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EDUCATIONAL BUILDING SUSTAINABILITY: STRATEGIES FOR EXPANDING SCHOOLS IN VIENNA'S URBAN CONTEXT.

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Professor: Arch. Marika Mangosio

Candidate: Italo Paulesu - s304114

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The aim of this thesis work is to illustrate the results of a project inspirated by a design competition held by the University of Vienna in cooperation with the municipality and a group of companies interested in green building, with a focus on the use of timber. The aim of the project was to integrate, expand and augment existing urban educational buildings.

The project involves the expansion of an existing primary school in Knöllgasse to include a new middle school for approximately 400 students. This intervention is designed to create modern educational spaces, adaptable to future changes in teaching and learning methods. In addition to responding to current spatial and didactic needs, the project integrates advanced pedagogical concepts, such as small group learning and afternoon care, with a focus on the study environment and its atmospheric quality, thanks to the use of wood as the main material. The school extension will create 4,500 m² of gross floor area, which will also include multifunctional spaces such as flexible classrooms, a gymnasium, outdoor recreation areas and a library with an open reading area. The project is located in Vienna, in the 10th district, an area characterised by block-edged structures and exemplary buildings such as Harry Glück's terraced house (1974) and Rüdiger Lainer's 'House with verandas' (2008). o. The project strategically locates the new building to the north of the existing school in order to preserve the existing green spaces and trees. The courtyard areas are divided in such a way that school breaks can take place separately for the primary school and the new middle school, favouring an efficient organisation of spaces. A key element of the project is the functional separation between the gymnasium and the school complex, allowing the gymnasium to be used independently during the evenings or weekends without the need for access to the entire school building. This was achieved through a careful layout of the entrances and internal routes, with direct connections on the first floor between the school and the gymnasium. This thesis explores the potential of wood as a building material for the extension and regeneration of established urban centres, focusing on the interaction with existing buildings and the harmonious development of new urban spaces. The aim of the project is to preserve natural resources, improve the existing urban fabric and create liveable and functional spaces, responding to contemporary needs.

Wood, with its ecological and sustainable characteristics, represents an innovative choice to meet the challenges of modern urban design. The project developed provides a concrete example of the design approach used to solve the complex challenges of constructing wooden school buildings. The choice of wood as the protagonist of the project is motivated by several technical and environmental advantages. Wood offers ideal tactile and atmospheric qualities for educational spaces, creating an environment conducive to learning. Furthermore, modern timber construction techniques, characterised by a high degree of prefabrication and standardisation, allow for short construction times, efficient site management and a reduced ecological footprint. The construction details described in the project highlight the use of advanced technologies for timber construction, with a focus on sustainability and efficient energy management. The façades are designed to provide thermal insulation, with the integration of natural ventilation systems and green roofs to improve rainwater management. The structure includes prefabricated wooden elements, which ensure durability and reduce construction time. In addition, the building has strategically placed escape routes to ensure the safety of the occupants, with external emergency stairs and short, easily accessible evacuation routes. In summary, this project represents an advanced example of how timber architecture can be used not only to create functional and sustainable school buildings, but also to contribute to context-sensitive urban regeneration and the surrounding environment. The detailed planning of architectural volumes, the efficient management of green spaces and the integration of innovative building technologies make this project a round proposal of sustainable urban development.

1 TARGET IDENTIFICATION

1.1 PROJECT DEFINITION

The city of Vienna is facing the challenge of coping with high growth and increasing population numbers. The need for new infrastructure and public facilities is increasing, especially in high-density residential neighborhoods.

The framework area is located in Vienna's 10th district south of Matzleinsdorfer Platz and borders the Favoriten Clinic area to the west. With few exceptions, such as Harry Glück's terraced house built in 1974 or Rüdiger Lainer's "House with verandas" built in 2008, the "Grätzel" is strongly characterized by block-edged structures.

At the school site on Knöllgasse in 1100 Vienna, 430 children are currently being educated in 19 classes in an open elementary school (OVS). The purpose of the design of this site is to expand the area to include a new middle school for about 400 students. Particular attention is paid to taking into account contemporary pedagogical concepts and changing needs of use such as: B. afternoon care or small group learning.

Wood, with its tactile, atmospheric and olfactory qualities, is ideal as a material for creating school buildings with a good learning atmosphere and transforming the school into a space for exploration and experience. But there are also other advantages of modern wood buildings that must be expertly exploited, such as the high degree of standardization and prefabrication down to the space module, short construction time, low weight, small footprint, and dry site management with just-in-time delivery and assembly.

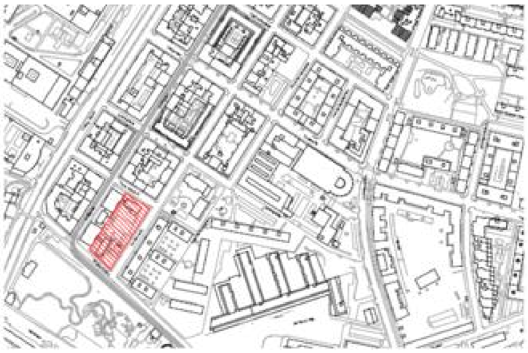

Figure 1 - Planimetry 1:5000

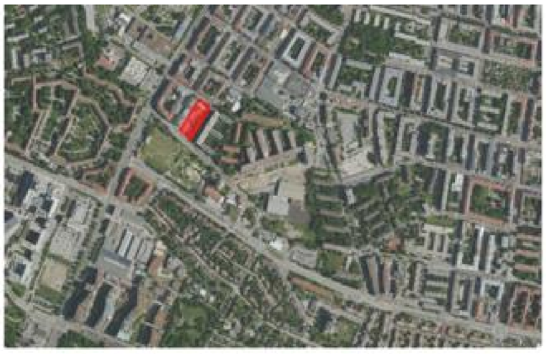

Figure 2 - Aereal picture 1:10000

1.2 PROJECT REQUESTS

When carrying out the design work, the following points in particular must be taken into account:

- The newly created volume should provide at least 3,300 m2 usable space (4,500 m2 GFA) in addition to the existing school building. The modern spatial and teaching requirements of a contemporary school building should be taken into account.
- The new building must be spatially connected to the existing building in the sense of flexible, future-oriented planning. This ensures spatial flexibility when conditions change. In this regard, the connection heights of the existing stairs can be found in the attached inventory plans.
- The approximate functional structure of the project can be found in the functional organisation chart. The main classrooms should be oriented around the common quarters, also called 'mufus'.
- In addition, for the existing primary schools and the new middle school, a standard gymnasium, a refectory with adequate common and break areas as well as delimited exercise and outdoor spaces are planned.
- The additional provision of optional free lessons is encouraged, as well as a library with an open reading area or a multi-purpose hall for events or musical performances.
- Care should be taken to include economically and functionally sensible access areas in the planning.

1.3 SITE CONSTRAINS

At its meeting on 22 May 2013, Pr. Zl. 1251/2013-GSK, the municipal council adopted the passed the following resolution:

In the determination of the zoning plan and the development plan for the area shown in the application plan no. 8054 with the red dotted line between **Knöllgasse, Franz-Schuhgasse and Knöllgasse, Franz-Schuh-Gasse, Zur Spinnerin and Windtenstraße in the 10th district, Cat. G. Inzersdorf Stadt**,

the provisions set out in paragraphs I and II are hereby adopted pursuant to § 1 of the Vienna Building Code (BO)are adopted:

I.

The previous zoning plans and development plans, insofar as they are located within the area covered by this plan, shall lose their legal force.

II.

1. provisions of the plan the red plan symbols are deemed to be newly established. For the legal significance of the plan symbols, please refer to the enclosed ‘Explanation of symbols for the zoning plan and the development plan’ (§§ 4 and 5 of the BO for Vienna) dated 1 September 2007. September 2007, which forms an integral part of this resolution.

2. provisions for the design of the cross-sections of traffic areas:
For the design of traffic areas with a total width of 11.0 metres or more, insofar as they are located within the planning area:
Pavements at least 2.0 m wide must be constructed along the alignment lines.

3. provisions without designation of the area of application with the planning symbol BB:

3.1 The highest points of the roofs may not exceed the specified building height by more than by a maximum of 4.5 metres.

3.2 Base areas that are not built on but can be built on are, unless they are paved not required for use as a sports area or playground area, must be landscaped.

4. provisions with designation of the area of application with the planning symbol BB:

4.1 For the areas labelled BB1, the following provisions apply:

The interruption of the closed construction method is permitted.

4.2 For the areas labelled BB2, the following is stipulated:

The buildings may only be used for educational and childcare facilities and for social facilities.

4.3 The following is stipulated for the areas designated BB3:

Roof areas up to an inclination of 5° are to be used for new buildings and extensions with a floor area of 200 m² of floor area or more. The fastening of the surface of the roofs for use as accessible terraces up to an extent of

50 per cent of the roof area as well as the construction of technical and lighting structures is permitted.

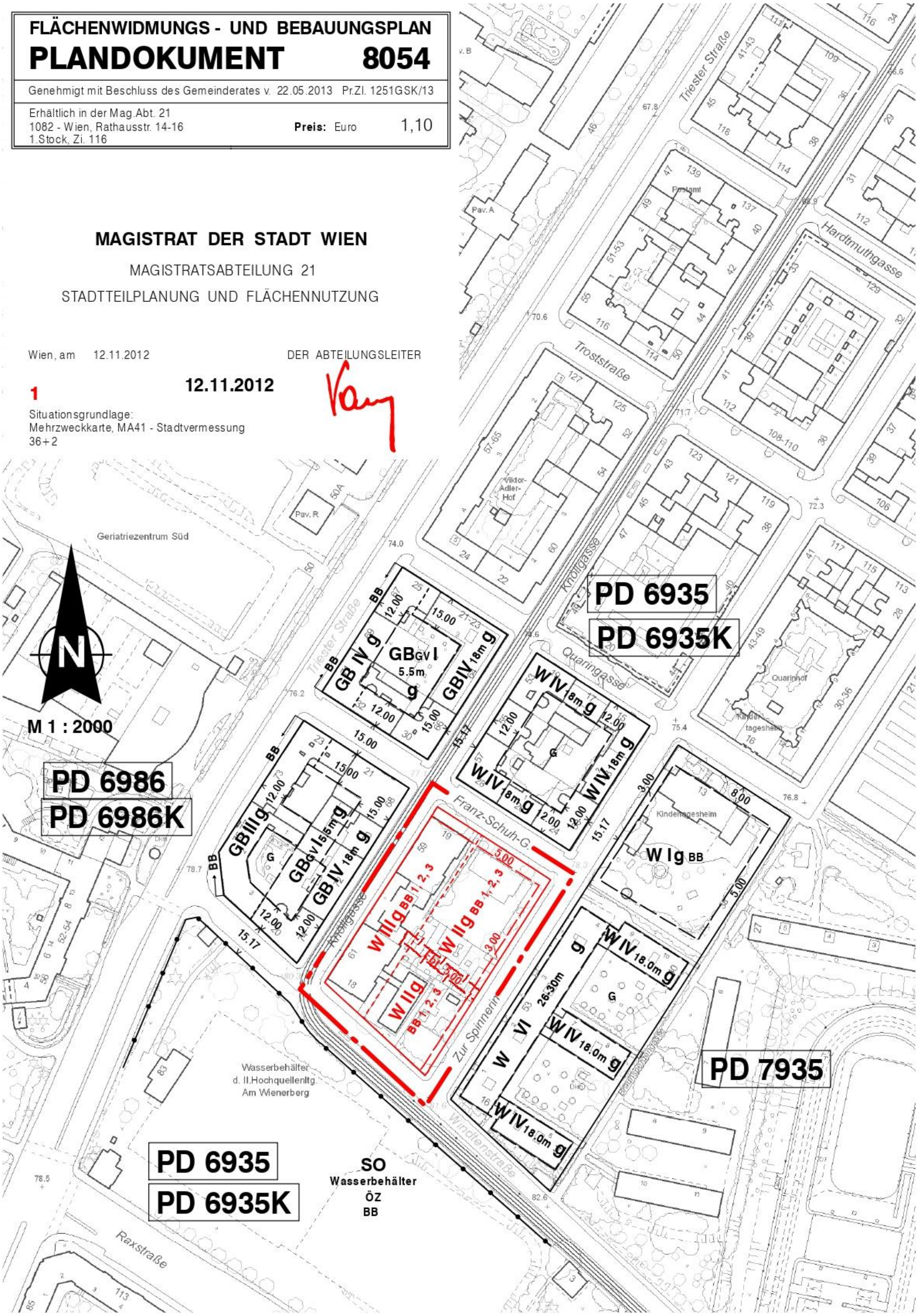

Figure 3 - Planar view of the site with constraints

1.4 SITE DESCRIPTION

The site has an area of 5753 m2, of which 1645 m2 is occupied by the existing school. The lot is located between:

- Knöllgasse to the West
- Windtenstraße to the South
- Zur Spinnerin to the East
- Franz-Schuh-Gasse to the north

In addition, the site has an elevation difference of 3.2 m, the lowest point being on the Franz-Schuh-Gasse side at a height of 78.4 m above sea level, while the highest point is reached on the opposite side, Windtenstraße, which is at a height of 81.6 m above sea level.

