facade on the sea side
- keep the central tower as a main characterizing element of the construction
- keep the intervention confined within the existing volume of the building



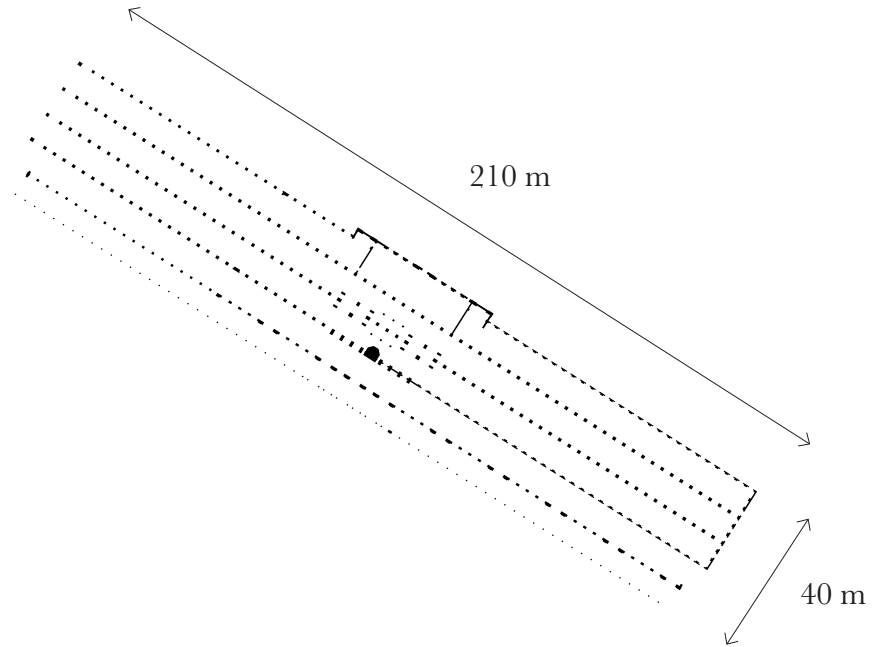
## MUNICIPALITY

- public functions must be 51% of the total surface
- proposed main functions:
  - public services
  - hotel
  - market
- proposed secondary functions:
  - private services
  - shops/retail
  - local community spaces (max 10%)
  - parkings (not necessarily within the plot)

GROUND FLOOR IN THE CONTEXT



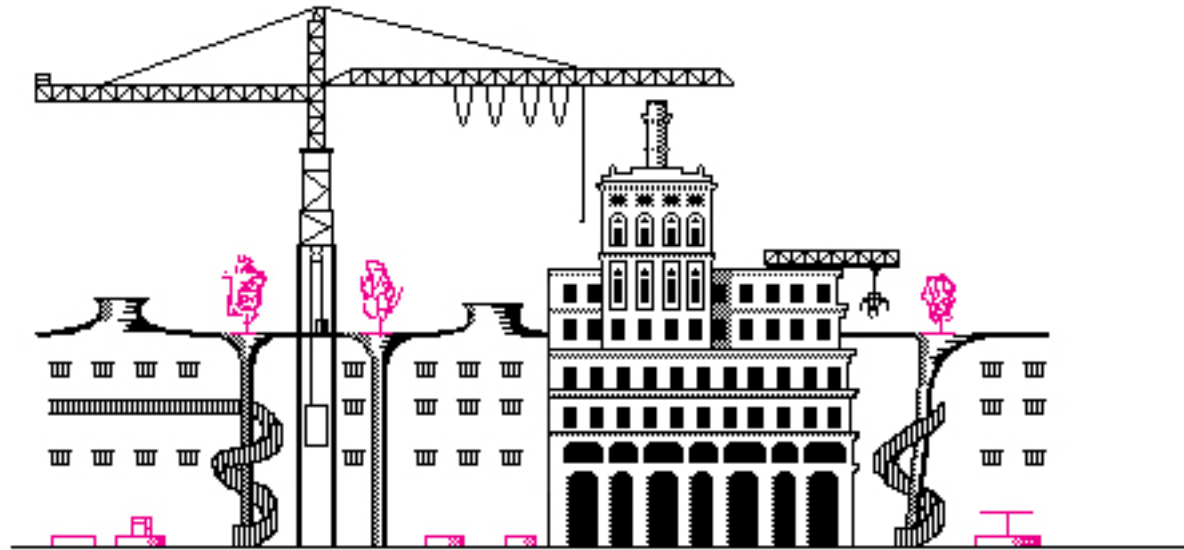
# STRUCTURAL LAYOUT





How is it possible to push the boundaries of architecture, while maintaining the greatest possible degree of feasibility and complying with the restrictions?

### 3.CONCEPT





Terrazze di marmo  
Ignazio Gardella Sr.  
1835 - 1886



Terrazze di marmo  
Ignazio Gardella Sr.  
1835 - 1886

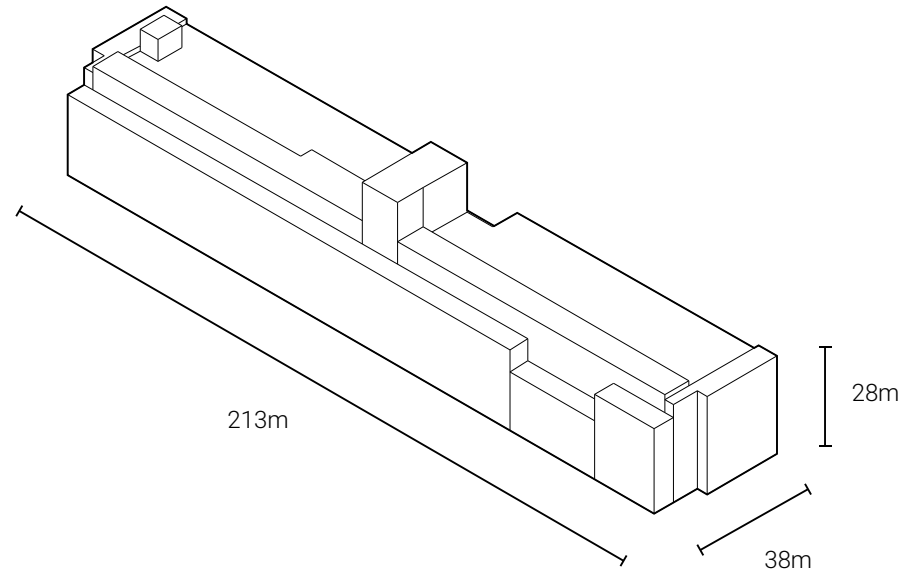
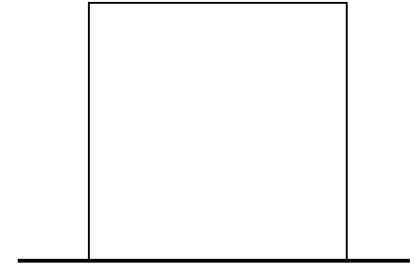
CONCEPT



CONCEPT

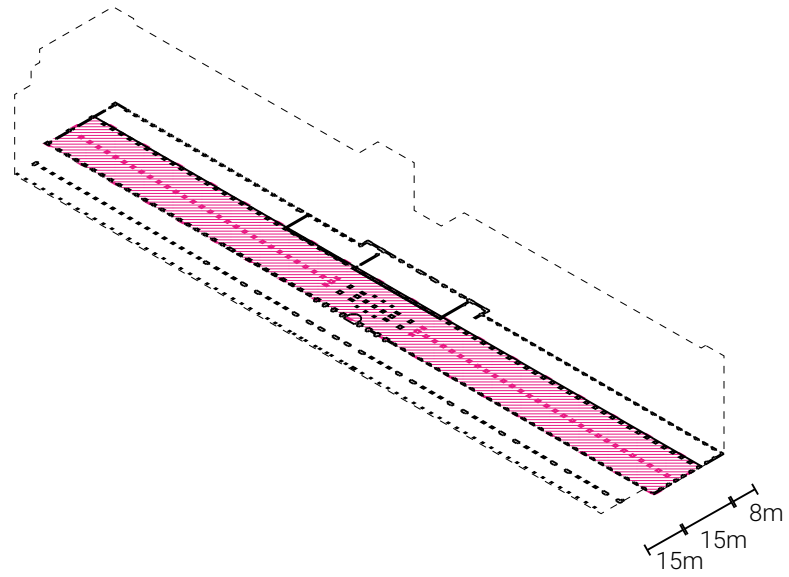
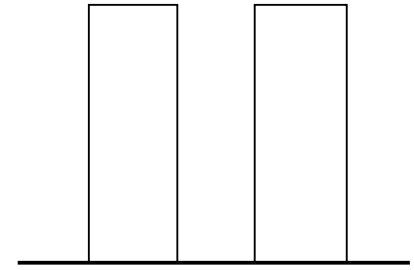


STEP 0



Existing situation

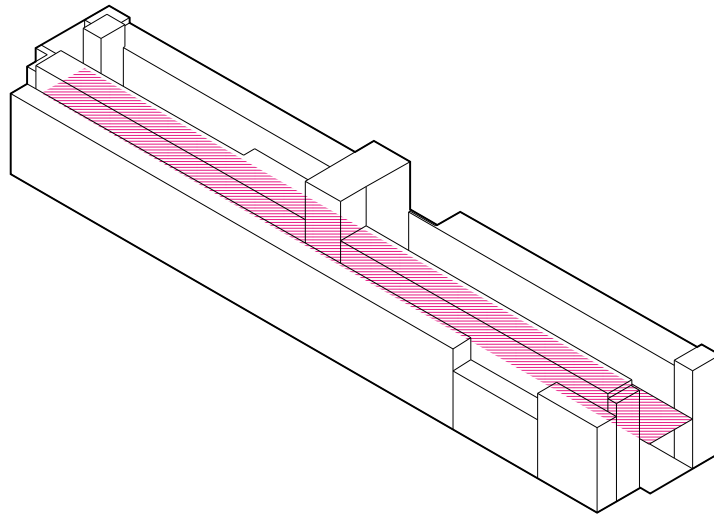
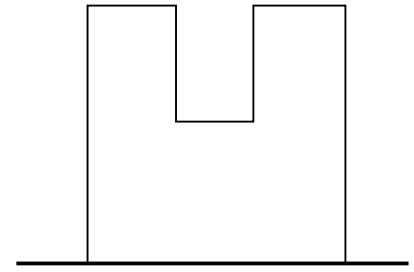
STEP 1



Split

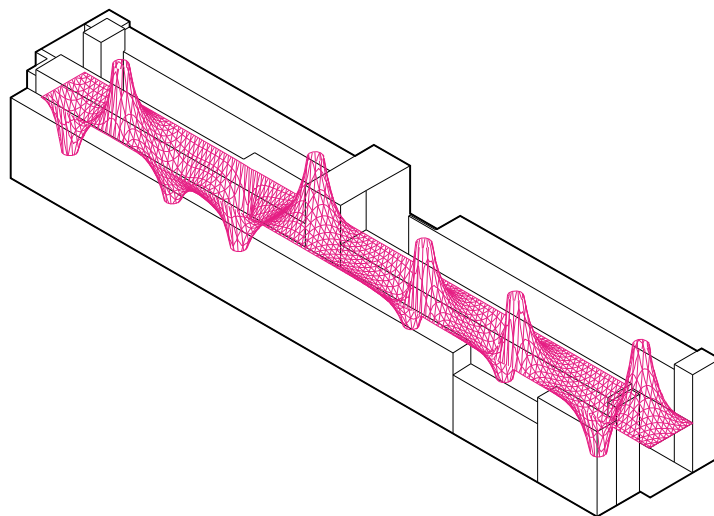
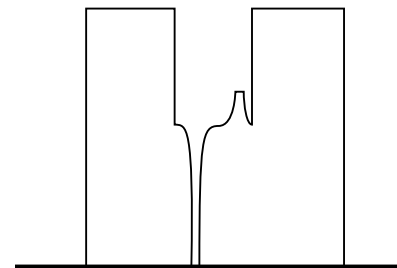


