CZECH TECHNICAL UNIVERSITY IN PRAGUE

FACULTY OF CIVIL ENGINEERING

DEPARTMENT OF INDOOR ENVIRONMENTAL AND BUILDING SERVICES ENGINEERING

HVAC IN AN OFFICE BUILDING

MASTER´S THESIS

Bc. DOMINIKA CALDERWOOD

SUPERVISOR: **prof. Ing. Karel Kabele, CSc.**

2018/2019

ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE
Fakulta stavební
Thákurova 7, 166 29 Praha 6

ZADÁNÍ DIPLOMOVÉ PRÁCE

I. OSOBNÍ A STUDIJNÍ ÚDAJE

Příjmení: Calderwood Jméno: Dominika Osobní číslo: 424428

Zadávající katedra: K 11125 TZB

Studijní program: Budovy a prostředí

Studijní obor: Budovy a prostředí

II. ÚDAJE K DIPLOMOVÉ PRÁCI

Název diplomové práce: Vzduchotechnika administrativní budovy

Název diplomové práce anglicky: Office building HVAC

Pokyny pro vypracování:
Zpracujte studii pro daný objekt na téma "Snižování tepelné zátěže stínicími prvky" s využitím nástrojů pro modelování a simulaci.
Zpracujte projektovou dokumentaci vzduchotechniky na úrovni rozšířené dokumentace pro vydání stavebního povolení dle vyhlášky 499/2006 Sb.

Seznam doporučené literatury:
[1] Gebauer G., Horká H., Rubinová O. Vzduchotechnika, Era - vydavatelství, ISBN: 80-7366-027-X, 262 s., 2005.
[2] Garlík, B. Technická zarízení budov / Elektrická instalace v budovách, Vydavatelství CVUT, ISBN: 978-80-01-06342-2, 414 s., 2017.
[3] Santamouris, M; Wouters, P. Building ventilation: the state of the art, Earthscan, ISBN: 9781844071302, 313 s.,2006. (NTK TH7654 .B85 2006)
[4] Papež K.,Vyoralová Z., Marková L., Garlík B., Jokl M. Energetické a ekologické systémy budov 2. Vzduchotechnika, chlazení, elektroinstalace, umelé osvetlení. Fakulta stavební, 1. vydání, ISBN: 978-80-01-03622-8, 2007. (NTK TH6021 .P37 2007 z)
[5] Mitchell, J. W., Braun, J. E. Principles of Heating, Ventilation, and Air Conditioning in Buildings, Wiley, ISBN 9780470624579, 600 s., 2013. (NTK TH7222 .M58 2013).

Jméno vedoucího diplomové práce: prof. Ing.Karel Kabele, CSc.

Datum zadání diplomové práce: 8.10.2018 Termín odevzdání diplomové práce: 6.1.2019
Údaj uveďte v souladu s datem v časovém plánu příslušného ak. roku

Podpis vedoucího práce Podpis vedoucího katedry

III. PŘEVZETÍ ZADÁNÍ

Beru na vědomí, že jsem povinen vypracovat diplomovou práci samostatně, bez cizí pomoci, s výjimkou poskytnutých konzultací. Seznam použité literatury, jiných pramenů a jmen konzultantů je nutné uvést v diplomové práci a při citování postupovat v souladu s metodickou příručkou ČVUT „Jak psát vysokoškolské závěrečné práce" a metodickým pokynem ČVUT „O dodržování etických principů při přípravě vysokoškolských závěrečných prací".

8. 10. 2018
Datum převzetí zadání Podpis studenta(ky)

I hereby declare that all information in this document has been obtained and presented in accordance with all academic rules and ethical codes of conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

In Prague on 6th January 2019 Signature

Acknowledgements:

I would like to thank my supervisor prof. Ing. Karel Kabele, CSc. for his professional approach to leading my master´s thesis and for his valuable help. I would also like to thank the architectural studio Cuboid architekti s.r.o for providing me with the drawing documentation for the Parkview building.

Annotation in English:

This thesis has two main sections. Both parts deal with the same administrative office building, Parkview, with nine above ground floors. The building serves several purposes such as an office space, a restaurant and retail space.

Firstly, because of the character of the building and the used materials, part of this thesis is a theoretical study focused on possible sun shading alternatives and their impact on solar heat gain. This study arises from the obvious problem with overheating inner spaces. This analysis is based on an energy simulation using DesignBuilder.

Secondly there is a practical part to this thesis concerning the design of an air-conditioning system for the inner premises of the same building. The air-conditioning system should ensure a comfortable work environment throughout the year.

Annotation in Czech

Tato diplomová práce se skládá ze dvou hlavních částí. Obě části se zabývají stejným objektem a to administrativní budovou Parkview s devíti nadzemními patry. Budova poskytuje zejména prostory pro administrativu, restauraci a obchody.

Jako první je zpracována teoretická část práce zaměřená na studii možných stínících prostředků vhodných pro tuto budovu a jejich vlivu na solární tepelné zisky. Studie je vhodná zejména kvůli častému problému s přehříváním takovýchto budov. Studie je vypracována s využitím softwaru pro energetické simulace DesignBuilder.

V druhé, projektové části byl zpracován projekt vzduchotechniky pro stejný object, který má zajistit příjemné vnitřní pracovní prostředí po dobu celého roku.

Keywords in English:

Air conditioning, modern office building, HVAC, sun shading elements, glass curtain wall façade, cooling, window blinds, louvres

Keywords in Czech:

Klimatizace, moderní administrativní budova, vytápění-vzchuchotechnika, stínící prvky, prosklená fasáda, chlazení, žaluzie, slunolamy

The goal of the master's thesis

The goal of this thesis is to design a viable and efficient HVAC system that will cover the cooling, heating and ventilating needs of the inner premises of the given building. The system should ensure a comfortable inner environment without disturbing the users in any way.

