Light Catcher

Exploration of the use of textiles on exterior window wall

Chalmers University of Technology Department of Architecture and Civil Enginerring
Architectural Experimentation
Xiaofei Deng

ACEX35 Master's thesis in Architecture
Spring 2024 | Architectural Experimentation

Chalmers School of Architecture
Department of Architecture and Civil Engineering

Examiner
Jonas Lundberg

Supervisor
Erica Hörteborn

Thanks to

Erica Hörteborn
Jonas Lundberg
Peter and Tabita
Naima and Jessica
Family & Friends

ABSTRACT

Many architectural design concepts draw inspiration from the knitting/weaving techniques of textiles and their properties. For example, woven bamboo, timber construction and decoration, metal building shells, ceramics and cement plasticity can all draw inspiration from the unique knitting/weaving methods and the softness of textiles, resulting in striking exterior designs and unique spatial effects. However, today textiles themselves are rarely used as building materials, especially in large-scale architectural projects and exterior designs. At the same time, there are a lot of research teams working on how to expand the use of textiles in architecture. As a special material close to people's life, it can bring people a sense of kindness, comfort and beauty. And in the context of sustainable development, people are looking for various materials to replace or optimise existing materials, then textiles are also one of the optional materials.

The use of textiles in windows can date back more than a thousand years, when most windows in China were made of textiles and oiled paper rather than the glass like today. Textile and oiled paper windows have gradually dropped out of sight due to their vulnerability to breakage, poor sound proofing, and inability to withstand extreme weather conditions, etc. Nowadays, textiles are mostly placed inside and outside of glass windows for shading and privacy. This master thesis will explore the spatial diversity, advantages and disadvantages of restating textiles to replace glass as the main material for architectural windows. It will focus on demonstrating the special/beautiful light and shadow outcome produced by textiles on architectural spaces, learning from shadow play, light art and textile knitting/ weaving methods.

In order to incorporate the actural spatial design, the glass facade of an old building, the Meilac Cinema, located in the centre of a small town in southern China, will be transformed into textile windows.

Keywords : Textile; Window; Light; Shadow

TABLE OF CONTENT

1.

Fig 1.0.1 Mongolianyurts in Xinjiang, China. © Dongli Zhao

Fig 1.0.2 Ceramic-House in Netherland. ©Riccardo De Vecchi photographer

Fig 1.0.3/1.0.4 'swooshy' pillars outside Gothenburg city library.

1.0
INTRODUCTION

Textiles have a long history as facade materials and are still widely used in some places. The lightweight and easy-to-install nature of textiles make this building material is ideally suited to the traditional nomadic lifestyle. Although more and more people are changing their lifestyle and building permanent housing made of concrete, some residents still live in yurts. (Mauvieux, Reinberg& Touitou, 2014) These building serve as evidence that textiles can be employed as facades material for buildings in harsh weather.

The knitted textiles have also inspired various designs for building facades. In the Netherlands, the architecture firm Studio RAP transformed a boutique facade on Amsterdam's P.C. Hooftstraat (Fig 1.0.2). According to Studio RAP, the wave-like facade inspired by the craft of knitting garments, the elegant pleats, interlocking yarns and organic stitching of textiles allow it change as viewers approach. Algorithmic languages, 3D-printed ceramics, and hand glazing were utilized in the construction of the facade to ensure the accuracy of the façade shape.

Recently, freelance lighting designer Niklas Pohlman used Anolis ArcSource 4 MCs LED fixtures to illuminate 'Do you come here often?', three striking pillars with a bronze fabric effect at the entrance to the Gothenburg City Library created by sculptor Yvonne Thornqvist (Fig 1.03.3/1.0.4). The library is a centre of literary vitality and learning, as well as a meeting place and an active community and social space. Since the columns are located in the shadows of the entrance's first-floor overhang, the artist specifically wanted them to be lit so that they could be appreciated after dark.(Campos.G, 2018)

1.1
RESEARCH QUESTIONS

This design/research aims to explore the wider use of textiles as building materials in architectural design, the possibilities of knitted/woven textiles as ***architectural facades***, and the advantages and disadvantages compared to other materials (glass, wood, steel, etc.). Specifically, the following research questions can be summarized:

1. How do external/natural and internal/artificial light combined with the properties of textiles themselves, affect the light and shadow effects of textiles in the setting of textile windows?

