

STURM FABRIK

STORM FACTORY

NEOVERNACULAR
BY THE MEANS OF ARCHITECTURE

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1 TASK		4
2 SITE		6
3 CONCEPT		12
4 DESIGN		16
5 STRUCTURE		28
6 CONSTRUCTION		32
7 BUILDING PHYSICS		38
	SUMMER	 40
	WINTER	 46
8 CALCULATIONS		52
9 MODEL		68
10 SOURCES		73

CONTENT

TASK

How can we (once again) construct buildings in such a way that they can provide at least the minimum requirements for warmth, coolness, light, fresh air and comfort from within themselves?

How can the climatic potential of a location be exploited through appropriate architecture without resorting to technical compensation systems or building services?

How should the basic design tools offered by architecture itself, the physical properties of materials and the sufficient possibilities for using spaces and buildings be applied to achieve this?

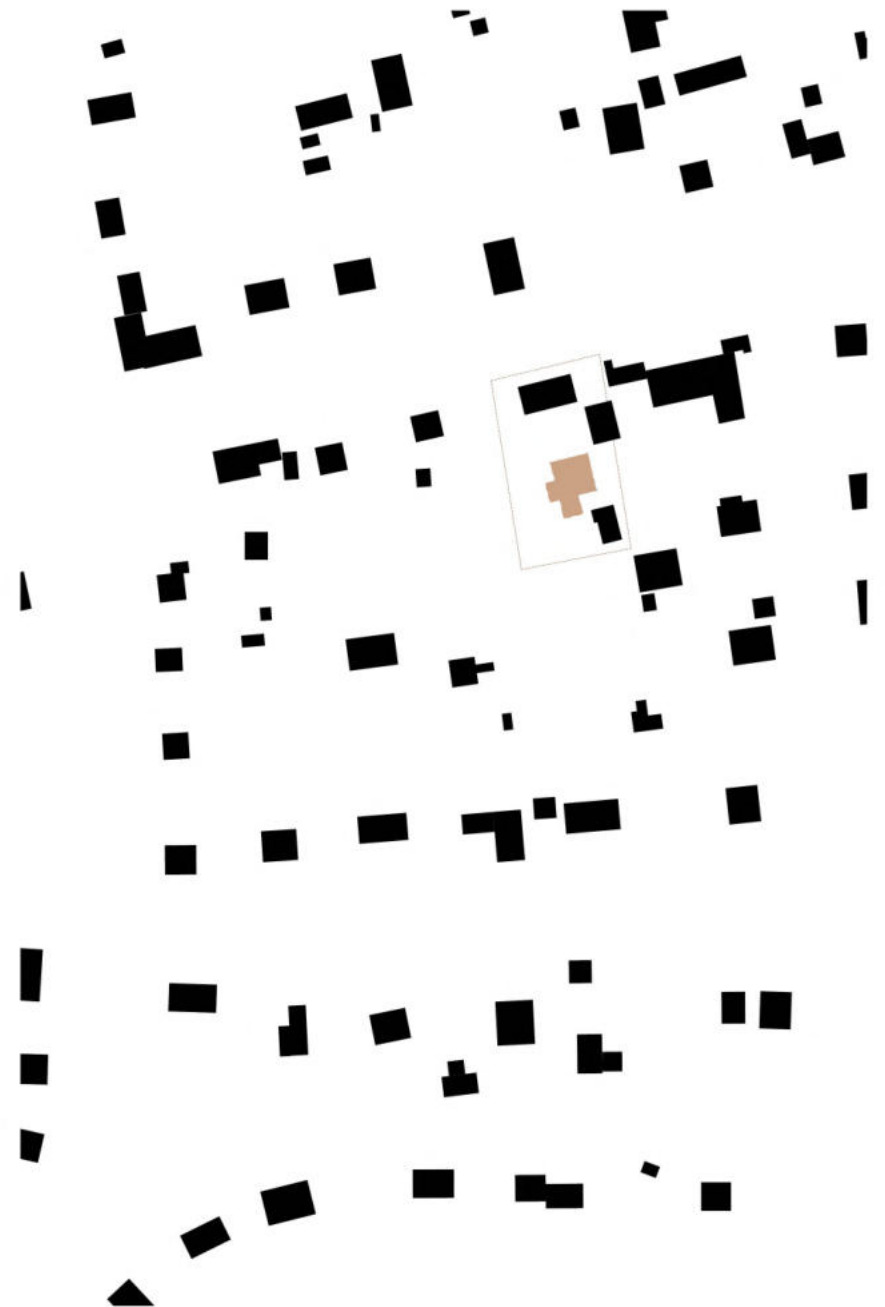


IMPRESSION HARTMANNSHOFEN

SITE

Hartmannshofen is an old district in the north-west of Munich. Founded in 1919, the Hartmannshofen settlement developed as a building cooperative. At that time, far outside the city, a development structure of single-family houses was created on comparatively large plots of land with hereditary building rights, which were intended to provide cultivation areas for self-sufficiency. This special characteristic is still noticeable today, except that the gardens are now largely overgrown with vegetation. Thus, here – in the middle of the city – there is a relatively low-density residential area with a high quality of life, interspersed with forest and park-like open spaces.

This offers urban development potential for redensification and the creation of living and working space, while at the same time preserving the special, scenic character of the area.





SITE PLAN WITH FLOOR PLAN AND ACCESS

BETHLEHEMSKIRCHE
(CHURCH OF BETHLEHEM)

BETHLEHEMSTADEL
(COMMUNITY STADEL BETHLEHEM)

PFARRHAUS
(RECTORY)

JUGENDHAUS BETHI
(YOUTH HOUSE BETHI)



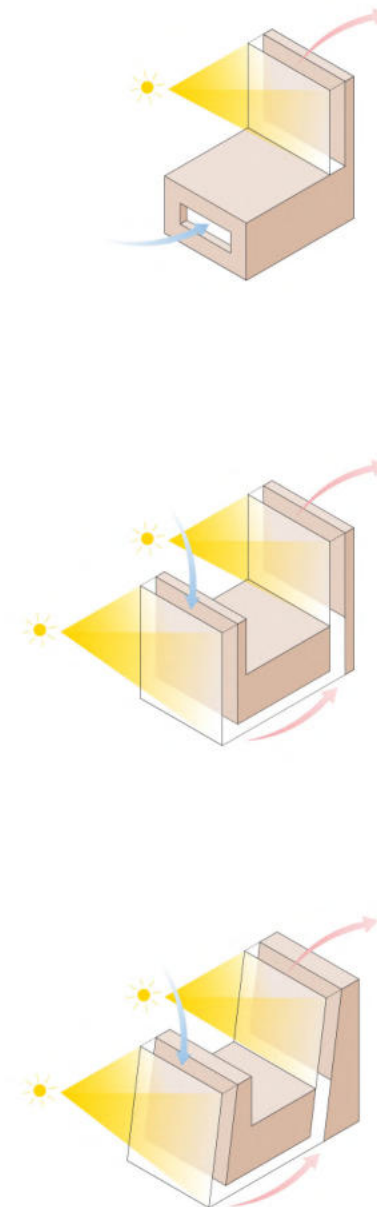
SITE PLAN WITH EXISTING STRUCTURES

CONCEPT

The principle of a solar chimney serves as the starting point for the concept development of the Sturmfabrik. A solar chimney consists of a solid wall with glazing at a short distance in front of it. The inside of the wall is painted black, and a Venturi plate is used as an attachment on top of the tower.

The aim of a solar chimney is to maximise the heating of the air in the shaft between the wall and the glazing, which is initiated by solar radiation and maximised as much as possible by the black surface. The heated air rises in the chimney, drawing cool air from the room.

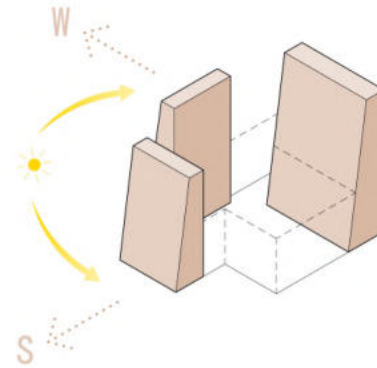
A combination of two solar chimneys as a supply and exhaust air system complements summer ventilation in winter by pre-conditioning the outside air to provide a constant supply of heated fresh air.



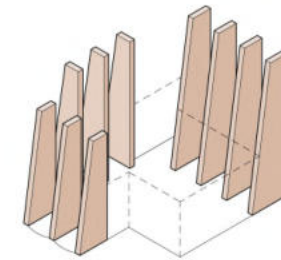
Solar chimney as a means of extracting warm air

Combination of two solar chimneys as supply air and exhaust air towers

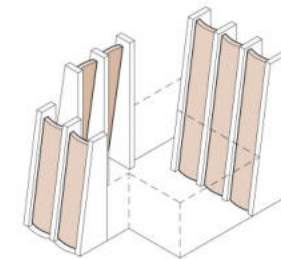
Tilt of towers for static stabilisation



Alignment of 3 towers according to the position of the sun



Dismantling of the massive towers into brick ribs



Connection of ribs with brick caps

In order to achieve optimal results from the solar chimneys, adapted to the use of a neighbourhood meeting place, two solar towers were placed in the south and west and one exhaust tower in the north, facing south. The west tower guarantees a supply of warm air, especially in the afternoons and evenings, while the south tower operates almost all day long.

As a structural concept, the massive towers were divided into brick ribs. Based on brick as the main building material, the linear ribs were connected with slanted brick caps.

This creates a space between the solar towers that is used as a neighbourhood meeting place. The Sturmfabrik opens its gates (and towers).

DESIGN

Motivated by the existing youth centre 'Bethi', a neighbourhood meeting place is to be created on the plot next to the church – a place for exchange and gathering between the otherwise introverted facilities. Here, the Sturmfabrik is to offer an open space for seminars, self-organised events or balmy summer evenings as well as cold winter hours, expanding the small youth centre for the entire neighbourhood throughout the year.

Under the motto 'By us – for us', the neighbourhood is organising itself. The Sturmfabrik provides the space for activities. The public plot offers opportunities for barbecues and campfires, vegetable beds for cultivation and an orchard for self-sufficiency. A terrace connects the new Sturmfabrik with the existing 'Bethi' youth centre.