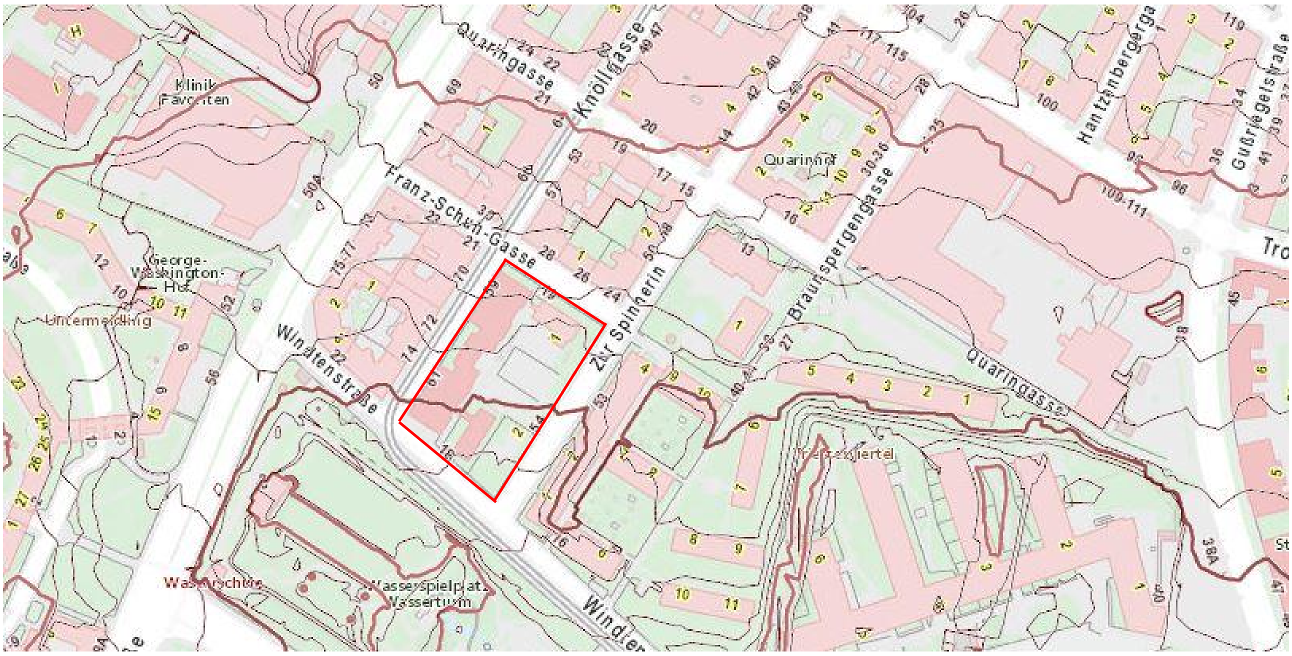

Figure 4 - Contour lines

It should be noted that the construction of the school extension, with the addition of the middle school, respects the constraints required by the municipality to leave a distance of 3 metres from the lot boundary located on Zur Spinnerin and 5 metres from Franz-Schuh-Gasse.

2 THE PROJECT

In the following chapter, the technical, design and energy choices for the new school complex will be set out and discussed.

2.1 GENERAL CONSIDERATIONS

As mentioned above, the project described concerns the extension of an existing school in Knöllgasse, Vienna, with the addition of a new middle school for approximately 400 students, with a focus on contemporary pedagogical concepts and changing educational needs. Exploring the various aspects of this initiative implies not only an architectural and design assessment, but also a pedagogical, social and ecological one. In this reflection, we will look in detail at the main considerations related to the project: the pedagogical approach, the use of wood as a building material, sustainability, logistics and the efficiency of the construction process.

One of the central aspects of the project is the **focus on modern pedagogical concepts**. The school system has undergone a significant transformation in recent decades, with a shift from traditional teaching models, based on face-to-face lessons in large groups, to more flexible models that emphasise individual, cooperative and small-group learning. The design of this school takes these changes into account, providing spaces that adapt to the needs of modern learning. In particular, the inclusion of areas for afternoon care and small group learning is crucial. These needs emerge from the recognition that learning does not only take place during formal lessons, but also in moments of informal interaction and individual support. The availability of dedicated spaces for afternoon care, for example, indicates that the school is designed to be more than a place where lessons take place: it becomes a community centre, where students can also be looked after outside traditional school hours. This is especially important in an urban context like Vienna, where many families work and need more extensive support. Furthermore, learning in small groups reflects the trend towards personalised education, which recognises the importance of meeting the individual needs of students. This type of approach requires flexible spaces that can be reconfigured according to the needs of the moment. The design of school environments that facilitate interaction, collaboration and autonomous learning thus becomes crucial.

Another distinctive aspect of the project is the **use of wood** as the main construction material. Wood is chosen not only for its aesthetic and tactile properties, but also for its technical and environmental advantages. The choice of wood reflects a growing trend towards the adoption of sustainable materials in construction, particularly for school buildings, where the creation of a healthy and stimulating environment is crucial. Wood has a beneficial effect on the quality of the indoor environment. Its tactile and olfactory properties help create a cosy, warm and natural atmosphere, which promotes the psychological well-being of students and teachers. Studies show that the use of wood in interior spaces can reduce stress and improve concentration, making it ideal for school environments. In terms of construction, wood offers a number of advantages. It is a light, yet durable material that allows for quick and precise construction, thanks also to the high degree of prefabrication that can be achieved. Modern timber construction techniques allow parts of the building to be constructed in the factory, reducing construction time and improving efficiency. This is especially important in urban settings such as Vienna, where site management can be complex due to limited space and the need to minimise impact on surrounding areas.

Sustainability is a key element of this project. The use of wood, a renewable material, underlines the commitment to ecologically responsible construction. Compared to traditional materials such as concrete or steel, wood has a significantly smaller ecological footprint. Its ability to store carbon makes it an ideal choice at a time when reducing greenhouse gas emissions is a global priority. Furthermore, the adoption of dry construction, as mentioned in the text, helps to reduce the environmental impact of the construction site. This type of construction generates less waste and uses less water, increasingly valuable resources. The energy efficiency of timber buildings is also remarkable: thanks to its natural insulating properties, wood helps to reduce energy consumption for heating and cooling indoor spaces.

The project uses a high degree of **standardisation and prefabrication**, with the aim of optimising construction time and costs. Prefabrication offers significant advantages in terms of efficiency, allowing construction time on site to be minimised while ensuring greater precision and quality in assembly. Standardisation allows greater speed in the assembly of prefabricated parts, reducing error margins and ensuring greater consistency in the quality of the final product. This is particularly important for school projects, where construction times must be strictly adhered to in order to minimise disruption to students and school staff. The 'just in time' concept mentioned in the text refers to the possibility of precisely coordinating the delivery and assembly of prefabricated materials. In a dense urban environment such as Vienna, this approach greatly reduces the need for on-site storage, which can be difficult to manage in areas with limited space.

In summary, the Knöllgasse school extension project is an example of how school architecture can respond to the needs of the 21st century, both pedagogically and environmentally. The creation of flexible and multifunctional learning spaces, the use of sustainable materials such as wood, and the adoption of innovative construction techniques such as prefabrication and dry construction demonstrate an integrated and holistic approach. The focus on the environment and the well-being of students, combined with the efficiency and speed of the construction process, makes this an example of how architecture can go beyond simply creating buildings, becoming a true educational tool and a catalyst for social and ecological innovation.

2.2 GROUND FLOOR

The ground floor of the new school complex is designed to be a hub for both students and the local community, with spaces that can also be used outside school hours. This level accommodates some of the most important functions of the entire complex, such as the library, the assembly hall and the gymnasium, which, thanks to their flexibility, offer a wide range of opportunities for use.

The main entrance, located at the bottom of the floor plan, opens onto a large atrium with 5 metre high ceilings, creating a welcoming feeling of openness and space. This atrium is the focal point from which all the internal routes on the ground floor are distributed. From the entrance area, there is direct access to the main rooms on the floor, including the library, the lecture hall and the gymnasium, as well as the service and support spaces that ensure the proper functioning of the building.

One of the central elements of this floor is undoubtedly the library. This space is designed not only as a repository of books, but as a versatile and multifunctional environment where students can work individually or in small groups. The presence of study rooms makes the environment even more suitable to meet the different needs of students, offering quiet spaces for individual study and more collaborative areas for group work. A special feature of the library is the possibility of transforming part of it into a lecture hall. This multifunctional space is designed to host school and cultural events of various kinds, such as conferences, presentations and meetings, making it a focal point for both school and community activities. The fact that the library, and in particular the assembly hall, is also accessible during out-of-school hours amplifies its usefulness, creating a link between the school and the surrounding area.

On the opposite side from the library is the gymnasium. This space, in addition to serving the students' motor activities during the school day, is designed to be used by the community outside school hours. In fact, the separate access allows the gymnasium to function independently, opening its doors to sports and recreational events organised by the citizens. This type of use responds to the growing demand for public spaces dedicated to physical and social wellbeing, transforming the school into a true meeting place.

A key concept that emerges in the design of the ground floor is that of flexibility. The spaces have been designed to adapt to different uses and needs, offering solutions that go beyond the simple school context. The possibility of using the library and gymnasium during extracurricular hours is a demonstration of this flexibility, allowing the building to respond not only to the educational needs of the students, but also to the cultural and social needs of the community. The lecture hall, which can host public events, and the gymnasium, accessible outside school hours, allow this building to extend its function, becoming a living, participatory space beyond school hours. This focus on the community makes the project not only an educational space, but a meeting and sharing place for the neighbourhood.

A crucial aspect of the ground floor is also the connection to the existing school building. This connection allows for a seamless flow between the two buildings, facilitating the movement of students and staff between spaces and integrating the new building into its existing context. This architectural dialogue between old and new is fundamental to ensuring a fluid and unified school experience.

