IN FAVOR OF FLOW
AN INNOVATIVE PROJECT OF RESIDENTIAL TOWER BASED ON THE ENFORCEMENT OF NATURAL VENTILATION IN TIRANA CITY CENTER.

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ABSTRACT

IN FAVOR OF FLOW
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Building cooling, heating or ventilation accounts for 40% of the total amount of building energy used globally. In this aspect there is an increasing demand to implement low energy strategies which promote natural ventilation and passive cooling especially in hot climate conditions. Albania as part of the Mediterranean is subjected to a rather hot summer, and Tirana as its capital and most dense city suffers this phenomena even more, thanks also to the urban heat island effect. This study proposes strategies to develop a residential tower by using innovative approaches in natural ventilation. Through research and multiple proposals an optimal scheme is chosen to be developed which will perform best under the hot weather of Tirana.

Keywords: Sponge concept; Sustainable architecture; Natural ventilation; Parametric design, Residential tower

ABSTRAKT

NE FAVOR TE RRYMES
NJË PROJEKT INOVATIV I KULLËS SE BANIMIT, BAZUAR NË ZBATIMIN E VENTILIMIT NATYROR, NË QENDËR TË QYTETIT TË TIRANËS.

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Ftohja e ndertesave, ngrohja dhe ventilimi perbejne 40% te energjise qe perdoret ne ndertesa boterisht. Ne kete drejtim vihet re nje kerkese ne rritje per te zbatuar strategji te cilat kerkojne pak energji dhe qe promovojne ventilim natyror dhe ftohje passive ne kushte klimaterike te nxehta. Shqiperia si pjese e mesdheut ndodhet nen veprimin e nje vere te nxehte, dhe Tirana si kryeqytet is saj dhe njekohesisht qyteti me I dendur e vuan kete fenomen edhe me shume, fale gjithashtu veprimit te ishujve urban. Ky studim propozon strategji per te zhvilluar nje kulle residenciale duke perdorur perqasje inovatore ne ventilim natyror. Perms metodave kerkimore dhe disa propozimeve, nje skeme optimale zgjidhet e cila performon mire nen motin e nxehte te tiranes.

Fjalët kyçe: Koncepti ‘sfungjer’; Arkitekture e qendrueshme; Ventilim natyror; Dizenjim parametrik, Kulle banimi.

Dedicated to my little brother!

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Proper design of energy-conscious buildings requires a balance between the acceptable quality of the indoor climate in terms of thermal comfort, ventilation effectiveness and indoor air quality. Ventilation is the movement of air within a building and between the building and the outdoors. The control of ventilation is one of the most subtle and yet the most important concerns of the building designer [Roaf, 2001]. Ventilation can be categorized as mechanical or natural, where mechanical involves fans to drive the flow of the outside air into a building, while natural utilizes the natural air pressure to ventilate the building.

It is a very used practice to use wind for natural ventilation, nevertheless the two are not the same things since in dry climates wind ventilation is undesired. Wind presents itself in lots of forms, from weak air current to strong pressure wind, therefore wind design is an ultimate concern regarding comfort. To produce a good ventilated house, it is first necessary to develop a relationship with wind. To do this understanding the regional and local climate of the site, plus the form and surroundings of the building is of primary importance. Moreover, other key elements, are the building's occupants and their comfort requirements [Roaf, 2001]. Ventilation is needed for fresh air supply, for direct comfort ventilation of the occupants, and for the indirect ventilation for heating and cooling.

As a result, natural ventilation improves thermal, air quality and visual performance, thus improving productivity and comfort.

1.1. Identification of the topic

This work examines the relationship between building design and natural ventilation. Building heating, cooling, and ventilation energy consumption account for nearly 40% of the total building energy use mainly in the US but also globally [U.S Department of Energy, 2008]. The potential for saving energy through building control systems varies from 5% to 20% based on recent market surveys.

In Albania the energy going for building use accounts a considerable percentage, given also the fact of possessing a hot dry summer which requires extensive cooling energy. The major problematic is the absence of standardization and the requirements of some minimal self-sufficiency.

After the totalitarian regime, the state proved to be incapable to monitor the building sectors, which was the most critical sector in need to be developed. All of this resulted in a high unsustainable growth, majorly due to informality and partially due to the absence of well-prepared architects. The booming sector of construction monopolized by private investors generated low cost dwellings which in the long term proved to be inefficient and costly to maintain human comfort.

Now, 25 years later, while informality is being treated in national level, there is still an absence for same regulations in the construction sector. Especially Albania, located in the Mediterranean, suffers from hot dry climate in summer which extended for nearly 5 months necessitated sustainable ways of cooling which will perform well in the long term. Ventilation exist only as a definition in the vocabulary of most architects in Albania, for by now is hard to find a good example of a well-ventilated building. To continue except the lack of some ventilation regulations in dense cities like Tirana, there is also the problematic of pollution, which provided there exists a good air flow in buildings would also need to assess the problem of polluted ventilation.

The aim of this project is to experiment with a well-ventilated tower residential typology in the center of Tirana and test the results of this kind of intervention. The lack of urban spaces in the center creates the need for high-rise which will take in consideration environmental factors namely: ventilation, sun exposure, building geometry.

1.2. Object of study

The object of study is a high rised residential building, located alongside the Lana river near the police headquarters. Based on the criteria of natural ventilation and urban requirements, the proposal will involve a 15 storey high building with improved natural cross ventilation with the final goal of having a new type of tower design in Albania.

1.3. The aim of the study

The purpose of the research is to design a residential high-rise eco sustainable tower. This project aims to minimize the energy consumption on mechanical equipment and to enhance the quality of the building in terms of comfort improvement and indoor air quality. This will be achieved in several steps:

- To create a set of rules to deal with tower typology (sponge design).
- To design a model of implementation.
- To demonstrate the effect natural ventilation design has on the sustainability of tower building typologies

1.4. Identification of the design question

How does architecture affect the natural ventilation in buildings and more important how does natural ventilation affect architecture? The project will deal with identifying the effect of different types of tower morphologies in the natural ventilation of each apartments.

1.5. Methodology

The purpose of the study is to generate a new building typology which is self-sufficient in terms of cooling strategies. The preliminary conclusions include: Minimization of losses, Maximization of solar gains in terms of light, Maximization of passive cooling methods.

In continuation three different abstract models will be generated namely: a-Traditional, b-Courtyard, c-Sponge design. Each of these modes will be further tested in order to pick the best performing one.

Through software like ‘Autodesk Flow Design’ the results can be tested in terms of ventilation, marking a new paradigm in dealing with tower typologies in Albania.

Selection of the model based on the desired criteria.

Preparation of the selected model in a detail level of 1/200.

Analysis of the group of constrains which shape the building like: Regulatory plans, Index of development, environmental factors etc.

CHAPTER 2

LITERATURE REVIEW AND CASE STUDIES

2.1. Natural ventilation and building shape

Today more and more emphasis is given to natural ventilation as a sustainable way of development and carbon emission reduction. Since people spend most of their time in indoor activities, good ventilation is an essential factor for the occupant's comfort. We ventilate buildings to provide fresh air supply, for direct comfort like cooling the rooms, for indirect comfort to cool the building structure which will further cool the rooms indirectly, and to use free energy more efficiently [Roaf, 2001]. Generally speaking, there are two major categories in which ventilation occurs, all of which because of the pressure's difference between the regions. Cross ventilation and single sided ventilation are the elements a building can incorporate with the first one being far more preferred since it provides the necessary pressure difference for air flow *(Fig. 1)* [Andersen *et. al.*, 2002].

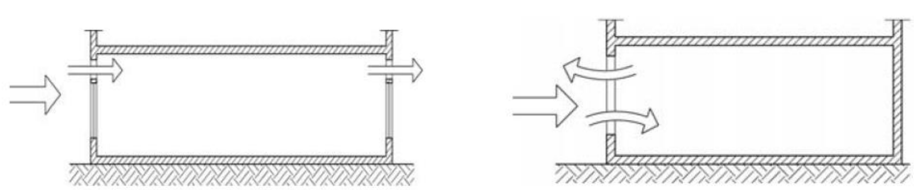


Figure 1. Cross ventilation and single sided ventilation Source: [Andersen *et. al.,* 2002]

The pressure difference can be achieved in two ways: either by using the natural difference created between indoor and outdoor spaces or by using the pressure difference created by the pressure variations within the house [Roaf, 2001] Nevertheless the main step of achieving a good ventilation design is to know the wind, its angle, speed, and its temperature. Cross ventilation is indeed mainly driven by the wind properties as long as the height difference of the openings is the same [Larsen, 2006]. With a difference in height the cross ventilation will also be affected by the divergence of temperature [Larsen, 2006].

Roaf (2001) describes the different types of air circulation depending on the positioning of the apertures *(Fig. 2).* The results show that buildings with openings which face each other tend to be more ventilated compared to the ones which have openings adjacent to one-another. Also in a combination of both adjacent and frontal openings the results show that the wind becomes weaker when passing the apertures.

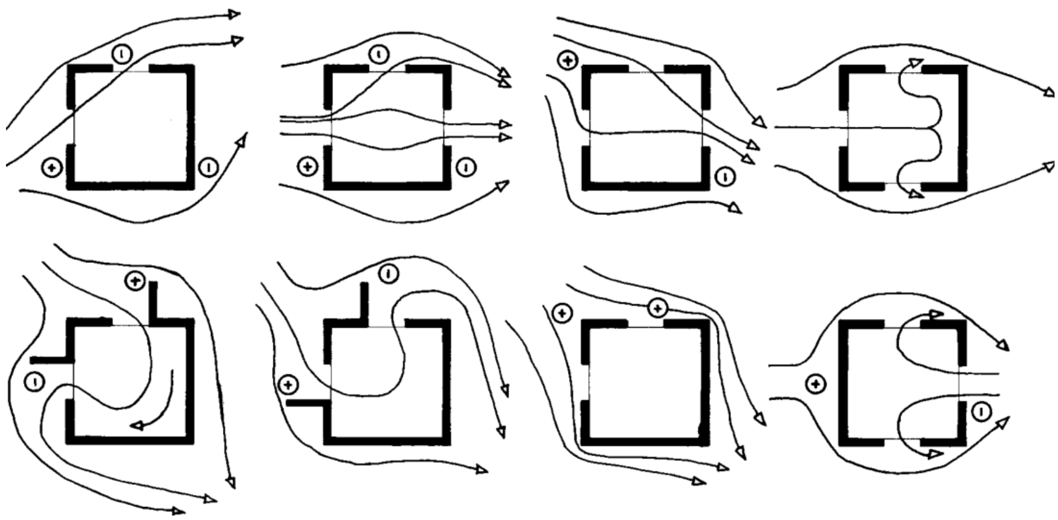


Figure 2. Different combinations of cross ventilation [Roaf 2001].

To continue the ventilation is not only dependent by planar distribution of windows, but also by the outer design of the building envelope. In this context Kindangen (1997) has studied the effect of the wind in the façade with opening varying from each proposal *(Fig. 3)*. The section cut of the samples shows that the lower the distance from one opening to the other the greater the wind speed and pressure exerted in the interior. The desired output in ventilation design is to have strong pressure even in the deepest parts.

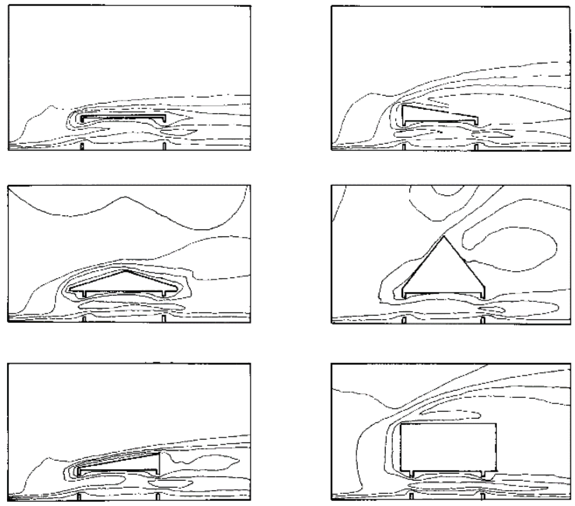


Figure 3. The greater the distance the more pressure in the façade facing the wind and the less in the opposite façade [Kindangen, 1997]

Another factor which directly influences cross ventilation is the exposure to the sun. Roaf (2001) suggests that in order to have different air pressure for ventilation we need to maintain a difference in temperatures from the outside to the inside thus a need emerges to diminish the solar gains in summer. Also it is necessary to have a greater thermal mass in order to maintain good passive ventilation and reduce the peak temperatures peak in the summer.

As a rule of thumb, but not limited to it, rooms which use cross ventilation can be two times longer than those which use only single sided ventilation. These parameters are also related with the height of the ceiling *(Fig. 4)* [Roaf, 2001].

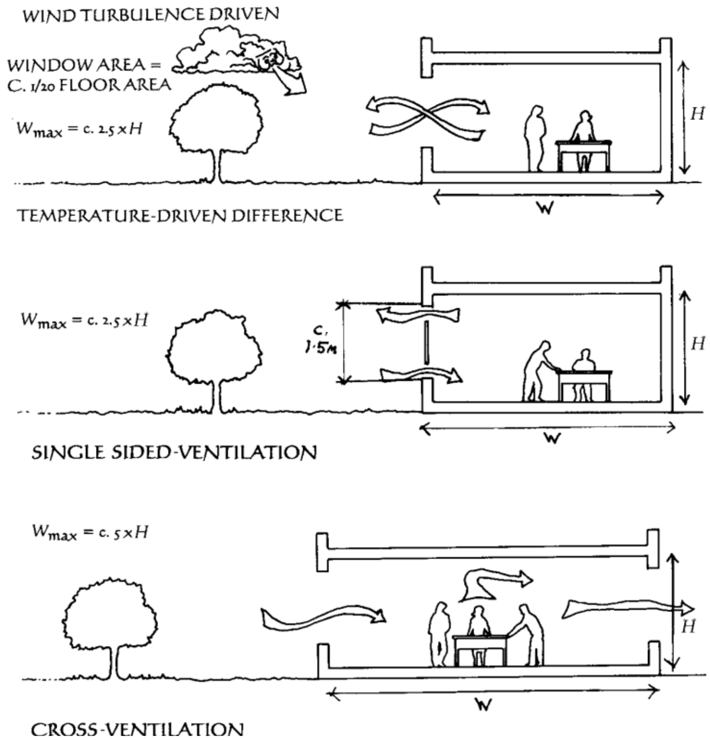


Figure 4. Single-sided and cross-ventilation with rules of thumb for their use in different [Roaf, 2001]

Wind ventilation is also studied in terms of passivity or, the area of the house which doesn't need mechanical systems to function adequately. The passive zone is the distance from the envelope to the interior of the house, the width of which is double the height of the ceiling. This part is naturally lit and ventilated, differently from the remaining part called active zone *(Fig. 5).* In order to provide low energy techniques in building design it is important to maintain a low ratio of passive to non-passive zone [Rati *et. al.,* 2005].