STEP 2



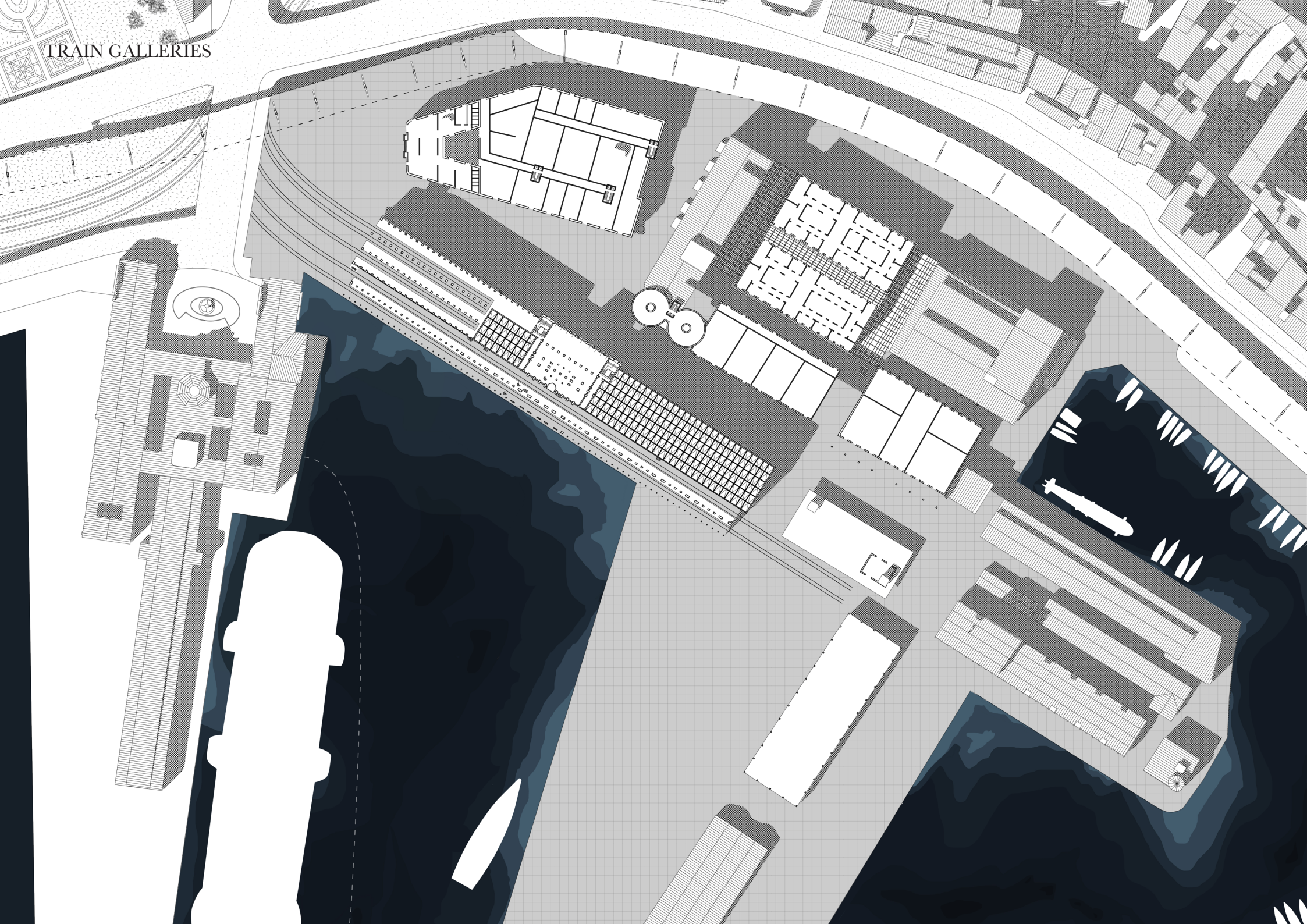
Elevate

STEP 3

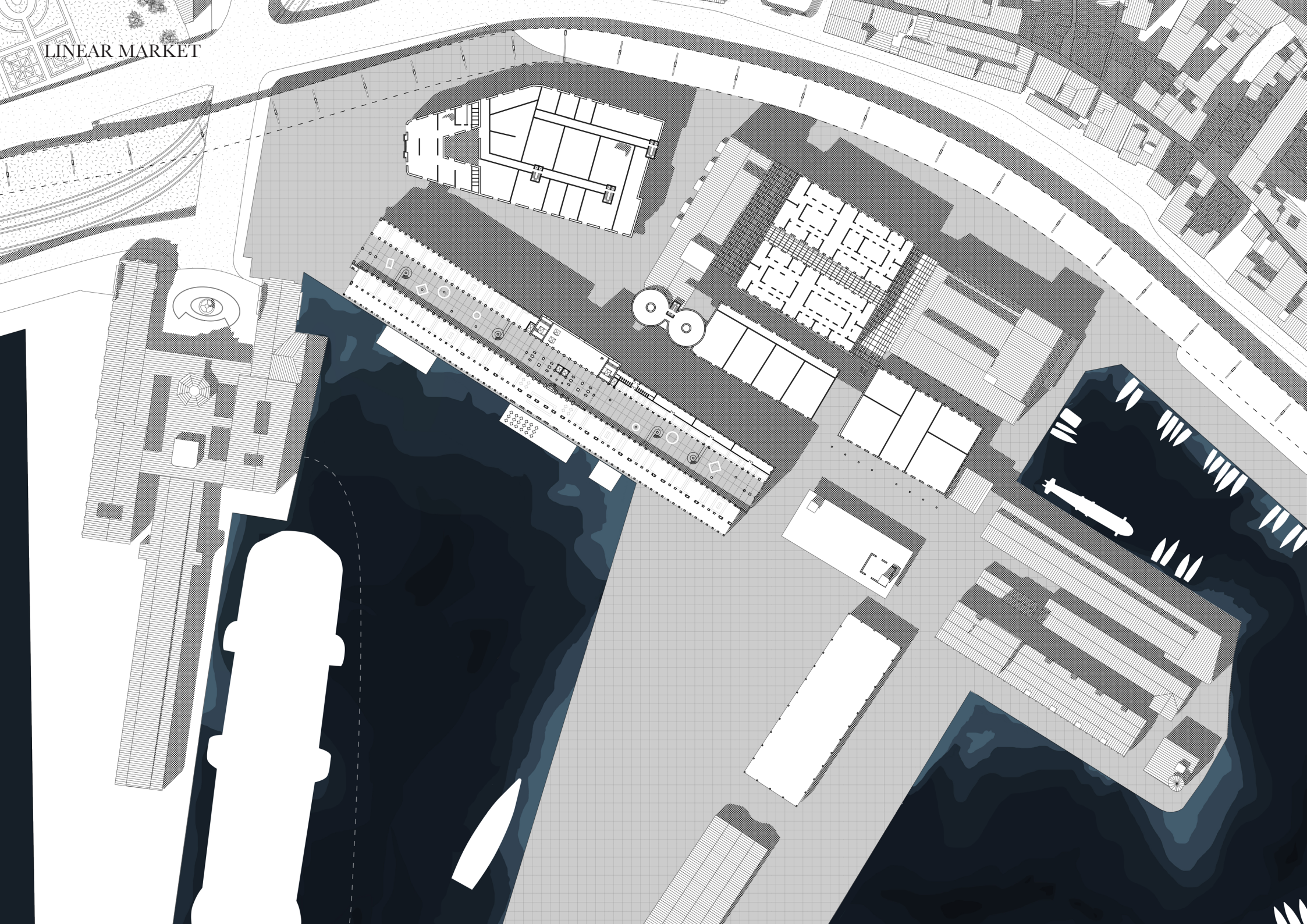


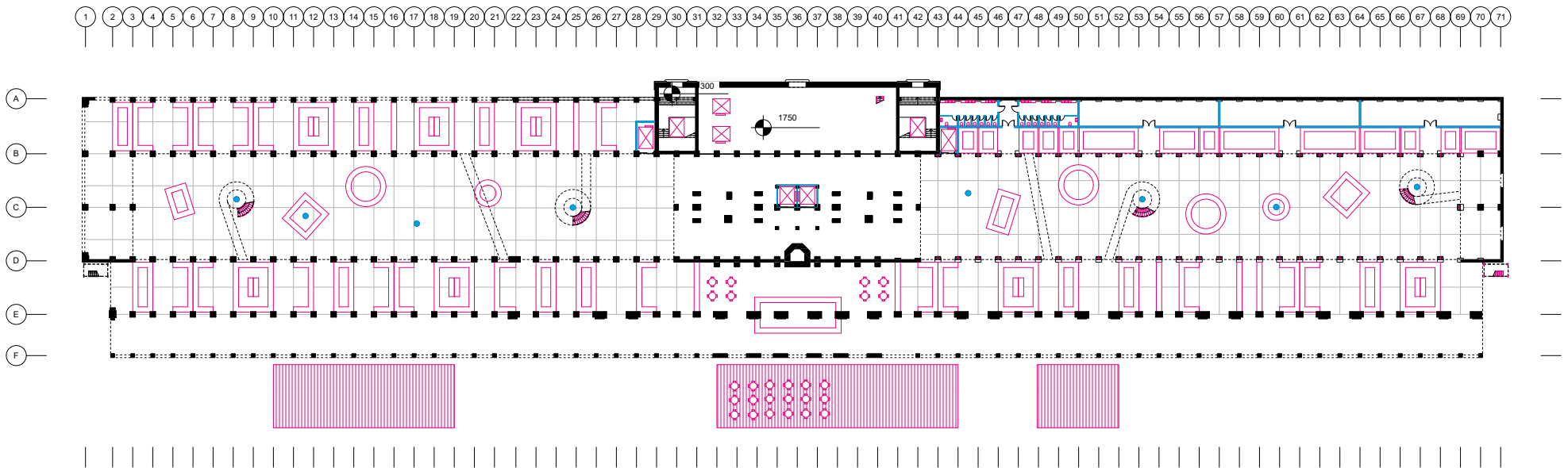
Articulate

TRAIN GALLERIES



LINEAR MARKET

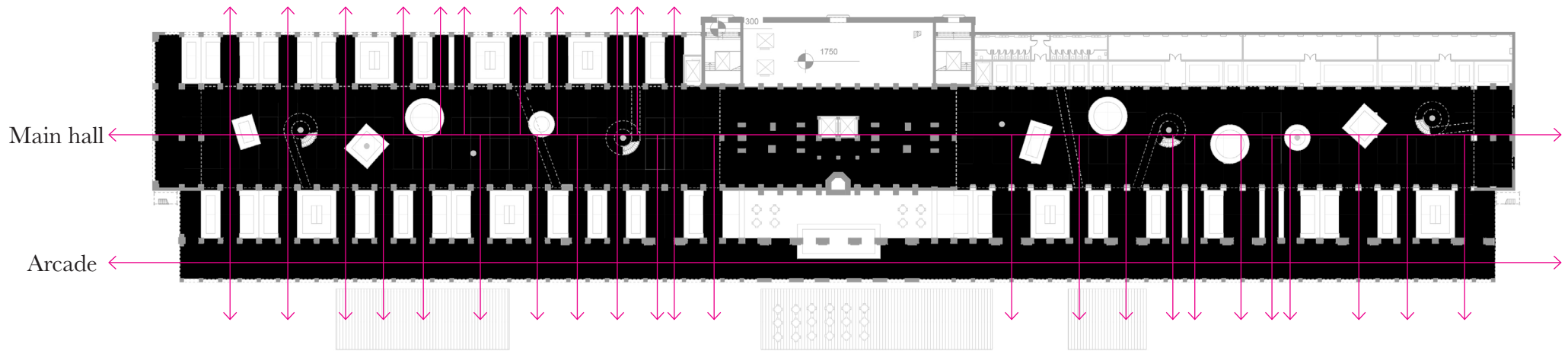




Groundfloor

POROSITY

Cross cuts



Groundfloor



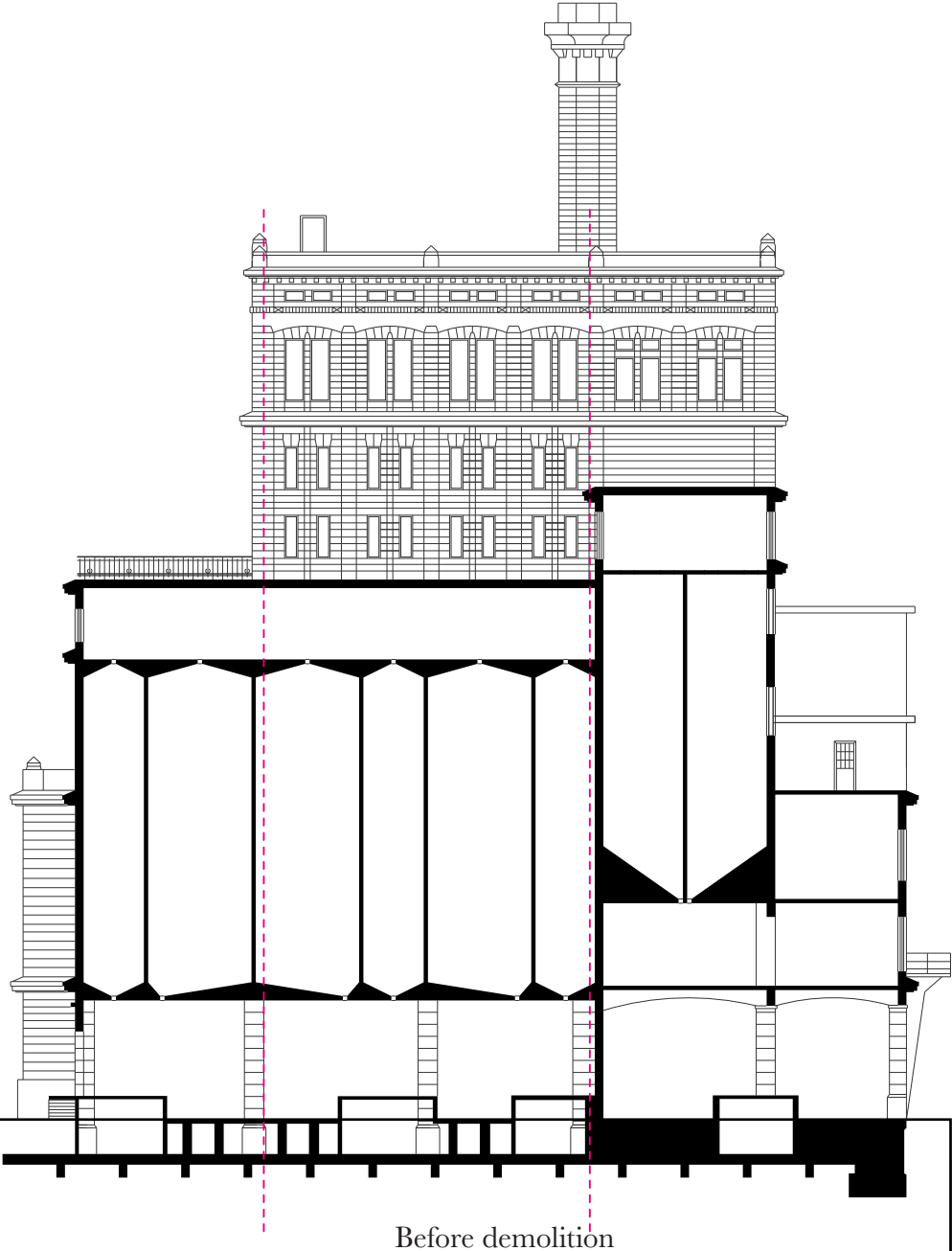
The arcade



Cross cut towards the sea

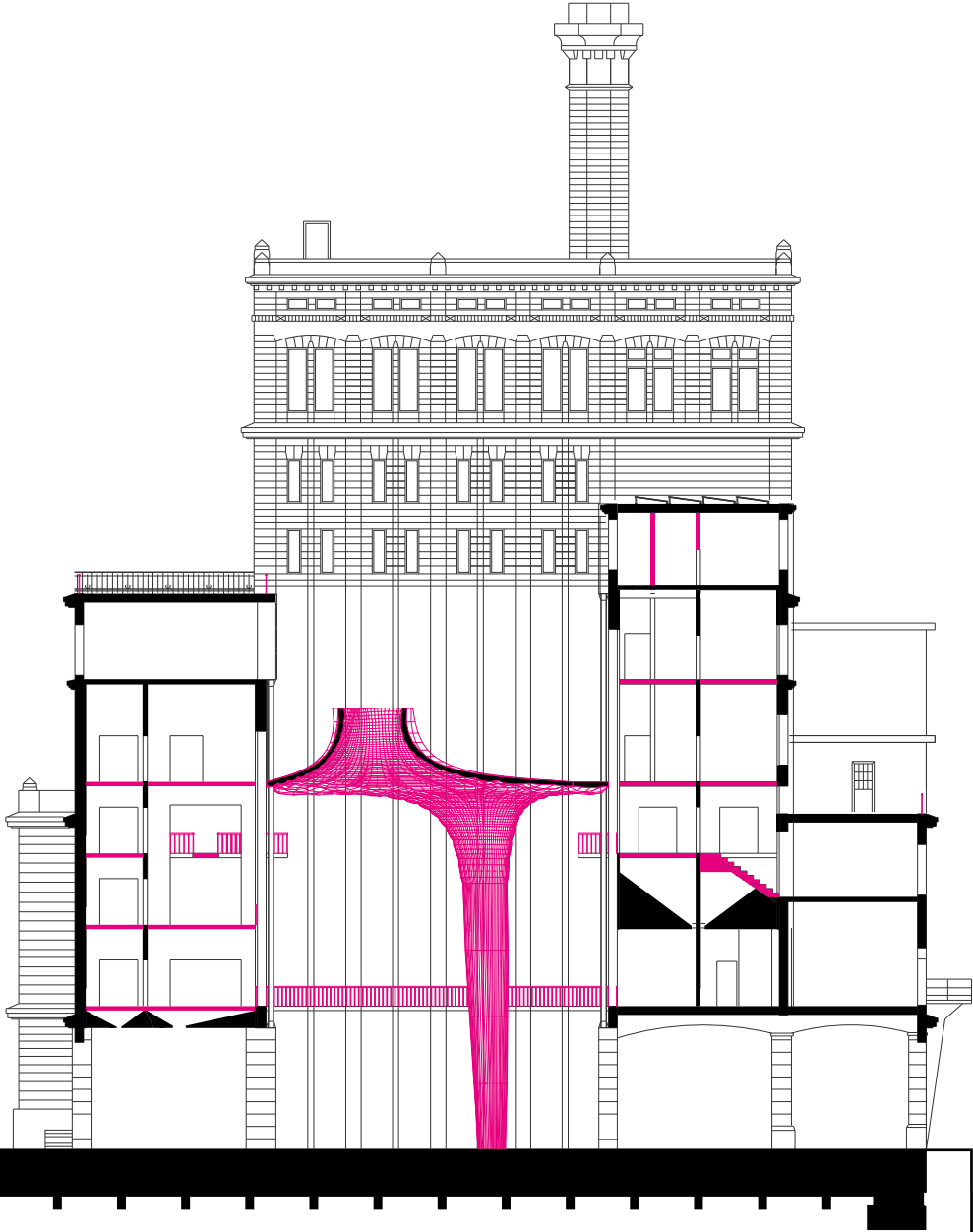


STRATEGY



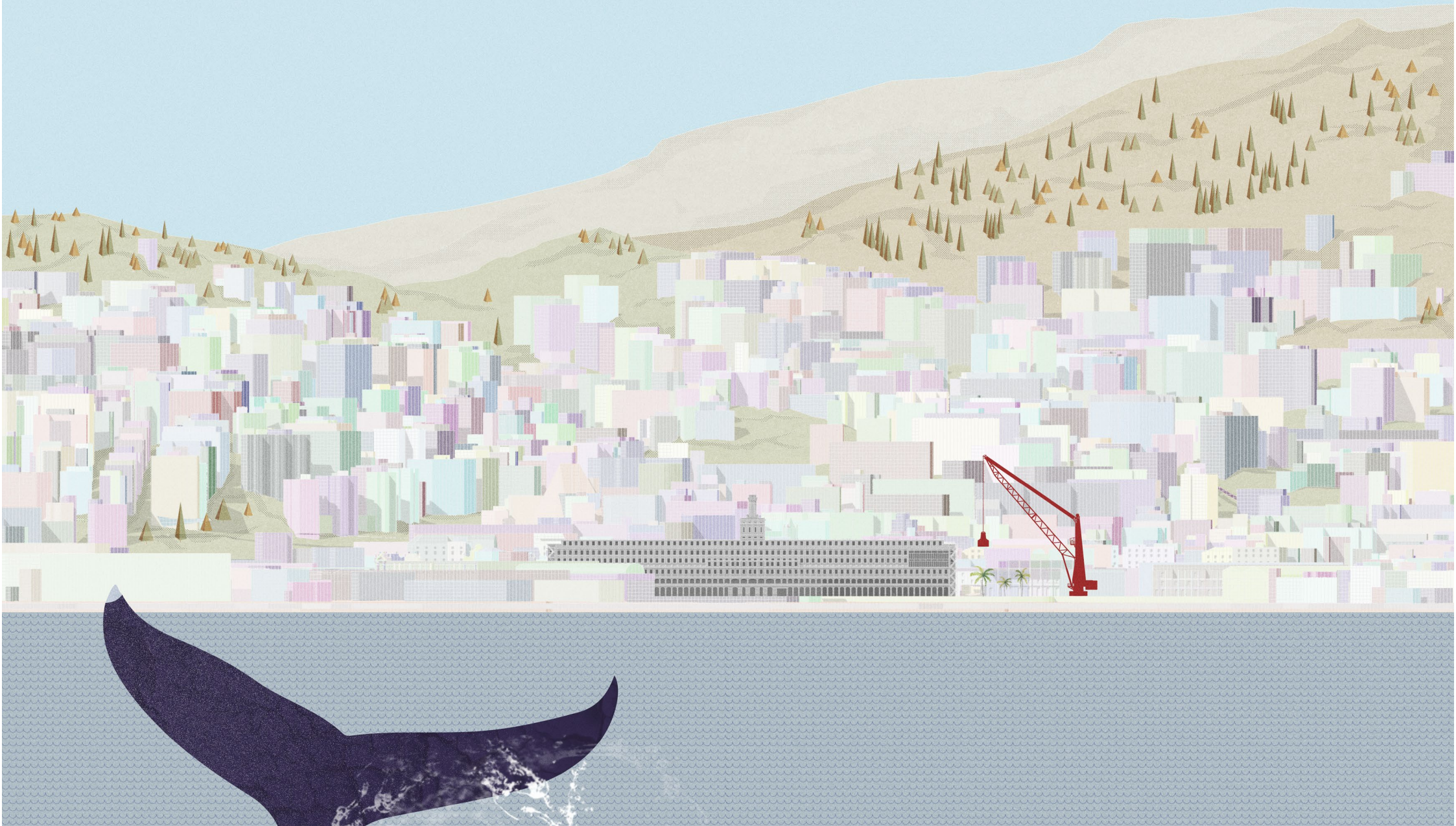
Before demolition

STRATEGY

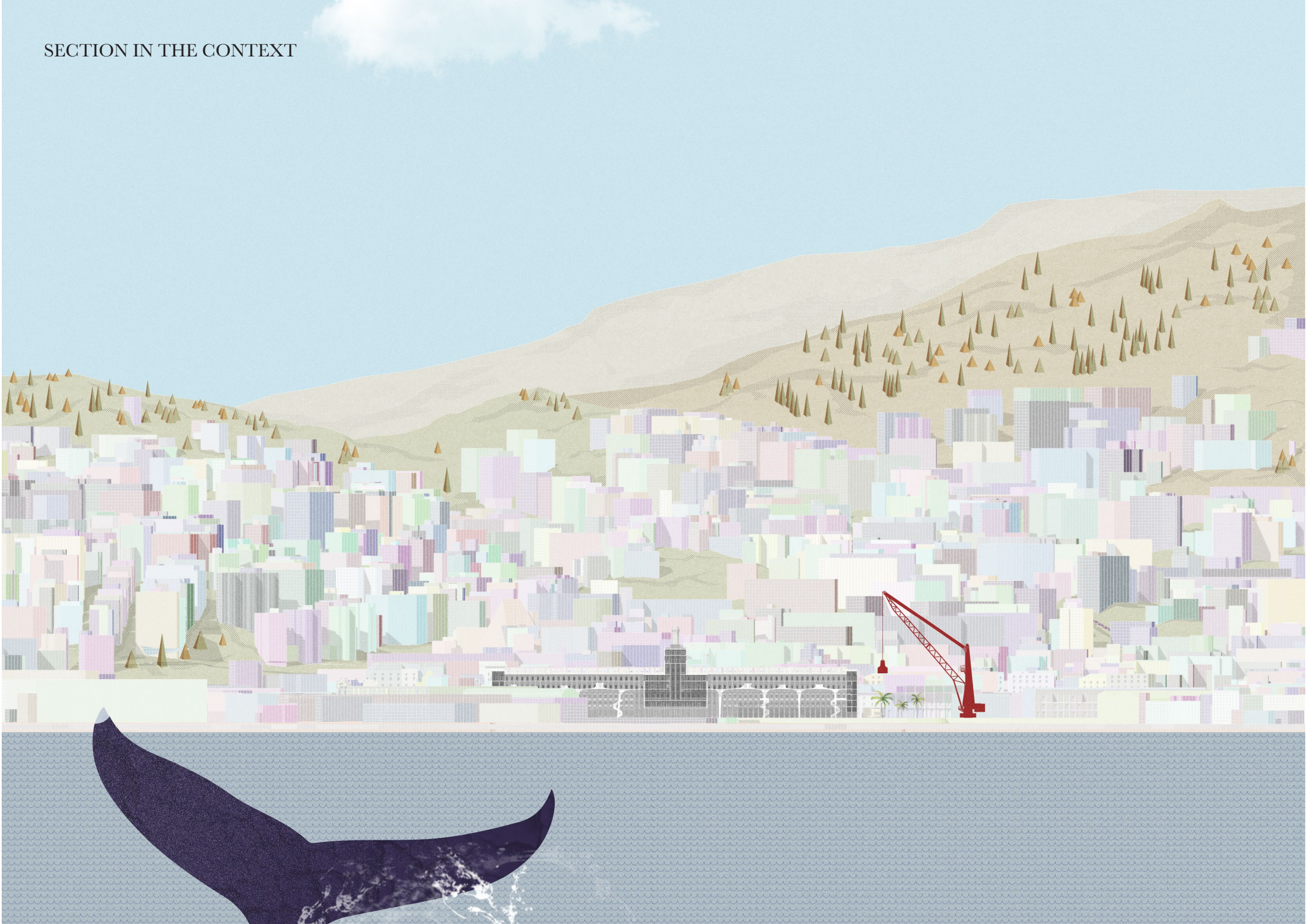


After demolition

ELEVATION IN THE CONTEXT

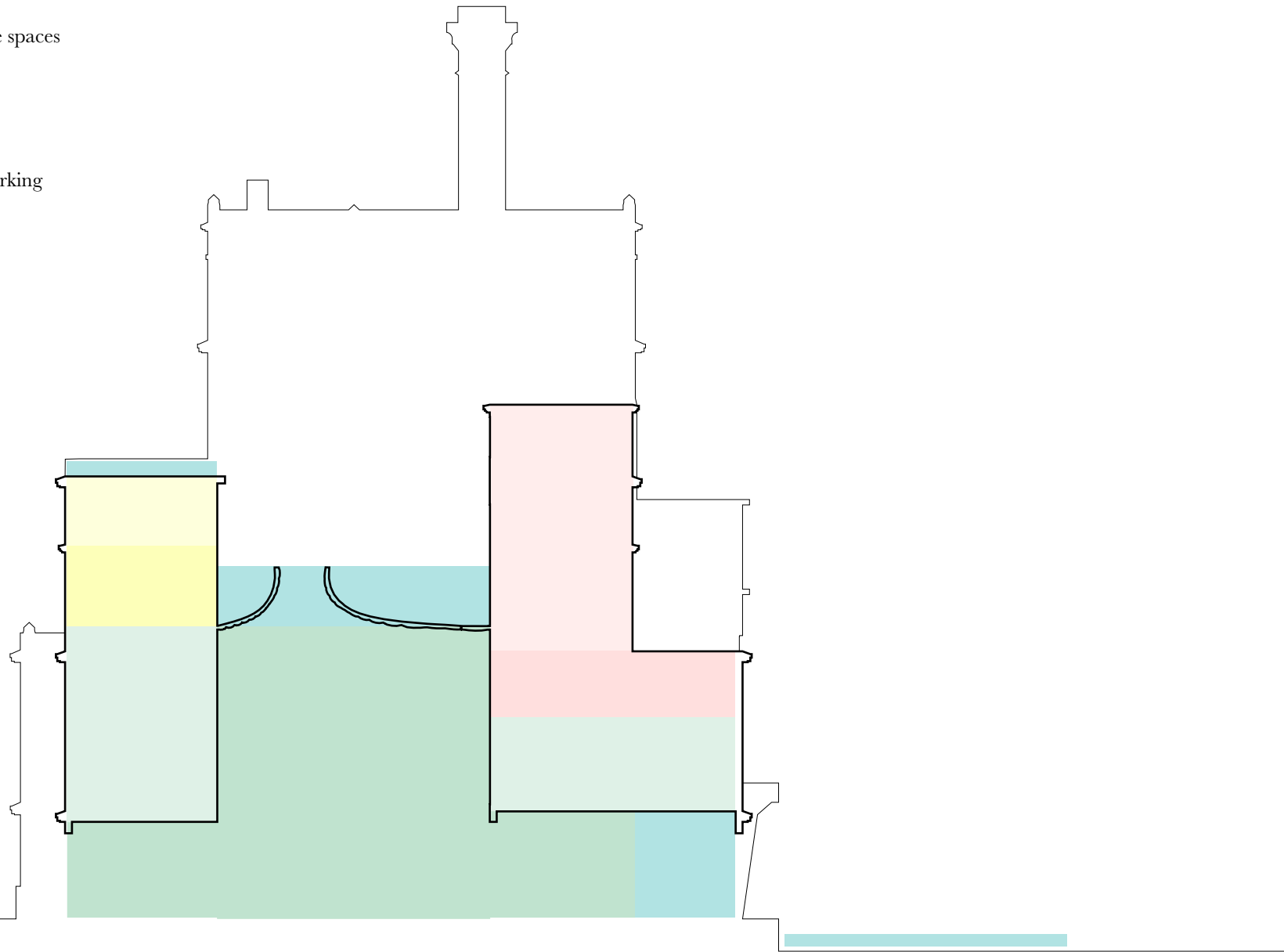


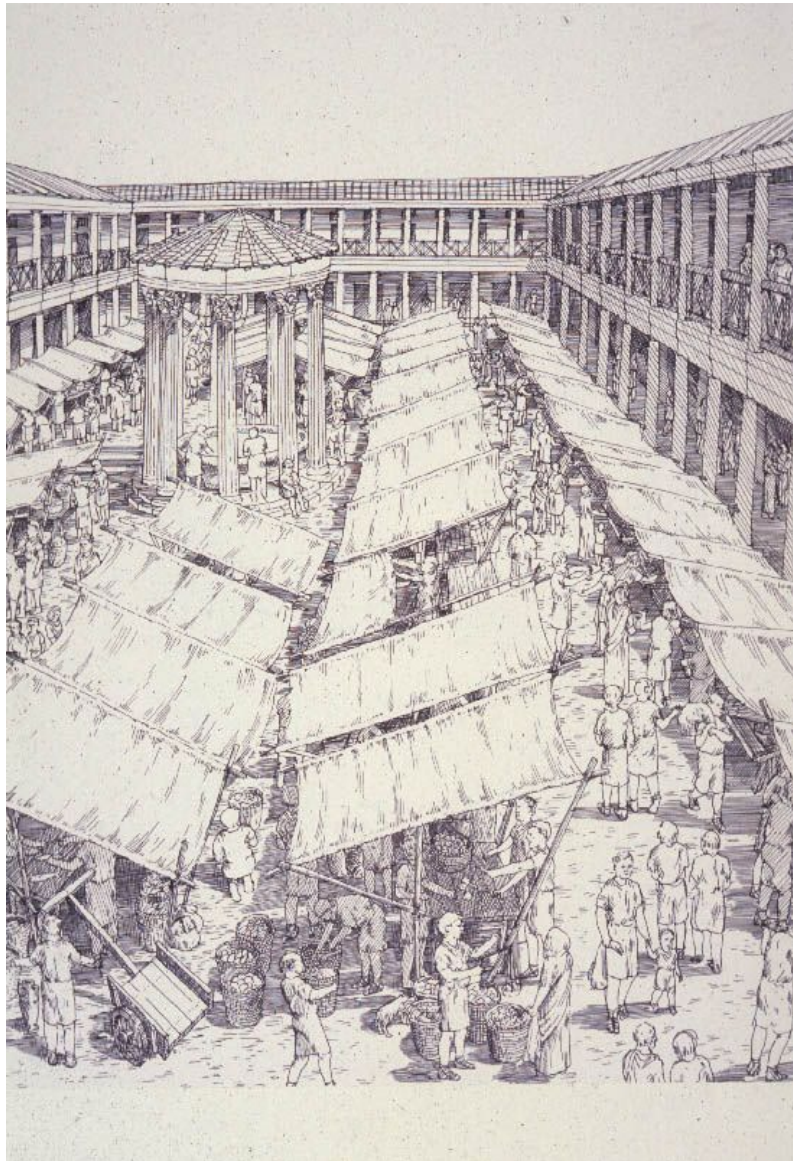
SECTION IN THE CONTEXT



# PROGRAM

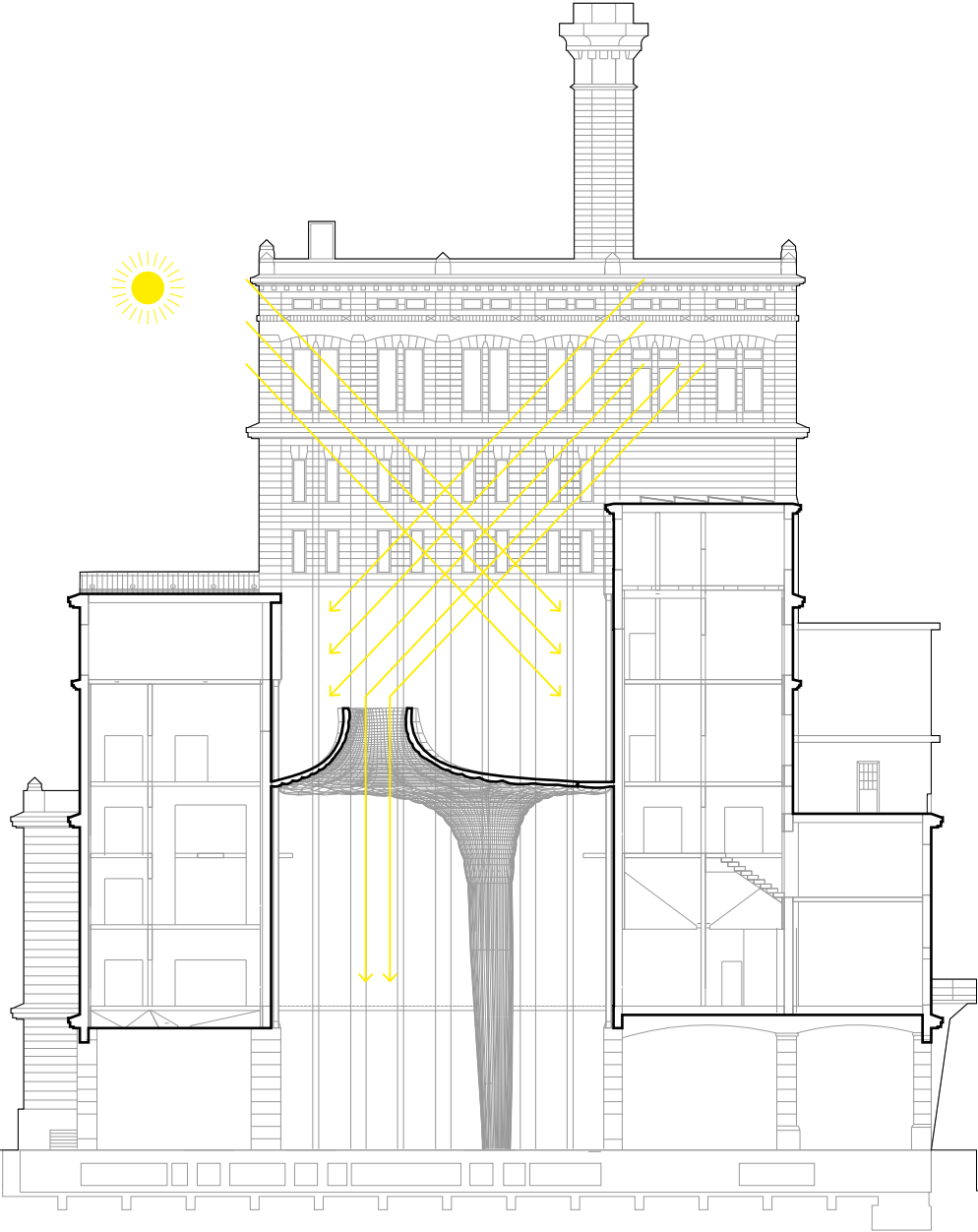
- hotel
  - Rooms and service spaces
  - Spa and gym
- offices
  - Open space co-working
  - Office space
- market
  - public terraces
  - Restaurants/Bars
  - Informal market