The courtyard was conceived not only as a recreation area, but also as a true extension of the educational spaces. Large windows and direct access from the ground floor allow easy use of this space, which becomes a natural extension of the activities taking place inside the building. Students can use the courtyard during breaks or as a place for outdoor learning, exploiting the outdoor environment in synergy with the classrooms and common areas inside. Both the library and the gymnasium, located on the ground floor, have privileged accesses to the courtyard. The library, designed as a flexible space for study and meetings, offers the possibility of using the courtyard as a reading or outdoor study area. This direct connection allows students to move easily between indoors and outdoors, enhancing the school experience with a greater variety of usable spaces. Similarly, the gymnasium can benefit from this connection, allowing for outdoor physical activities or sports events involving the outdoor area, integrating the courtyard into daily and extracurricular activities. The connection to the courtyard is designed to be fluid, without interruptions, ensuring a natural transition between the indoor and outdoor spaces. The large windows allow natural light to illuminate the ground floor, making the environment more welcoming and bright. At the same time, the courtyard becomes an easily accessible space, ready to be used at any time of the school day, for recreational, educational or social activities.

2.3 FIRST FLOOR

The organisation of the spaces was designed to maximise functionality and efficiency, taking into account the different educational and social activities that take place within the building.

On the right-hand side of the plan, we find the working groups indicated with the number 1, associated with an outdoor space. This area is designed for collaborative and group activities, where students can work more flexibly. The adjacent open-air classroom represents an extension of the indoor spaces towards the outside, encouraging direct interaction with the natural environment.

The spaces with the number 2 are intended for teaching rooms, distributed along the top and right-hand side of the floor plan. The classrooms are spacious and bright, designed to foster a comfortable and stimulating learning environment. The distribution of spaces ensures the presence of numerous classrooms around the perimeter of the building, allowing access to natural light through large windows.

The area marked with number 3 is located in the centre of the plan and is a community and break area. This includes a library and a space for students to study and socialise. The central location of this area facilitates access to all classrooms, allowing students to easily use the space during break times or for educational activities.

Spaces marked with the number 4 are reserved for science and art laboratories. These spaces are designed to accommodate practical and experimental teaching activities related to subjects such as natural sciences and art. The laboratories offer flexible environments for practical activities, providing adequate tools and equipment to stimulate students' creativity and innovation.

Area number 5 is dedicated to teaching staff and serves as a meeting and resting space for teachers. This area is located so that it is easily accessible from the rest of the building, but also offers a more private area, away from the areas most frequented by students, to ensure a quiet and comfortable environment.

In the centre left of the plan, the area marked with the number 6 represents the changing rooms for the gymnasium. This area is closely connected to the gymnasium located on the ground floor, facilitating changing rooms for students during sports activities.

Number 7 refers to an outdoor sports area, located on the left of the plan. This space is designed to accommodate outdoor sports activities, and is accessible directly from inside the building, allowing students to easily switch from indoors to outdoors for physical education classes.

The floor plan features several pathways connecting with the outdoor spaces, with direct access to the courtyard and the outdoor sports area. The large windows and direct exits help to create a continuous connection between the interior of the building and the outdoor environment, encouraging a more dynamic interaction between students and nature.

Overall, the first floor is well organised to meet the needs of students and teachers, with a clear division between spaces dedicated to teaching, practical activities, socialising and rest. Attention to the connection with the outdoors and the presence of numerous common areas make the environment welcoming and functional, supporting the various activities that take place there.

2.4 SECOND FLOOR

Areas marked with the number 1 indicate working groups, which also include an outdoor classroom. These spaces are designed to promote group work, with a strong emphasis on outdoor education, encouraging interaction between students in a natural environment. The outdoor classroom is located on the left side of the floor plan, in connection with the outdoor green area and the courtyard.

The classrooms are represented by the number 2 and are distributed around the perimeter of the floor plan, similar to the layout of the first floor. These spaces are dedicated to traditional teaching and provide versatile environments for lessons. Large windows ensure good natural lighting and a study-friendly environment.

As in the lower floor, there is a direct connection to the outdoor spaces. The courtyard to the left provides access to a large sports area, which can be used for both educational and recreational activities. This connection between indoors and outdoors represents an added value for the building, allowing the integration of the natural environment with school activities.

The second floor is clearly intended for mixed educational use, combining traditional teaching spaces with areas dedicated to group projects and activities related to the natural environment. The spatial organisation aims at fostering a versatile and stimulating learning environment, with special attention to the use of outdoor spaces.

2.5 THIRD FLOOR

As on the lower floors, the areas marked with the number 1 are intended for working groups. These spaces are designed to encourage collaboration between students in small groups and also include an outdoor classroom, accessible from the left side of the building. The arrangement of tables and seating suggests the possibility of flexible use of the space, for brainstorming activities, discussions and collaborative learning.

The teaching rooms, identified with number 2, are distributed around the perimeter of the building and are configured to accommodate traditional lessons. These spaces follow a classical layout, with desks and chairs arranged in front of the teacher, thus ensuring an appropriate environment for teaching. Large windows provide abundant natural lighting, enhancing visual comfort during school activities.

Even on this level, the building maintains a strong connection to the outdoors, in particular through access to the open-air classroom, which allows students to make use of outdoor spaces for educational activities.

The third floor is mainly dedicated to flexible teaching use, offering both formal spaces for traditional lessons and areas for group work and more interactive activities. The inclusion of the outdoor classroom provides an opportunity to encourage outdoor learning and further integrate the building with the surrounding landscape.

2.6 ROOF

The upper roof of the building houses a large green roof covering a large area. This area, located at a higher elevation, contributes not only to the thermal and acoustic insulation of the building, but also to the reduction of environmental impact through its ability to retain rainwater and the mitigation of urban heat islands.

The second roof, located at a lower level, is distinguished by the presence of windows in addition to the green roof. These skylights on the lower green roof allow natural light to enter the spaces below, contributing to a brighter and more comfortable interior environment, reducing the need for artificial lighting during the day. Their location and orientation is strategic to ensure even lighting in the interior spaces, while maintaining all the environmental benefits offered by the green roof.

The benefits of hedging turn out to be:

- **Sustainability and environmental comfort**: Green roofs, together with the natural ventilation provided by windows, improve indoor thermal comfort, reducing the need for heating and cooling. In addition, the rainwater retention capacity of green roofs lightens the load on drainage systems.
- **Sound insulation and natural lighting**: The layering of soil and vegetation provides an excellent acoustic barrier, while the windows integrated in the lower roof maximise natural light, enhancing the liveability of the spaces below.
- **Aesthetics and urban continuity**: The presence of green roofs at different heights creates a dynamic effect that breaks up the monotony of the roof, encouraging a harmonious integration of the building with the surrounding landscape. The windows on the lower roof also add a functional element that enhances the experience inside the building without compromising the aesthetics of the green roofs.

The green roofs, with their distinctive lower roof windows, represent a balancing element between environmental sustainability, energy efficiency and living comfort. The alternation of elevations creates movement and visual depth, while maintaining a strong connection with the surrounding natural environment.

2.7 ENERGETIC EVALUATION

The energy assessment of a building is a process that takes into account a number of parameters to ensure efficient energy use and minimise environmental impact. These parameters include the local climate (such as outdoor temperature and humidity), orientation of the building with respect to the sun, use of renewable energy sources, thermal insulation capacity and natural ventilation. The objective is to minimise energy consumption for heating, cooling, lighting and ventilation, while maintaining a high level of comfort for occupants. Good energy-efficient design takes into account specific environmental factors, such as solar pathway, relative humidity and outdoor temperature, to maximise efficiency through passive and active solutions. In the design of school buildings, energy efficiency becomes particularly important to reduce operating costs and promote healthy and comfortable learning environments.

The project analysed concerns a school building designed to optimise energy performance and integration with its surroundings. One of the distinctive features of the project is the use of green roofs on two separate levels, which contribute to thermal insulation and improve the building's overall energy efficiency. In addition to the insulation provided by the green roofs, the presence of windows on the lower roof allows for better natural lighting, reducing the need for artificial lighting during the day. This further contributes to the reduction of energy consumption while improving the quality of interior spaces.

Main values for energy evaluation:

- **The outdoor** temperature is a crucial factor in the design of heating and cooling systems, as well as in the choice of thermal insulation materials. For this project, the seasonal temperature assessment was used to design an envelope that minimises heat loss in winter and overheating in summer.

MONTH	OUTDOOR TEMPERATURE (°C)
January	0.5
February	2.0
March	6.0
April	10.5
May	15.0

June	18.5
July	20.5
August	20.0
September	16.0
October	10.5
November	5.0
December	1.0

Table 1 - Outdoor temperature

- **Relative humidity** affects indoor comfort and the performance of air-conditioning systems. Accurate humidity control is essential to maintain ideal environmental conditions without having to resort to energy-intensive dehumidification or air conditioning systems. The project is designed to encourage natural ventilation, taking advantage of the arrangement of windows and skylights to maintain a good balance between air exchange and indoor comfort.

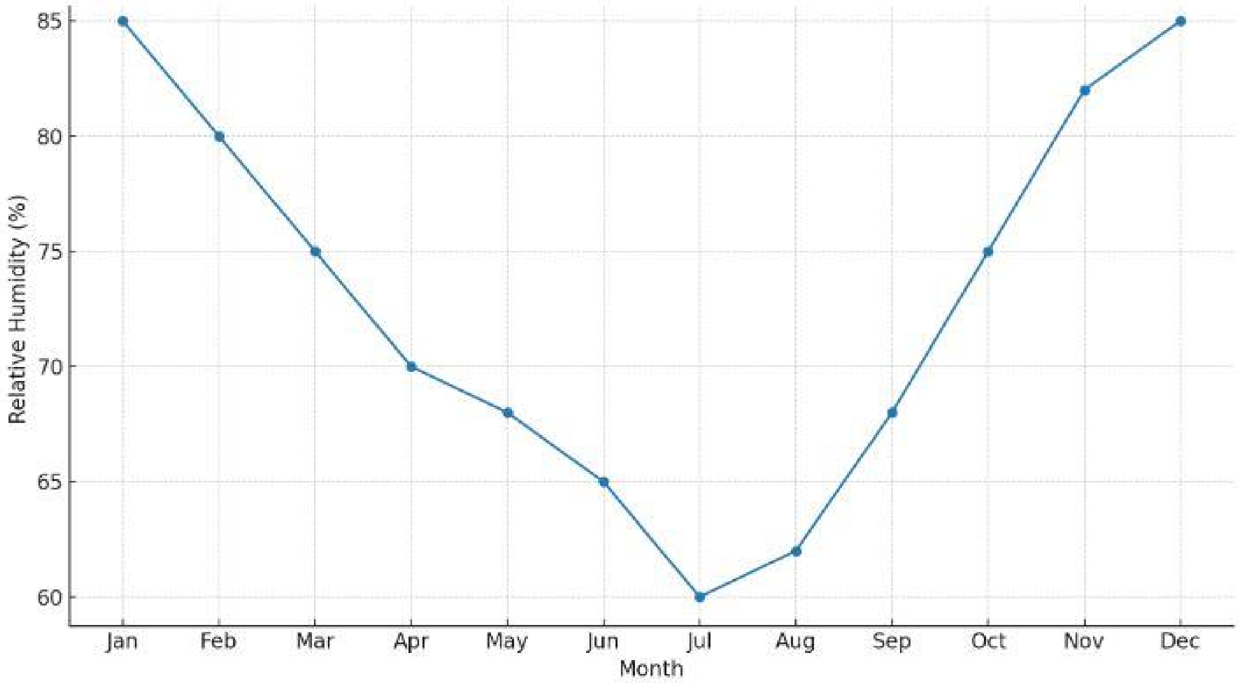

Figure 5 - Relative humidity

- The orientation of the building and the distribution of the openings were planned according to **the solar path**, thus optimising the supply of natural light. Windows and skylights in the roofs allow sunlight to enter during the day, reducing the need for artificial lighting. In winter, passive solar gain helps to heat the rooms, while in summer, appropriate shading and shading reduce overheating.