The system is designed to be controllable by the users in every space, where longer continuous usage is expected.

The study focused on sun shading should analyze the possible sun shading elements, and compare and simulate their practical impact on the building using the simulation software DesignBuilder.

CZECH TECHNICAL UNIVERSITY IN PRAGUE

FACULTY OF CIVIL ENGINEERING

DEPARTMENT OF INDOOR ENVIRONMENTAL AND BUILDING SERVICES ENGINEERING

HVAC IN AN OFFICE BUILDING

THEORETICAL PART: A STUDY OF REDUCING SOLAR HEAT GAIN WITH SUN SHADING ELEMENTS

Bc. DOMINIKA CALDERWOOD

2018/2019

TABLE OF CONTENTS

A-THEORETICAL PART

B-PROJECT: HVAC IN AN OFFICE BUILDING

B1) A TECHNICAL REPORT

B2) CALCULATIONS:

1. Airflow volumes calculation
2. Air-handling units' design
3. Heat loss/heat gain calculations
4. Air distribution products' design
5. Hydraulic calculation -duct sizing, pressure loss
6. Attenuators' design

B3) DRAWINGS:

1.	Functional schematic	
2.	3rd basement HVAC floor plan	1:75
3.	2nd basement HVAC floor plan	1:75
4.	1st basement HVAC floor plan	1:75
5.	1st floor HVAC floor plan	1:60
6.	2nd-4th floor HVAC floor plan	1:60
7.	5th-8th floor HVAC floor plan	1:60
8.	9th floor HVAC floor plan	1:60
9.	Roof HVAC floor plan	1:60
10.	Section view A	1:75
11.	Section view B	1:75
12.	Mechanical engine room 1	1:50
13.	Mechanical engine room 2	1:50
14.	Mechanical engine room 3	1:50
15.	Mechanical engine room 4	1:50
16.	Mechanical engine room 5	1:50
17.	Detail of a typical office	1:30
18.	Detail of an air door curtain	1:30
19.	Detail of the restaurant kitchen	1:30
20.	Detail of the retail space 1	1:30

B4) ANNEX: TECHNICAL SPECIFICATIONS

1 INTRODUCTION

For the purpose of the thesis, I chose a 9-story administrative building in Pankrác area of Prague, named "Parkview", the construction of which will be finished in the next couple years.

In this thesis I am dealing with a current problem, which is the immense/excessive heat gain in newly constructed buildings whose façade consists mainly of a glass curtain wall. Buildings of this type tend to act like a greenhouse, since their glass envelope has a very high U-value (est. 1W/m^{2}K) plus it allows direct sunlight to pass through into the interior of the building. The heat is then trapped inside. Since a lot of these buildings are also designed for office purposes (usually using an open-office concept), the heat from outside is not the only source of heat and we have to take into consideration the inner gain from all the electronic equipment and people. In addition, these buildings usually don't have enough accumulative abilities, resulting in very rapid temperature change which is not being compensated for by inner heat/cold accumulation.

Architects and engineers try to at least partially solve this issue by adding various shading elements, such as inner or outer blinds, reflective foils, awnings or many different kinds of metal sunshades. If sunshade solution is selected, it can be considered a part of the architectural concept but a lot of the times the architects do not allow the installation of any kind of physical barrier in front of the façade which results in a more extensive and expensive HVAC solution.

The goal of this work is firstly to summarize the different kinds of shading options that could be used for this building, compare their advantages and disadvantages and simulate their impact on the inner solar heat gain of the building. For the simulation, DesignBuilder software will be used. Secondly, I will design a HVAC system for the whole building and prepare drawing documentation supported by calculations and a technical report.

2 THE BUILDING

2.1 Description of the building

The building has three underground floors, serving mainly as a parking area and nine above ground floors. The structure itself is a combination of reinforced concrete skeleton and monolith. The structure is mostly enclosed by a modern style glass curtain wall, providing a contemporary, open feel to the users. Certain walls, especially on the ground floor, are brick or concrete monolith with continuous exterior insulation.

Figure 1: A visualisation of the building no.1 [website source: www.skanska.cz]

Figure 2: A visualisation of the buildinf no.2 [website source: www.skanska.cz]

The ground floor offers two retail stores, a restaurant and a spacious lobby that connects all nine above ground levels and offers an open staircase up to the fourth floor.

All the other above ground floors serve as an office area with meeting rooms, archives, server rooms, kitchenettes, sanitary facilities.

Layouts of the 1st and 2nd floor are visible on the figure no.3 below.

Floors 3-9 have the same functional layout as the 2nd floor with minor changes.