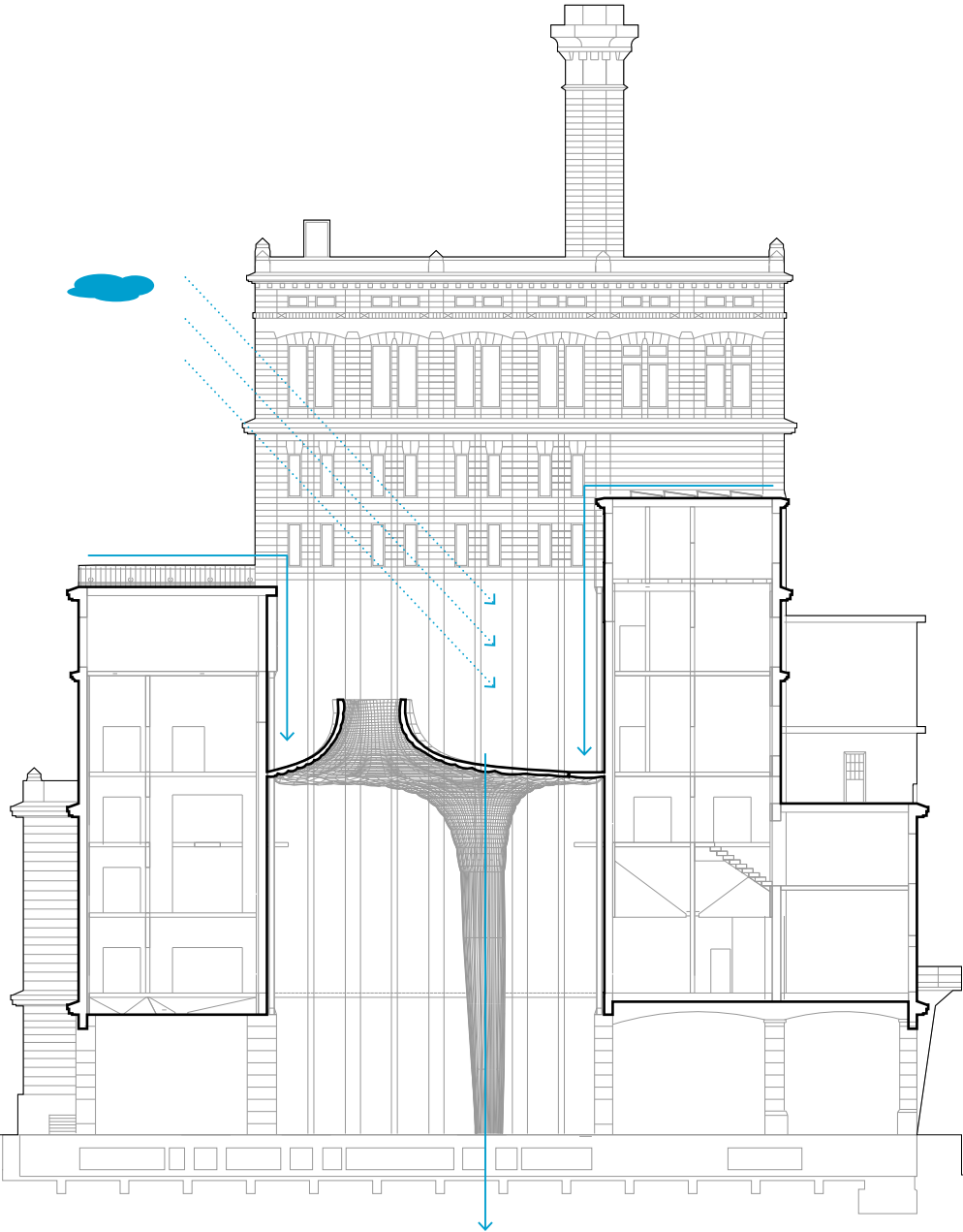
Organization and layout

SUSTAINABILITY



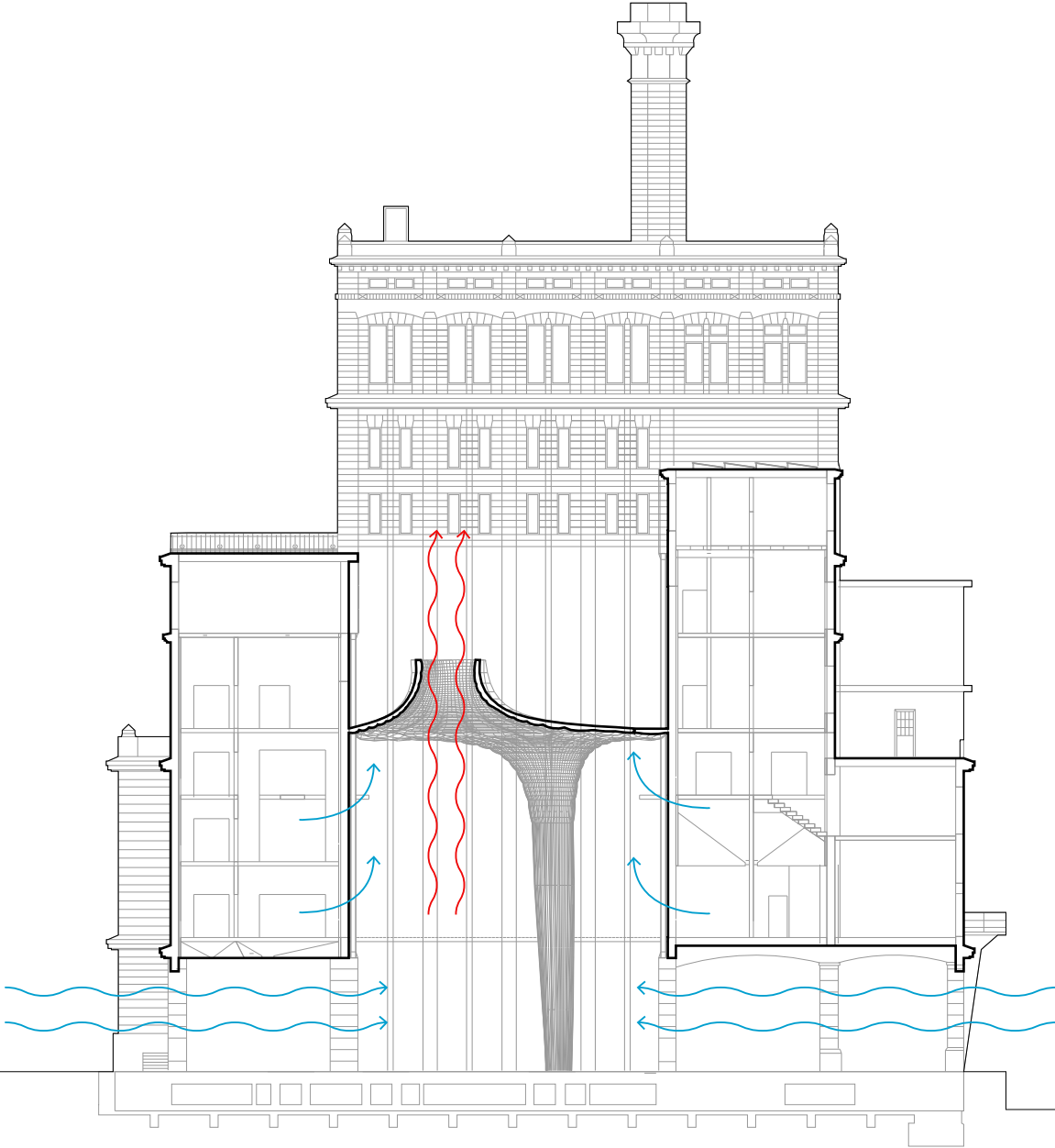
light diagram

SUSTAINABILITY

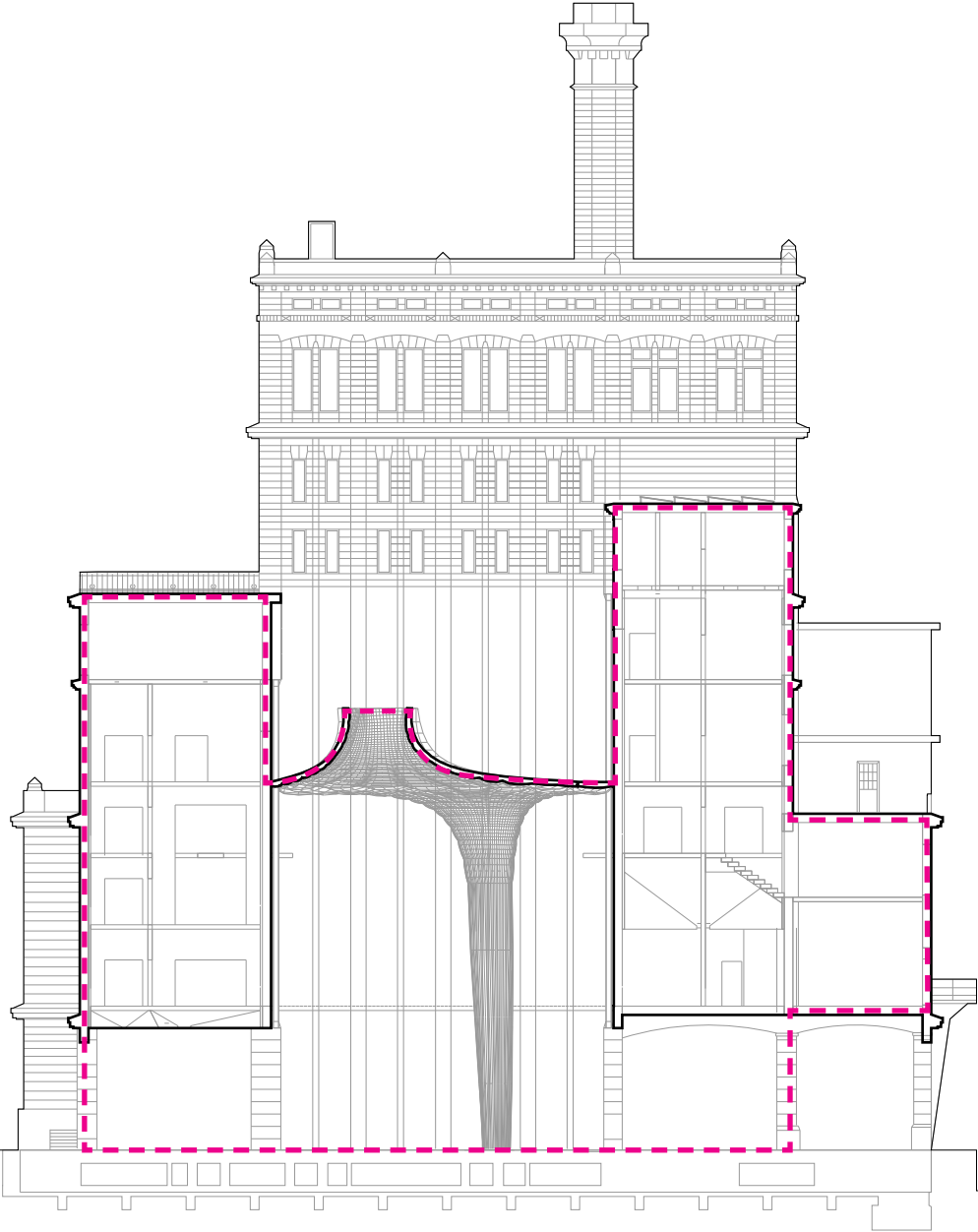


Water management



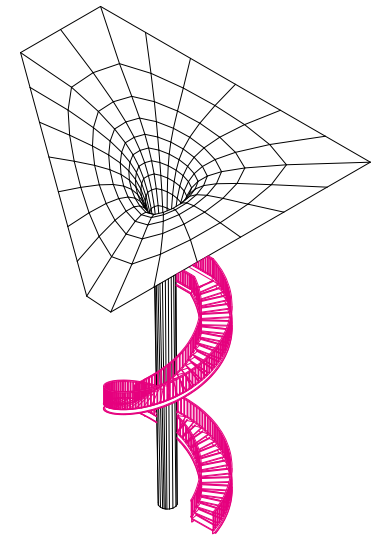
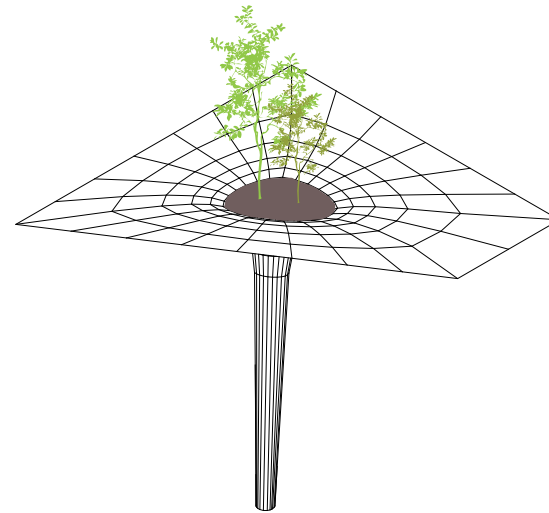
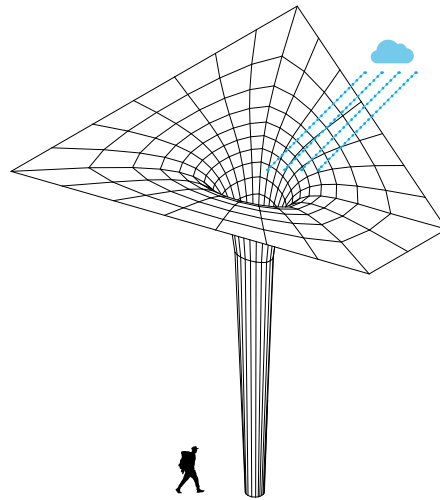
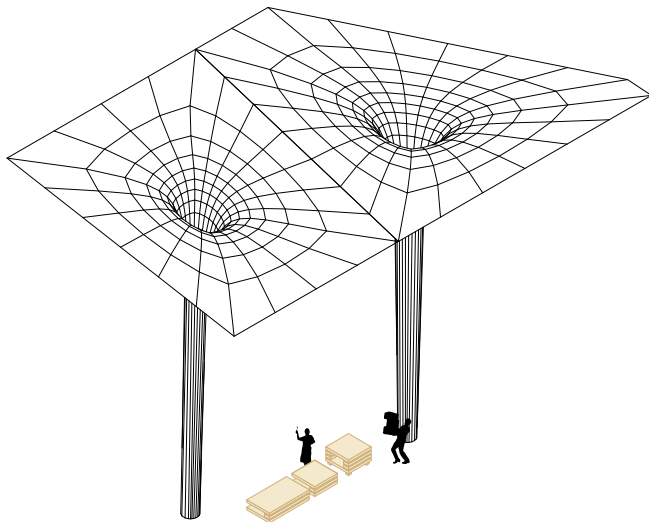
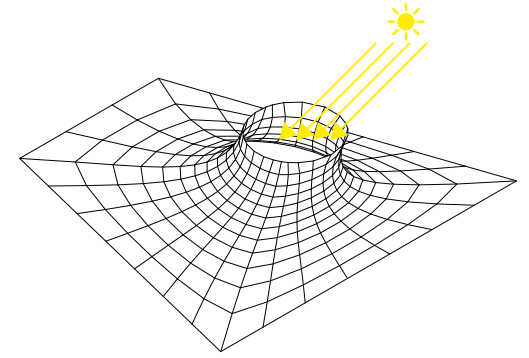
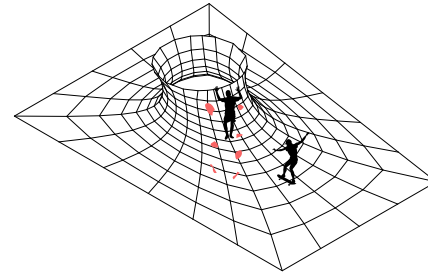
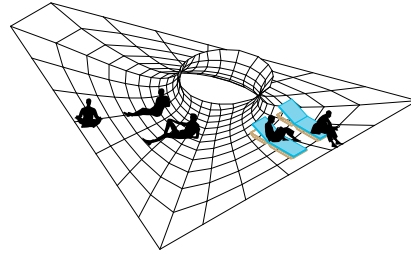
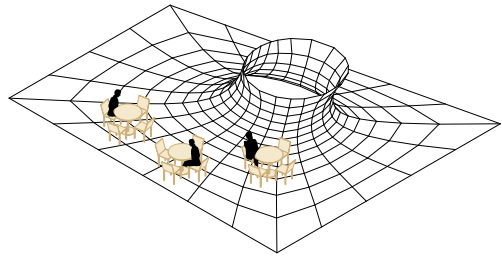


Climate and air flow



Thermal line

# USES OF THE SPACE



## 4.RESEARCH

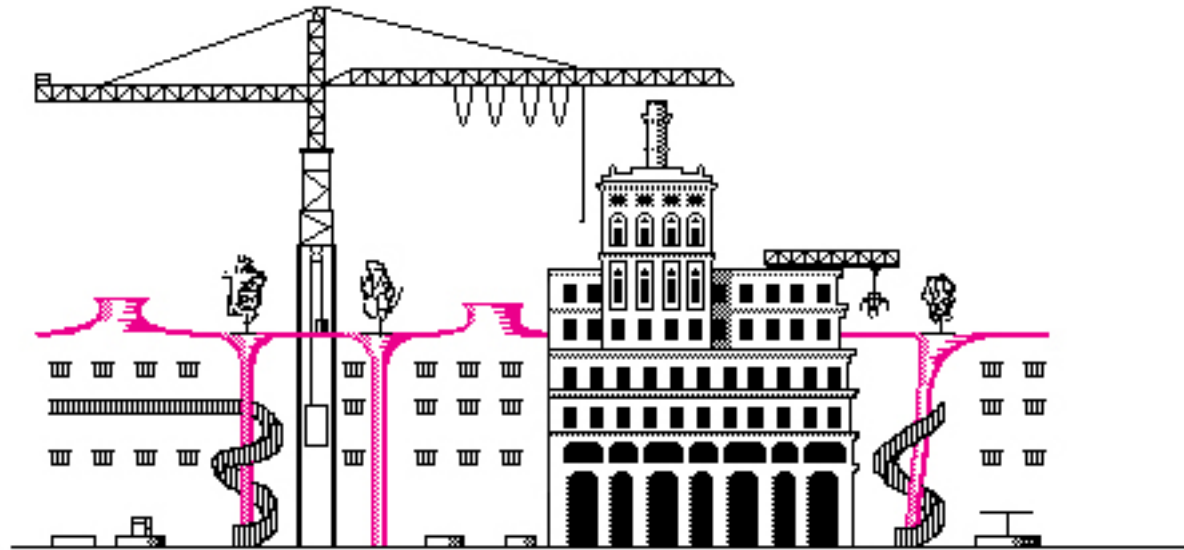
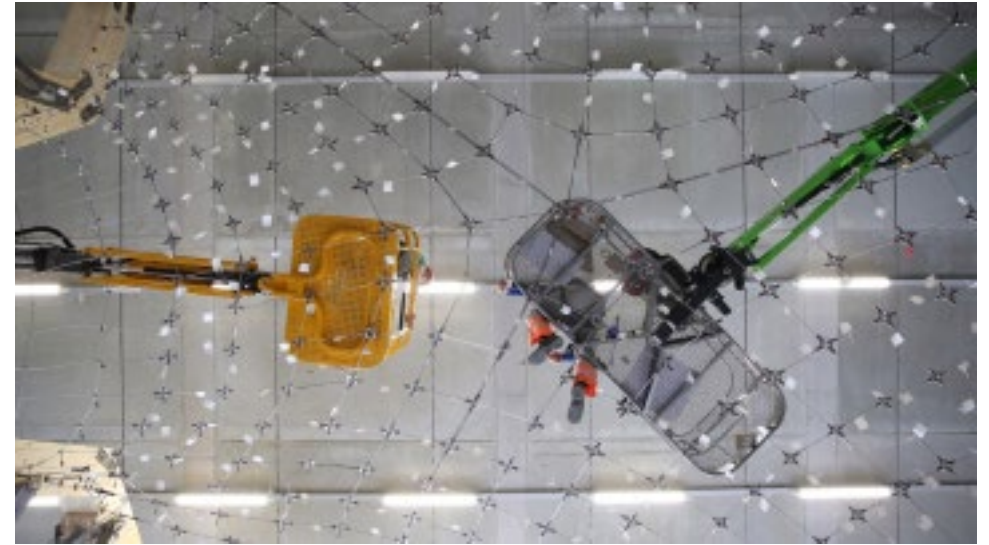
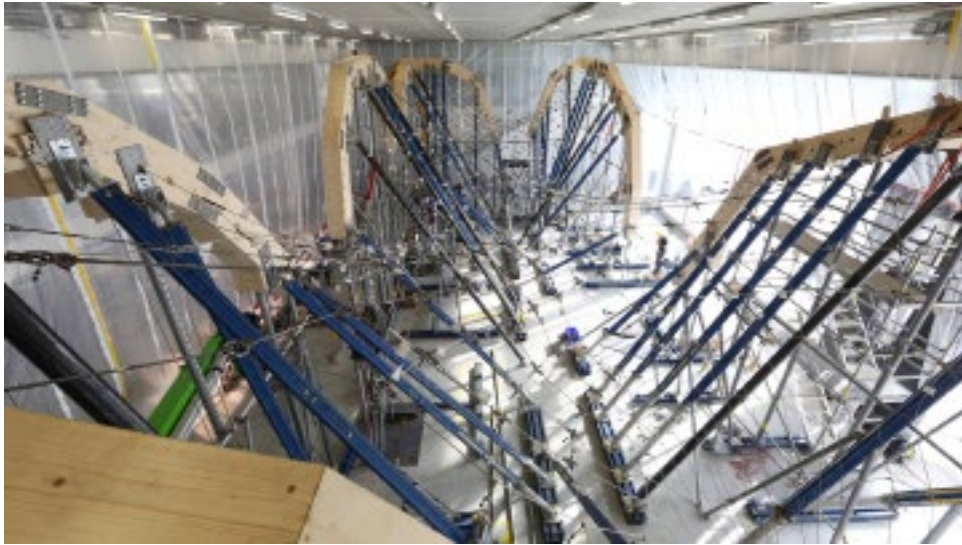




Table 2.1: Comparison of various formwork methods

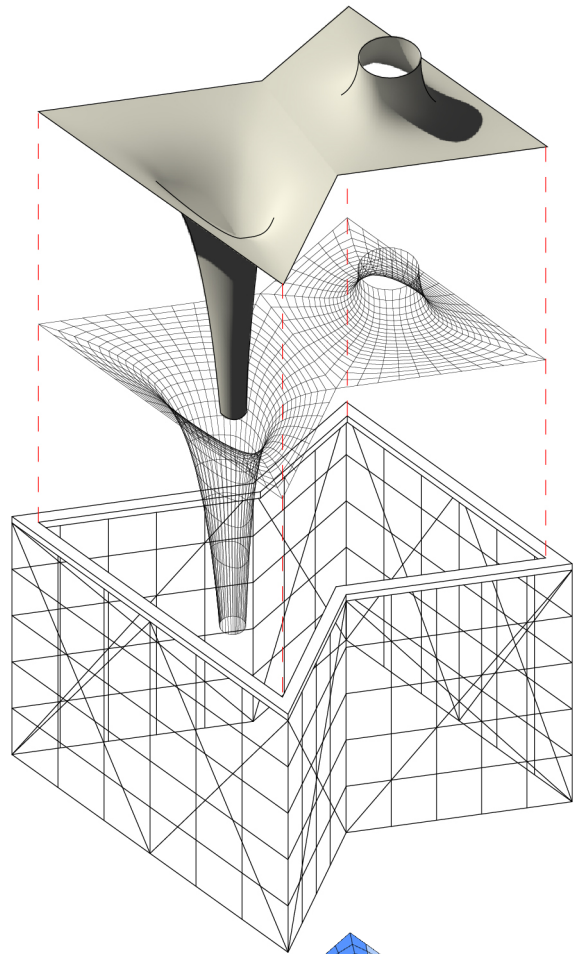
method	amount of manual labour needed	machining and tooling	costs	speed of shaping	freedom of form	surface quality	reuse of shaped elements	recycling of raw material
<b>timber formwork</b>	large, usually on-site	high-tech only if complex shape	high	low	large, but complex shapes require CNC	medium (shuttering generally visible)	limited, and if same shape	yes
<b>steel formwork</b>	limited, due to repetition	high-tech only if complex shape	high	low	limited (double- curved is expensive)	high	often, if same shape	yes
<b>CNC-milling</b>	average, mainly finishing	high-tech	high	medium	practically unlimited	high, if finished properly	only in mould banks	partially
<b>hot-wire-cutting</b>	average, mainly finishing	medium- tech	medium	medium	only ruled surfaces	high, if finished properly	only in mould banks	partially
<b>fabric formwork (air)</b>	limited, during erection of inflatable shape	cutting patterns / sewing	medium	high	limited to controllable pneumatics	high, depending on fabric	yes, if same shape	partially
<b>fabric formwork (concrete)</b>	limited, during preparation	cutting patterns / sewing	low	high	limited to controllable form-finding	high, depending on fabric	limited, if same or similar shape	partially
<b>3D-printing</b>	limited, set-up of installation	high-tech, presently not on full building scale	high	low	large, but limited resolution	low (at present, but improving rapidly)	not applicable	not applicable
<b>flexible mould</b>	limited, edge positioning	medium- tech	unknown	high	large, but less than CNC	high	formwork is reshape-able	possible

General need for a flexible mould principle



HiLo roof, ETH Zurich, 2017



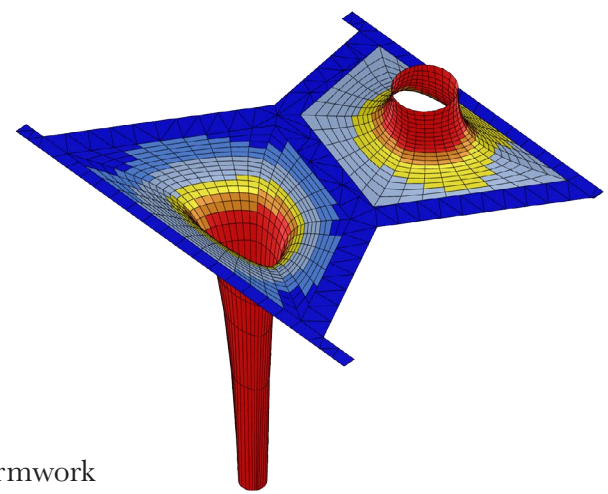
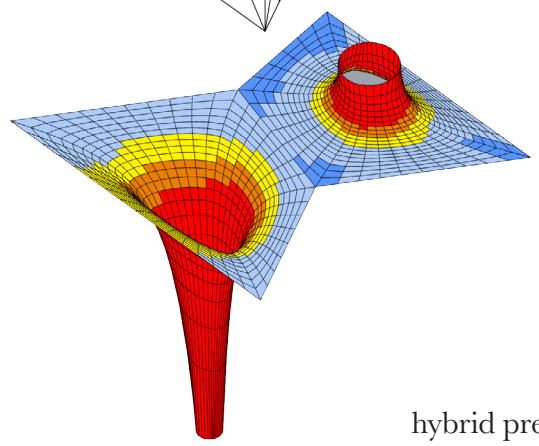
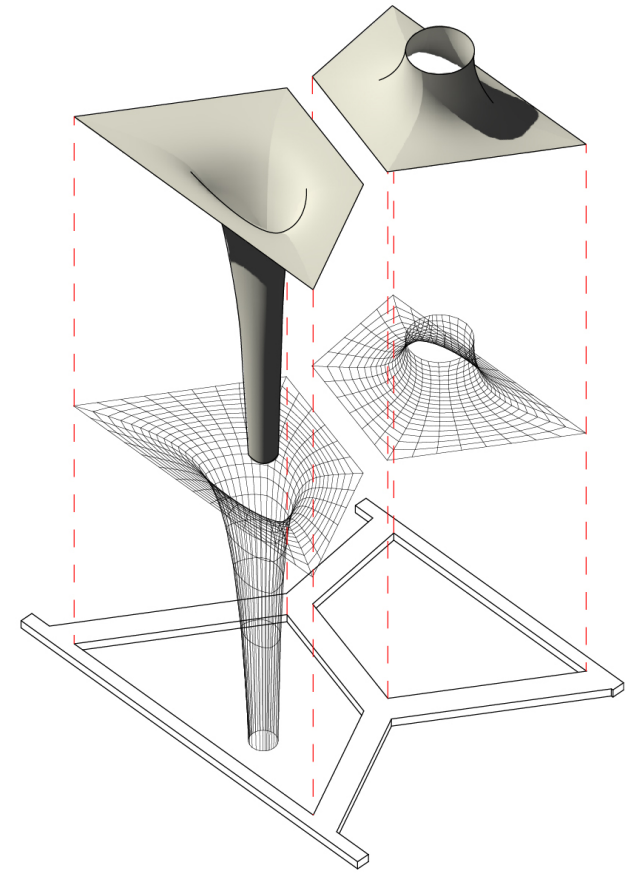