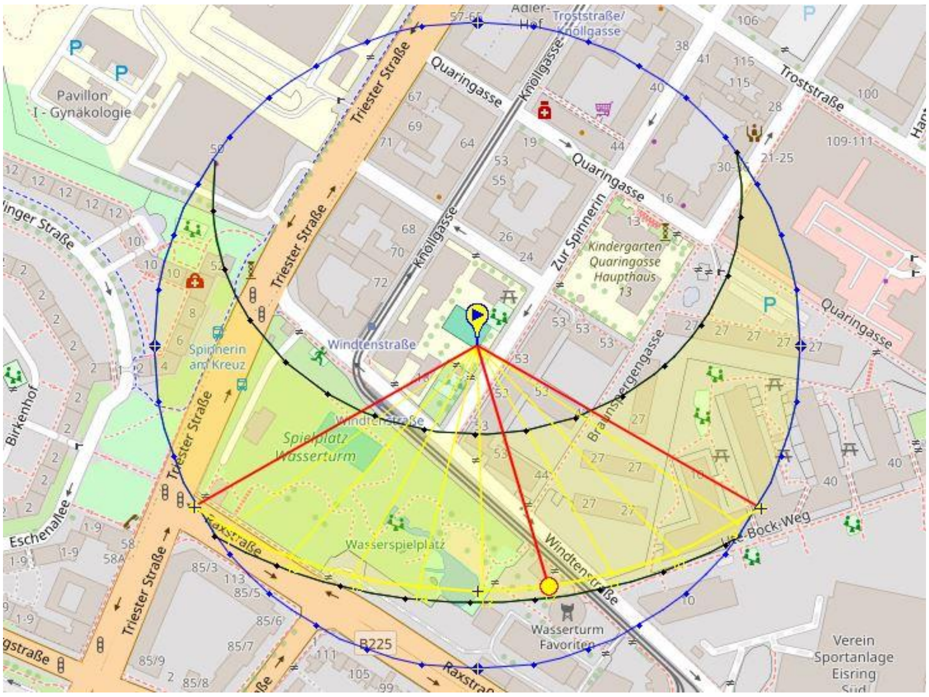

Figure 6 - Sun path for the 21th of January

Figure 7 - Shadow analysis on the 21th of January

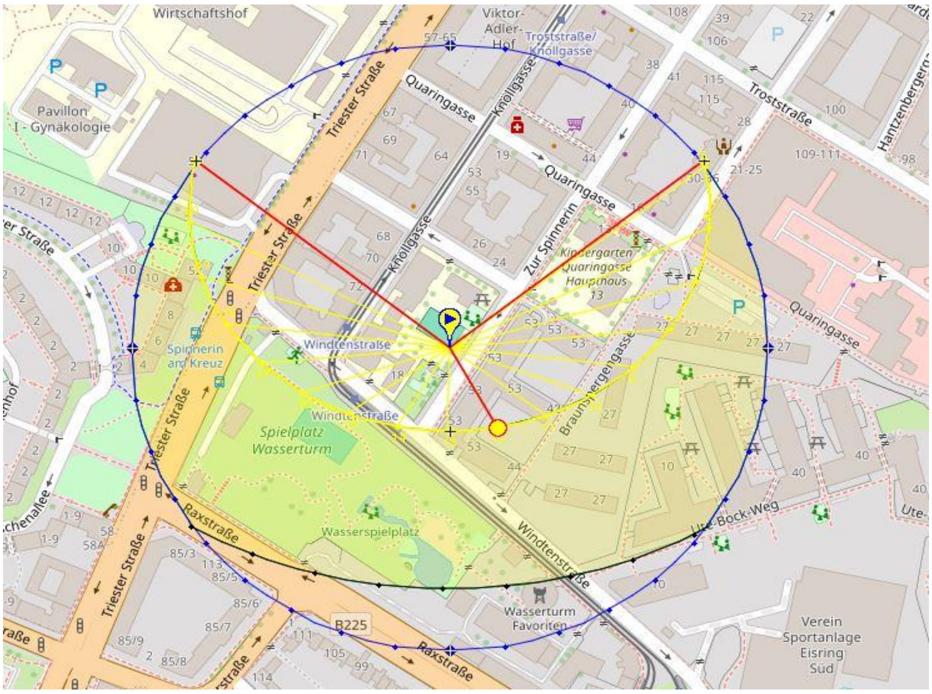

Figure 8 - Sun path for the 21th of July

Figure 9 - Shadow analysis on the 21th of July

Shadow analysis shows that the new building will not be subject to overheating problems during the summer months. Thanks to the studied orientation and the presence of natural and architectural shading elements, such as green roofs and solar shading, excessive direct sunlight is prevented during the hottest hours of the day. In addition, the use of well-calibrated glass surfaces and a natural ventilation system help to maintain a comfortable interior temperature, avoiding overheating without the need for excessive mechanical air conditioning.

In the energy assessment process of the project, several technical parameters affecting the performance of the building were considered. One of the key aspects was the **control of the thermal transmittance** of the materials used. The use of materials with low transmittance reduced heat loss, ensuring that the building maintains optimal internal temperatures with minimal energy consumption. Proper insulation of the walls and green roofs was crucial to ensure this performance, reducing both heating costs in winter and cooling costs in summer.
In the process of calculating thermal transmittance, a mixed construction system was adopted in our project. The ground floor mainly uses a structure based on a system of glued laminated timber beams and pillars, ensuring a good insulating capacity. For the upper floors, on the other hand, an XLAM (Cross Laminated Timber) system was used, known for its excellent thermal and acoustic insulation properties, as well as for its sustainability and speed of assembly. This mix of construction techniques was chosen to optimise the building's resistance and thermal performance, while ensuring high living comfort and reduced energy consumption.

Below are the thermal transmittance (U) limit values for the various components of the building envelope:

BUILDING ELEMENT	TRANSMITTANCE LIMIT VALUE (U) [W/m²K]
External wall	0.35
Internal wall	Unregulated (generally non-critical, since within the thermal envelope of the building)
Roof	0.20
Ceilings towards unheated rooms	0.25
Slabs towards the ground	0.30
Ceilings to heated interior rooms	Unregulated (generally non-critical, since within the thermal envelope of the building)
Window	1.40 (up to 1.10 for passive buildings)
External door	1.40

Table 2 - U-value for Wien

The technological choices developed in this project and the calculations performed show that:

- **EXTERNAL WALL** has a thermal transmittance U = 0.17 W/m²K.
- **ROOF** has a thermal transmittance U = 0.15 W/m²K.
- **SLAB TOWARDS THE GROUND** has a thermal transmittance U = 0.27 W/m²K.
- **WINDOW** has thermal transmittance U = 1.08 W/m²K

It can be seen that all the elements taken into account for this project are below the threshold limit imposed by Austrian and City of Vienna standards.
It is important to note that the windows, which play a thick role in this project, especially on the ground floor, have a thermal transmittance value such that both thermal and acoustic comfort is excellent.

Optimising natural lighting is another key aspect. The integration of large glazed surfaces and skylights allows maximum use of daylight, reducing dependence on artificial lighting. This approach not only improves the quality of interior spaces, making them brighter and more welcoming, but also reduces the energy consumption associated with lighting, improving the building's overall efficiency.

In the project, special attention was paid to room ventilation, combining two strategies to ensure maximum comfort and high air quality. On the one hand, natural ventilation was favoured through large glass surfaces and strategically placed windows, both on the walls and on the roofs, as in the case of the green roof at a lower level. This solution allows the natural passage of air and makes the most of the wind path to create a natural exchange of air in the interior spaces. However, to ensure constant control of air quality, especially during seasons when natural ventilation may not be sufficient (for example, during colder periods), a mechanical ventilation system has also been integrated. This system ensures an adequate exchange of air in all areas, regulating humidity and CO2 levels, thus helping to maintain optimal indoor air quality. To summarise, the combination of natural and mechanical ventilation makes it possible to respond effectively to the needs for comfort, efficiency and healthiness of the spaces, guaranteeing a healthy environment for users and students both during school hours and after school hours.

3 TECHNOLOGICAL CHOICE

The project in question adopts an innovative combination of construction solutions, sustainable materials and advanced technologies to ensure a comfortable, energy-efficient and compliant environment. Particular attention was paid to the choice of structural materials and building envelope solutions, ensuring high thermal insulation, optimal indoor climate control, and efficient management of natural resources.

One of the distinctive features of this project is the combined use of glulam beams and pillars and XLAM (Cross-Laminated Timber) panels for the load-bearing structures, a choice that enhances the sustainability and strength of wood, contributing to a solid, environmentally friendly building. For the ground floor, the load-bearing structure was mainly made of glulam, an ideal solution to guarantee great structural strength and design flexibility. Glulam, composed of layers of wood glued together in alternating directions, gives the structure excellent resistance to loads, both static and dynamic, as well as high anti-seismic performance. The use of glulam beams and pillars guarantees high durability, as well as a warm and natural aesthetic. This material integrates perfectly with the building's sustainability goals, being a renewable resource with a low CO2 life cycle. On the upper floors, an XLAM system was used, consisting of prefabricated cross-layered panels that combine lightness and strength. The XLAM system offers considerable advantages in terms of thermal and acoustic insulation, as well as guaranteeing rapid installation thanks to its prefabrication. The cross-laminated timber also allows an even distribution of stresses, making the structure particularly suitable for multi-storey buildings. In this project, the use of XLAM helped to reduce construction time and improve the building's overall energy performance. The adoption of a mixed glulam-XLAM system made it possible to combine the technical qualities of the two systems, resulting in a strong structure on the ground floor, suitable for supporting the heaviest loads, and a light but high-performance structure on the upper floors.

The foundation of the building was built with a reinforced concrete slab. This solution was chosen primarily to compensate for the height difference on the site of approximately 3.5 metres, thus creating a uniform and solid base on which to erect the timber structure. The choice of reinforced concrete for the slab guarantees not only great stability of the building, but also effective insulation against moisture and ground movements. Concrete, with its compressive strength properties, is able to bear and evenly distribute the loads transmitted by the upper timber structure. In addition, a concrete slab provides a perfect base for anchoring vertical glulam elements and XLAM panels, thus ensuring optimal interaction between different materials. In terms of energy performance, the slab has been thermally insulated to prevent heat loss from the ground floor to the ground. This insulating layer is essential to reduce the building's energy consumption, avoiding thermal bridges between the floor and the outside.

Another innovative aspect of the project is the inclusion of green roofs at different heights. This solution not only improves the energy efficiency of the building, but also contributes to reducing the environmental impact, favouring the microclimate and reducing the urban heat island phenomenon.

- **Thermal Function**: Green roofs act as an excellent thermal insulator, protecting the building from heat in summer and reducing heat loss in winter. The plant layer, in combination with the draining and insulating substrate underneath, creates a natural barrier against temperature fluctuations, improving the overall energy efficiency of the building.
- **Windows on the Lower Roof**: It is important to note that, in addition to its insulation features, the lower roof of the complex is equipped with zenithal windows, which maximise the entry of natural light into the floors below. These windows are designed to avoid overheating, thanks to passive shading systems, and contribute to creating a well-lit indoor environment without having to rely excessively on artificial lighting.

A key element in the building's energy efficiency is the use of high-performance windows. These windows were selected with very strict criteria regarding thermal transmittance (U-value), sound insulation and air permeability. The windows adopted in the project feature triple glazing, with low-emissivity glass and anti-reflective treatments, which significantly limit heat loss while ensuring adequate natural light. This type of window makes it possible to minimise energy consumption for heating in winter and cooling in summer, making the most of sunlight throughout the year. Thanks to their high insulation performance, these windows also contribute to the reduction of thermal bridges and the maintenance of a comfortable indoor environment, preventing condensation and ensuring excellent air quality. Reduced air permeability and resistance to weathering also make them particularly suitable for a school building, where the frequency of use and exposure to outdoor elements require durable, high-performance solutions.