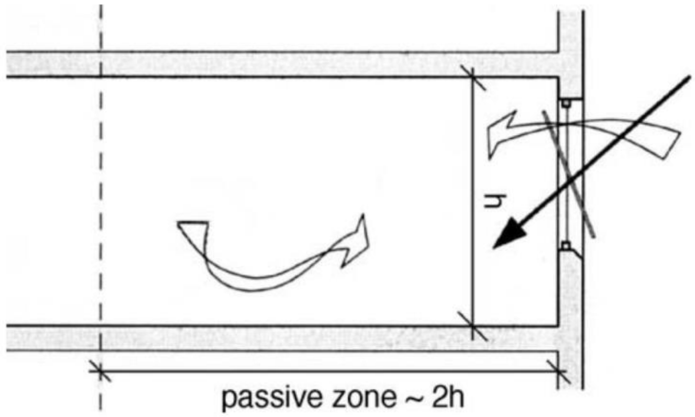


Figure 5. Passive zone concept. [Rati *et. al.,* 2005].

2.2. Case studies

Different concepts of natural ventilation have different architectural footprints, consequences and possibilities. Based on their footprints, the building typologies are three: a. traditional, b. courtyard and c. sponge typology.

- **Traditional building Typology**: Istanbul Sapphire / Tabanlioglu Architects, 2.Büro Ole Scheeren unveils the "Future of Vertical Housing" in Vancouve

- **Courtyard building typology**: 1. 1 Bligh, 2. WOHA's Met Tower, 3. The Genzyme Center in Cambridge, 4. Ardmore residence, 5. Markthal Rotterdam / MVRDV

- **Sponge building typology**: 1. Arts Building for University of Iowa / Steven Holl Architects

2.2.1 Istanbul Sapphire

The Istanbul Sapphire by Tabanlioglu Architects, is the highest structure in Turkey with an area of 165169 m^2. It is a residential, leisure and shopping center built in 2011. The building, despite being high rised still has nature-friendly facilities like vertical gardens behind the façade with two independent shells *(Fig. 6).*

The outer shell protects the interior from adverse weather conditions while also serving as a buffer zone between the indoor area and the outside. It also has a positive effect on structural solutions. The interior space of the shell is treated as garden terraces with modules of three storeys, where the first one is the garden and the other two overlook it. The garden zone is naturally ventilated though the louvers, which take the air in at the lowest level and push it out at the top *(Fig. 6)*. The louvers automatically open and close according to weather conditions maintaining an optimal temperature for the building. Environmental friendly systems of the construction grant low energy consumption.

Figure 6. Sapphire building (left), Double shell façade (center), Partial section (right) [Tabanlioglu Architects, 2011].

2.2.2. Büro Ole Scheeren

The "Future of Vertical Housing" by Büro Ole Scheeren located in Vancouver, Canada, is a proposal for the future of vertical living. Designed to serve as an "urban pivot" the multifaceted tower features a system of interchanging apartment modules and outdoor terraces that extend horizontally to capture the city skyline (*Fig. 8).* It possesses a unique balance of urban conditions surrounded by nature that creates a whole new atmosphere for living in an environmental-friendly city. The design of the building plans to go beyond the traditional idea of tower while connecting architecture with the natural environment. It is mostly known for its transparency and for its unorthodox functional openings which give the building an enhanced natural ventilation *(Fig. 7).*

Figure 7. Vertical housing view (left), Building view (right) [Scheeren, 2015].

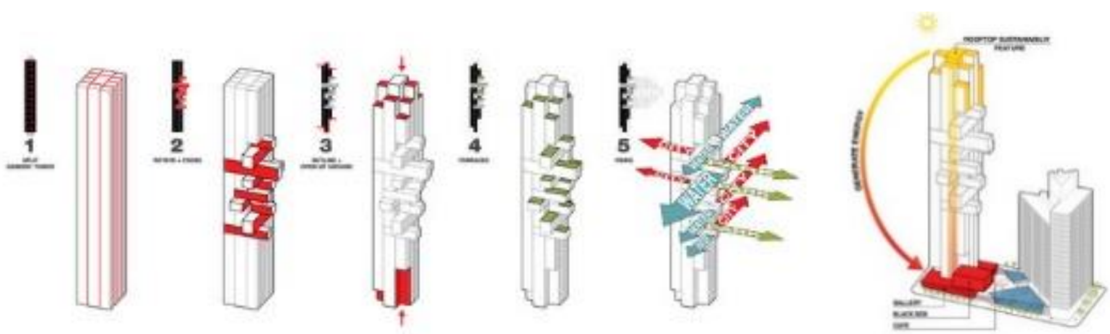


Figure 8. Form evolution (left), Sustainability (right**)** [Scheeren, 2015].

2.2.3. 1 Bligh

The 1 Bligh projected by Ingenhoven architects is a high rise office building constructed in 2011 and located in Sydney, Australia *(Fig, 10).* It provides 27 levels of office space that combine technology, sustainability and avant-garde design in one of the world's frequented cities. 1 Bligh in the market place of Australia is regarded as an innovation in design. Some key word characterizing this building are central atrium, double skin façade, energy generation system, solar panels, black water recycling and recycled rain water *(Fig. 9).*

As a solution for natural ventilation and low energy demand the architect have applied a glass atrium through all the building’s height, which not only provides fresh air but also gives a sense of openness. In the aspect of the technology used, 1 Bligh is the first high rise office in Australia to incorporate double skin façade as an efficient feature to control the sun radiation.

In order to reduce energy consumption and to maximize the comfort level it is used a hybrid structure combining a variable air volume with a chilled beam air conditioning system installed. It also uses solar energy to generate the necessary amount of energy deman. 1 Bligh incorporates black water recycling and rain water recycling with the first one used to irrigate a feature 9.7 m high green wall.

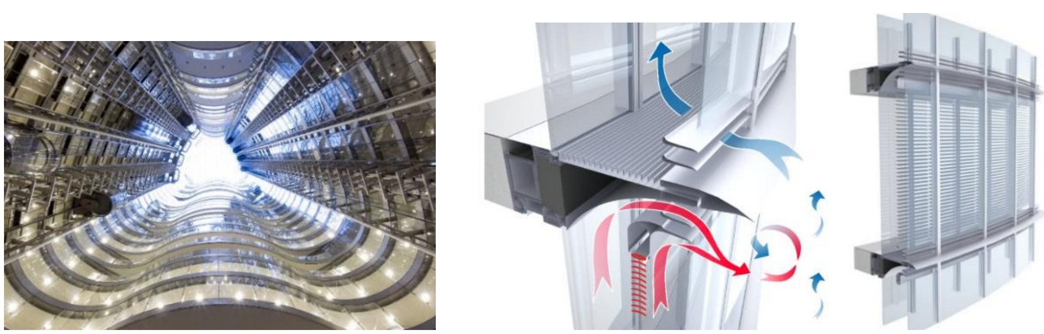


Figure 9. Glass atrium (left), Perimeter panel (center), Double skin façade (right) [Ingenhoven architects, 2011].

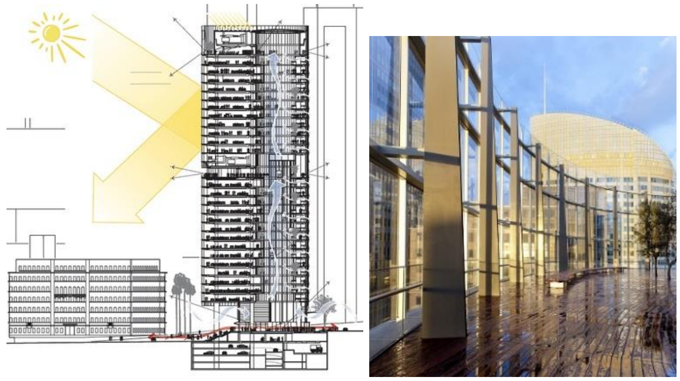


Figure 10. Section through atrium (left), Rooftop terrace (right) [Ingenhoven architects, 2011].

2.2.4. WOHA's Met Tower

The Met designed by Woha architects is located in Bangkok, Thailand completed in 2005. The Met Tower despite being a high rise, was designed following the logic of low-rise tropical housings with a layout that allows cross-ventilation through the introduction of open-space terraces, verandas and gardens *(Fig. 11).* The courtyards also create more surface in the façade which makes possible more heat loss during the night, and achieve a good thermal mass to use during the hot days. It incorporates typical Thai elements such as ceramic tiles, textiles and timber paneling. The building is dominated by two design strategies- populating horizontal surfaces with vegetation and walls with creeper screens for shading.

Figure 11. Plan (left), Vertical vegetation (right) [WOHA, 2005].

2.2.5. The Genzyme Center

The Genzyme Center is located in the midst of other dynamic research institutions close to the Charles River in Cambridge. It is designed by Günter Behnisch in 2000-2004. The concept was to develop a building from the inside out. Except creating a positive health impact, this center also aimed creating a positive impact on the environment. The Genzyme Center has created a global standard for all facilities in terms of overall performance. The building is organized with individual dwellings and as ‘a vertical city’. There is a vertical staircase in the middle which forms the so called ‘vertical boulevard’. This 12 stories atrium in the interior makes possible the flooding of daylight and the natural illumination of all the areas aided by a combination between re-directional blinds at the perimeter which reduce the building’s dependence on cooling and heating systems *(Fig. 12).* The louvres deflect the direct skylight and diffuse in throughout the atrium *(Fig. 13).* The building is an optimal example of what can be achieved through the application of sustainable strategies. Iit was been awarded the USGBC Leed Platinum Rating since it uses 45% less electricity than other conventional office buildings.

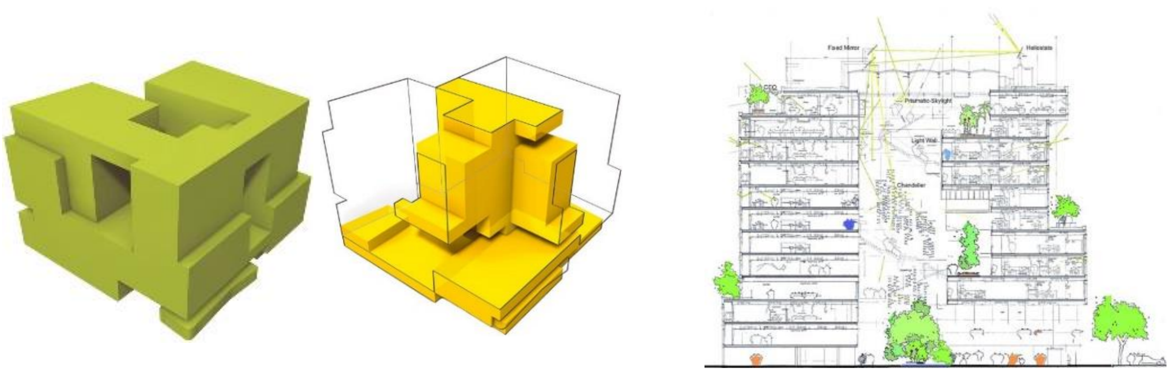


Figure 12. Solid void relationship (left), Longitudinal section (right) [Günter Behnisch, 2004].

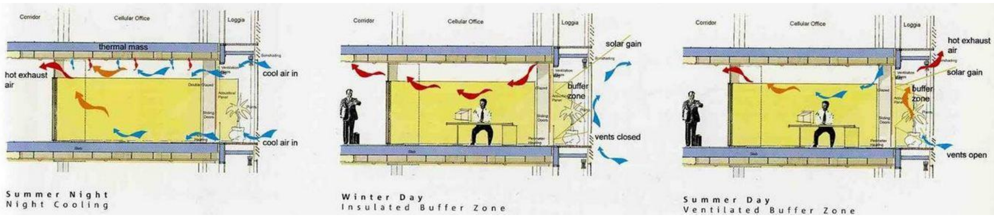


Figure 13. Section showing air movement [Günter Behnisch, 2004].

2.2.6. Ardmore residence

The Ardmore 36 storey Residence designed by UN studio, is located in Singapore. The primary concept for the design of the 17.178 m² residential tower is a response to the natural landscape inherent to the ‘Garden City’ of Singapore. The concept of landscape is integrated in the façade in four different approaches namely: the articulation of the facade, which creates various organic patterns; large glazed areas make possible and expanded view of the city, bay windows and double-height balconies; and the introduction of transparency and connectivity to the ground level gardens by means of a raised structure supported by an open framework.

While moving around the building one can sense an organic mutation and transition thanks to the various openings in the concrete panel (Fig. 14). The apartments in the Ardmore Residence embody the idea of a ‘living landscape’, with large windows and double height balconies. The interior is protected by undesired radiation through bay windows which create also a good area for vegetation.