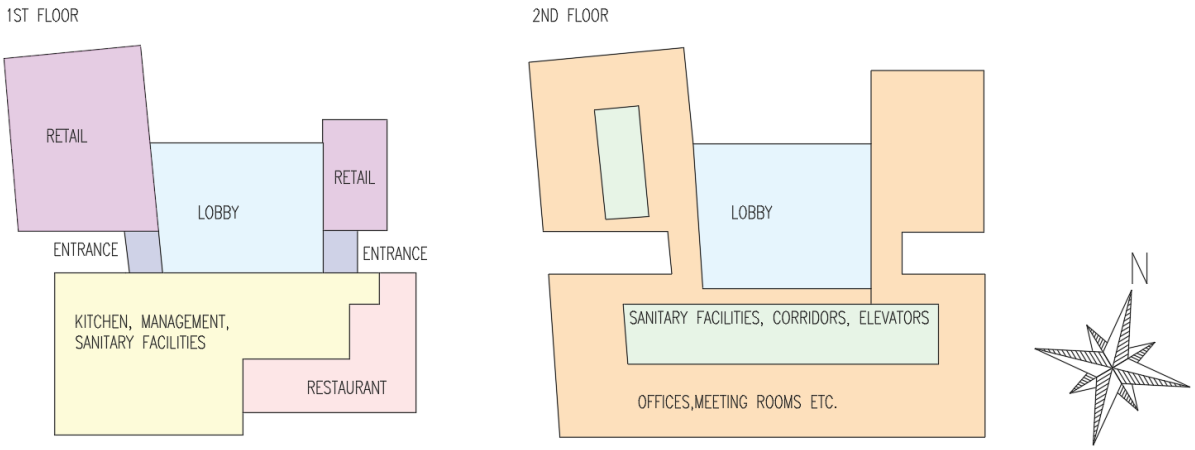

Figure 3: A layout of the building [A schematic created by Dominika Calderwood]

2.2 Location

The office building is located in a Pankrác neighborhood in Prague 4. It is a lucrative location in the center of a newly developed business area, easily accessible by public or private transportation. This building is located right next to a city park, offering nice open views and a feeling of greenery in the workplace. The location offers easy access to many facilities, such as restaurants, gyms, shops, other office buildings, etc.

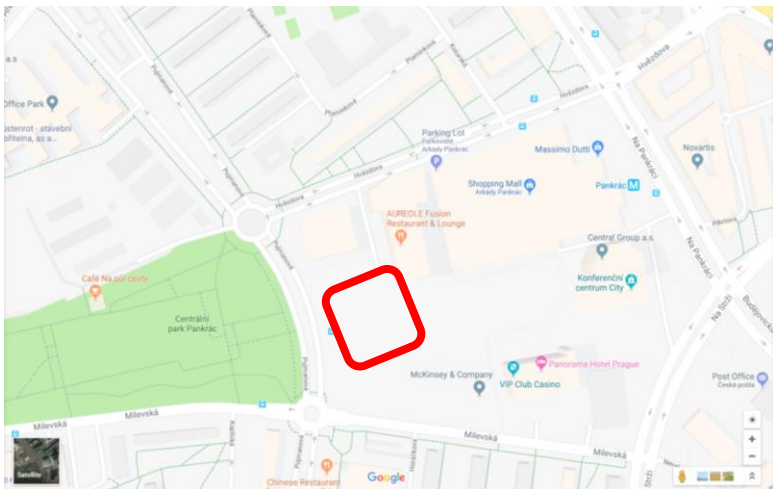

Figure 4 : Location marked on the map [website: www.google.com/maps]

Figure 5: An areal view of Pankrác area [website: www.google.com/maps]

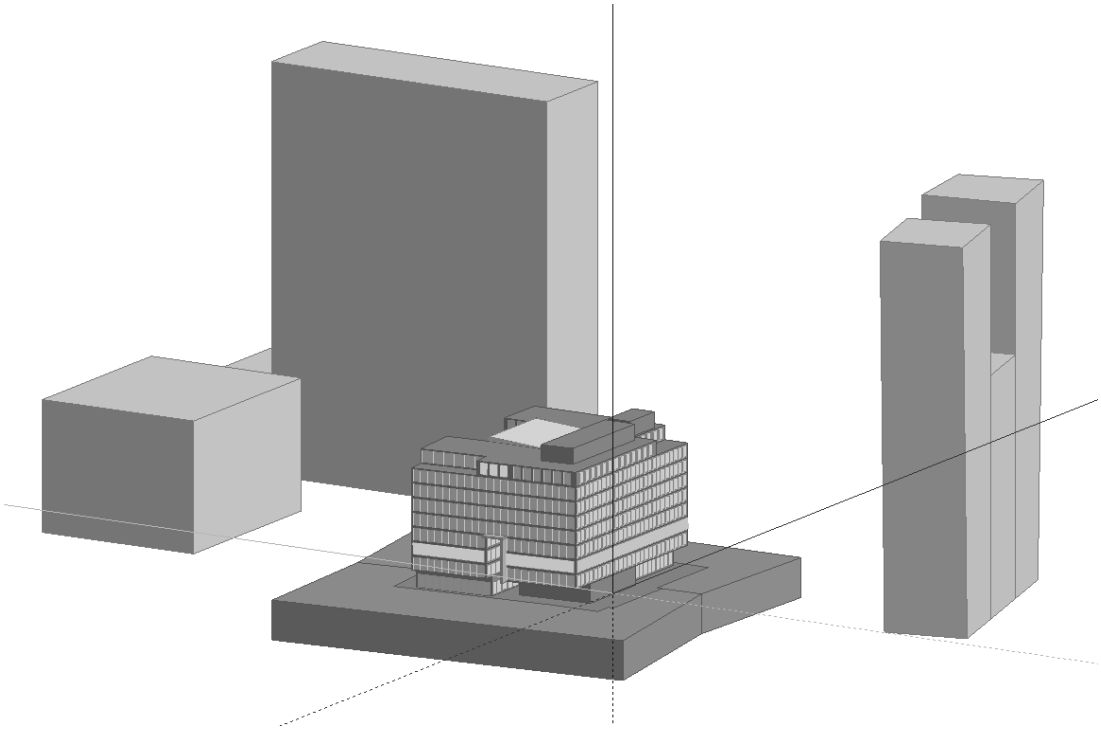

Figure 6: A DesignBuilder model of Pankrác area [A model created by Dominika Calderwood]

2.3 Boundary conditions

Location: Prague Ruzyně (weather data file)

Indoor design temperatures in offices:

Winter:	20°C
Summer:	25°C

Outdoor design temperatures:

Winter:	-12°C
Summer:	32°C

2.4 Operation description

The building will be occupied mainly from 7am to 7pm, or during the business hours of the individual renters.