4 STANDARDS

For the construction of a new secondary school in Vienna, the most relevant regulations are:

- **OIB-Richtlinie 6** (Energy Efficiency).
- **Wiener Bauordnung** (Vienna Building Ordinance).
- **ÖNORM B 8110** (Thermal insulation).
- **ÖNORM B 8110** (Austrian Ministry of Education Guidelines (Minimum surfaces for classrooms and offices).
- **ÖNORM B 1600** (Accessibility for the disabled).

These regulations cover aspects of energy (insulation, thermal transmittance), space (minimum room dimensions) and safety (fire protection and accessibility).

5 CONCLUSIONS

The project is a virtuous example of sustainable and efficient architecture, thanks to the integration of advanced technologies and the use of natural materials such as wood. The adoption of a mixed structure of glulam and XLAM panels ensures a combination of strength, lightness and sustainability, reducing environmental impact through the use of renewable materials with a low carbon footprint.

The building's thermal insulation, achieved through the use of high-performance windows, green roofs, and efficient insulation materials, reduces energy consumption for both heating and cooling. Green roofs, in addition to improving insulation, contribute to sustainable stormwater management by promoting natural absorption and reducing runoff.

The integration of a mechanical ventilation system ensures optimal air exchange, helping to maintain a healthy and comfortable indoor environment. This system, together with natural ventilation, ensures high indoor air quality without compromising energy efficiency.

The design solutions adopted allow the building to comply with local energy efficiency regulations, reducing consumption and emissions, and make it suitable for achieving high energy certifications. In summary, this project combines aesthetics, functionality and sustainability, laying the foundation for efficient and environmentally friendly school buildings fit for the future of construction.

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7 ATTACHMENTS

Educational building sustainability:
Strategies for Expanding Schools in Vienna's Urban Context.

SHEET NAME: Groundfloor planar view

Scale 1:100

NAME OF DRAWING

D 01

POLITECNICO DI TORINO A.Y. 2023/2024
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Track: Green Building

PROFESSOR:
Prof. Arch. Marika Mangosio

STUDENT:
S304114 Italo Paulesu

NAME OF DRAWING

D 02

Scale 1:100

SHEET NAME:
Groundfloor dimensions

Educational building sustainability:
Strategies for Expanding Schools in Vienna's Urban Context.

STUDENT:
S304114 Italo Paulesu

PROFESSOR:
Prof. Arch. Marika Mangosio

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Track: Green Building

NAME OF DRAWING

D

03

Scale 1:100

SHEET NAME:
First floor planar view

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STUDENT:
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Track: Green Building

NAME OF DRAWING

D 04

Scale 1:100

SHEET NAME:
First floor dimensions

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STUDENT:
S304114 Italo Paulesu

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NAME OF DRAWING

D 05

Scale 1:100

SHEET NAME:
Second floor planar view

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S304114 Italo Paulesu

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NAME OF DRAWING

D 06

Scale 1:100

SHEET NAME:
Second floor dimensions

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STUDENT:
S304114 Italo Paulesu

PROFESSOR:
Prof. Arch. Marika Mangosio

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Prof. Arch. Marika Mangosio

STUDENT:
S304114 Italo Paulesu

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SHEET NAME:
Third floor planar view

Scale 1:100

NAME OF DRAWING

D 07

NAME OF DRAWING

D 08

Scale 1:100

SHEET NAME:
Third floor dimensions

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PROFESSOR:
Prof. Arch. Marika Mangosio

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Prof. Arch. Marika Mangosio

STUDENT:
S304114 Italo Paulesu

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SHEET NAME:
Roof planar view

Scale 1:100

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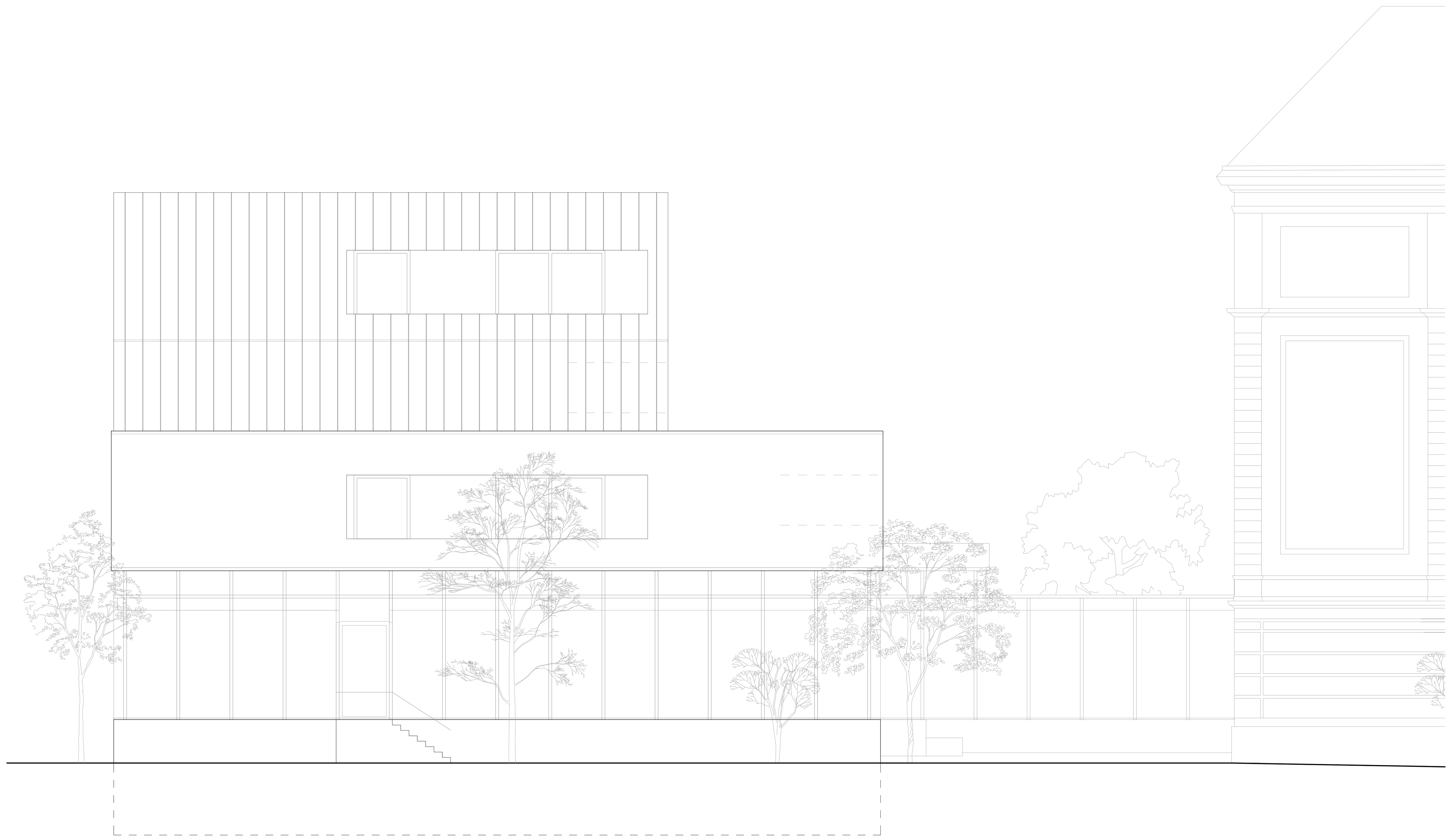
D 09

E01 - South-Est Elevation



E02 - Nord-East Elevation

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D 10

Scale 1:100

SHEET NAME:
Elevations 01 and 02

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STUDENT:
S304114 Italo Paulesu

PROFESSOR:
Prof. Arch. Marika Mangosio

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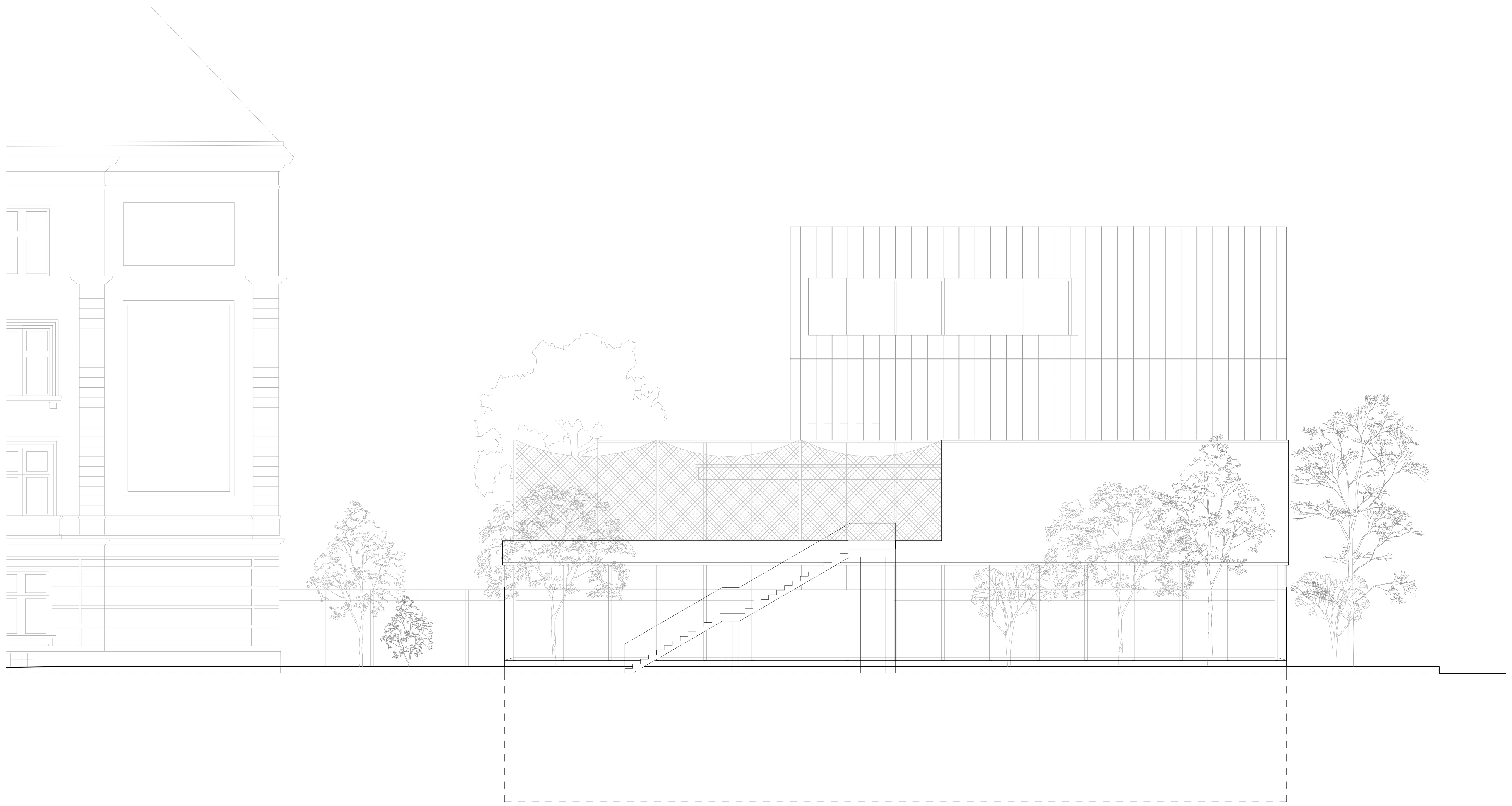
E03 - West Elevation



E04 - South-West Elevation

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D 11

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SHEET NAME:
Elevations 03 and 04

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STUDENT:
S304114 Italo Paulesu

