DENSIFYING POST WAR STAIRCASE ENTRANCE APARTMENTS

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ABSTRACT
This paper explores the densification of nontraditional post-war staircase entrance apartments in the Netherlands as a potential solution to the housing shortage. It examines the characteristics of nontraditional construction systems and their load-bearing capacities. The study employs methods such as literature review, research by design, and calculations. The results identify various densification strategies such as changing accessing, repurposing storage spaces, adding stories, and other extensions. The challenges associated with each strategy are analyzed. Calculations and literature research reveal that the foundation's capacity typically limits vertical extensions, recommending a maximum additional weight of 10-12%. Additionally, the inclusion of galleries is essential for certain densification types, with a maximum depth requirement of approximately 2000mm to comply with Dutch building regulations.

KEYWORDS: DENSIFICATION, NONTRADITIONAL CONSTRUCTION METHODS, STAIRCASE ENTRANCE APARTMENTS, POST-WAR CONSTRUCTION, FOUNDATION CAPACITY, HOUSING SHORTAGE, STRUCTURAL MODELING, LOAD-BEARING CAPACITY, EQUIVALENT DAYLIGHT AREA

1. INTRODUCTION

1.1. Housing shortage

The Netherlands currently faces a housing shortage of approximately 390,000 homes, based on household and housing stock statistics. Over the next fifteen years, a population growth of approximately 1.4 million people and an increase of 916,000 households are anticipated, requiring the creation of dwellings to meet these needs. Nearly 1.3 million homes are projected to be added through new construction, home splitting, and the transformation of vacant properties by 2038 (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, 2023).

1.2. Stock of staircase entrance apartments.

In the Netherlands, approximately 10% of the housing stock consists of ‘staircase entrance apartments’. Many of these buildings were constructed in the post-war era as a response to the pressing housing shortage of that time. Driven by the urgent need for housing solutions, they were standardized for efficiency and rapid assembly (Hunnik, 1998) (BouwhulpGroep advies en architectuur, 2016). Now, over half a century later, these post war neighborhoods have matured, but it’s evident that the world has changed. Almost without exception, post-war areas are currently facing various transformation challenges. This led the government to incorporate Reconstruction as one of the five themes of the Heritage and Space Vision between 2012 and 2016. The most significant changes facing existing neighborhoods now are energy transition and climate adaptation (De rijksdienst van cultureel erfgoed Amersfoort & Eikenaar, 2018).

1.3. Research question

There is a need to improve post-war housing, alongside an urgent need for more dwellings. A part of the housing shortage can be solved by densifying post-war staircase entrance apartment buildings. To maximize the densification, research will be conducted into densification strategies and the load-bearing capabilities of these buildings. The aim is to increase the square footage of the existing buildings without significant changes to the load-bearing structure.

Research question:
How can we effectively maximize the densification of staircase entrance apartment buildings in the Netherlands while making maximum use of the existing loadbearing structure of the building?

To answer the research question the following sub questions will be answered:
1. *What are the characteristics of the buildings systems in terms of basic information, numbers, material, construction methods and measurements*
2. *What are the solution principles to add square meters to the buildings?*
3. *What are the limitations of the existing loadbearing structure regarding adding stories, removing (parts of) walls to improve flexibility or removing (parts of) of facades?*
4. *What is the maximum addition in terms of added depth to the dwelling or added galleries to comply with Dutch building regulations concerning sunlight (equivalent daylight area)?*

2. METHODS

2.1. Literature study

To gather information about the construction methods of post-war housing, a literature study will be conducted. This will include a brief research into the historical context, followed by analysis of three relevant construction systems, which will be selected after the initial literature research. These systems will be analyzed to answer subquestion 1.

2.2. Literature study and research by design.

To address subquestion 2, a combination of literature study and research by design will be employed. This approach will provide deeper insights into chances and challenges of the principles for adding square meters to the buildings.

2.3. Modeling and Calculations

To answer subquestion 3, three buildings representative of one of the three identified systems will be modeled. The load-bearing structures will be analyzed using Autodesk Robot Structural Analysis software. This software is chosen for its comprehensive analysis capabilities focused on building structures. The software allows for precise simulation of various loads and detailed examination of structural integrity, making it an useful tool.

2.4. Research by design and calculations

The maximum addition of added depth to the dwelling or added galleries to comply with Dutch building regulations concerning sunlight will be researched with calculations based on of the modelled buildings.

3. RESULTS

3.1. Nontraditional Building systems

3.1.1. Historical context of post-war staircase entrance apartments

By post-war neighborhoods, we refer to areas that were built roughly from 1946 to 1968. During that time, there was a housing shortage due to an economic crisis and the aftermath of the war. Seventy percent of the early post-war housing stock was traditionally built with load-bearing party walls (Van Battum, 2002).

To address the housing shortage quickly, the emphasis was placed on quantity and production speed. Nontraditional labor-saving industrial construction methods were developed. Concrete was the primary material. The new systems were advantageous for larger projects. There are estimations that about 38% of apartments part of complexes with minimal of 100 dwellings are built with nontraditional constructions (Van Battum, 2002). Between the ,almost always, concrete systems, there are some differences. The systems are divided into four categories:

- **Stacking construction:** Stacking large concrete blocks.
- **structural elements construction:** Prefabricated concrete slabs as structure walls.

- **Finished structural elements construction**: Prefabricated slabs including inner wall, cavity and outer wall
- **Pouring concrete construction**: Cast-in-place concrete systems.
  (6% are staircase entrance buildings, therefore not considered relevant in this research) (Van Battum, 2002).

Three systems are examined: Rottinghuis, MuWi, and BMB. The systems are chosen because they represent each relevant category and were built in significant numbers. This paragraph gives a short introduction of the systems. Detailed images can be found in appendix 6.1.

System	categorie	Amount
Rottinghuis	Structural element	17.000
MuWi	Stacking construction	36.000
BMB	Finished structural element	30.000

Tabel 1 systems and amounts

3.1.2. Rottinghuis system

Approximately 17.000 dwellings were realized with the Rottinghuis system. From 1965 on, another company also used the system. That is why the system is known by two names Rottinghuis and IBC (Rijksdienst voor het Cultureel Erfgoed & bouwhulpGroep, 2016b). The system is a structural element construction method. Large concrete elements are produced with openings for windows and doors. On the construction site, elements are assembled into a frame and finished with an on-site brickwork cavity wall. The elements are connected by fixing the ends of the reinforcement with concrete. Consoles, facade columns, bands, and roof edge elements are anchored to the supporting structure using steel anchors (Andeweg, 2013). Due to its element-based construction method, certain conditions are required at the construction site. Cranes are necessary for assembling the dwellings, meaning a minimum size of 100 dwellings is required. With regular cranes, mid-rise buildings (up to four stories) can be constructed (Rijksdienst voor het Cultureel Erfgoed & bouwhulpGroep, 2016b).