2. How can textiles be used in an architectural design for an exterior curtain wall that serves both as a ***wall*** and a ***window***?

1.2
RESEARCH OBJECTIVES

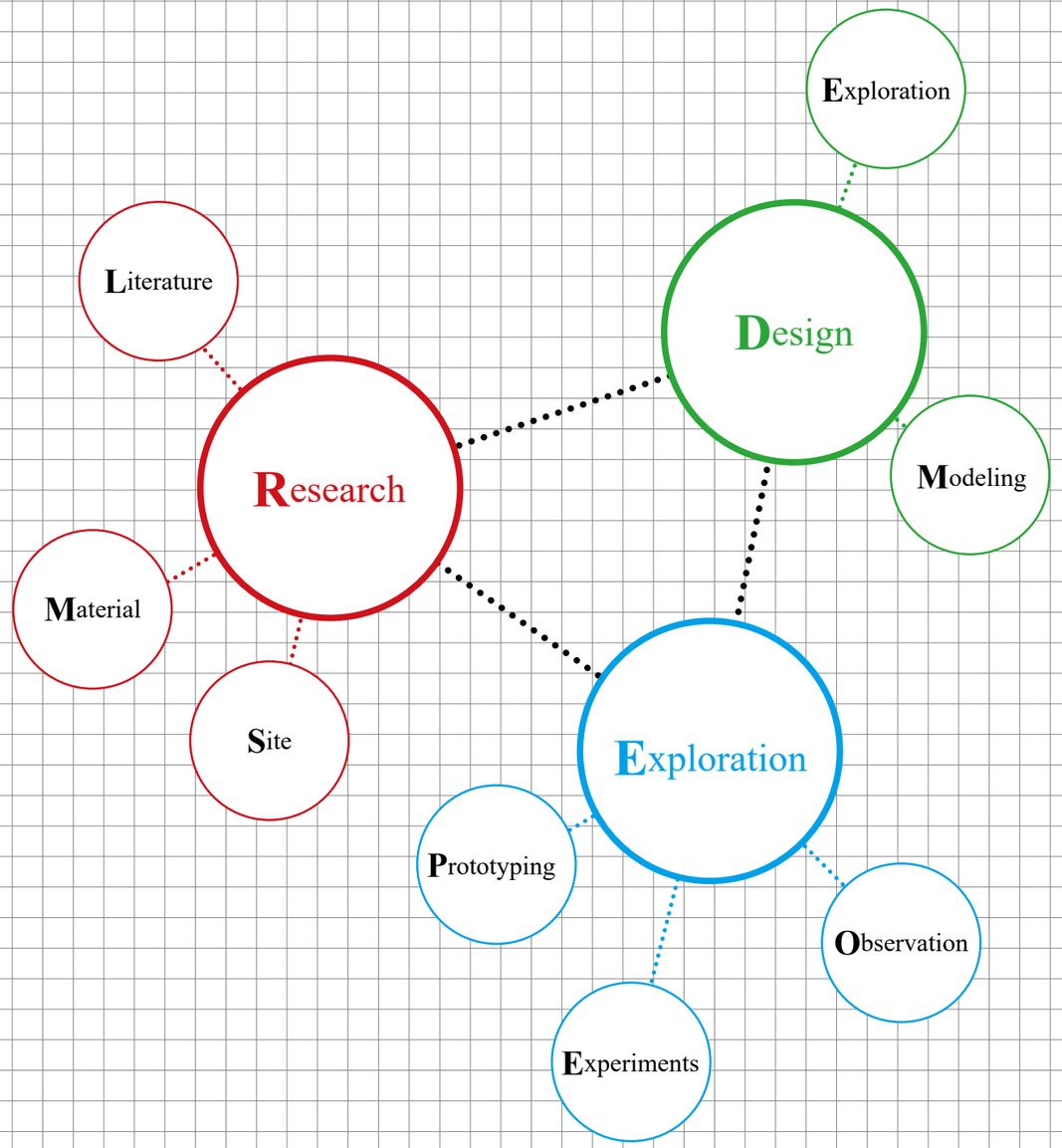
The research objectives specified for the research questions are summarized as follows:

1. Showing the arrangement of textiles in different colour combinations and with different treatments, exploring the changes in light and shadow of textiles under external/natural and internal/artificial light.