STUDENT BREAKFAST
BREAKFAST FROM THE NEIGHBOURHOOD
FOR HUNGRY STUDENTS
EVERY MORNING FROM 7 AM TO 9 AM

BAR EVENING
OPEN BAR EVENING WITH CAMPFIRE
FOR ALL YOUNG PEOPLE
WEDNESDAY FROM 7 PM

HANGOUT
OPEN HOUSE FOR HANGING OUT
OR DOING HOMEWORK
DAILY FROM 2 PM TO 7 PM

SELF-SUPPLY
COOKING AND BAKING TOGETHER
FOR ALL GENERATIONS
MONDAY AND THURSDAY FROM 4 PM TO 6 PM

CREATIVE DESIGN
VARIED CREATIVE ACTIVITIES
FOR ALL AGES
TUESDAY AND FRIDAY FROM 10 AM TO 12 PM

**WEEKLY
PROGRAMME**

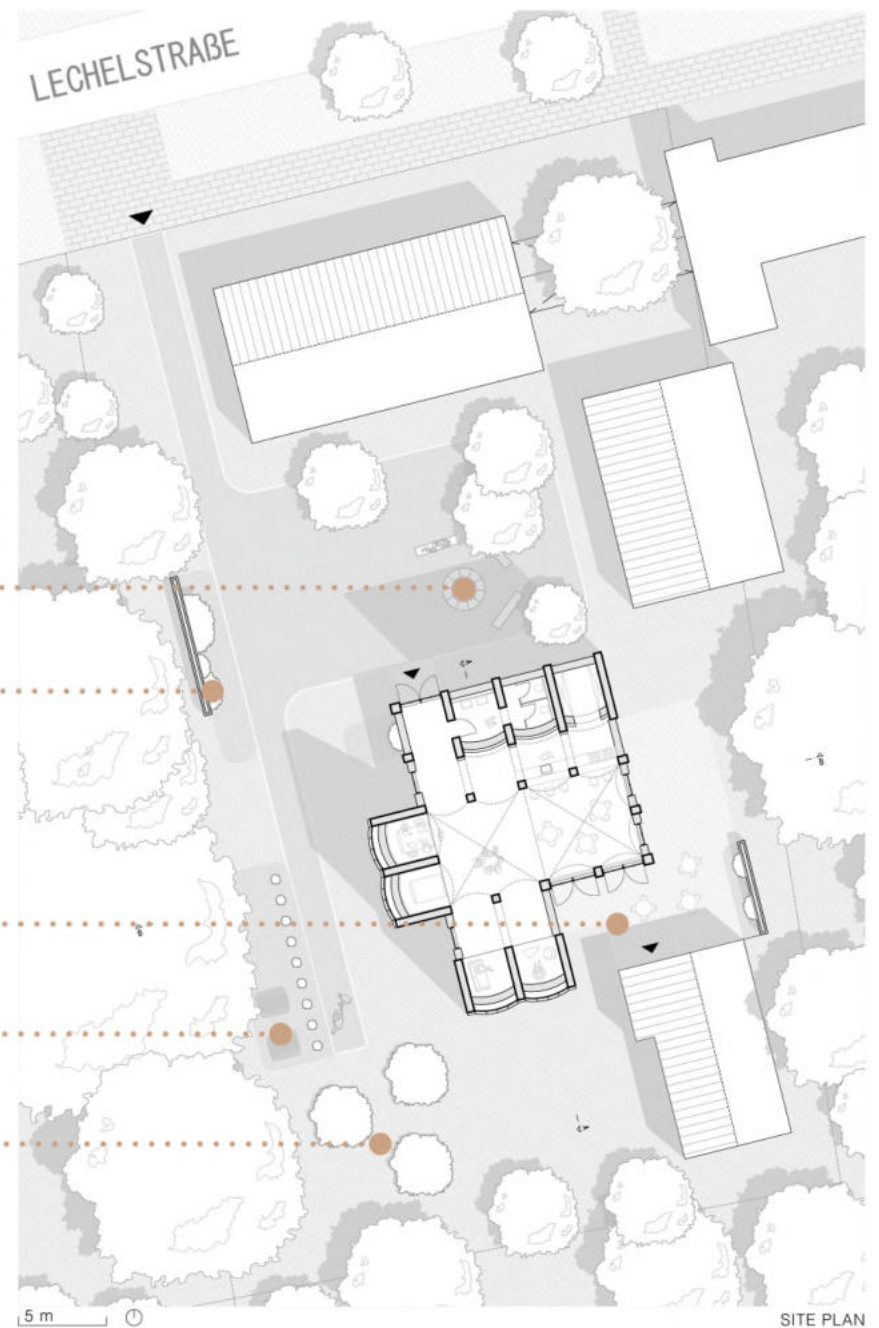
FRONT GARDEN WITH BARBECUE AREA

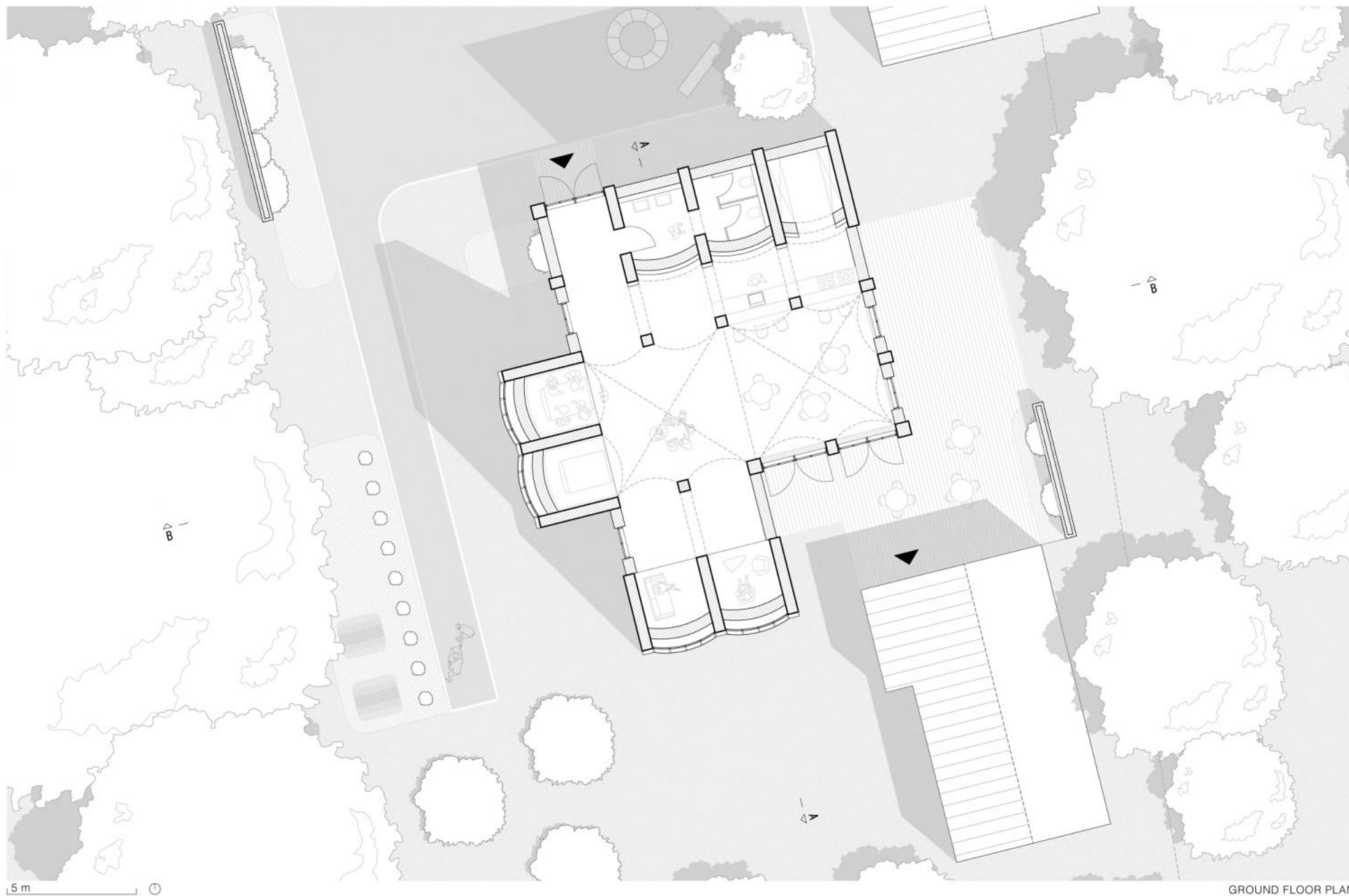
SUPPLY AIR WALL WITH SHRUB BED

TERRACE

VEGETABLE GARDEN

ORCHARD



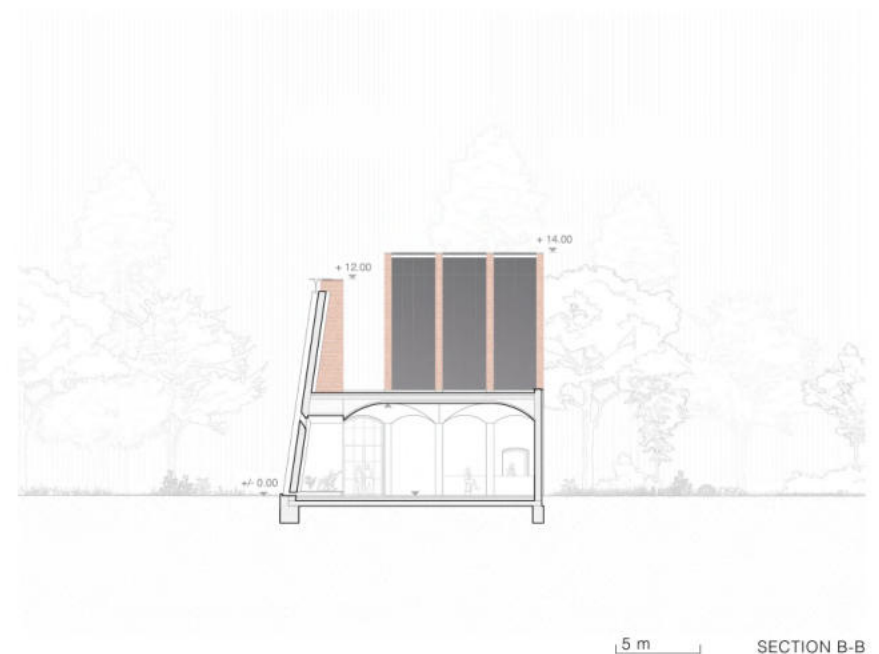
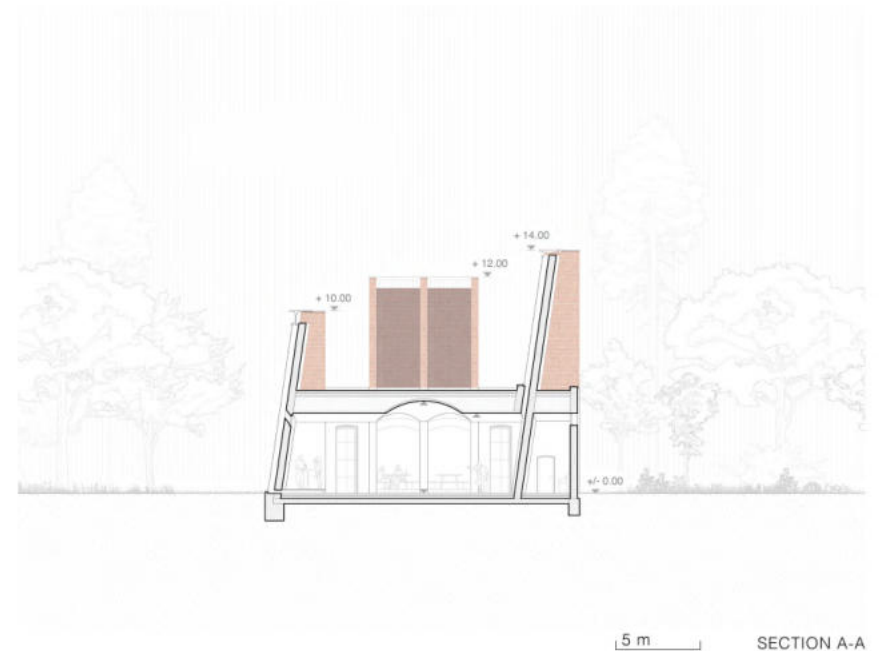


GROUND FLOOR PLAN

The floor plan develops from the ribs of the solar towers. While a central space spans between the towers, the individual ribs are used for niches and utility rooms.

The central space is covered with a barrel/monastery vault, from which domed ceilings connect the towers to the central vault. This results in a hierarchical sequence of spaces, given by the higher vault and the lower domes. The vault and the cap ceilings result from the choice of brick as the material and the associated construction methods. The vault construction also follows the connecting caps of the tower ribs.

The three towers of the Sturmfabrik differ in height. The south tower is 10 m high, the west tower 12 m and the extraction tower 14 m.





ELEVATION NORTH 5 m

5 m ELEVATION SOUTH



ELEVATION EAST 5 m

5 m ELEVATION WEST

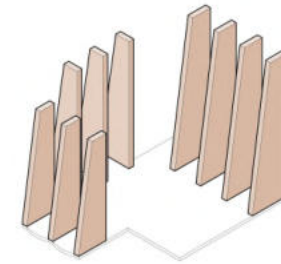


INTERIOR PERSPECTIVE

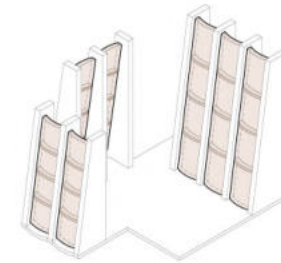
STRUCTURE

The supporting structure of the Sturmfabrik is based on brick. The concept of the solar tower results in the subdivision of the towers into brick ribs. These ribs are connected by sloping brick caps, which also ensure the stability of the ribs with tension anchors.

