# BETON

## CONSTRUCTION ET PREFABRICATION

UE-P 2014

FACULTE DE L'ENVIRONNEMENT NATUREL, ARCHITECTURAL ET CONSTRUIT
LABORATOIRE D'ARCHITECTURE URBAINE ET REFLEXION ENERGETIQUE
ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE

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SUISSE 2014

# Systematic methodology for defining an anti-seismic building over a parking structure

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**Abstract**

A rationally structured building exterior liberates the buildings interior space. Moving paraseismic walls to the exterior edge of a building allows for an open floor plan, a dynamic internal circulation core, and free movement through subterranean parking levels. A design strategy for combining a buildings paraseimic structure, circulation core, and urban form allows for optimized urban spaces with mitigated seismic risk while reducing the impact of above ground parking structures on the urban landscape by moving these structures below the buildings they service.

**Keywords**
parking, seismic, subterranean, paraseismic, urban, pre-fabricated, façade, element

## 1. Introduction

Attached multi-unit dwellings, also known as apartment buildings, are an archetypal staple of the modern cities. With the advent and dramatic rise in ownership of automobiles in the 1920's, planning for parking these vehicles grew as a priority for urban planners [1], who tasked architects with integrating parking into the urban fabric in the form of parking lots, and later following the explosive increase in automobile purchases following WWII, parking garages. With increased densification in cities and urban space at a premium, comes the sensible decision to place these parking structures underground [2]. On-site parking has a high degree of impact on the overall building form [3]. If that parking is subterranean, the structural considerations for the building located above are impacted, especially seismic considerations.

Earthquake risk mitigation in Switzerland began in the mid 1990's [4], with SIA norms 260 and 267 being introduced in 2003 that outline optimal paraseismic details in new construction [5]. The act of putting a parking lot below a building presents obvious design issues within the domain of structural stability, specifically, how does one place a large open space, with the embedded necessity of unrestrained vehicular movement, under a multi-story structure; furthermore, how can that structure be designed to resist seismic activity and be code compliant?

## 2. Requirements and constraints

The inherent issue in this design endeavor is the conflict between seismic stability and an open floor plan. Our research for this project involved examining a variety of strategies for building over a subterranean parking garage. Each member of a team of student researchers was given a parking plan then instructed to design a nine story mixed-use structure above it. The researcher's objectives were to maximize the usability of the space while designing a rationally constructed, well-lit, anti-seismic building plan.

### *2.1 Investigation parameters*

The specific parameters of the investigation were as follows:

- Students were given a subterranean parking lot measuring 39 meters by 31.2 meters. This particular dimension of subterranean lot allowed for three parking spaces corresponding to Swiss Standard 640 291 a [6] between the building's structural support columns.
- A nine story high building with floor heights of 2.8 meters was then designed above the underground parking lot. The building's floors were grouped into three programming blocks of three stories each. The students were then directed to designate these different blocks as

residential, office, and retail programming. Additionally, each programming block should be evident in the buildings architecture by shifting the buildings geometry for each block on the buildings z-axis. The resulting building form must correspond to VKF AEAI regulations for fire protection [7].
- The exterior of the building is a structural skin, allowing for maximizing the available interior space. A software tool used to generate building envelopes, developed at the EPFL [8] was used to create a panel layout of archetypal precast concrete elements utilizing O-shaped, T-shaped, or mullion/beam configured façade elements, each with 50% glazing.

The execution process for this investigation commenced with the students measuring the distance between the corners of the top floor plan, then determining the number of prefabricated elements the floor can be composed of in multiples with a maximum length of 8 meters. After the prefabricated panel size is determined and façade grid laid out, the window size is determined separately to arrive at a 50% opaque façade.

The top floor design is then translated into an overall urban form. The location of paraseismic walls within the building is determined by comparing the top floor plan and subterranean parking plan. The tension between open, navigable space in the parking garage below the building versus rigid, structural logic for the buildings load bearing supports and seismic attenuation is most evident at this point in the design process.

*2.2 Circulation core*

The design goal for the exterior of the building's urban form is the immediate recognition of its three, three story, programming blocks. A successful design achieves this through shifting the mass of each programming block to create a dynamic movement between building layers, resulting in the powerful spatial element of an internal corridor rising through the building to connect its circulation paths.

For adequate circulation it is ideal for each floor to have a centrally located space with a surface area equal to the floor plan of that story scaled down by 33%. This allows equidistant access to the building's circulation space from the entire external boundary of that building floor.

*2.3.1 Refining paraseismic structure*

The contention between these shifting layers and the necessity of monolithic seismic elements traversing the building longitudinally is mitigated by linking each floor's torsional seismic axis [9]. Initiating the exploration of the paraseismic wall plan involves finding the centroid of the building plan using the plumb line method [10]. This process is conducted by hanging a cardboard cut-out of the floor plan from an anchor point located at one corner. A line is traced vertically down the cut-out starting at the anchor point toward the floor. Next, the cut-out is hung from another corner, and another line is traced. The intersection of these lines is the floor plans center of gravity.

After the center of gravity for all three of the buildings programming blocks and the parking area are found, the floor plans are stacked with their center of gravity points aligned. These points are the seismic rotation axis for the building. Once this axis is established, the paraseismic walls can be arranged to run through the building in a manner where they will impede the building from rotating around this axis during a seismic event.

*2.3.2 Optimal paraseismic wall placement*

Three wall configuration:

- Two walls are placed equidistant and asymetrically parallel as far from the torsional axis of the building as possible, while the third wall runs across the torsional axis perpendicular to the paired walls.

Four wall configuration:

- The walls are placed in two pairs.
- Each pair is placed equidistant and located asymmetrically as far from the torsional axis of the building as possible.
- Each pair of walls is aligned so that a vector drawn along the length of the wall in the first pair will pass at a right angle through a vector drawn along the length of a wall in the second pair.

*2.4 Lighting*

Once the paraseismic system, floor plans, and circulation core have been arranged, the next step is to ensure that natural light enters the spaces, especially around the building's paraseismic elements. Elements of the building's structural system may have to be shifted or adjusted to receive natural light. The consideration of light entering the building normally relegates the paraseismic walls to the opposing corners of the building so that at least one face of each room benefits from natural light.

**3. Results**

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**4. Discussion**

A new international style of architecture is developing that Integrates paraseismic attributes within buildings from the beginning of the design process to reduce risk and maximize space. Through their research the students found it beneficial to place the paraseismic walls as close to the buildings exterior as possible. This configuration aided in opening up the parking area for increased mobility, and placing the walls further from the core made a more stable building by decreasing the propensity for structural torsion during a seismic event. By having externally visible paraseismic attributes, seismic considerations become a new architectural form generator.

Possible avenues of research for this system include buildings with irregular subterranean floor plans, internal balconies, and different glazing percentages within their precast panels.

**6. Conclusions and outlook**

Through their investigative process the students found it advantageous to place their paraseismic walls at the exterior of the building and couple them with a structural column grid, rather than using the traditional design of internally located load-bearing walls. This configuration allowed for architectural freedom when designing the floor plan – a highly rational exterior structural system leading to a liberated interior space.

**Acknowledgements**

The authors would like to thank Prelco for their research facilities and expertise, and Katrin Beyer with Earthquake Engineering and Structural Dynamics Laboratory (EPFL / EESD).

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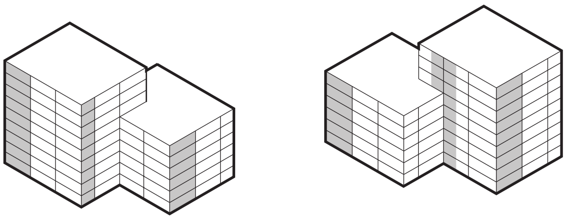

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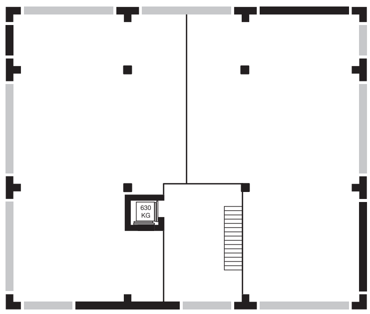

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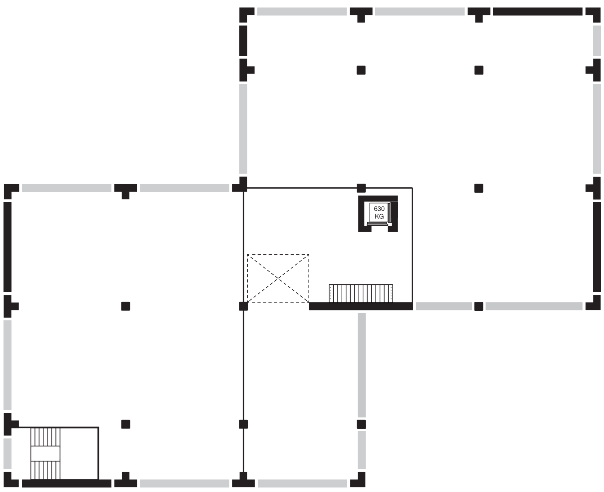

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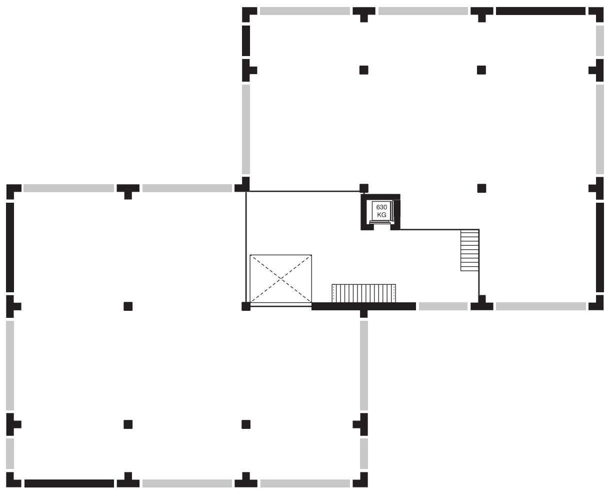

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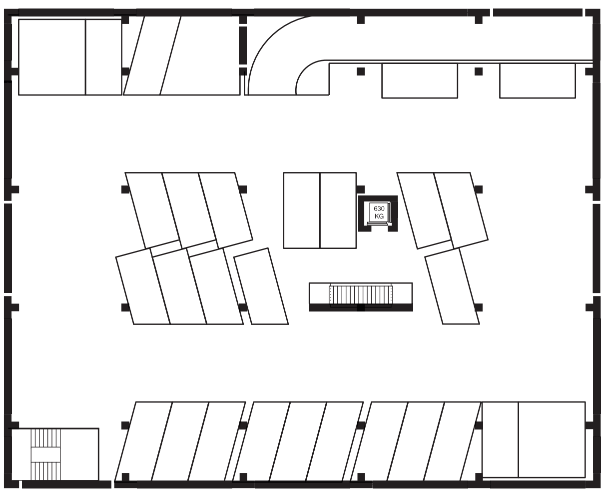

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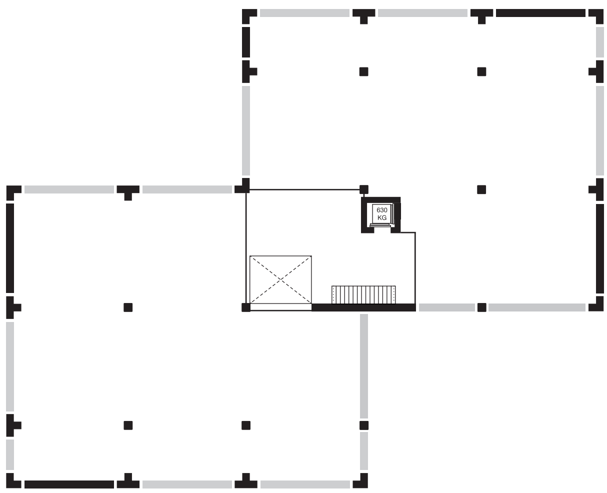

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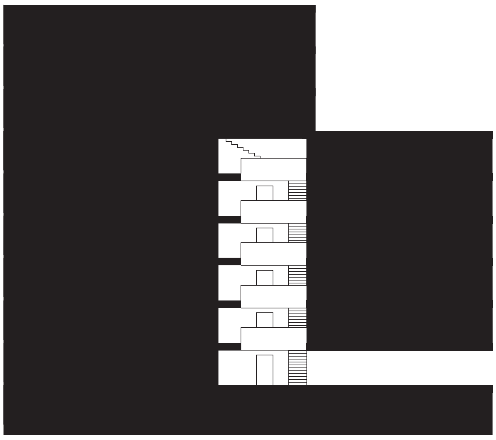

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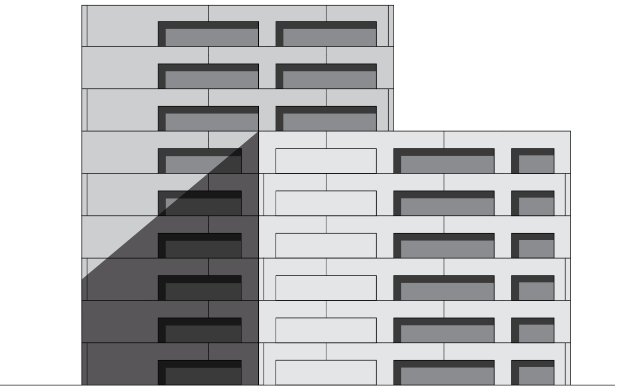

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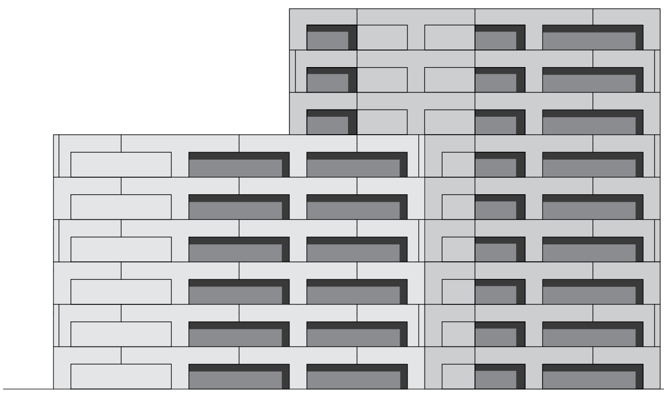

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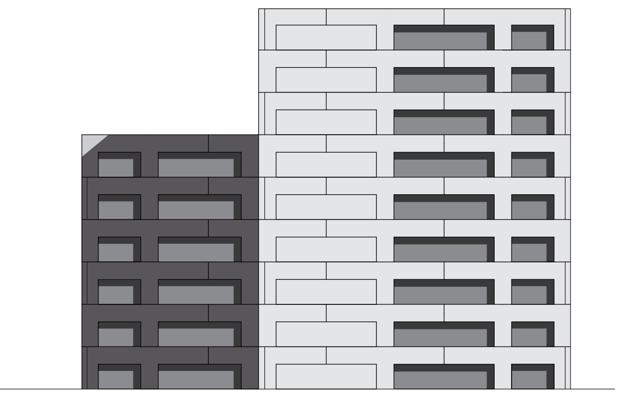

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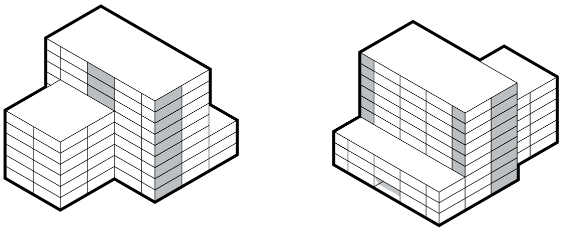

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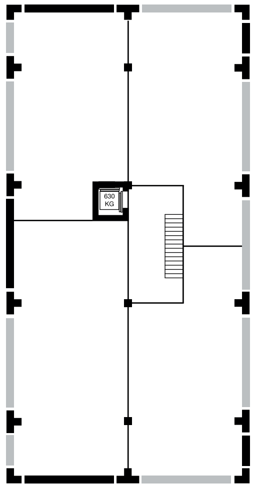


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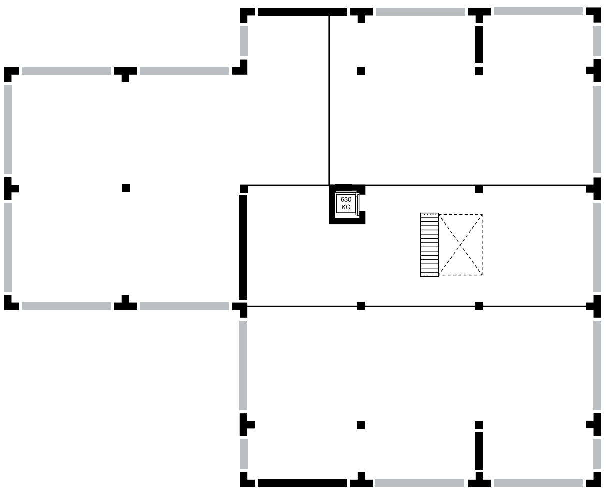


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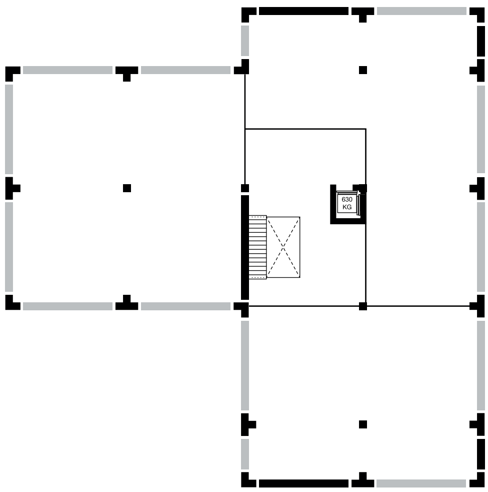


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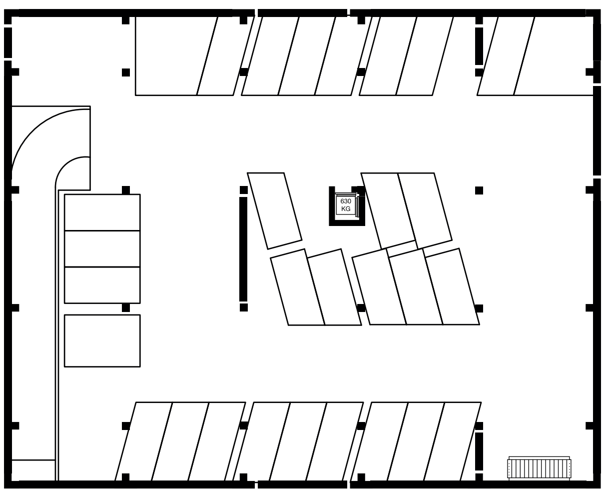


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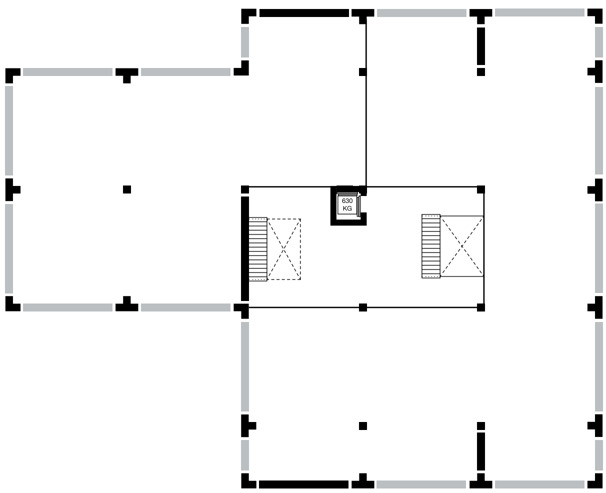


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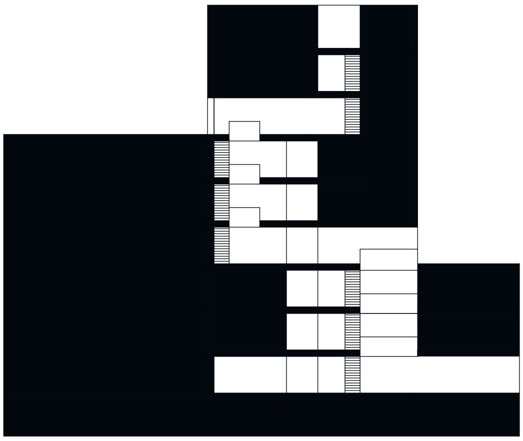