cost breakdown  
150/300 €/m<sup>2</sup>

33%  
textile

12%  
cable mesh

55%  
support structure

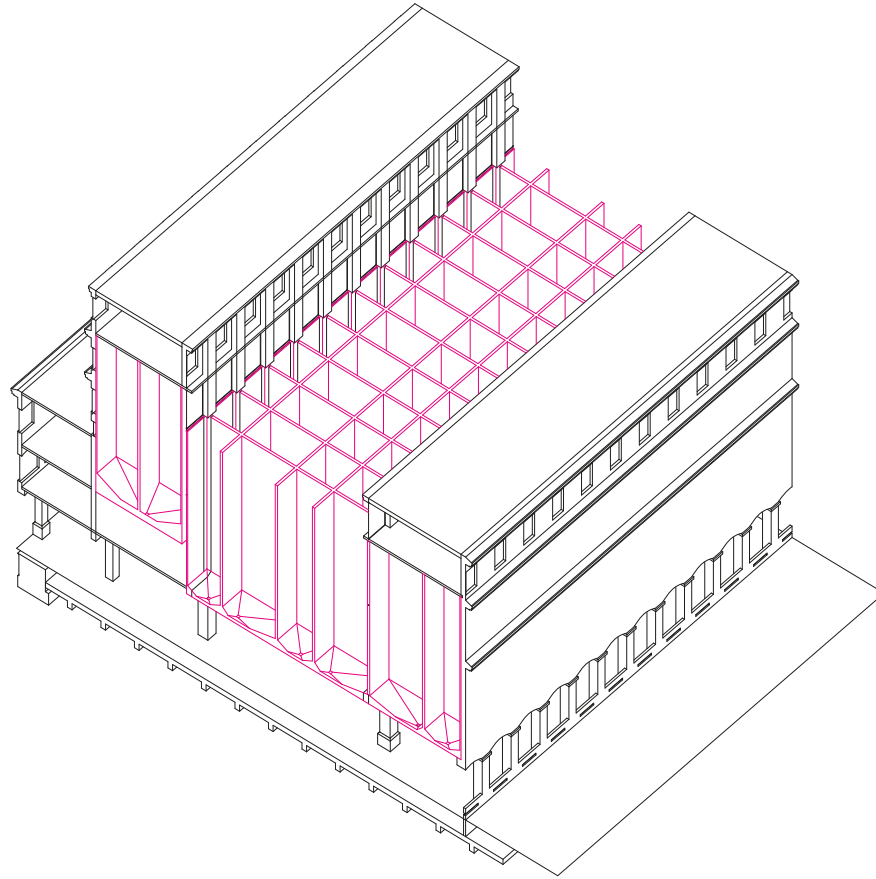


Classic fabric formwork  
vs

hybrid prefabricated system for fabric formwork

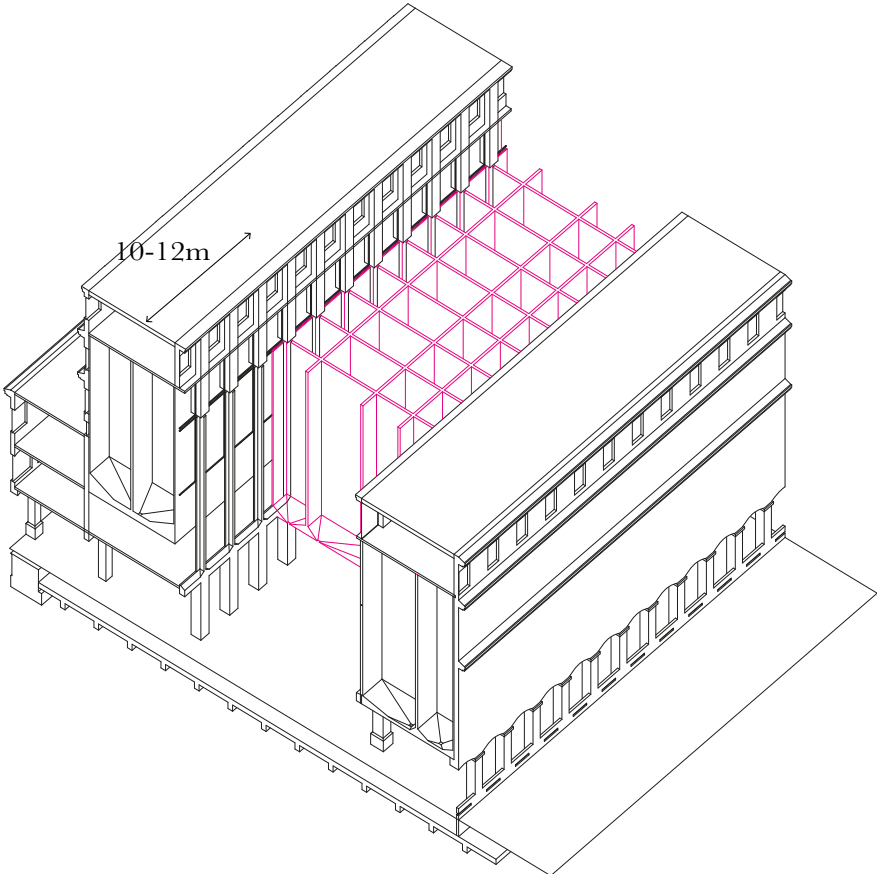


# CONSTRUCTION PROCESS



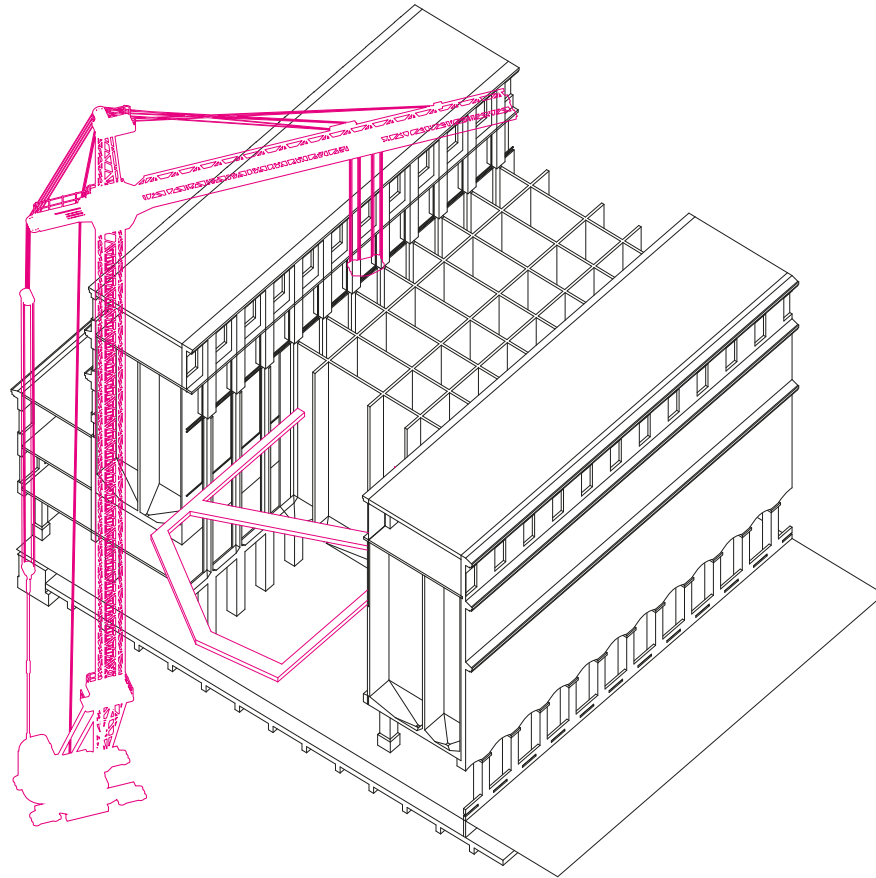
Existing situation

CONSTRUCTION PROCESS



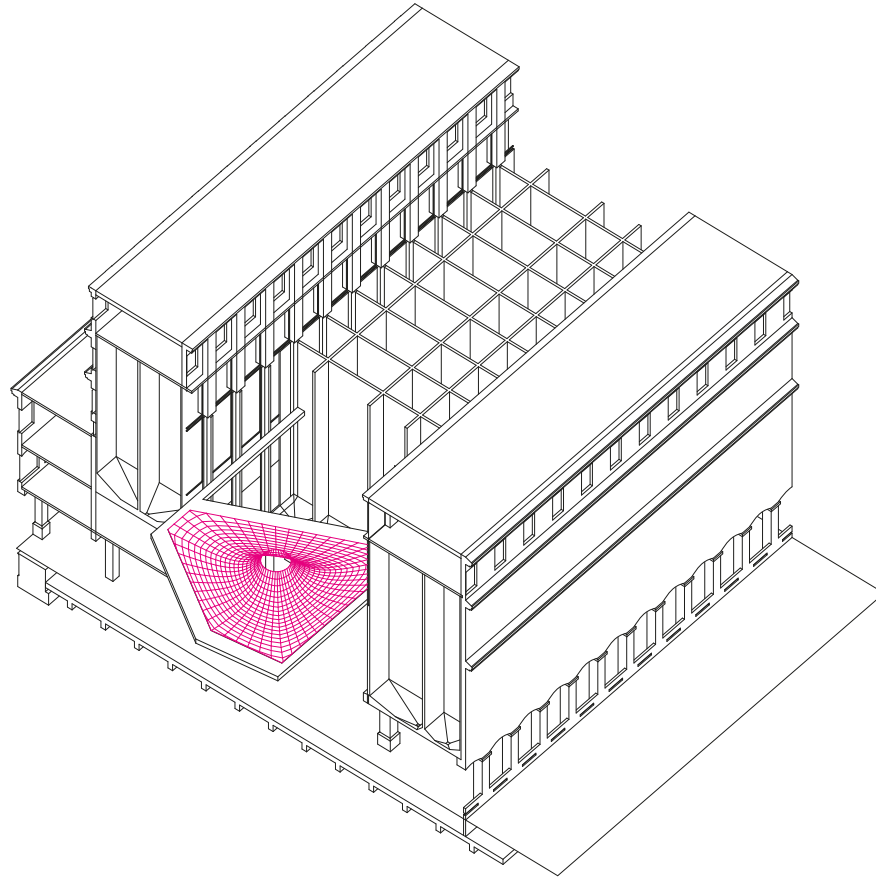
Partial demolition

CONSTRUCTION PROCESS



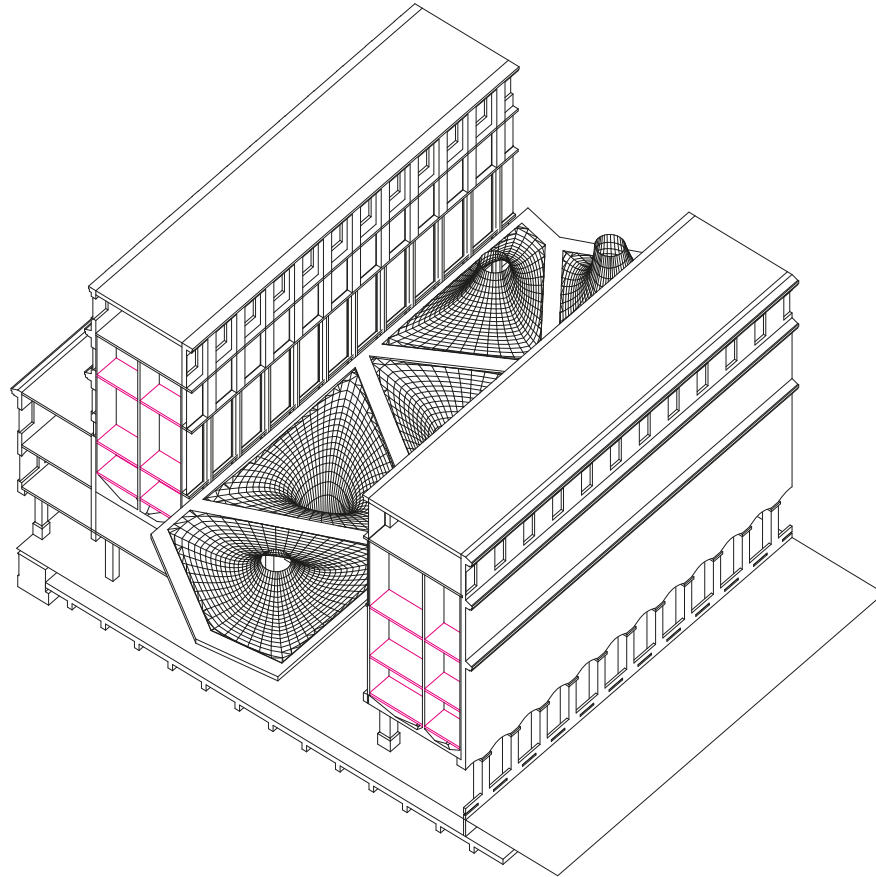
Prefabricated beam

CONSTRUCTION PROCESS



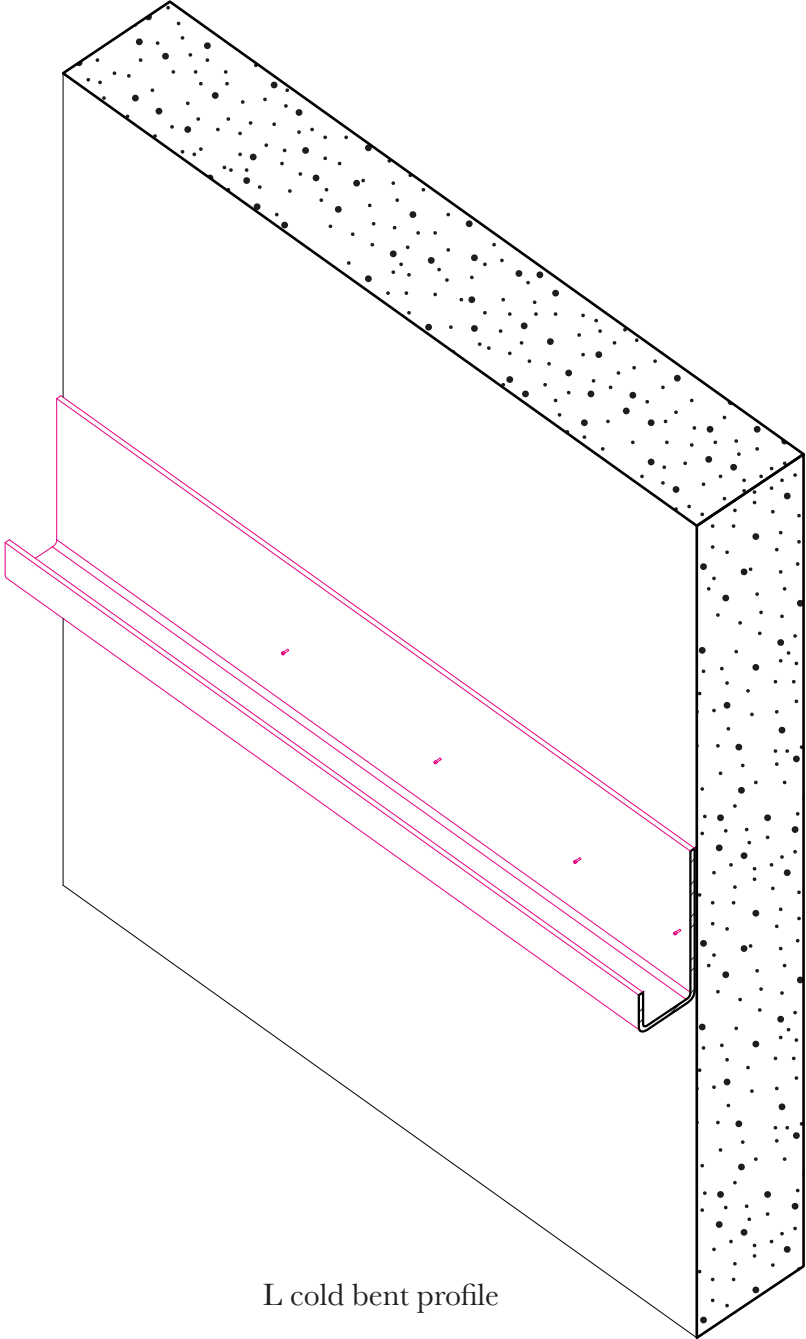
Wire mesh + fabric

CONSTRUCTION PROCESS



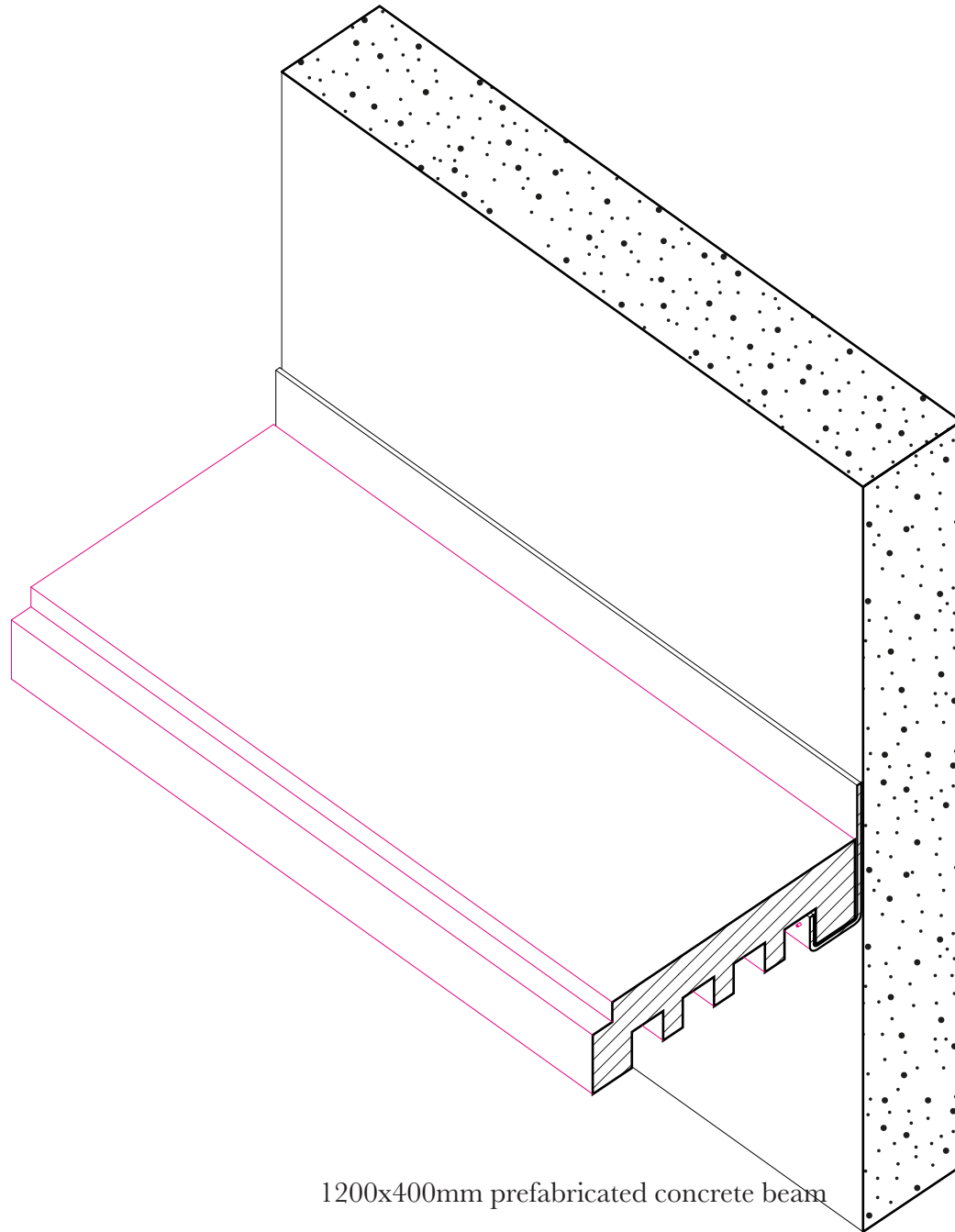
Completed roof structure

CONSTRUCTION PROCESS



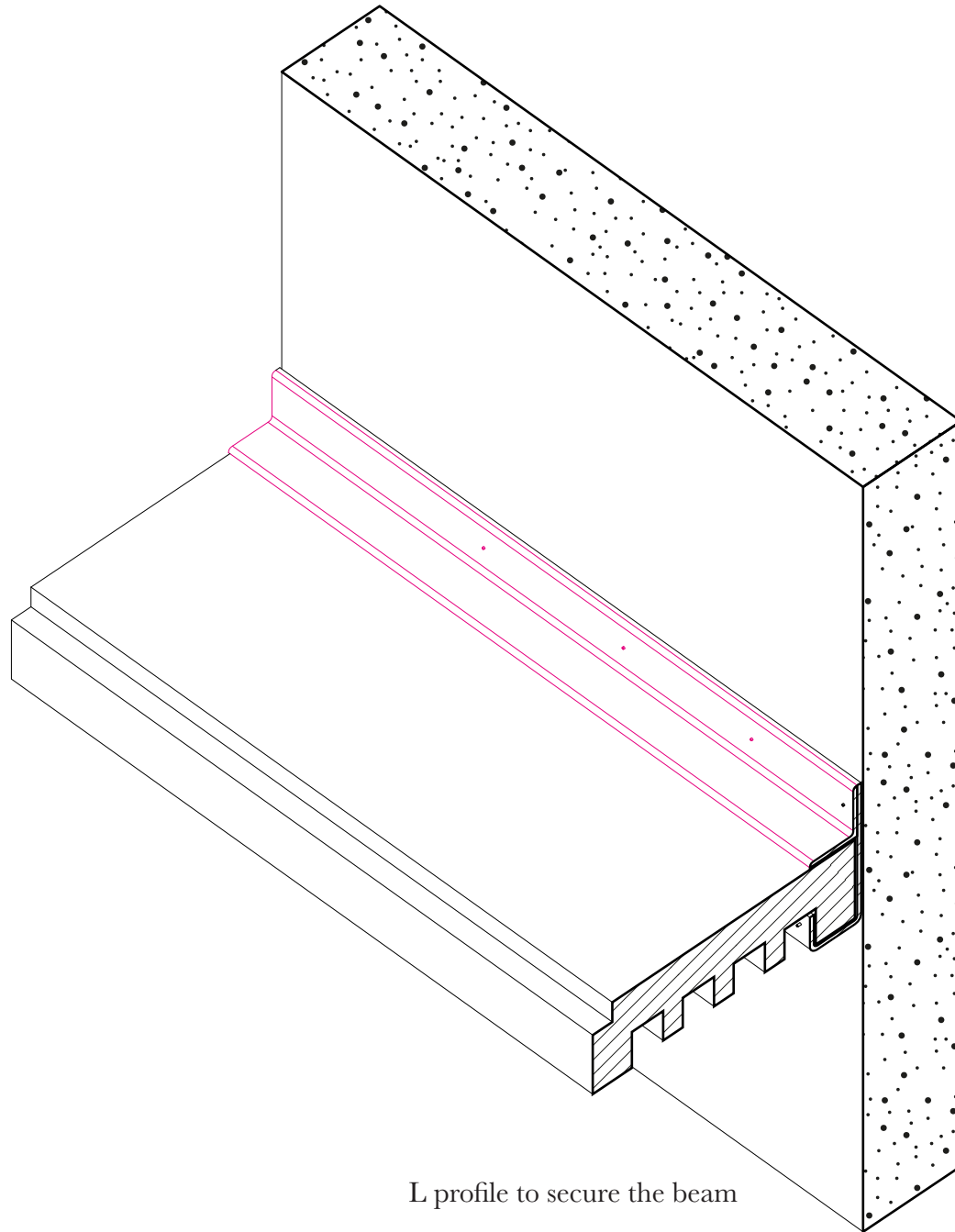
L cold bent profile

CONSTRUCTION PROCESS



1200x400mm prefabricated concrete beam

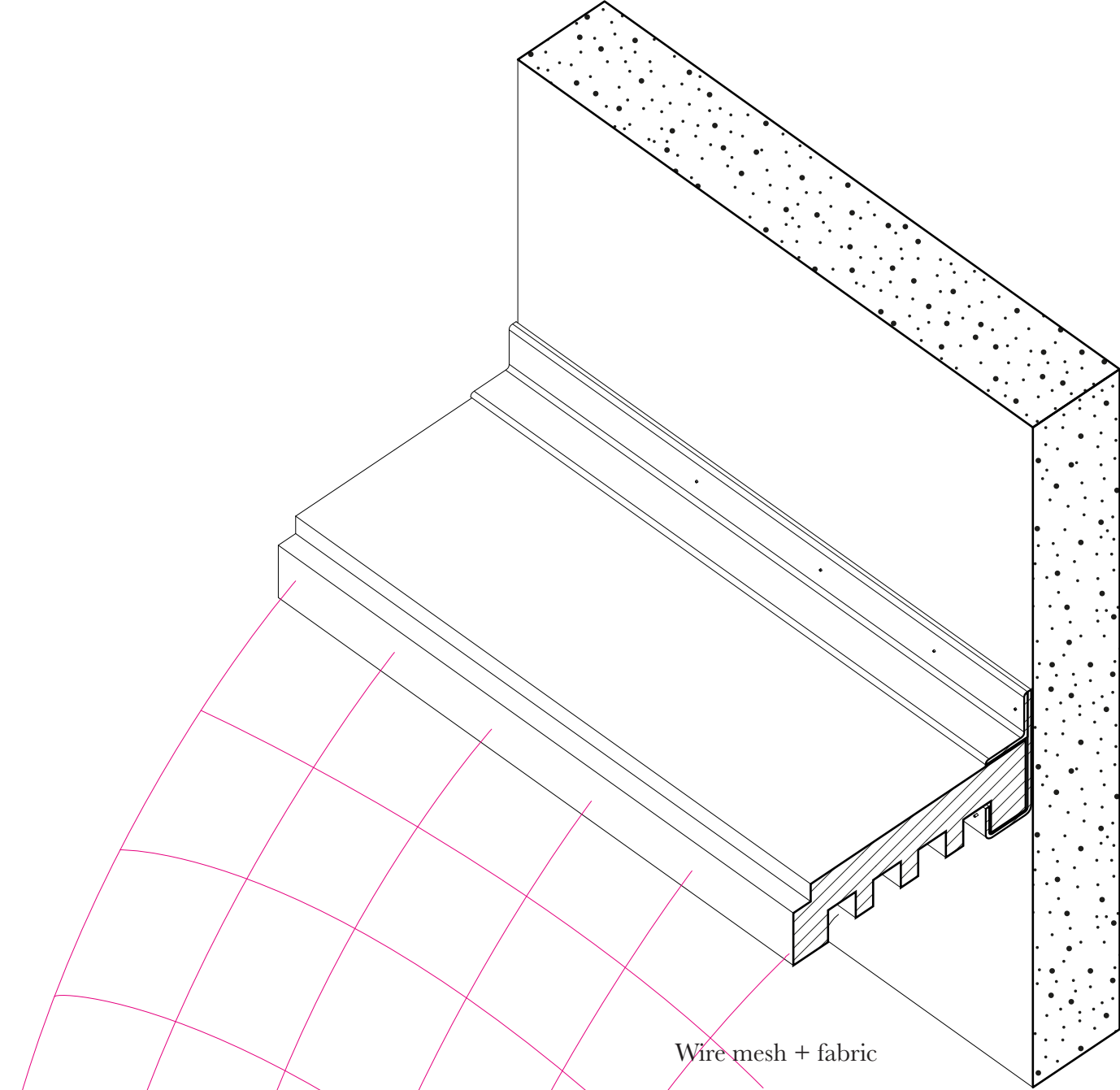
CONSTRUCTION PROCESS



L profile to secure the beam

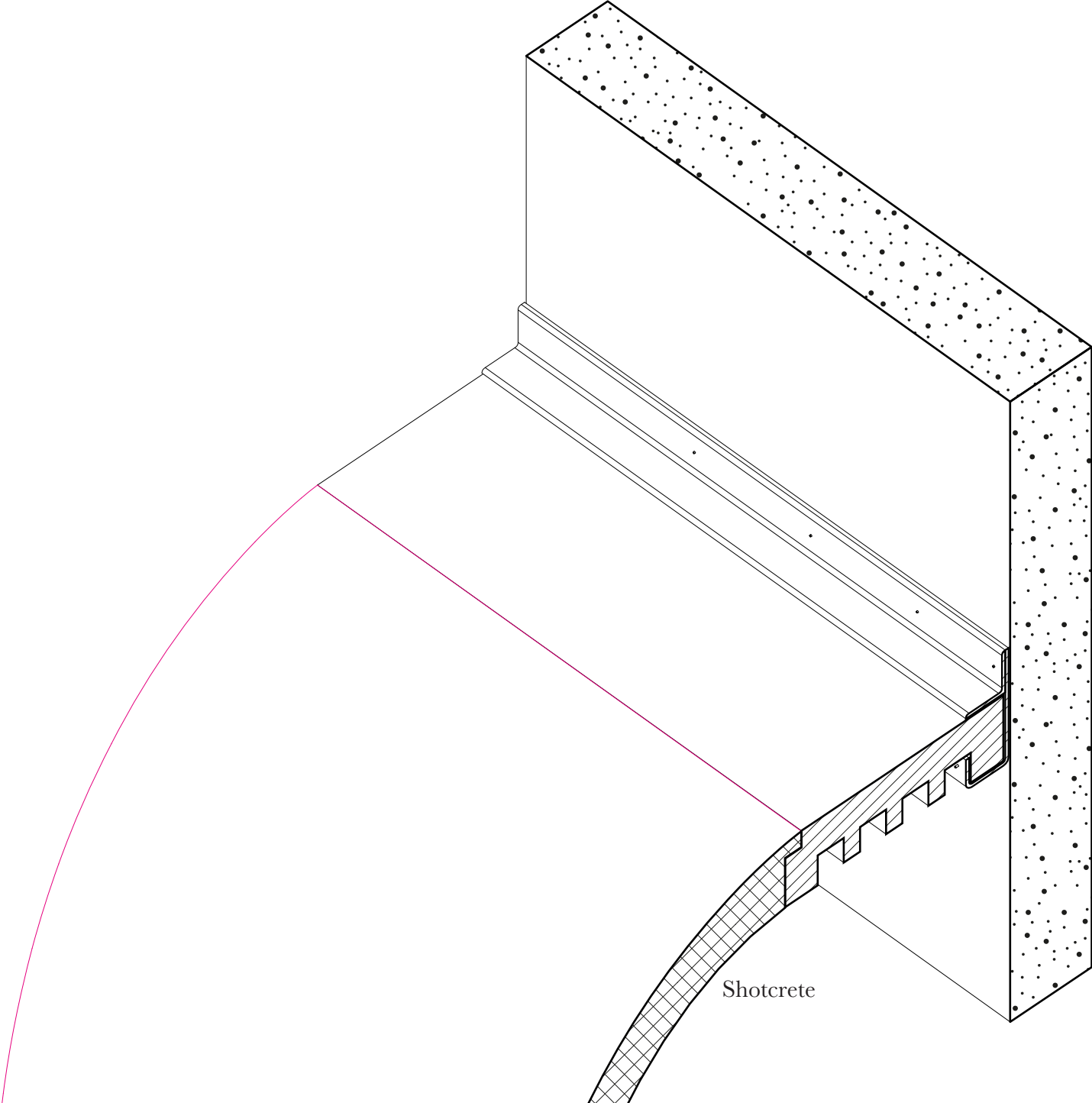


CONSTRUCTION PROCESS



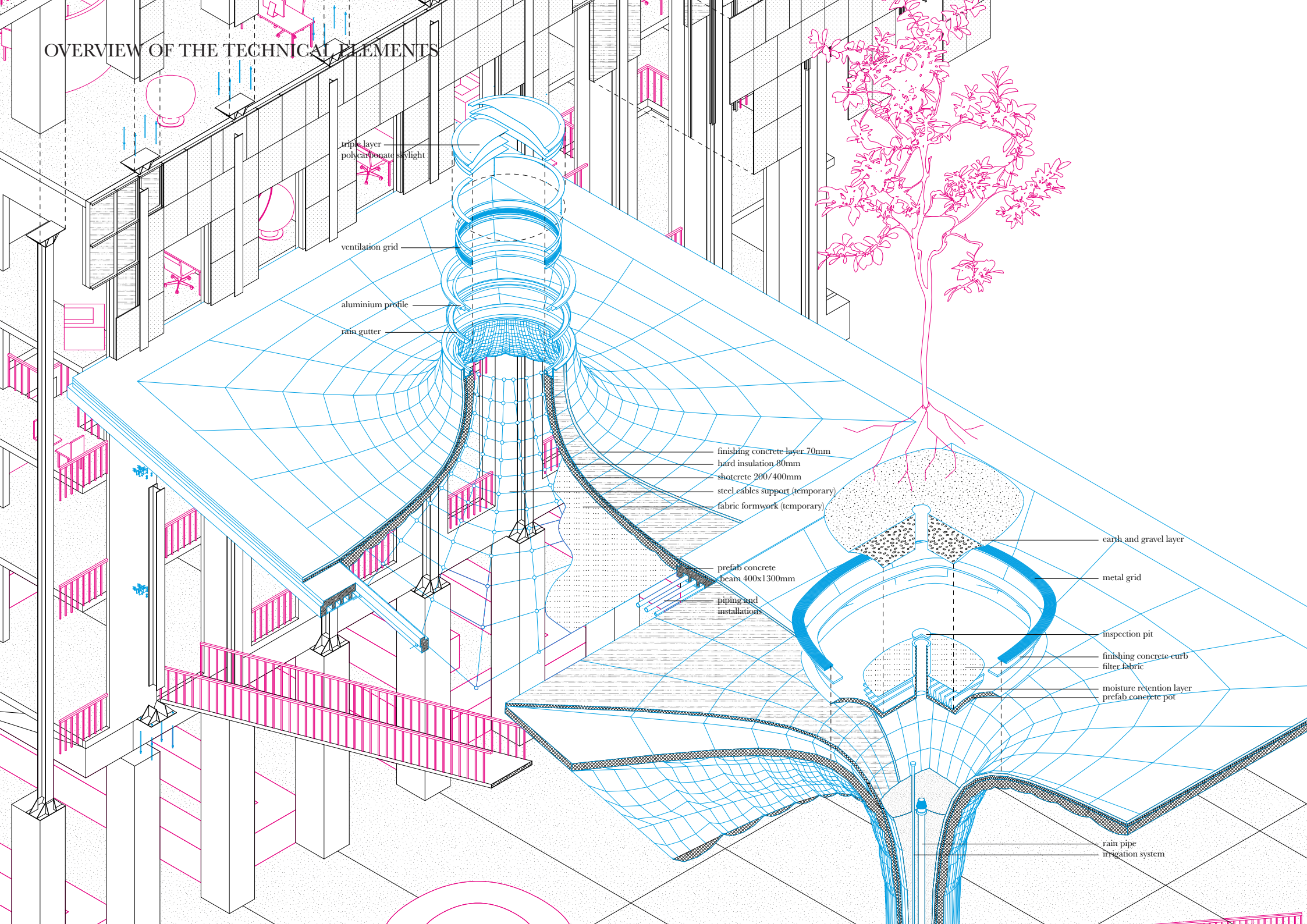
Wire mesh + fabric

CONSTRUCTION PROCESS



Shotcrete

# OVERVIEW OF THE TECHNICAL ELEMENTS



triple layer polycarbonate skylight

ventilation grid

aluminium profile

rain gutter

finishing concrete layer 70mm  
hard insulation 80mm  
shotcrete 200/400mm  
steel cables support (temporary)  
fabric formwork (temporary)