2. Develop a prototype of a textile exterior wall, exploring the potential of natural textiles as ***architectural walls/windows***, and compare advantages and disadvantages with other materials.

Delimitations

This master thesis does not focus on producing a textile window that meet contemporary building regulations or have the same properties as the glass window. But one focus on the process of exploring textiles as the main windows components and showing the possibilities and aesthetics of textile use in building facades.



1.3
METHODS AND WORKFLOW

METHODS

Research

The process of this thesis began with literatures and material study, with the aim of deepening the understanding of textiles architecture and narrowing down the scope of the research interest. Literature readings ranged from an introduction to textile architecture to light and comfort senses of textile, as well as shadow puppetry, projection technology and knitting technology, etc. Getting in touch with material and study is also important for the exploration of the functional, physical and aesthetic value of textiles. In addition to literature reading and material study, the research phase also included site visit and research.

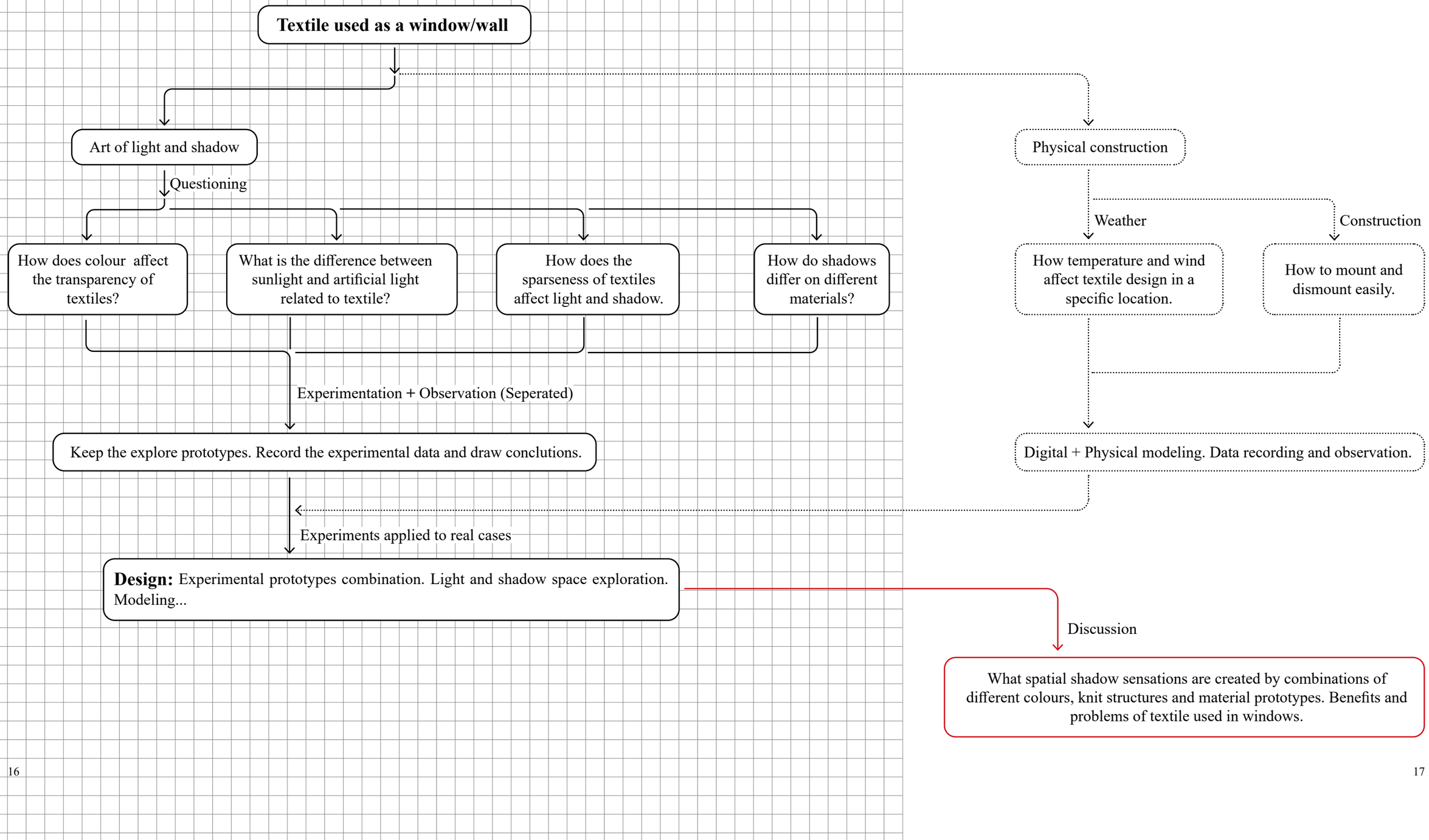
Exploration

After narrowing down the research direction and interests, a series of experiments will be used to explore the feasibility and aesthetics of textiles as architectural windows, while relevant literature is needed for theoretical support. The experiments include how different colours and materials affect transparency, how light intensity and knitted shapes and techniques influence light and shadow, and how temperature and wind affect textile design in different seasons. The conclusions and prototypes obtained from the experiments will be applied to the designs phase.

Design

The exploration phase is correlated with the design phase, as both phases are interdependent and work together to realise the potential of the material. During the design phase, I investigated how three layers of textiles could be combined to create a flexible textile wall space, focusing on the effects of light and shadow as well as the possibilities of implementation.

WORKFLOW


Textile used as a window/wall
Art of light and shadow
Questioning
How does colour affect the transparency of textiles?
What is the difference between sunlight and artificial light related to textile?
How does the sparseness of textiles affect light and shadow.
How do shadows differ on different materials?
Experimentation + Observation (Seperated)
Keep the explore prototypes. Record the experimental data and draw conclutions.
Experiments applied to real cases
Design: Experimental prototypes combination. Light and shadow space exploration. Modeling...
Physical construction
Weather
Construction
How temperature and wind affect textile design in a specific location.
How to mount and dismount easily.
Digital + Physical modeling. Data recording and observation.
Discussion
What spatial shadow sensations are created by combinations of different colours, knit structures and material prototypes. Benefits and problems of textile used in windows.