3.1.3.MuWi

From 1951 to 1973, over 36,000 homes in the Netherlands using the MUWI system. Approximately 53% are staircase entrance apartment buildings, mostly built before 1965 (Rijksdienst voor het Cultureel Erfgoed & BouwhulpGroep, 2016a). MUWI is a stacking construction system. Lightweight concrete blocks (494x194x210mm) are stacked on top of each other and then filled with concrete. At floor height a reinforced concrete beam is poured in which the floor beams are anchored. This gives the system its recognizable look, concrete beams in the facades, dividing the stories. The floors are Concrete beams with concrete infill elements measuring 500-650mm. A screed is poured to create a cohesive whole. The roof uses the same system as the floor. The front and rear facades are mainly closed off by assembly frames. The side facades consist of a concrete MUWI inner wall, a cavity, and a masonry. Masonry is not structural and needs to be supported.

3.1.4.BMB

From 1949 until 1973, approximately 30,000 homes were produced using the BMB system (Rijksdienst voor het Cultureel Erfgoed & BouwhulpGroep, 2016c). BMB is a structural and finishing construction system with two types: BMB-I and BMB-II. The Prefabricated elements are provided with a tongue and groove joint, and connected with mortar. On site. The attachment to adjacent wall constructions is done with embedded anchors that fit into a recess and are finished. The façade consists of a half-brick exterior cladding panel, typically in a half-brick bond connected with a textured concrete inner cladding panel by galvanized strip steel anchors and a cavity. In the BMB-I system the element height has a maximum of half a story. The gross floor height is 2800mm (44 brick courses). Facade elements contain the entire cavity wall construction and are. In the BMB-II system the element height improved to one story height and a width of 4500mm (Systeembouw in Amsterdam. n.d.).

3.2. Strategies to densify

Now that research has been conducted into the history of post-war housing and the different building systems, dwellingsplans built with the three systems have been recreated. There was a masterplan for these kind of dwellings. Sizes were based on the minimal demands of the time. In the years following a lot of dwellings were still based on this example plan and show a lot of similarity see appendix 6.2. For clarity, three plans from old building drawings have been recreated and are visible in appendix 6.3. All the dwellings have the same basic layout, implying that the densification process and methods to extend/add square meters should be similar. In this chapter, the Rottinghuis system will be used as an example. A 3D model is made to explore various methods for adding square meters. Additionally, the challenges associated with these methods will be examined. A table with an overview of all the types of densification can be found in appendix 6.4.

3.2.1. Inside the building

3.2.1.1. Access

The accessibility can be changed from a staircase entrance to a gallery access. Each staircase typically serves two apartments on each floor. In a large residential block, this is not the most efficient use of space. Additionally, it is not possible to install an elevator due to space issues. By replacing the staircases by floor surface, more living space can be created. Calculations made clear that this could be an addition from 5,5 – 8,5% see appendix 6.5. This is different per building, but it gives an indication. The challenges are:

- Changes to apartment layouts: The hallways of the apartments are located in the middle of the plan. Changing the access requires shifting the hallway space to make the apartments accessible from the facade.
- Addition of galleries is needed. These galleries are connected to one big collective access. This means that it is more efficient to place an elevator, because it can be used by alle the inhabitants of a building.

3.2.1.2. Storage

Many postwar buildings feature ground-floor storage areas that could be repurposed into residential units. While this conversion does not increase the overall square footage of the building, it does add valuable living space. These ground-level dwellings, once realized, significantly could alter the appearance of the apartment complex and contribute to street-level vibrancy and safety. Challenges are:

- Every dwelling still needs to have storage space. Post war staircase entrance buildings often have storages bigger than the minimal requirements, maybe not all but a part of the storages can be transformed.
- Room height. These storages were built to be storage, so the room height could be insufficient regarding regulations.

3.2.2.On top

Extra stories can be added on a building. There are two ways to achieve this: with a new load-bearing structure to support new stories, or to use the existing load-bearing structure. It offers a significant increase in square meters, but it presents some challenges:

- Addition of accessibility: The new dwellings need to be accessed. This requires the addition of an accessibility structure
- Load-bearing challenges: The additional floors impose extra vertical forces on the walls and foundation. Additionally, the increased height of the building amplifies the wind forces, resulting in greater moment on the foundation.
- Urban tissue challenges: Not every area or building is suited for additional height due to factors such as shadow casting and changes to the urban environment.
- Fire safety requirements.

3.2.3. Underneath

Instead of adding living space on top of buildings, it can also be added underneath a building. This method is quite expensive. In cities like London, this phenomenon emerged at the beginning of this century, particularly among the most expensive properties in the city, and in recent years, it has also appeared in some of the more upscale neighborhoods in Amsterdam (Klaveren et al., 2021). The possibilities and costs depend on factors such as soil conditions, foundation, and location. Sometimes, during necessary foundation repairs, which are already a significant operation, a basement is added simultaneously. There are some big challenges:

- Installing a basement can affect groundwater flows, especially when basements are occasionally built within closed building blocks.
- Excavating a basement is a major renovation involving factors such as: inconvenience, including for neighbors, and temporary relocation.
- It is challenging for daylight entry and air circulation in dwellings.

3.2.4. Besides

To expand the building, the footprint can be enlarged by constructing new dwellings adjacent to the existing structure, either in a similar or different architectural style. This decision typically lies with the architect and is influenced by urban planning considerations. Several challenges need to be addressed:

- The addition requires a foundation next to the existing building.
- Impact on Natural Light. Many staircase entrance apartments have windows on the short facades. The addition of a new section may block these windows, resulting in reduced natural light within the apartments.

3.2.5. In front

The building's footprint can be expanded by deepening the structure, allowing for the extension of residential units. Partial deepening is also feasible. For instance, the ground floor can be expanded in front storage areas that do not require natural light. Alternatively, many post-war apartments feature recessed balconies, which can be repurposed as living space by extending the building's facade forward. Subsequently, new exterior spaces, such as galleries or balconies, can be added. There are challenges:

- The addition requires a foundation next to the existing building.
- Dwelling plans must avoid excessive depth, as sufficient natural light is crucial for habitable spaces, overly elongated dwellings are impractical.

3.3. 3D modeling and calculations

3.3.1.Introduction to calculation process

With the challenges of the proposed additions outlined, calculations regarding the load-bearing structure can now be conducted. Using information gathered from the literature review, table 2 summarizes key characteristics of the systems. All systems utilize concrete for the load-bearing walls, with typical thicknesses around 200mm (210mm for the MUWI system). While there are minor differences in the weight of the floors across the systems. The grid dimensions are also quite similar, as can be seen in appendix 6.3. This indicates that the buildings exhibit similar load-bearing capabilities. Calculations will be conducted for one case: the Rottinghuis system. The plans used for these calculations are from a project in Boerhaavewijk, Haarlem, Netherlands. Before the start of the calculation process, information was gathered from a concrete structure expert. A summary of the interview can be found in the appendix 6.6. The expert suggested that it is unlikely that the existing load-bearing wall structure is insufficient to support one or more additional stories. The limiting factor is probably the building's foundation. Adding new stories will increase the vertical forces on the foundation and the moment in the foundation caused by the wind. Another crucial factor to emphasize is the state of the building. The structure must be inspected for cracks to check the concrete quality to determine if it is strong enough. It is important to calculate conservatively.

The professor explained that it is unnecessary for this research to do an analysis by software. Because the buildings consist out of a concrete slab structure. This structure should be easy to calculate manually, as it contains linear monolithic elements. The calculation is conducted manually with excel sheets provided by the TU Delft.