prefab concrete beam 400x1300mm  
piping and installations

earth and gravel layer

metal grid

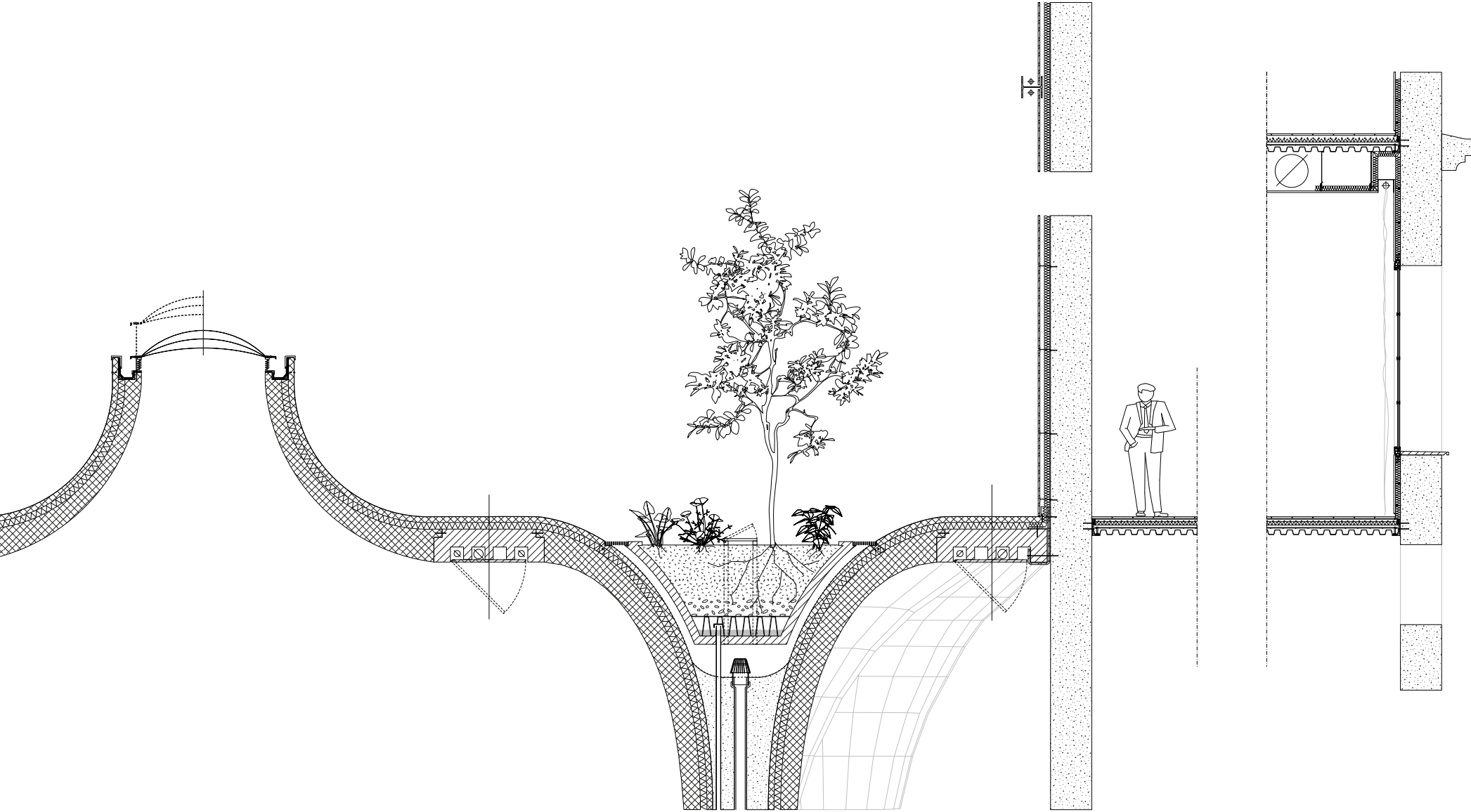
inspection pit

finishing concrete curb  
filter fabric

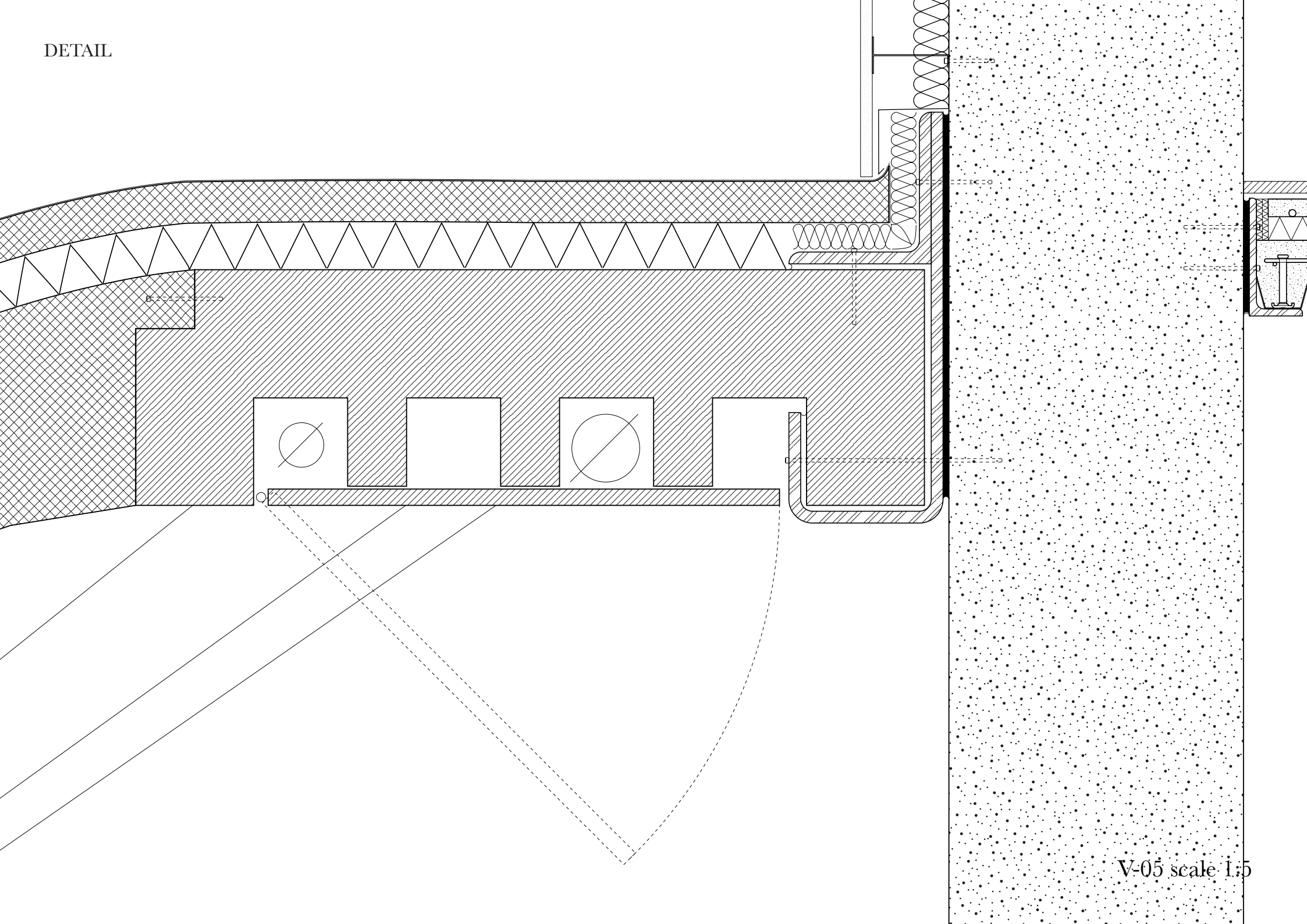
moisture retention layer  
prefab concrete pot

rain pipe  
irrigation system

OVERVIEW OF THE TECHNICAL ELEMENTS



DETAIL

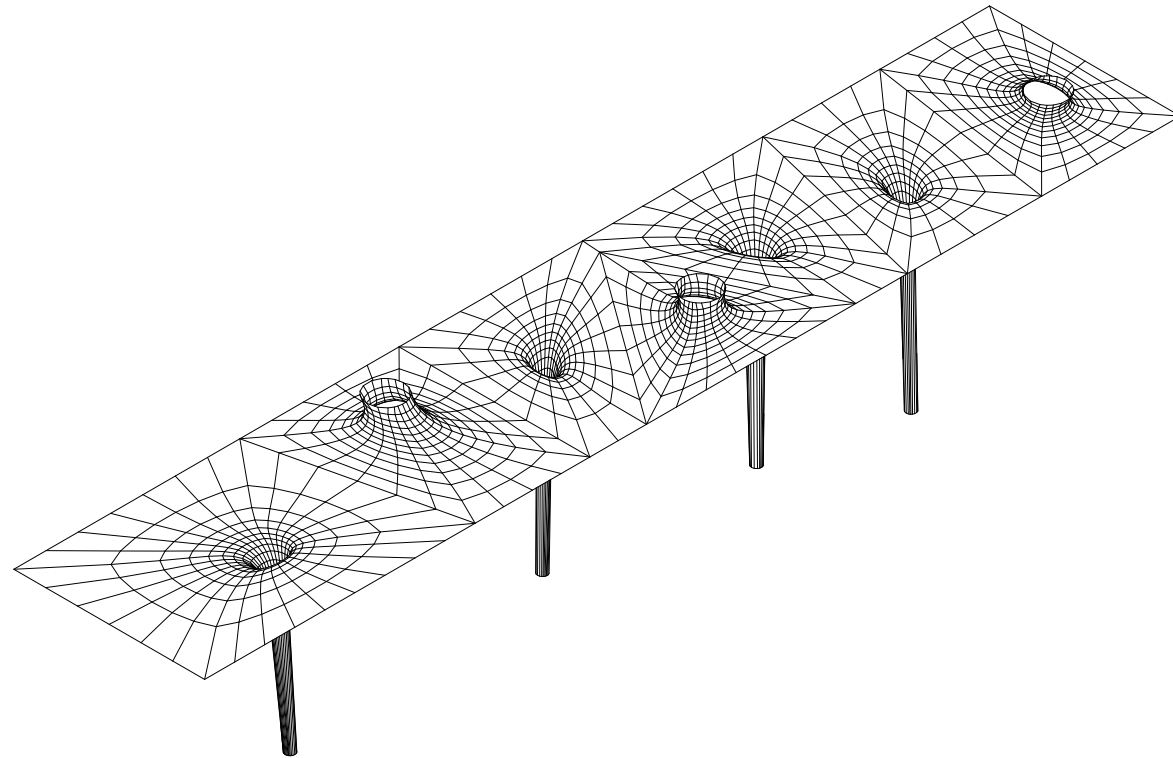


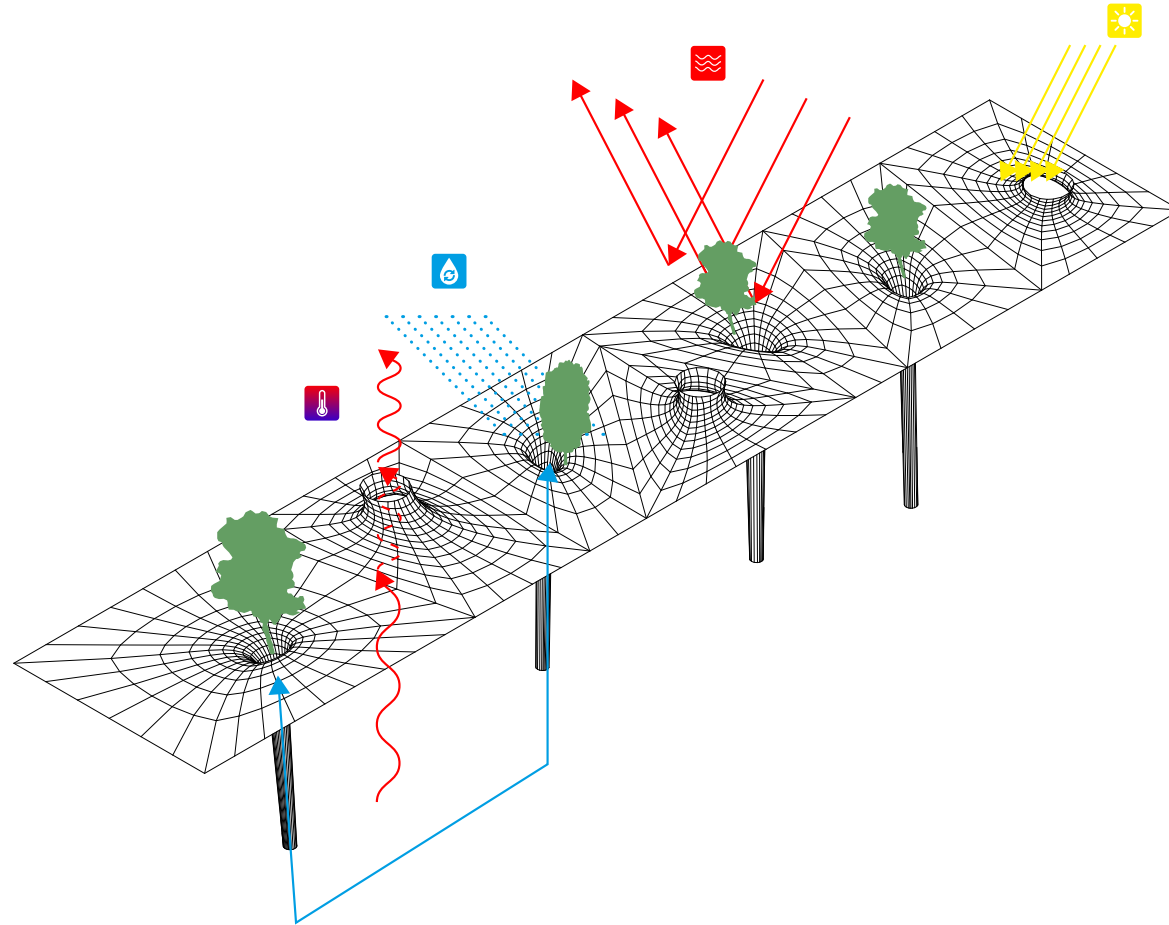
V-05 scale 1:5

Table 2.1: Comparison of various formwork methods

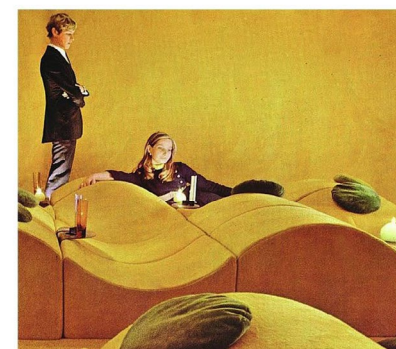
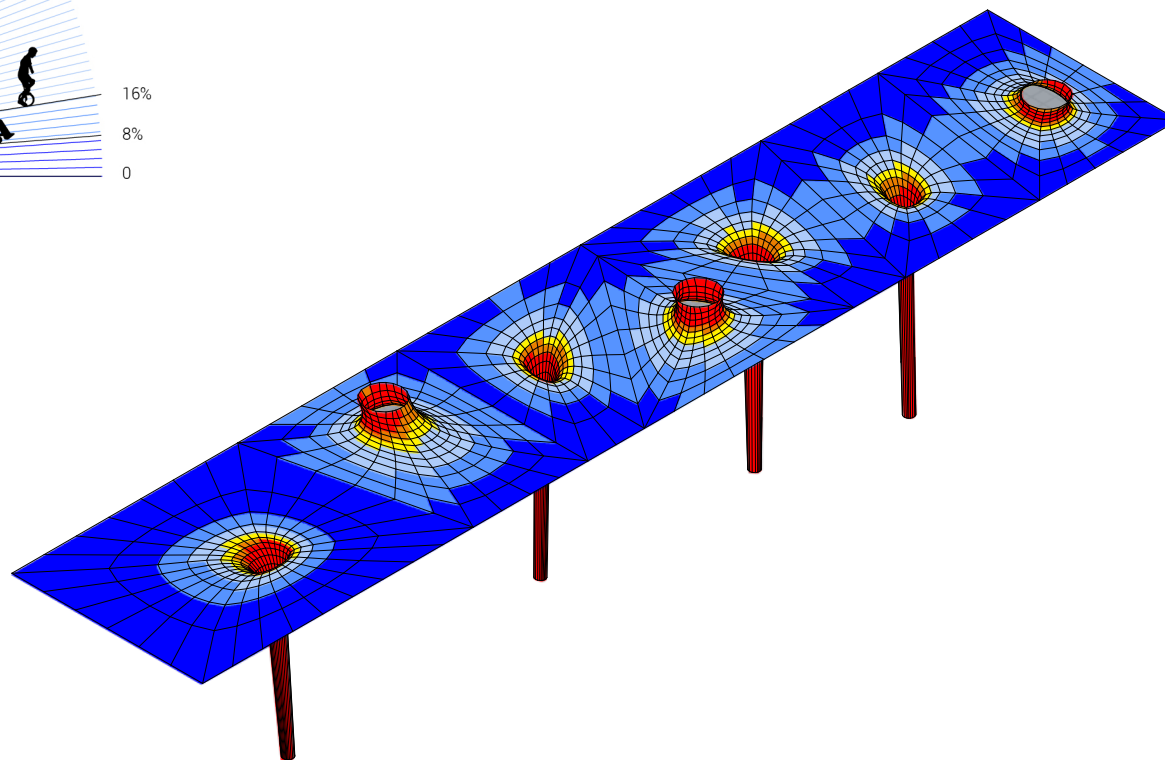
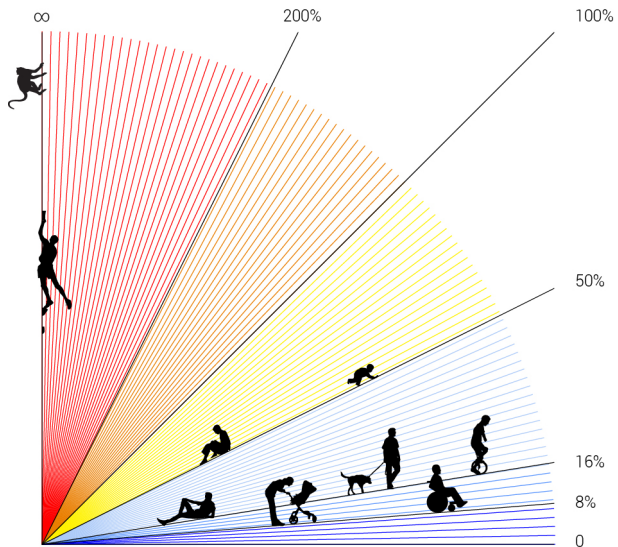
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General need for a flexible mould principle