The floor plan is designed to increase the amount of daylight and take full advantage of the panoramic views. The wings can operate together or be active at different times of the day *(Fig. 15).*

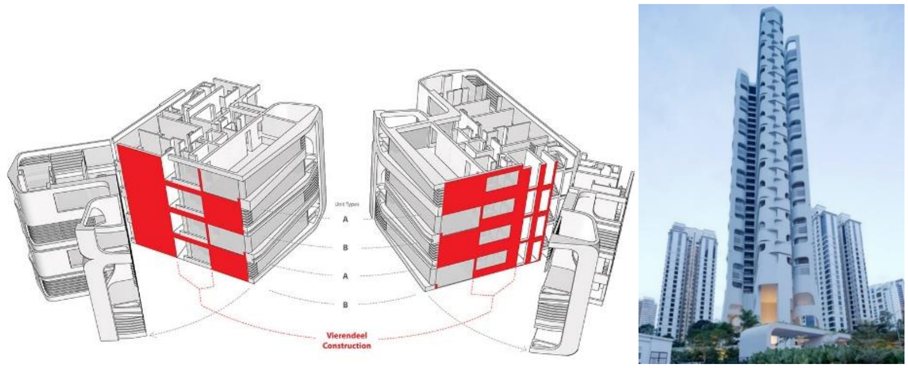


Figure 14. Unit types of construction (left), Ardmore view (right) [UN studio, 2013]

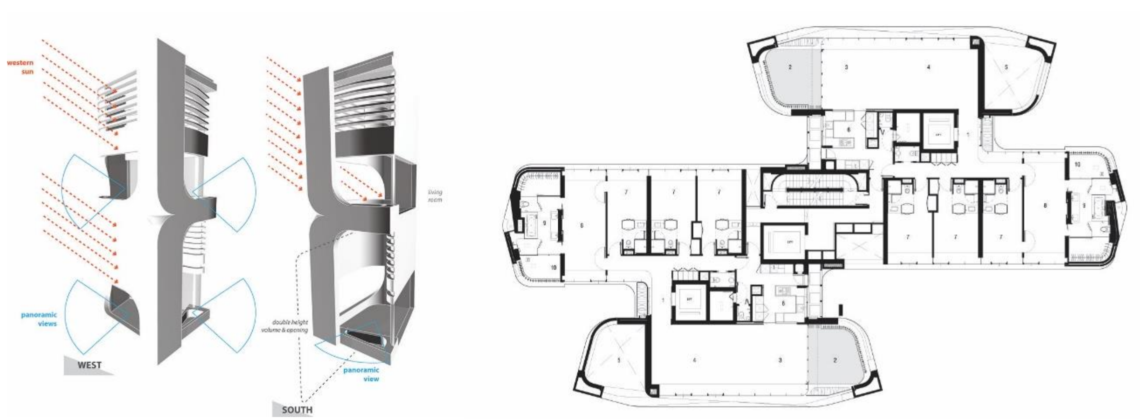


Figure 15. Western and southern façade (left), Plan (right) [UN studio, 2013]

2.2.7. Markthal Rotterdam

Markthal by MVRDV is located in Rotterdam, Netherlands and holds the BREEAM Very Good certificate. The most noticeable aspect of the building is the hall which represents the major part of it. Extensive research was conducted to create a comfortable interior climate for the hall with an extremely low energy use. It is naturally lit and ventilated *(Fig. 16),* where underneath the glass façade, the air flows freely and leaves through the shafts in the roof.

Figure 16. Merkthal building view (left), Void space (right) [MVRDV, 2014].

This thermic system can function without any installation, but for more performance the building is connected to an underground system which heats the entire city. This combination of natural and mechanical systems creates an appropriate thermal comfort for the users *(Fig. 17).* The combination of housing, shopping centers, parking and market hall makes the installation technology more efficient. Advanced technology was used inside the market, where an information panel illustrates the current energy use and CO_2 savings of the building.

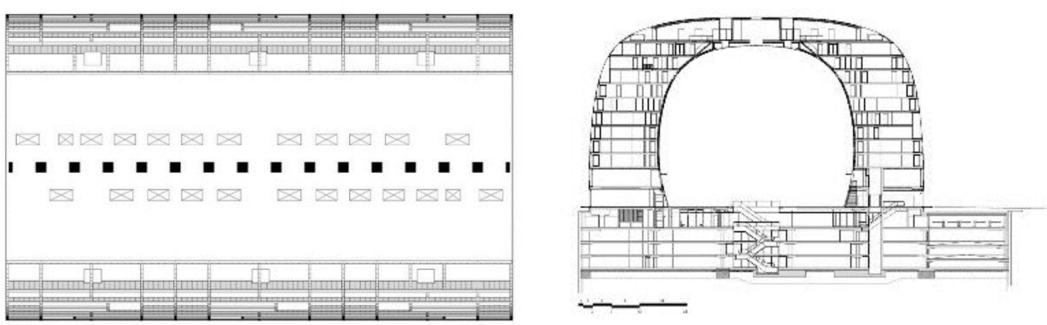


Figure 17. Top view (left), Section (right) [MVRDV, 2014].

2.2.8. Arts Building for University of Iowa

Designed by Steven Hall architects and located in the United States, the building concept is to be vertically porous and volumetrically composed. Special focus was given to the interconnections and the crossover due to it being an art building. The interconnection is achieved through carving out a large portion of the floor plans *(Fig. 18).* To achieve natural light and ventilation, the architect creates seven cutouts which also encourages the interaction between the four levels. Furthermore, these cutouts create multiple balconies which serve for meeting places but also as exterior working places. The overall geometry is characterized by shifted layers where one floor plate slides past another *(Fig. 19).* The original grid leaves place to an irregular geometry which is simplified in the new campus space of the "Arts Meadow". The natural ventilation is supported by a system of smart operable windows.

The punched concrete in the exterior provide an adequate thermal mass, while the interior "bubble" slabs provide radiant cooling and heating.

Figure 18. Arial photo_Site view(left), Street view (center), Centers of light (right) [Steven Holl Architects, 2016].

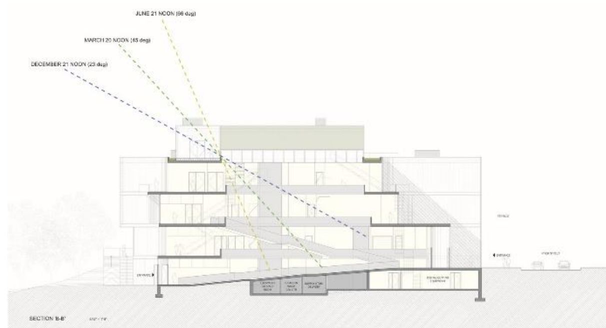


Figure 19. Circulation stairs (left), Section (right) [Steven Holl Architects, 2016].

2.3. Definitions and terms

Natural ventilation definitions in different years:

- Ventilation provided by thermal, wind, or diffusion effects through doors, windows, or other intentional openings in the building [ASHARE 62.1].
- Using local wind and temperature differences between the inside and outside of the building to move air through the structure [Chastain, 2000].
- The process of supplying and removing air through an indoor space by natural means [Roulet, 2002].
- Passively supplying outdoor air to a building interior for ventilation and cooling [Busby, 2005].
- Wind and thermal buoyancy as driving forces to create the desired thermal environment and transport away undesired contaminants [Kleiven, 2003].
- Providing the “fresh” outdoor air into a building and circulate it in the building or a room to dilute or remove pollutants [Li, 2003].

- Pressure differences between the inside and the outside of the building [UFC, 2004].

Sponge concept definition:

Porous building, with the presence of some openings or voids (large or small), which allows matter to pass through.

CHAPTER 3

ANALYSIS OF THE PRELIMINARY PROPOSALS AND THE PROJECT SITE

3.1. Site Selection

The selected site is located in Tirana, Albania, along the Lana river, near the ‘ Drejtoria e Policise’. It is facing the second main Boulvard in Tirana *(Fig. 20),* in a residential zone with a high rise development. Bonded by the roads: Sami Frasheri, Nikolla Jorga and Gjergj Fishta *(Fig. 26),* the experimental site is a rectangular shape plot with an area of 1400m^2. In the south-eastern part the site stands in front of the public park (Lana River) facing five storey buildings *(Fig. 24).* On the north-western side *(Fig. 23),* the site faces a 15 storey residential building, whereas in north-eastern side it faces a 14 storey residential building *(Fig. 21,22).* On the south-western side there is an empty plot serving as a parking space *(Fig. 25).* Differently from the main road’s row of buildings which go up to 15 storey, the second row consist of middle rised residential buildings. Mainly the constructions are made of concrete and glass. The entrance to the site is achieved through the secondary road of Nikolla Jorga *(Fig. 26).* In terms of transportation the site is located near two bus stations and a bridge *(Fig. 21,27).* The southern part of the site is free of construction and appropriate for the implementation of ventilation design and an optimal solar exposure. According to the regulatory plan 2008, this zone planned for high-rised building development.

Figure 20. Perspective view of the site from Lana river

Figure 21. Perspective view of the site from Lana river

Figure 22. Site location, southern view (left) and northern view (right)

Figure 23. Panoramic view of the site

Figure 24. Panoramic view of the eastern part facing the chosen site

Figure 25. Panoramic view of the north-east-south part facing the chosen site

Figure 26. Main road leading to the site (left), View from the corner (right).

Figure 27. Surrounding element: Lana river (left), The bridge (right).

Figure 28. Site sketch

The relatively small area of the site *(Fig. 28)* and the high requirement for dwelling in this high development zone requests for a tower typology capable to accommodate mixed used functions like residential and shopping activities.

According to the windfinder website, over the course of the year typical wind speeds vary from 0 m/s to 6 m/s (calm to moderate breeze), rarely exceeding 19 m/s. The wind is most often oriented out of the north (13% of the time) and south (12% of the time). The wind is less often out of the north east (1% of the time), east (2% of the time), and south west (3% of the time) *(Fig. 29).* [https://weatherspark.com/averages/31998/Tirana-Tirana-County-Albania].

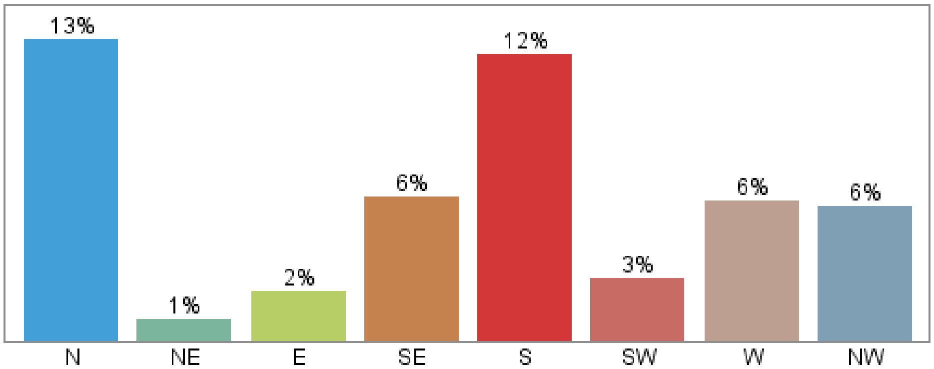
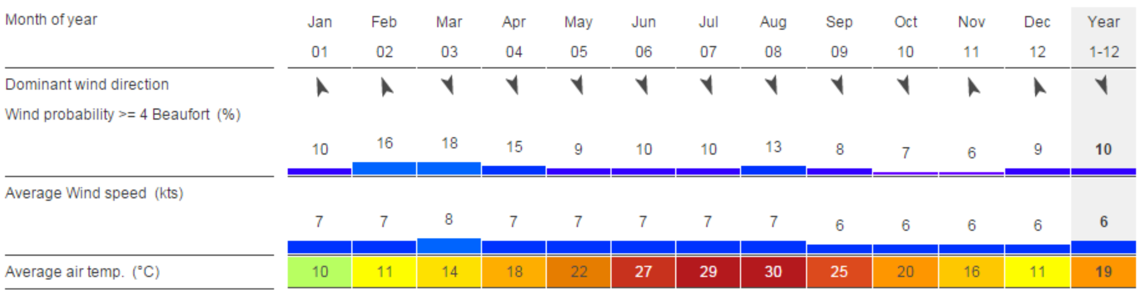


Figure 29. Wind direction over the entire year (%) [www.windfinder.com, 2016]



Month of year	Jan 01	Feb 02	Mar 03	Apr 04	May 05	Jun 06	Jul 07	Aug 08	Sep 09	Oct 10	Nov 11	Dec 12	Year 1-12
Dominant wind direction													
Wind probability >= 4 Beaufort (%)	10	16	18	15	9	10	10	13	8	7	6	9	10
Average Wind speed (kts)	7	7	8	7	7	7	7	7	6	6	6	6	6
Average air temp. (°C)	10	11	14	18	22	27	29	30	25	20	16	11	19

Figure 30. Wind speed over the entire year (m/s) [www.windfinder.com, 2016]

3.2. Identification of the three proposals

It is possible to create models for the assessment of natural ventilation in many different ways, thus no one fits all solutions, can be applied in this kind of design. As a result, the potential of the wind parameters in the specific site needs to be explored and models to test should be created, in order to select the best match between design, comfort, and efficiency. For the next step three abstract models are designed where one is a traditional high-rise while the other two are high-rise with a big potential of enhanced natural ventilation. The three proposals perform differently under the pressure of external wind. The first one *(Fig. 31 left)*, the traditional, is a standard urban tower with dimensions of 24x36m. Its way of natural ventilation works through the openings in two adjacent facades. The second proposal *(Fig. 31 center)*, a courtyard tower, involves the implementation of a tower 24x36m dimensions with a void in the center and the circulation core. This proposal has the same openings as the first one but this time for the same volume the building has a higher surface to volume ratio which aids in the building's heat loss, thus improving the natural ventilation through a higher difference in temperature from the inside to the outside. The third proposal *(Fig. 31 right)*, a sponge tower, is proposed to enhance ventilation through additional openings in the center of each individual apartment creating stronger cross ventilation. The created voids inside the building aim also to reduce the non-passive area by providing natural ventilation and light in the deepest parts. As suggested by Rati *et. al.*, (2005) the greater this ratio the smaller will be the energy demand of the apartments, thus increasing the buildings sustainability. Also this proposal has the potential of cross ventilation through different floor levels.