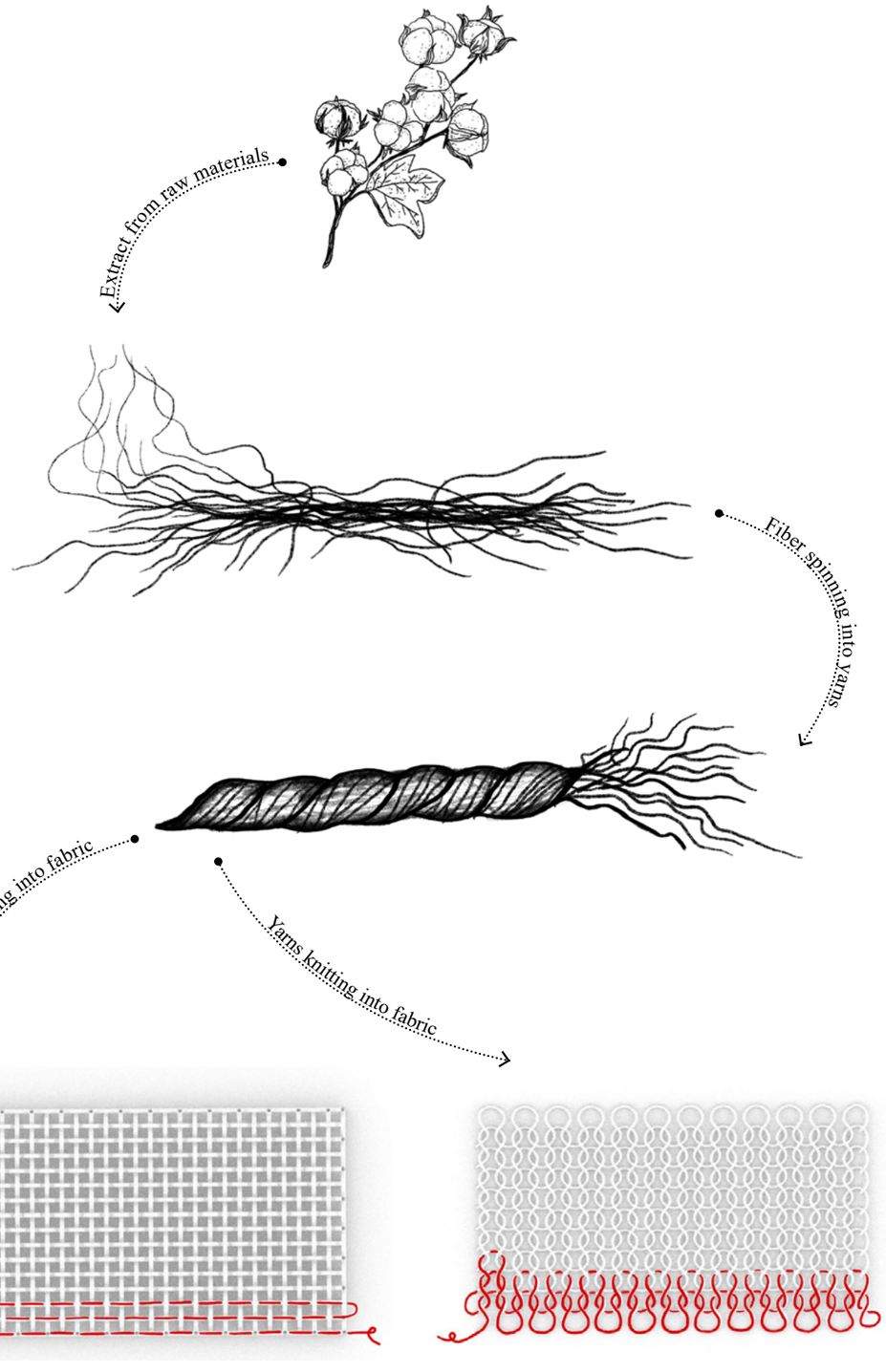


Fig1.4.3 Relationships diagram. Take cotton as an example

1.4
TEXTILE CATEGORY

CLASSIFICATIONS

According to the raw material, fibres can be divided into natural fibers and manufactured fibers. The main difference between them is that natural fibres are extracted from nature, whereas manufactured fibres are non-fibres that are converted into fibres. Natural fibers are divided into plant fibers, animal fibers, and mineral fibers according to the nature of source. While manufactured fibers are classified into synthetic fibers and regenerated