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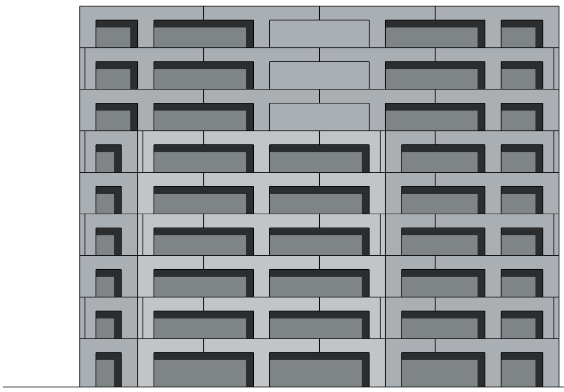

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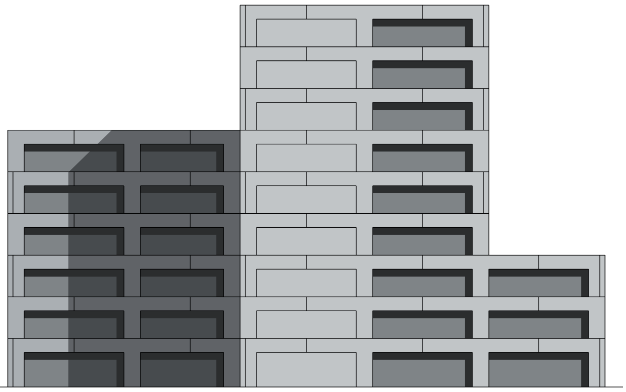

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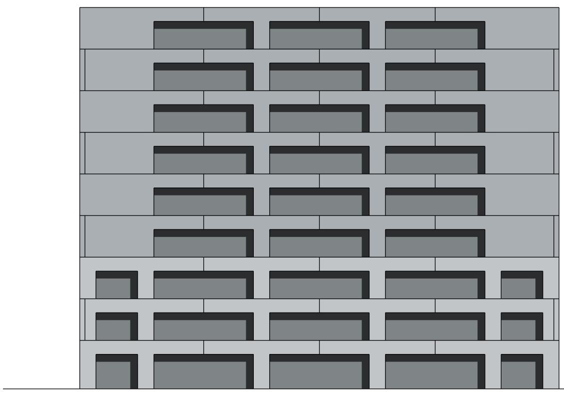

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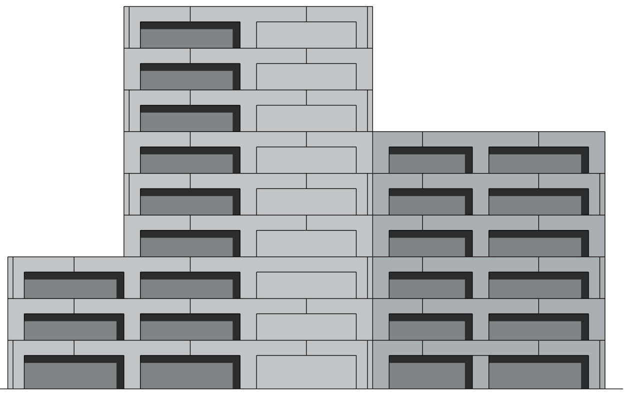

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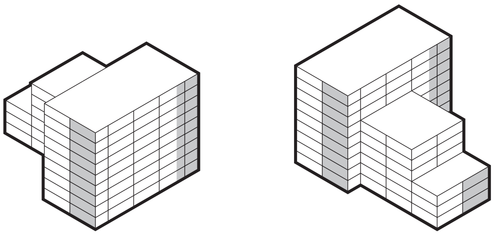

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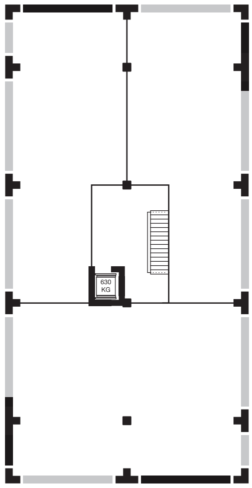


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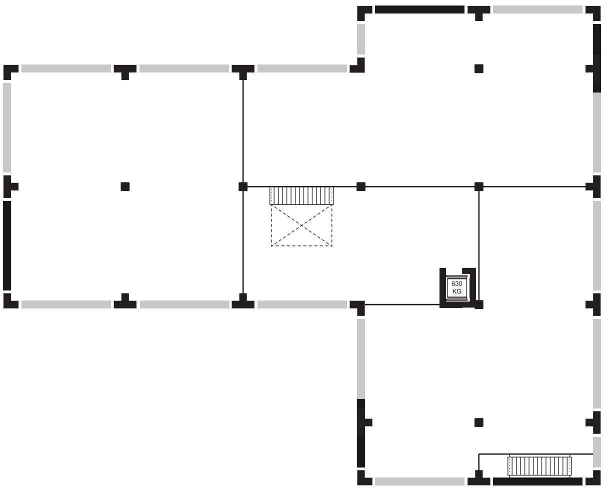


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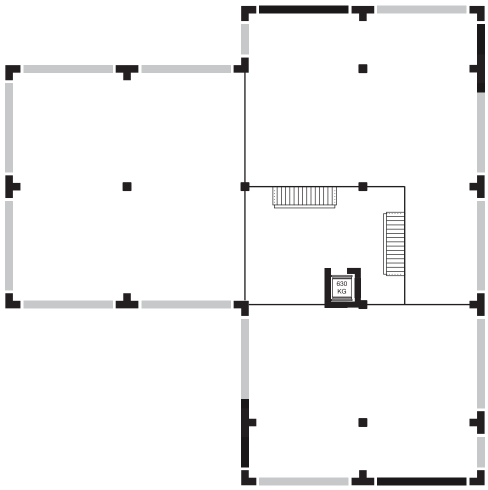


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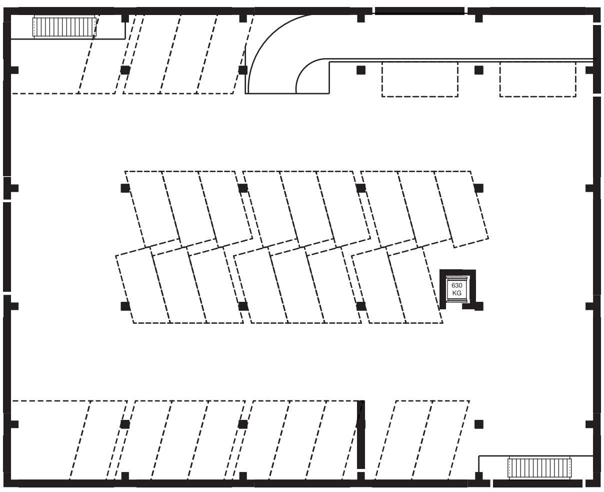


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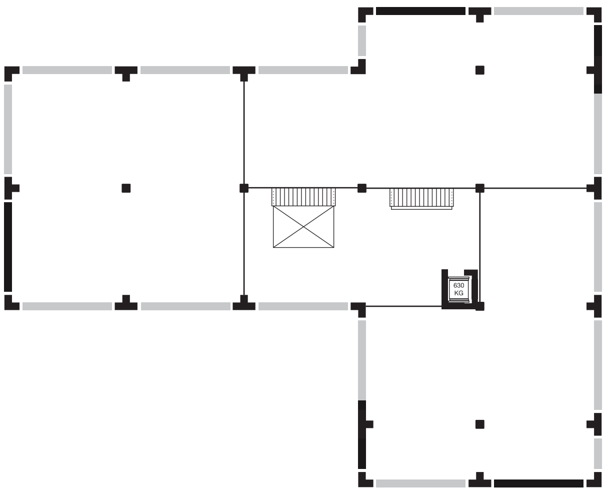


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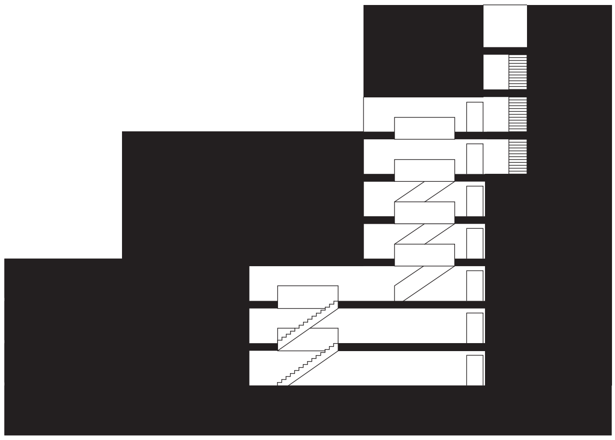

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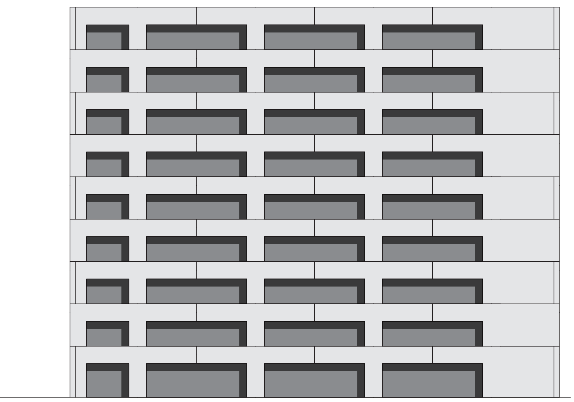

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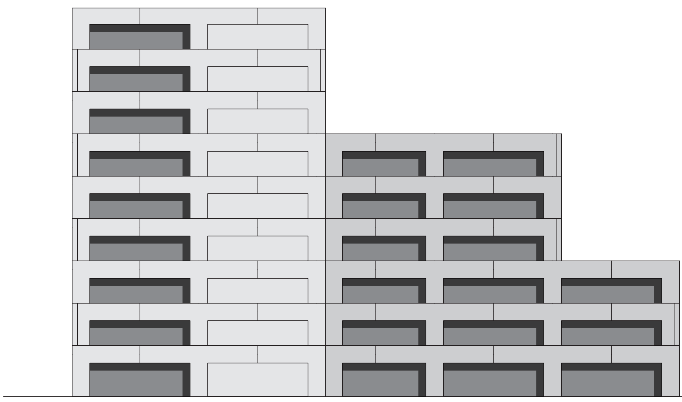

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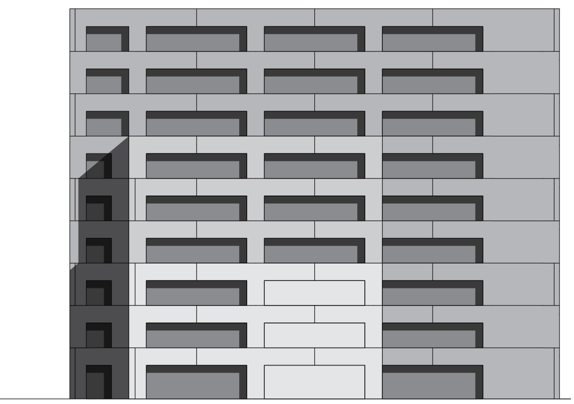

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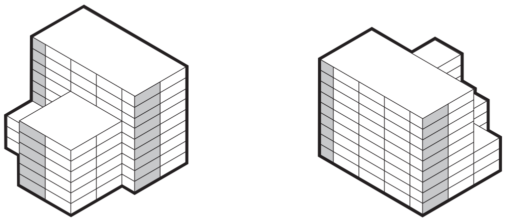

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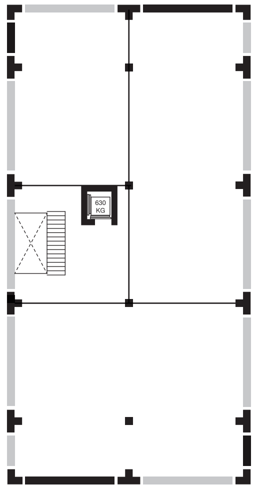

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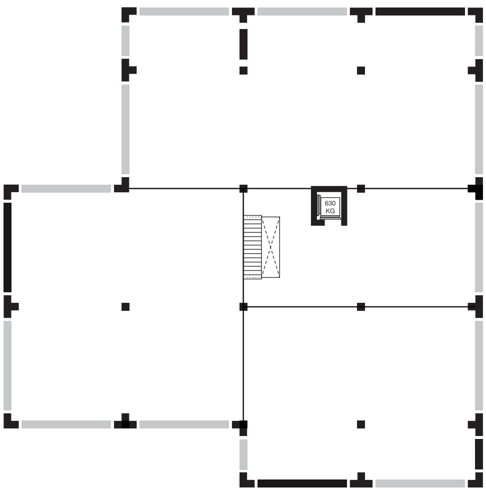

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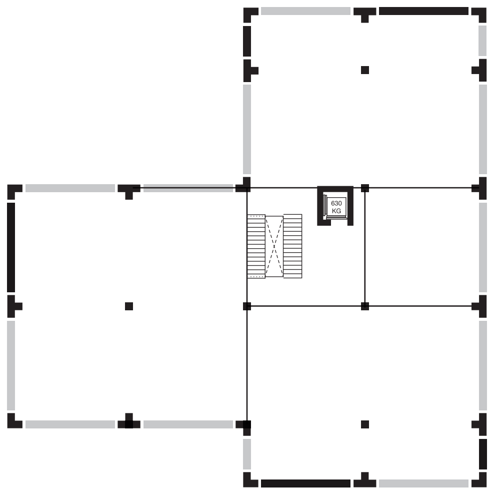

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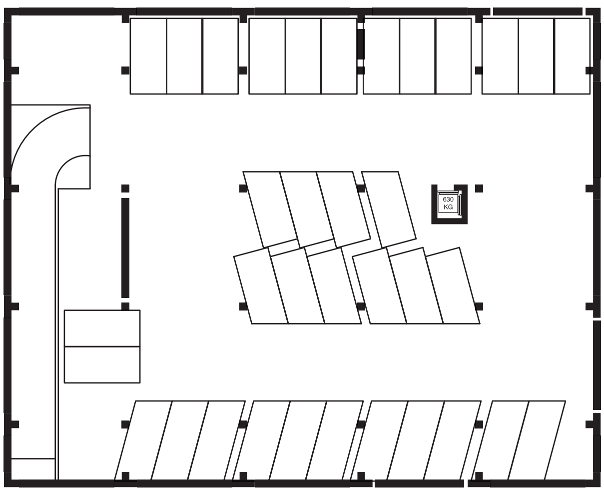

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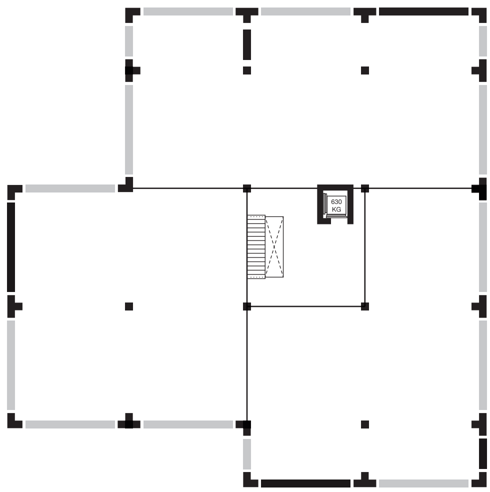

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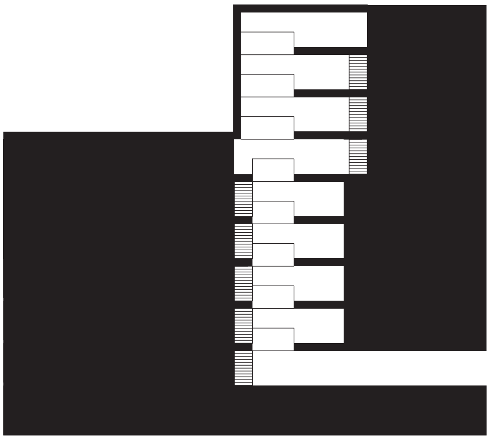

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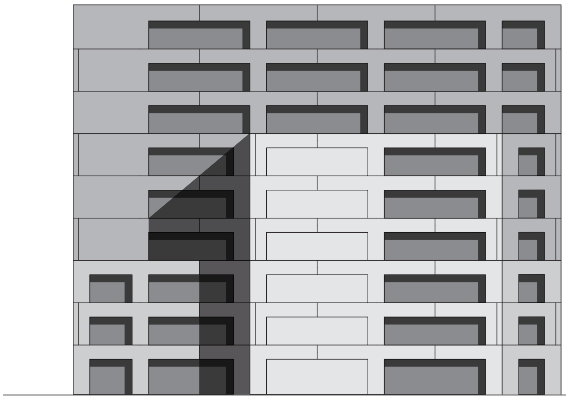

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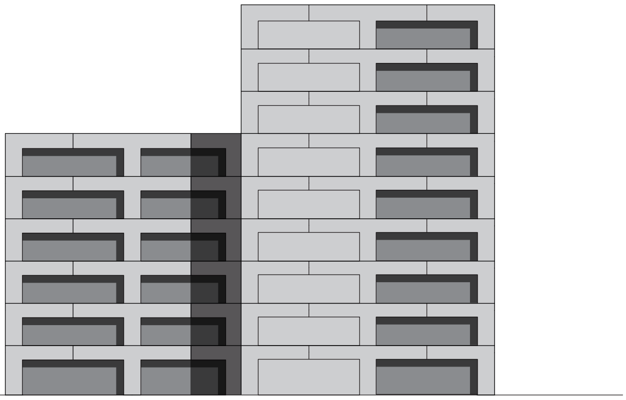

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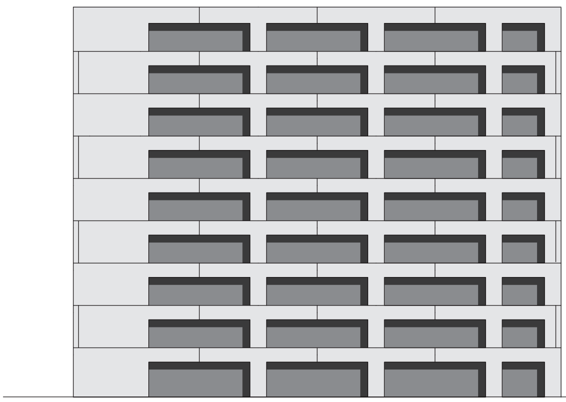

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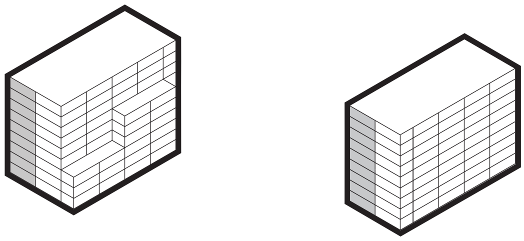

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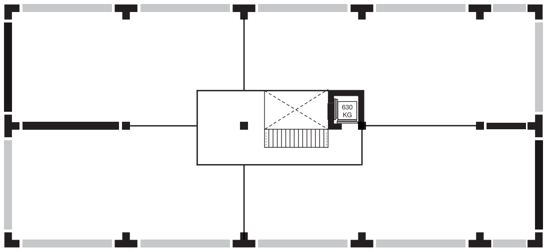


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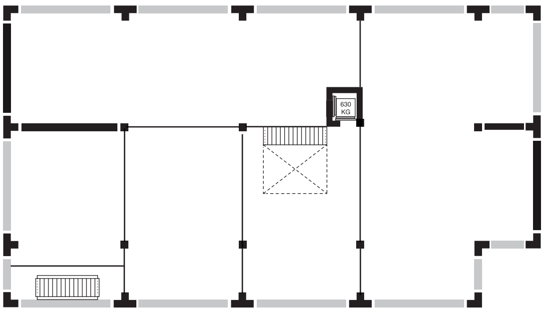


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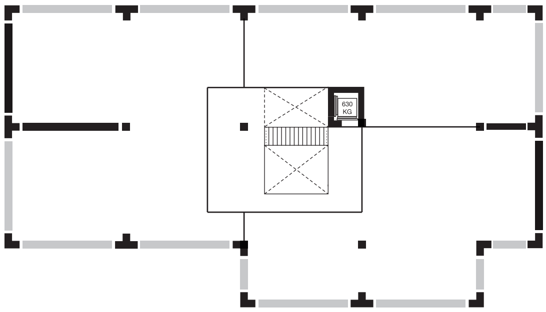