There are different schedules for: office floors, restaurant, kitchen, retail stores.

Offices are mainly used from 7am to 7pm

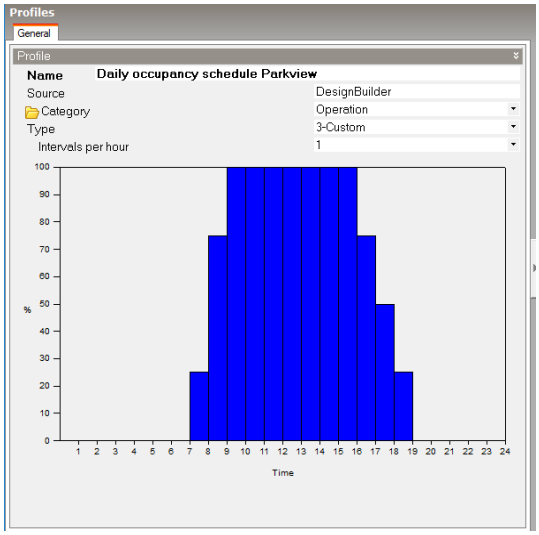

Figure 7: Daily occupancy of office floors [A model created by Dominika Calderwood]

3 STUDY OF SUN SHADING ALTERNATIVES

Today's market offers variety of shading options providing different shading results and appearance at variety of different price levels. Certain shading elements have to be a part of the initial project whereas others can be implemented after the fact. Which shading element is the best for a specific building is something we should take into consideration. Variables which we need to think about before making this decision are the type of space we are trying to shade, its usage during an average day, required illuminance levels, the size of initial investment a client is capable of providing and last but not least the targeted intelligence of the system. In this study I am going to compare various types of shading elements.

3.1 Software

A full student license of DesignBuilder was used for this simulation. DesignBuilder allows the user to model a building and simulate any time period during the year with its weather conditions. It is mainly used to compare different energy consumption scenarios in buildings i.e. heating, lighting, electricity et cetera.
V5.5.0.12 is the software version available at the time of this study.

3.2 DesignBuilder model

To begin with, I created a model that represents the real building as closely as possible. It was essential to enter designed assemblies, windows and doors, occupancy schedules, HVAC schedules, location details, lighting schedules etc. into the program.
Structures were given assemblies based on an obtained assemblies' list.
Surrounding buildings were also modeled at a basic level to fully represent the surrounding area. Most of those buildings are taller than the Parkview building and there therefore they may provide a partial (and free) shading effect. The other buildings were modeled as an outline block, a simplified mass-only kind of a structure.
The inner rooms of the Parkview building which don't have an exterior wall were not divided into individual rooms because their disposition does not influence the model's behavior and their heat gain is not altered by solar gains.
For the exterior windows the type of glazing had to be selected. The *SHGC* value which stands for solar heat gain coefficient was set at 0,45.
SHGC is based on the character of the window which has stripes of opaque material that reduces the light transmission. The other value that had to be determined was the *Light transmittance* which was set at 0,81.
The U-Value for the façade windows was set at 1 W/m^2K based on the manufacturer's specifications.

3.2.1 Assemblies

Exterior wall

Aluminum façade panels	4mm
Load bearing metal grid	55mm
Thermal mineral insulation	160 mm
Ceramic masonry	240mm
Mortar	2 mm

Inner wall

Lime mortar	4 mm
Reinforced concrete	200 mm
Lime mortar	4 mm

Partition

Lime mortar	4 mm
Masonry	150 mm
Lime mortar	4 mm

Underground wall

Polyurethane	2 mm
XPS extruded polystyrene	40 mm
Water insulation layers	9 mm
Penetration	2 mm
Concrete wall	350 mm