fibers. Some fibers are made from natural material but because the starting material does not resemble a fiber, these are not considered natural fibers.(Kadolph, 2014) The categories shown in Fig1.4.1.

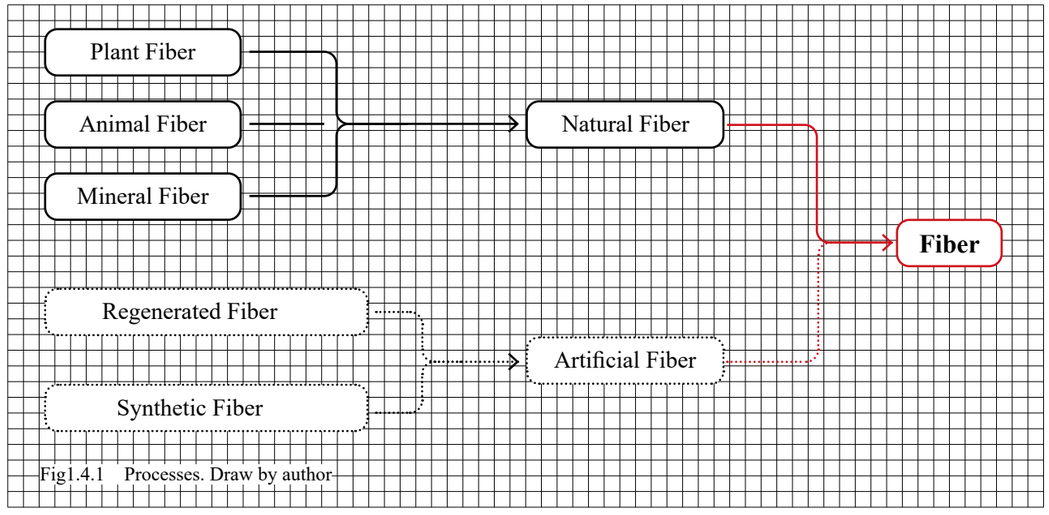


Fig1.4.1 Processes. Draw by author

PROCESS

Fibres, the raw material for textiles, undergo several processes to become fabrics. For natural fibers, the basic processes include spinning for producing yarns, weaving or knitting for making textile. Manufatured fibers need some specific treatments. The processes for natural fibers is shown in Fig1.4.2.