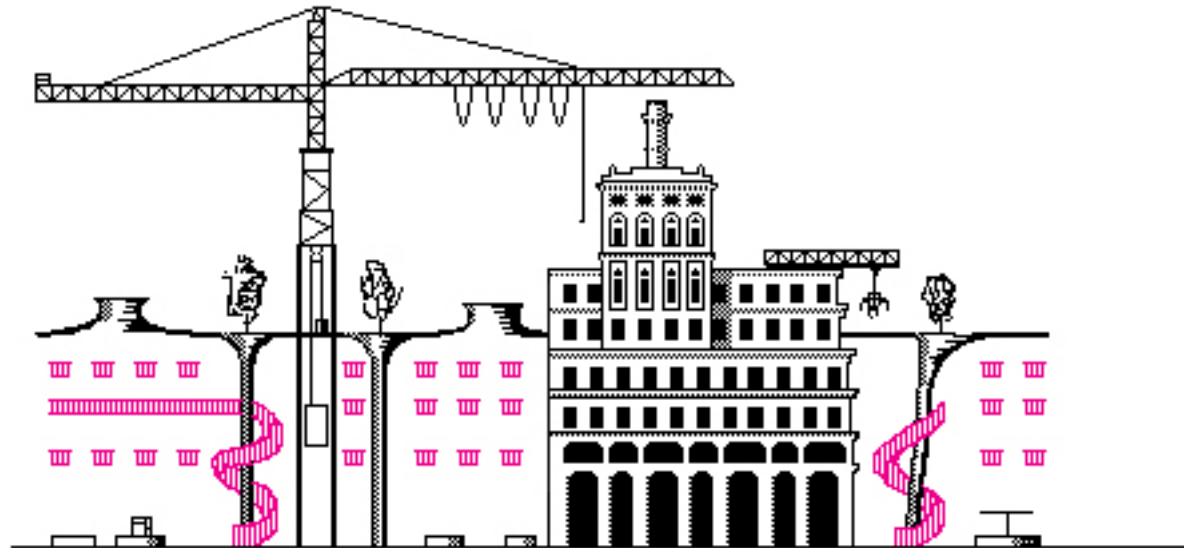




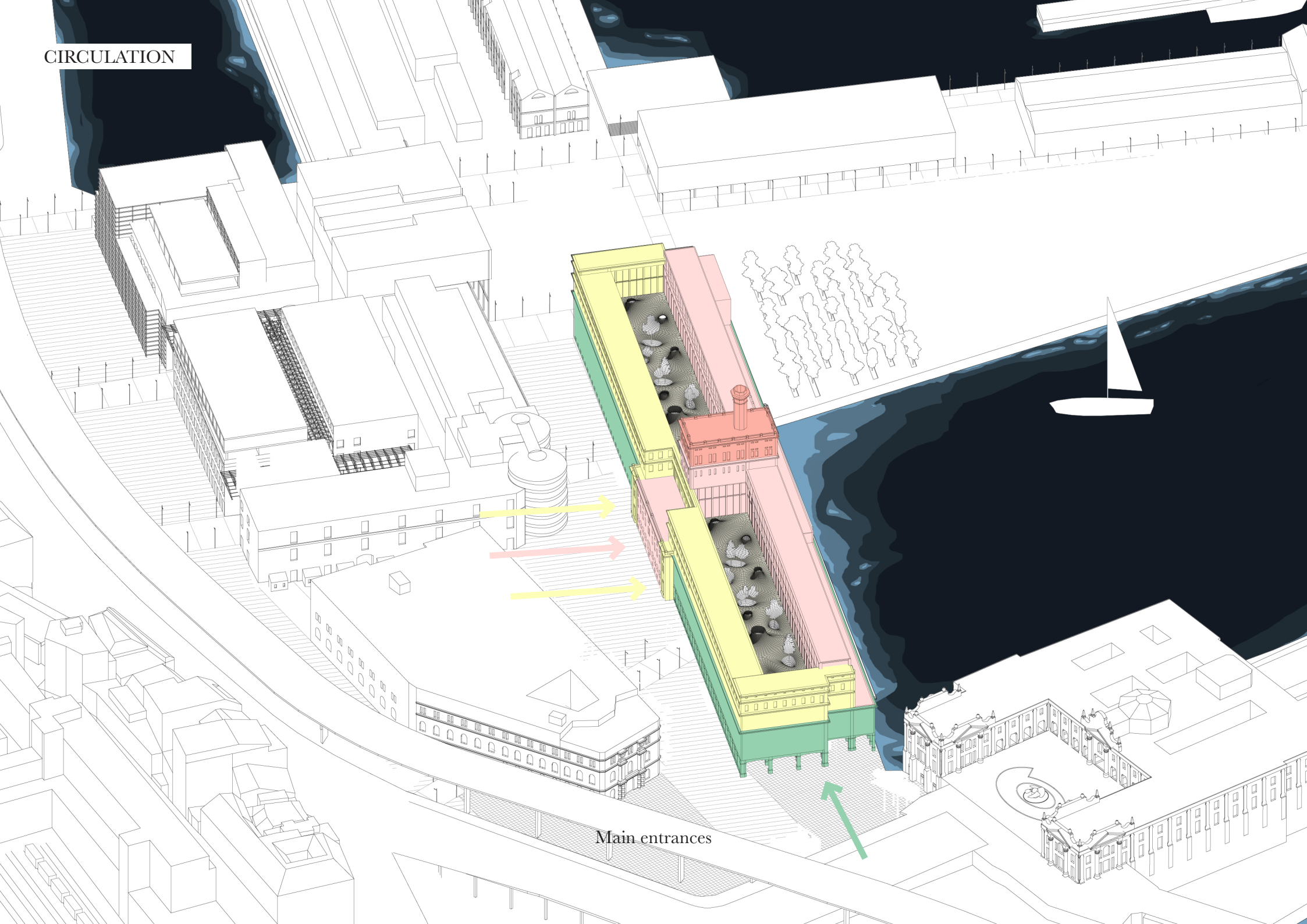


Public space as a playground

## 5.DESIGN

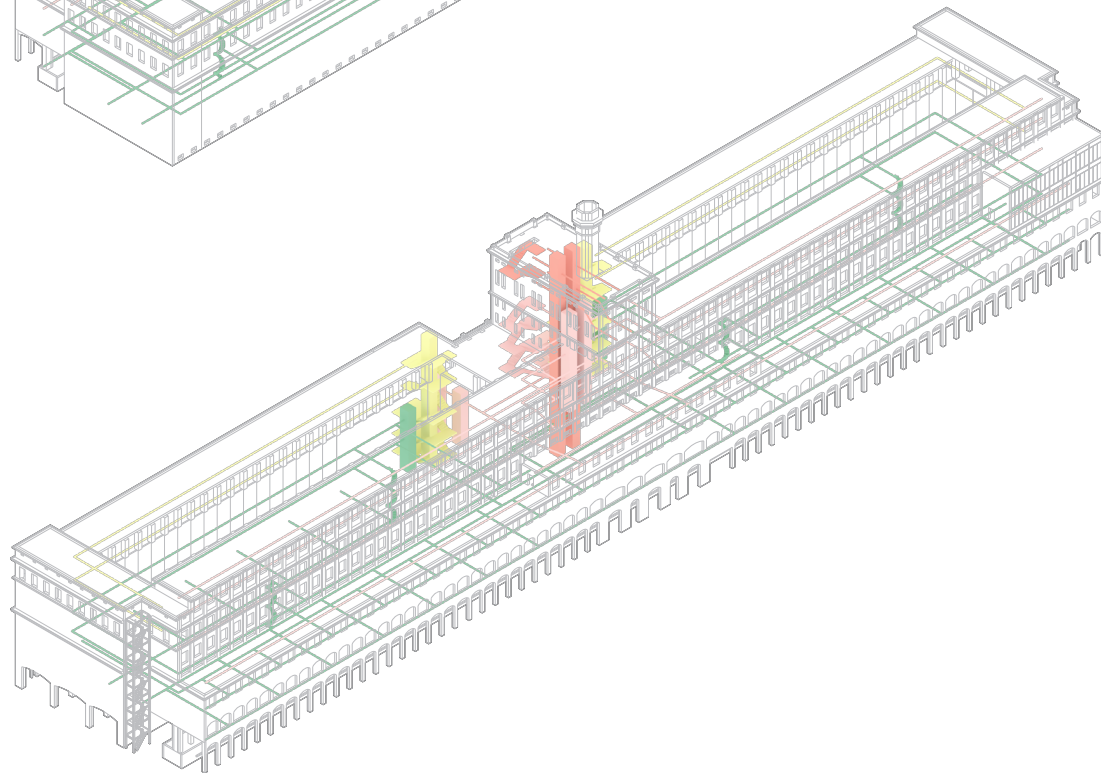
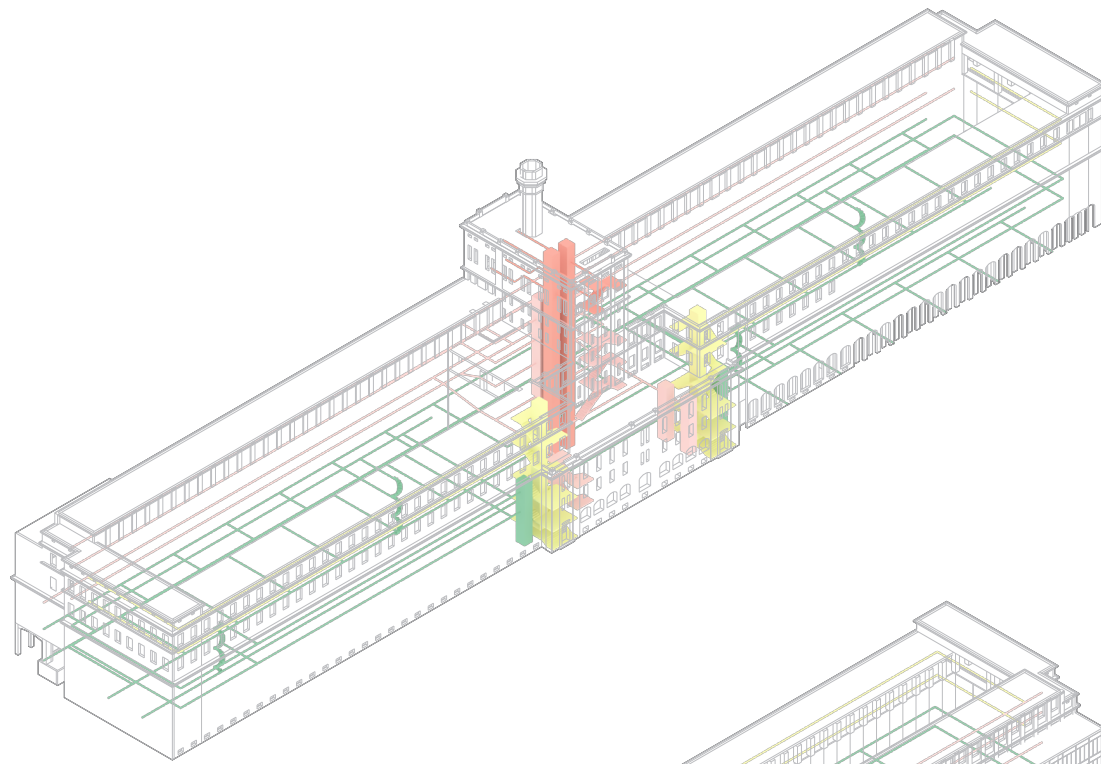


CIRCULATION



Main entrances

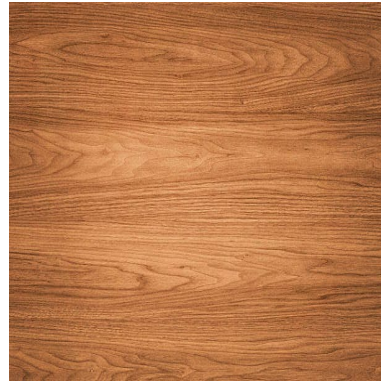
# CIRCULATION



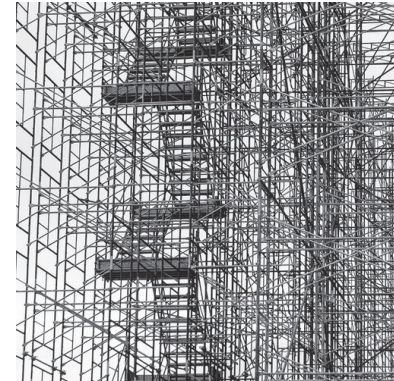
EXISTING/  
CONCRETE



NOT FIXED ELEMENTS/  
WOOD



INTEGRATIONS/  
STEEL



NEW/  
CONCRETE



CROSS SECTION



PROCESS READABILITY



Bumpy white  
concrete

Rough concrete  
post-demolition

Casted in-situ  
concrete

Prefab concrete  
tiles

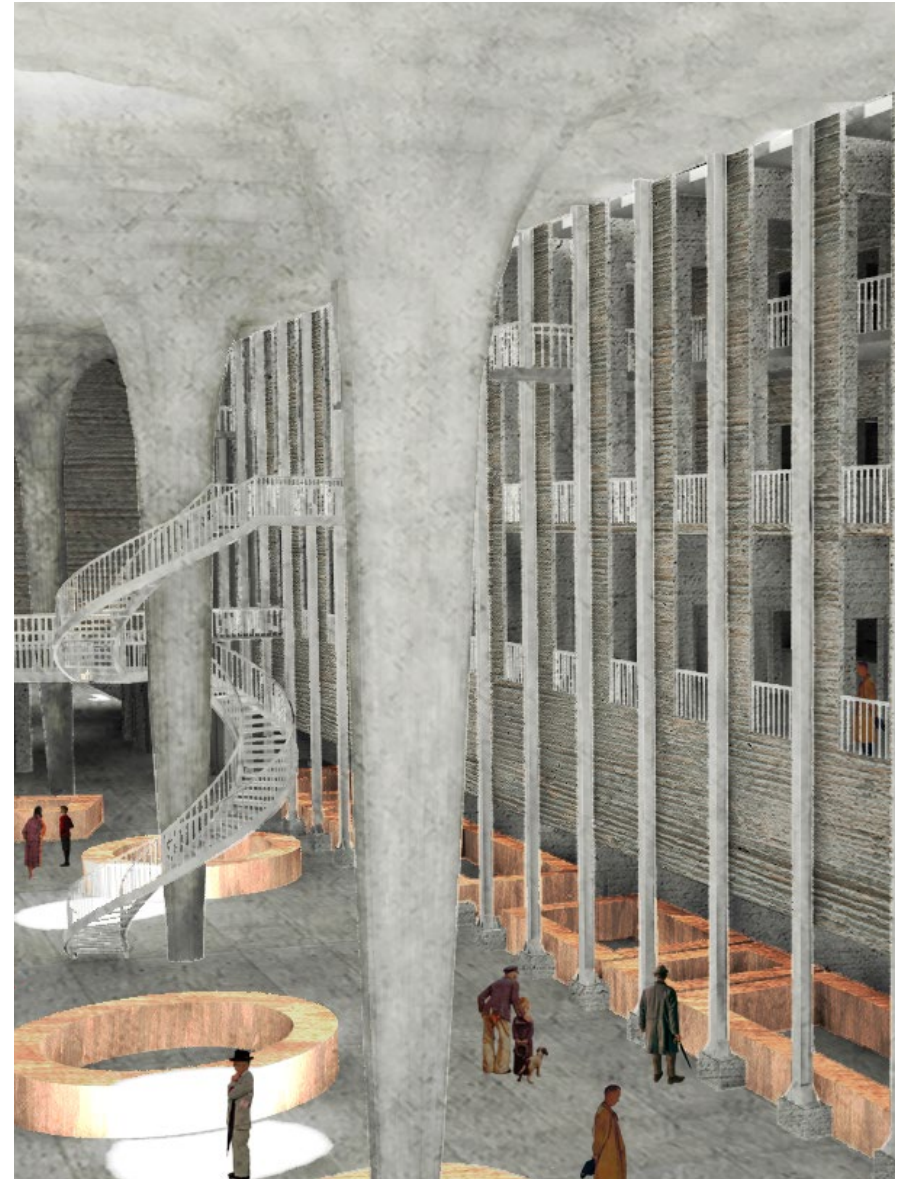




Main market hall

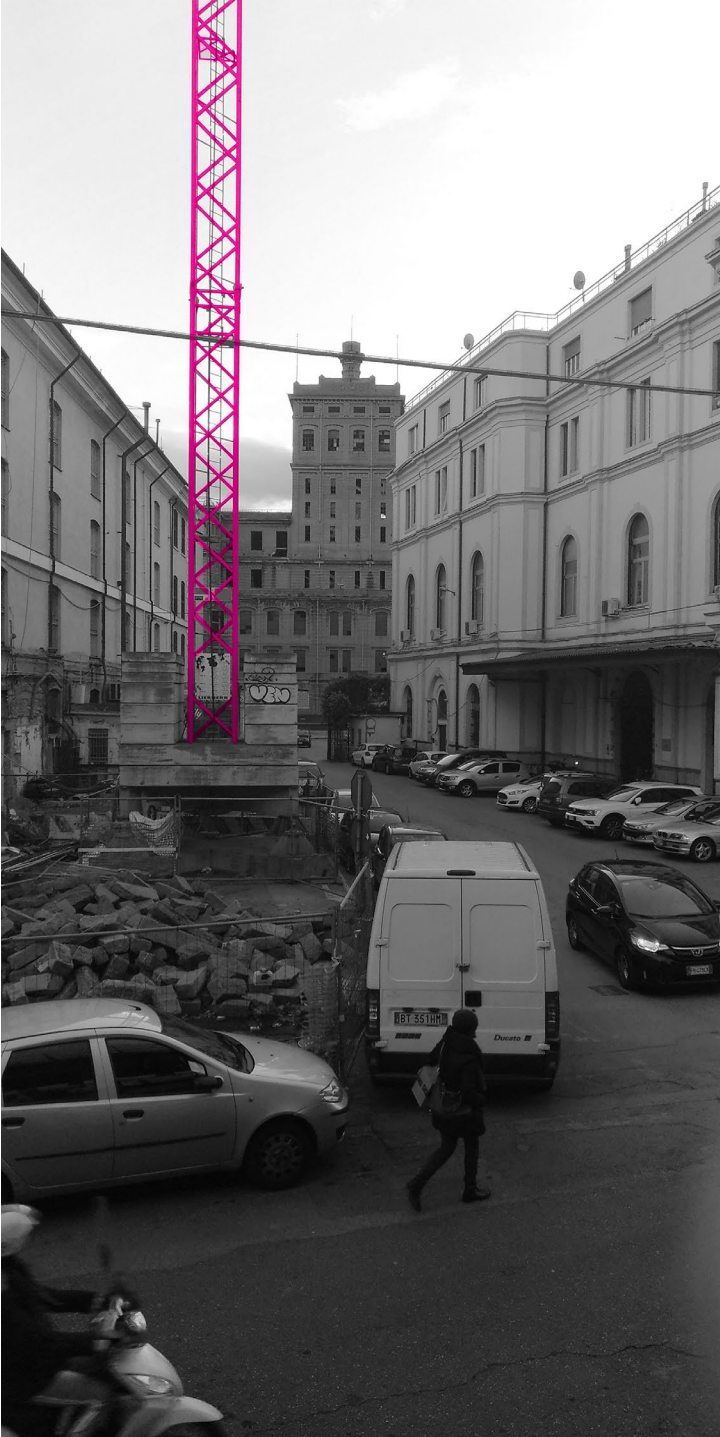
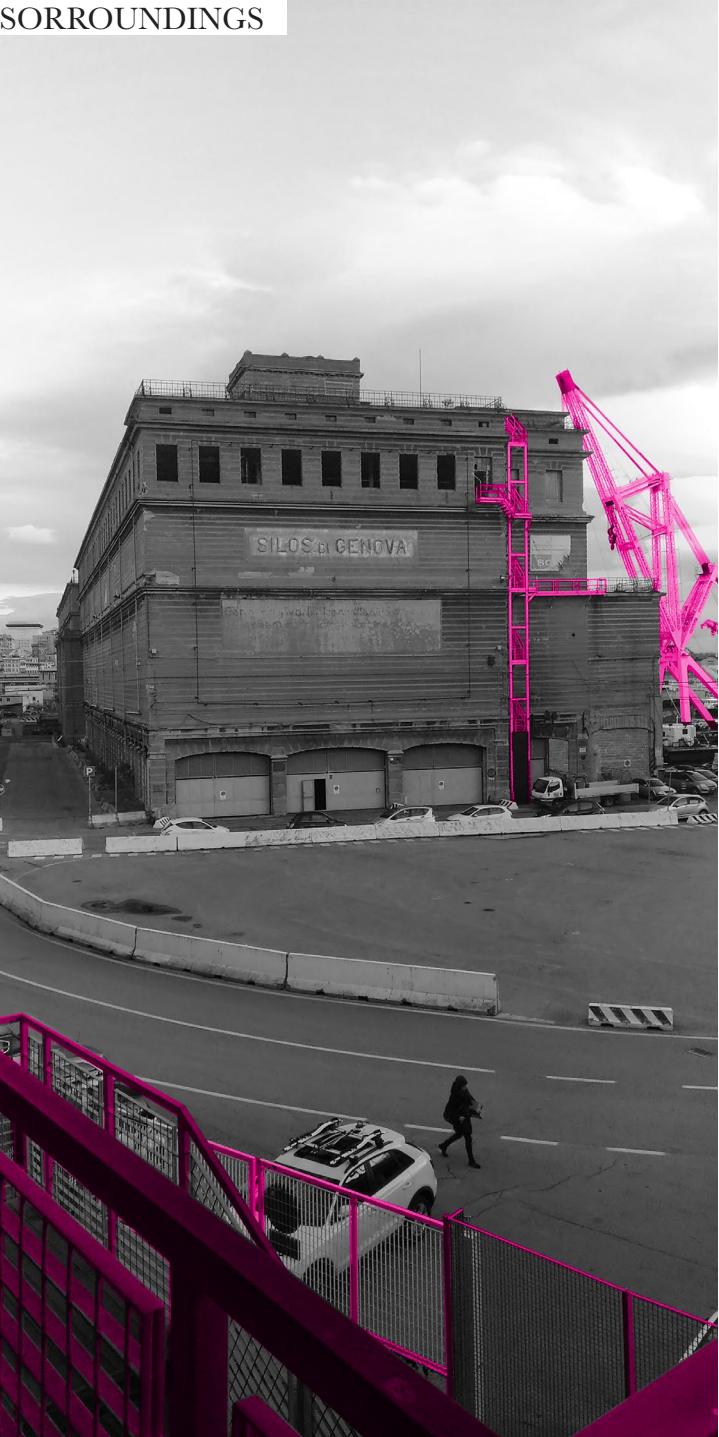


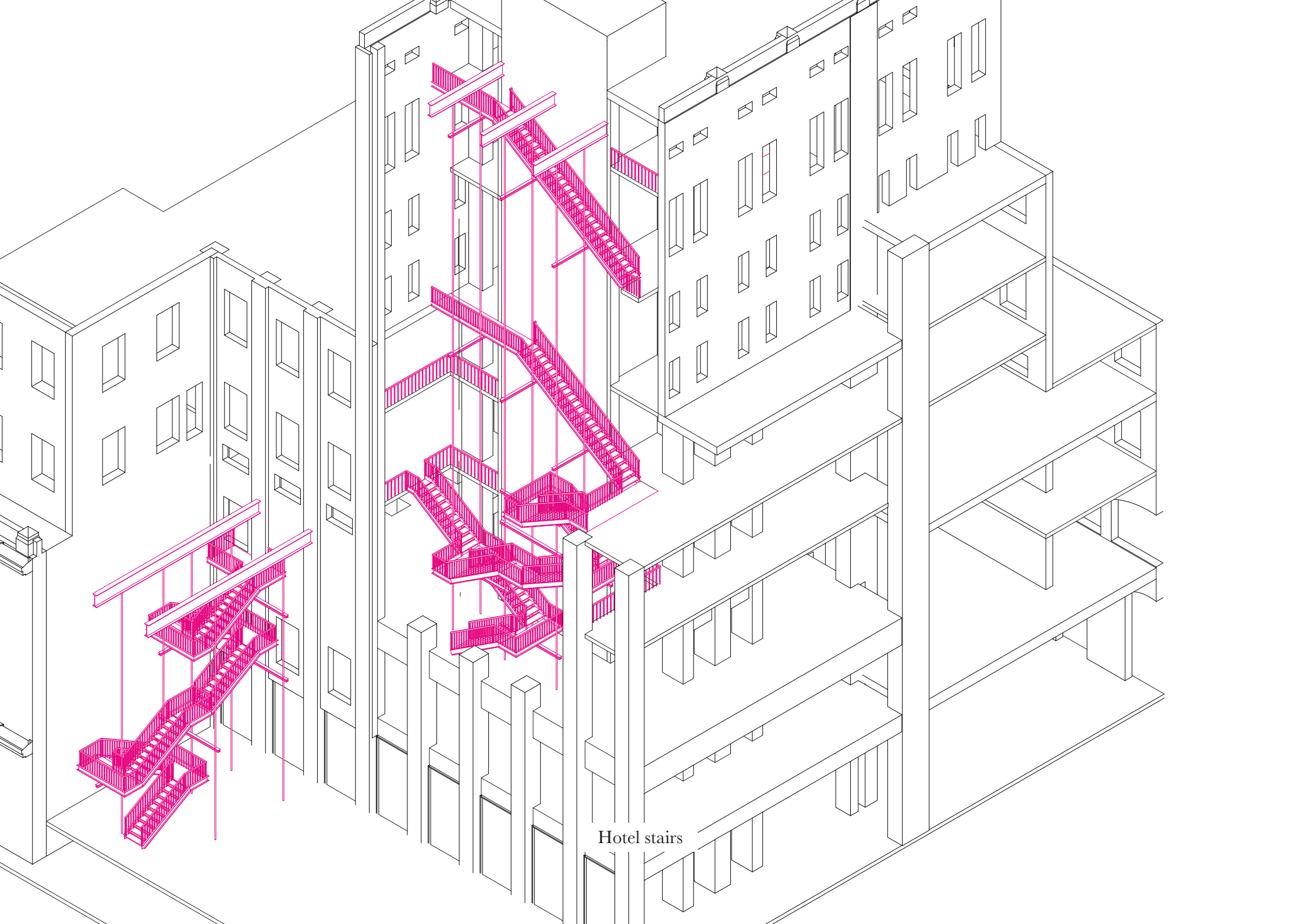
Zenital light



Sense of scale

SORROUNDINGS





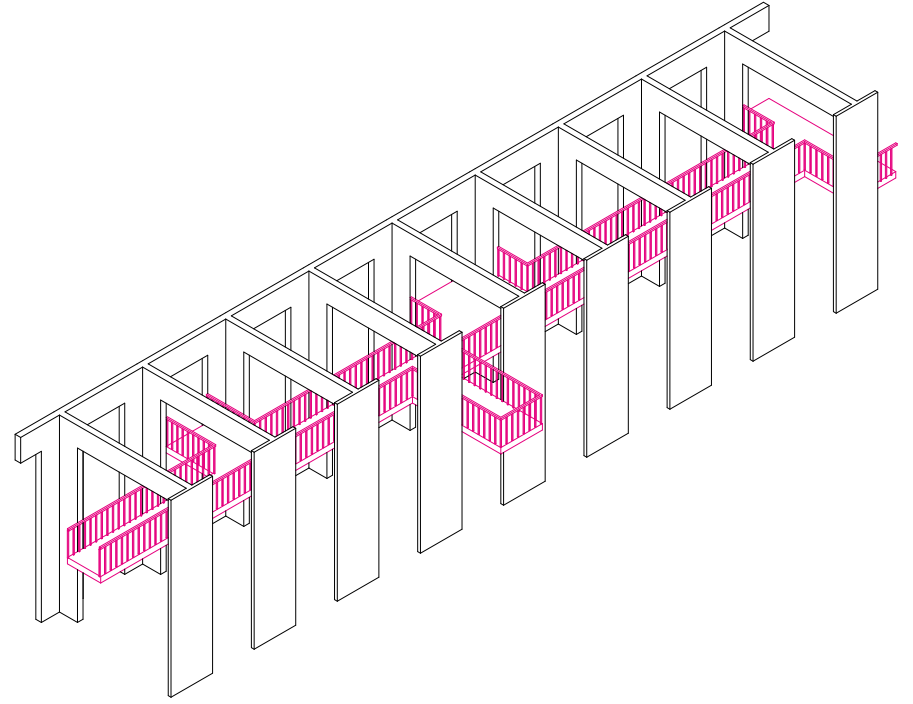
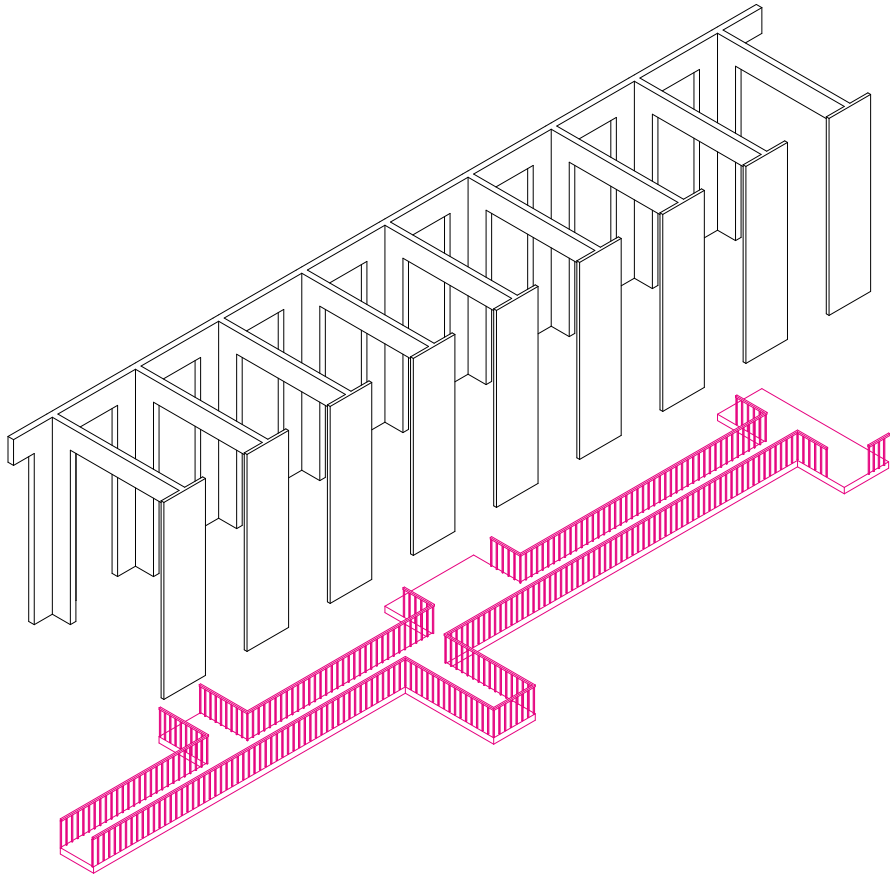
Hotel stairs