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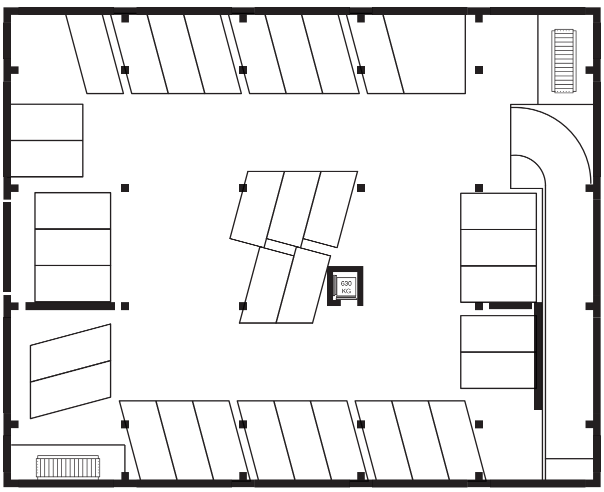


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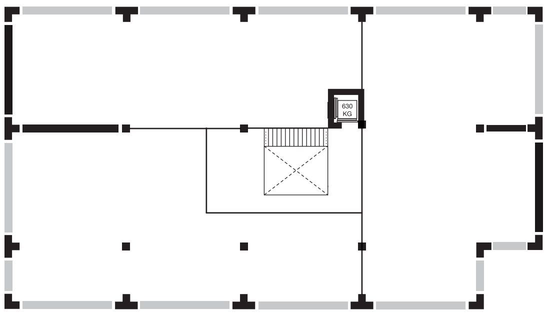


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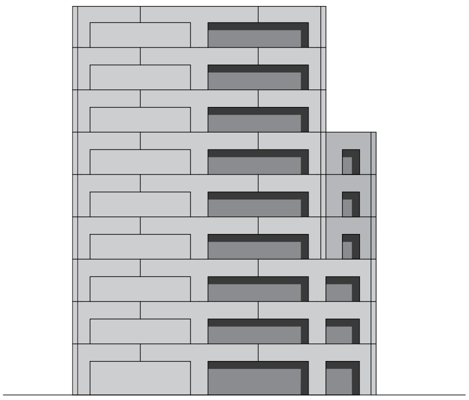

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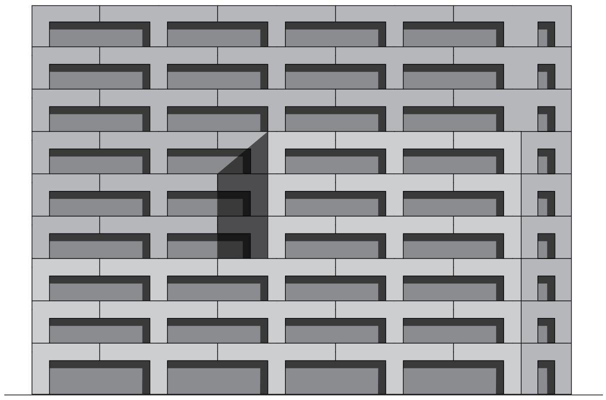

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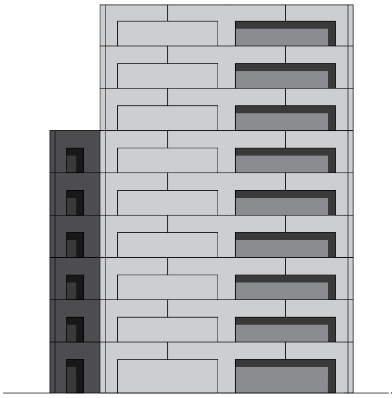

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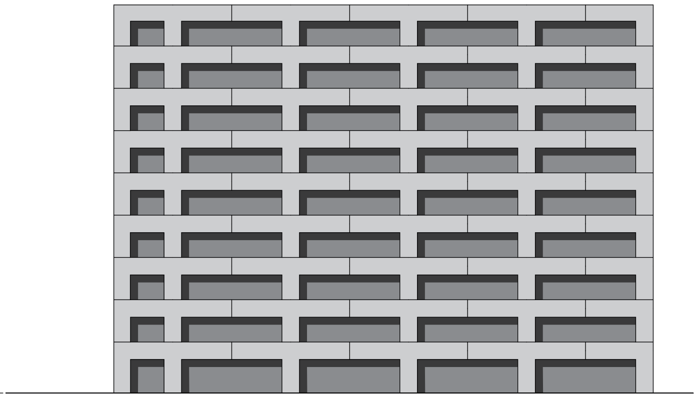

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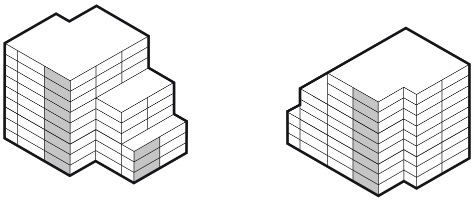
# SINDRE A. GÅSVIK



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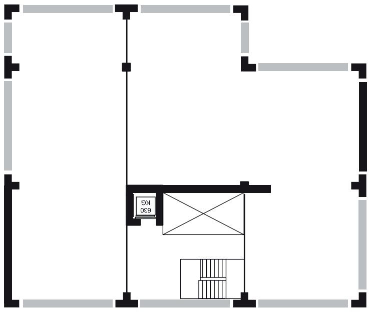

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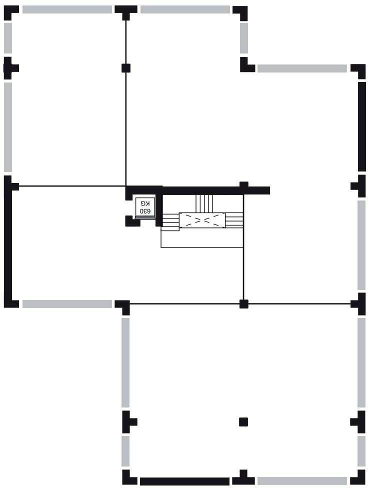

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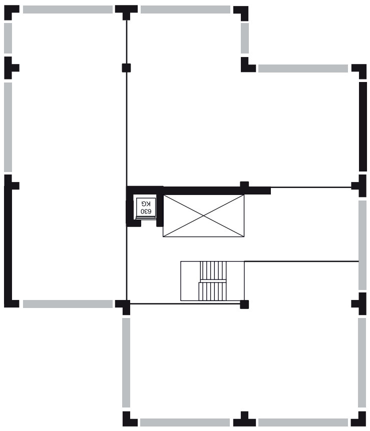

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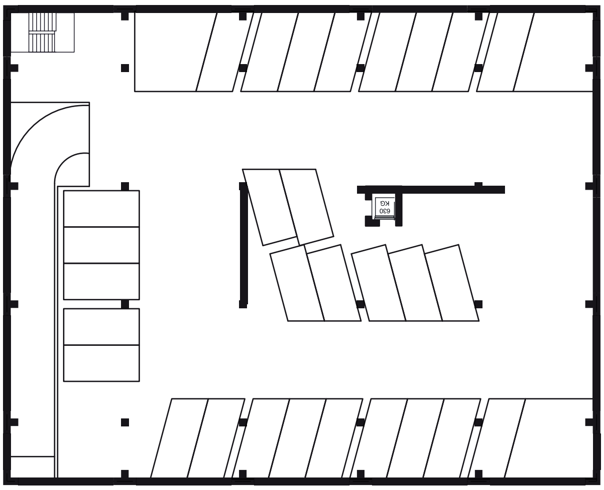

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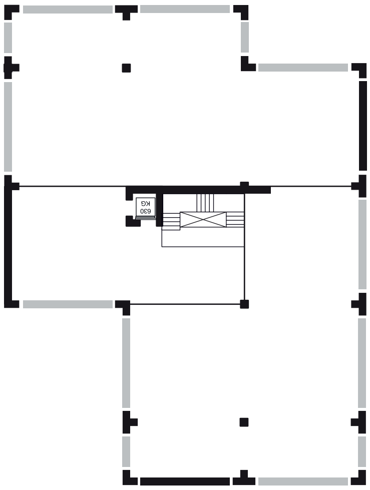

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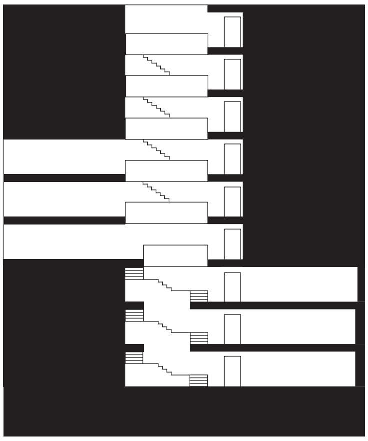

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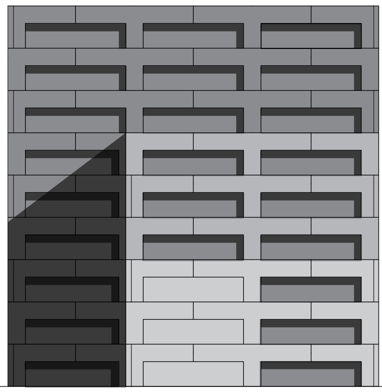

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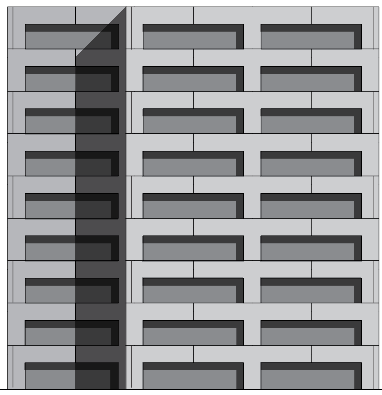

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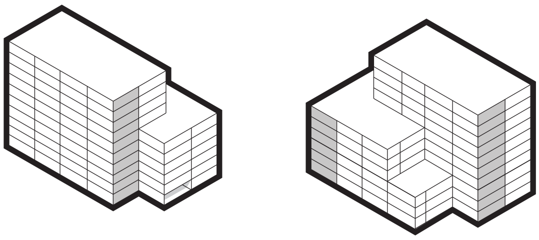

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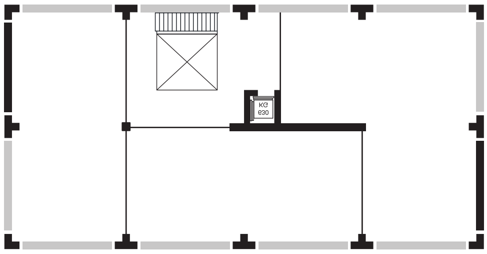

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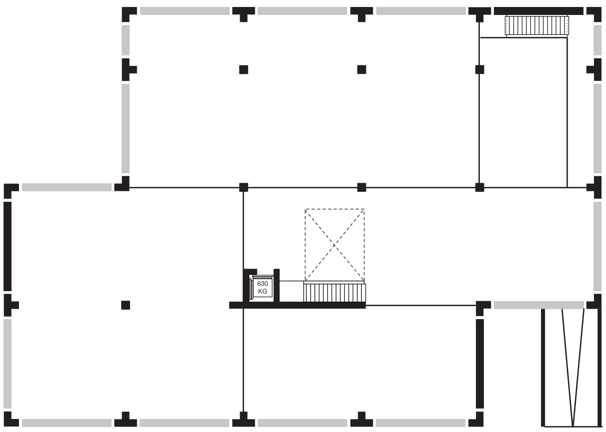


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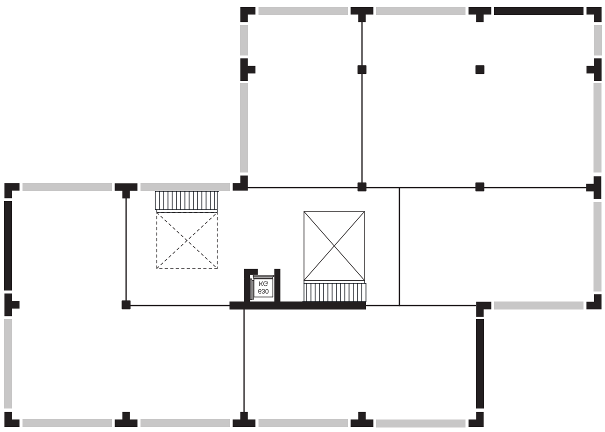

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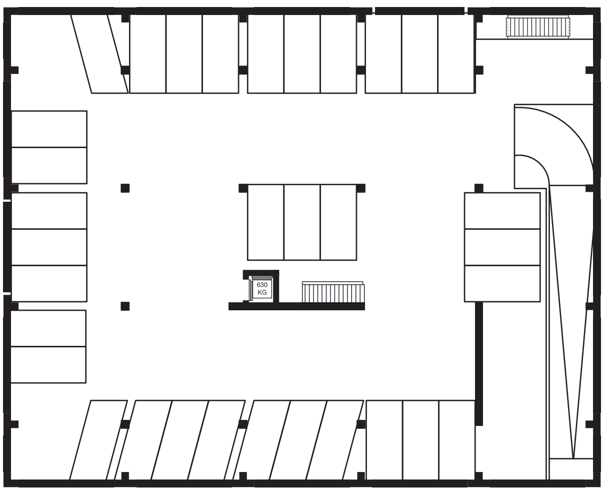


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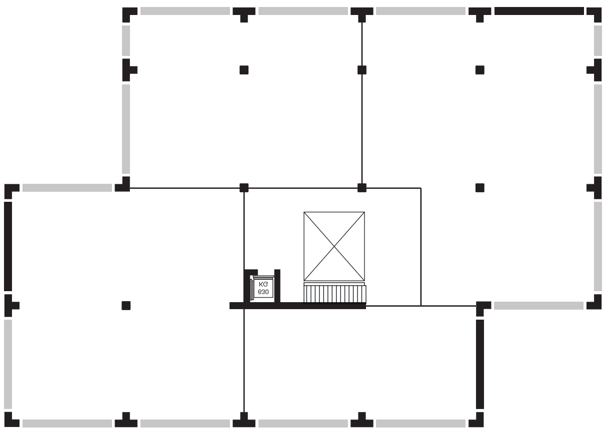

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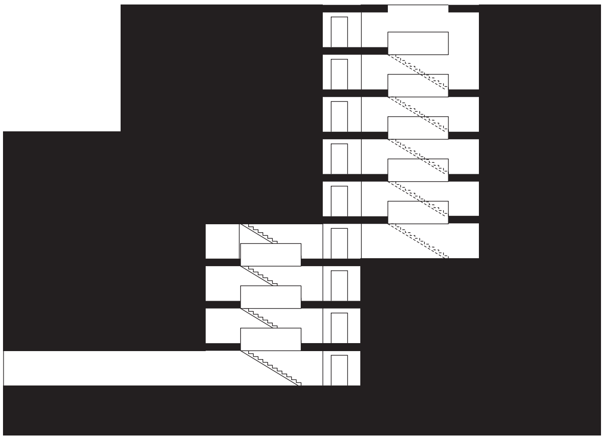

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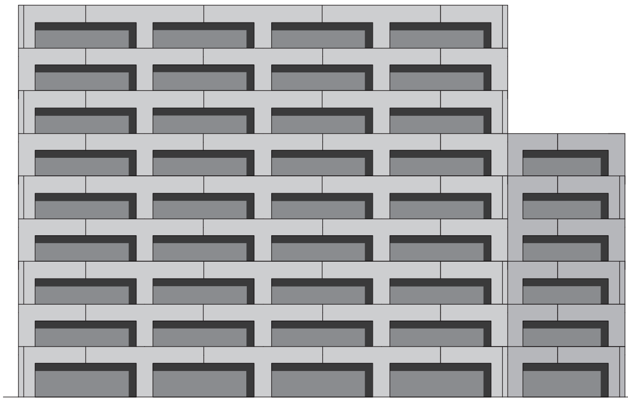

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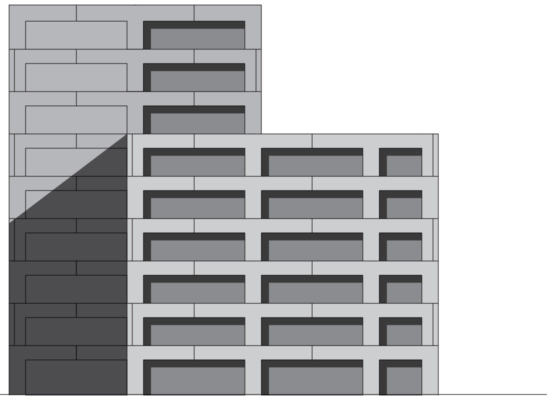

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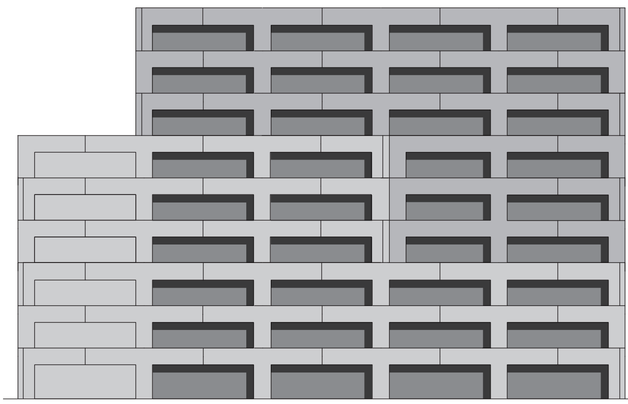

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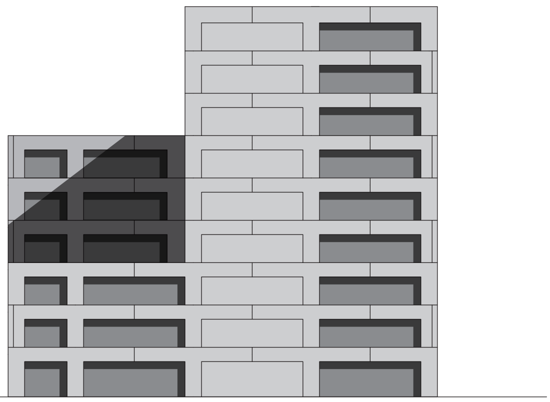

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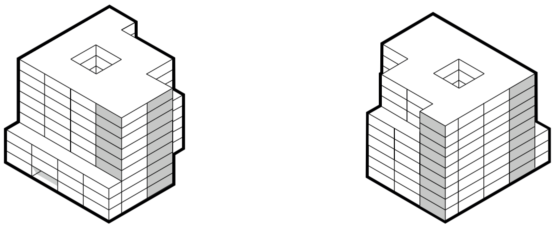

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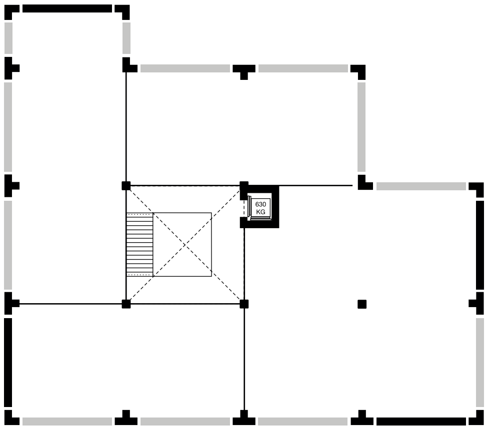


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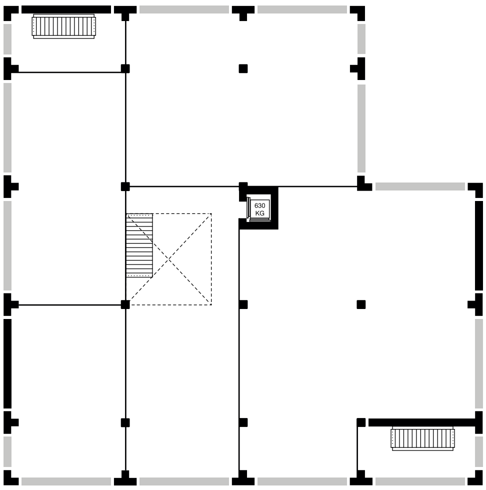


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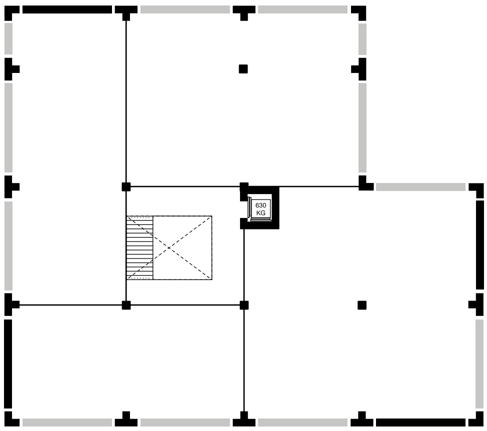