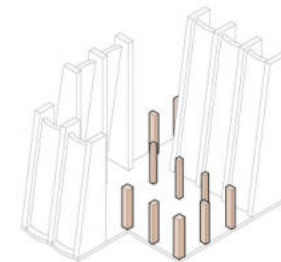
The towers form the main part of the supporting structure. The space between the towers is defined by brick posts. The posts follow the 3 m x 3 m grid of the towers.



Brick ribs



Curved caps
with tension anchors



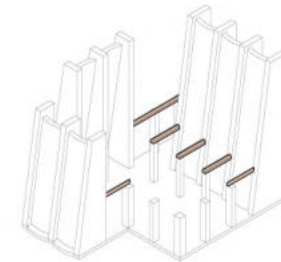
Posts

PICTOGRAM STRUCTURE

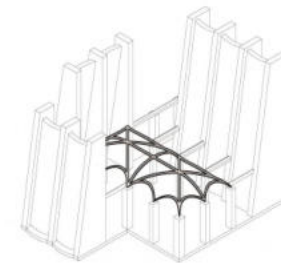
In the next step, bevelled ceiling beams are stretched from the supports to the brick ribs of the solar towers. These beams serve as the basis for the cap ceilings that will be installed later.

The base of the cross-ribbed vault spans the central space with a maximum span of 6 m x 12 m. The barrel/monastic vault is developed from the cross ribs.

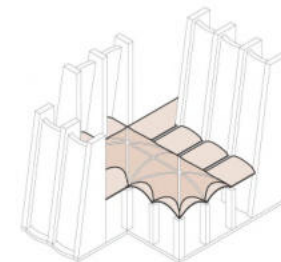
Finally, cap ceilings are connected to the vault. The caps take up the shape of the tower caps and connect them to the main vault.



Ceiling beams
Capped ceiling



Cross ribs



Monastery vault
with adjoining
cap ceilings

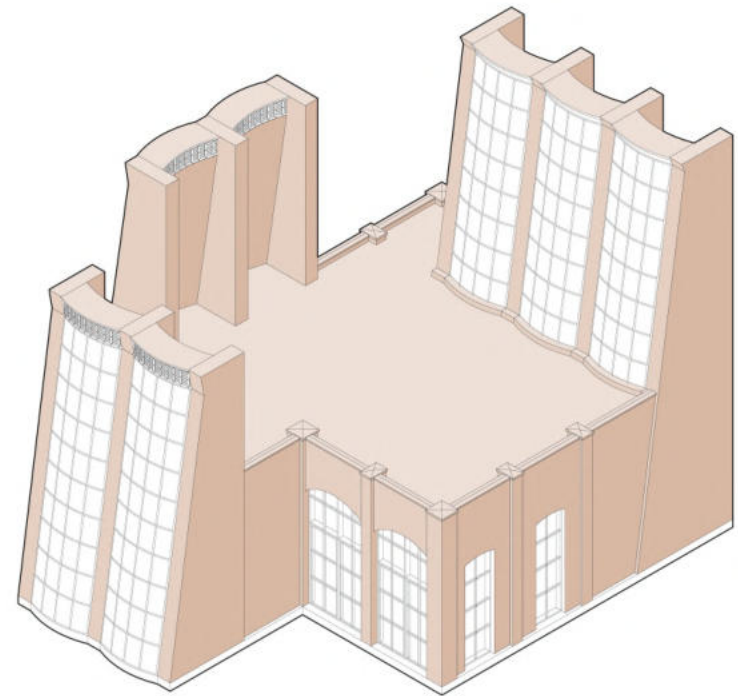
CONSTRUCTION

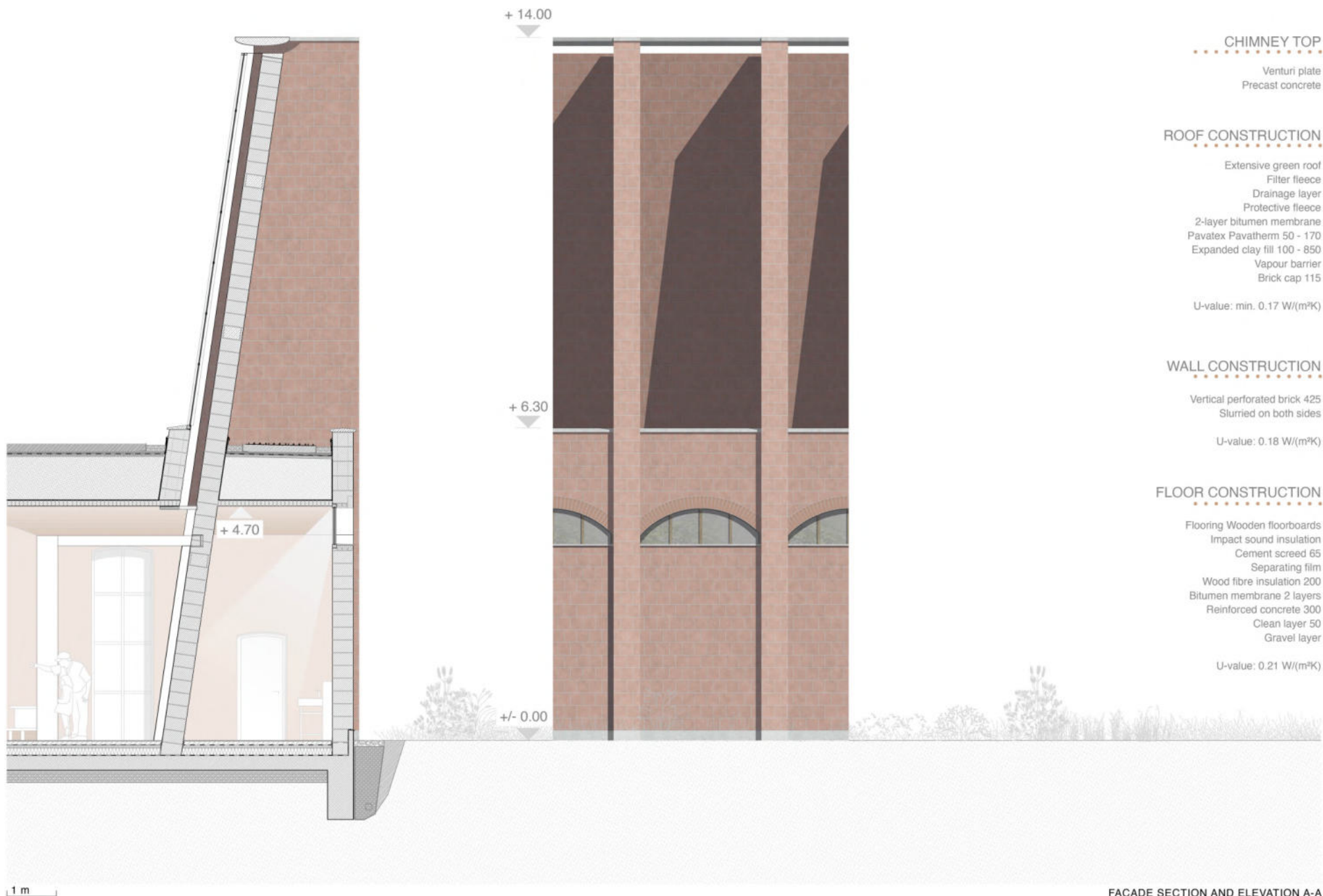
In terms of a single-shell wall construction and the height of the building, a vertically perforated brick with a thickness of 42.5 was chosen as the primary building material in order to comply with contemporary insulation standards and, at the same time, provide thermal mass.

In order to achieve a continuous brick construction, caps and domes were used for the sloping chimney surfaces and the roof construction so that the vertical forces could be dissipated in compression in a manner appropriate to the material.

The 11.5 cm thick brick vault is levelled with expanded clay fill and covered with a flat roof.

The vertically perforated bricks, which are slurred on both sides, stand out on the supports and chimneys, making the load-bearing structure tangible.





FACADE SECTION AND ELEVATION A-A

CHIMNEY TOP

Windeinfänger mit geneigten Lamellen
Ziegel-Betonfertigteil

ROOF CONSTRUCTION

Extensive green roof
Filter fleece
Drainage layer
Protective fleece
2-layer bitumen membrane
Pavatex Pavatherm 50 - 170
Expanded clay fill 100 - 850
Vapour barrier
Brick cap 115

U-value: min. 0.17 W/(m²K)

WALL CONSTRUCTION

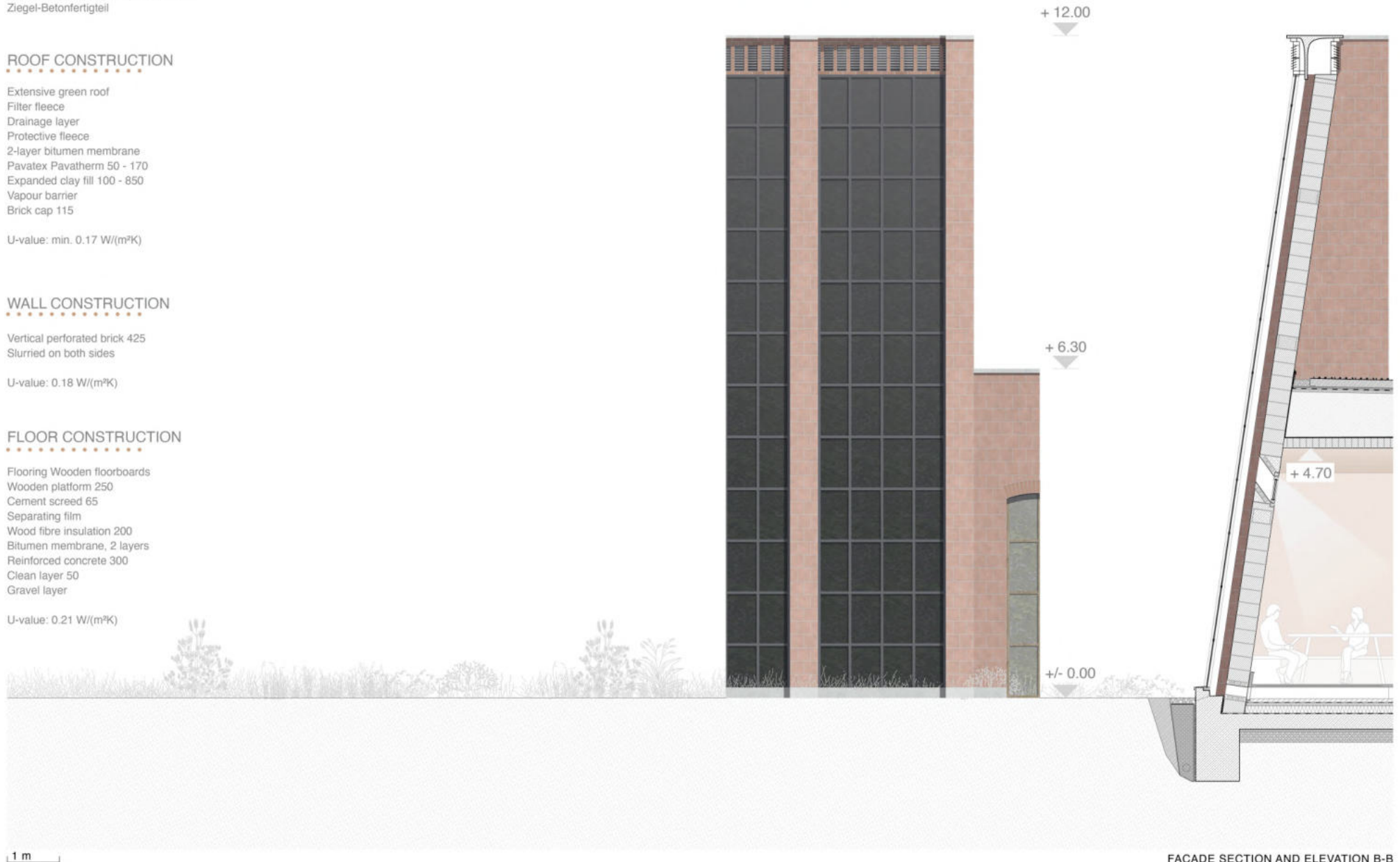
Vertical perforated brick 425
Slurred on both sides