Routing

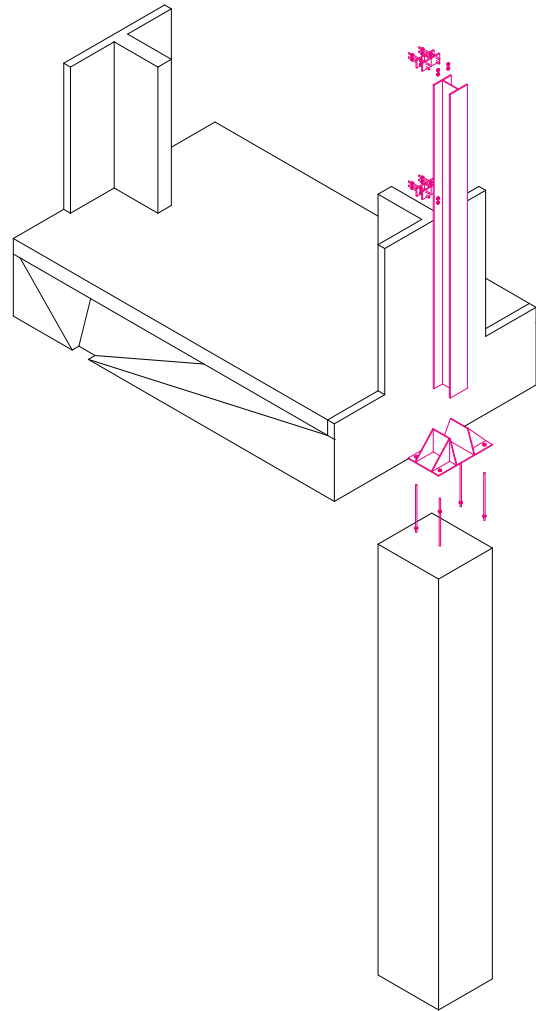


Hotel stairs

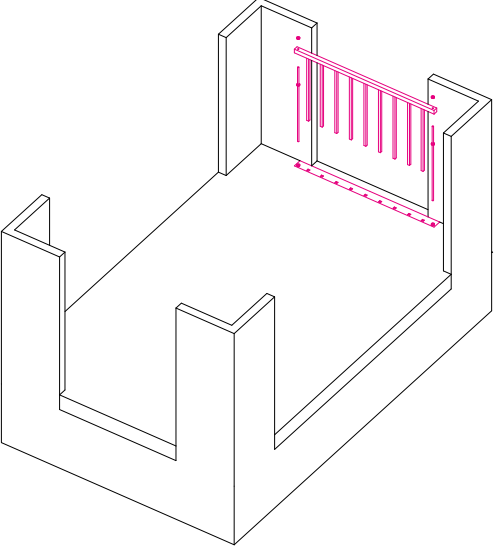


Market mezzanine

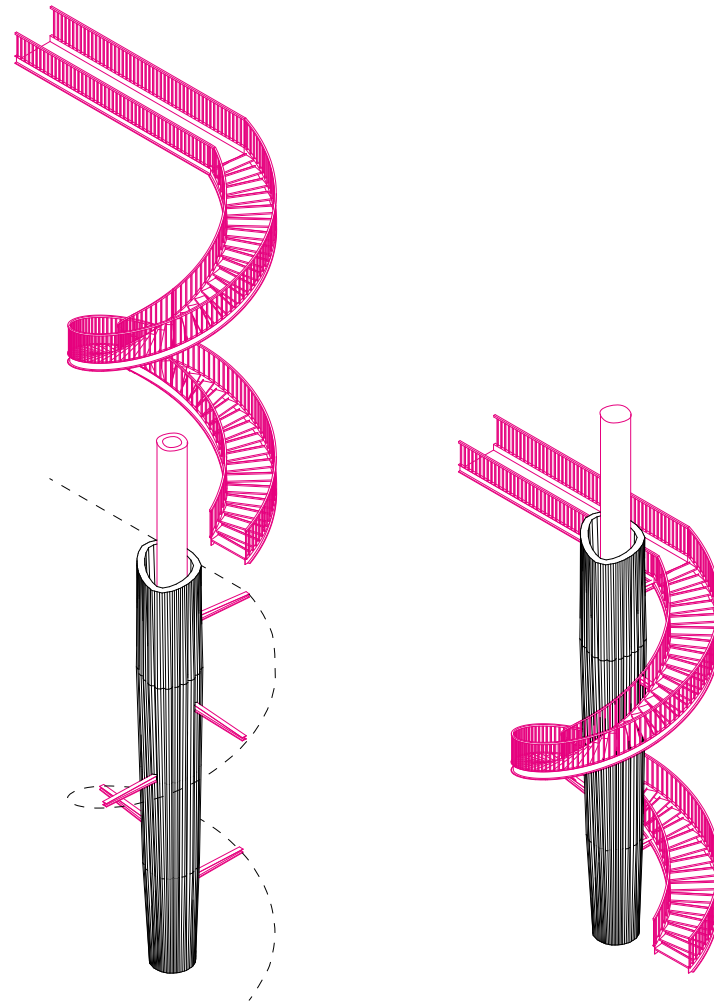




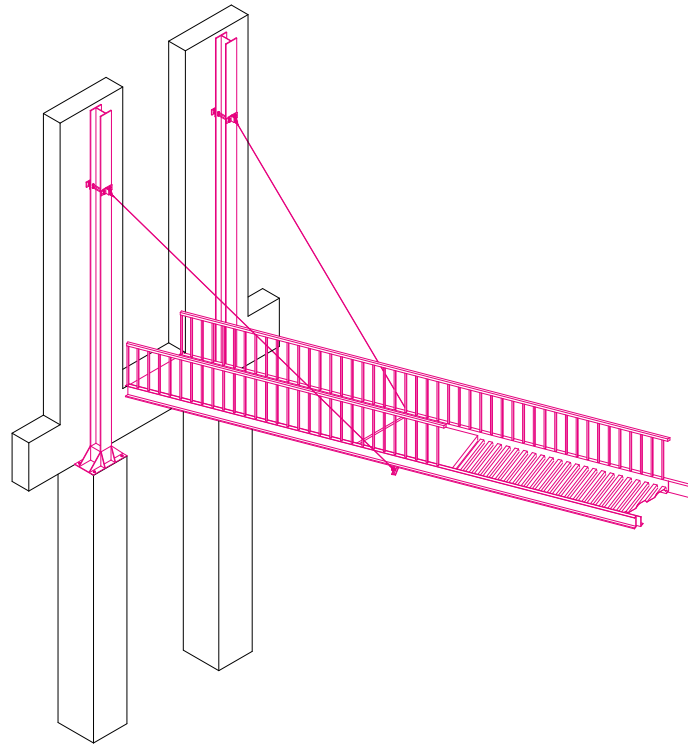
Support column in the main market hall



Handrail detail



Helicoidal stair in the main hall



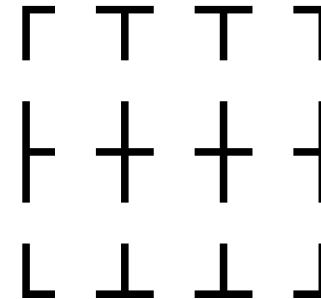
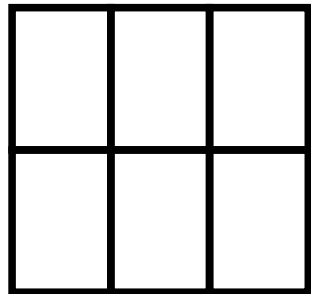
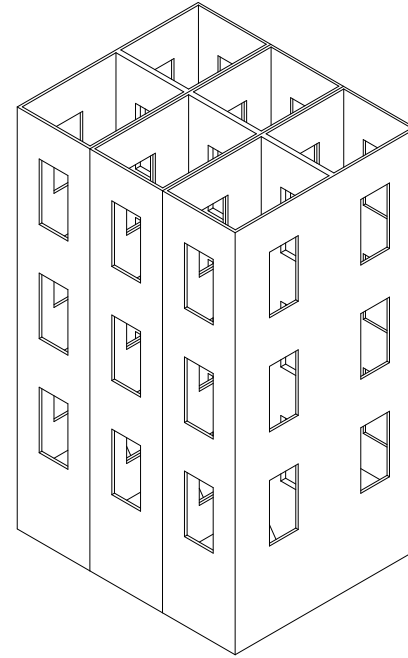
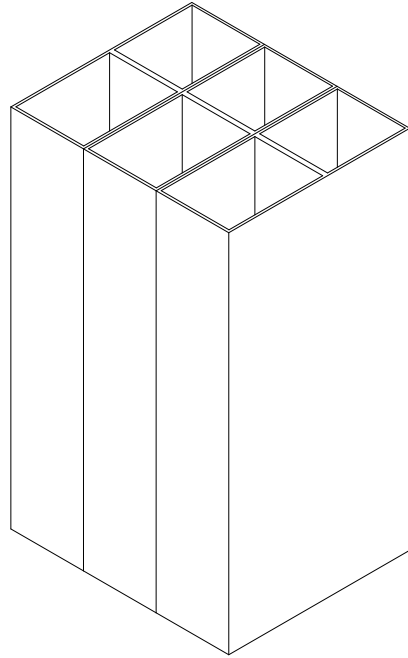
Bridge in the main hall



Material contrast

STRATEGY

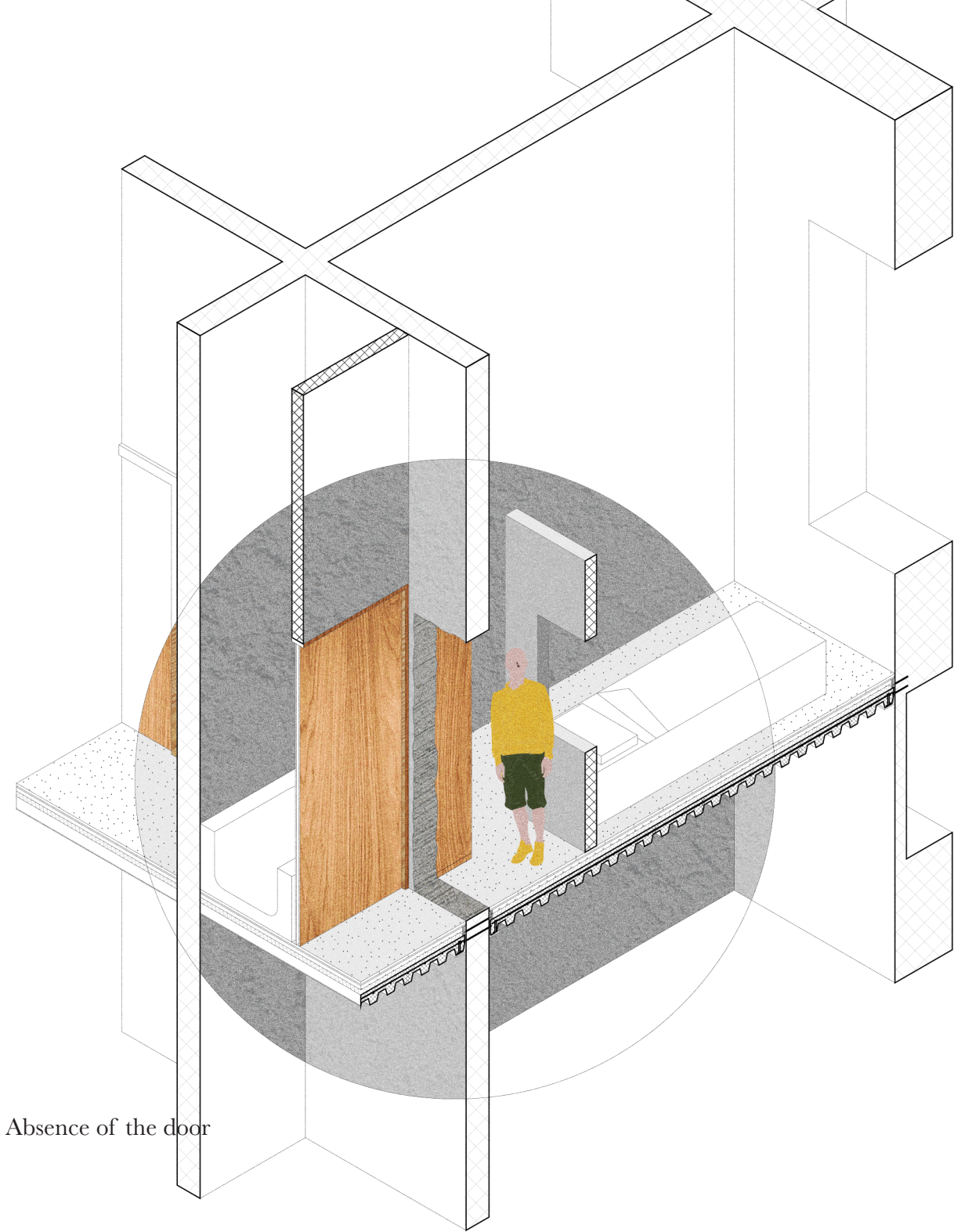
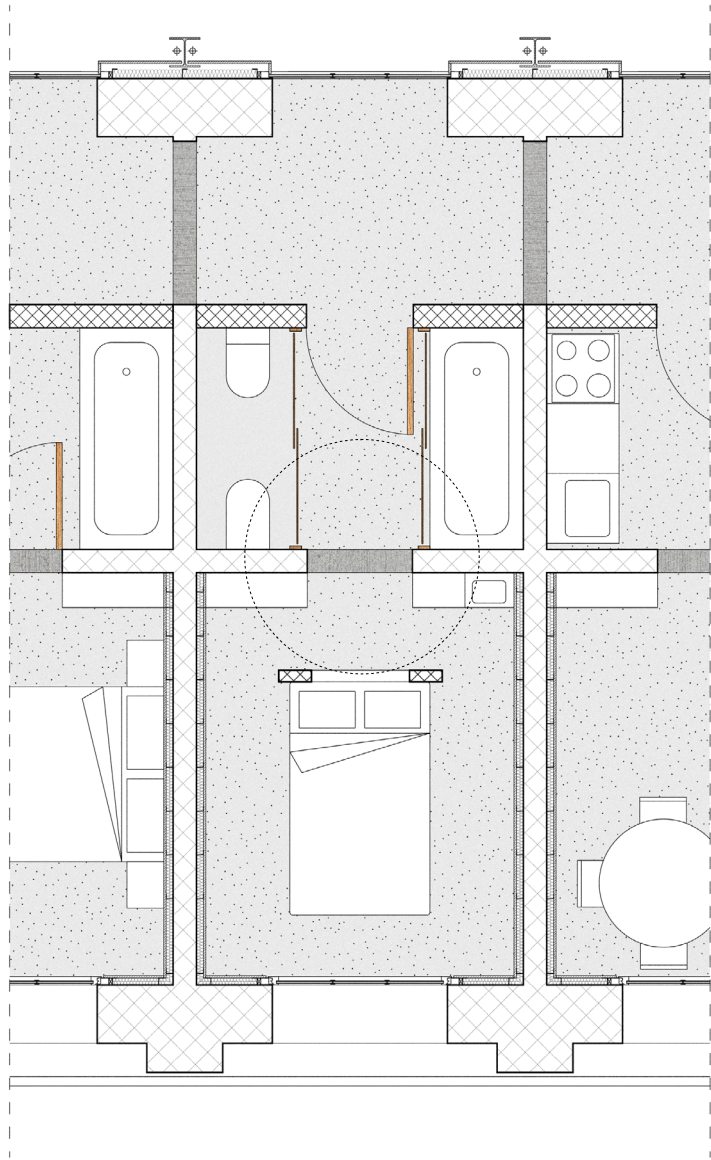
Demolition area <30% than the total area of the wall





Intervention evidence

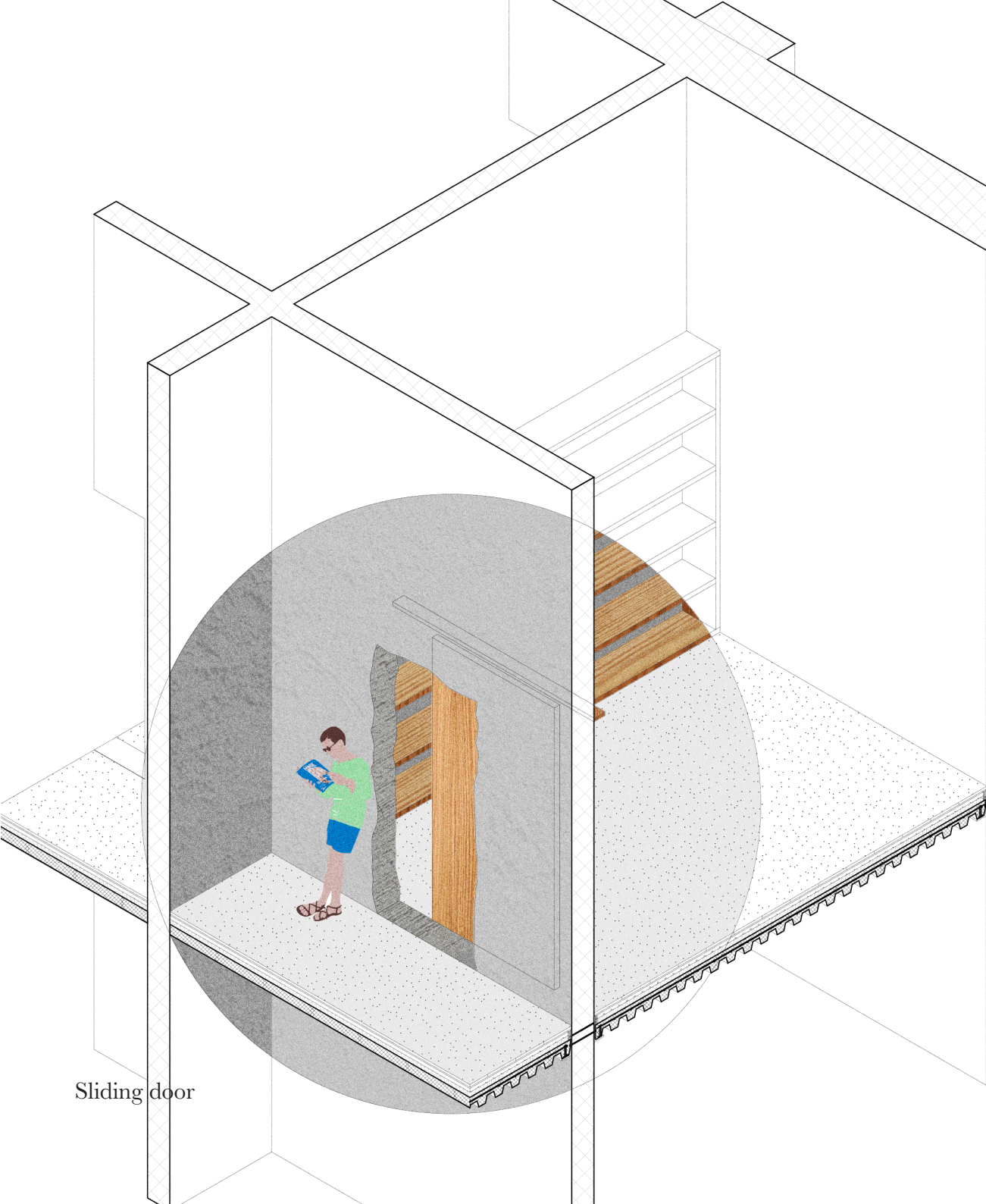
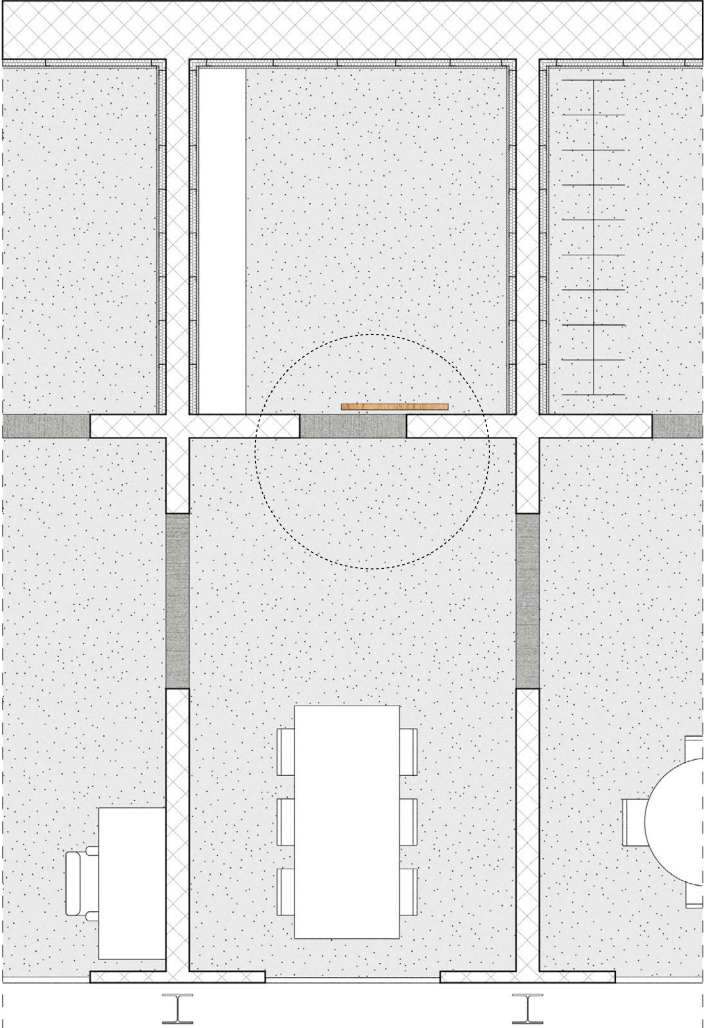
PROCESS READABILITY



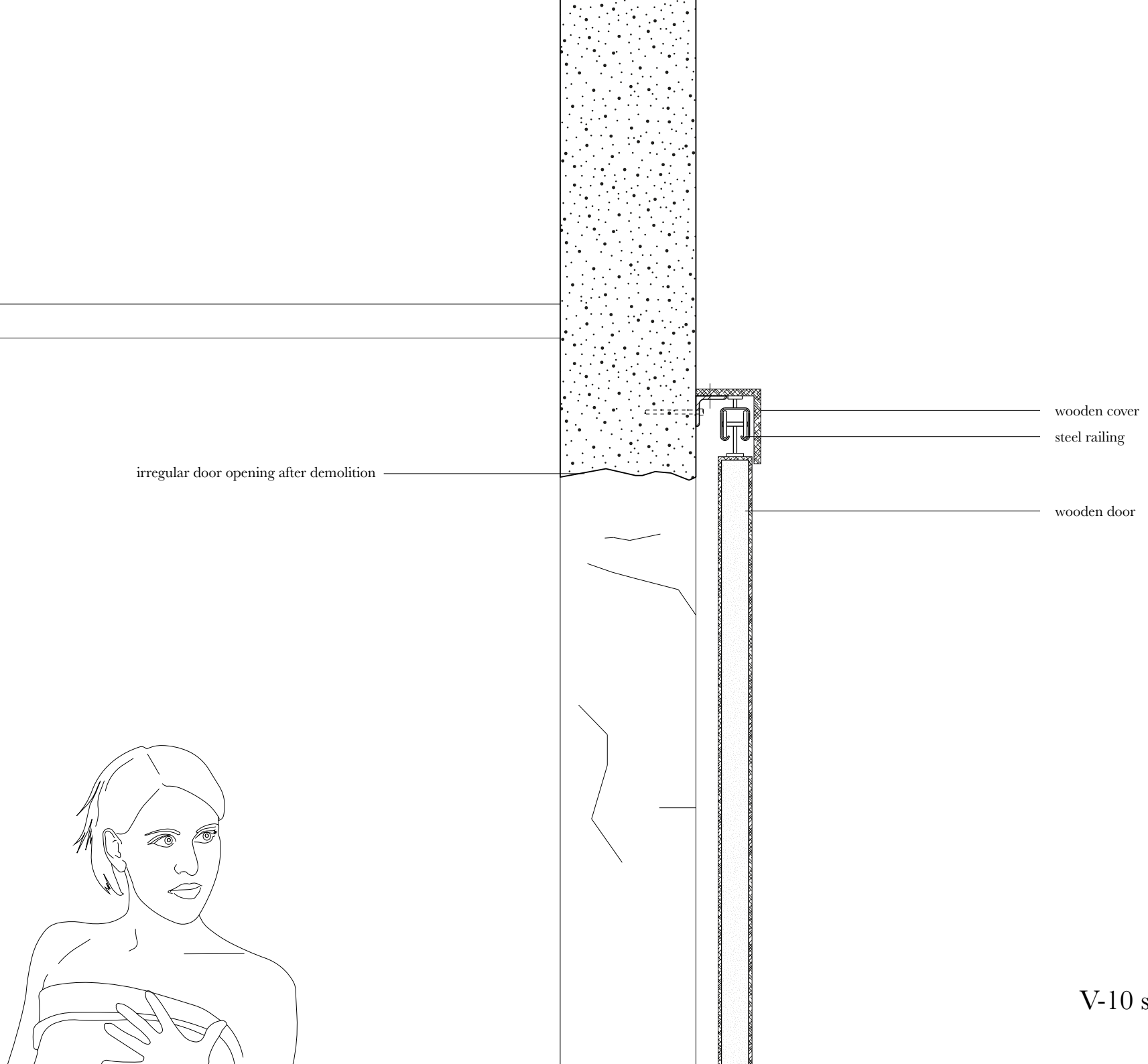
Absence of the door



PROCESS READABILITY

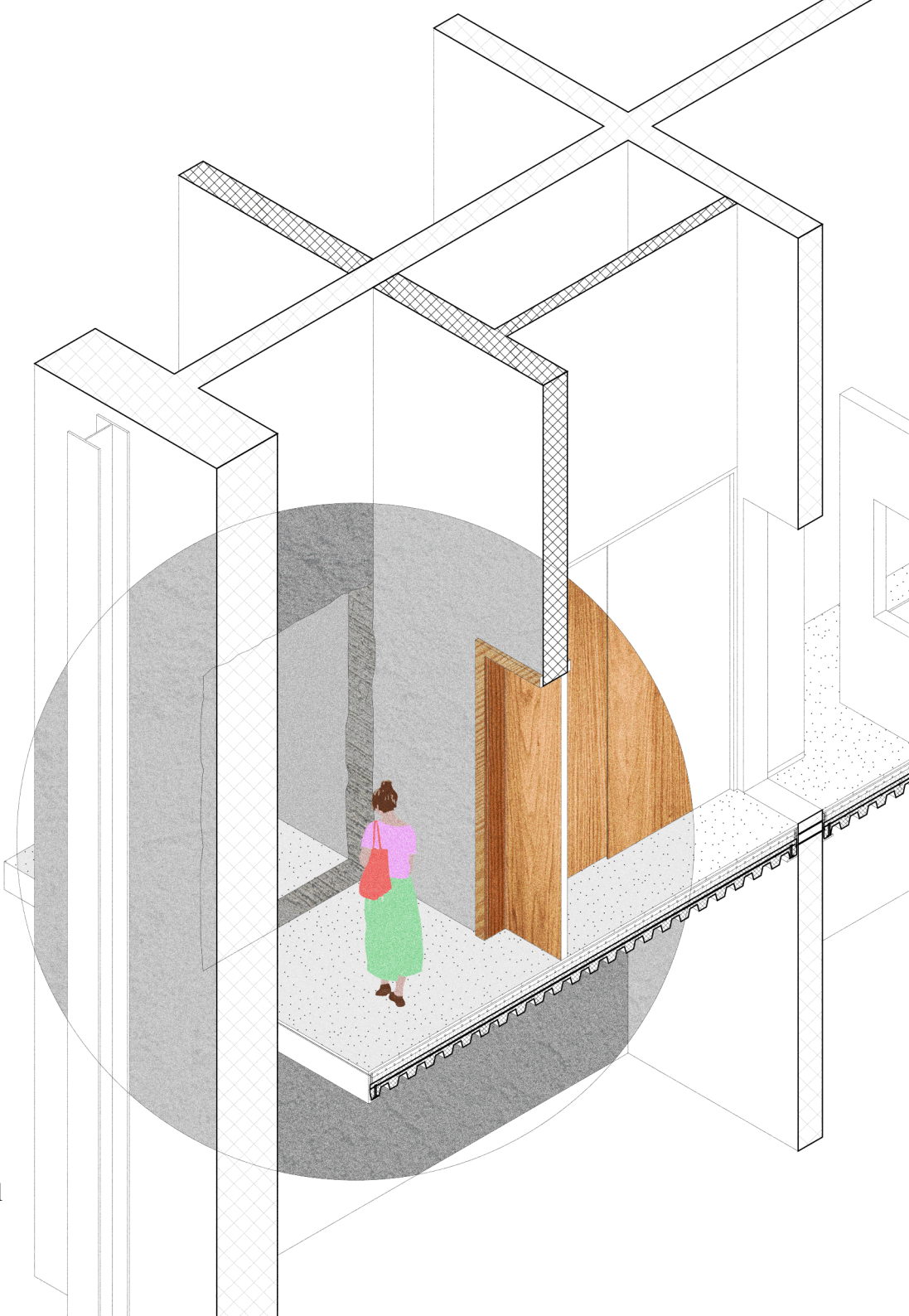
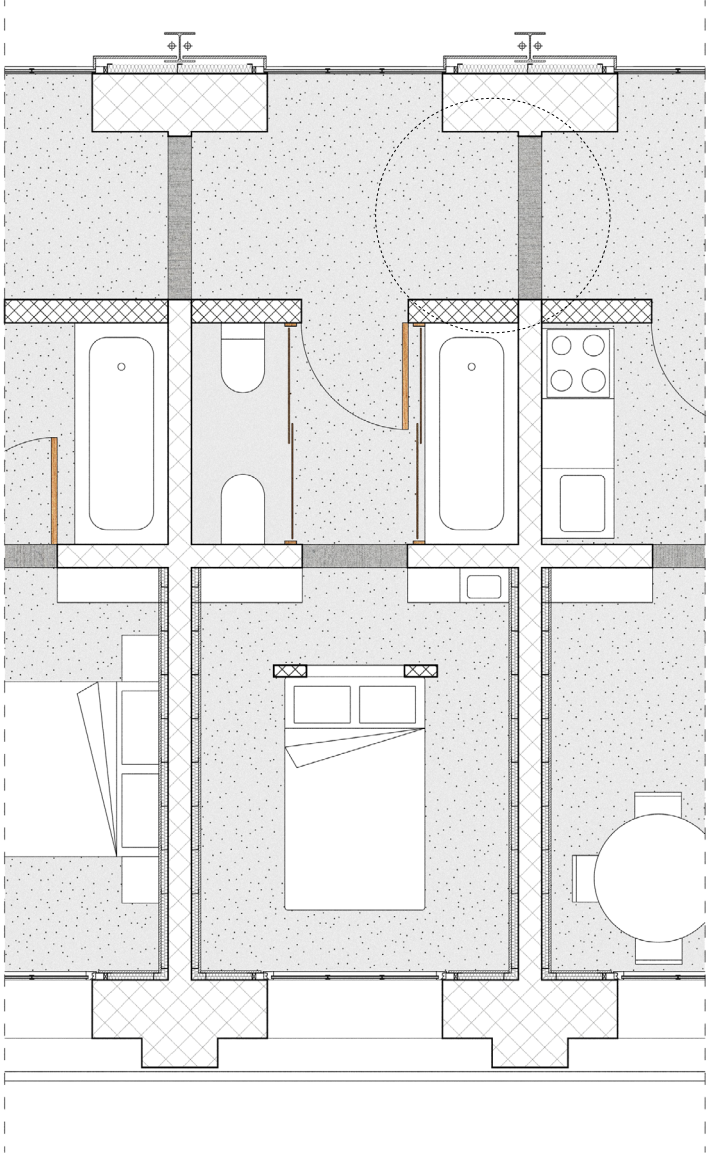