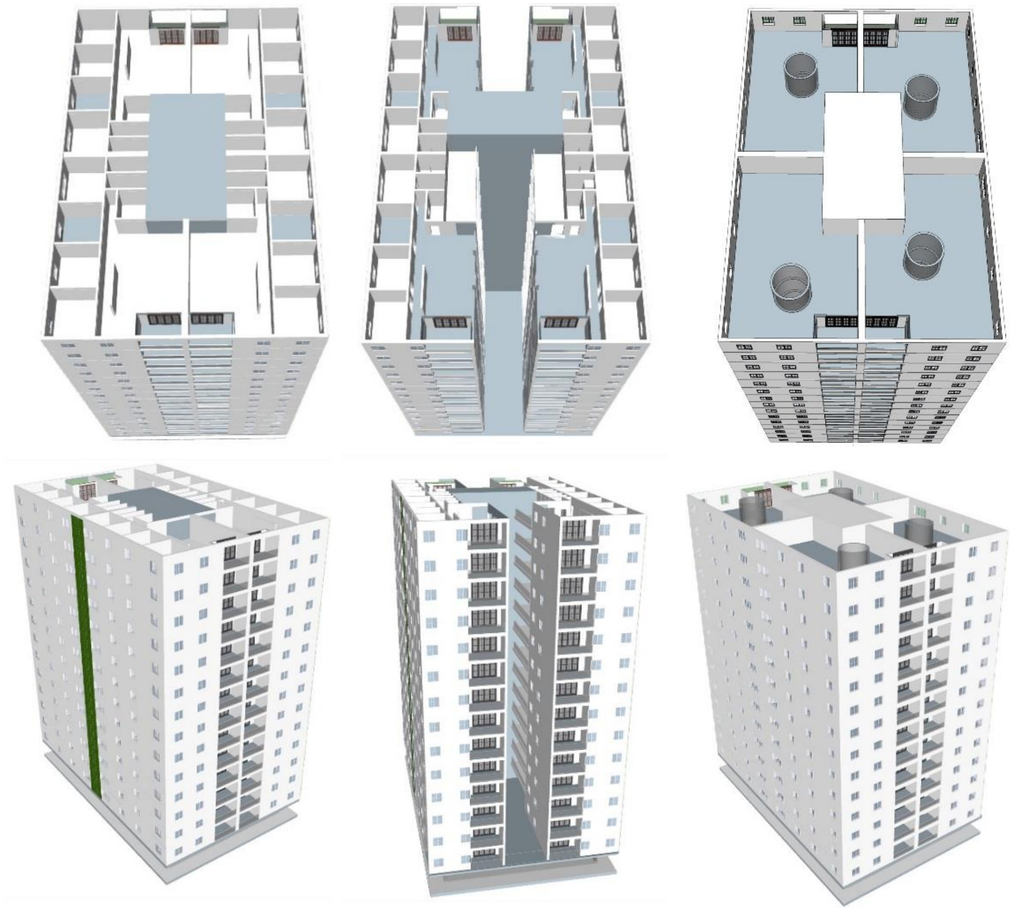


Figure 31. From left to right: Traditional, Courtyard, and Sponge tower

3.3. Testing process in wind tunnel

Autodesk Flow Design is a relatively easy to use computational fluid dynamic wind tunnel which aids architects and engineers to predict ventilation behavior around and inside their proposals. Specifically, these proposals will be tested in an environment with 7m/s speed and 30^{o} wind orientation in North West direction, which is the average angle of wind direction in the problematic summer climate in Tirana, Albania. [www.windfinder.com, 2016].

In order to test the key elements of the proposals, conceptual models with interior divisions are created and imported in flow design. Due to the early stages of development of this software, elaborated models could not be tested, thus the interior walls were removed to create a simpler volume and the buildings were tested based on wind speed and orientation.

In top view the wind shows the same properties since the boundaries of the house, the openings and, the dimensions for each proposal are the same. In 3d the pattern 3 proved to over perform the other two creating a cross ventilation not only inside the apartment but also between apartments of two different floors.

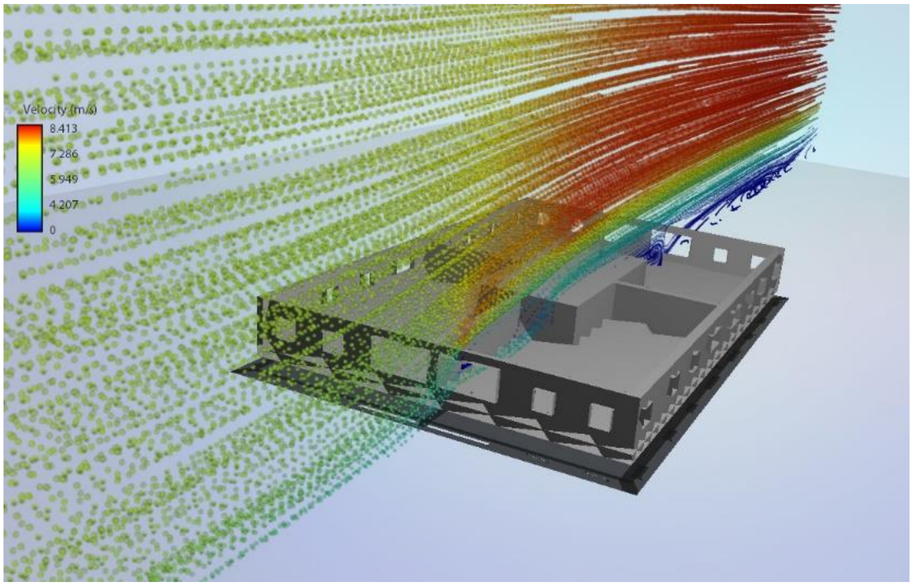


Figure 32. Traditional building during testing in design flow program

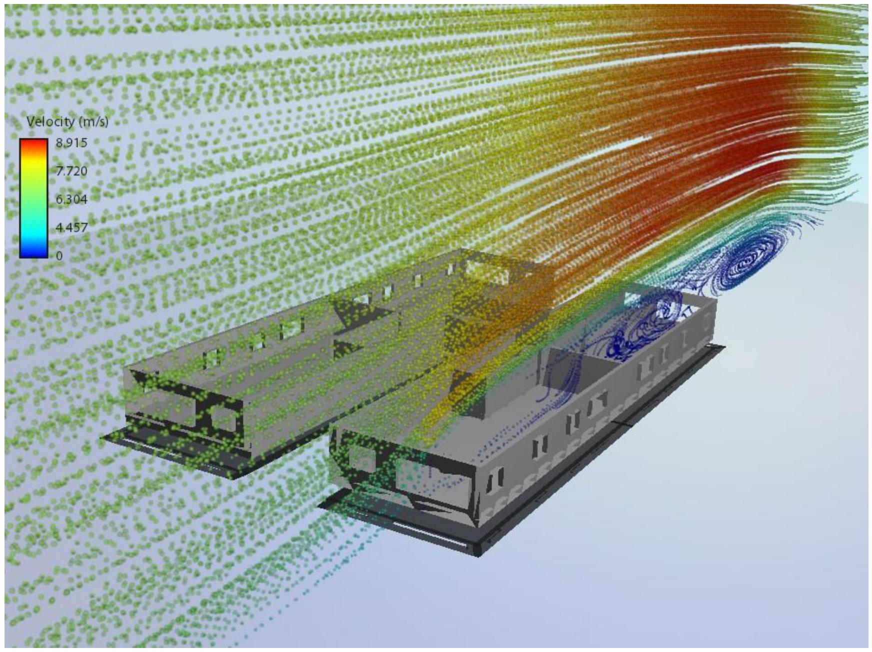


Figure 33. Courtyard building during testing in design flow program

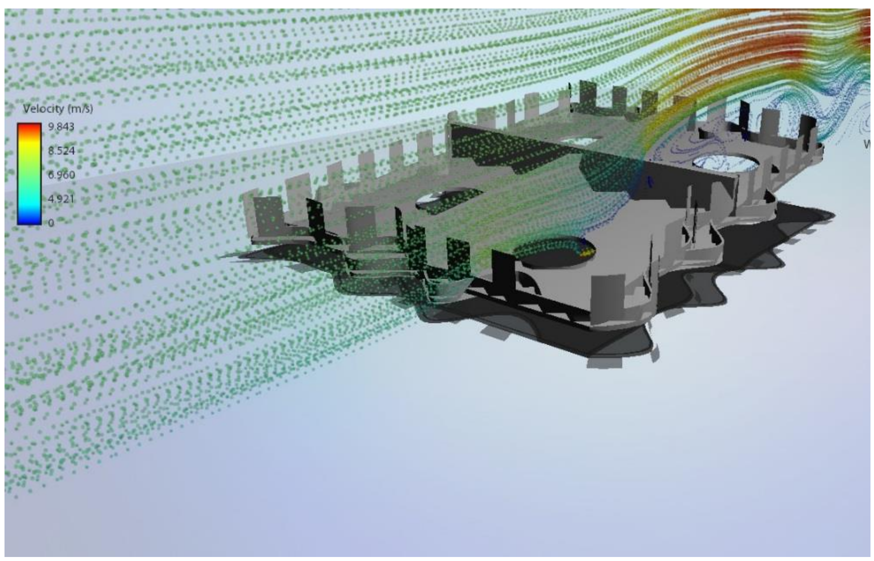


Figure 34. Sponge design building during testing in design flow program

As it can be seen in the two first proposals *(Fig. 32,33)* the wind which enters through the openings loses most of its speed. With a magnitude from 7m/s in the outside to 0-1m/s in the inside the wind becomes weak and incapable of ventilating the building to the depth. It is visible that for this two proposals the wind pattern created by the openings isn't comparable with the wind pattern created above their ceiling. On the other hand, the third proposal *(Fig. 34)*, shows to behave much differently when in the effect of winds. As it can be seen in the figure the wind enters with a higher speed in this proposal, specifically 5-6m/s and is down washed to the lower floor with a speed of 9m/s which is even higher than its predefined speed of 7m/s for Tirana. The reason wind enters with different speeds in the three models is that waves have the ability to influence the path they have already taken if their parameters are changed. By taking this pattern in every floor the wind receives the amount of speed necessary to arrive in the maximum depth of the building while also having a far less itinerary to make (from the envelope to the sponge, and then from the sponge to the end of the house). The final test shows that the third proposal with the concept of sponge outperforms the other two by a huge amount, making it likely a more successful concept, and thus making it also the object of the next step.

3.4. Analysis of the urban context, figure ground, street network, building heights, nature and vegetation, aerial view.

The site is located in the vicinity of the Lana River *(Fig. 35)*, next to two high rise buildings *(Fig. 36)*. It is bounded by two main roads *(Fig. 37 left).* Despite being in a site with a potential for high development *(Fig. 38)*, from the Figure-Ground analysis *(Fig. 37 right)* it is visible that the site it is yet in the early stages of development.

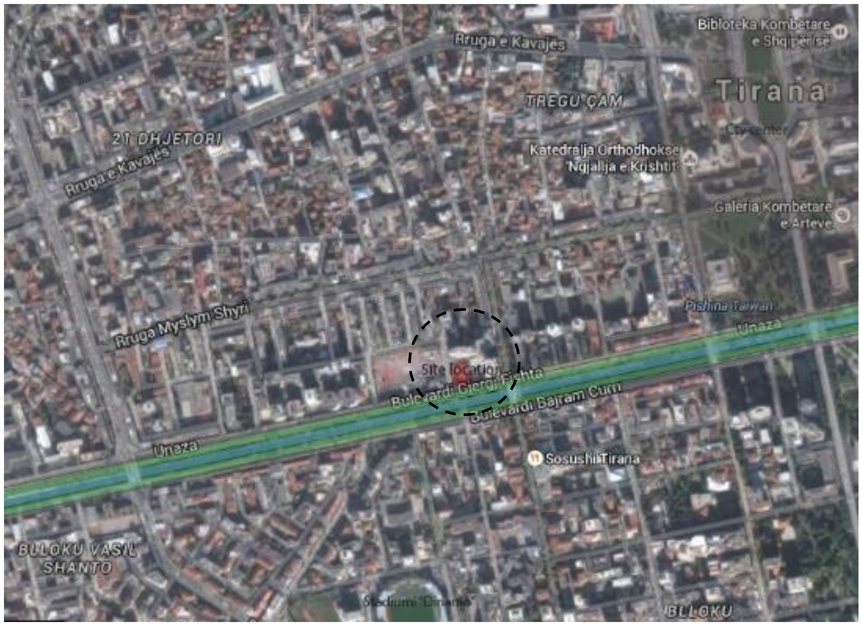


Figure 35. Arial view

Figure 36. Site location

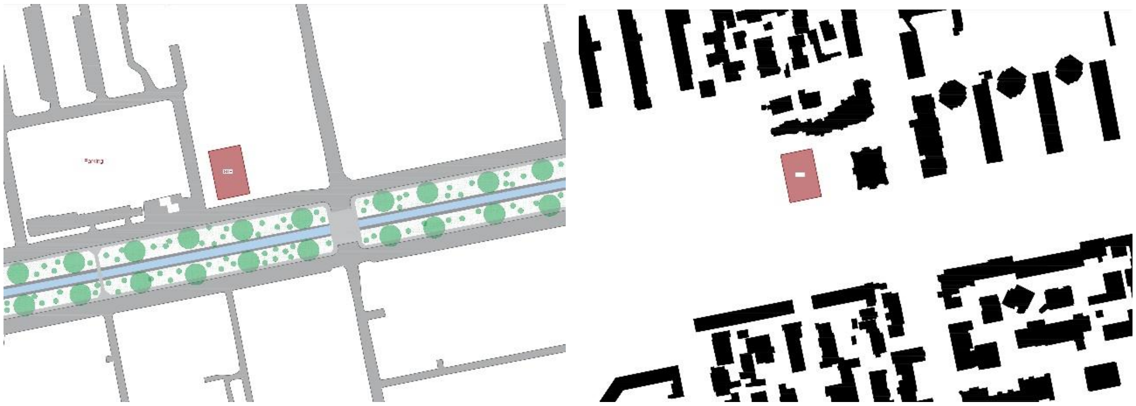


Figure 37. Street network (left)**,** Figure-Ground (right).