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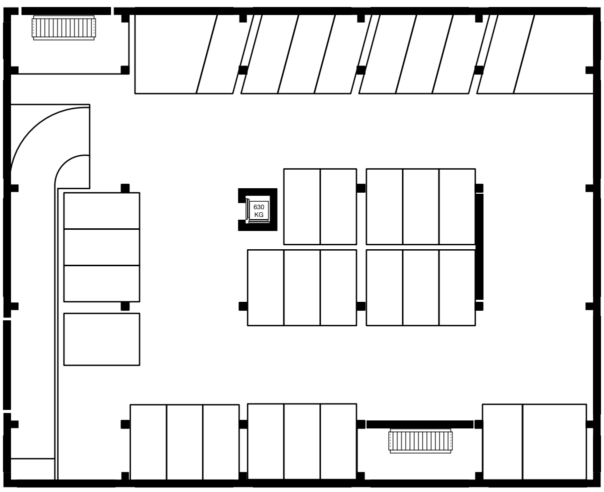


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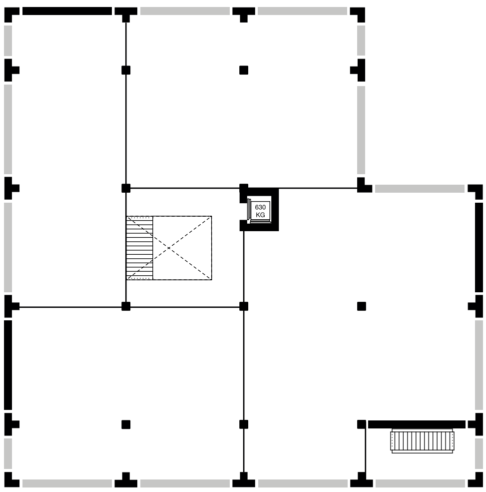


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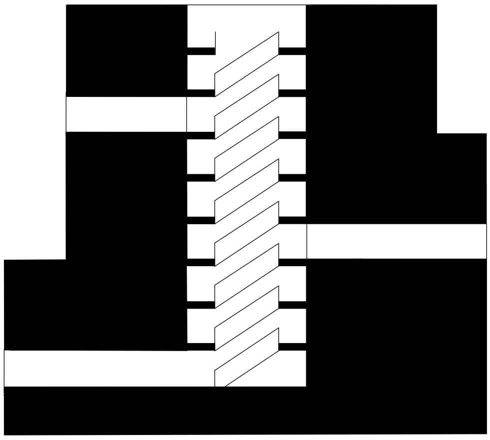

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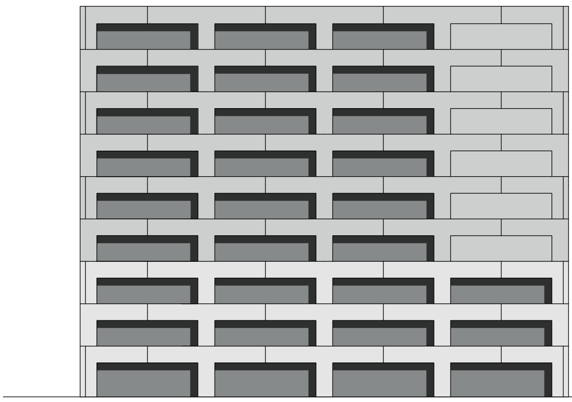

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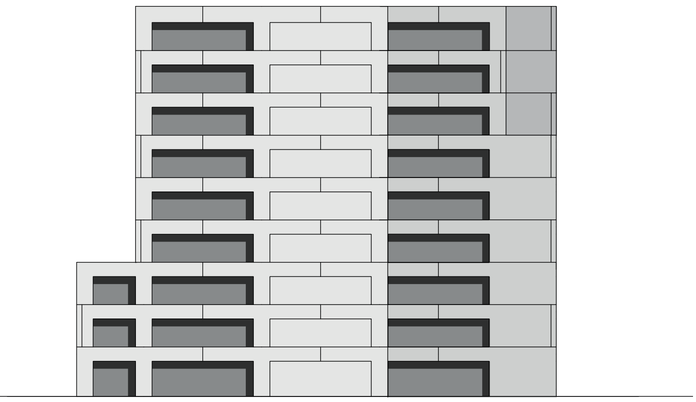

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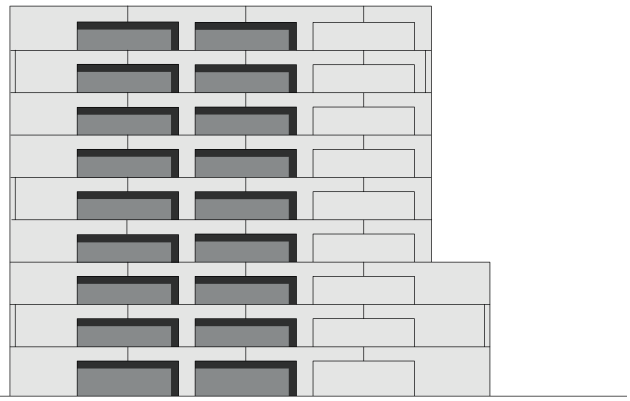

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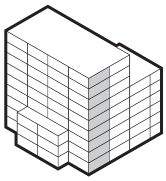

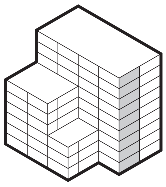

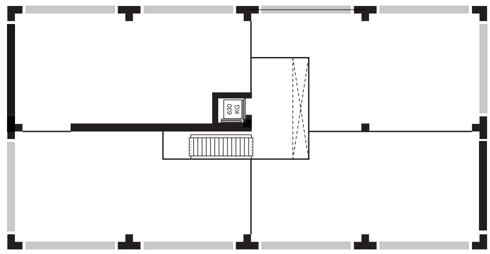

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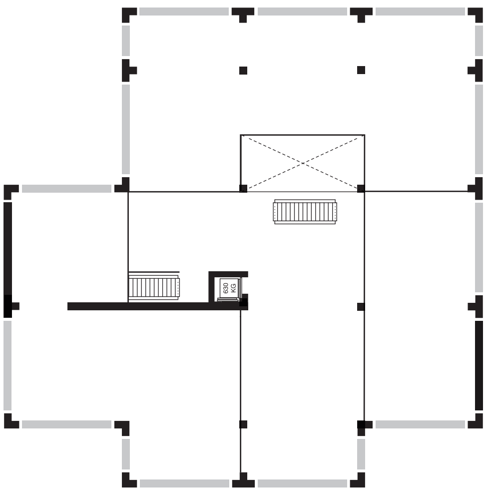

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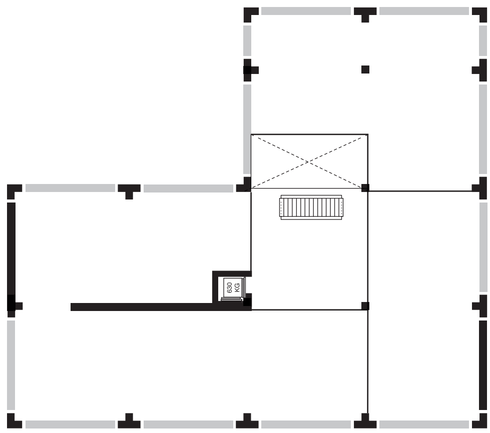

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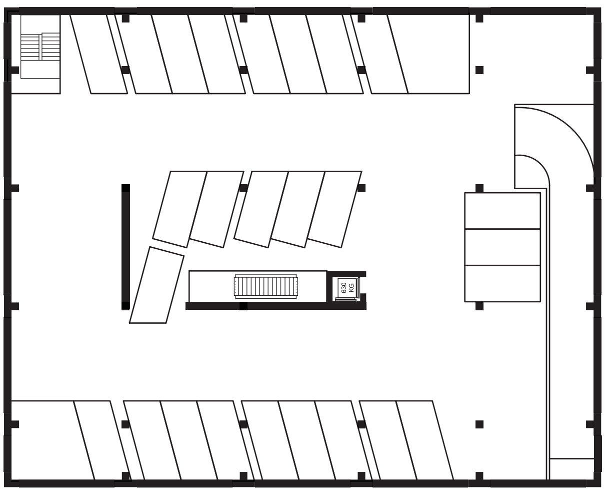

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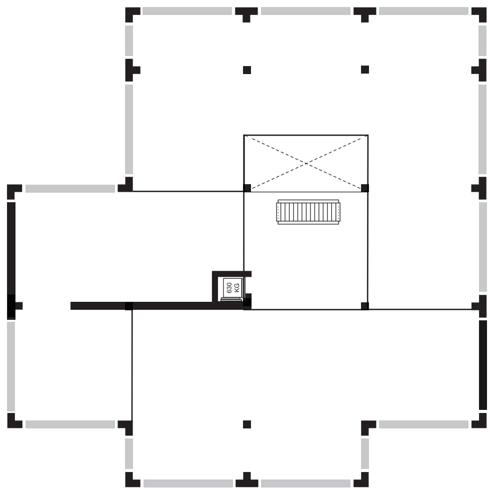

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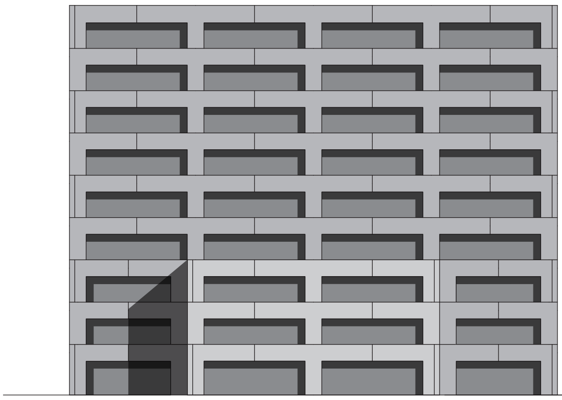

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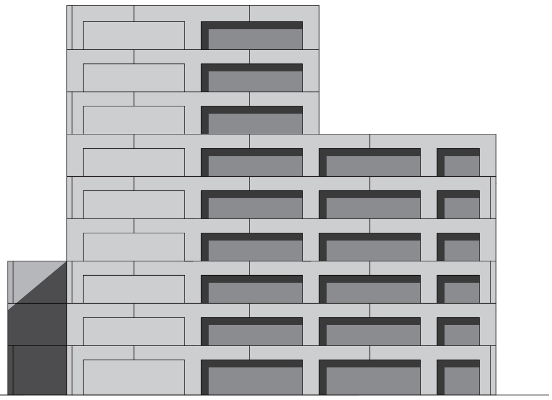

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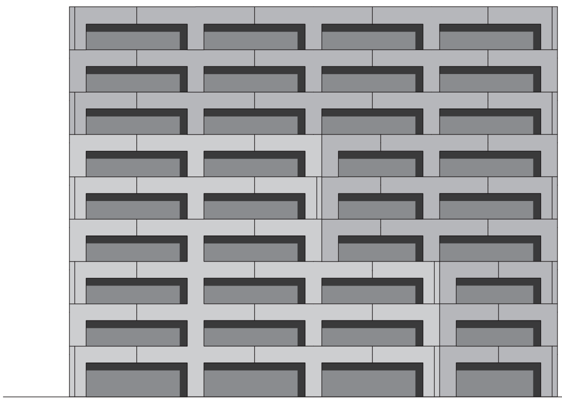

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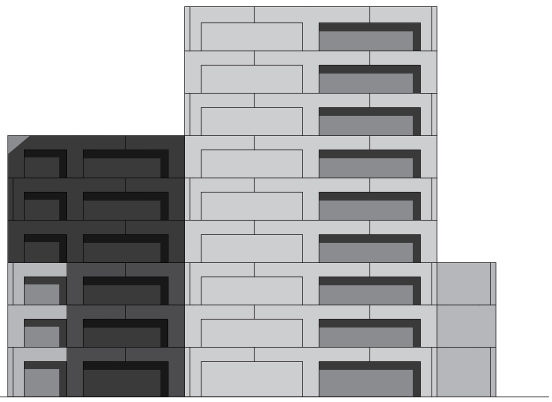

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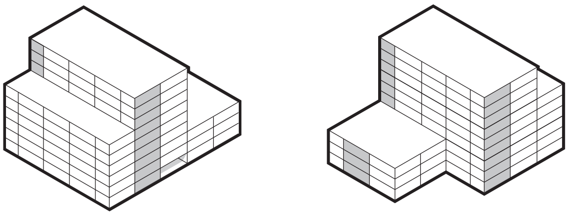

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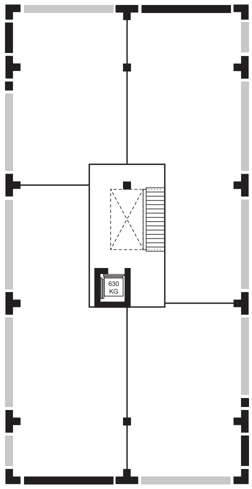

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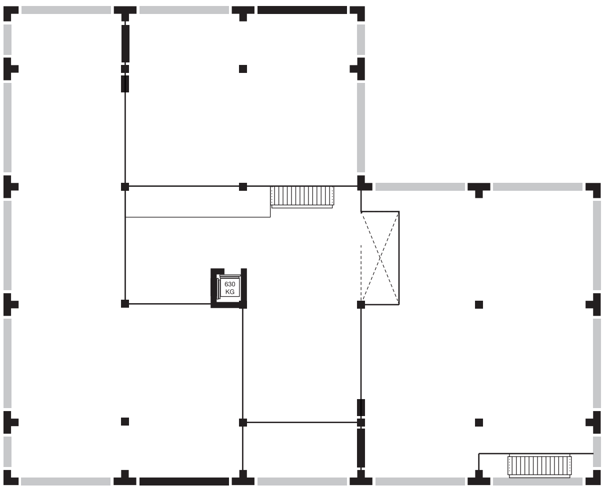

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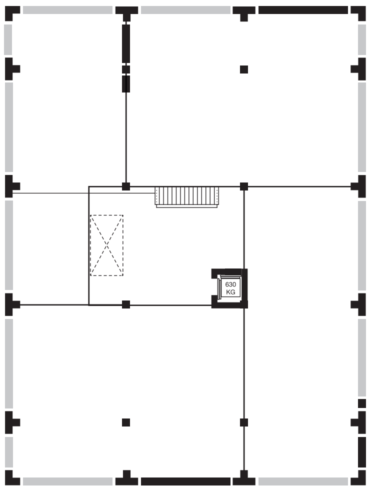

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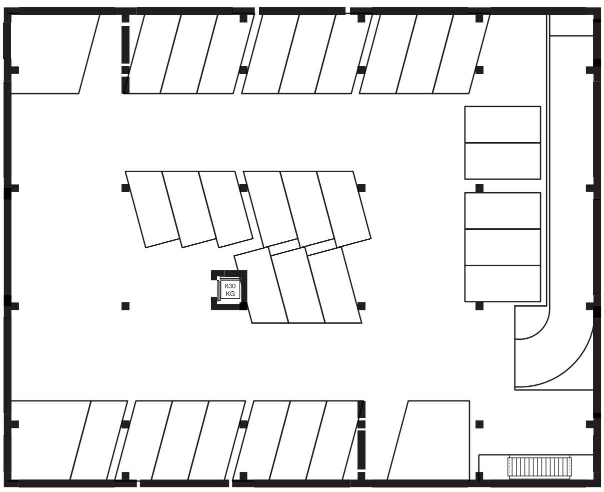

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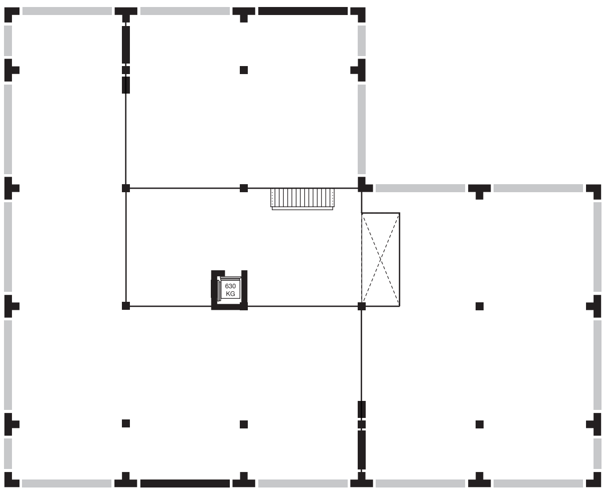

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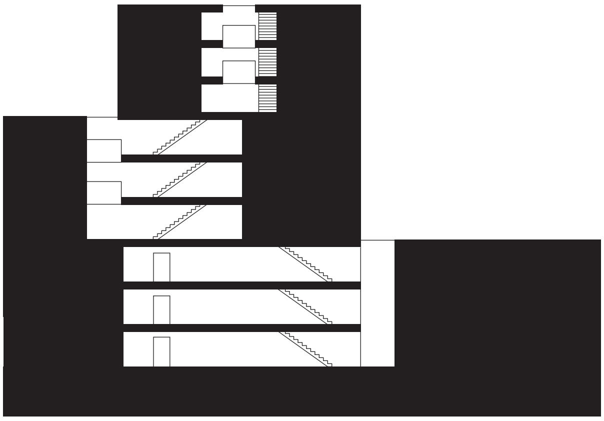

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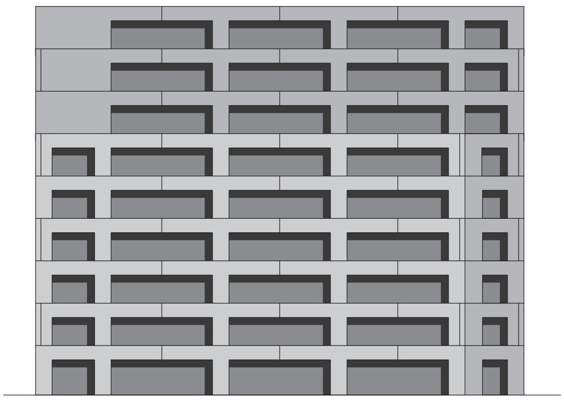

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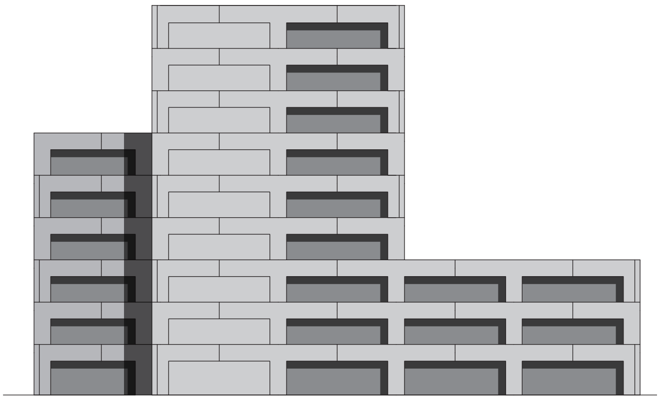

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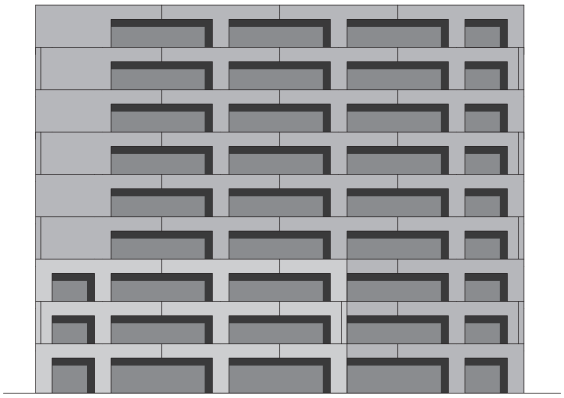

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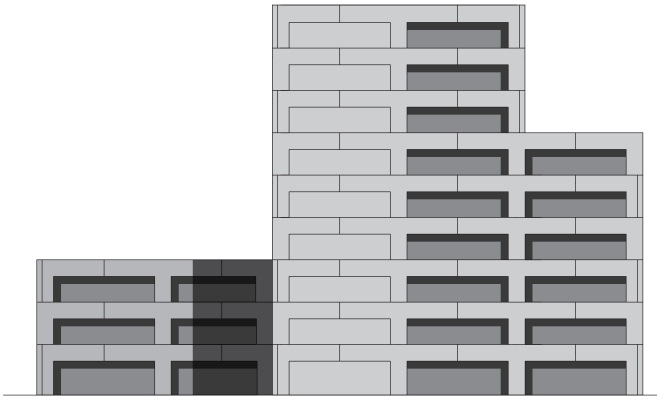