Curtain wall

Schüco window curtain wall	250mm

Floor garages

Polyurethan floor	3mm
Reinforced concrete slab	300mm

Floor

Carpet	8 mm
Air gap with metal grid	140 mm
Ceiling slab	250 mm

3.2.2 Original model visualisation

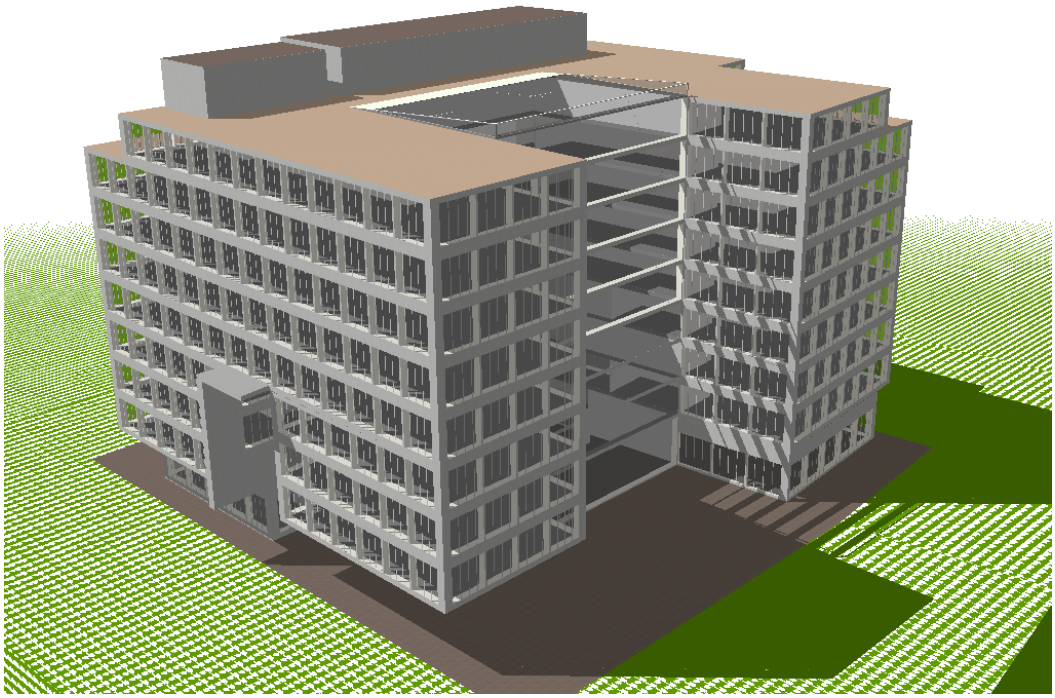

Figure 8: DesignBuilder model picture 1; north [A model created by Dominika Calderwood]

Figure 9: DesignBuilder model picture 2; south-west [A model created by Dominika Calderwood]

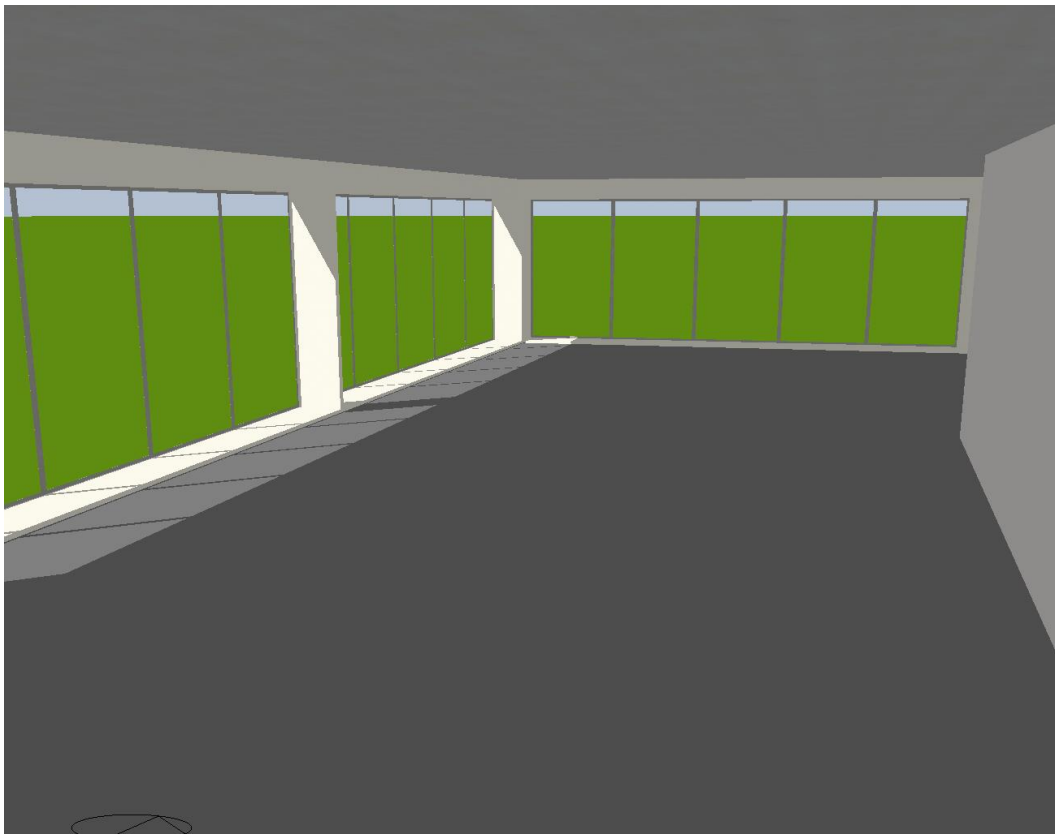

Figure 10: DesignBuilder model picture 3; office space [A model created by Dominika Calderwood]

3.3 Sun control and shading options

Below are stated sun shading solutions that would be suitable for Parkview building. Their main properties are described. For all sun shading elements, the control type was set to *Always on*. That way we will get a comparable set of results. In reality the sunshades that can be manually operated would not be used if the outdoor conditions would not cause a higher, uncomfortable amount of glare or solar heat gains.

3.3.1 Inner window blinds

Inner window blinds are one of the most common solutions for sunshading. Internal window blinds are usually easy to adjust depending on the sun. In addition to the ease of adjustment, maintenance is typically minor. Blinds, while typically the budget shading option, are also usually very effective at reducing light, glare, and helping to reduce cooling costs.

Figure 11: Inner window blinds [website: www.okna-vrata.cz/zaluzie-interierove]

Advantages and disadvantages

+ Inner blinds can be installed even if they were not a part of the original design.
+ Easy and relatively cheap to install, maintain, repair and replace.
+ A classic solution which can be comfortable for users because they are used to using it.
+ The non-automatic version does not require electricity to be operated.
+ Does not change the outer appearance of the building
+ Users can change the position or angle of the slats.
+ Automatic inner blinds can be programmed to adjust to the sun's position in the sky.
+ Automatic roller shades can be programmed to adjust to the sun's position in the sky.

+ The manually operated version does not require electricity to be used.
+ Does not change the outer appearance of the building.