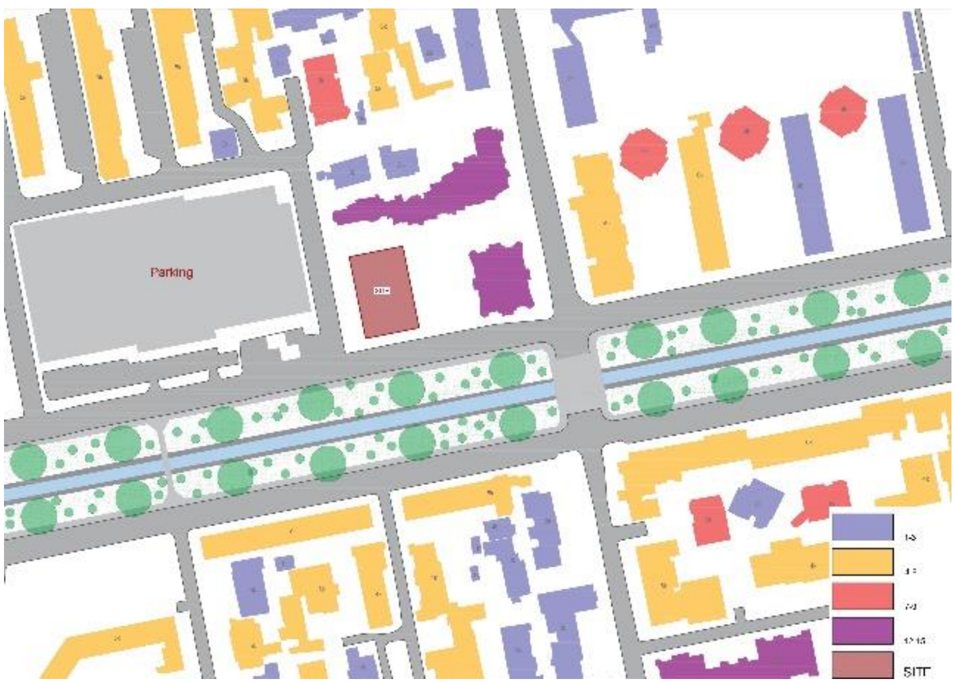


Figure 38. Building heights (left), Site location (right).

CHAPTER 4

IMPLEMENTATION OF THE SPONGE COCEPT

4.1 Project main concept

As a general concept of design for the shape of the sponge proposal, the logics of fluid dynamics will continue in the facade which through solid void relations embrace the flows and redirect it *(Fig. 40, 41).* In this context the concept of wave seems to blend well with the wind design not only as an artistical concept but also in scientific terms. Indeed, it is advisable to have movements in the façade which collect the wind and redirect it with higher speeds. As it can be seen from the pictures *(Fig. 41),* the wave design creates more wind variety, differently from *(Fig. 39),* and redirects the flow lines inwards the building, thus raising visibly the natural ventilation level of the units.

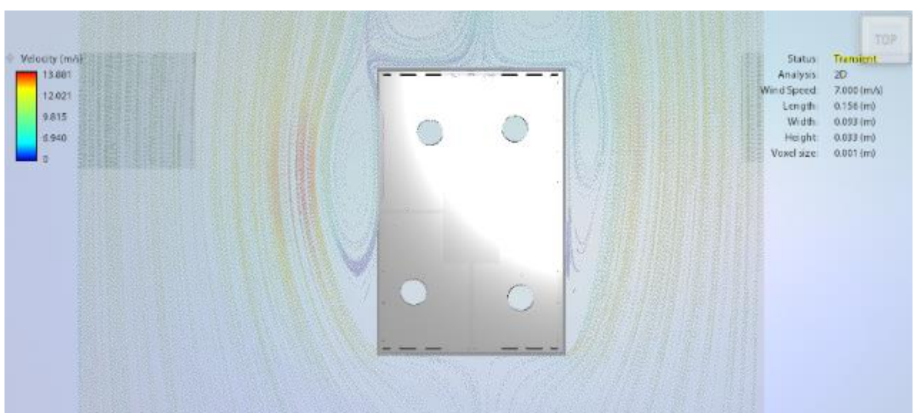


Figure 39. Sponge concept building during testing. First idea, without the waving envelope.

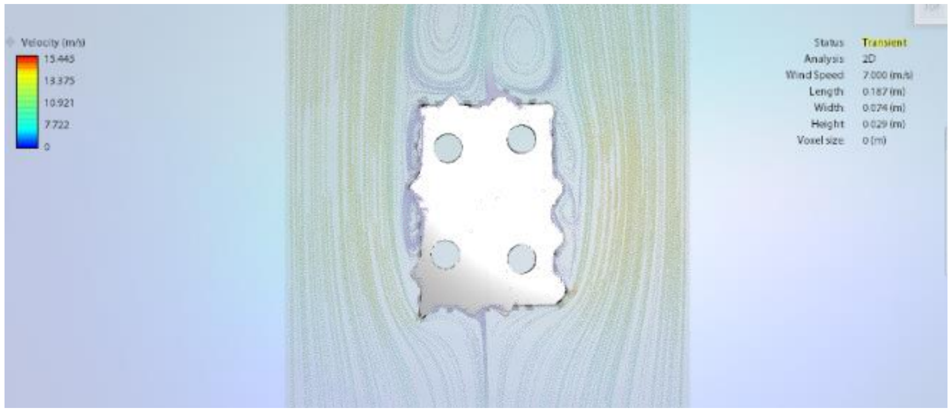


Figure 40. Sponge concept building during testing. Evaluation of the concept.

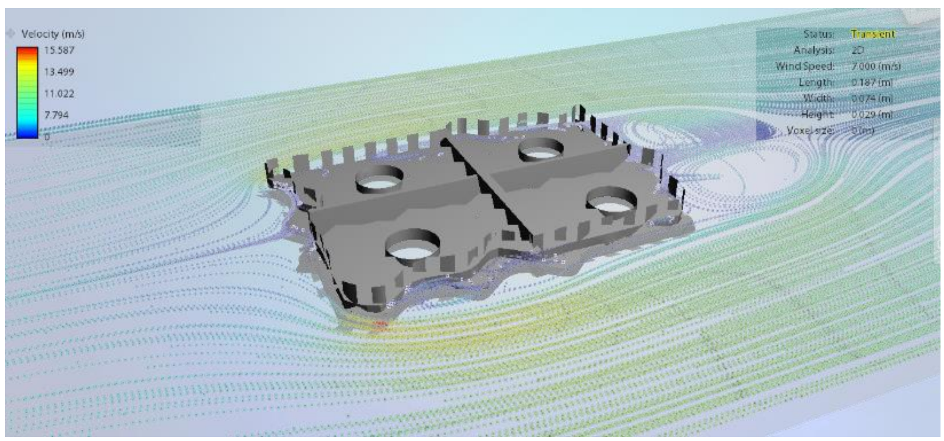


Figure 41. Sponge concept building during testing. Separation of the apartments

3.2 Algorithms

With the idea clear in mind it is now necessary to develop the project in a software that is highly adaptable and can perform the right calculations dealing with such forms, which to make things even more difficult, requires special footprints for each floor *(Fig. 42)*. Grasshopper plugin for Rhino can manage such forms and implement variations to the whole model if a parameter is changed. By creating a scrip which manages the floor slabs, façade, balconies, inner openings and shading elements based only on a waved polyline a tower can be created, and if necessary implemented changes to the initial polyline can change the whole structure

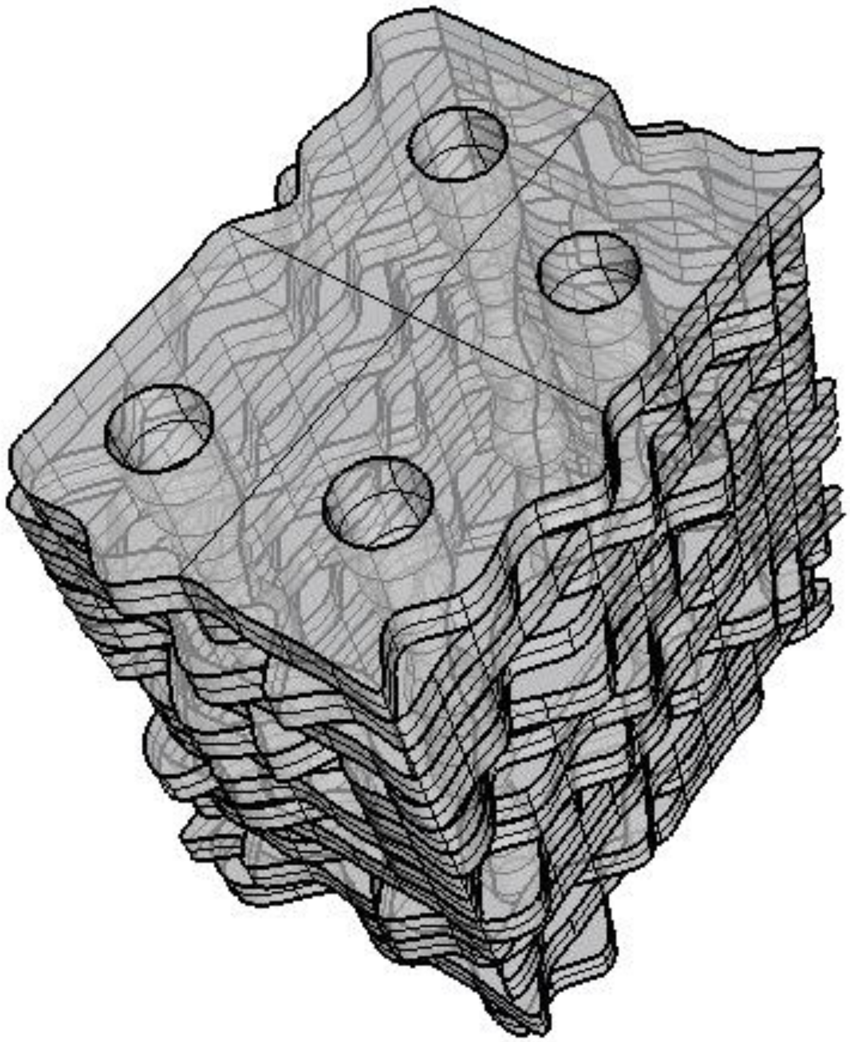


Figure 42. Concept of 3D massing

First a base rectangle is created with 36mx24m dimensions *(Fig. 43)* from which 40 points are extracted with equal distance between each other.

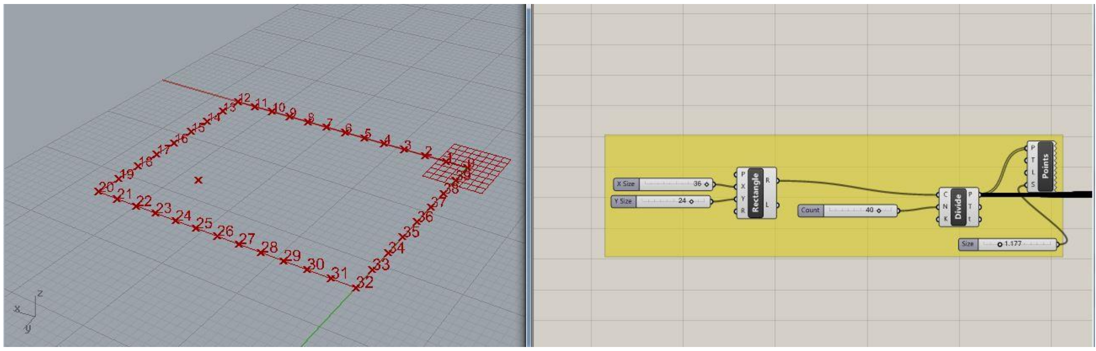


Figure 43. 36m×24m rectangle base of the project

The next step is to take each specific edge of the rectangle like in this case the edge between points from 12 to 19 and select randomly 3 of them *(Fig. 44)*. The seed parameter changes the selection of the groups of three creating different designs in the upper floors. This procedure is repeated for each edge.

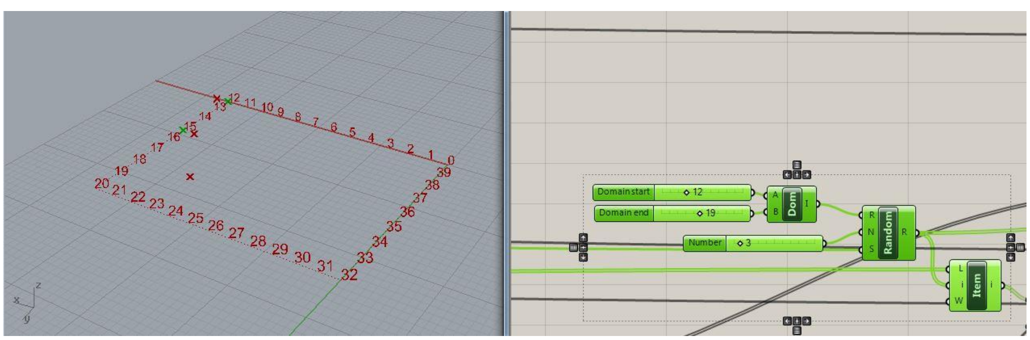


Figure 44. “Seed” parameter selecting randomly 3 points

Next, these three points for each edge are selected and dispatched (divided in two groups), in order for each group to move either inward or outward the initial rectangle *(Fig. 45)*.

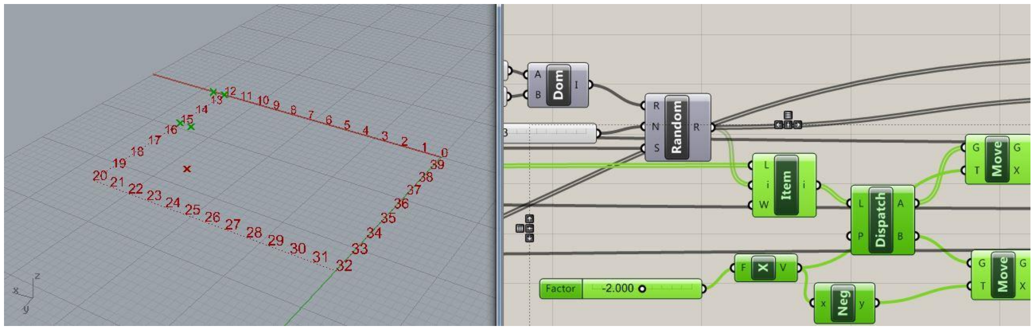


Figure 45. Moving points in different directions to form the curve (footprint)

The further step *(Fig. 46)* is to create a waved curve using the points of the rectangle and the weaved points of the previous step. This polyline will be the basis for all the future work like slab, facade etc, which also will affect each of the shading elements.