U-value: 0.18 W/(m²K)

FLOOR CONSTRUCTION

Flooring Wooden floorboards
Wooden platform 250
Cement screed 65
Separating film
Wood fibre insulation 200
Bitumen membrane, 2 layers
Reinforced concrete 300
Clean layer 50
Gravel layer

U-value: 0.21 W/(m²K)



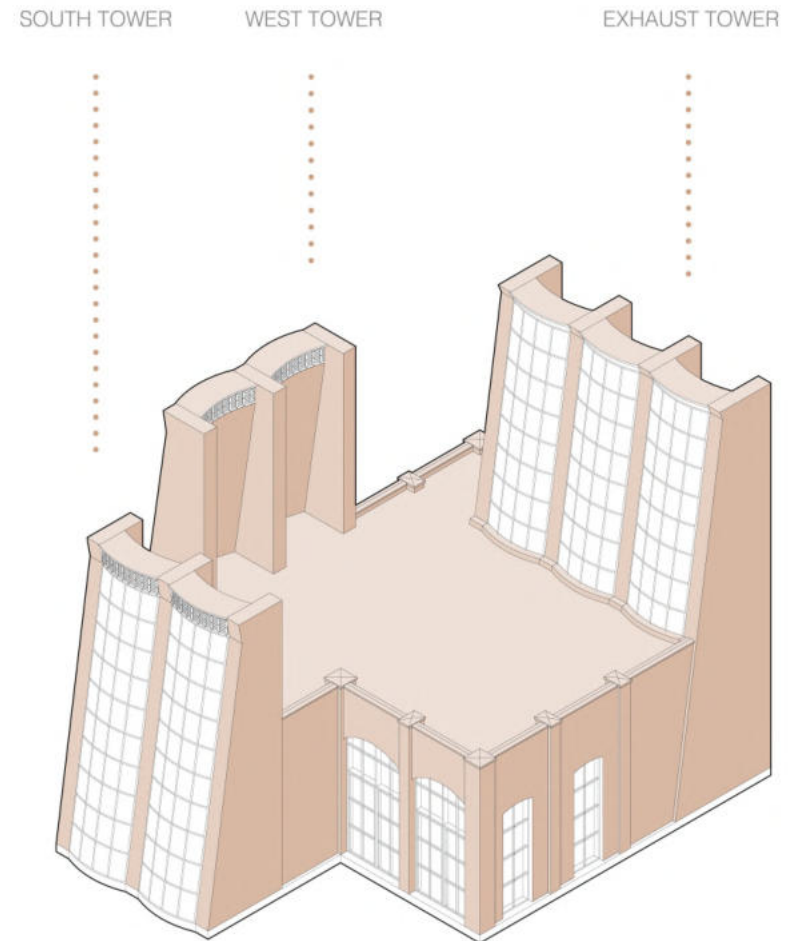
FACADE SECTION AND ELEVATION B-B

BUILDING PHYSICS

The Sturmfabrik is a self-regulating building based on the low-tech principle. Depending on the season, it makes use of a combination of the three solar towers.

The south tower, with a height of 10 m, faces south. As the south tower captures the most solar radiation, it requires the lowest height. The west tower faces west with a height of 12 m, which results from the lower solar input in the west compared to the south. The exhaust tower in the north faces south, is 14 metres high and extends over three grids instead of two like the south and west towers.

In both winter and summer, the exhaust tower serves to extract air from the room. The south and west towers adjust their mode of operation depending on the season.

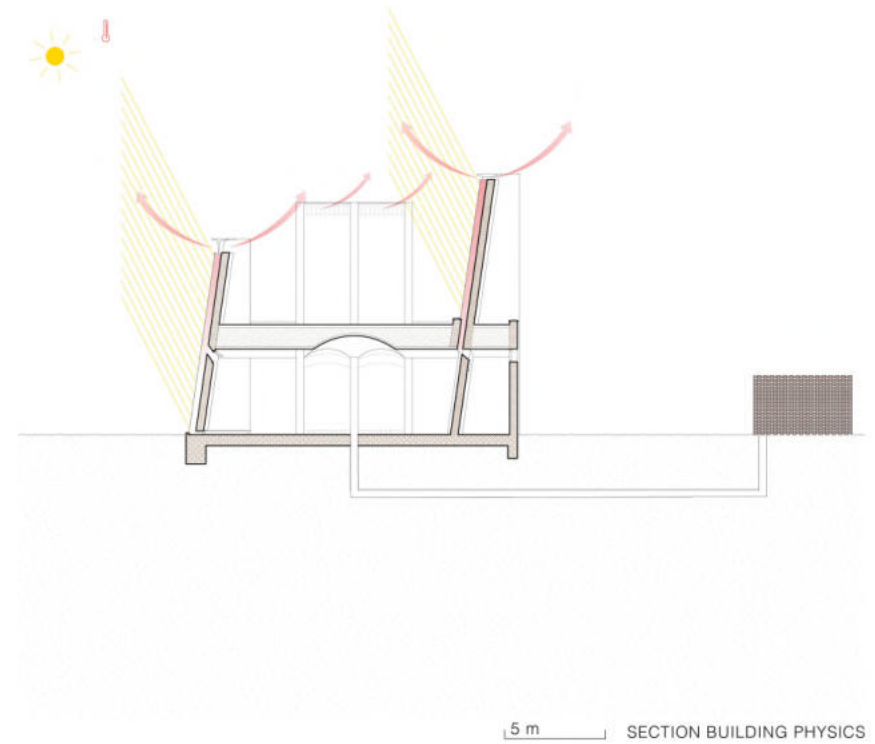


SUMMER

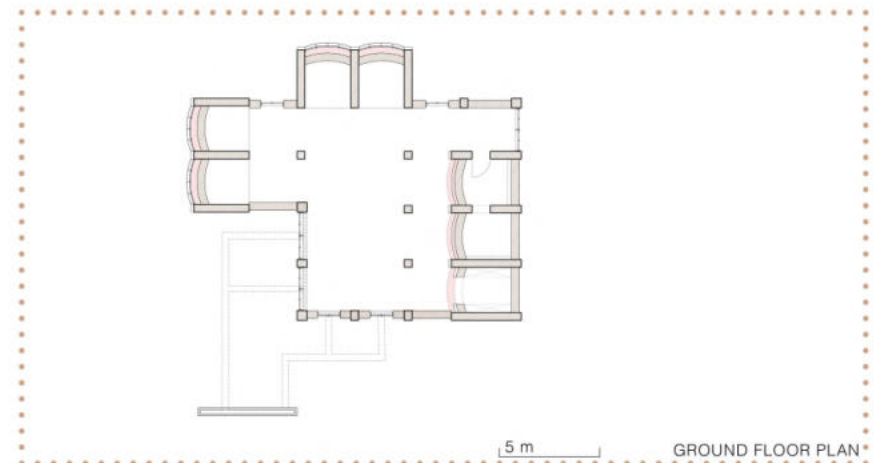
In the summerly cooling operation, the air in the solar tower first heats up to its maximum temperature due to solar radiation and the black surface inside the solar towers. As a result, the warm air rises in the chimney and is discharged through a Venturi attachment.

The shaft of the solar tower has a width of 35 cm. This accelerates the speed of the rising air, as this shaft width causes hardly any air turbulence. High air speeds are useful for increasing the effectiveness of the solar tower.

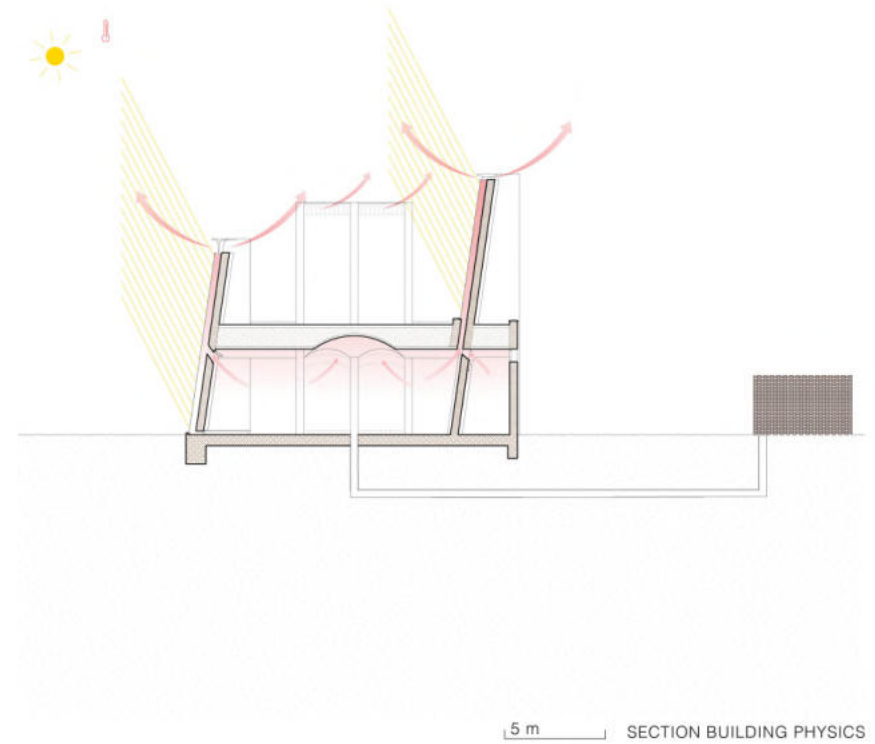
The Venturi attachment creates a shaped constriction at the exit of the solar tower, which further increases the speed of the outflowing air.