- The solar rays get inside the building, they are stopped on the inside of the glass
- Certain materials used to make roller shades may suffer more from wear and tear
- Roller shades, while effective, are not a stylish, modern solution. If style is important to the project, then roller shades can be a poor choice.

Model implementation

On the *Openings* tab under the section *Shading-window shading* the type was set to *Blind with medium reflectivity slats* with position *Inside* and control type *Always on.*

3.3.2 Outer window blinds

Outer window blinds are the most used outdoor shading element. Because the blinds are on the outside of the window, they create a better heat shield than interior window blinds which translates to an easier workload for the building's climate control system. While typically used on commercial and office building, outdoor window blinds are becoming increasingly popular in modern residential buildings.

Figure 12: Outer window blinds [website: www.svet-oken.cz/cz/stinici-technika/venkovni-zaluzie.html]

Advantages and disadvantages

+ Changing the angle of the slats changes the effect
+ Not a permanent feature of the façade, lowered if needed
+ Can have a contemporary feel
+ Horizontal blinds and louvers are more effective than most sun shading elements.
+ Users can change the position or angle of the slats.
+ Automatic outer blinds can be programmed to adjust to the sun's position in the sky.

- Creates thermal bridging
- Relatively expensive and difficult to install, maintain, repair and replace.
- Drastically alters the view from the building when used.
- Difficult to install, maintain, repair, replace and clean.
- Usually, horizontal louvres cannot be installed unless they were a part of the original design.

Model implementation

On the *Openings* tab under the section *Shading-window shading* the type was set to *Blind with medium reflectivity slats* with position *Outside* and control type *Always on.*

3.3.3 Horizontal sunshade

Horizontal sunshades are almost exclusively found on commercial and office buildings. While there is far less adjustability, horizontal sun shading elements offer a lot of advantages over indoor and outdoor blinds.

Figure 13: Horizontal sunshades [website: www.chinasteelgrating.com/application/sun-shade-panels.html]

Figure 14: Horizontal sunshade added in Designbuilder [A model created by Dominika Calderwood]

Advantages and disadvantages

+ Horizontal sunshades do not alter the view from inside of the building.
+ No electricity needed for operation.
+ Static element that requires no human or mechanical operation.

+ They help keep rain away from the windows, therefore keeping them cleaner.
+ Creates thermal bridging.
+ Changes the appearance of the exterior.

- Relatively expensive and difficult to install, maintain, repair and replace.
- Horizontal sunshades have to be a part of the original project. Usually it is not possible to add them later.
- Sun shades create thermal bridges.
- Significant architectural feature, takes away from the exterior design of the building.

Model implementation

On the *Openings* tab under the section *Shading-local shading* the type was set to *Horizontal sun shade*. *Horizontal sunshade* was created as an 1,5 m deep overhang above the windows.

3.3.4 Vertical sunshade / Sidefins

Vertical sunshade elements can bring an additional design element to a building. Vertical sunshades can be easily incorporated into any curtainwall system, making them a popular choice in modern glass curtainwall buildings.

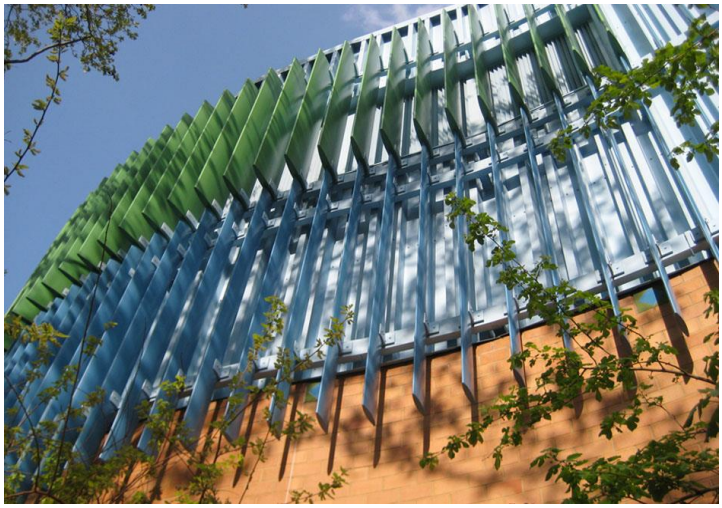

Figure 15: Vertical sunshades [website: www.c-sgroup.com/sun-controls/vertical-sunshades/vertical-sunshades]

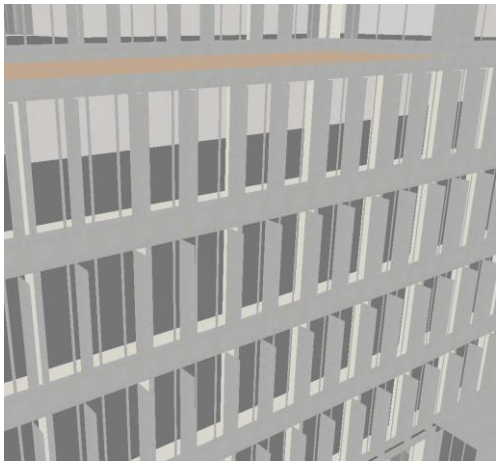

Figure 16: Vertical sunshade added in Designbuilder [A model created by Dominika Calderwood]

Model implementation

On the *Openings* tab under the section *Shading-local shading* the type was set to *Vertical sunshade*. *Vertical sunshade* was created as 0,7 m deep sidefins on each side of the window.

Advantages and disadvantages

+ A significant and usually positive architectural feature.