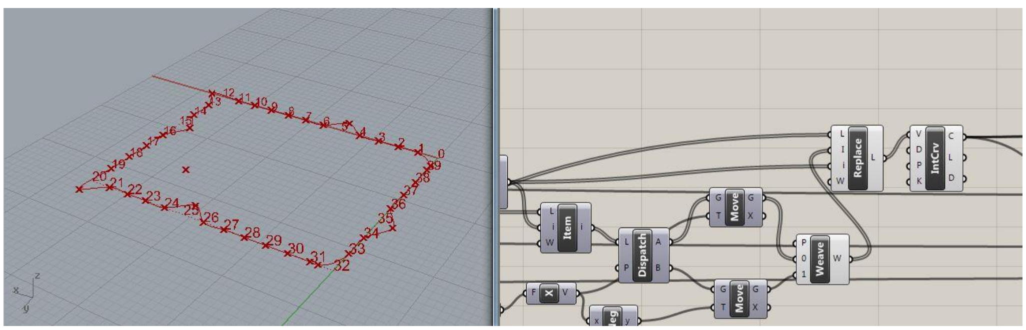


Figure 46. Creation of the waved curve

To continue the curve is offsetted 10 cm to create the distance between the curtain walls to the edge of the facade and then it is extruded with the floor height of 3m *(Fig. 47).*

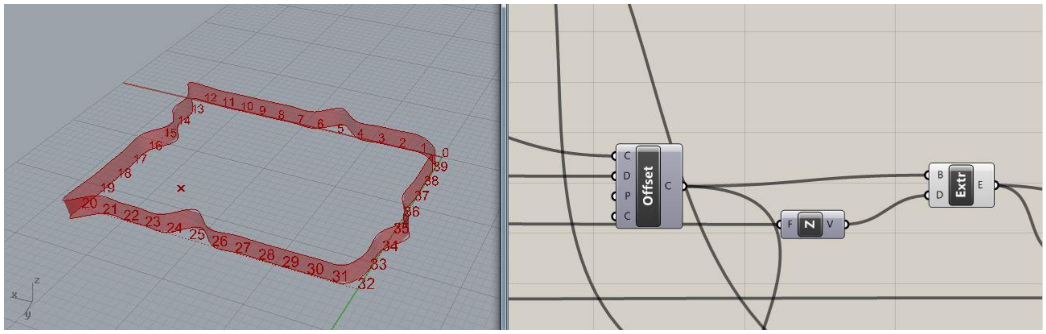


Figure 47. Extrusion of the curve, creating the envelope

Then this glazing surface is divided *(Fig. 48)* into sub surfaces which will form the glass panels. The number of the division (V) is achieved by dividing the total perimeter of the initial waved curve by the dimension of the desired panel which in the project is 80.

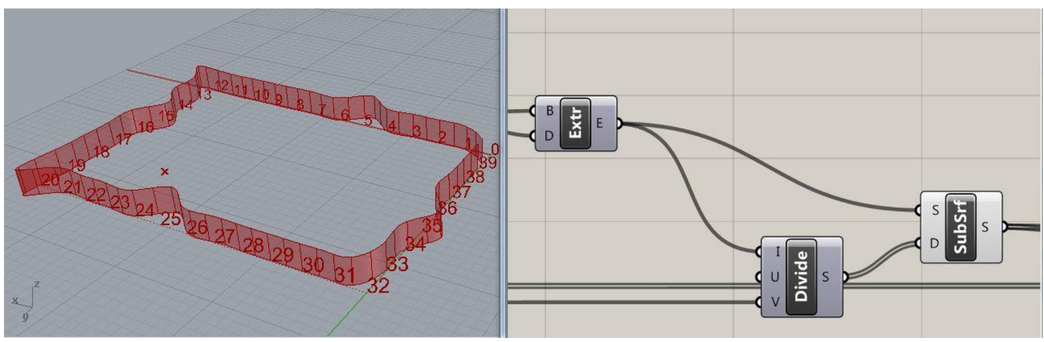


Figure 48. Creation of the glass panels

Next, another offset of the waved curve is created *(Fig. 49)* with 10cm on the outward. The curve is again extruded into a surface with 3m height and then divided again in 80 elements. Next through a randomly selection of panels only a few ones are maintained which will become the shading wooden elements of the structure.

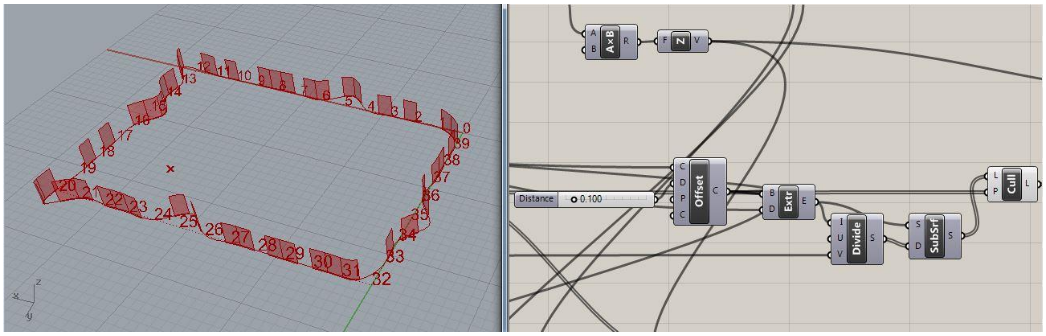


Figure 49. Creation of the shading elements

The result is a number of panels which hide the exterior glazing façade *(Fig. 50).*

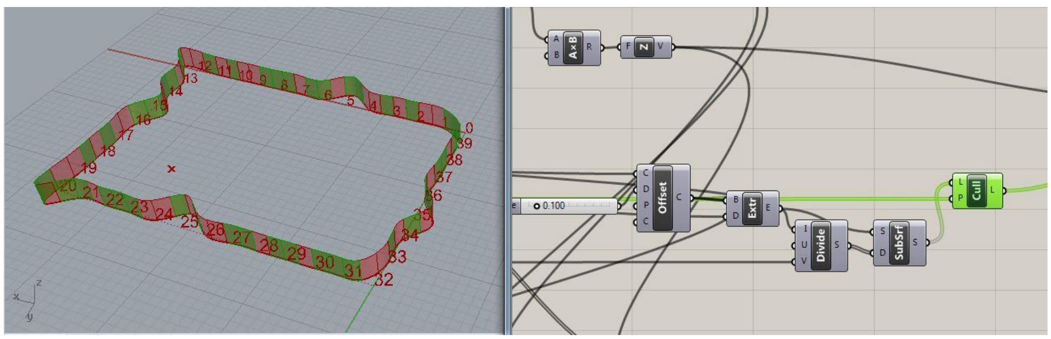


Figure 50. Creation of the envelope of the building (glass panels and shading elements)

Consecutively a boundary is created between the waved curves and it’s extruded with 20 cm to provide the floor slab *(Fig. 51).*

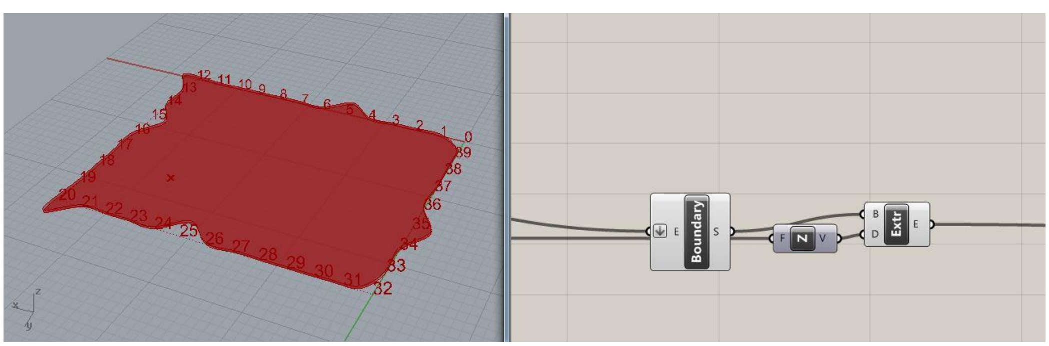


Figure 51. Creation of the floor slab

After the slab, the curve is offset inward 20 cm and extruded with 1.2 m to create the balcony *(Fig. 52).*

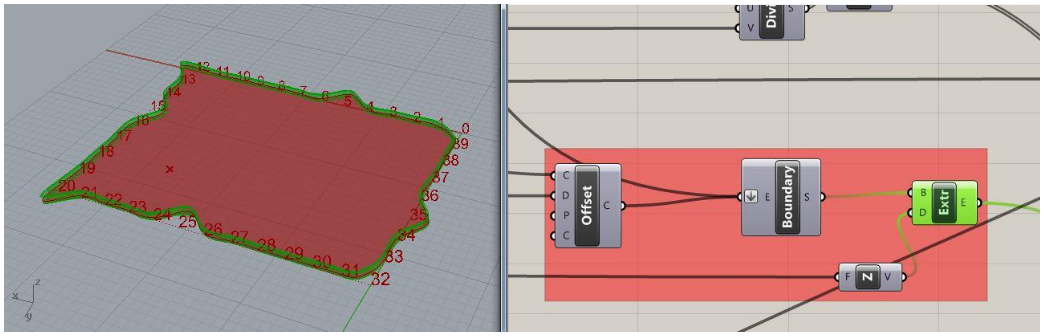


Figure 52. Creation of the balconies

The last step of creating the floor necessitates to insert the window frames *(Fig. 53).* In this case the frames are vertical elements with 5cmx15cm dimensions. To place the frames in the façade horizontal planes are created which will serve as base points for them. Again the waved curve is divided in 80 (the same as the window modules) where the horizontal planes will have as 0,0,0 coordinates this divisive points.

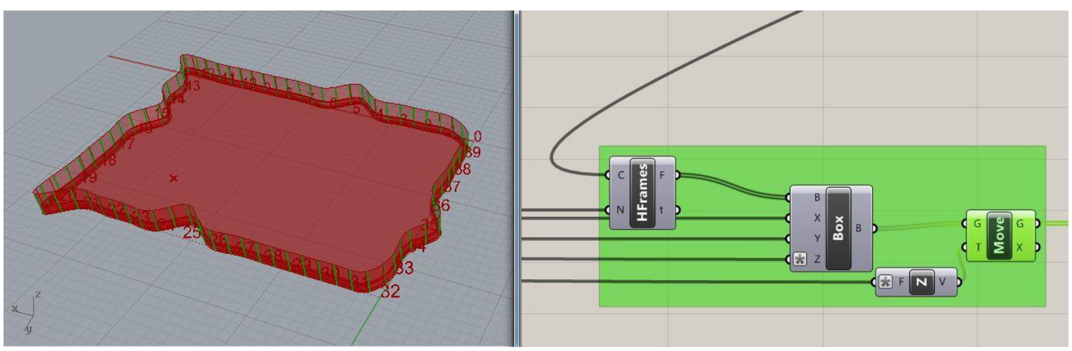


Figure 53. Creation of window frames

Last the floor and balcony are copied 3m upwards to create the ceiling and the parapet of the upper floor balconies.

Each of the floors with its respective elements are copied upward with a 3 m module to form the whole 15 stories building, and thereafter the seed used in the very first phase of the design is changed to propose different waving patterns for each floor *(Fig. 54).*

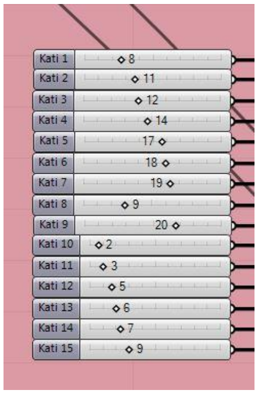


Figure 54. Seed parameter_Creation of different waving patterns for each floor

The last step is to create the sponge cut in the buildings *(Fig. 55).* It starts from a circle with a considerable radius of 2m.

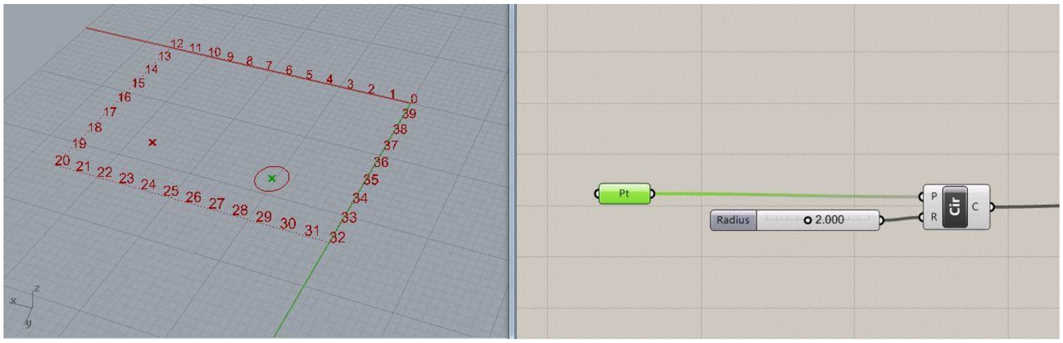


Figure 55. Creation of the circular elements in the interior

Next the circle is moved with a custom vector *(Fig. 56)*, which has as a parameter in the ‘z’ direction a series blocks, which copies different circles across all the floors with 3m distance, and as x and y parameter has a random domain which creates the movement if seen in top view.