PROFESSOR:
Prof. Arch. Marika Mangosio

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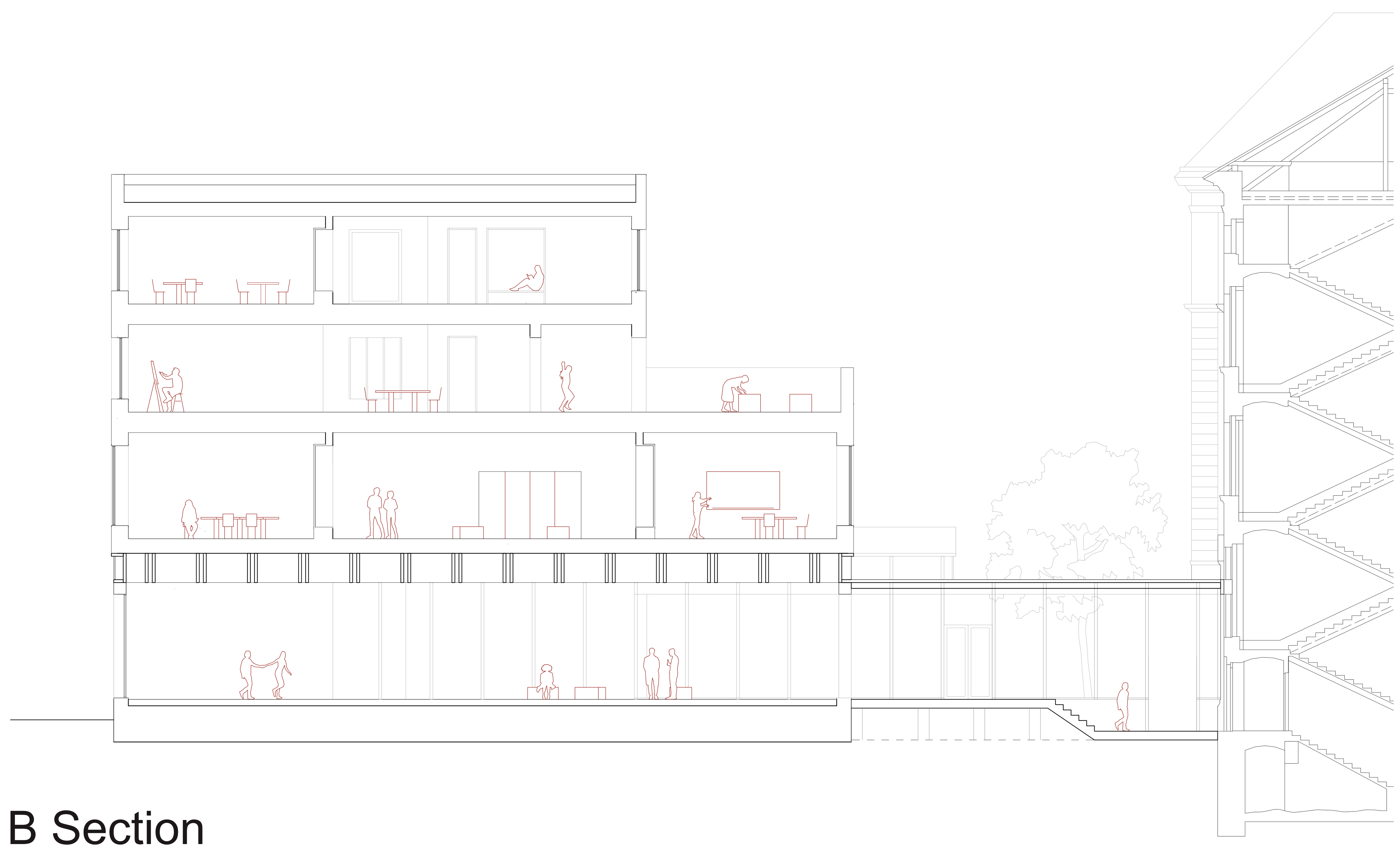
A Section



B Section

NAME OF DRAWING
D 12

Scale 1:100

SHEET NAME:
Sections A and B

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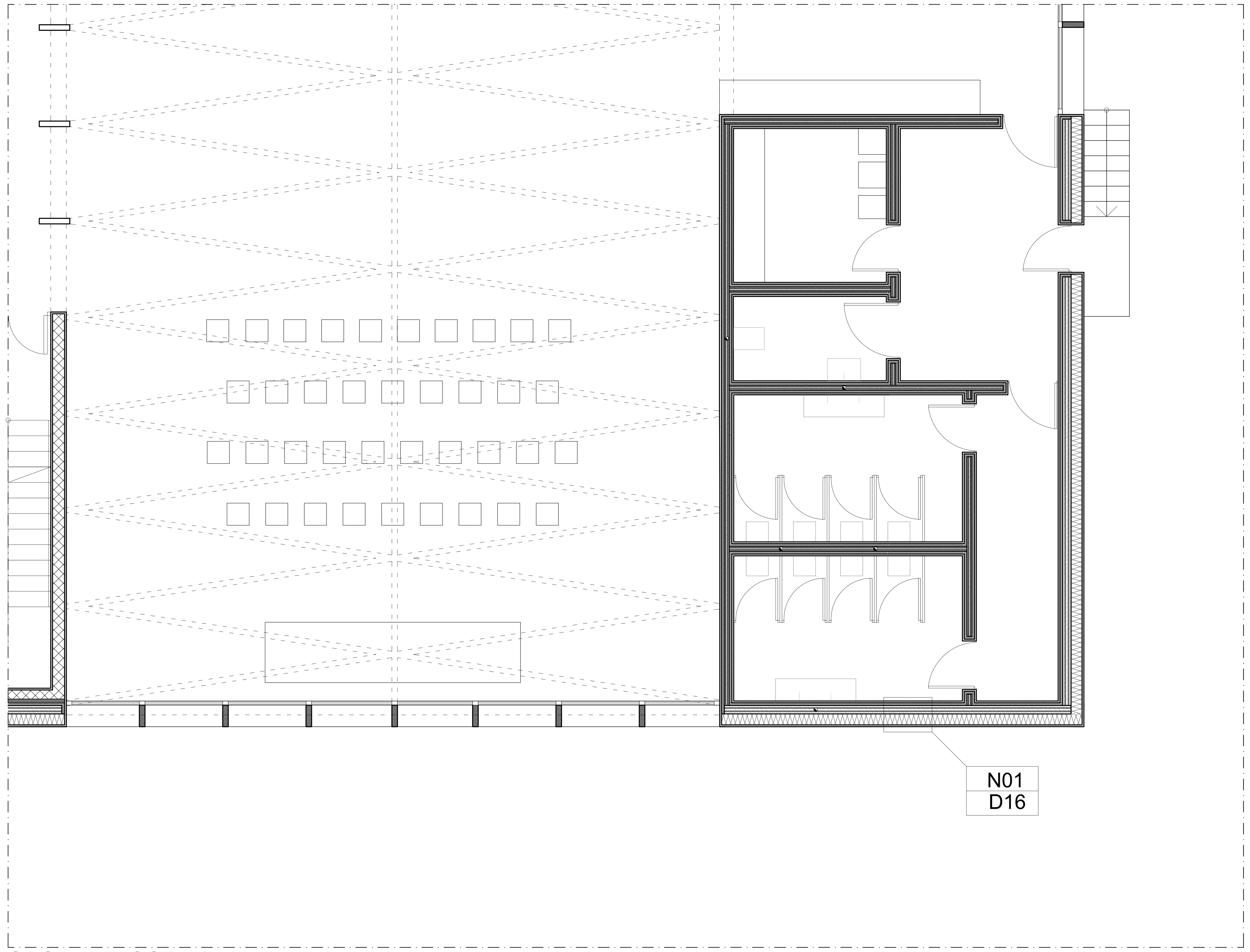
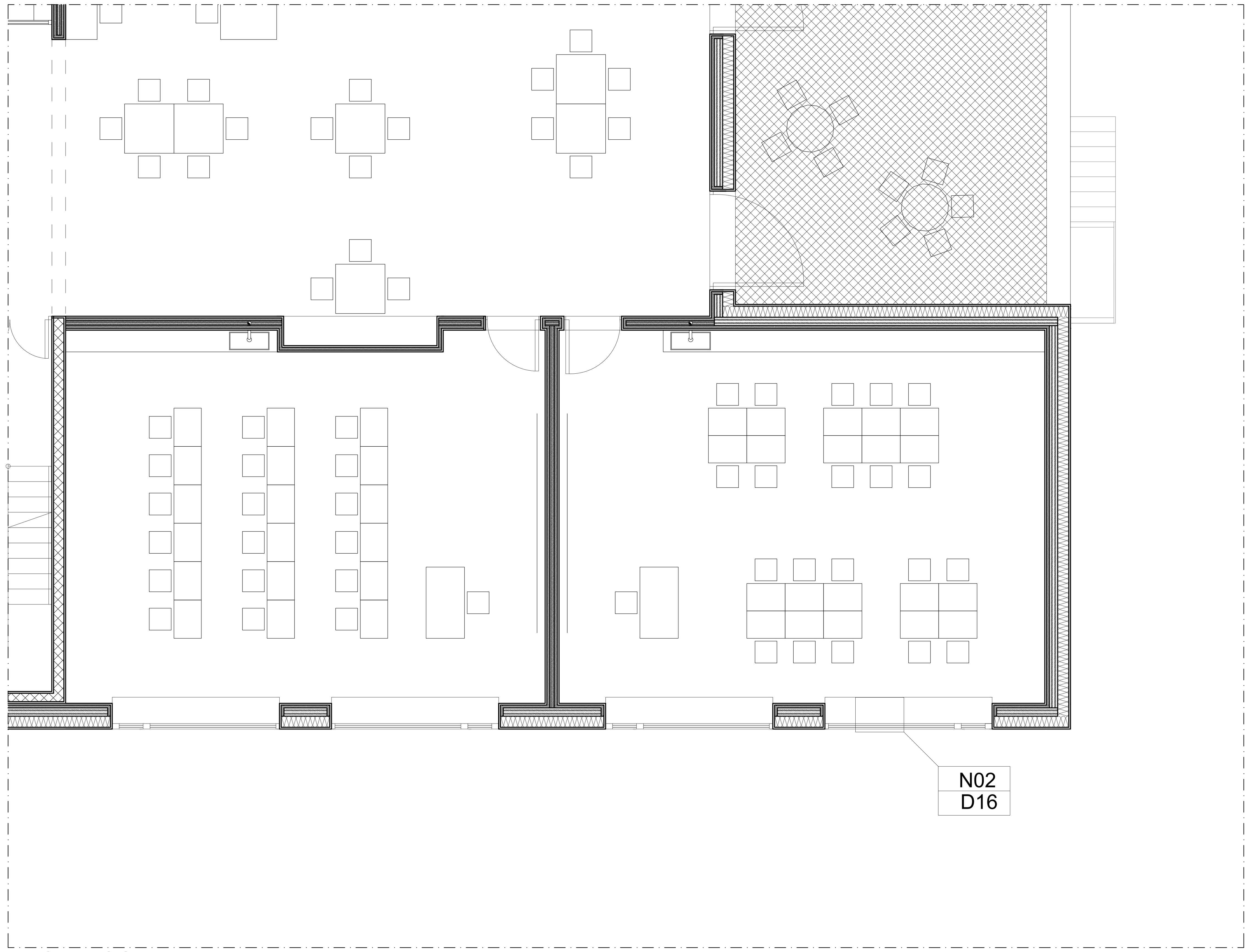


GROUNDFLOOR - 1:50



FIRST FLOOR - 1:50

NAME OF DRAWING

D 13

Scale 1:50

SHEET NAME:
Groundfloor and first floor

Educational building sustainability:
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S304114 Italo Paulesu