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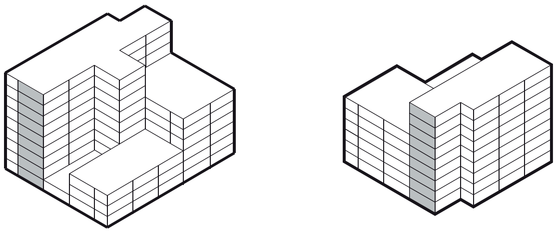

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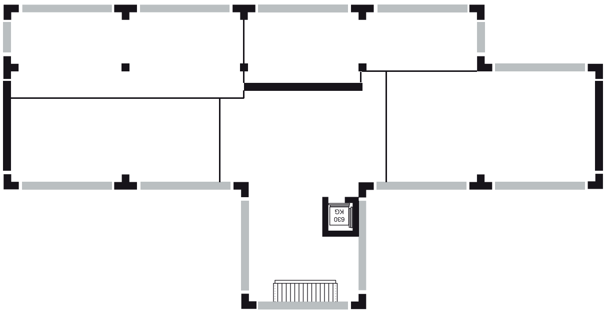

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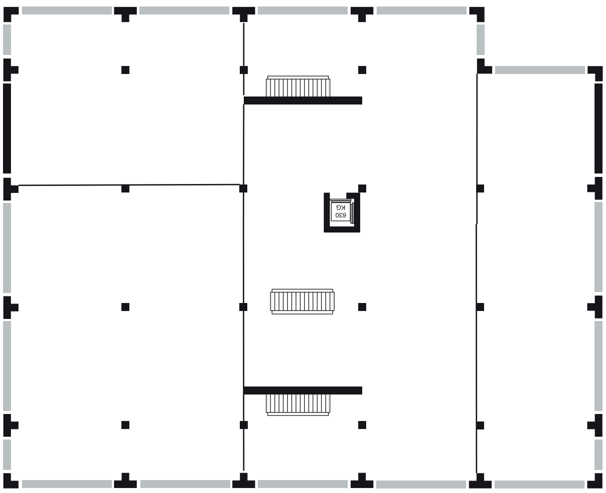

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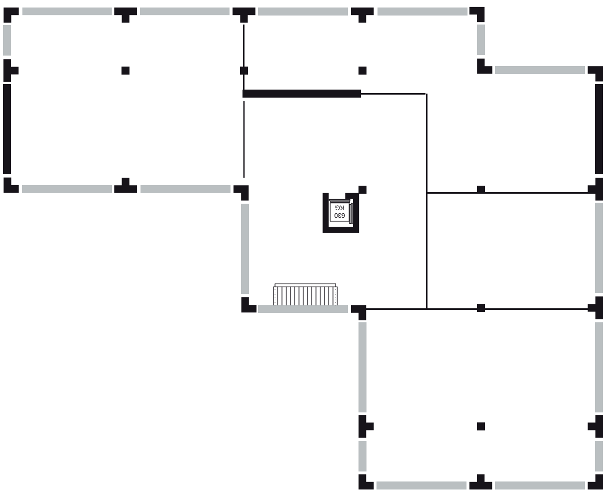

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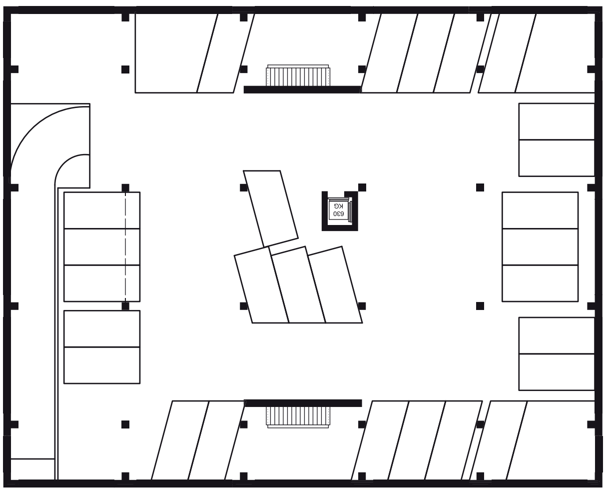

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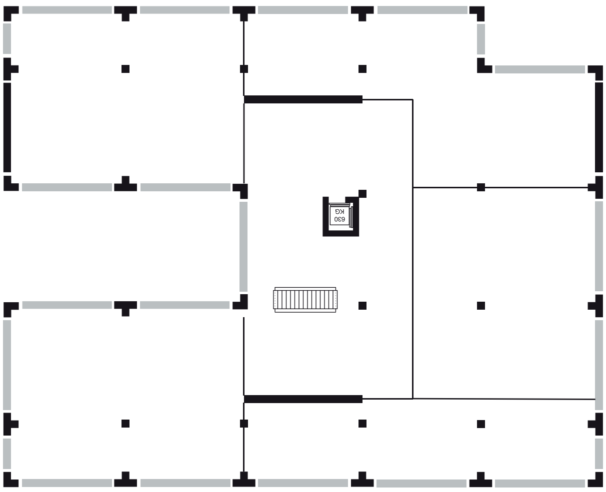

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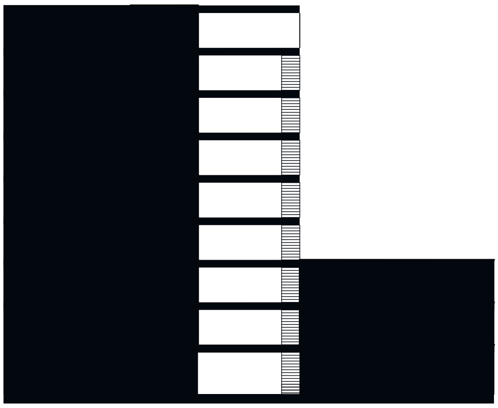

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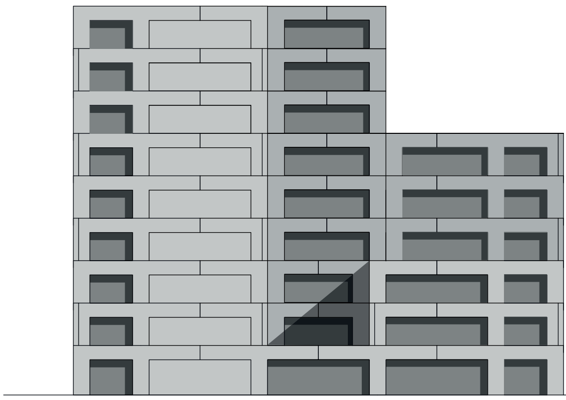

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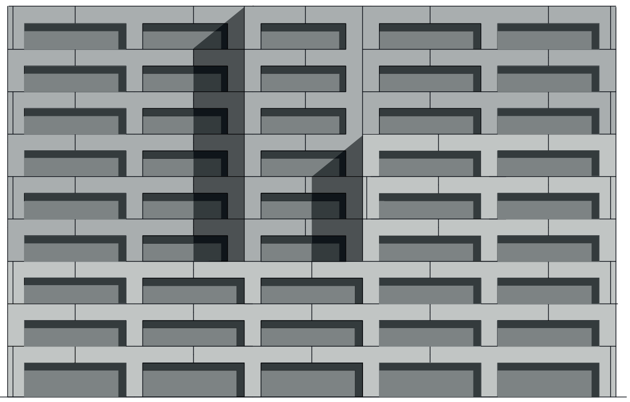

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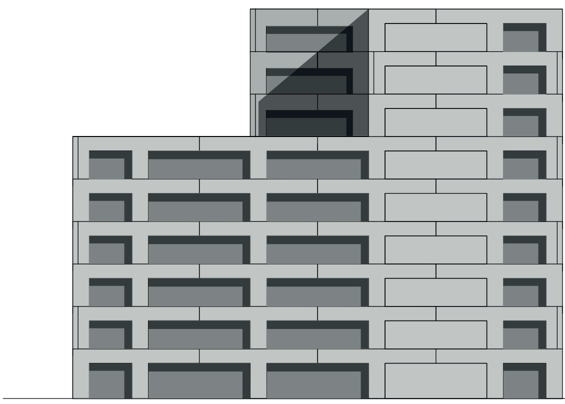

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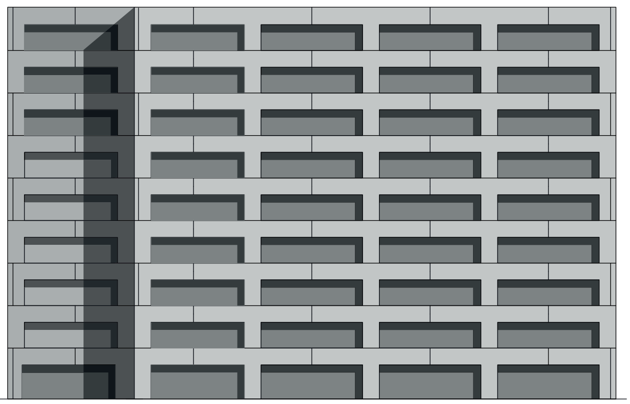

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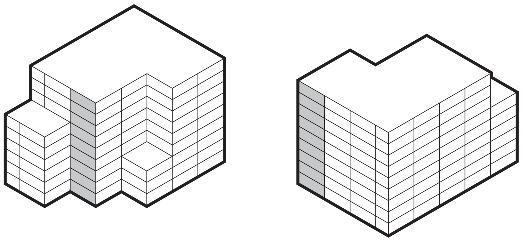

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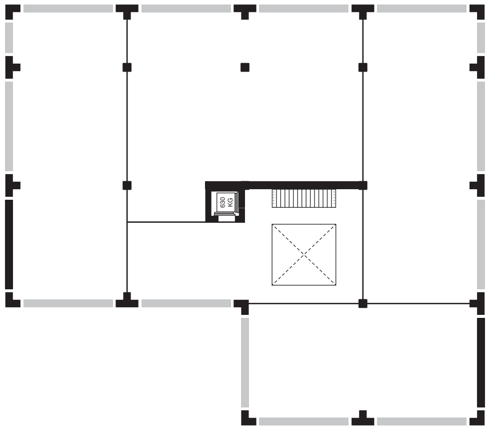

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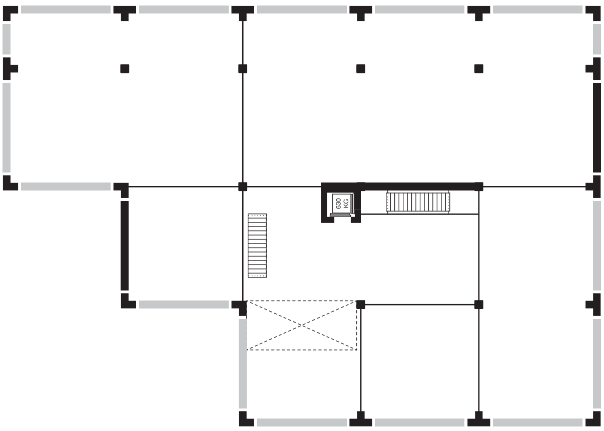

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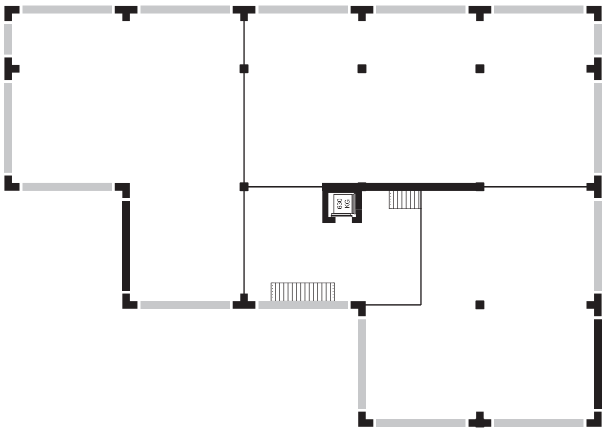

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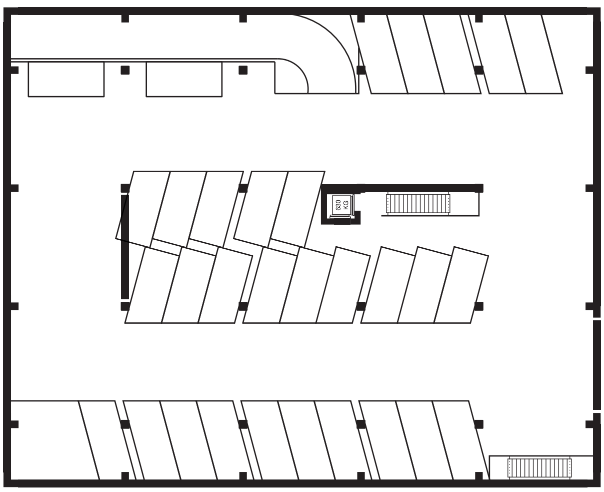

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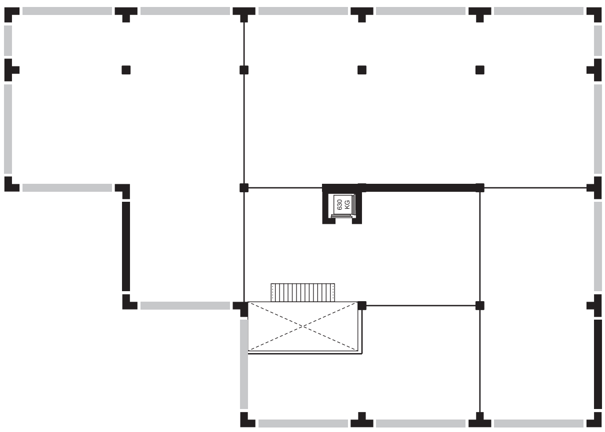

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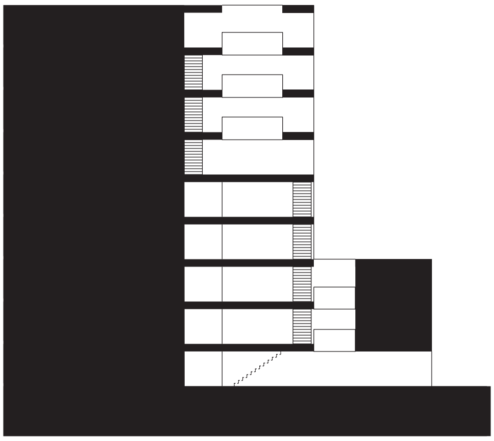

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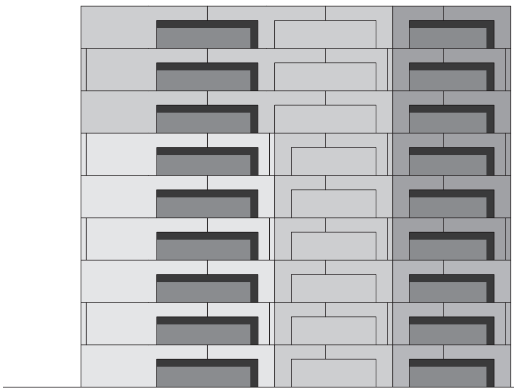

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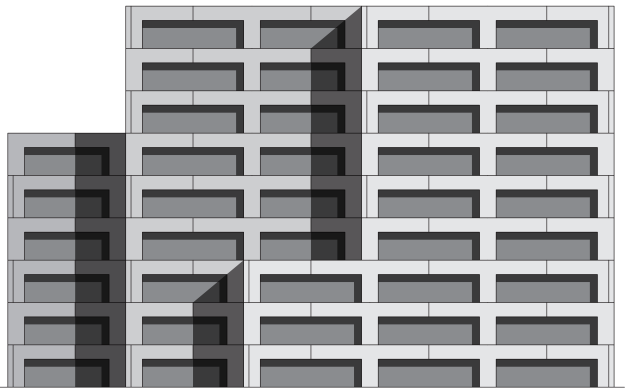

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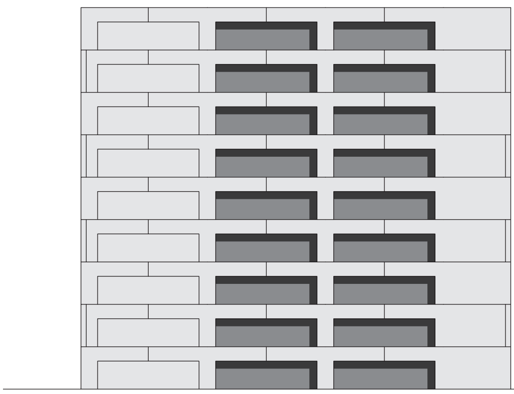

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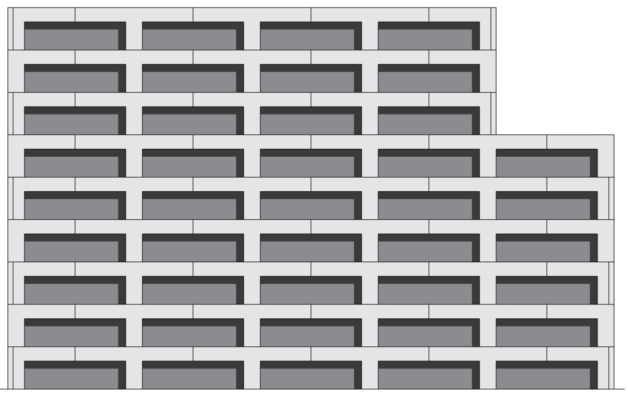

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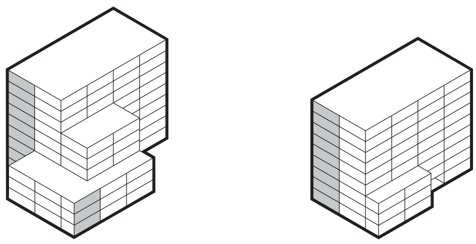

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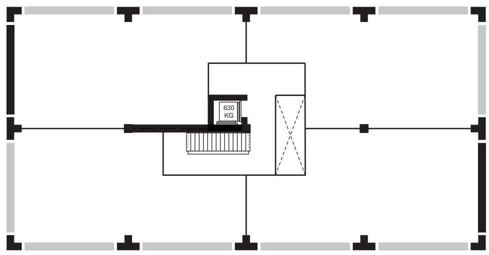


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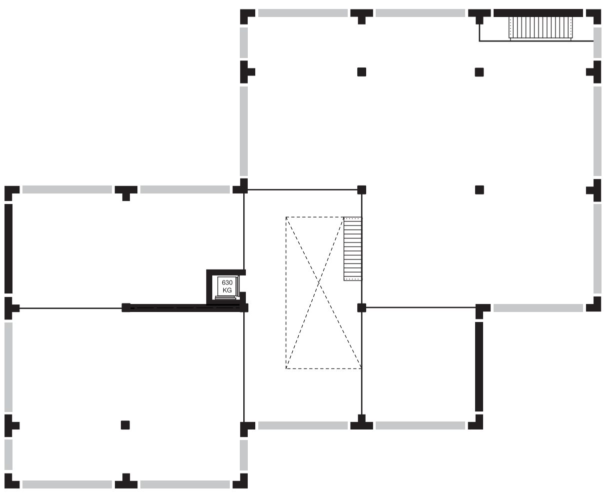


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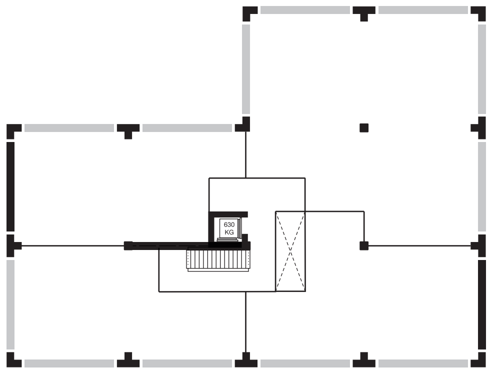


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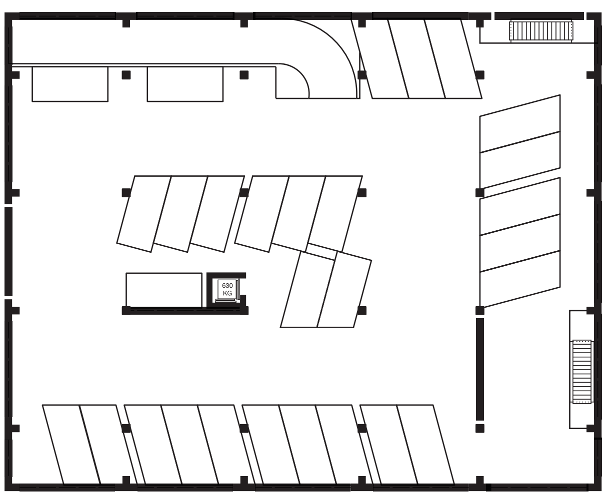