Tabel 2 system characteristics

System	Rottinghuis	BMB-I	BMB-II	MUWI
Amount	17.000	30.000* BMB-I and II together	30.000* BMB-I and II together	36.000
Categorie	Structural element	Finished structural element	Finished structural element	Stacking system
Loadbearing walls	Prefab concrete Story height, width = room size 90-200mm	Prefab concrete (with cavity, bricks) Half story height 200, 250, 300mm Max dimensions 1400mm height, 4000mm width	Prefab concrete (with cavity, bricks) Half story height 180mm Max dimensions 2700mm height, 4500mm width	Muwi blocks: 494x194x210mm after that filled with concrete → solid wall
	23 kN/m3	**23 kN/m3**	**23 kN/m3**	
Interior walls	Prefab concrete Story height 70-100mm	(Siporex, Gibo, Durox, etc.) Also, proprietary textured concrete panels of 70mm thickness.	DATO system is typically used. This consists of monolithic elements of 70mm lightly reinforced, foamed gravel concrete	Lightweight lava stone, gypsum, and concrete are the most common materials.
	23 kN/m3	**varies**	**(1700-1800 kg/m3).**	**varies**
Floors	Gravel concrete 50mm slab 165mm raised edge Nodes + wooden floor 55mm 2480x4070mm. 25mm of sand added for acoustic quality.	Gravel concrete **H-type**:1580mm x 6000mm a thickness 170mm. Recesses 205 x 115mm high. **M-type:** solid concrete 2000 x 4500mm max Thickness: 110, 120 etc – 180mm.	Gravel concrete **H-type**:1580mm x 6000mm a thickness 170mm. Recesses 205 x 115mm high. **M-type:** solid concrete 2000 x 4500mm max Thickness: 110, 120 etc – 180mm.	Concrete elements 500-650mm center-to-center 20mm 180 elements 20mm 220mmm total.
	1,61 kN/m².	**H-Type** **Volume weight of 2400kg/m3.** **240kg/m2.**	**M-Type**	**1,7 kN/m².**
Roof	Similar as floor + insulation + bituminous roofing material	Similar as floor + insulation + bituminous roofing material	Similar as floor + insulation + bituminous roofing material	Similar as floor + insulation + bituminous roofing material
Facade	Concrete elements with a cavity construction and brick masonry. Same elements as interior- and loadbearing walls.	Half-brick exterior cladding panel. Typically in a half-brick bond, a textured concrete inner cladding panel (100, 143, 193mm), and a cavity of 40 to 50mm. All elements are prefabricated and a maximum of half a story high. The width is maximum.		The side facades consist of a concrete MUWI inner wall, a cavity, and a masonry outer wall. Masonry is not structural and needs to be supported.

The calculations can be found in Appendix 6.7.4. The U.C. (Unity Check) has been calculated, and its value must be lower than 1 to meet safety requirements. The U.C. measures the ratio between the concrete's strength and the pressure exerted by the building on a specific wall. The calculated value is UC = 0,88141/8,4 =0,0857. This value is low, likely due to the fact that the wall dimensions were primarily designed to meet minimum acoustic requirements. As a result, the 200mm walls are over dimensioned regarding to their load-bearing capabilities. And could easily hold multiple extra stories.

3.3.2. Stability

The front- and back façades of staircase entrance buildings are commonly not load-bearing in terms of vertical forces. It needs to be noted that – sometimes - they provide stability for the structure. This means when removing them, stability needs to be gained from inner walls. In the plans in the appendix can be seen that the cross walls around the staircase area already provide stability. These need to stay intact.

3.3.3. Foundation

As mentioned the foundation is probably the limiting factor in the addition of extra stories on top of the buildings. There are guidelines that say that for the additional weight on the foundation, generally an additional 10-12% weight is considered to be the maximum for building blocks from the early post-war period (Van Battum, 2002 p. 119 The foundations are not part of the building systems and therefore vary between projects. As a result, no calculation has been conducted and the 10-12% value of the literature research will be used.

3.4. The equivalent daylight area

In paragraph 3.2, which addresses the types of densification, it is noted that the inner balcony space can be converted into living space, with the potential addition of new balconies or galleries. The densification method to add square meters inside the building in the place of staircases also requires a new accessing system including galleries. A critical limiting factor for this addition is the equivalent daylight area which needs to be 10% of the square surface of every living area according to Dutch Building Code requirements. To research this, calculations have been made of the existing as well as of a new plan. This research and calculations can be found in appendix 6.8

Tabel 3 equivalent daylight area

space number	β max	Overhang max
1. 1	67	2067mm
2.1	72	3886mm
2.2	67	2057mm
2.3	68	2239mm
4.1	70	2528mm

4. CONCLUSION

To answer the question: 'How can we effectively maximize the densification of staircase entrance apartment buildings in the Netherlands while making maximum use of the existing loadbearing structure of the building?' The subquestions will be answered.

4.1. What are the characteristics of the buildings?

Firstly, it can be concluded that the three researched nontraditional building methods share significant load-bearing similarities. This is primarily due to their common utilization of concrete as the primary building material. The thickness of loadbearing walls across these systems generally ranges from 180-210 mm, with occasional variations observed in certain cases where thicker walls are employed for specific purposes. While there may be slight variations in floor weights among these systems, the overall consistency in structural elements suggests a fundamental resemblance.
Most plans of the staircase entrance buildings are based on the 'masterplan' from the magazine Bouw on December 18, 1948. The room sizes were based on the minimal requirements of the time. This is why the grid-sizes show similarities. However, it is essential to acknowledge that deviations from this standardization exist, indicating that a one-size-fits-all solution system is not universally applicable.

4.2. What are the solution principles to add square meters to the buildings?

"It can be concluded that there are multiple ways to add or densify square meters in staircase entrance apartments. These methods include modifying access (3.2.1.1), repurposing storage (3.2.1.2), adding stories (3.2.2), creating a basement (3.2.3), expanding next to the building (3.2.4), and extending the front of the building (3.2.5). Some of these methods involve modifications within the existing building structure and do not require significant load-bearing adaptations. However, others, such as adding stories or creating a basement for living, require substantial changes to the load-bearing structure.

4.3. What are the limitations of the existing loadbearing structure

It can be concluded that the walls of the load-bearing structures are overdimensioned, allowing for the addition of extra stories. However, the foundation is the limiting factor. Foundations are typically not part of the prefabricated building system and therefore vary between buildings. Literature suggests that the limiting factor for vertical extensions is commonly a maximum additional load of 10–12%.
Based on this, it can be concluded that with lightweight construction methods, such as timber frame construction or similar techniques, it is possible to add two stories. Adding more than two stories would likely exceed the 12% additional weight threshold, necessitating interventions in the foundation. Further research into foundation reinforcement or expansion is recommended to explore these possibilities.
The values used in this study are sometimes estimations due to a lack of detailed information regarding the concrete strength and the weight of materials or structural elements. Conservative estimations have been applied to avoid creating unrealistic expectations about the load-bearing

capacity of the buildings. Finally, it is important to watch the structural stability of the buildings. The stability is sometimes provided by the facades, if these facades are (partly) removed, stability needs to be gained from inside the building.