+ There a many different materials and shapes that the vertical sunshade can have
+ During manufacturing they can be bent in a way to fit a specific sun shading need.
+ Contemporary feel
+ Static element that requires no human or mechanical operation
+ It does not block the view
+ Easy cleaning and replacement

- Relatively expensive and difficult to install, maintain, repair and replace.
- Vertical sunshades have to be a part of the original project. Usually it is not possible to add them later.
- If the underlying building design is important, then vertical sunshades can hide or seriously alter that design.
- Users cannot change the position or angle
- Any manipulation/service requires a professional company.
- Sun shades create thermal bridges

3.3.5 Horizontal louvres

Horizontal louvres are an easy sun shading solution. Having no mechanical parts, or need or electricity, these sun shading elements are excellent choices for certain commercial buildings. Since they are an exterior solution, like some of the previous solutions, they will change the look of the exterior of the building meaning they need to be taken into account when designing the building.

Figure 17: Horizontal louvres [website: www.alupro.com/en/products/facade-solutions/louvers/aluclik-facade-louver]

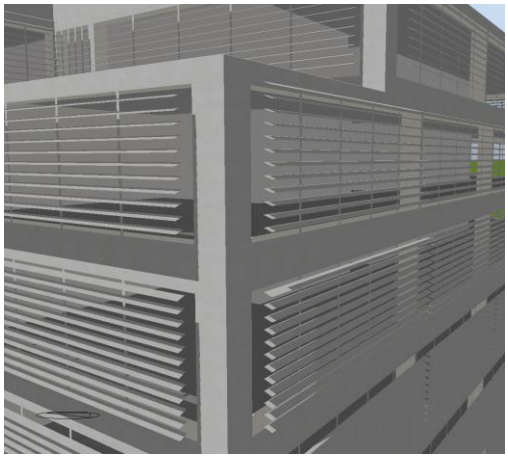

Figure 18 : Horizontal louvres implemented in the model [A model created by Dominika Calderwood]

Advantages and disadvantages

+ Static element that requires no human or mechanical operation
+ Can have a contemporary feel
+ Horizontal louvres are more effective than most sun shading elements.
+ A significant architectural feature

- Relatively expensive and difficult to install, maintain, repair and replace.
- It has to be a part of the original project. Usually not possible to add it later.

- It hides the building, it's a prevailing feature.
- Users cannot change the position or angle
- Drastically alters the view from the building
- Seriously changes the exterior appearance, sometimes for the worst.
- Difficult to install, maintain, repair, replace and clean.
- Usually, horizontal louvres cannot be installed unless they were a part of the original design.

Model implementation

On the *Openings* tab under the section *Shading-local shading* the type was set to *Horizontal louvres. Horizontal louvres* was created as 200mm deep slats under xxx angle.

3.3.6 Inner roller shade

Inner roller shades offer adjustable shade in a relatively inexpensive and easy to use format. A classic design that everyone can recognize, they are easy to maintain and have no effect on the exterior look of the building. Some varieties can be automated to help maintain the buildings climate with no effort on the part of the inhabitants, while others are completely manual.

Figure 19: Roller shades example [website: www.insolroll.com/blackout-roller-shades]

Advantages and disadvantages

+ Roller shades can be installed even if they were not a part of the original design.
+ Easy and relatively cheap to install, maintain, repair and replace.
+ A classic solution which can be comfortable for users because they are used to using it.
+ Automatic roller shades can be programmed to adjust to the sun's position in the sky.
+ The manually operated version does not require electricity to be used.
+ Does not change the outer appearance of the building.

+ The material used for the shade can have different visual properties based on what the client is looking for. The shade can be partially translucent, have different colours or thread count. These properties influence the light transmission.

- The automatic version, while less expensive to repair than exterior shading solutions, is prone to more expensive and difficult repairs, compared to the manually operated version.
- Certain materials used to make roller shades may suffer more from wear and tear and sun damage.
- Roller shades, while effective, are not a stylish, modern solution. If style is important to the project, then roller shades can be a poor choice.

Model implementation

On the *Openings* tab under the section *Shading-window shading* the type was set to *Shade roll – light translucent* with position *inside* and operation *Always on.*

3.4 Impact on the inner solar heat gain

All the previously mentioned sun shading elements were implemented one by one into the simulation software and their effect on the inner solar heat gains was calculated.

The simulation was executed using weather data from the summer months' (1st May through 31st October).

The OFFICE 1 is the room for which simulation results will be analyzed.

The day on which the heat gain in the office was the highest in the original model was the same day that I used in the comparison of the results.

The original model with no sun shading elements has also been run through a simulation to obtain its results to have a baseline for future result comparison.

Result value of 489 kW of the original building obtained from Designbuilder are lower than the results of the calculation in the project which were around 600kW. The project didn't calculate with any of the DesignBuilder results. DesignBuilder is a new method of calculating heat again in a less conventional way.