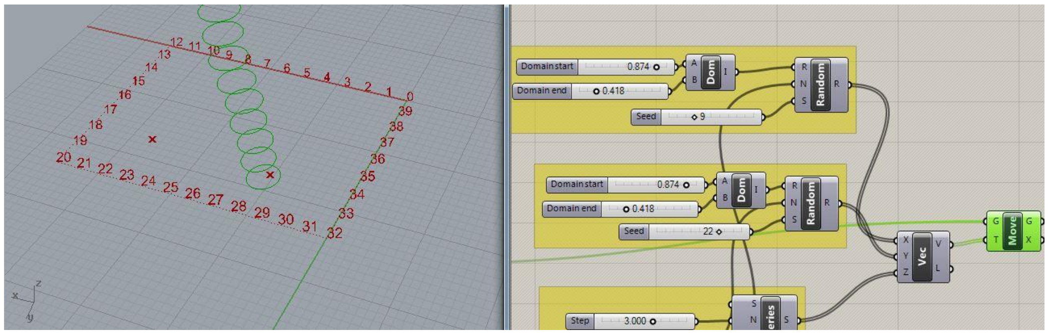


Figure 56. Creation of the circular elements in the interior

Next the circles are randomly scaled in between a specific domain in order not to pass a radius more than 2.6m and not less than 1.4m *(Fig. 57).*

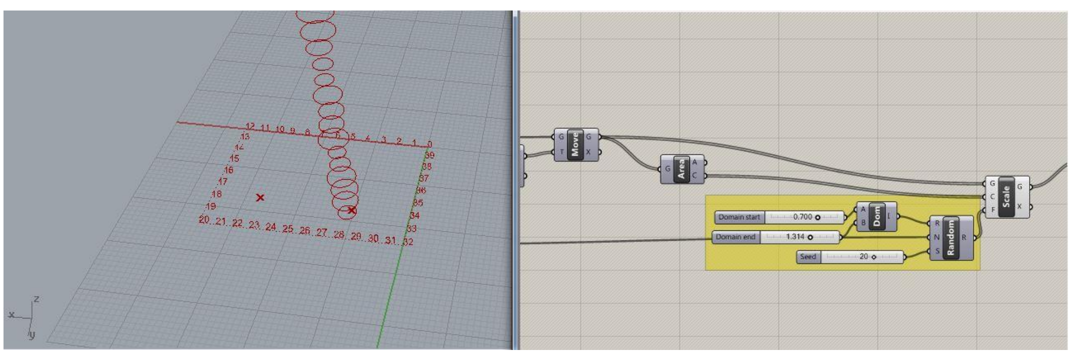


Figure 57. Creation of the scaled circular elements in the interior (radius 1.4-2.6m)

The penultimate step is to loft the circles together *(Fig. 58)*, cap them to convert them in volumes and, place all the canyons in four points of interest.

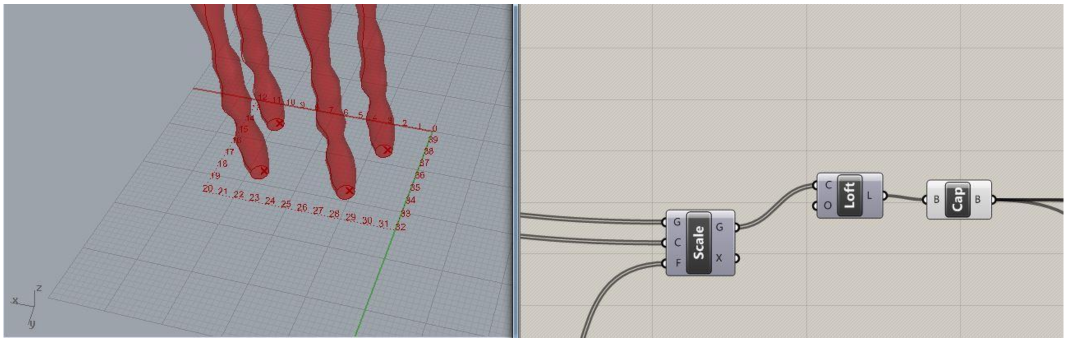


Figure 58. Creation of the circular volumes (void parts in the inner spaces)

Finally, a solid extrusion is performed between the slabs and the canyons. To form the desired internal sponge design *(Fig. 59).*

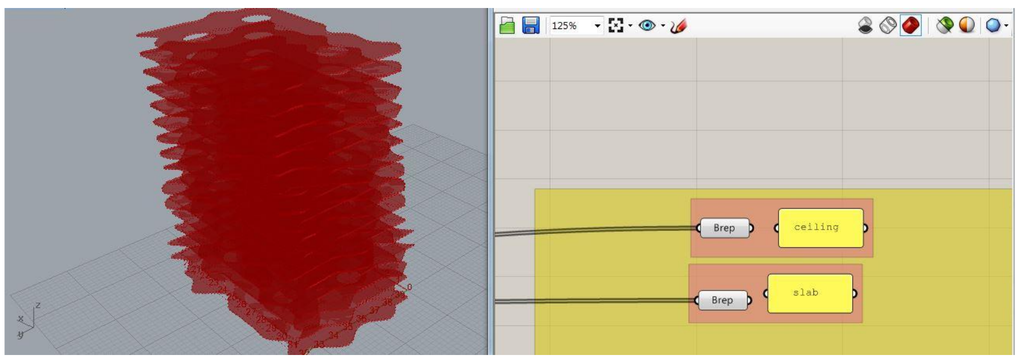


Figure 59. Creation of the slabs

The final product after all the geometries are baked will look like this *(Fig. 60).*

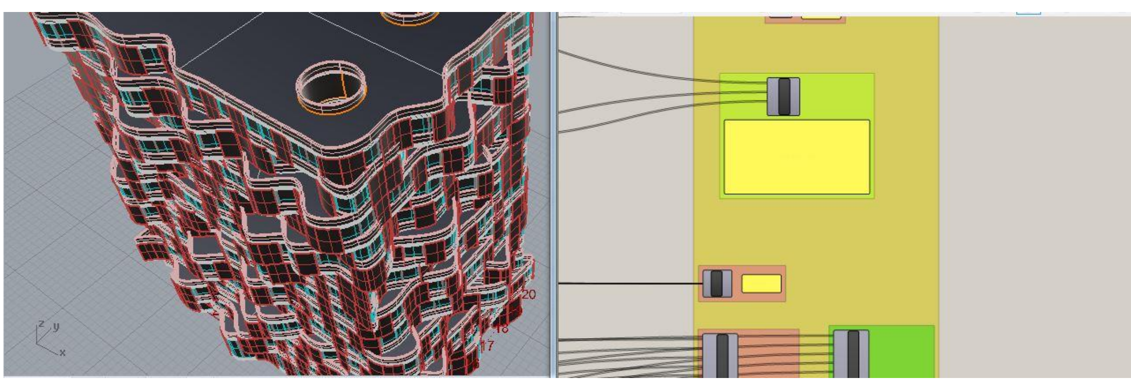


Figure 60. Creation of the final structure (final design)

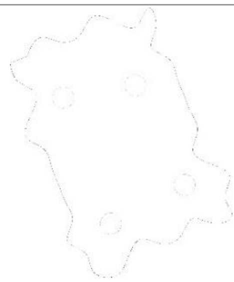
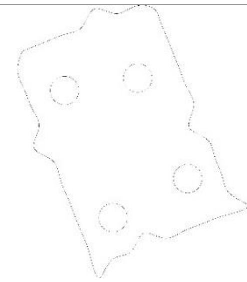
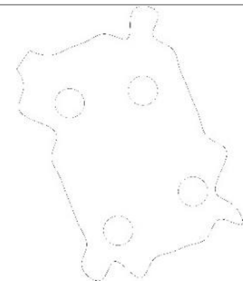
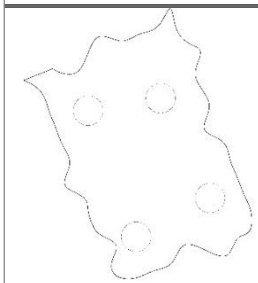
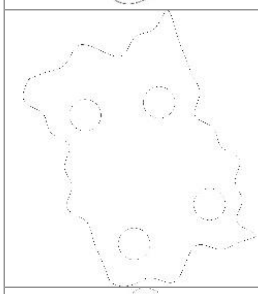
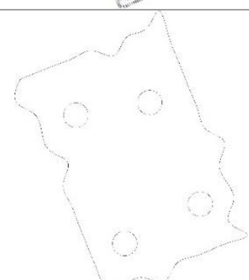
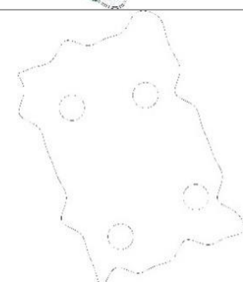
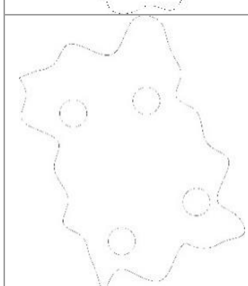
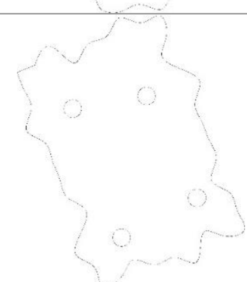
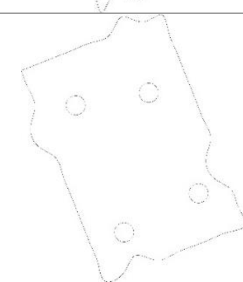
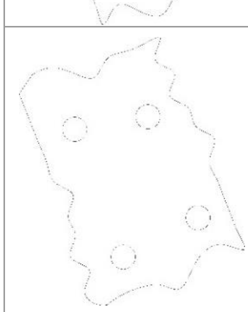
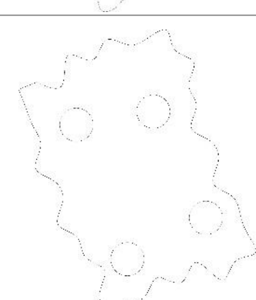
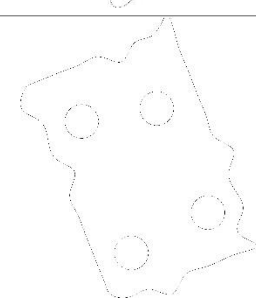
4.2 Project development

The development of the project will consist specifically in the interior solutions for two of the floors which are consecutive. It will involve the development of 1/200 plans and sections drawings. The interior solution will involve distribution of spaces, circulation, openings and furnishing.

4.2.1 Plans, inner space arrangements

The 15 storey high rised 24x36m has a total floor area of 940m^2, which differs in every floor. The floors are composed of four apartments with a surface area varying from 180m^2 to 230m^2. In the transversal axis the circulation core is located composed by the stairs, elevators and common walking area with 24x3m dimensions. Each individual apartment has located in its center a circular void which lowers its overall area from 8 to 20m^2. This void is positioned in the middle to allow cross ventilation with the envelope and also the entrance of natural skylight *(Table. 1).*

__Table 1.__ Breakdown structure of the 15 floor plans

 **1st floor plan**	 **2nd floor plan**	 **3rd floor plan**
 **4th floor plan**	 5th floor plan	 6th floor plan
 **7th floor plan**	 8th floor plan	 9th floor plan
 **10th floor plan**	 11th floor plan	 12th floor plan
 **13th floor plan**	 14th floor plan	 15th floor plan

The entrance divides the building in two parts namely: living area and wet spaces. The apartments have the same logical distribution while only differing in the outer envelope morphology, which is random for each of the fifteen floors.

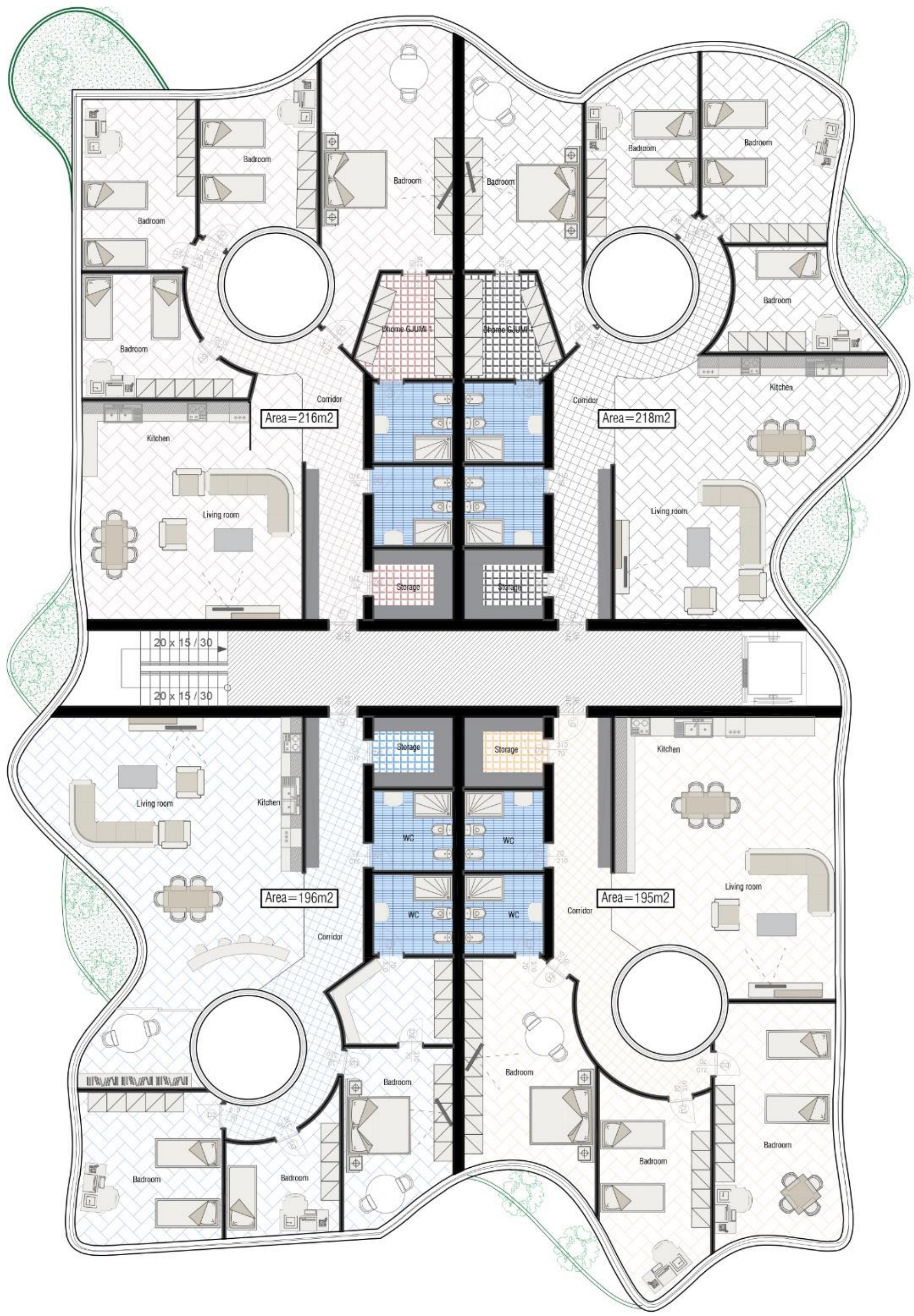


Figure 61. 5th floor plan

The internal circulation is positioned around the circular void which connects to all the rooms. Near to the entrance the living room and the wet spaces core are located whereas further are positioned the bedrooms. The apartment's typology according to the number of rooms varies from 3+1 to 4+1. The apartments have two bathrooms, one storage and a changing room for the master bedroom each and also each of them has at least one green terrace for recreation. *(Fig.61, 62)*