5 m SECTION BUILDING PHYSICS

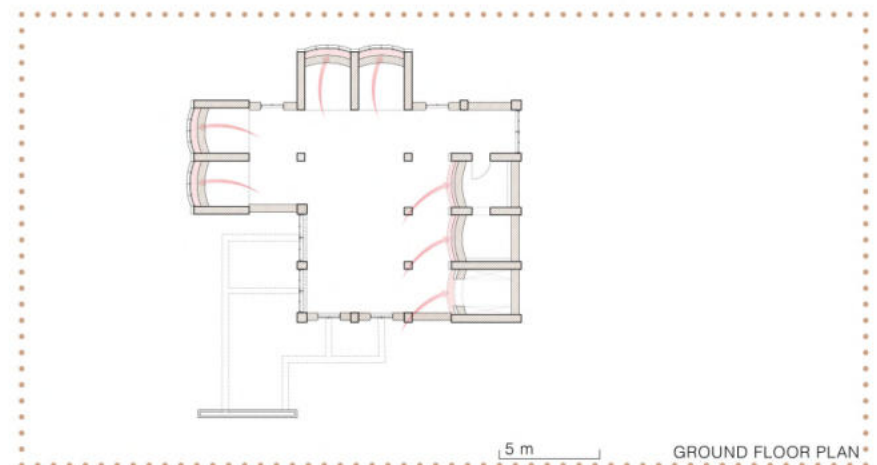


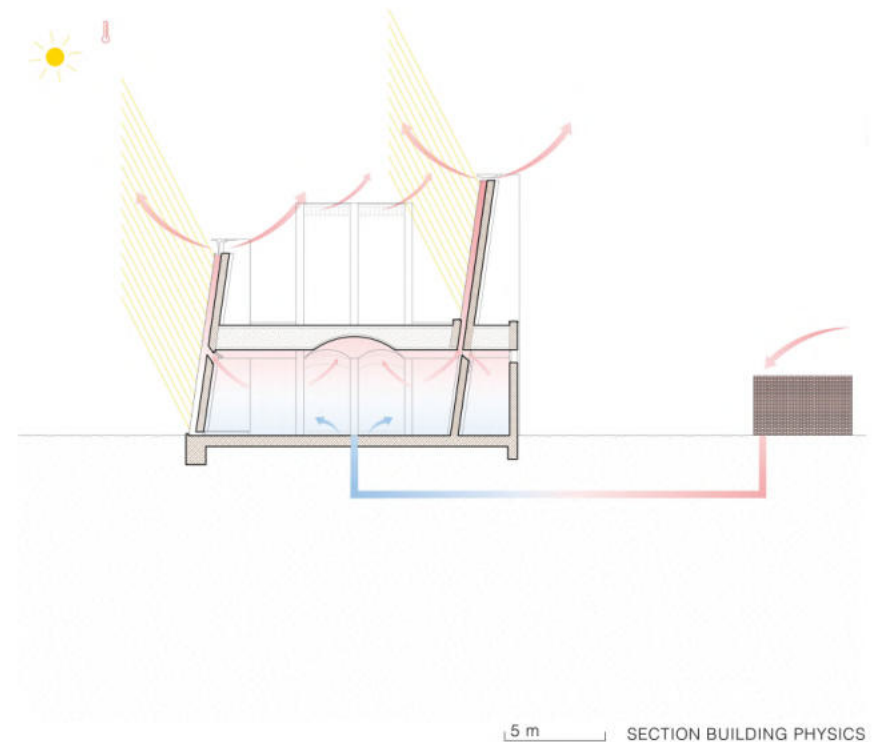
5 m GROUND FLOOR PLAN



The rising of the heated air in the solar tower creates negative pressure in the chimney, which draws air from the room. The used and heated air in the room is thus extracted upwards through the solar towers.

Sliding flaps are located at the highest point of the room under the ceiling to extract the heated air. These are opened in summer.



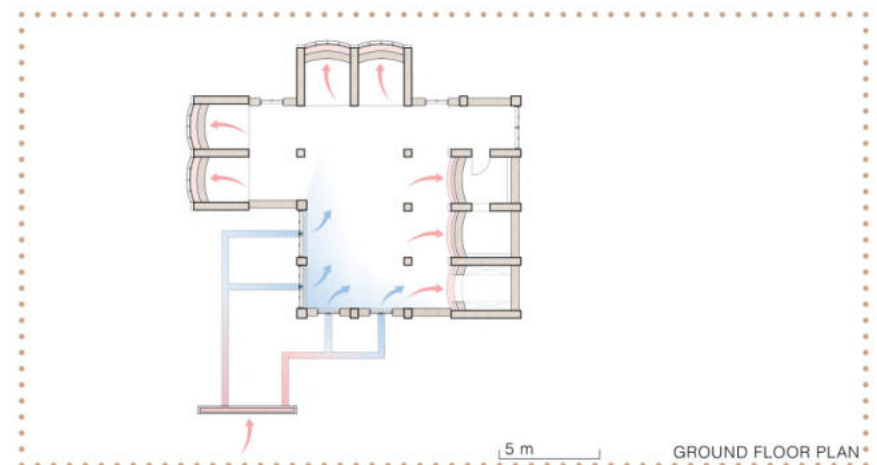


5 m SECTION BUILDING PHYSICS

To achieve a pleasantly cool indoor climate, fresh air cooled via underground ducts is fed into the room. The air is cooled in the underground duct to the temperature of the soil, approximately 8°C.

The permanent supply of fresh air is boosted and maintained by the pressure system in the room. In addition, the Sturmfabrik uses storage mass in the single-shell wall construction and the floor slab.

The usage times of the Sturmfabrik vary due to its flexible use as a neighbourhood meeting place. In summer, the solar towers cool the room even when not in use.

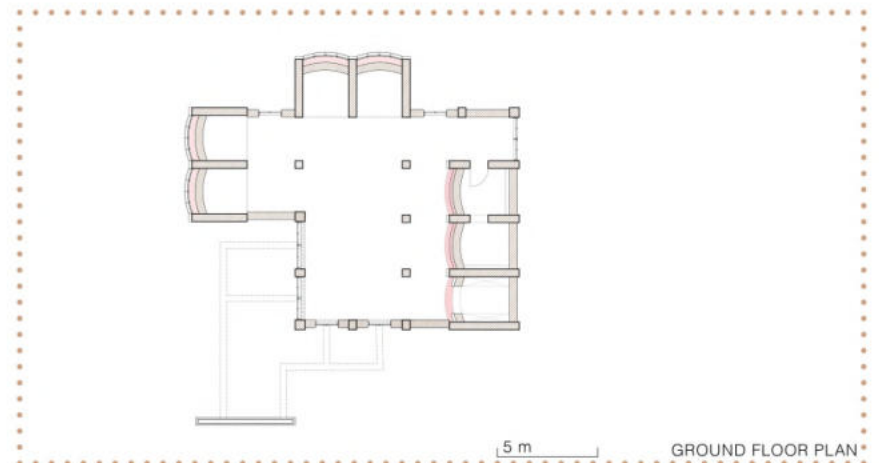
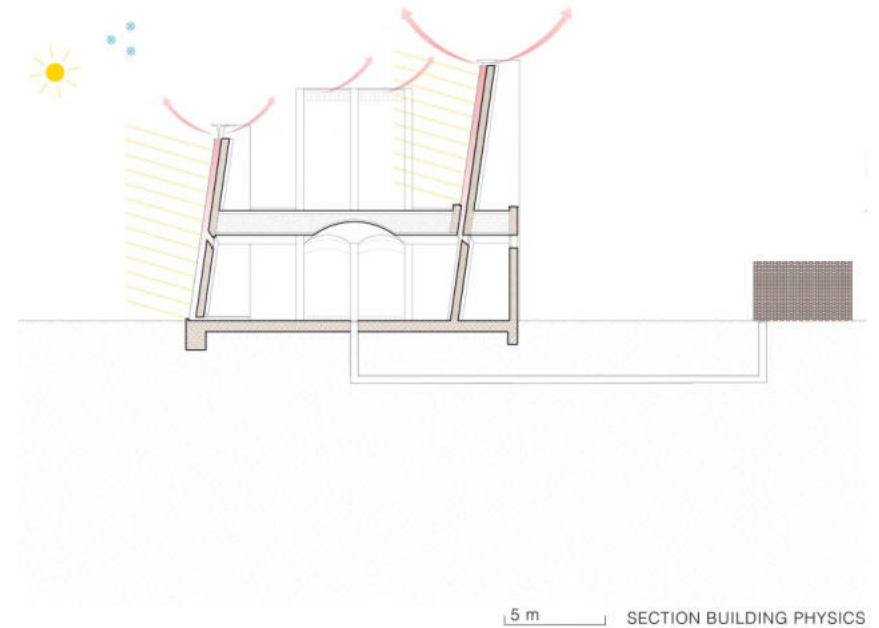


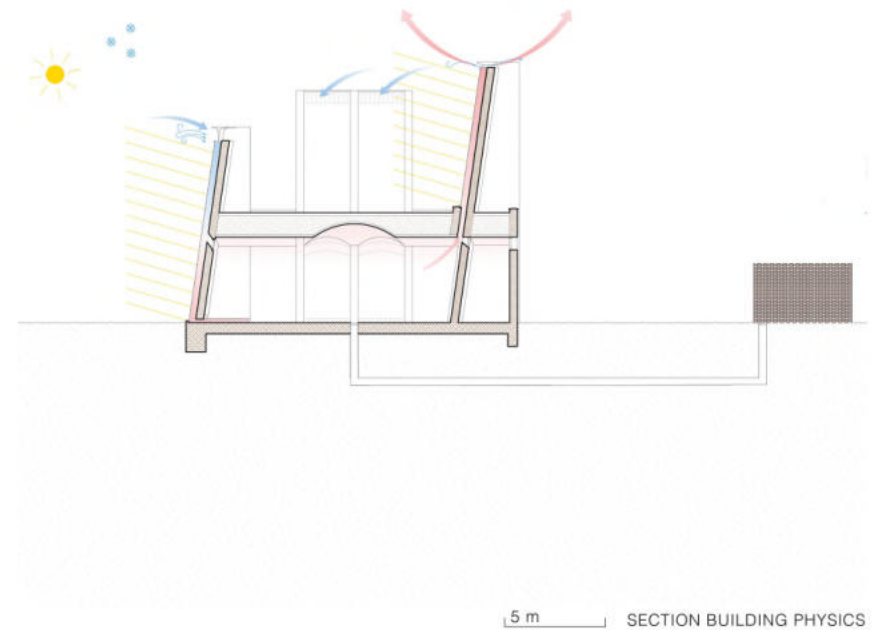
5 m GROUND FLOOR PLAN

WINTER

In winter, solar towers initially operate according to the same principle as in summer. Solar radiation heats the air in the chimney, which then rises and is discharged from the chimneys. This creates negative pressure in the chimney, which draws air from the room.

The flaps under the ceiling of the room are now closed so that the warm air in the room does not immediately leave the room. In addition, the underground channel responsible for cooling in summer is sealed airtight. This temporarily cuts off the air supply to the room.



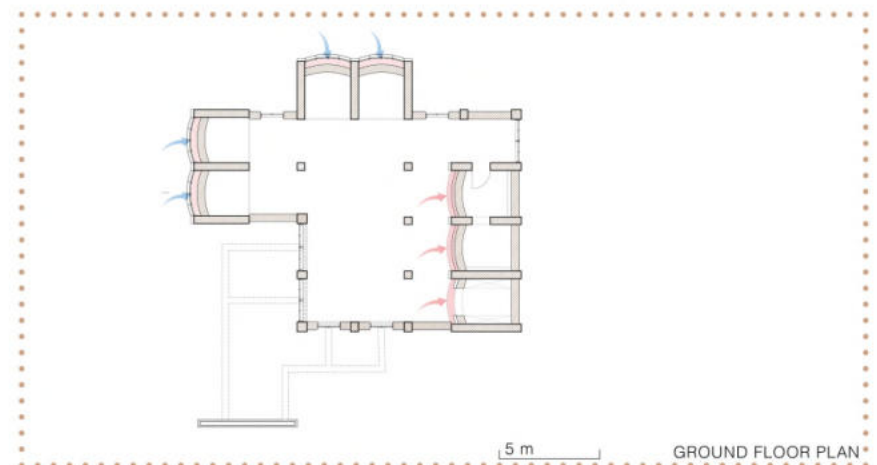


5 m SECTION BUILDING PHYSICS

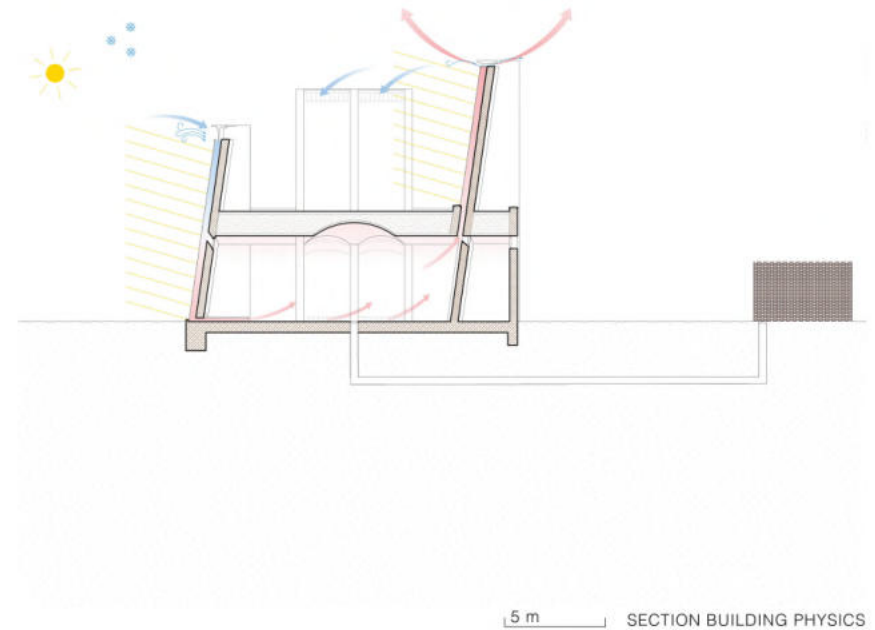
Now the difference in height between the individual towers comes into play. The exhaust tower generates the decisive negative pressure due to its dominant height and inflow area and can draw the air backwards through the supply air chimneys.