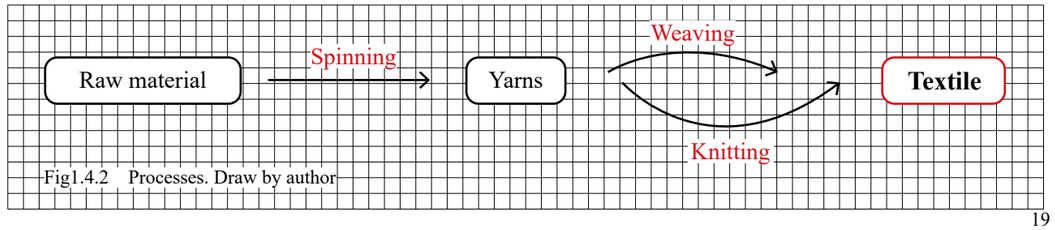


Fig1.4.2 Processes. Draw by author

Fig 1.4.4 Cotton.

Fig 1.4.5 Cotton yarns dyed yellow.

Fig 1.4.6 Jute.

Fig 1.4.7 Jute yarns.

Fig 1.4.8 Hemp

Fig 1.4.9 Hemp yarns.

NATURAL FIBERS

Plant fibres

Plant fibres include cotton, flax, hemp, jute and other fibres which are produced by plants. Due to the source limited, only hemp, jute, cotton yarns and textile uesd for the material exploration in this thesis.

Cotton

Cotton is grown in the seeds of the boll (or protective husk) of the cotton plant. Immature and weak cotton has a cloudy appearance, while mature cotton appears bright and has a thick cell wall. It is not easily damaged by sunlight; gradual loss of strength occurs on longer exposure to sunlight. Being cellulosic in nature, it dissolves in the concentrated solution of acids, but has excellent resistant to alkalis. A strong caustic solution causes the fibers to swell. (Nawab, Hussain, Ashraf, Rasheed, Ahmad, Ali& Abdulbasit, 2016)

In addition to natural creamy white there is also natural colored cotton. Natural creamy white is easier to print and dye to meet customer needs, while natural brown, red, rust, beige, and green colored cotton are healthier and environmentally friendly (Kadolph, 2014).

Jute

Jute belongs to bast fiber category, is 61 percent cellulose while hemp is around 20-30 percent (Kadolph, 2014). Jute fiber offers strength, low cost, high durability, and versatility. It is most popular in the agriculture sector to control soil erosion, seed protection, and weed control. Jute is being replaced by synthetic materials for many of these uses, but the biodegradation and sustainability are the main advantages of jute over synthetic fibers.

Hemp

The stalk of the hemp plant produces two types of fibers: long (bast) fibers and short (core) fibers. Bast fibers can be cleaned, spun and then woven or knitted into many fabrics suitable for durable and comfortable clothing and housewares. Fabrics with at least 50 % hemp content block the sun's UV rays more effectively than the other fabrics. In comparison with cotton, hemp fibers are longer, stronger, more lustrous, absorbent, and more mildew resistant (Nawab, Hussain, Ashraf, Rasheed, Ahmad, Ali& Abdulbasit, 2016). Hemp is a high producing fibre, 250 percent more than cotton and 600 percent more than flax on the same land (Kadolph, 2014).

Fig 1.4.10 Angolan goat. © Sharon chestnutt at English Wikipedia

Fig 1.4.11 60% Mohair 40% Acrylic.

Fig 1.4.12 Cashmere goat. © Charles Esson at English Wikipedia

Fig 1.4.13 Cashmere yarns.

Fig 1.4.14 Merino sheep.
By Original: User:Fir0002 Derivative work: Charles Esson at en.wikipedia

Fig 1.4.15 50% Merino wool 50% Acrylic.

NATURAL FIBERS

Animal fibres

Animal fibres are fibres taken from the hair, fur or caterpillar of animals. In this thesis, only mohair and cashmere are used and none of them are 100% natural fibers for multiple reasons.

Mohair

Mohair is the hair fiber of Angora goat and it is a lightness and fluffiness because the air space between the cells. Compared to wool fibres, mohair fibres are more resilient, smooth and lustrous and are very easy to dye. In addition, mohair is naturally flame resistance, insulating and sound absorbing (Kadolph, 2014). These properties make it ideal for use in curtains and blankets.