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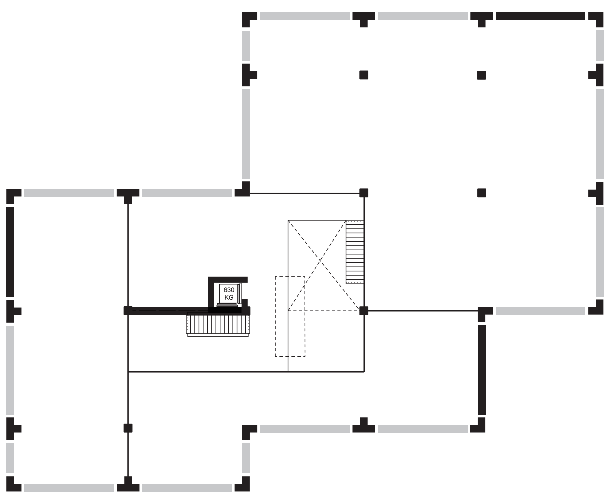


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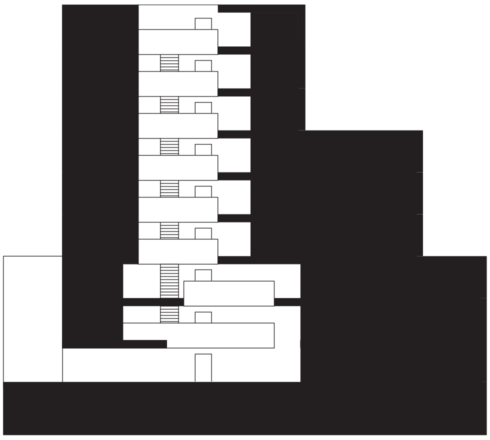

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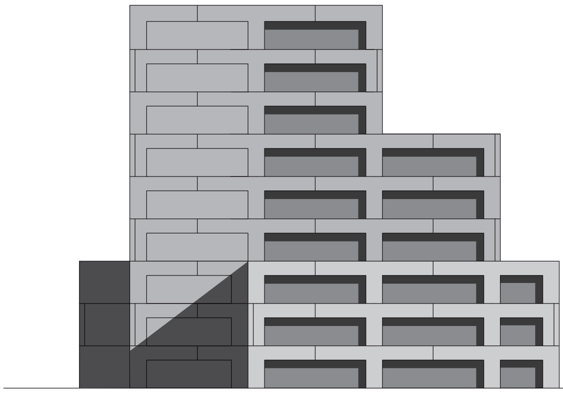

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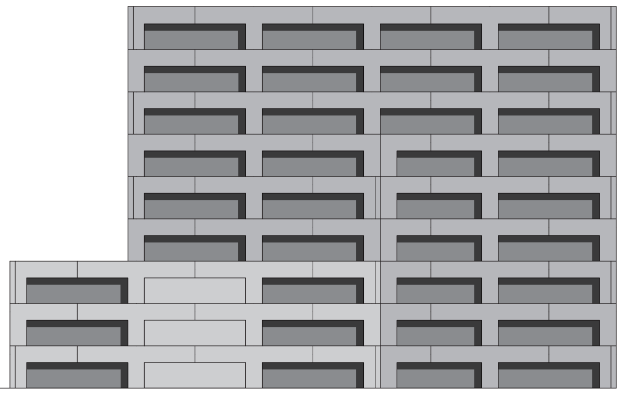

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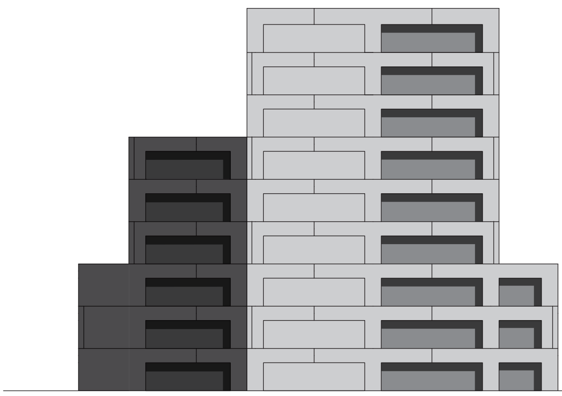

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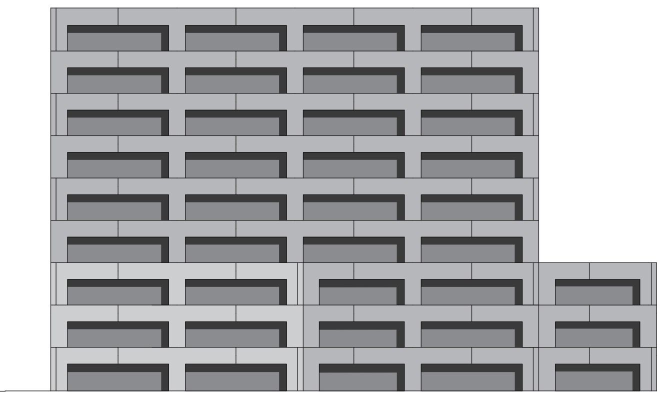

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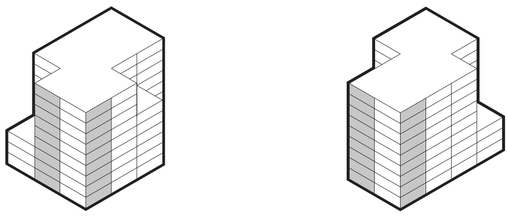

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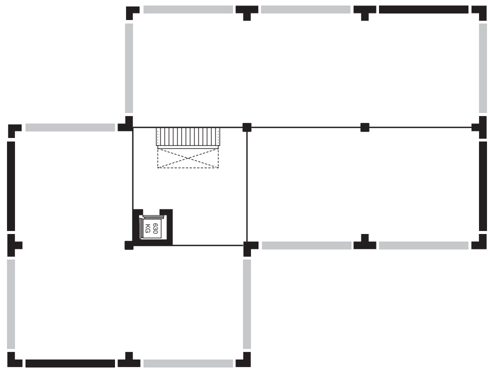

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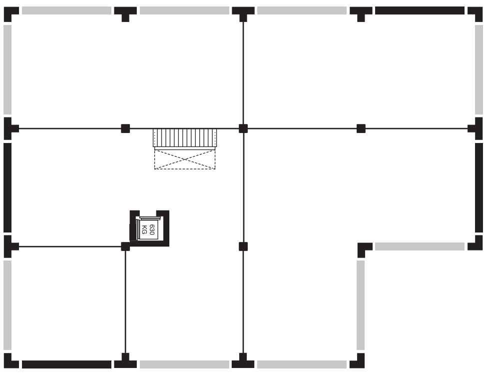

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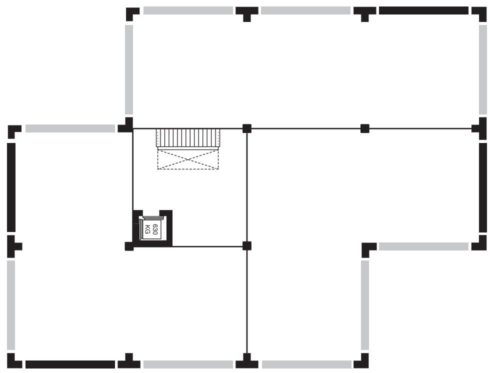

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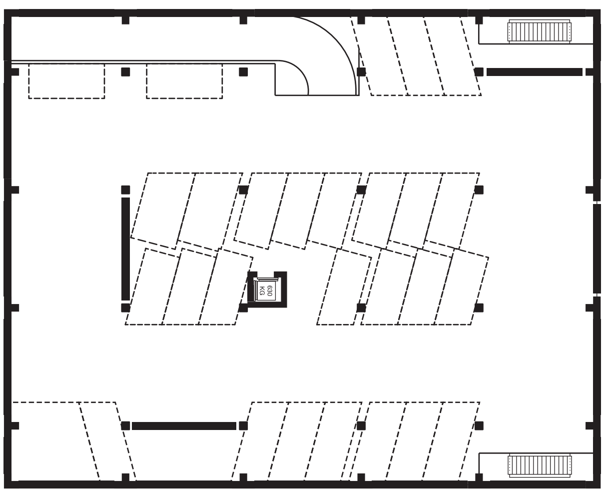

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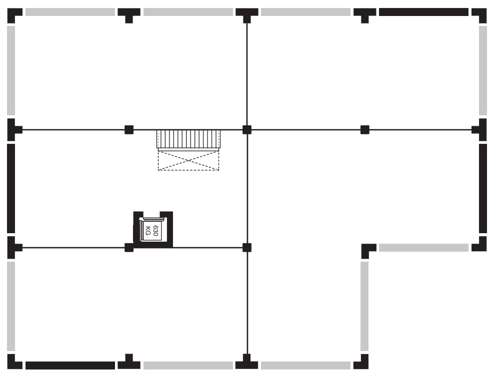

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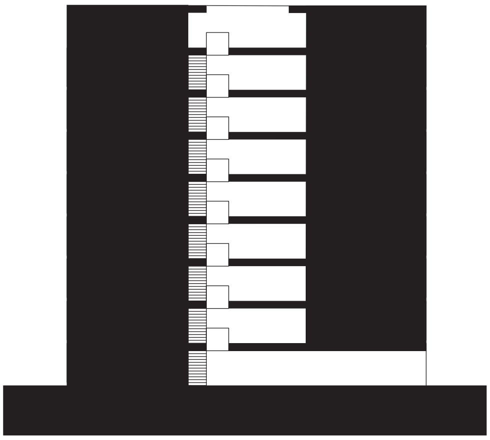

FIGURE INTERNE

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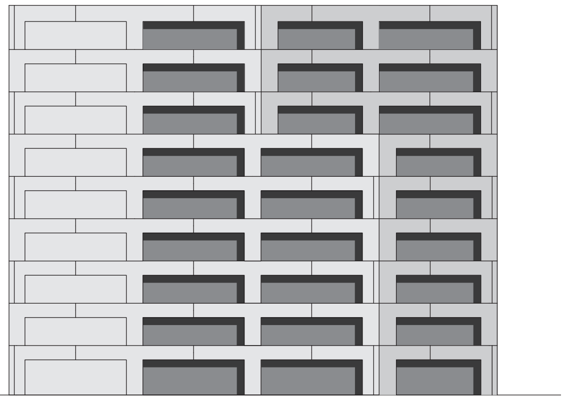

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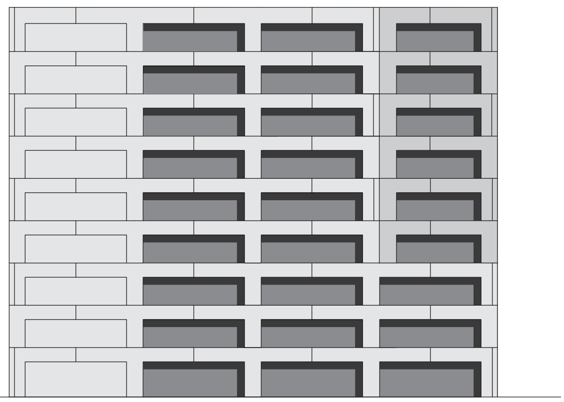

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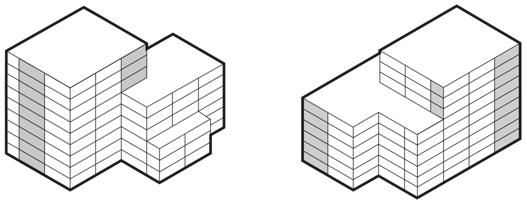

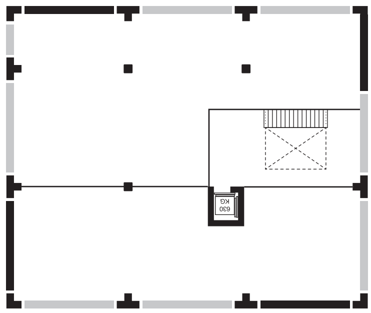

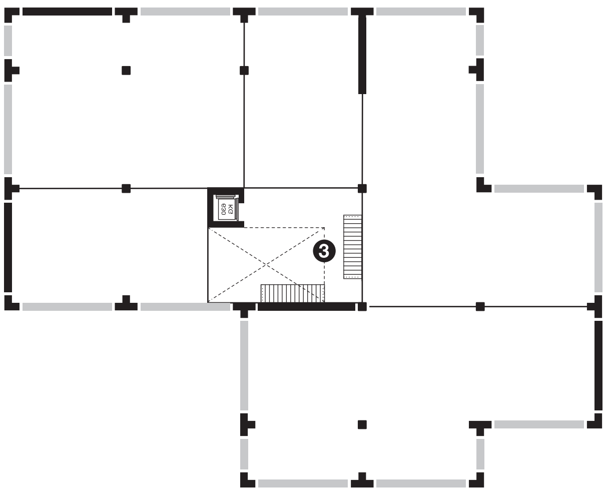


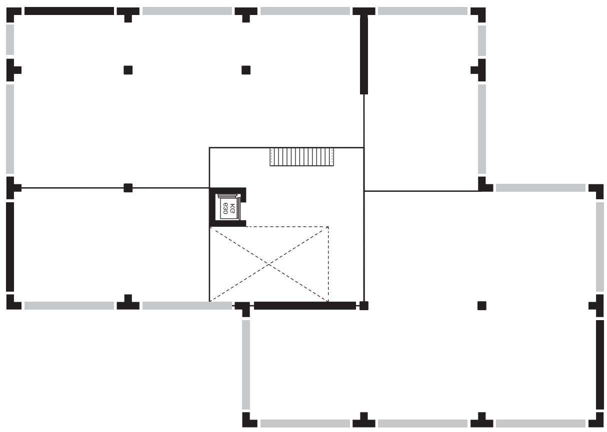

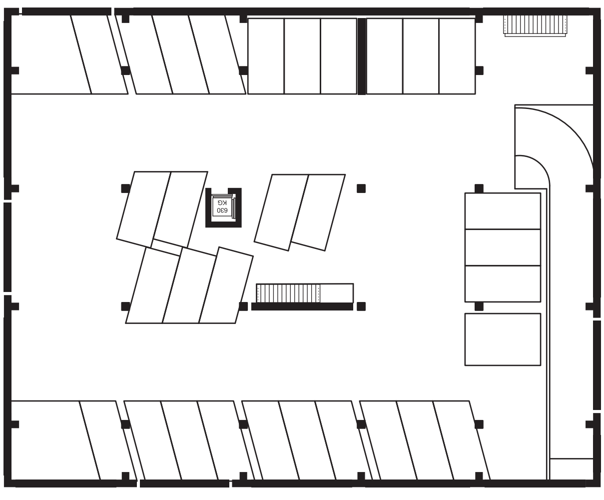

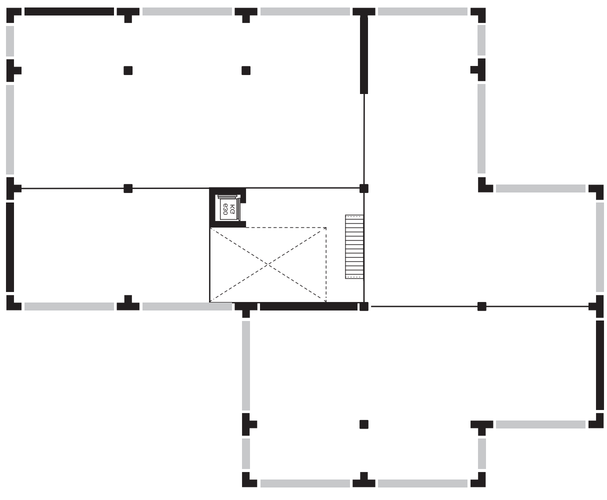

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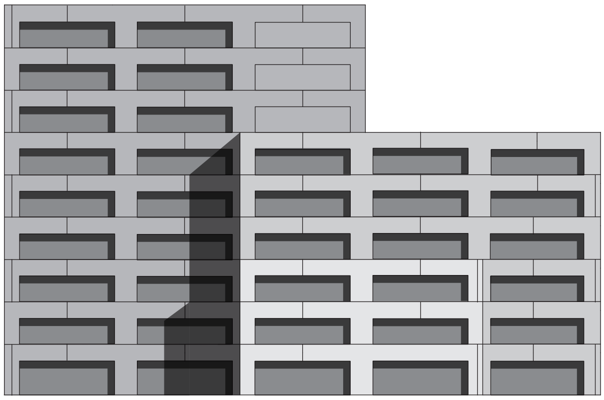

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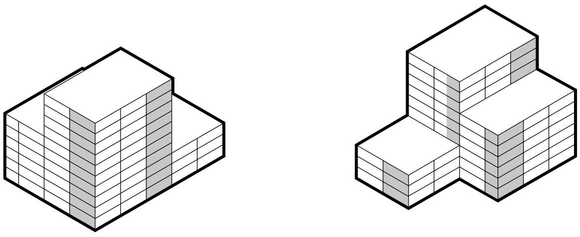

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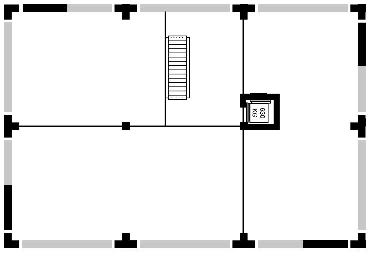

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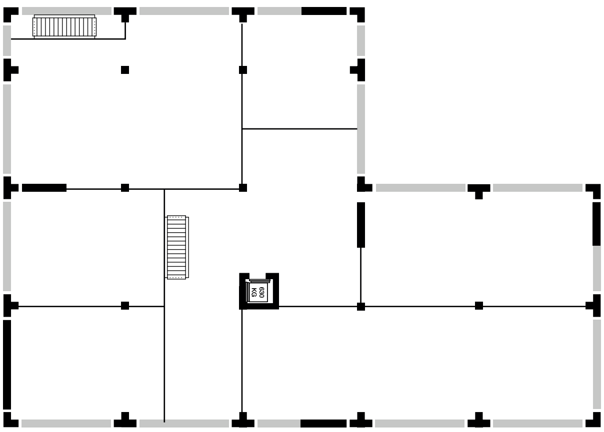

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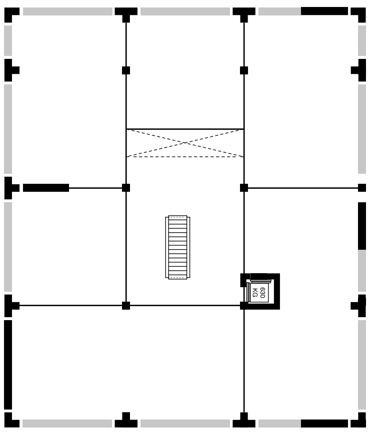

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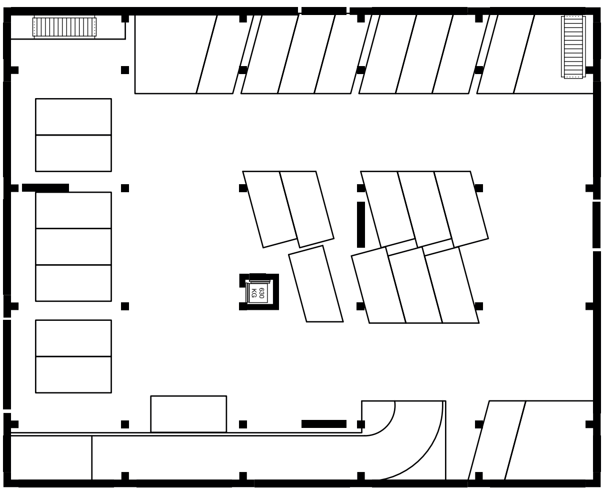

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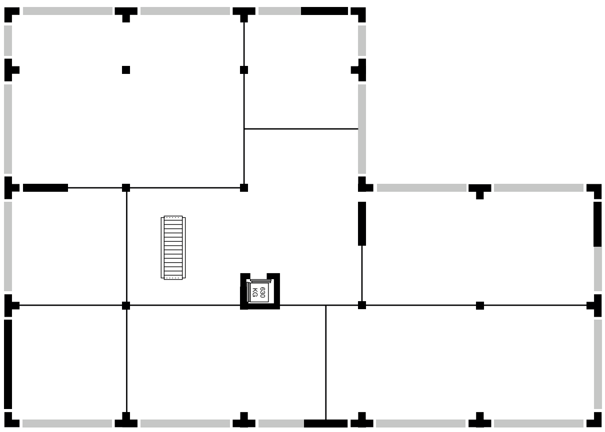