In addition, wind catchers attached to the south and west towers help to capture the wind, which means that the suction in the supply air tower, triggered by the exhaust effect of the highest tower, is further enhanced by wind pressure from outside.

On its way through the glazed chimney shaft, the air is heated by solar radiation and can flow into the room in a pre-conditioned state. Depending on the month and the corresponding radiation intensity, the outside air is heated, which can significantly reduce the heating load and ventilation heat losses. This statement is tested in the following calculations.



5 m GROUND FLOOR PLAN

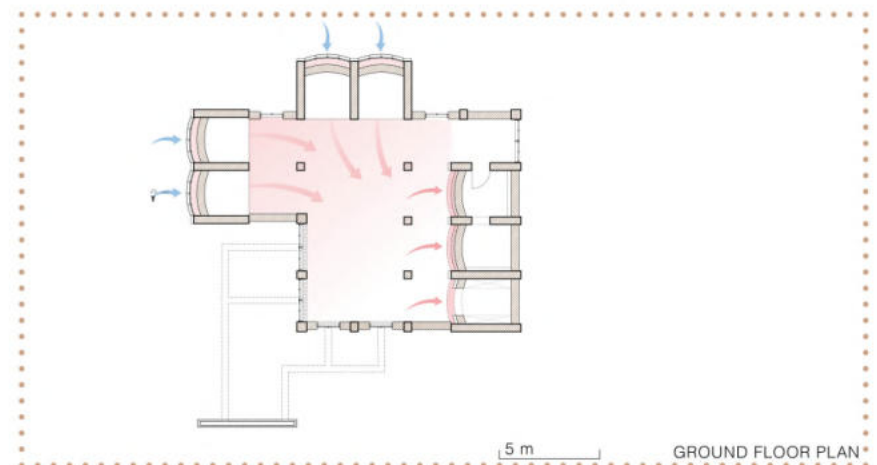


5 m SECTION BUILDING PHYSICS

The air, which has now been pre-conditioned and heated in the chimneys, can flow into the interior space. To heat the air in the chimney for as long as possible, the flap under the ceiling is closed and a flap under the raised floor in the chimney ribs is opened. This allows the air to enter at the lowest point of the room and distribute evenly from bottom to top.

In order to supply the interior of the Sturmfabrik with pre-conditioned air as evenly as possible, the supply air towers are arranged in the floor plan so that the greatest possible distance between the supply air and exhaust air towers is achieved.

The purely mechanical and structural ventilation and pre-conditioning of the building requires no intervention on the part of the users, is independent of usage times and provides an uninterrupted supply of fresh air in the Sturmfabrik in both summer and winter.

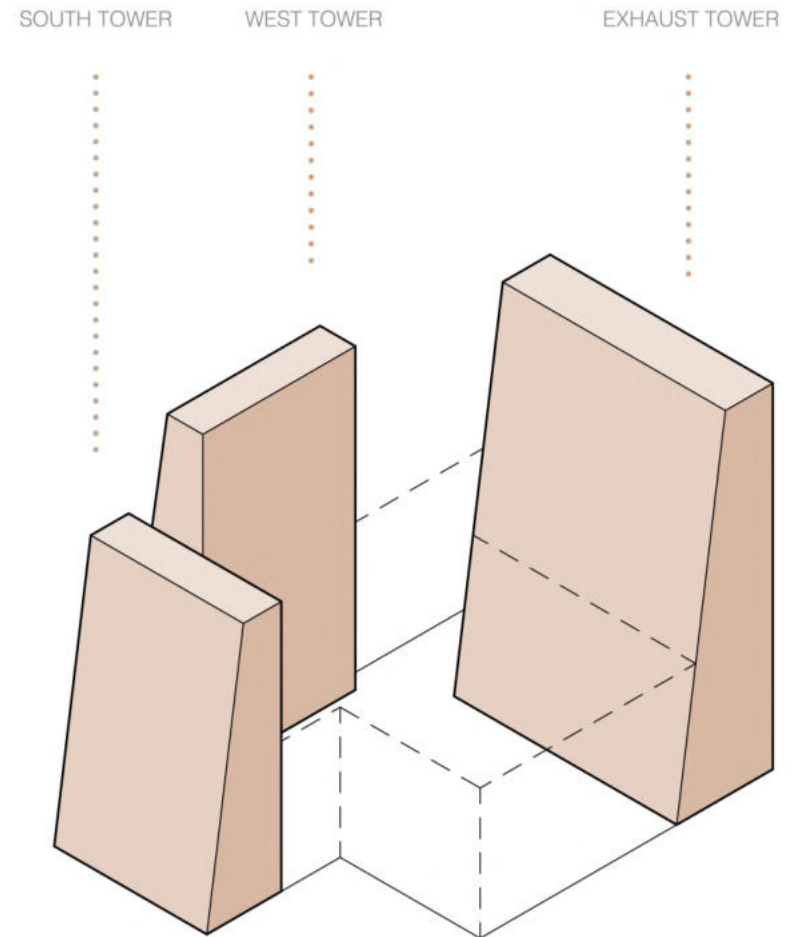


5 m GROUND FLOOR PLAN

CALCULATIONS

The development of the building focused on the challenge of creating a self-regulating building based on the low-tech principle. To meet this requirement, the Sturmfabrik uses a combination of three solar chimneys, which are used as air conditioning depending on the season or to pre-temper the supply air in winter. The Sturmfabrik concept requires validation by calculating the effectiveness of the solar towers.

In summer, a sufficient air exchange rate guarantees the supply of fresh air and cooling of the building. In winter, it must be proven whether the principle of combining two solar towers with height differences to introduce pre-conditioned air into the room is successful. In addition, it must be proven how much heating can be generated by the solar towers in winter and whether the solar towers can subsequently help to heat the building.



1 | AIR EXCHANGE RATE

Required Volume flow = 30 m³/h per person

Occupancy with 60 people:

Volume flow = 30 m³/h per person x 60 people = **1800 m³/h**

Volume flow in the Sturmfabrik:

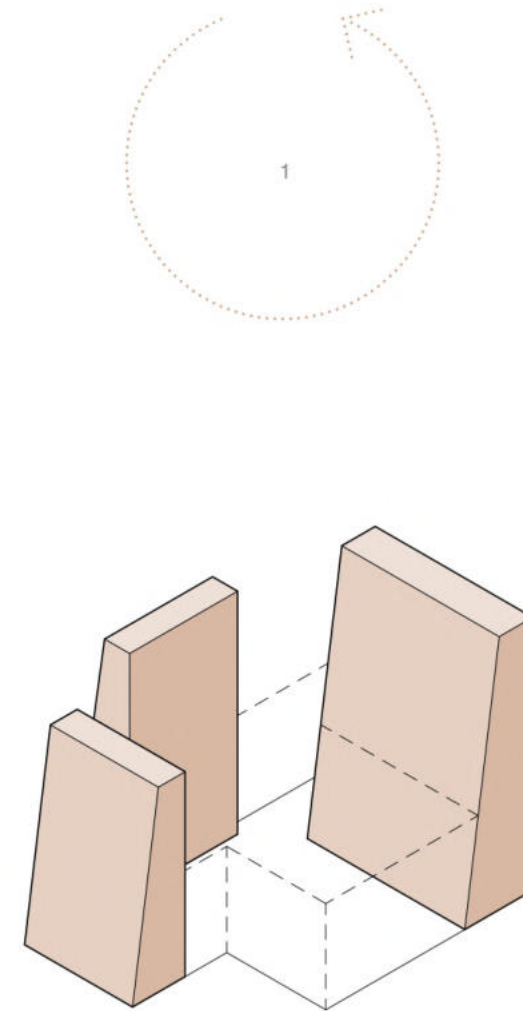
$Q_{\text{Luft}} = 0.57 \text{ m}^3/\text{s} = \mathbf{2063.9 \text{ m}^3/\text{h}}$

Air exchange rate $n = 2063.9 \text{ m}^3/\text{h} / 700 \text{ m}^3 = \mathbf{2.9/\text{h}}$

AIR CHANGE RATE

The constant ventilation of the solar towers allows fresh air to flow continuously into the interior without requiring additional window ventilation. When the neighbourhood meeting place is occupied by 60 people, a minimum volume flow of 1800 m³/h is required. The solar towers achieve a volume flow of 2063.9 m³/h, i.e. 2.9 times the air volume of the room is exchanged per hour.

(cf. list of sources [1])



1 | HEATING BY SOLAR RADIATION

min. heating of the air by solar radiation in december = **4,2 K**

2 | HEATING BY BLACK SURFACE

min. heating of the air by black surface in december = **3,5 K**

3 | TOTAL HEATING CAPACITY OF THE AIR IN THE CHIMNEY

min. total heating capacity in december = $4,2 \text{ K} + 3,5 \text{ K} = \mathbf{7,7 \text{ K}}$

4 | UPWARD PRESSURE OF THE AIR IN THE CHIMNEY

Correct direction of flow (with opening area $A = 1,82 \text{ m}^2$):

Upward pressure = $3,40 \text{ N/m}^2 \times 1,82 \text{ m}^2 = \mathbf{6,19 \text{ N}}$

Incorrect direction of flow (with opening area $A = 1,82 \text{ m}^2$):

Upward pressure = $11,34 \text{ N/m}^2 \times 1,82 \text{ m}^2 = \mathbf{20,64 \text{ N}}$

5 | WIND PRESSURE OF AIR IN THE CHIMNEY

Wind pressure (with opening area $A = 1,82 \text{ m}^2$):

Wind pressure = $8,78 \text{ N/m}^2 \times 1,82 \text{ m}^2 = \mathbf{15,98 \text{ N}}$

6 | TOTAL PRESSURE

Correct direction of flow:

Upward pressure - Wind pressure = $6,19 \text{ N} - 15,98 \text{ N} = \mathbf{- 9,79 \text{ N}}$

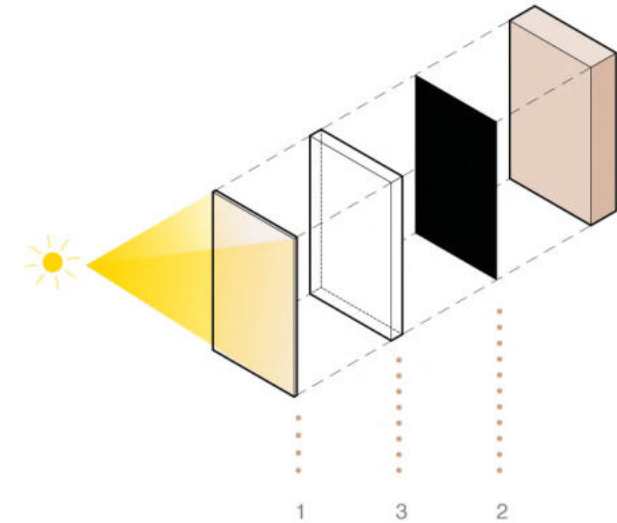
Incorrect direction of flow

Upward pressure - Wind pressure = $20,64 \text{ N} - 15,98 \text{ N} = \mathbf{4,66 \text{ N}}$

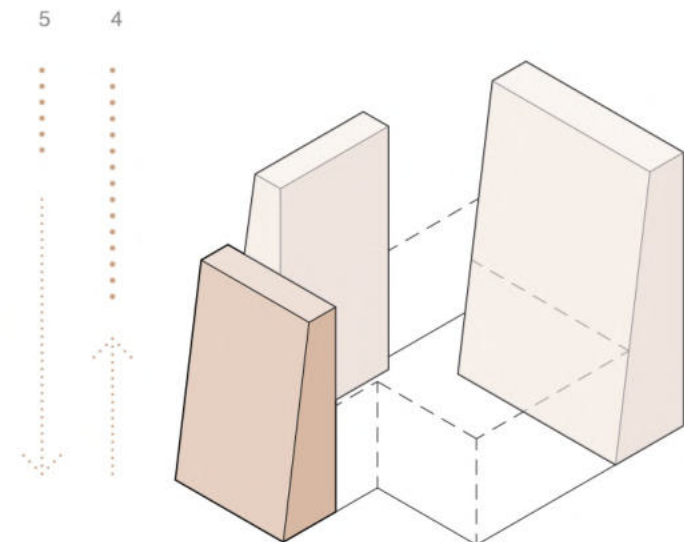
SOUTH CHIMNEY

The south tower thus generates at least a 7.7°C increase in the air temperature in the chimney in December, i.e. when the average monthly solar radiation is at its lowest. Accordingly, the combination of solar towers supplies the room with fresh air heated solely by the south tower.