4.4. What is the maximum addition of added depth?

Multiple densification types require the addition of galleries or new balconies. These additions could be maximized to improve the quality of the outside space and therefore improve the quality of the building. It is calculated that the maximal addition for the Rottinghuis building in Boerhaavewijk is 2 meters. This value can be used as a guideline in projects, but will diver per building. In further research these calculations can be made for more project to get more average numbers. From created plans it seems that façade openings and plans are similar, so the expectation is that the outcome is similar, but this is not been proven yet.

4.5. Further research

It would be interesting to research various techniques for strengthening the foundations of post-war structures. Conventional methods often pose a problem due to the vibrations they cause. However, there are techniques with reduced vibrations that can be implemented adjacent to buildings, minimizing interference with existing structures.

5. References

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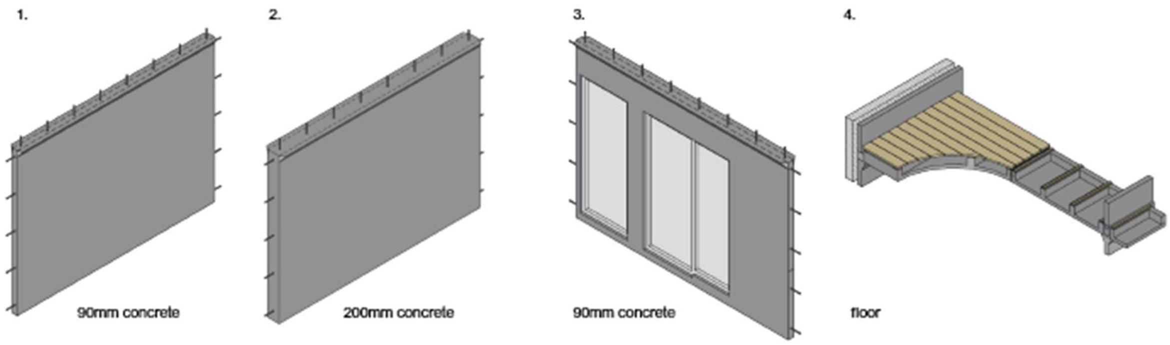
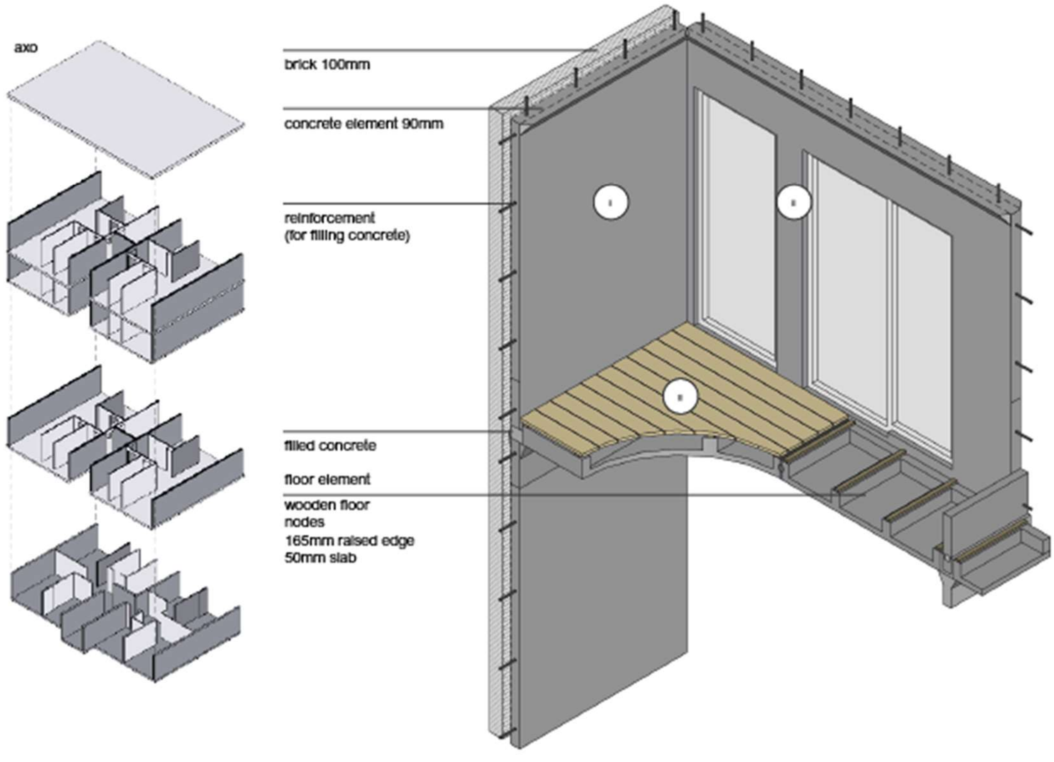
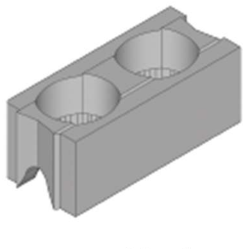
6. APPENDIX
6.1. EXPLAINING IMAGES
6.1.1. ROTTINGHUIS





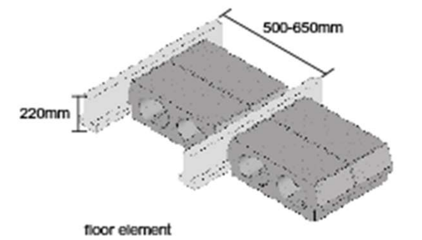
6.1.2.MUWI

1.

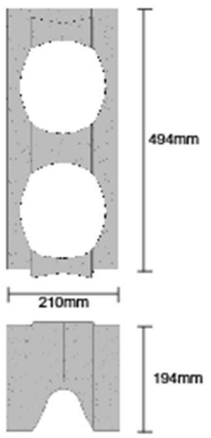


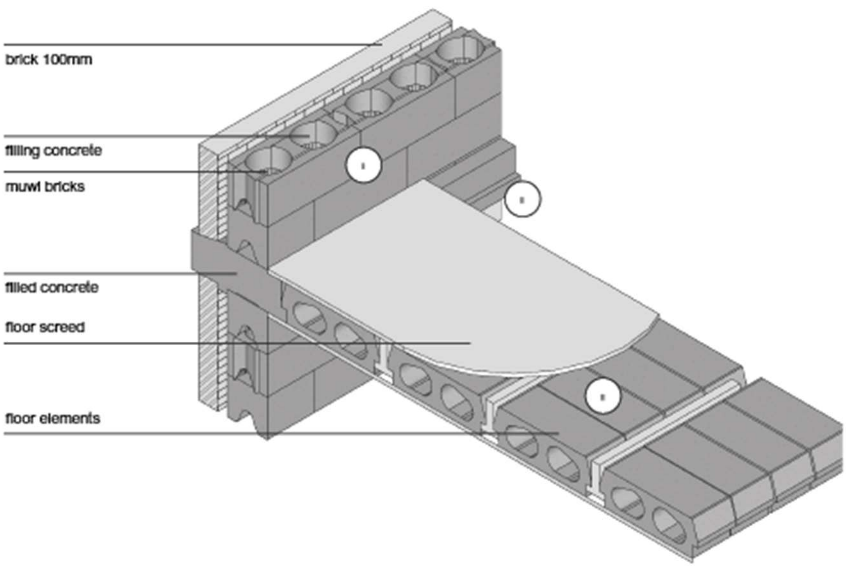
muwi element

2.