PROFESSOR:
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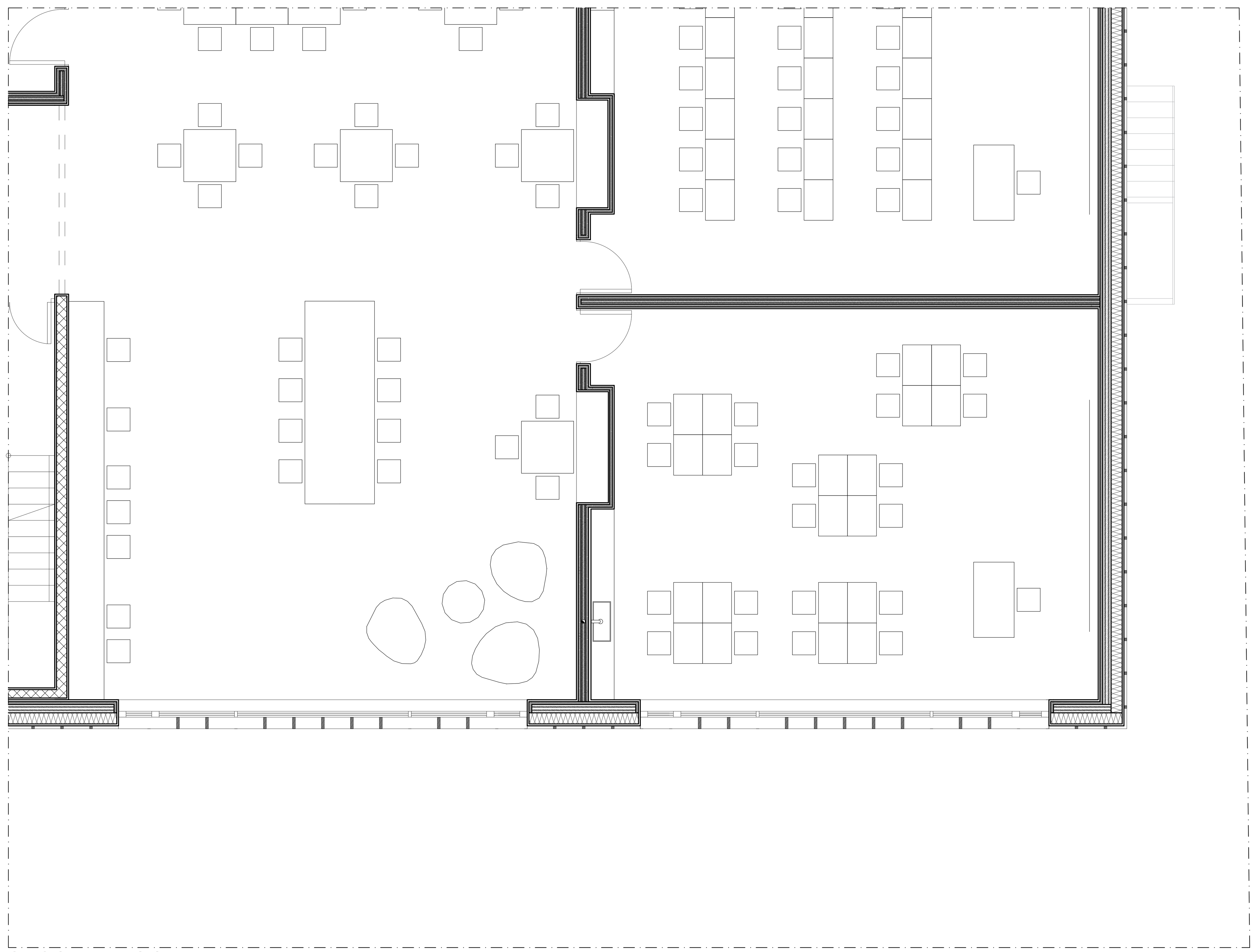

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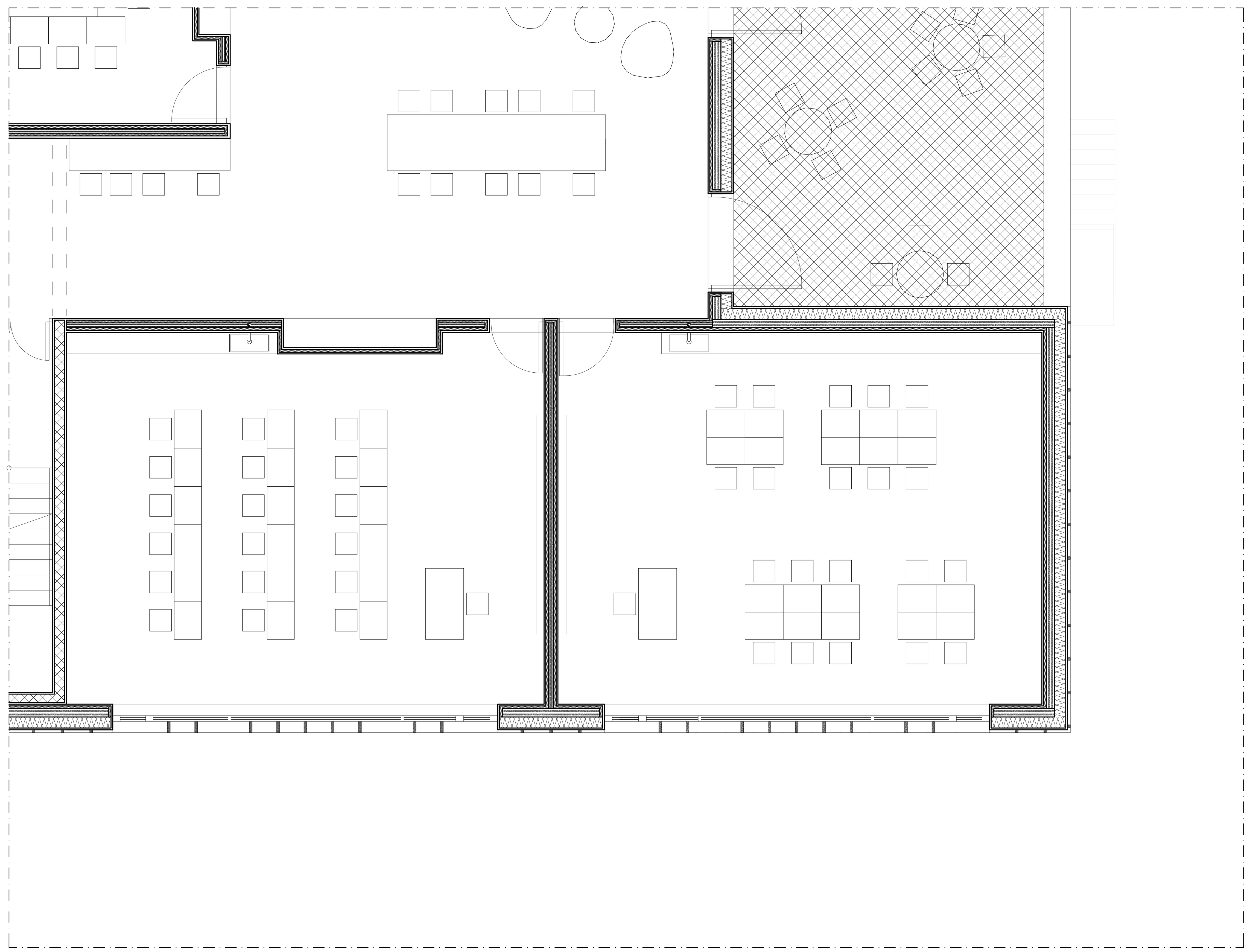

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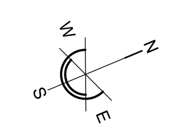

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STUDENT:
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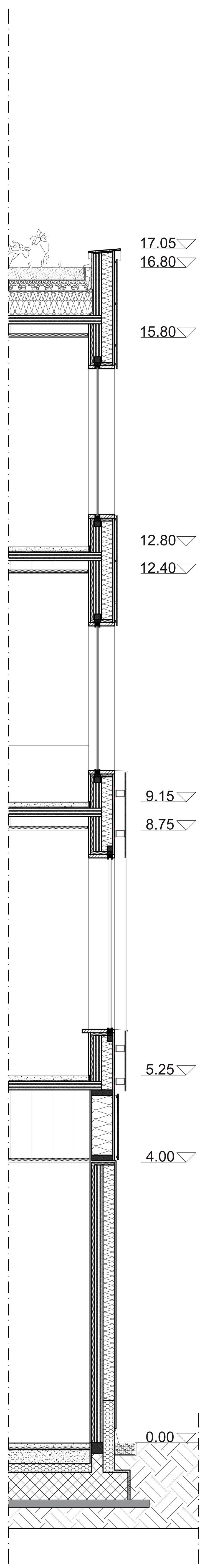
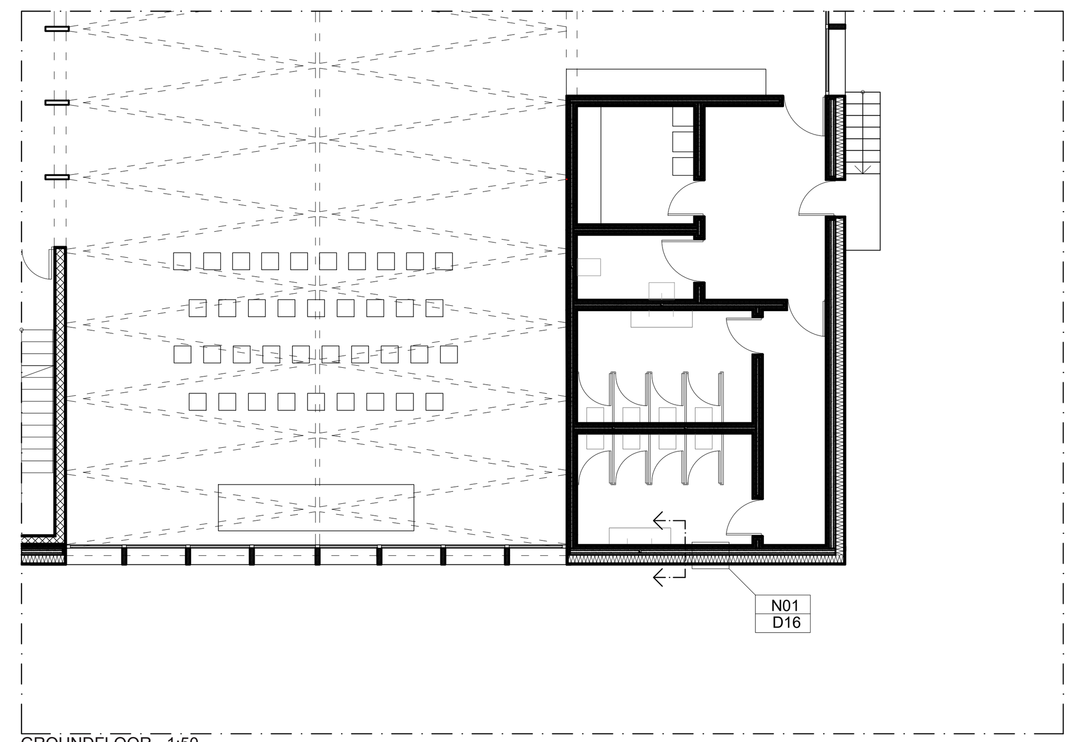
SHEET NAME:
Second floor and Third floor