(cf. list of sources [1] - [9])



PICTOGRAM SOLAR CHIMNEY



PICTOGRAM SOUTH TOWER

1 | HEATING BY SOLAR RADIATION

min. heating of the air by solar radiation in december = **2,0 K**

2 | HEATING BY BLACK SURFACE

min. heating of the air by black surface in december = **1,8 K**

3 | TOTAL HEATING CAPACITY OF THE AIR IN THE CHIMNEY

min. total heating capacity in december = $2,0 \text{ K} + 1,8 \text{ K} = \mathbf{3,8 \text{ K}}$

4 | UPWARD PRESSURE OF THE AIR IN THE CHIMNEY

Correct direction of flow (with opening area $A = 1,82 \text{ m}^2$):

Upward pressure = $2,02 \text{ N/m}^2 \times 1,82 \text{ m}^2 = \mathbf{3,68 \text{ N}}$

Incorrect direction of flow (with opening area $A = 1,82 \text{ m}^2$):

Upward pressure = $11,56 \text{ N/m}^2 \times 1,82 \text{ m}^2 = \mathbf{21,04 \text{ N}}$

5 | WIND PRESSURE OF AIR IN THE CHIMNEY

Wind pressure (with opening area $A = 1,82 \text{ m}^2$):

Wind pressure = $8,78 \text{ N/m}^2 \times 1,82 \text{ m}^2 = \mathbf{15,98 \text{ N}}$

6 | TOTAL PRESSURE

Correct direction of flow:

Upward pressure - Wind pressure = $3,68 \text{ N} - 15,98 \text{ N} = \mathbf{- 12,30 \text{ N}}$

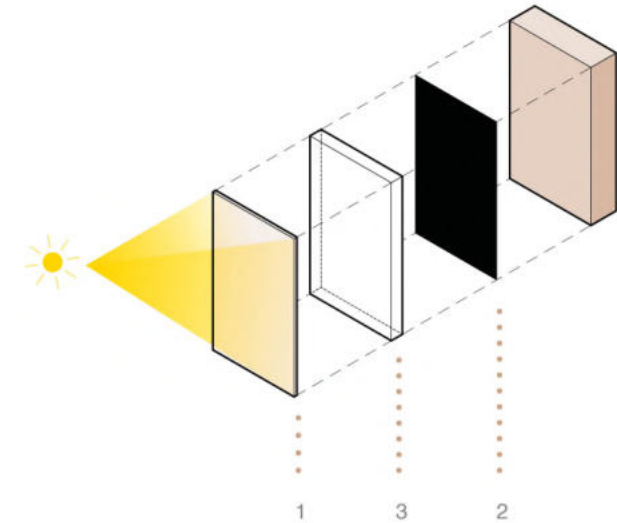
Incorrect direction of flow

Upward pressure - Wind pressure = $21,04 \text{ N} - 15,98 \text{ N} = \mathbf{5,06 \text{ N}}$

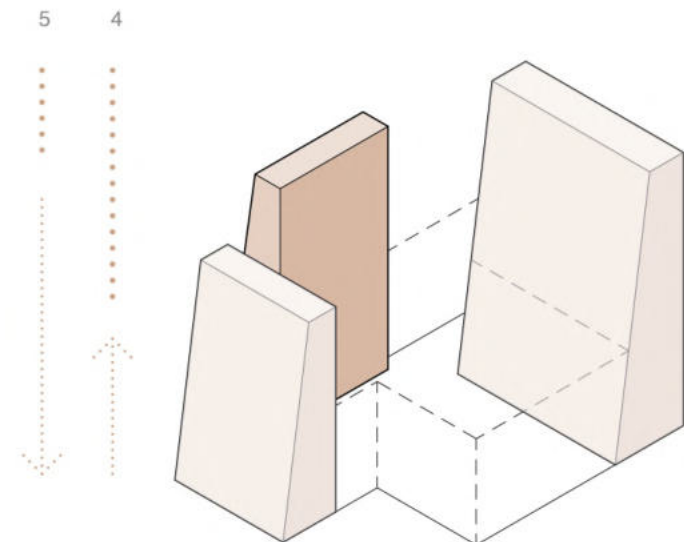
WEST CHIMNEY

The west tower also generates at least a $3,8^\circ\text{C}$ increase in the air temperature in the chimney in December, i.e. when the average monthly solar radiation is at its lowest. Accordingly, the combination of solar towers with west and south towers supplies heated fresh air to the room.

(cf. list of sources [1] - [9])



PICTOGRAM SOLAR CHIMNEY



PICTOGRAM WEST TOWER

1 | UPWARD PRESSURE OF THE AIR IN THE CHIMNEY

Correct direction of flow = $3,40 \text{ N/m}^2 \times 1,82 \text{ m}^2 = \mathbf{6,19 \text{ N}}$

Incorrect direction of flow = $11,34 \text{ N/m}^2 \times 1,82 \text{ m}^2 = \mathbf{20,64 \text{ N}}$

2 | WIND PRESSURE OF THE AIR IN THE CHIMNEY

Wind pressure = $8,78 \text{ N/m}^2 \times 1,82 \text{ m}^2 = \mathbf{15,98 \text{ N}}$

3 | TOTAL PRESSURE

Correct direction of flow = $6,19 \text{ N} - 15,98 \text{ N} = \mathbf{-9,79 \text{ N}}$

Incorrect direction of flow = $20,64 \text{ N} - 15,98 \text{ N} = \mathbf{4,66 \text{ N}}$

4 | UPWARD PRESSURE OF THE AIR IN THE EXHAUST TOWER

Upward pressure (with opening area $A = 2,73 \text{ m}^2$)

Upward pressure = $14,92 \text{ N/m}^2 \times 2,73 \text{ m}^2 = \mathbf{40,64 \text{ N}}$

5 | PRESSURE RATIOS

Correct direction of flow:

Upward pressure south tower < Upward pressure exhaust tower

$\mathbf{-9,79 \text{ N} < 40,64 \text{ N}}$

Incorrect direction of flow:

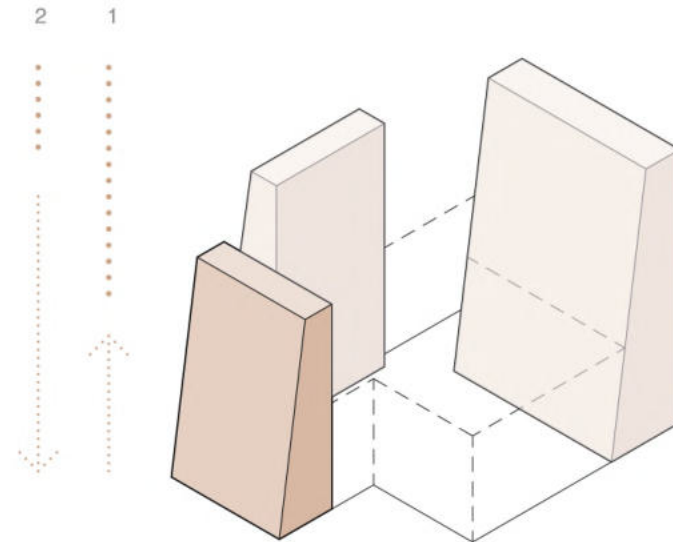
Upward pressure south tower < Upward pressure exhaust tower

$\mathbf{4,66 \text{ N} < 40,64 \text{ N}}$

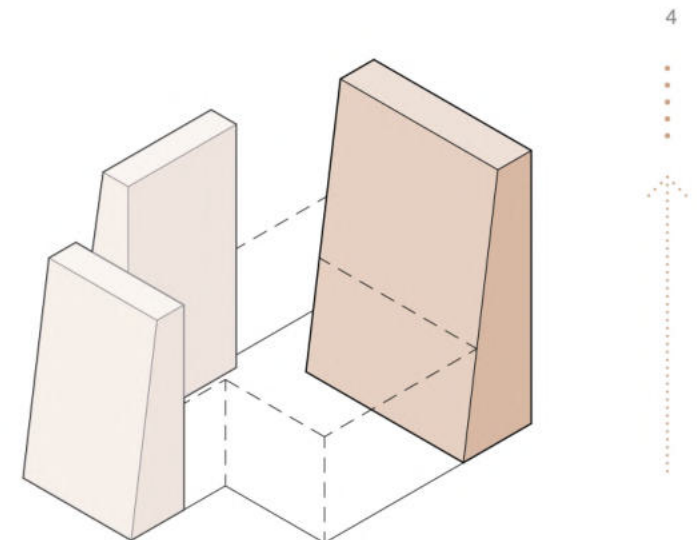
EXHAUST CHIMNEY SOUTH

To prove that both the south and west towers function as supply air towers in winter, the upward pressure of the exhaust tower is also calculated while the south tower is in operation. Since the upward pressure of the exhaust tower is greater than the total pressure of the south tower, the difference in height and the suction effect draw air into the south tower and direct it into the room.