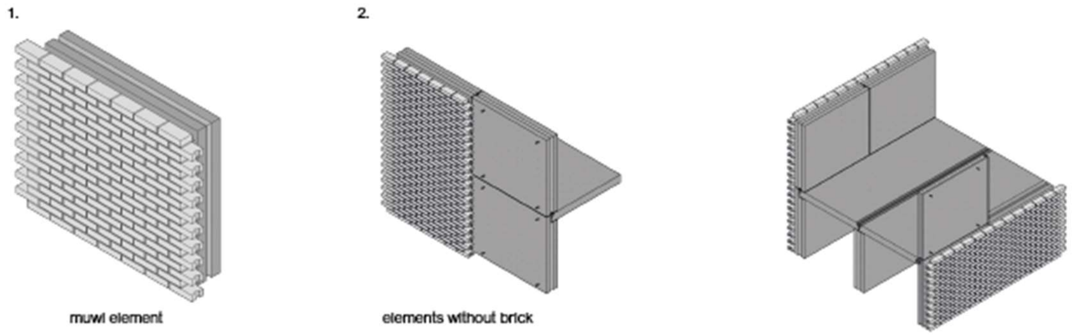


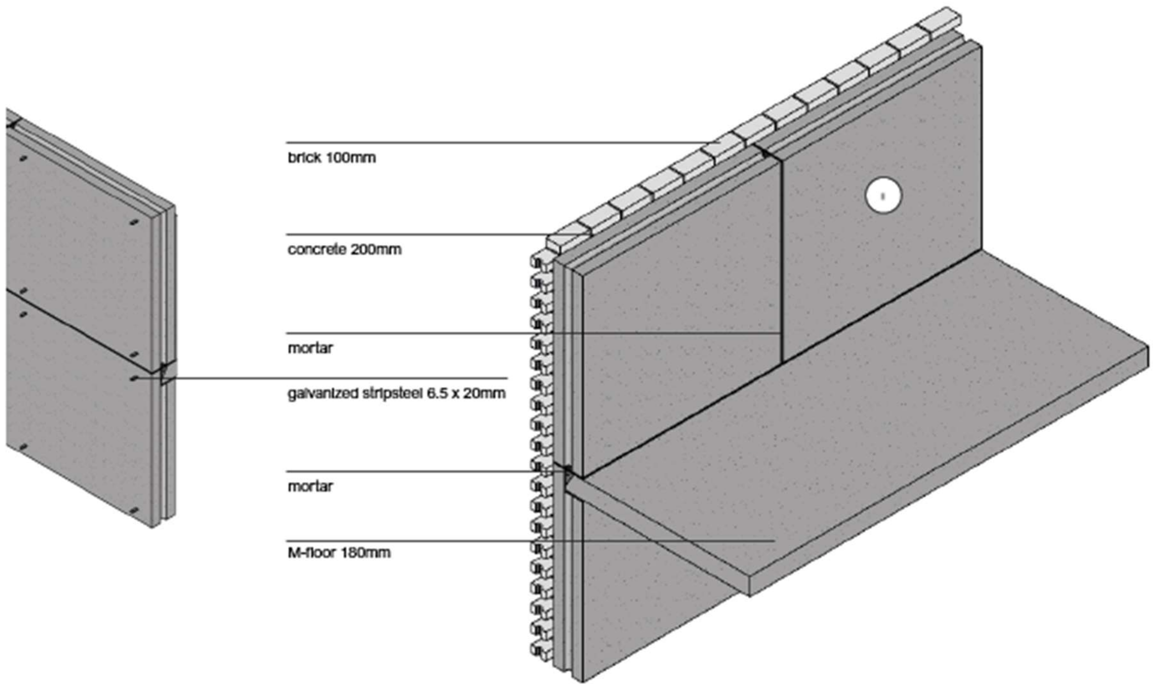
floor element





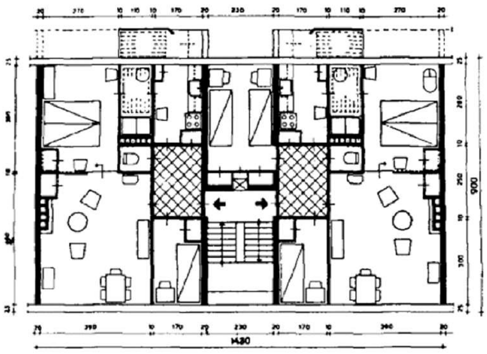
6.1.3. BMB


1.
2.
muwi element
elements without brick


brick 100mm
concrete 200mm
mortar
galvanized stripsteel 6.5 x 20mm
mortar
M-floor 180mm

6.2. PLANS OF STAIRCASE ENTRANCE APARTMENTS

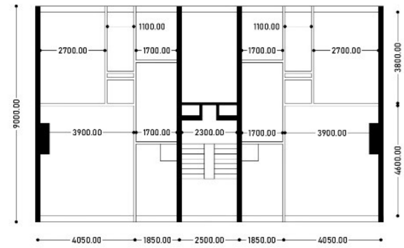
The standard floor plans relating to staircase entrance apartments were published in the magazine Bouw on December 18, 1948, and in the Bouwkundig Weekblad in 1952 on pages 910 to 932. In 1967, a classification was added to this collection of standard floor plans, which was published in the magazine Bouw. The most common plan is type E (8.3.1).



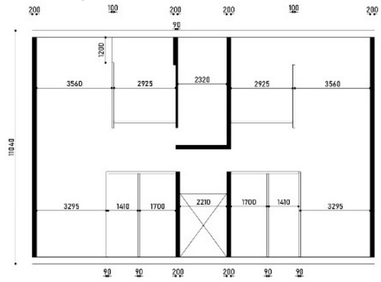
A dwelling falls under this category if the living room has the largest dimension perpendicular to the facade and if the kitchen is accommodated in the adjacent bay and is located on the other side of the facade. The main bedroom is then located behind the living room in the same bay. The dimensions were determined by the minimum standards prescribed in the then-current Regulations and Guidelines. In addition to these minimum dimensions, the dwelling also had to have a certain surplus. The location where this surplus was provided was the choice of the architect. The width of the bay in which the living room is accommodated had to be at least 3.50 meters. In reality dimensions between 3,50 and 3,90m were used. The changing room was often considered the double childrens room. The minimum width for this was 2,30meters. This resulted in a staircase hall of the same width. The depth of the staircase hall was determined by a common stair slope of 42 degrees and the usual floor height of 2.80 meters, resulting in a depth of 3.60 meters. Two homes are accessed via the portal. There are two types: the front doors next to each other or the front doors opposite each other (Van Battum, 2002).