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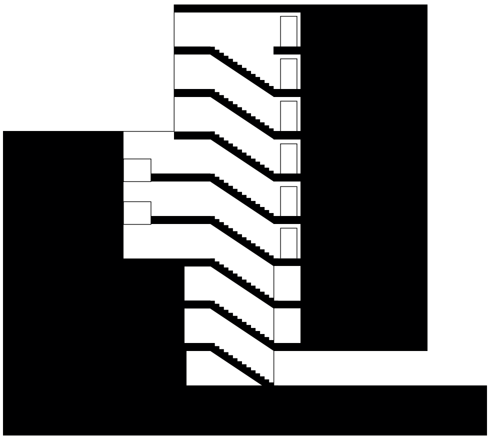

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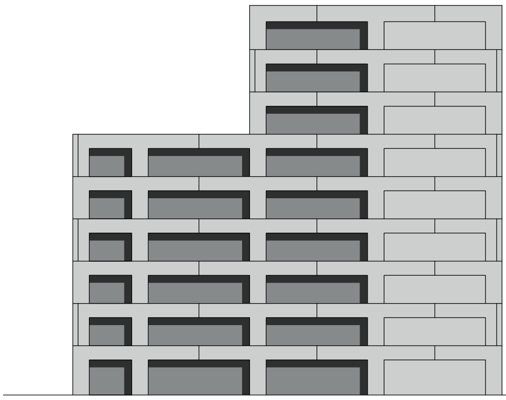

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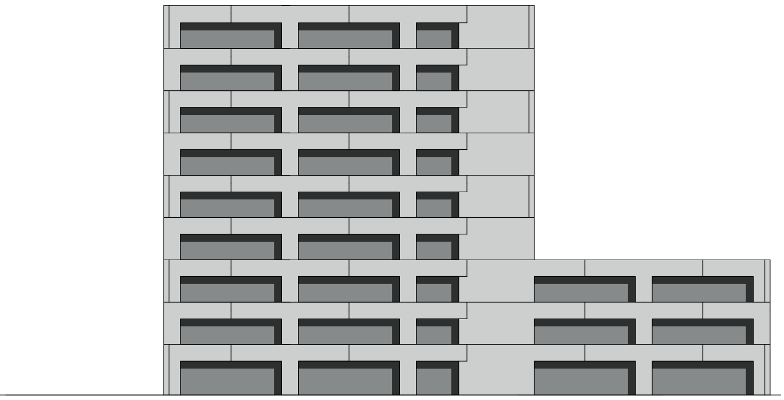

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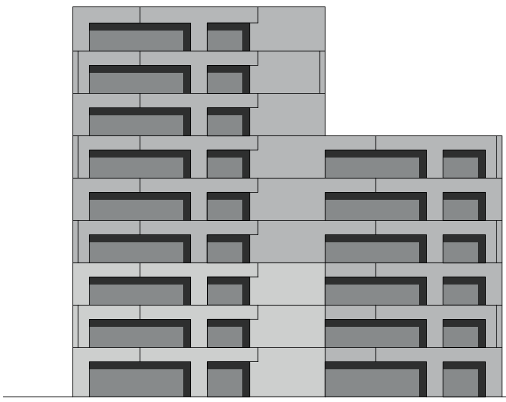

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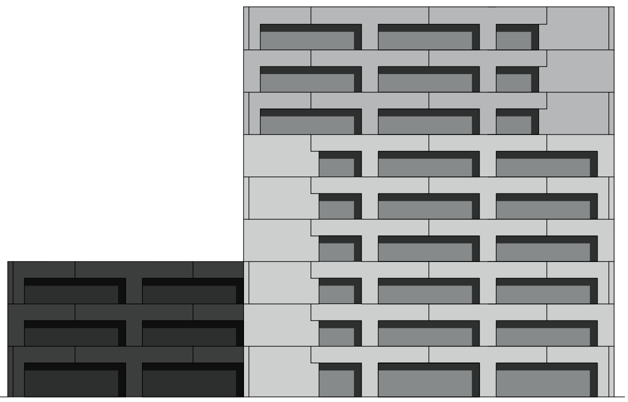

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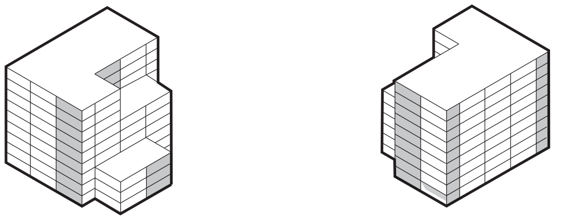

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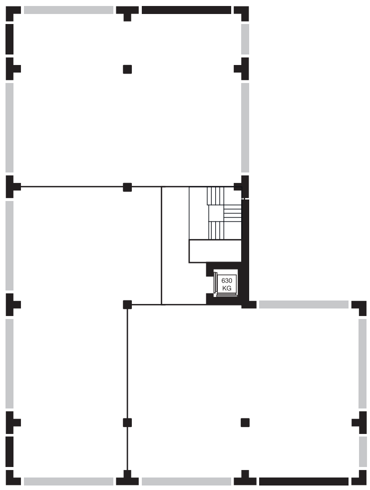


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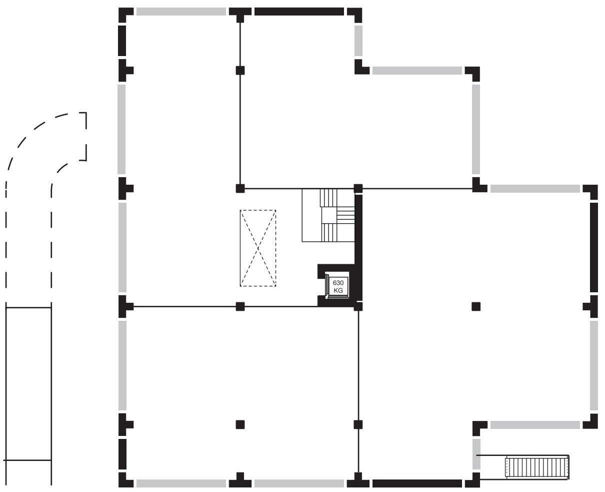


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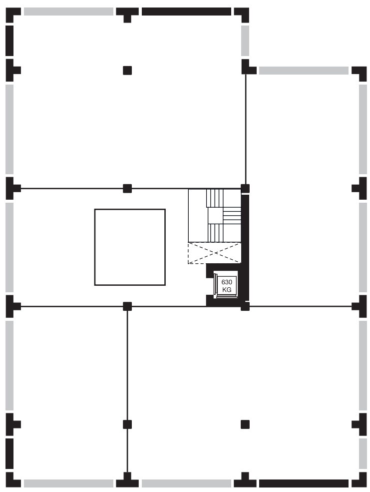


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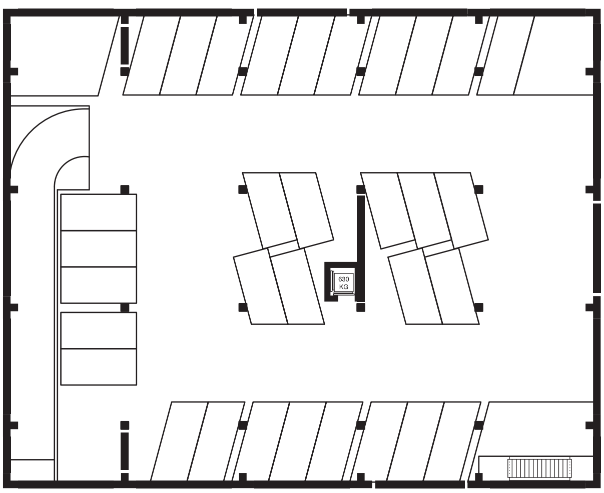


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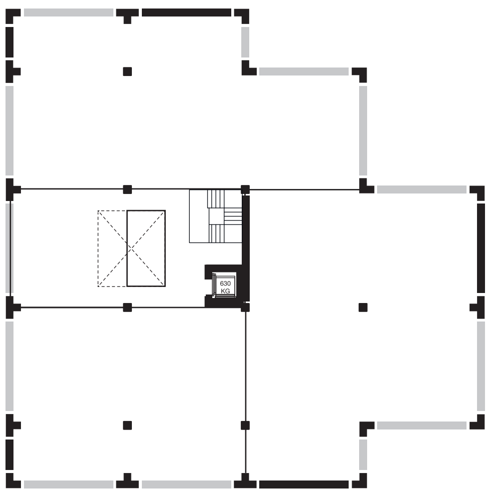
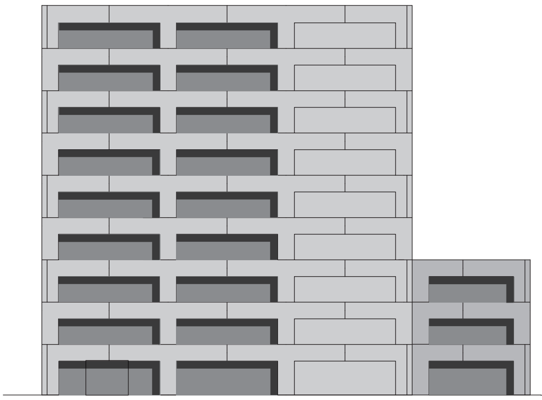



ETAGES 1-2

FIGURE INTERNE



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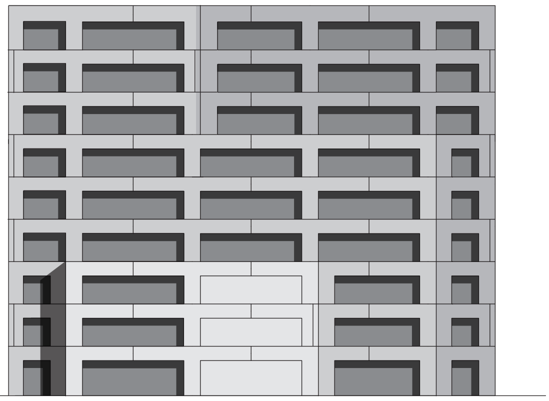

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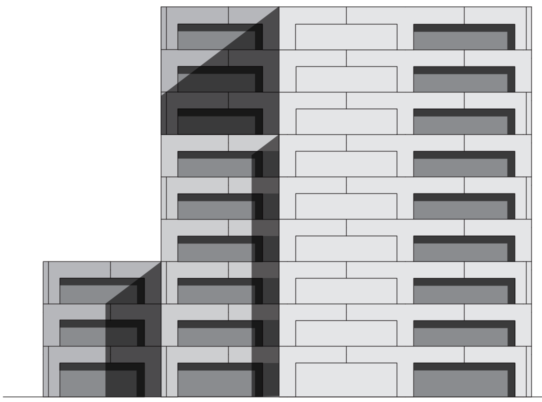

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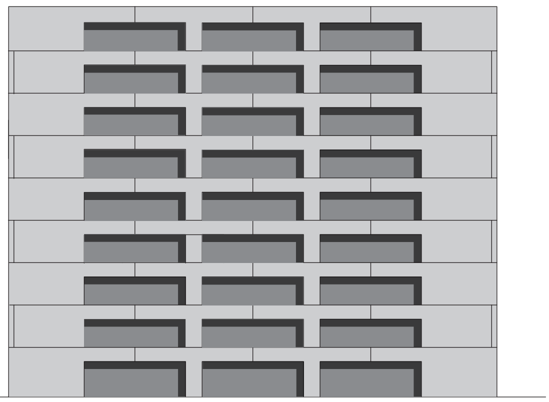

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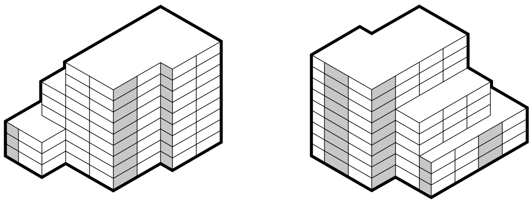

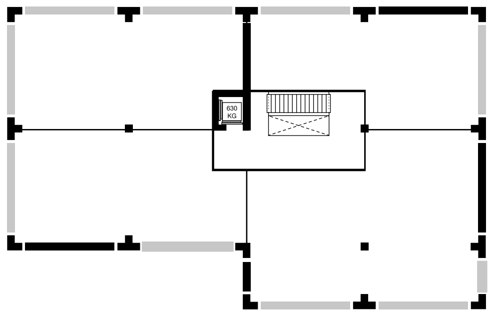


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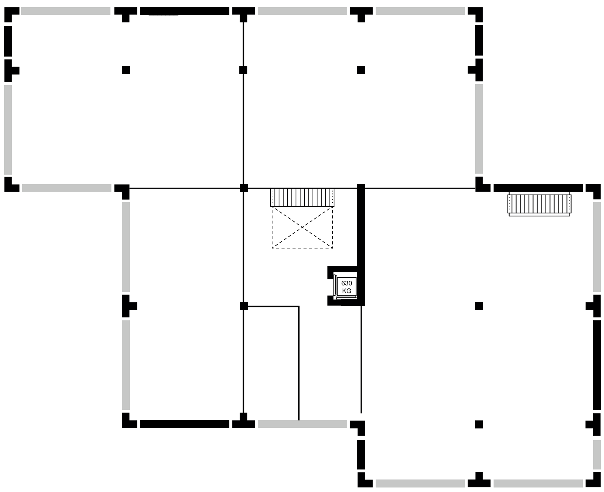


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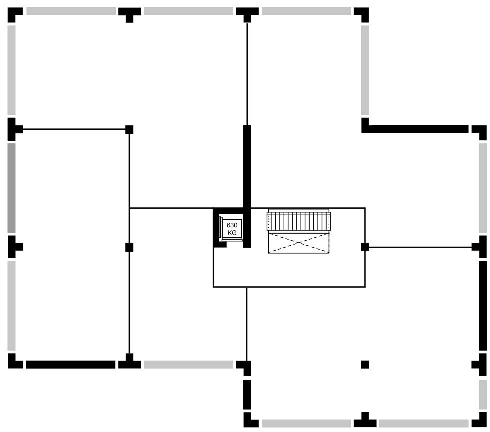


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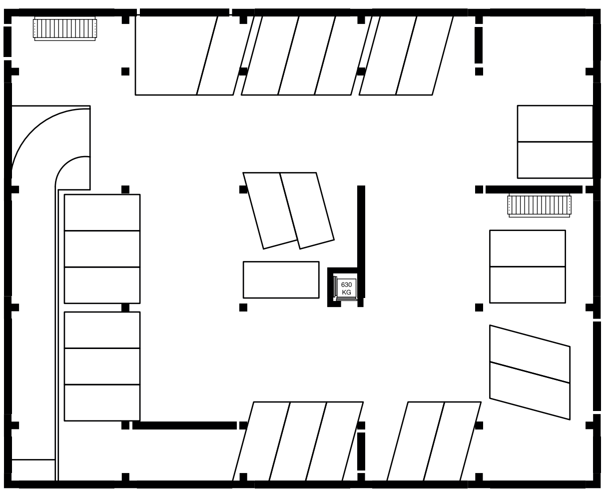


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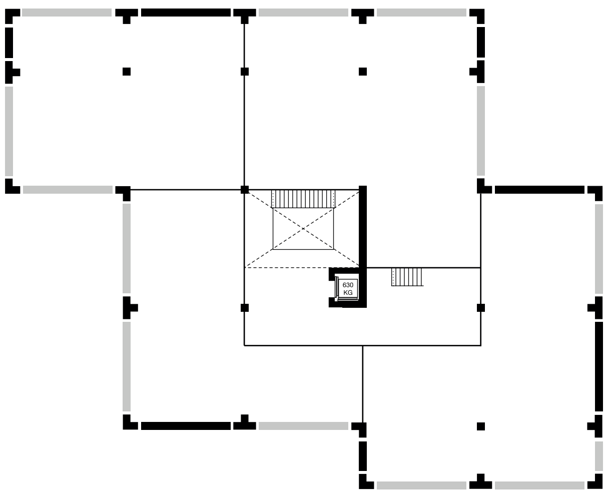


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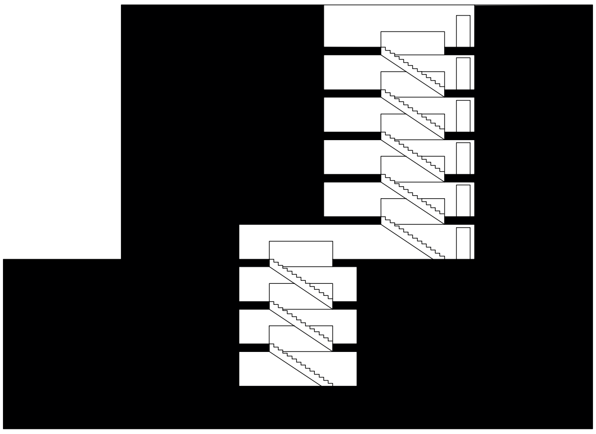

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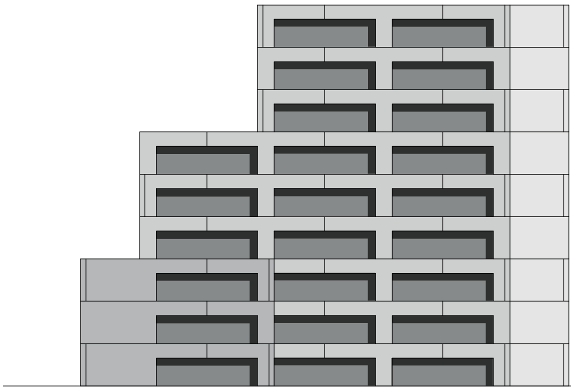

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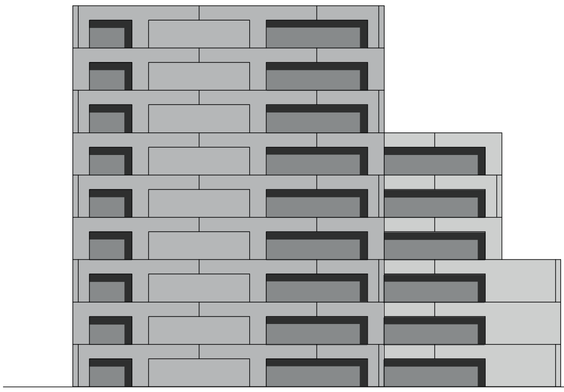

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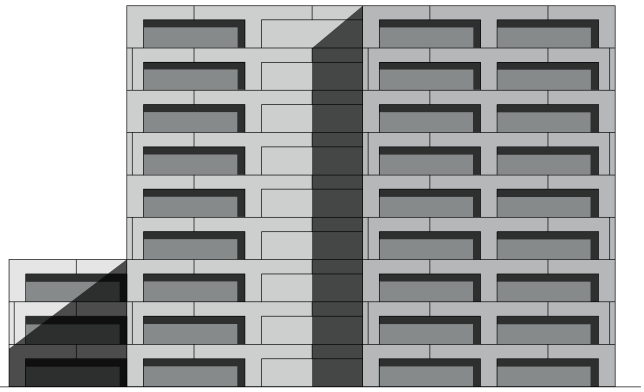

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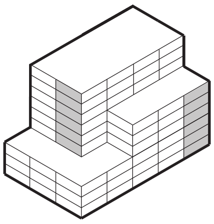

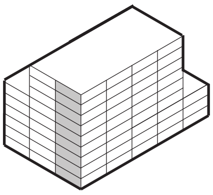

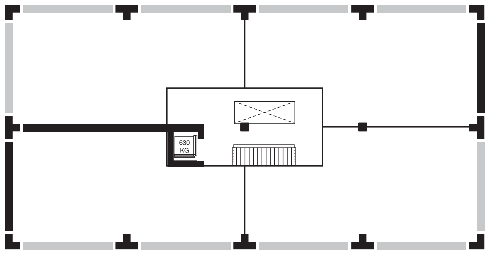


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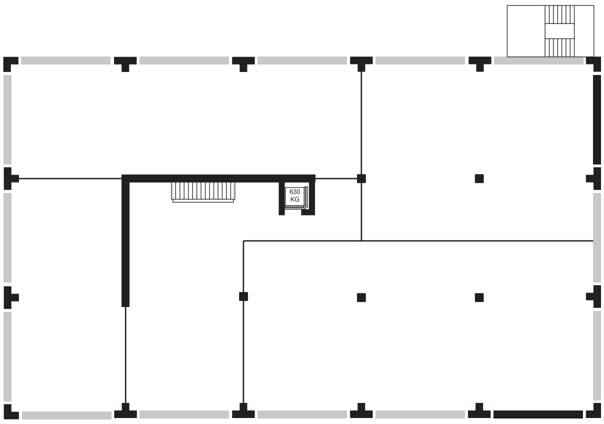