Cashmere

Cashmere is produced by small cashmere goat and has a range of color from white to gray to brownish gray. Because of the low production and high demand, cashmere fibers are often blended with other fibers to make yarns or fabrics.

Merino wool

Merino wool is produced from merino sheep and is the most valuable wool. Wool fabrics are durable and flexible, it can bent back on themselves 20,000 times without breaking as comparing with 3,000 times for cotton(Kadolph, 2014). Wool is a very comfort and high appearence retention rate fibers with high absorbency, thermal retention, resilliency and elastic recovery.

Fig 1.14.16 100% Nylon

Fig 1.14.17 100% Acrylic

Fig 1.14.18 100% Polyester

Fig 1.14.20 65% Acrylic 35% Polyester

Fig 1.14.21 80% Acrylic 20% Rayon

Fig 1.14.22 100% Acrylic

Fig 1.14.23 60% Mohair 40% Acrylic

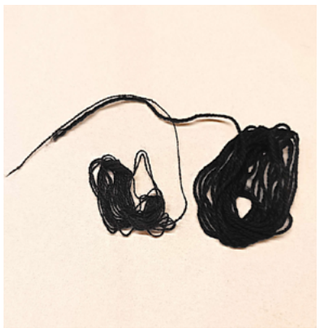


Fig 1.14.24 85% Acrylic 15% Cashmere

MANUFACTURED FIBERS

Manufactured fibres are the result of an effort to improve the properties of natural fibres. These fibres are made by extruding polymeric materials, which are generally derived from petrochemical products. In this thesis only rayon, nylon, acrylic and polyester which under synthetic fibers group are used, either as a single material or mixed with other materials such as mohair.

Rayon

Rayon is 100 percent cellulose and was the first regenerated cellulosic fiber. The texture of fabrics made from rayon can be close to that of cotton, linen, wool and silk by controlling its luster, length and diameter (Kadolph, 2014).

Nylon

Nylon was the first synthetic fiber and widely used in sporting goods, car interior, etc. As a manufactural fibers, it has an excellent durability (abrasion resistance, tenacity, elongation) and appearance retention (resiliency, dimensional stability, elastic recovery) (Kadolph, 2014).

Polyester

The properties of polyester are close to those of nylon, but it has nearly the same appearance and texture as natural fibers. Heavy metals and toxic chemicals are used in the manufacture process which contaminating water and soil. From the energy perspective, it needs less energy than nylon but much higher than natural fibers like cotton (Kadolph, 2014).

Acrylic

Acrylic is a wool-like manufactural fiber with moderate durability, thermal retention, appearance retention. Acrylic use more energy and water in the manufacture process than polyester and it is not recycled (Kadolph, 2014). Because of the raw material (petrochemicals), it is not biodegradable even though it looks similar to wool fiber.

LIST OF PROPERTIES

Types of fibres (those used in this thesis)	**Tenacity** Dry / Wet. Durability	**Light resistance** Durability	**Elongation** Durability	**Thermal retention** Comfort	**Resiliency** Appearance retention	**Elastic recovery** Appearance retention	**Abrasion resistantce** Durability	**Acids** **Alkalis**
Glass	9.6/6.7 (1)	(1)	3.1/2.2 (3)	/	/	/	/	Resistant Resistant
Natural fibers								
Cotton	3.5-4.0/4.5-5.0 (2)	(2)	3-7/9.5 (3)	(3)	(3)	75 (3)	(2)	Harmed Resistant
Wool	1.5/1 (3)	(3)	25/35 (2)	(1)	(1)	99 (1)	(3)	Resistant Harmed
Flax (Hemp/Jute comparison)	3.5-5.0/6.5 (2)	(2)	2.0-2.2 (3)	(3)	(3)	65 (3)	(2)	Harmed Resistant
	* Hemp —— Hemp has similar properties to flax. It is resistant to ultraviolet light and mold but has only 5 percent elongation(3). Coarser and stiffer than flax.				*Jute —— One of weakest of the cellulosic fibers, has poor elasticity(3), poor elongation(3), low sunlight resistant(3)...It will deteriorates quickly when expose to water.			
Manufactrual fibers								
Nylon	3.5-7.2/3.0-6.5 (2)	(3)	Nylon 6 30-90/42-100 (2) Nylon 6.6 16-75/18-78 (3)	(2)	/	Nylon 6 98-100 (2) Nylon 6.6 82-89 (2)	(1)	Harmed (especially nylon6) Resistant
Acrylic	2.0-3.0/1.8-2.7 (2)	(1)	35-45/41-50 (2)	(1)	(2)	92 (2)	(2)	Resistant to most acids Resistant to weak alkalis
Polyester	2.4-7.0 (1)	(1)	12-55 (3)	(1)	(2)	81 (3)	(1)	Resistant Degraded by strong alkalis
Rayon	HWM 2.5-5.0/3.0 (2) viscose 1.0-2.5/0.5-1.4 (3)	(2)	HWM 9-18/20 (3) regular 8-14/16-20 (3)	(3)	(3)	HWM 96 at 2% (2) regular 95 at 2% (2)	(3)	Harmed Resistant to weak alkalis