DETAIL

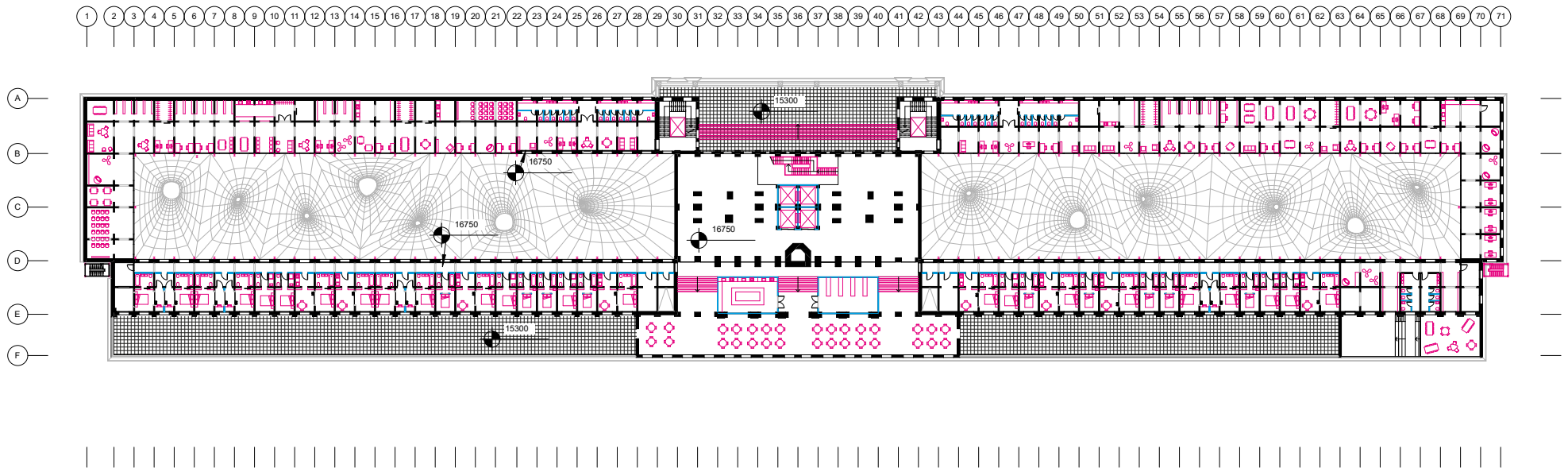


V-10 scale 1:5

PROCESS READABILITY

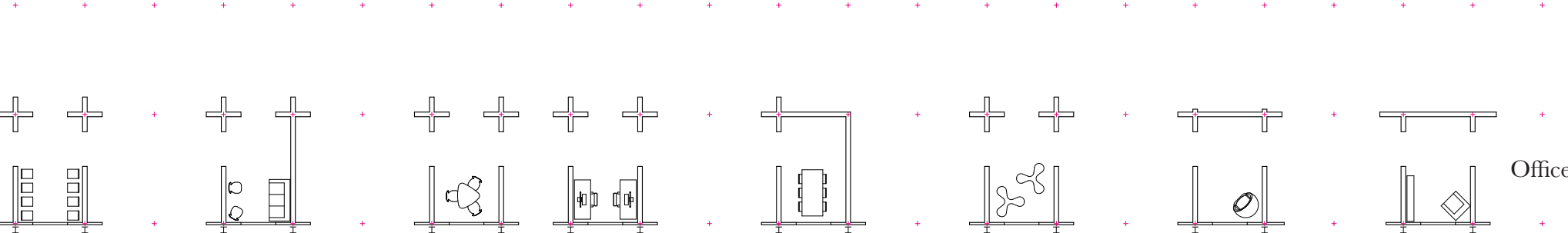
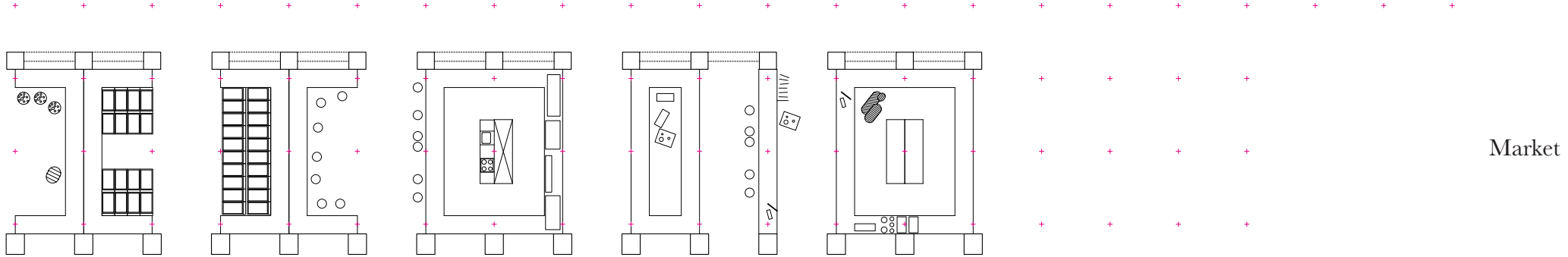
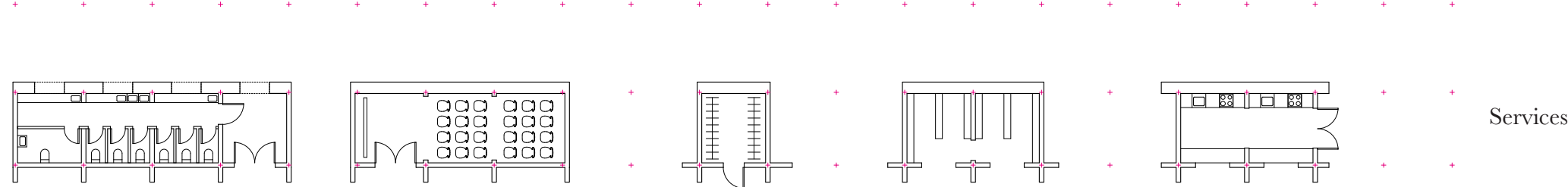
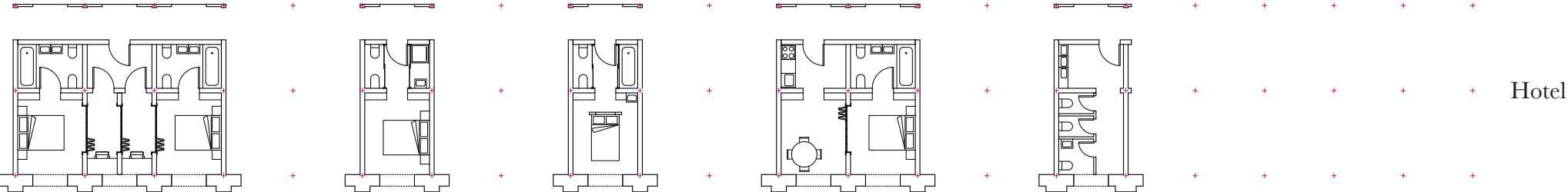


Wall



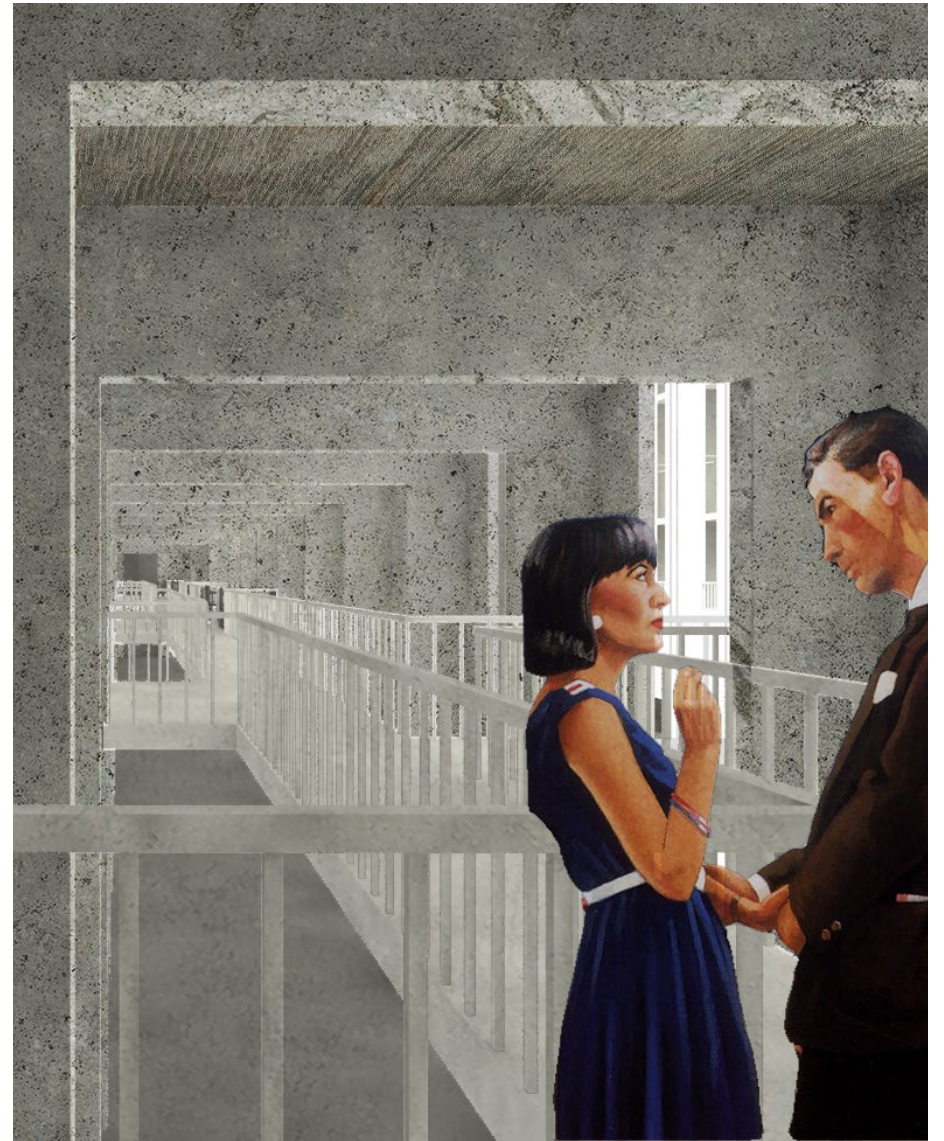
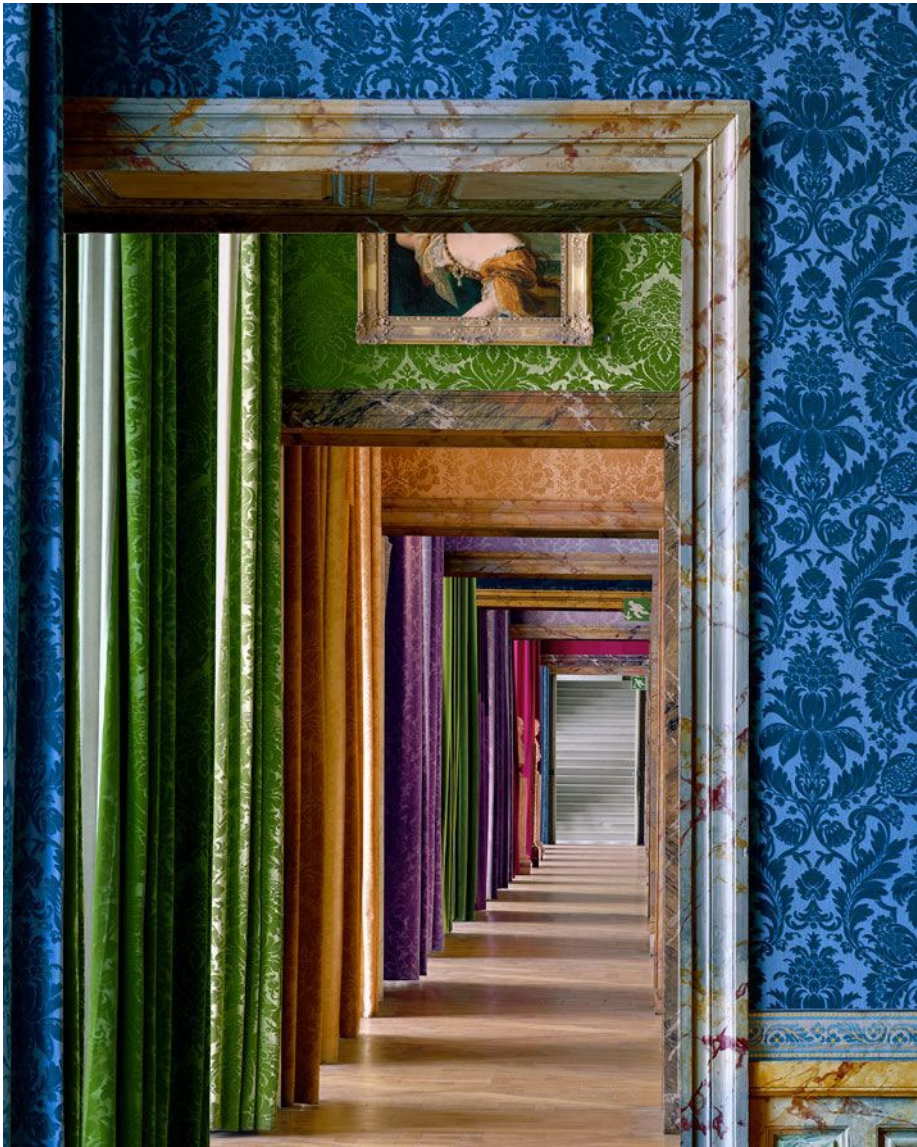
Level 7 (+16,75m)

PROGRAMMATIC FLEXIBILITY THROUGH MODULARITY





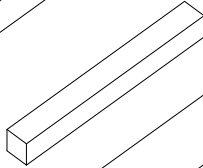
Co-working spaces



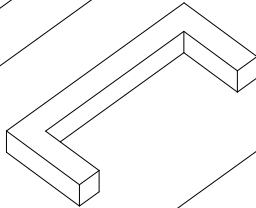
Sense of perspective

PROGRAMMATIC FLEXIBILITY THROUGH MODULARITY

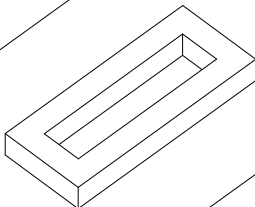
linear



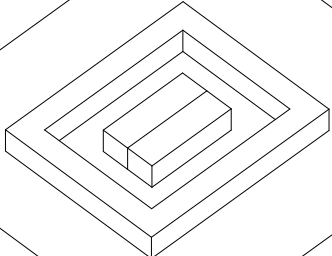
basic shapes



U shape

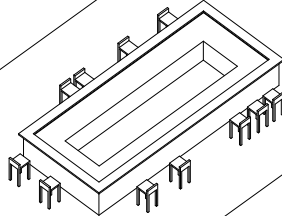
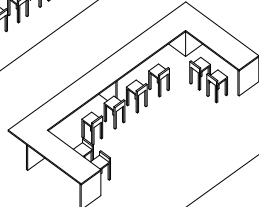
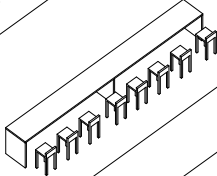


O shape

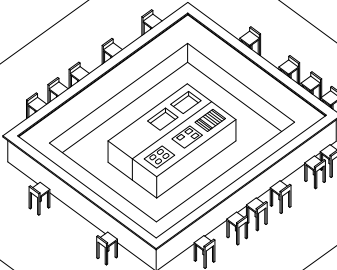
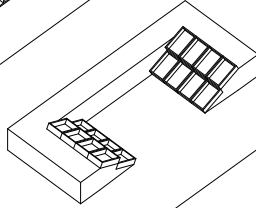
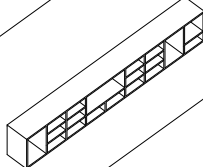


double

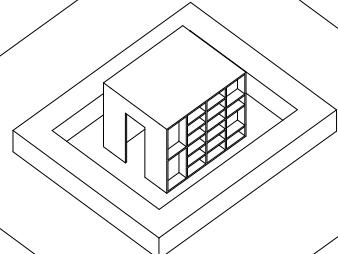
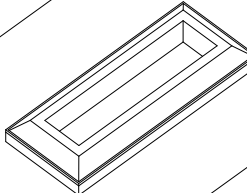
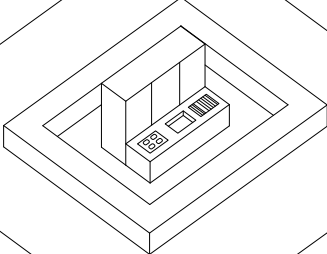
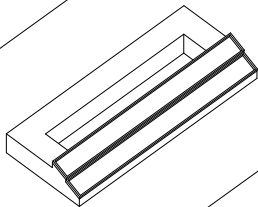
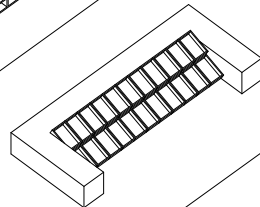
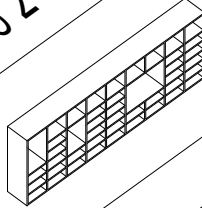
dining



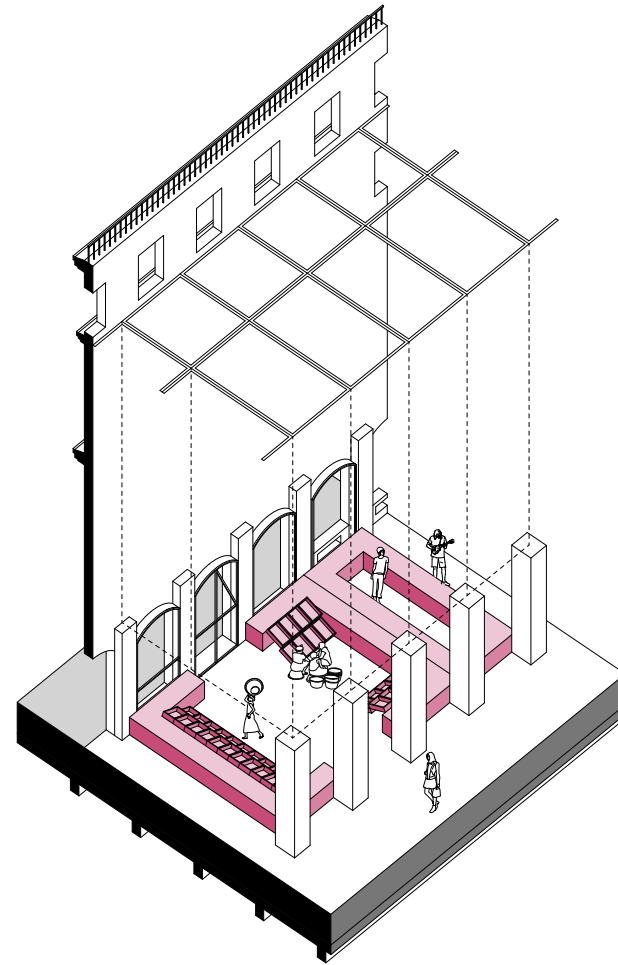
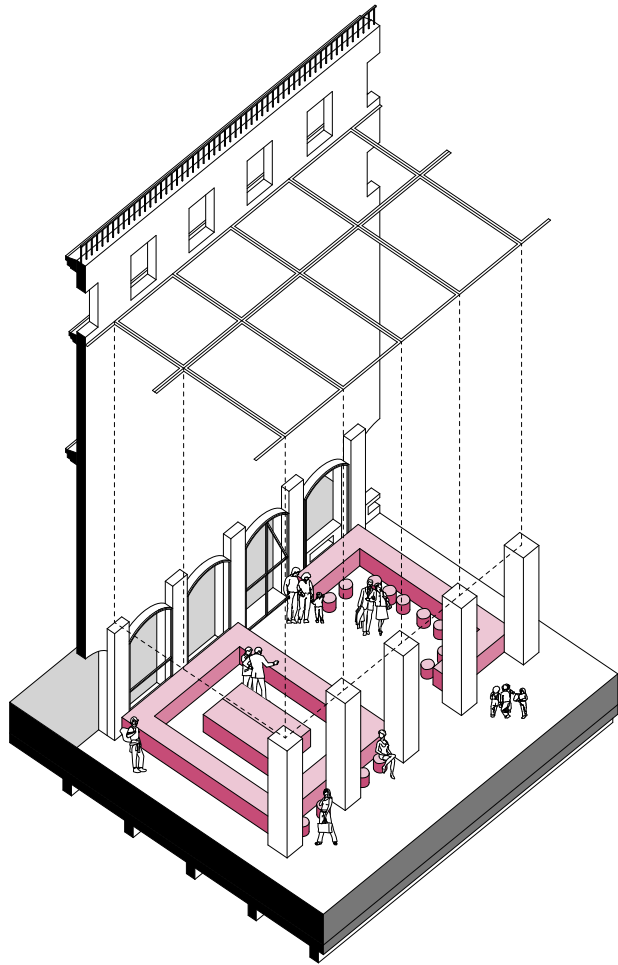
expo 1



expo 2



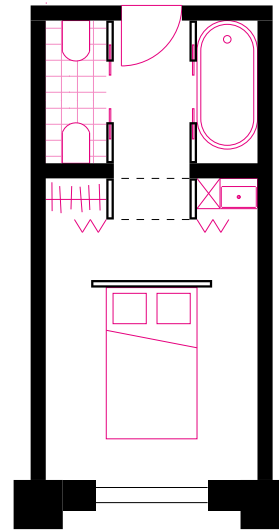
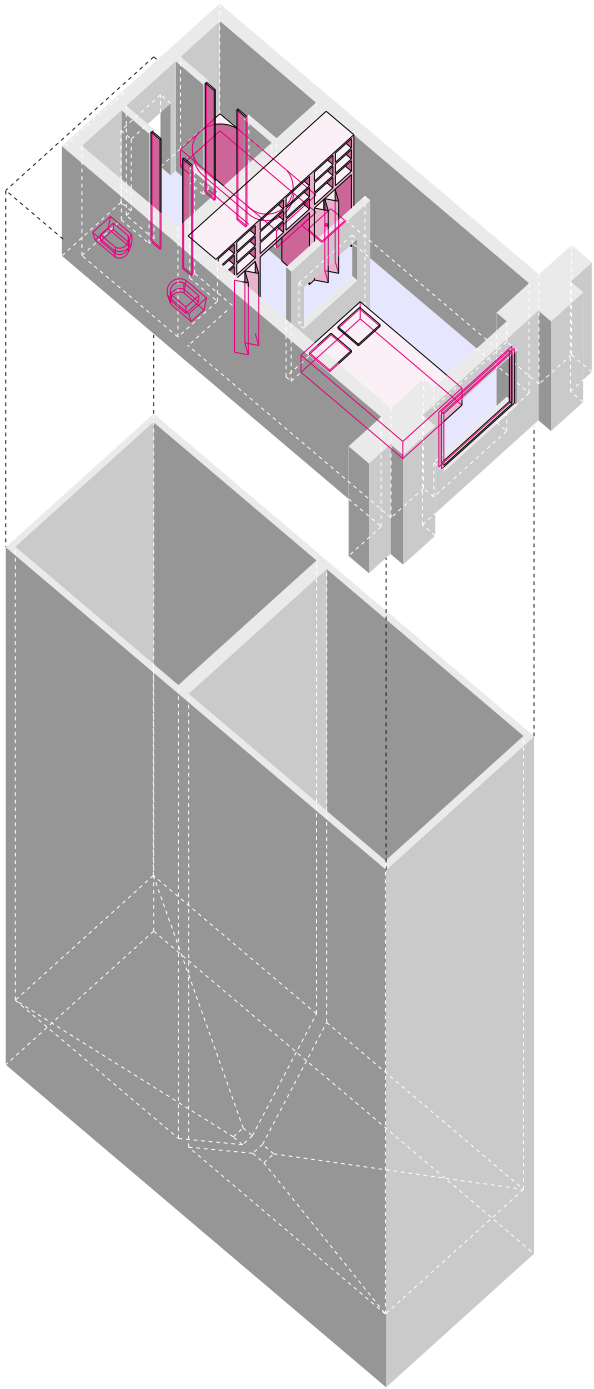




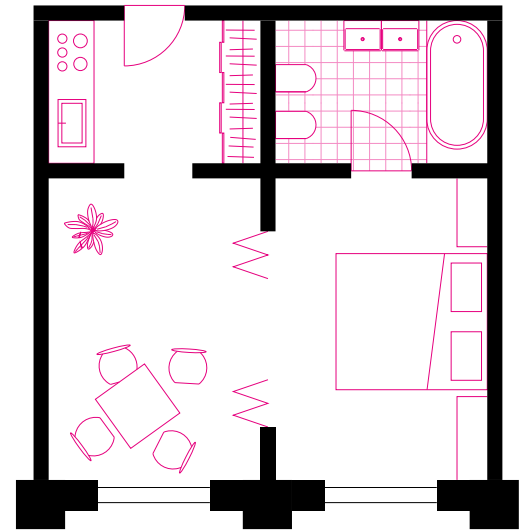
Market stalls



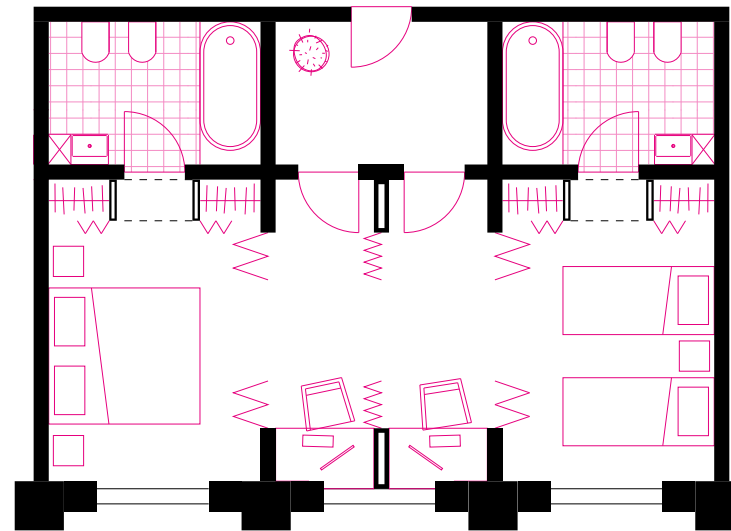
Market stall



single/double  
room  
1-unit



suite  
room  
2-unit



communicating  
room  
3-unit

Hotel units

scale 1:100



Single unit room - closed



Single unit room - open