6.3. PLANS

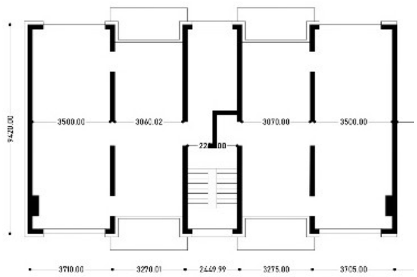
Traditional 57m2 and 48m2



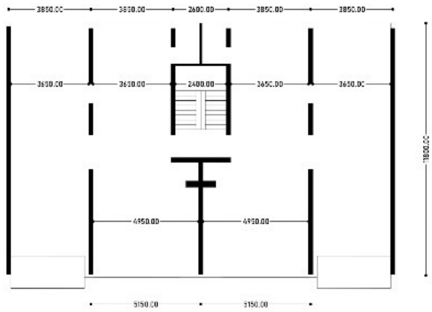
Rottinghuis / IBC 71m2 and 59m2



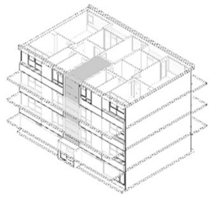
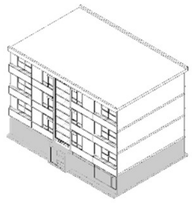
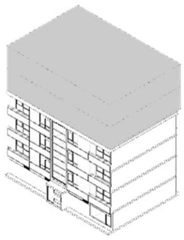
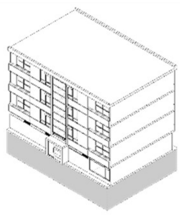
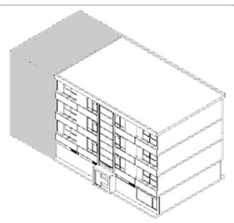
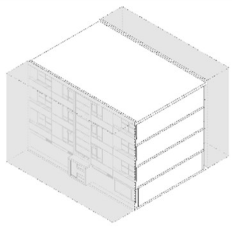
MuWi 66m2 and 57m2



BMB 93m2 and 93m2

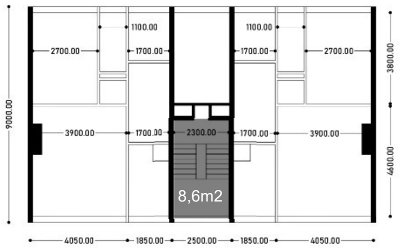


6.4. Densification strategies

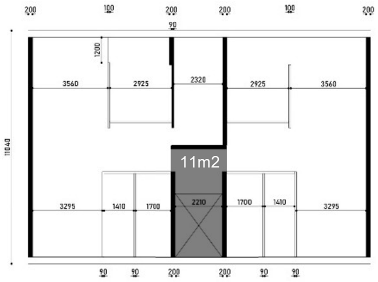
Chapter	Image	Challenges	Opportunities
3.2.1.1 access		Plan layout New galleries	More spacious apartment plan Qualitive galleries access Elevator
3.2.1.2 storage		Still need enough storage space Room height Access	less anonymous building social security
3.2.2 top on		Access Urban tissue, height Shadow casting Loadbearing construction - foundation - walls - on-top weight	Big addition of dwellings Architectural chances, change looks
3.2.3 basement		Expensive Very big intervention Groundwater Ventilation Natural light	Big Addition of space Can be combined with fixing foundation issues
3.2.4 next		Blocking existing windows New foundation against existing foundation Urban tissue	Big addition of space Architectural chances, change looks
3.2.5 front		Blocking existing windows New foundation against existing foundation Urban tissue Deep dwelling plans	Architectural chances, change looks Using non used space Only a few stories

6.5. PLANS NO STAIRCASE

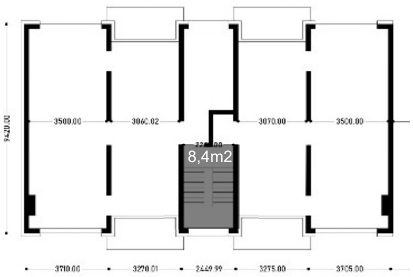
TRADITIONAL 57m2 and 48m2



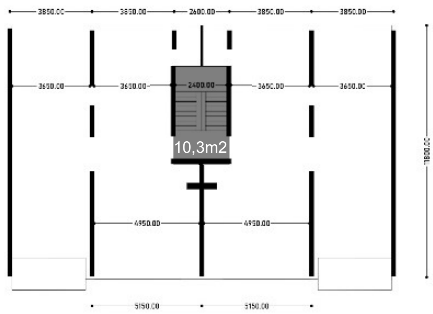
ROTTINGHUIS 71m2 and 59m2



MUWI 66m2 and 57m2



BMB 93m2 and 93m2



system	m2 dwelling 1	m2 dwelling 2	m2 dwellings togehter	m2 staircase area	addition percentage
traditional	57	48	105	8,6	8,2%
rottinghuis	71	59	130	11	8,5%
muwi	66	57	123	8,4	6,8%
BMB	93	93	186	10,3	5,5%

6.6. Summary conversation with Prof.ir. A.Q.C. van der Horst (translated)

- All concrete systems can be considered as equivalent slabs in the calculations if they have the same width. The quality of the concrete is difficult to determine, but use the qualities from the found documents, if not make low estimations.
- The systems from that time are over-dimensioned. This also relates to other factors such as acoustics, etc. The breaking point for adding additional weight will likely not be the wall structure, but the foundation.
- There is an important difference in foundation types. Do research into the foundation from the cases. It will probably be pile foundations, but could be foundation.
- First, conduct a feasibility study of Rottinghuis. The biggest breaking point on the foundation is likely the wind load.
- The foundation can be strengthened, but this is very complicated. A combination foundation is possible, but very difficult to calculate and not preferred. The renovation piles used in such cases have a different stiffness than the original ones.
- Do a manual calculation for the systems, it does not need to be too complicated. Assume concrete strength from literature as previously mentioned. Mention that a technical inspection must always be conducted first in the case of transformation/renovation/densification.
- Wind shape factor can diver from shape of the optopping.
- The problem with piling is the vibrations. Sheet piling, vibrating in, risk of damage.
- Concrete quality. Use conservative values. This is due to the chemical processes used at the time that have a influence on the concrete.
- 2250P 30N/m³ cube
- Strengths: BB22.5, 30, 45 compressive strength.
- Prefab likely has reasonable quality.

6.7. Load-bearing calculations

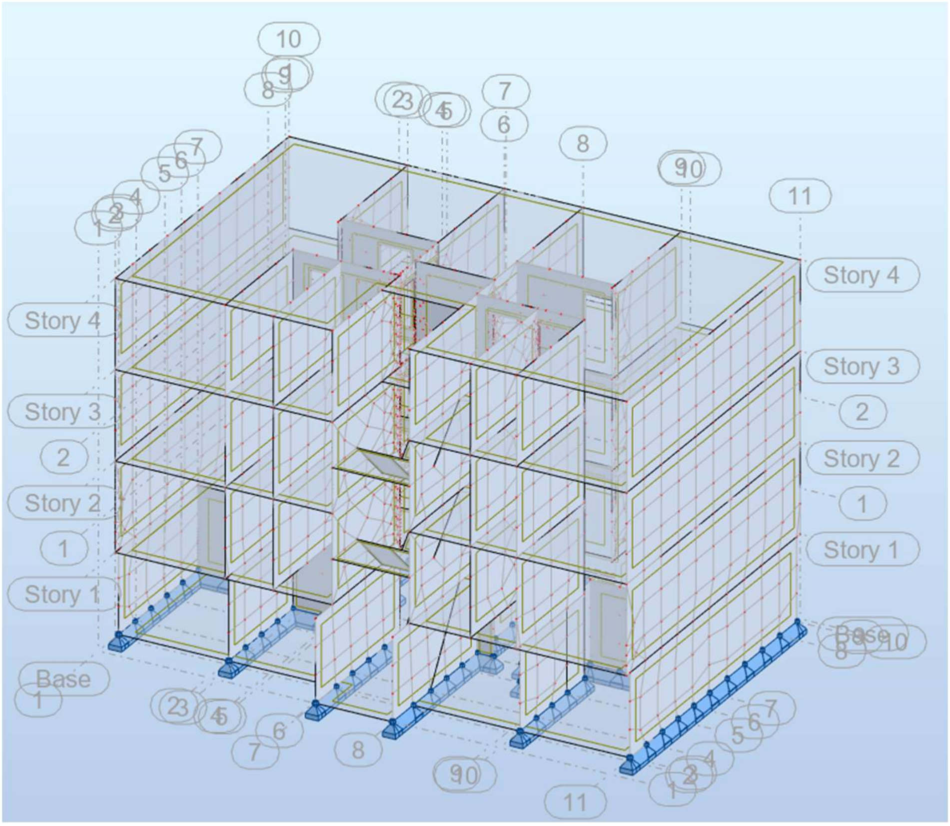
6.7.1. Calculation floor weight Rottinghuis