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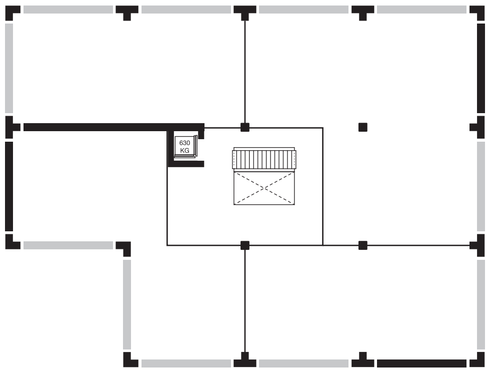


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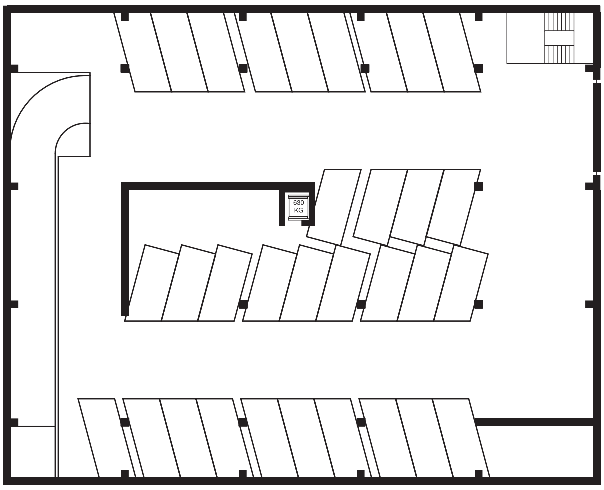


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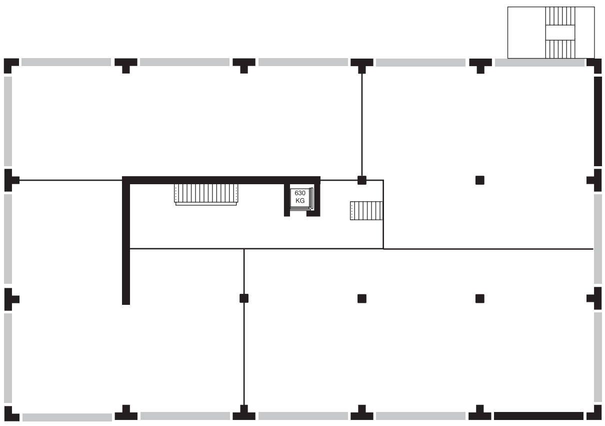

ETAGES 1-2

FIGURE INTERNE

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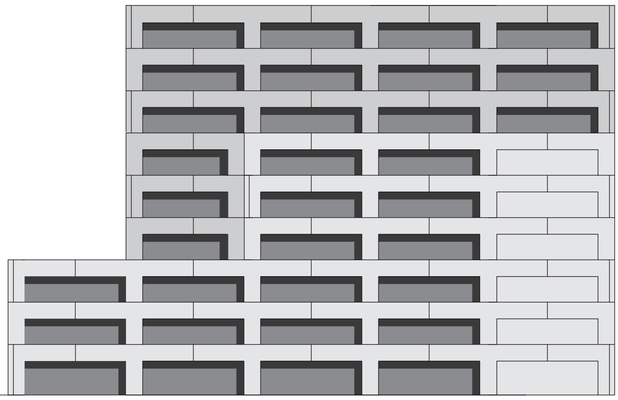

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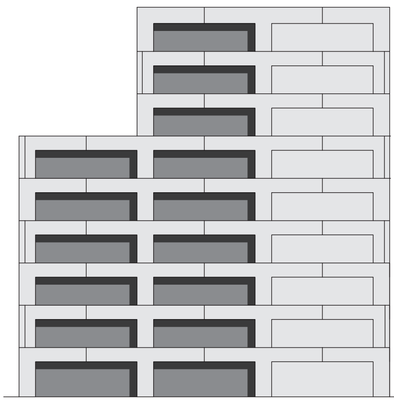

OUEST

SUD

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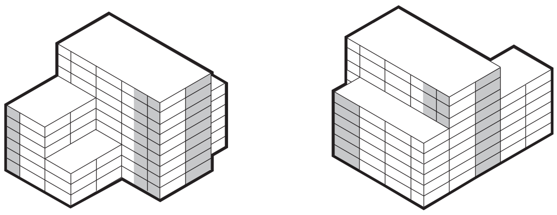

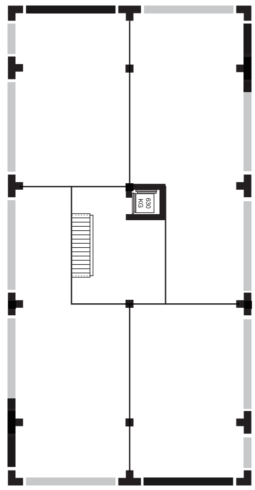

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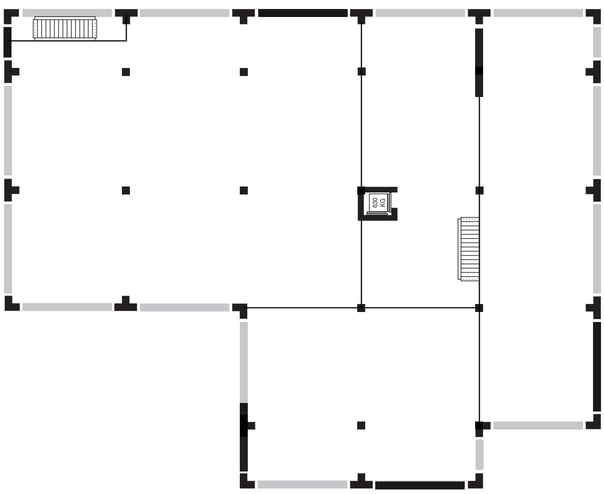

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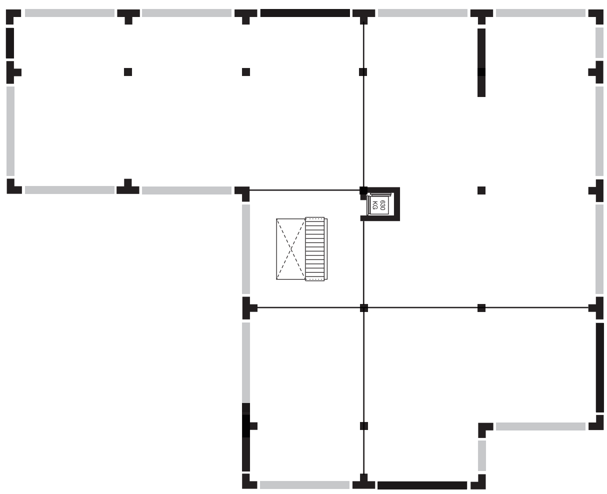
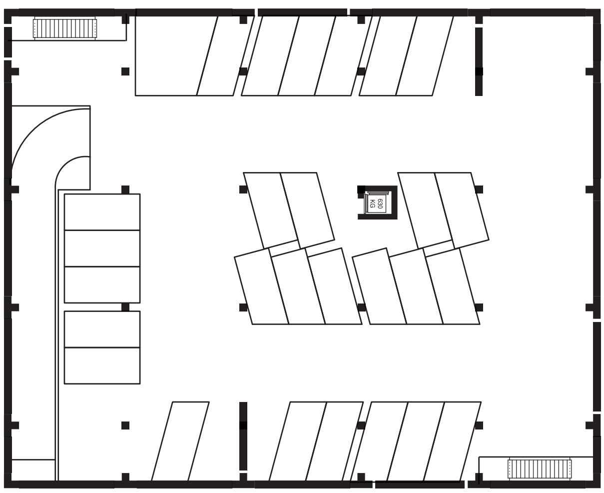


ETAGES 3-5



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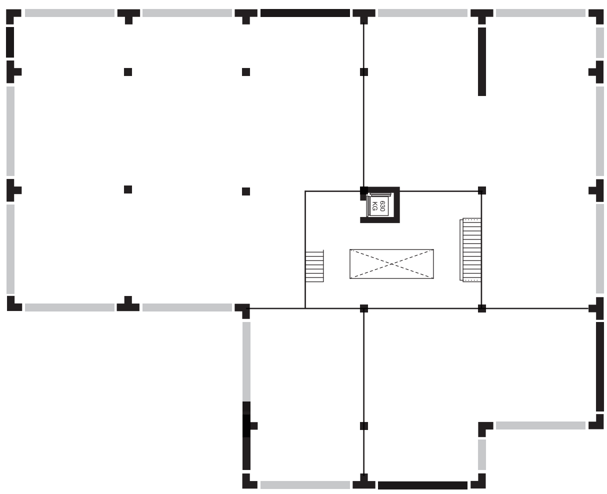

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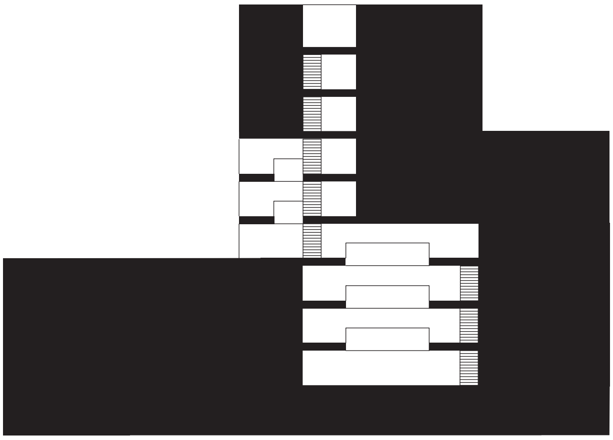
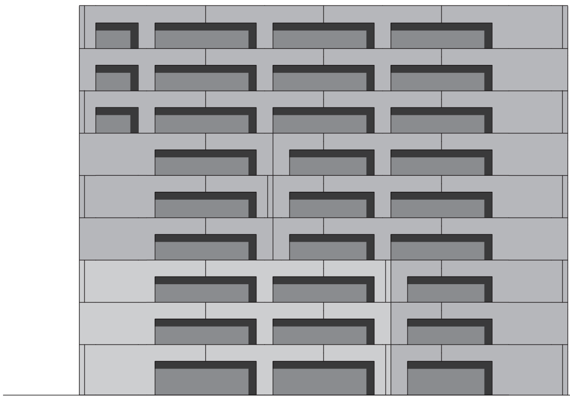


FIGURE INTERNE



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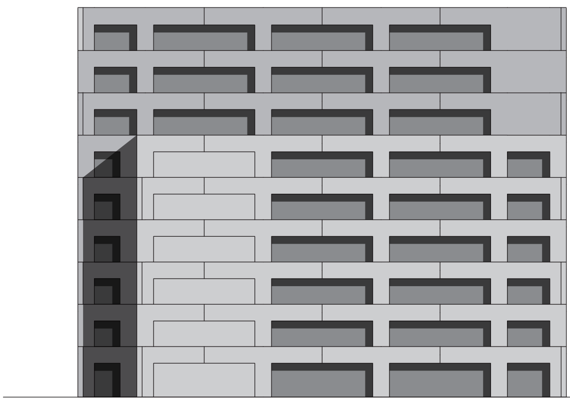
SUD



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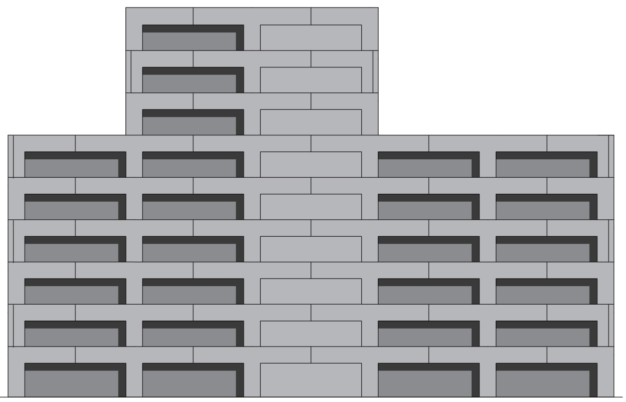
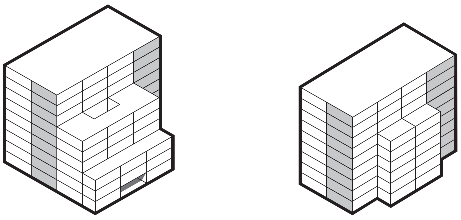


NORD

# DANIEL ZETTERBERG



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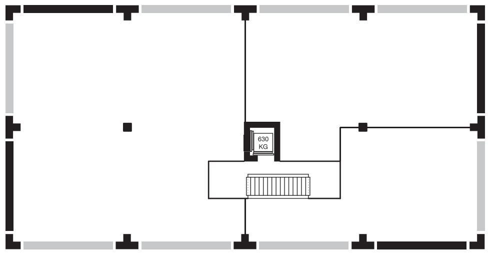


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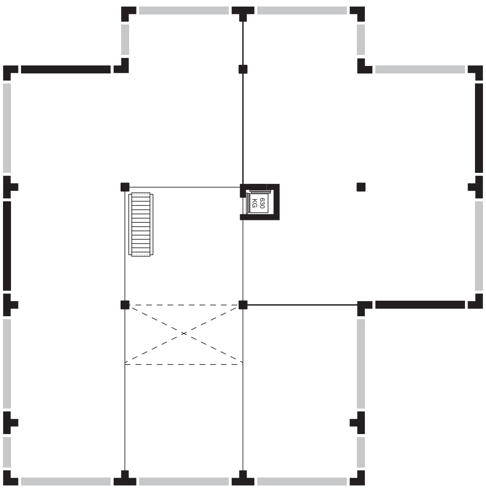

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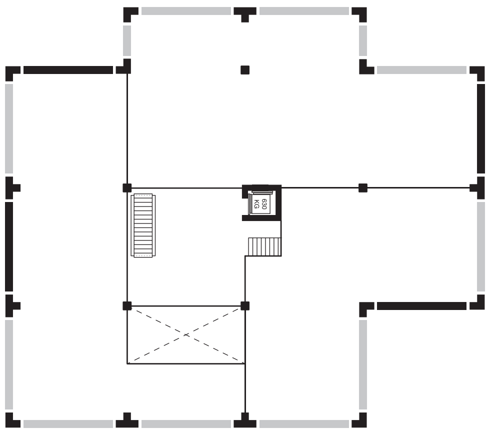

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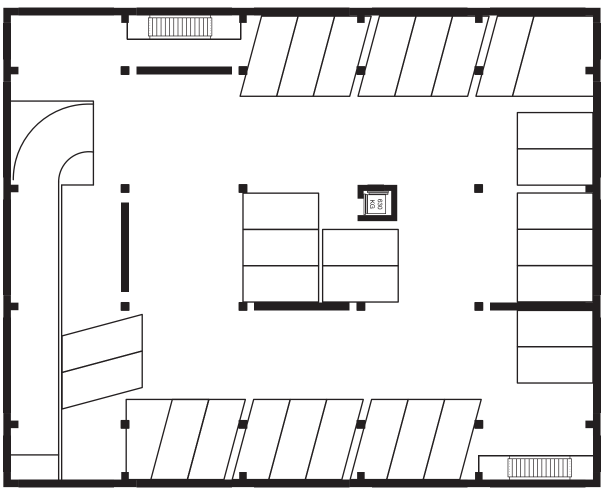
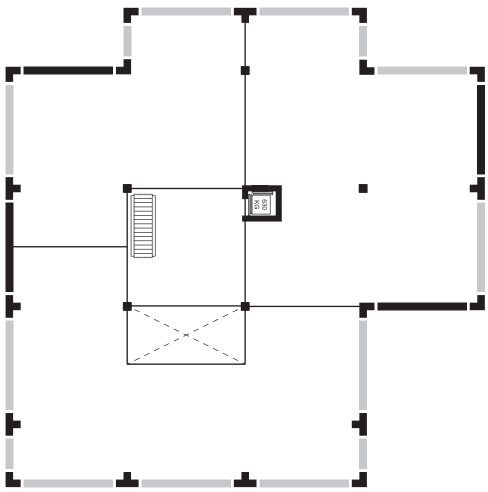


SOUS-SOL



ETAGES 1-2

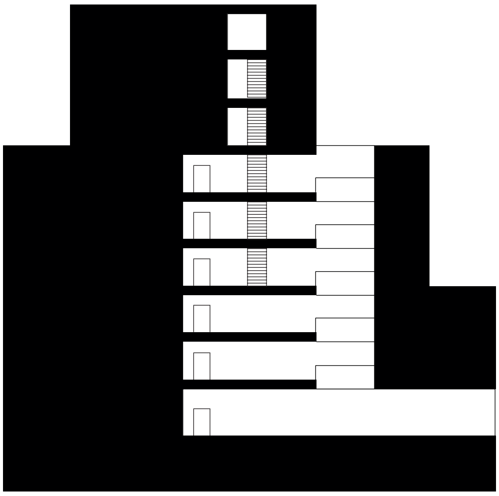
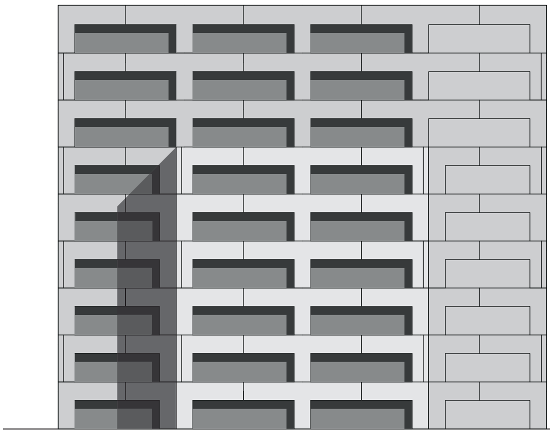


FIGURE INTERNE



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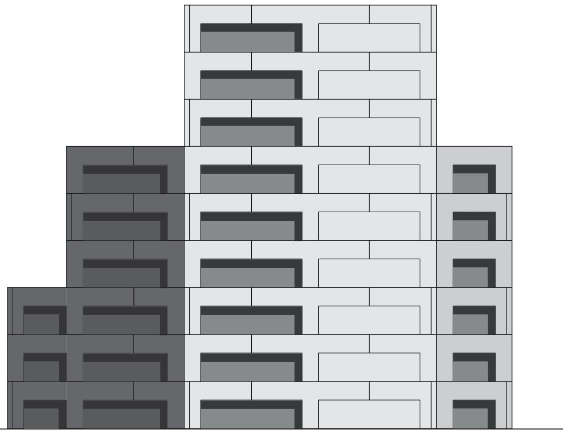

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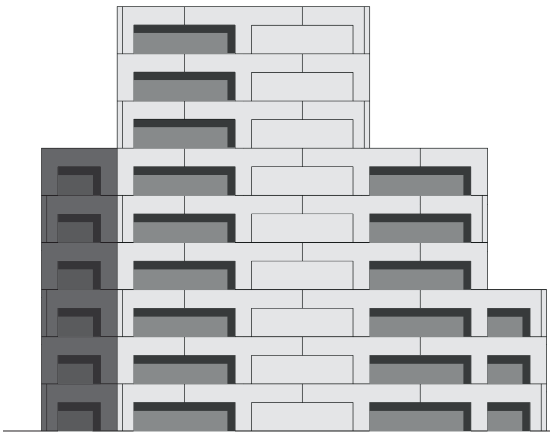

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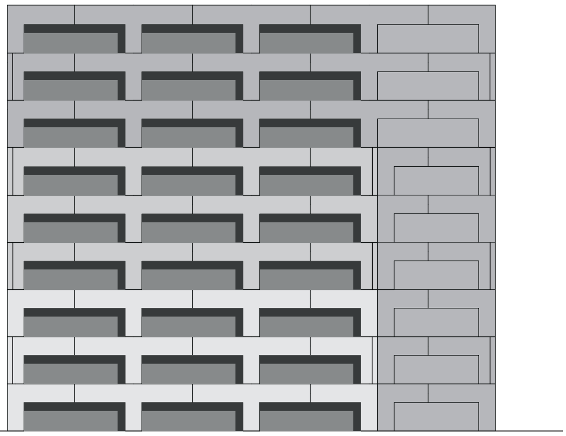

SUD