(cf. list of sources [1] - [9])



PICTOGRAM SOUTH TOWER



PICTOGRAM EXHAUST TOWER

1 | UPWARD PRESSURE OF THE AIR IN THE CHIMNEY

Correct direction of flow = $2,02 \text{ N/m}^2 \times 1,82 \text{ m}^2 = \mathbf{3,68 \text{ N}}$

Incorrect direction of flow = $11,56 \text{ N/m}^2 \times 1,82 \text{ m}^2 = \mathbf{21,04 \text{ N}}$

2 | WIND PRESSURE OF THE AIR IN THE CHIMNEY

Wind pressure = $8,78 \text{ N/m}^2 \times 1,82 \text{ m}^2 = \mathbf{15,98 \text{ N}}$

3 | TOTAL PRESSURE

Correct direction of flow = $3,68 \text{ N} - 15,98 \text{ N} = \mathbf{-12,30 \text{ N}}$

Incorrect direction of flow = $21,04 \text{ N} - 15,98 \text{ N} = \mathbf{5,06 \text{ N}}$

4 | UPWARD PRESSURE OF THE AIR IN THE EXHAUST TOWER

Upward pressure (with opening area $A = 2,73 \text{ m}^2$)

Upward pressure = $12,58 \text{ N/m}^2 \times 2,73 \text{ m}^2 = \mathbf{34,34 \text{ N}}$

5 | PRESSURE RATIOS

Correct direction of flow:

Upward pressure west tower < Upward pressure exhaust tower

$\mathbf{-12,30 \text{ N} < 34,34 \text{ N}}$

Incorrect direction of flow:

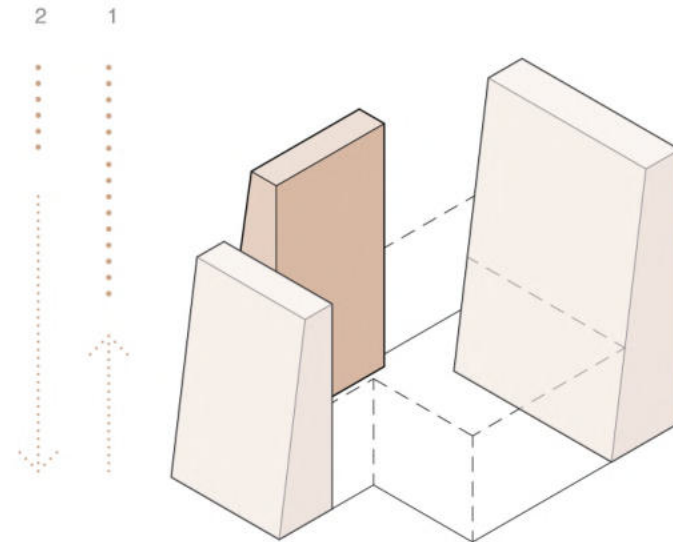
Upward pressure west tower < Upward pressure exhaust tower

$\mathbf{5,06 \text{ N} < 34,34 \text{ N}}$

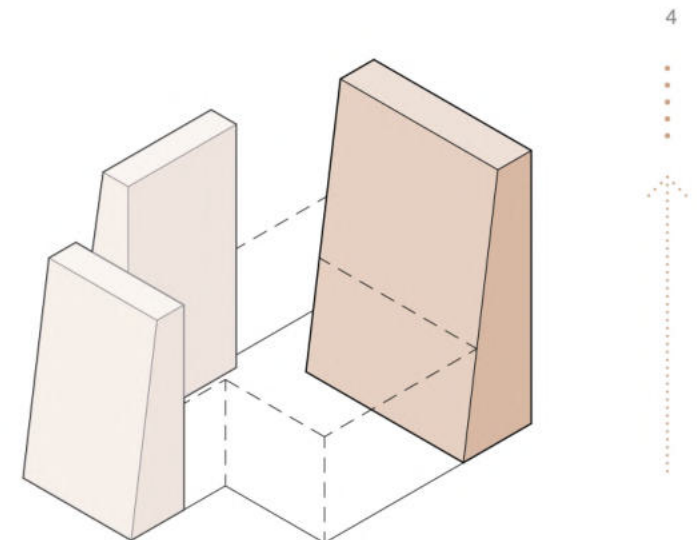
EXHAUST CHIMNEY WEST

To prove that both the south and west towers function as supply air towers in winter, the upward pressure of the exhaust tower is also calculated while the west tower is in operation. Since the upward pressure of the exhaust tower is greater than the total pressure of the west tower, the difference in height and the suction effect also draw air into the west tower and direct it into the room.

(cf. list of sources [1] - [9])



PICTOGRAM WEST TOWER



PICTOGRAM EXHAUST TOWER

1 | TABULAR LIST OF VENTILATION HEAT LOSSES

The table shows the heating of the air in the solar tower during the winter months, followed by the ventilation heat losses of the building without solar towers and with solar towers.

2 | GRAPHICAL REPRESENTATION OF VENTILATION HEAT LOSSES

The graph illustrates the values shown in the table.

3 | TOTAL VENTILATION HEAT LOSSES

Ventilation heat losses without solar tower = **34140,6 kWh**

Ventilation heat losses with solar tower = **2325,3 kWh**

4 | SAVINGS IN VENTILATION HEAT LOSSES

Savings = $100\% - (2325,3 \text{ kWh} \times 100\%) / 34140,6 \text{ kWh} = 93\%$

5 | SHORTENING OF THE HEATING PERIOD

Preconditioning the air in the solar tower can reduce ventilation heat losses in winter by up to 93%. As a result, the **annual heating period can be shortened by the months of october, march and april**, i.e. in winter, additional heating is only required from november to february.

VENTILATION HEAT LOSS

Solar towers are very effective as a ventilation principle in summer. But even in winter, the designed combination of solar towers can effectively shorten the heating period of the Sturmfabrik by up to three months. Compared to an equivalent Sturmfabrik building without solar towers, the south tower alone can save up to 93% of ventilation heat losses.

(cf. list of sources [1] - [9])



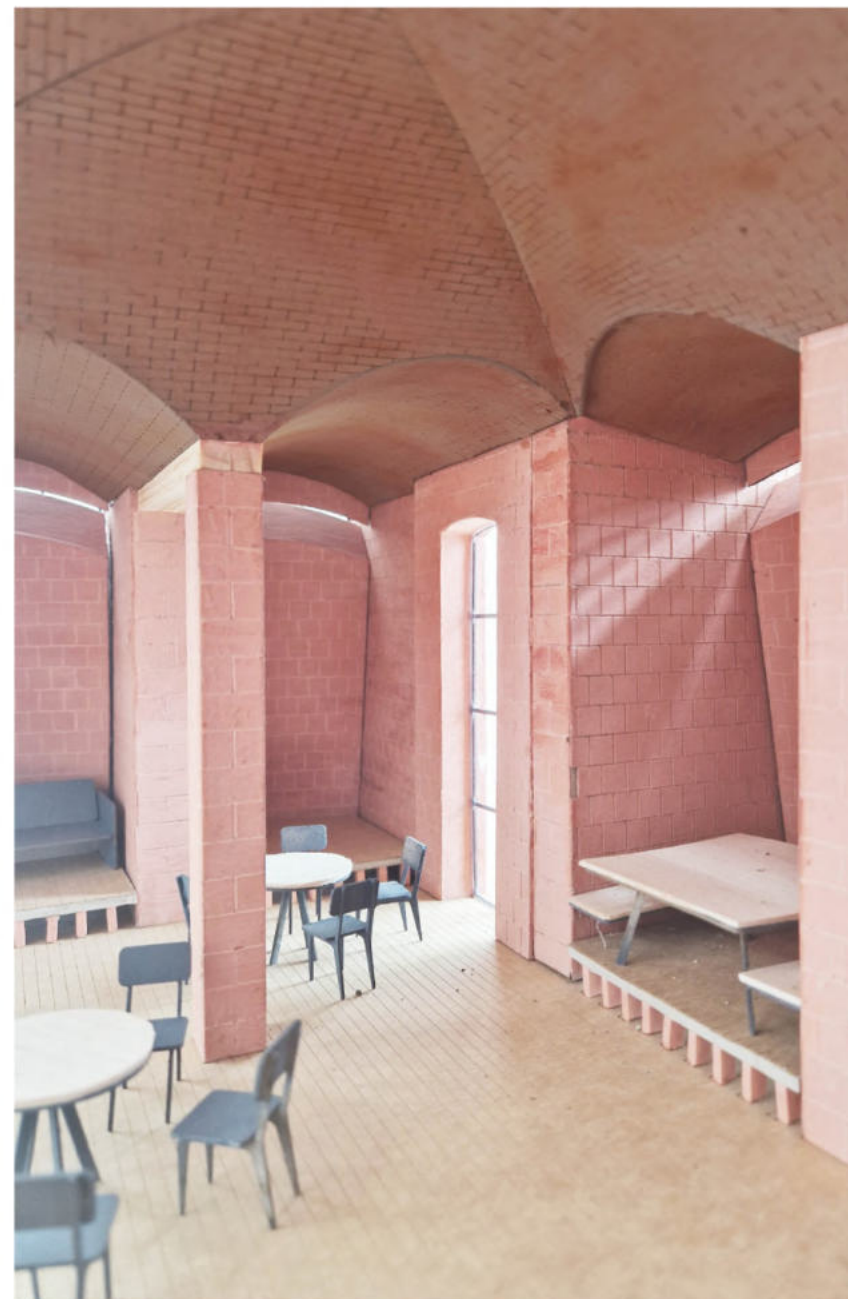


EXTERIOR PERSPECTIVE

MODEL

The 1:20 scale section model provides an impression of the interior and the structural components of the building.

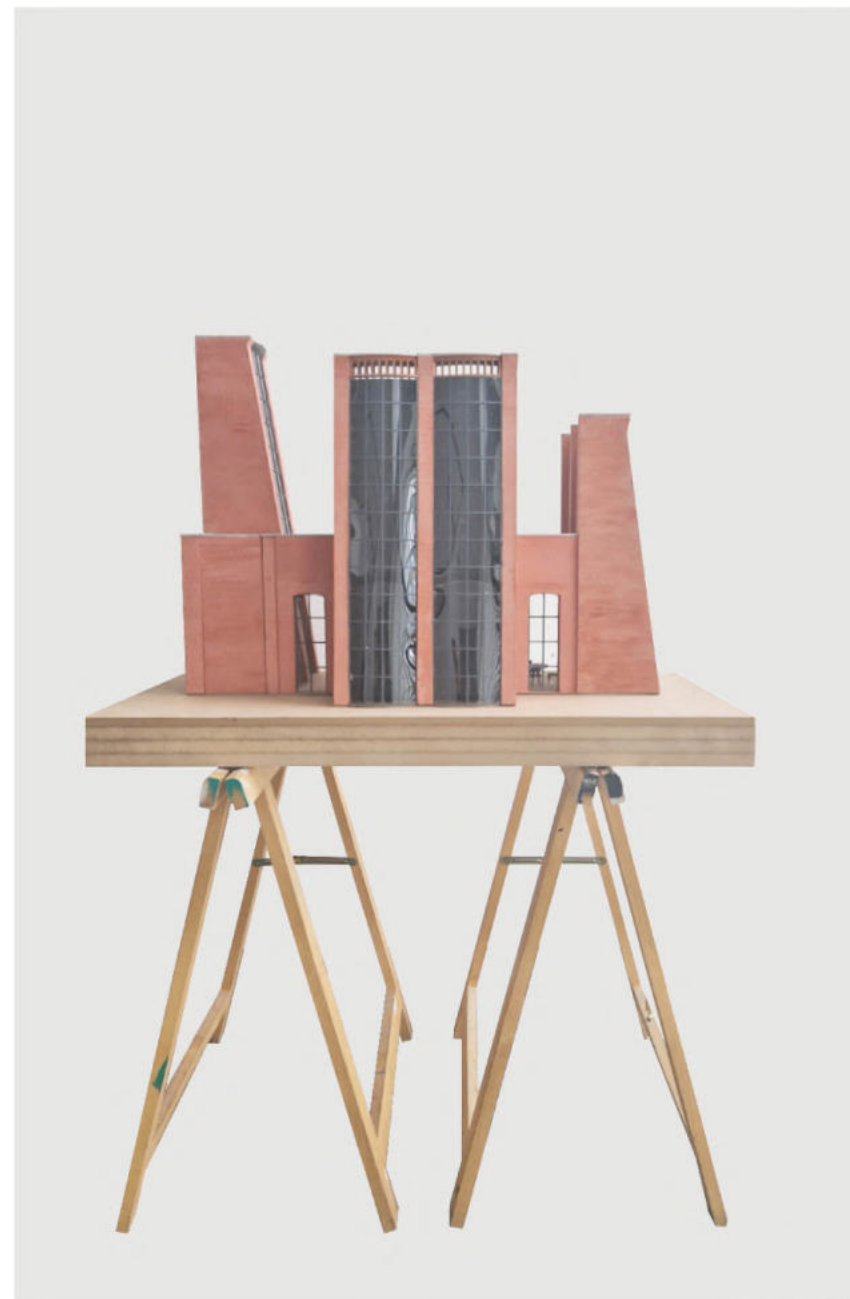
The 1:50 scale structural model shows all the primary structural elements – the brick ribs, columns, beams for the cap ceilings and the cross ribs of the vault.



SECTION MODEL



SECTION MODEL



SECTION MODEL



STRUCTURAL MODEL

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- [9] | K. Iten, „Klimadiagramme weltweit. Deutschland/München.“ iten-online, [n.d.]. [Online]. Available: <https://www.iten-online.ch/klima/europa/deutschland/muenchen.htm>. [Accessed 23.06.2024].

SOURCES



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