Volume per element: 1 element 0,2 m³
Total volume per 8: 0,2 m³/element x 8 elements = 1,6 m³
Material density: 2100 kg/m³
Total mass: 2100 kg/m³ * 1,6 m³ = 3360 kg
Surface: 20,47 m²
weight per square meter: 3360 kg / 20,47 m² ≈164 kg/m²

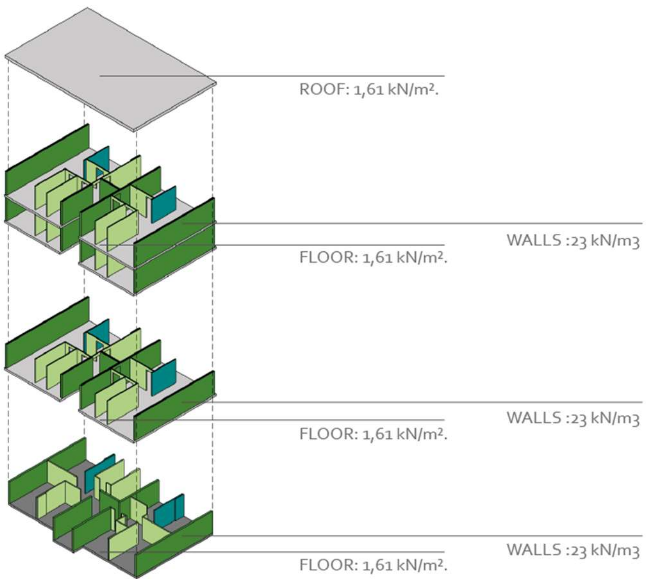
kg to N: 1 kg = 9,81 N
Force = kN/m²: 164 kg/m² ×9,81N/kg= 1608,84N/m²
1 kN = 1000 N
1608, 84 N/m²÷1000=1,60884 kN/m²
Conclusion
The weight of the floor is 164 kg/m² / 1,61 kN/m².

6.7.2.Calculation floor weight Rottinghuis

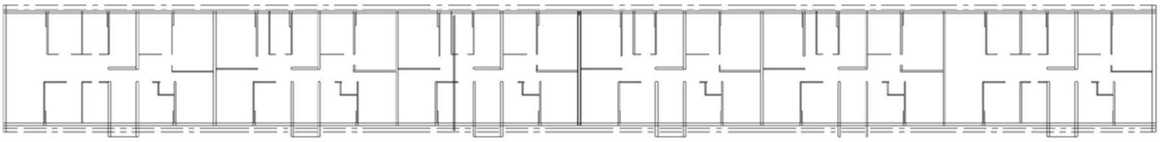
Analysis in Robotic structural analysis

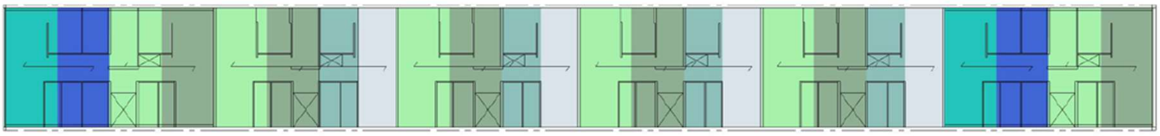


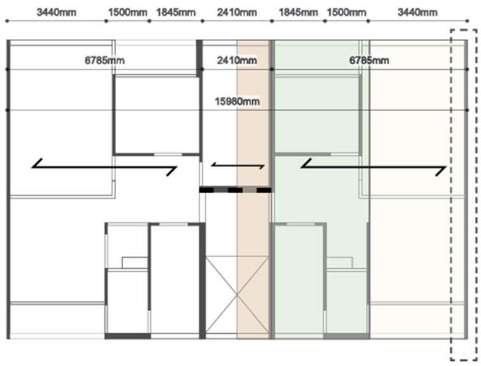
6.7.3. 3D model with weight Rottinghuis

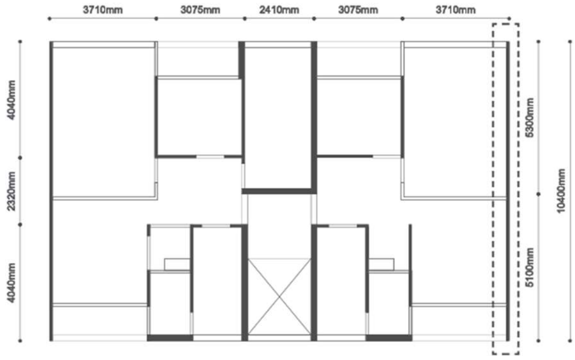


6.7.4. Load-bearing plans and calculations.









forcetype	Eurocode [kN/m2]		
weight floor	story floor: 1,61[kN/m2]	Groundfloor (check)	
weight walls	200mm 4,6kN/m2	100mm 2,3kN/m2	facade: 1,5 kN/m²
Imposed load	floors1,75 balcony: 2,5	stairs: 2,0	roof: 1,0
wind load	0,8		

gewichtstabel Eurocode

materiaal wand: beton wandbreedte: 10400 mm wanddikte: 200 mm

Gewichtstabel	lengte [m]	breedte (hoogte) [m]	bel./m²	blijv. belast. [kN]	tot. blijv. per verd. [kN]	verand. belast. [kN]	factor ψ	Te reken. ver. bel. [kN]
Dak								
Opgelegde belasting =	10,4	6,88	1			71,552	1	71,552
Gew. dakconstr. =	10,4	6,88	1,61	115,2				
Gewicht wand =	10,4	2,59	4,6	123,91				
--->					292,564			
4de verdieping								
Opgelegde belasting =	0	0	0			0	0	0
Gew. vloerconstr. =	0	0	0	0				
Gewicht wand =	0	0	0	0				
--->					0			
3de verdieping								
Opgelegde belasting =	10,4	6,88	1,75			125,216	1	125,216
Gew. vloerconstr. =	10,4	6,88	1,61	115,2				
Gewicht wand =	10,4	2,59	4,6	123,91				
--->					292,564			
2de verdieping								
Opgelegde belasting =	10,4	6,88	1,75			125,216	0,4	50,0864
Gew. vloerconstr. =	10,4	6,88	1,61	115,2				
Gewicht wand =	10,4	2,59	4,6	123,91				
--->					292,564			
1ste verdieping								
Opgelegde belasting =	10,4	6,88	1,75			125,216	0,4	50,0864
Gew. vloerconstr. =	10,4	6,88	1,61	115,2				
Gewicht wand =	10,4	2,39	4,6	114,34				
--->					278,916			
totaal in kN =				blijvende belasting = G:	1156,61		ver. bel. = Q:	296,941