	Sun shading element used	**Solar heat gain of the whole building**	**Solar heat gain of the office 1**
1	Original model-none	489,26 kW	37,2 kW
Solar heat gain peak occurred aon the 8th September at 14.00			
2	Inner window blinds	260 kW	8,077 kW
3	Outer window blinds	255,4 kW	8,3 kW
4	Horizontal sunshade	366 kW	22,54 kW
5	Horizontal louvre	215 kW	15,28 kW
6	Vertical sunshade	416 kW	29,08 kW
7	Inner roller shade	325 kW	20,73 kW

Table 1: Sun shading alternatives: Results. [Results of a model created by Dominika Calderwood]

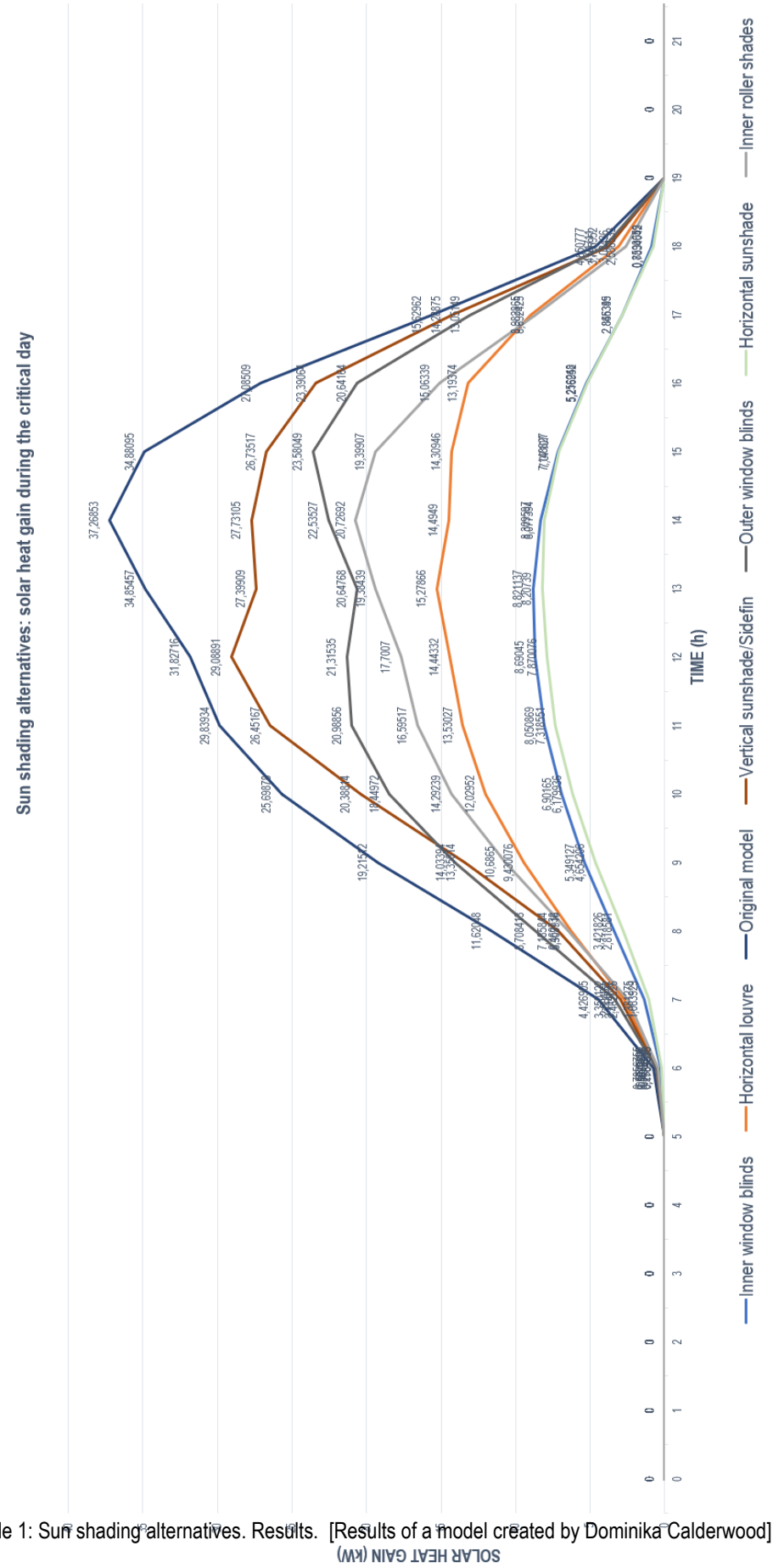

Table 1: Sun shading alternatives. Results. [Results of a model created by Dominika Calderwood]

4 CONCLUSION

Based on the DesignBuilder model that was created and used for simulation it is obvious that the inner and outer blinds with the roller shade gave the best results when it comes to solar heat gain. We can mainly attribute that to the fact that all those 3 options cover the whole surface of the window, by which they block the light and the sun rays from getting in. These sun shading elements are suitable for a quick easy cooling solution but as a permanent feature they don't perform the way the user would need. By covering the window, you make the rooms dark which is unwanted.

Horizontal louvres also made a significant impact on the solar heat gains. This solution might not be ideal because majority of architects would not consider designing these as the façade.

Other sun shading elements did not perform well enough to consider them. Especially the vertical sunshades proved themselves to be inefficient.

Taking all the results into consideration I would recommend installing the horizontal louvres.

5 REFERENCES

5.1 Initial source of data

Architectural Studio Cuboid s.r.o

For the purposes of this thesis architectural drawings owned by Cuboid studio were used.

5.2 Software

Autocad 2018, student's license [online]. [cit. 2018-11-20]. Dostupné z: https://www.autodesk.cz/products/autocad/free-trial

DesignBuilder V5.5.2.003 [online]. [cit. 2019-01-02]. Dostupné z: https://www.designbuilder.co.uk/download/software/release-software

5.3 Literature

[1] MITCHELL, John W. a James E. BRAUN. *Principles of heating, ventilation, and air conditioning in buildings*. Hoboken, NJ: Wiley, c2013. ISBN 9780470624579 (NTK TH7222 .M58 2013).

[2] WOOD, Antony a Ruba SALIB. *Natural ventilation in high-rise office buildings*. New York: Routledge, 2013. ISBN 978-0415509589.

5.4 List of tables

5.5 List of figures