Scale 1:50

NAME OF DRAWING

D 14





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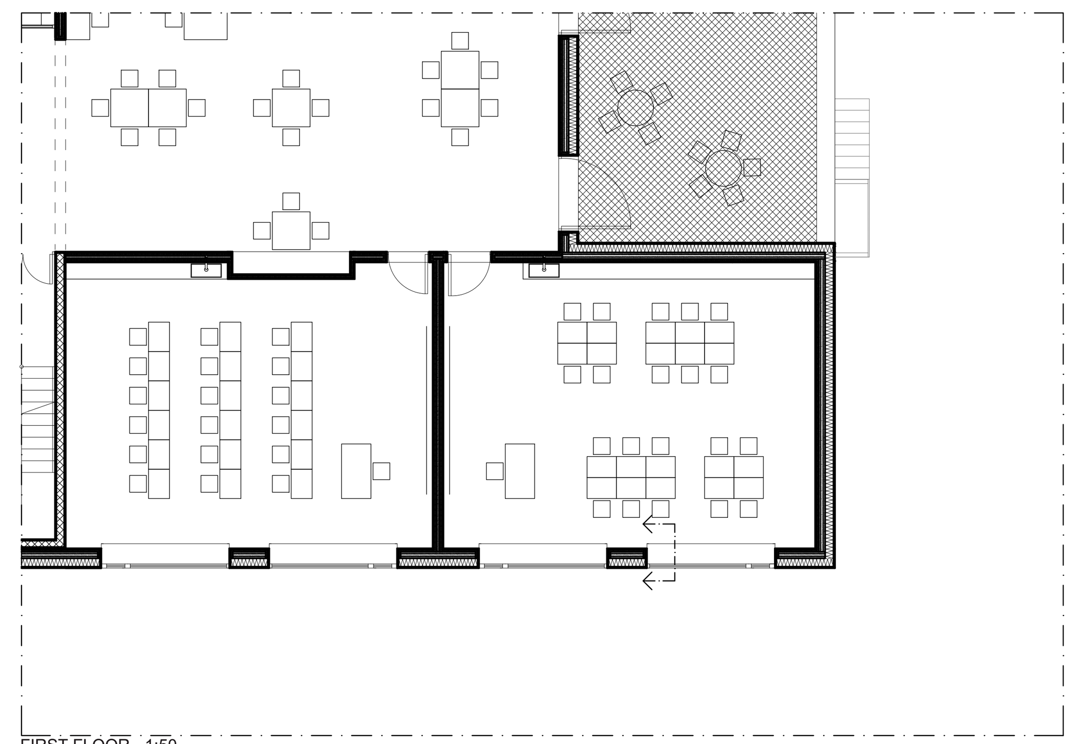
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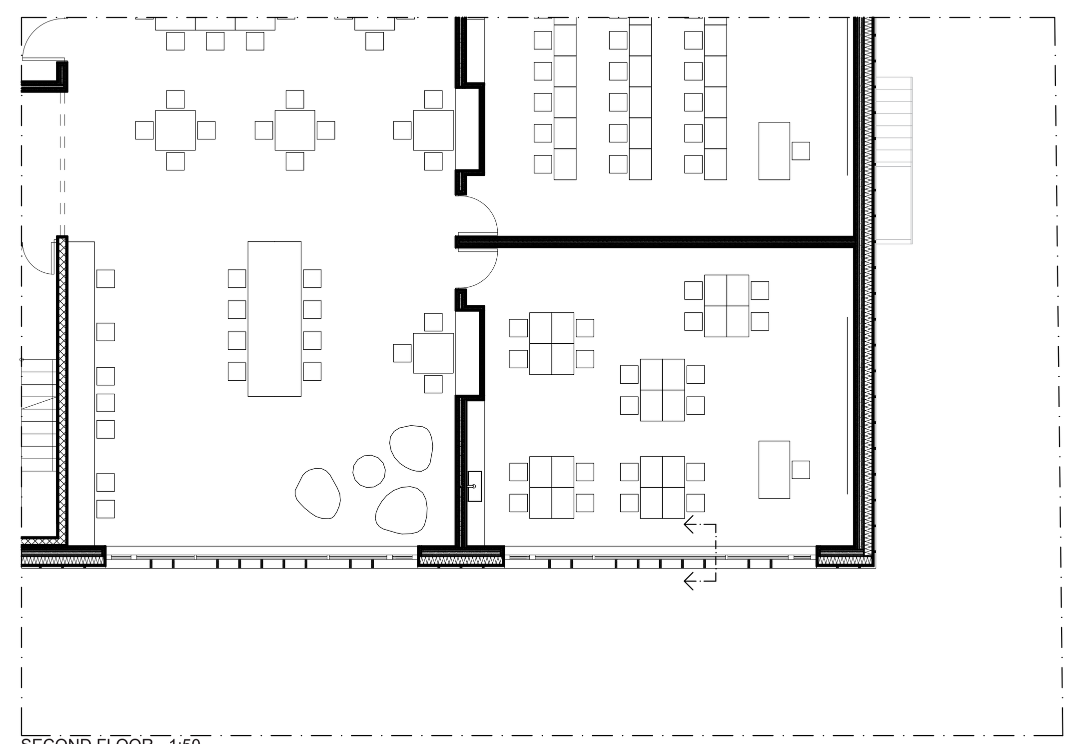
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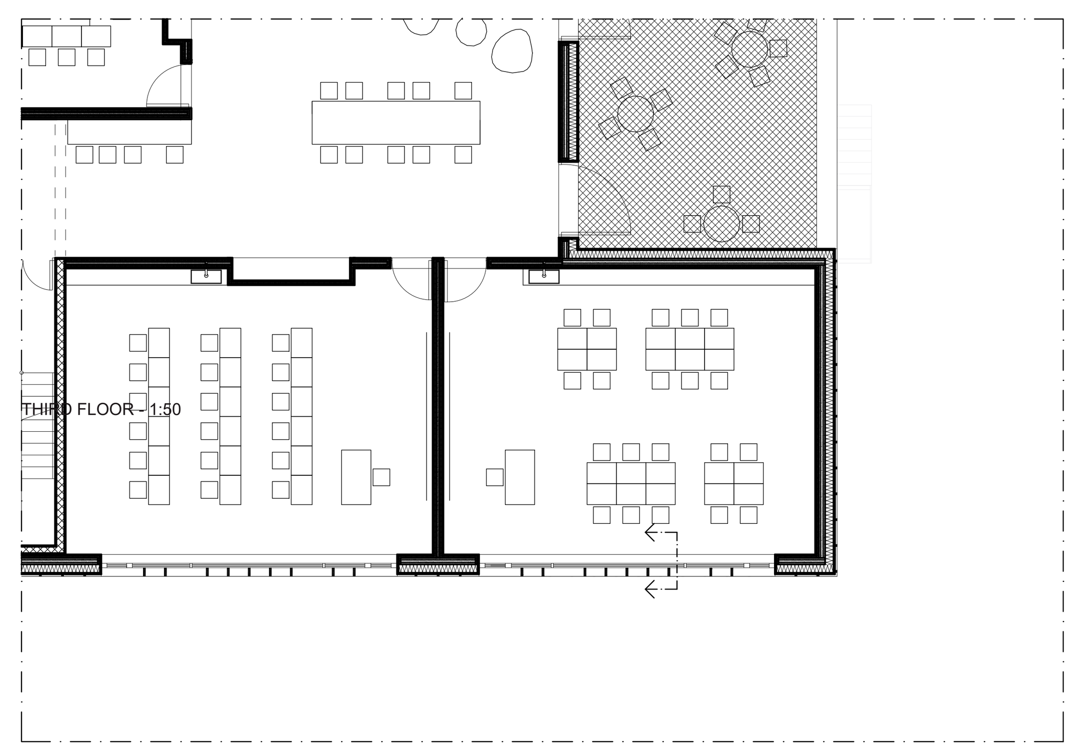
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SHEET NAME:
Section

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STUDENT:
S304114 Italo Paulesu

PROFESSOR:
Prof. Arch. Marika Mangosio

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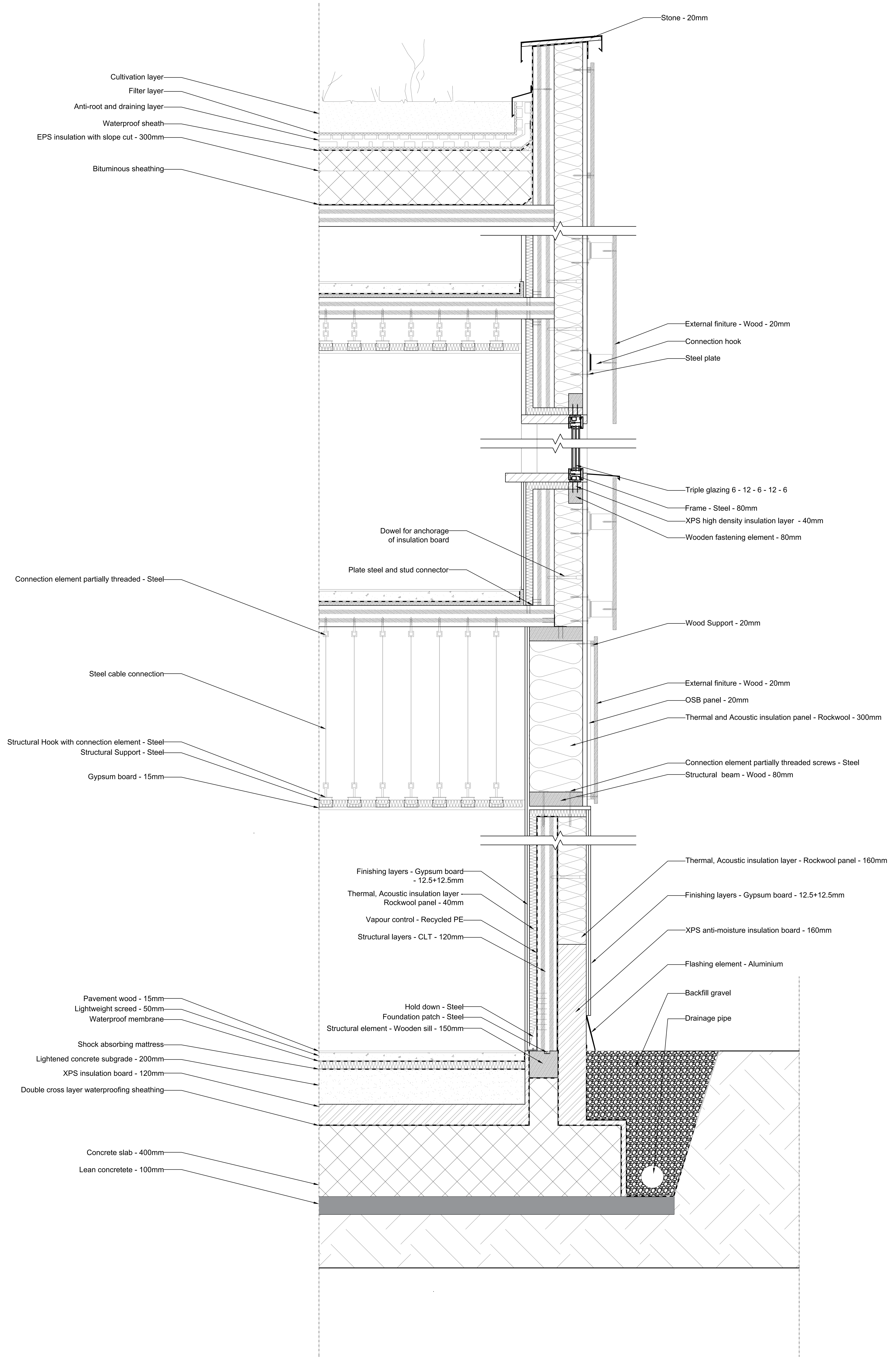

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Prof. Arch. Marika Mangosio

STUDENT:
S304114 Italo Paulesu

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SHEET NAME:
Nodes 01 - 02 - 03

Scale 1:10

NAME OF DRAWING

D 16