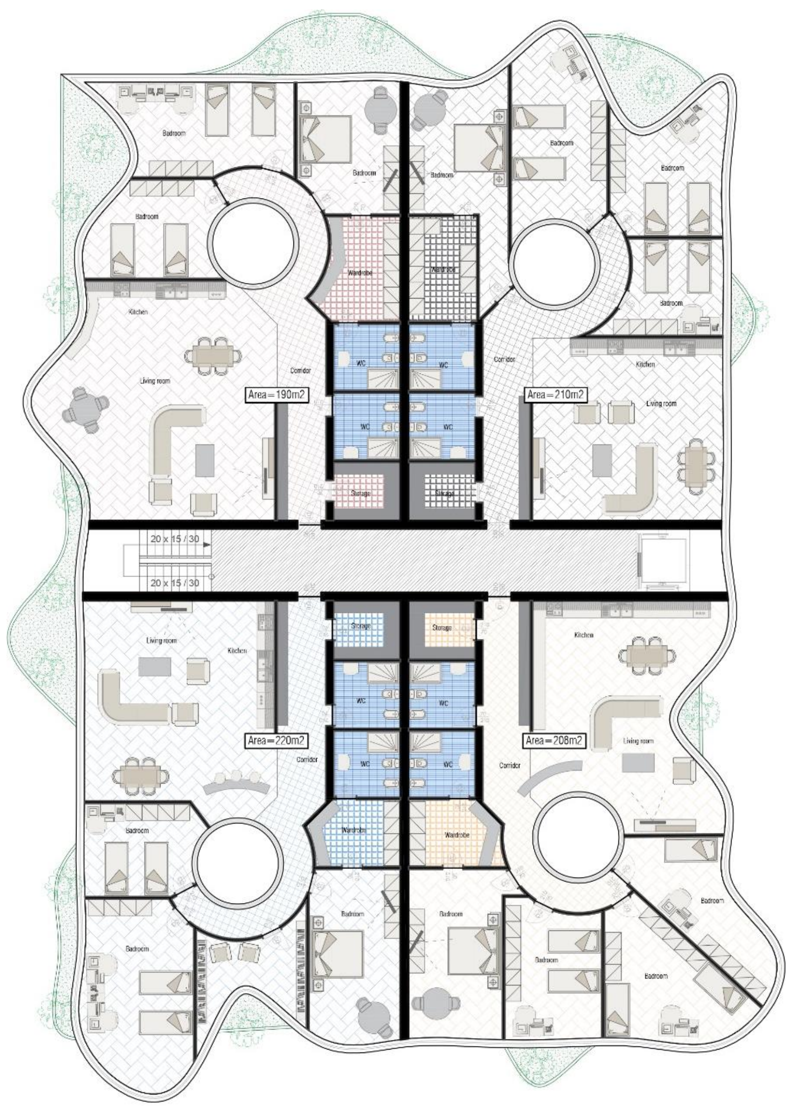


Figure 62. 6th floor plan

4.2.2 Section

In the section view *(Fig. 63)* the part of interest is the sponge concept. The vertical void creates an interconnectivity between all the apartments which despite promoting air circulation, create also minor problematic of privacy. These problematics are assessed through the implementation of parapets 1.1m high which decrease the angle view from the lower apartments to the upper ones, but also provide security in the circulation cores.

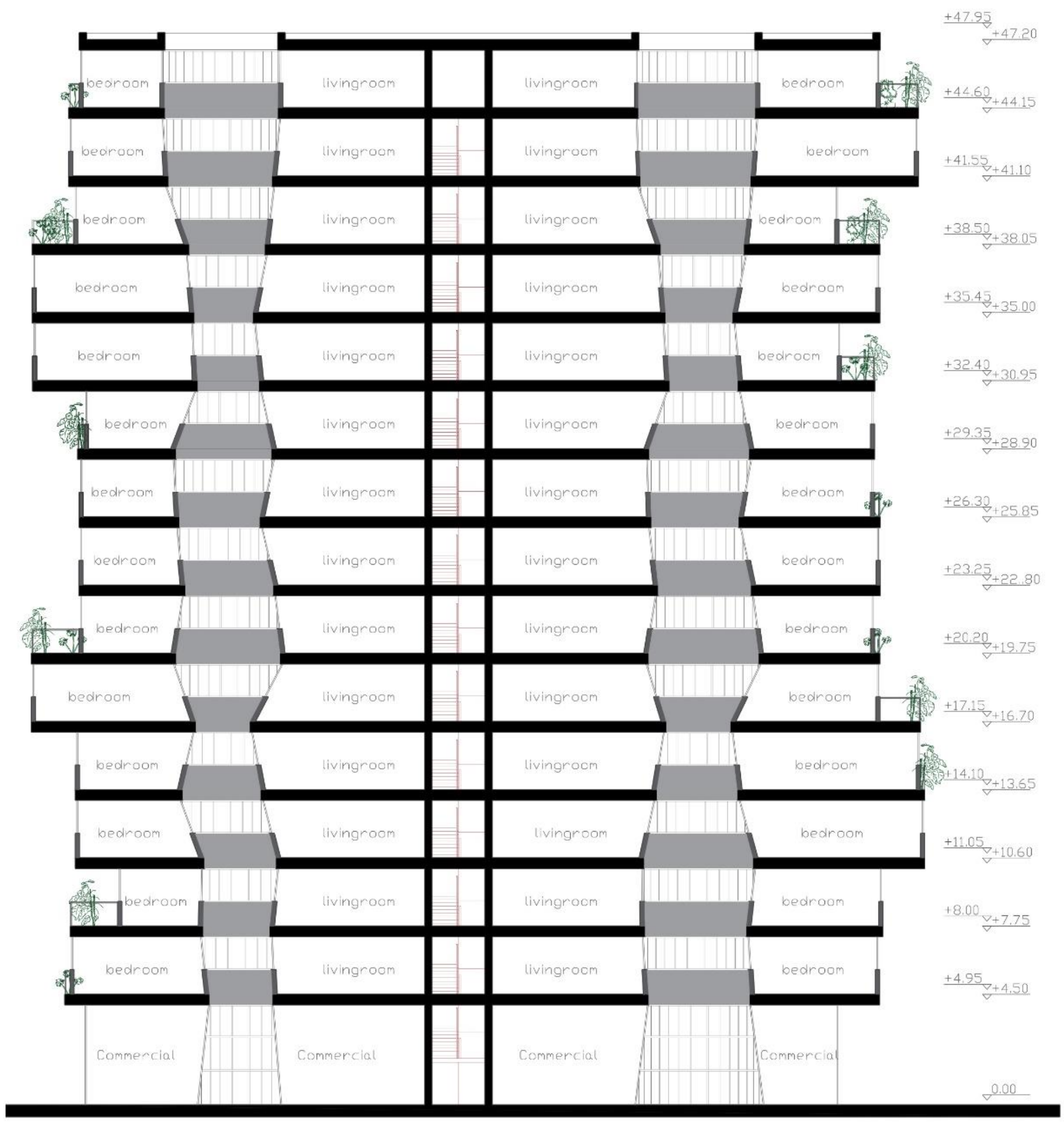


Figure 63. Section

4.2.3 Elevations

Figure 64. Elevations: N-W elevation (up left), N-E elevation (up right), S-E elevation (down left), S-W elevation (down right).

The façade *(Fig. 64)* consists of three parts incorporating elements like white washed concrete, glass wall and wood panels for shading. Each of the floors has 1.1m high white washed balcony which emphasizes the horizontality but also the shape of the building. The exterior glazing is 1.5m above the balcony in order to provide the highest amount of light in the interior. Next shading wood panels are placed in an approximate way outside the building to break the excessive amount of sun. As a final touch greenery is placed in each balcony giving a sense of wilderness to the structure and also a feeling of a lighter volume.

4.2.4 Renders

This subchapter exposes the final product of the research and design in terms of computer generated imagery, in different parts of the day. More renders are attached in the Appendix.

Figure 65. Perspective view from Lana River

Figure 66. Perspective view from southern part

Figure 67. Perspective view from eastern part

CHAPTER 5

CONCLUSION

During the research, a strong shift of interest was perceived regarding natural ventilation, which many important worldwide architects had been experiencing, since the relationship between the building's form (designer's work) and ventilation is interdepended. In Albania as well, exists the necessity to incorporate this practice in order to assess free sustainable energy for passive cooling. In this aspect, the study proposed a framework of how to deal with ventilation design for a residential tower typology, while also making use of parametric tools for quick development of concepts.

The project started with a research on how to deal with wind design and the identification of the main elements to be taken in consideration. Consecutively, based on the observations, three proposals were generated in Grasshopper for Rhino with the scope of reducing drafting time but also getting aid from the use of parametric tools. Next all the proposals were exported to the Autodesk wind tunnel simulation software, where the actual site parameters were set, and with the final result of having the sponge design proposal as the best performing in our climate. Also as a general concept the external factors were used to shape the outer envelope of the building, which by incorporating parametric tools made possible to achieve an undulating façade that redirected wind inward the building and created a more responsive and adaptive design. Next this undulating facade solution was tested against the traditional façade with the result of performing far better in terms of ventilation.

As a final proposal the project consisted of a high rise with interior voids (sponge design) and undulating façade, which created cross ventilation in the interior of the building to a depth of 10m, created variations of winds in the facades and redirections towards the apartments and, last, created supplemental sources of light from courtyards which can lit the interior of the apartments. To conclude the project also created a methodology of how to assess wind potential in residential design making also use of simulation software which help in achieving vibrant but also fully functional concepts.

REFERENCES

Andersen K.T., Heiselberg P., Aggerholm S., ‘Naturlig ventilation i erhvervsbygninger. Beregning og dimensionering, Statens byggeforskningsinstitut’. ISBN 87-563-1128-1 (2002).

ASHRAE Standard (American Society of Heating, Refrigerating and Air-Conditioning Engineers). ‘Ventilation for Acceptable Indoor Air Quality’, Atlanta. ASHRAE 62.1-(2007).

Busby, Perkins and Will “Gurtekin-Celic presentation: Natural Ventilation” (2005).

Chastain J. P., “Design and Management of Natural Ventilation Systems.” Department of Agricultural and Biological Engineering, Clemson University. (2000).

Kindangen J., Krauss G., and Depecker P., ‘Effects of windshapes on wind-induced air motion inside buildings.’ Building and Environment 32(1), Jan., 1–14 (1997).

Kleiven, T., “Natural Ventilation in Buildings: Architectural concepts, consequences and possibilities.” Thesis for the degree of Doktor Ingenior at Norwegian University of Science and Technology. (2003).

Larsen T. S., ‘Natural Ventilation Driven by Wind and Temperature Difference’. Res.9 (2006).

Li, Y., “Indoor and outdoor air quality.” Indoor Air Quality.Hong Kong. (2003).

Ratti C., Baker N., Steemers K., “Energy consumption and urban texture” 6-16 (2005).

Roaf S., ‘Ecohouse: A design guide’ p. 95-122 (2001).

Roulet, C., Germano, M., Allard, F., Ghiaus, C., “Potential for Natural Ventilation in Urban Context: An Assessment Method.” Proceedings, Indoor Air Movement and Natural Ventilation. (2002).

Unified Facilities Criteria (UFC). “Cooling Buildings by Natural Ventilation.” (2004).

U.S Department of Energy., ‘Energy Efficiency Trends in Residential and Commercial Buildings’, 4 (2008).

http://www.archdaily.com/141615/istanbul-sapphire-tabanlioglu-architects (lastly visited on 12 June 2016).

http://www.archdaily.com/448924/ardmore-residence-unstudio (lastly visited on 12 June 2016).

http://www.archdaily.com/40378/the-met-woha (lastly visited on 12 June 2016).

http://www.archdaily.com/553933/markthal-rotterdam-mvrdv (lastly visited on 12 June 2016).

http://www.archdaily.com/641728/buro-ole-scheeren-unveils-the-future-of-vertical-housing-in-vancouver (lastly visited on 12 June 2016).

http://www.archdaily.com/169173/1-bligh-office-tower-ingenhoven-architects (lastly visited on 12 June 2016).

https://archidialog.com/tag/sponge-concept/ (lastly visited on 12 June 2016).

https://www.windfinder.com/windstatistics/tirana/ (lastly visited on 12 June 2016).

APPENDIX A

RENDERS OF THE FINAL PROPOSAL

Figure 68. Perspective view from the bridge.

Figure 69. South-West view during day.

Figure 70. South-West view at night.

Figure 71. Perspective view from the southern part, night render.

Figure 72. Perspective view from the crossroad.

Figure 73. Perspective view from Lana River.

Figure 74. View from the bridge, night render.

Figure 75. View from the bridge, night render.

Figure 76. Proximity with other buildings

Figure 77. Perspective view from the southern part.