partiële factor $\gamma_{f,G}$ =	1,2	part.fact. $\gamma_{f,Q}$ =	1,5	$F_{G;d}$ = 1387,93	$F_{Q;d}$ = 445,411
F_{cd} =	1833,3	x 1000 =	1833342 N	A = 2E+06	$\sigma_{cd} = F_{cd}/A$ = 0,88141

the plans of the whole building get repeated. as can be seen in the information above. The calculations will be made for the most critical wall. The wall that carries the most weight. This wall is shown in the drawings. information about the loads can be found in the table. The floor span being supported measures 2 x 3.44 meters. This information will be entered into an Excel sheet.

Additionally, the facades are supported by the floor and, consequently, by the load-bearing wall. This adds another load equivalent to 3.44 x 2 x (height), where the height is 2.59 meters. Since this applies to both sides, the load is multiplied by 2.

stories:
facade load: 6,88m x 2,59 x 1,5 x 2 = 53.46kN
ground floor:
Facade load = 6.88m × 2.39m × 1.5kN/m2 × 2= 49.38kN
The total load will be added into the calculations for each story in the Excel sheet.

With all the available information, the Eurocode calculations can be performed. These are shown in the table on the right. To determine whether the calculation meets the Eurocode requirements for precast concrete, we need to verify the ratio of compressive stress σ cd to compressive strength f cd. This ratio gives the utilization coefficient (U.C.), which must be less than or equal to 1.

To determine this, we need to know the compressive strength of the material. This refers to the compressive strength of the concrete used in the Rottinghuis system in the 1960s. Based on the advice of Prof.ir. A.Q.C. van der Horst, conservative values are used. This is due Due to the chemical processes applied at the time, which influenced the concrete's properties, a conservative compressive strength of 22.5 MPa is assumed.

The compressive strength of concrete is calculated using the formula:
f cd = α * (f ck,cilinder/ γ c).

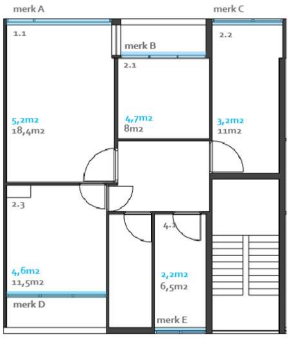
A deterioration factor of 0.7 is applied because the structure is older than 20 years. This means
f cd oud =
f cd = 0,7 x (18 / 1,5)= 8.4MPa.

UC = 0,88141 / 8,4 = 0.0857.

This indicates that the strength of the wall is much greater than what is actually required, resulting in significant over-engineering. One reason for this is that the building was constructed using a standard-prefabricated system, which means there was no variation in wall thicknesses. Additionally, many of these wall widths were designed primarily to meet minimal acoustic requirements, rather than being optimized for their load-bearing capacity.

6.8. SUNLIGHT

6.8.1. Rules and information



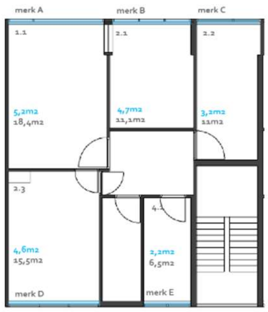
The Dutch building regulations categorize a building with a residential function into two types of rooms: living spaces and non-living spaces. Living spaces include rooms such as bedrooms, living rooms, dining rooms, and workrooms. These spaces have a specific square meter value and require a minimum equivalent daylight area (Aeq), which must be at least 10% of the room's surface area.

Calculations have been made based on the plans of the Rottinghuis system. The building used for the calculations is a staircase entrance apartment building in Boerhaavewijk in Haarlem. The plan with the values of the window- and room surfaces can be seen next to here. With these values the following table is filled in:

m2 space	space number	W. frame	Ad:i W.surface	α	β	Cb:i	Cu:i	CLTA	Aeq	0,5m2?	10%	meets 10%? Requirement
18,4	1. 1	merk A	5,2	20	0	0,8	1	1	4,16	yes	1,84	yes
8	2.1	merk B	4,69	20	51,9	0,6	1	1	2,814	yes	0,8	yes
11	2.2	merk C	3,2	20	0	0,8	1	1	2,56	yes	1,1	yes
11,5	2.3	merk D	4,6	20	53,6	0,58	1	1	2,668	yes	1,15	yes
6,5	4.1	merk E	2,2	20	0	0,8	1	1	1,76	yes	0,65	yes

There are certain rules to the window surfaces. Window surface underneath 600m from the floor does not count within the surface (Ad:i). The Cu:i has to to due with surrounding obstacles and is not relevant here. There are two angle which are relevant and give Cb:i.
α the angle between the middle of counting window surface. β is the angle between the bottom of the window surface and the height of an obstacle. The minimum value of this angle is always 20 degrees. It is not exactly clear which type of glass is used in the windows, but it is currently either single or double glazing. For single glazing, the LTA (Light Transmission Area) typically ranges from 0.85 to 0.90. For double glazing, specifically HR++ double glazing, the LTA is usually around 0.75. Since both types of glass have an LTA greater than 0.60, the CLTA (Corrected Light Transmission Area) is 1.

6.8.2.Calculations



The goal of the calculation is the calculate the maximum measurement of the overhang of the galleries or balconies. The value which is needed is the angle β. This value can be read from the table NEN2057:2011 and is connected with angle α.

For calculating the new plans will be used. In this plans the existing inner balcony is transformed into living space and a new outside space is created. This plan can be seen here with the values. The same window frame are used, they are moved 1200mm to the front of the facade to create more living space. Therefor the Ad;i will still the same

The formula for calculating Aeq is as follows:

$Aeq = Ad;i\ x\ C\ b;i\ x\ Cu;i\ x\ CLTA$ → Given that CLTA=1 and Cu;i = 1 → $Aeq = Ad;i\ x\ C\ b;i$ → $Cb;i = Aeq/Ad;i$

Now calculations can be done, because these values are available for every space. In the table the created formula is filled in. Given that angle α is 20 degrees the angle β can be read from table 1 in NEN 2057:2011. The following table is filled in now:

m2 space new	space number	W. frame	Ad:i W.surface	10%	Cb;i	β max
18,4	1. 1	merk A	5,2	1,84	0,354	67
11,1	2.1	merk B	4,69	1,11	0,237	72
11	2.2	merk C	3,2	1,1	0,344	67
15,5	2.3	merk D	4,6	1,55	0,337	68
6,5	4.1	merk E	2,2	0,65	0,295	70

All the values of the angles can now be modelled in the 3d model. In every room the maximum angle has been modeled to generate the maximum overhang. The measurements are shown in every living space.