* High / Excellent (1) Medium / Good (2) Low / Moderate+Poor (3)

* More datas and information can be found in ***Textiles / Sara J. Kadolph. 2014*** and ***Textile Engineering : An Introduction.***

* Glass is used as a comparator for other fibres, as this thesis will explored the possibilities and differences of replacing glass windows with textiles made from these fibers.

* Even though some manufactural fibers look like natural fibers, their properties are very different, like Acrylic and Wool.

Tab 1.4.1 Fibre (those used in this thesis) properties summarization. Source: Kadolph, 2014.

Fig1.4.25 Yarns of fibers used in this project.

Connection

This section is the material study backgound. Since textiles are the material to be used in this thesis, a basic understand of how many types of fibers/yarns are available today and the process of getting from raw material to textile is required. By visiting some textile stores, the above common yarns were selected and the properties datas were taken from some textile introduction books for comparison.

Connect to Context

According to the list of properties, cotton has better tenacity, light resistance and abrasion resistance than wool. From the Fig 14.25 and Tab 1.4.1, some artificial yarns look similar to natural yarns and have better properties like tenacity, light resistance and abrasion resistance. According to the climatic and architectural space analysis of the site (In Chapters 2/ 4), thermal resistance is not a major consideration for the use of textiles window on the site. In the latter design, cotton yarns and some artificial yarns will be used and assumed to be mounted on the building's windows.

However, these properties are not specific to the use of textiles in architectural design, and it is also difficult to find other related books. Therefore, these data can only be used as a reference.

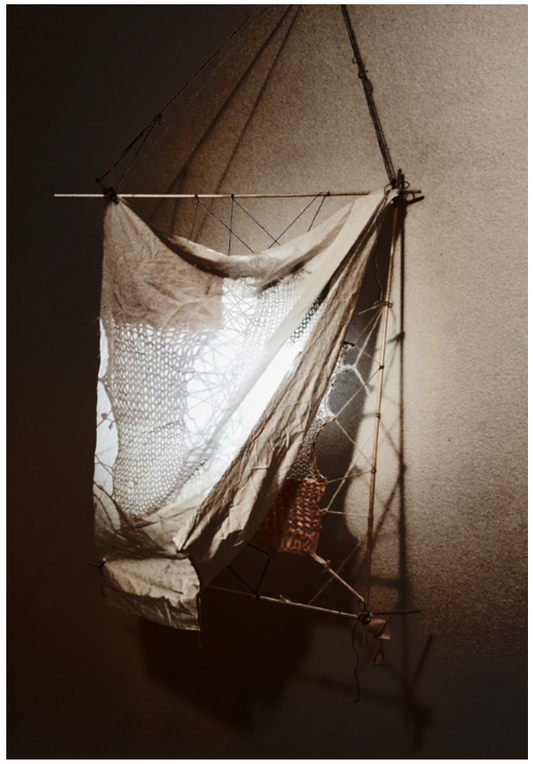


Fig1.4.26 White cotton transparent woven textile

Fig1.4.27 Sample made of yarns in Fig. 1.4.25 combine with the white cotton transparent woven textile in Fig 1.4.26 together with the flash.

Fig 1.5.1 Mongolianyurts in Xinjiang, China. © Dongli Zhao

Fig1.5.2 Outdoor shade shelter
Restaurant, Hungary.

Fig1.5.3 Temperary news stand
Hongkong, China.

Fig1.5.4 Temperary night market
Hongkong, China.

Fig1.5.5 Outdoor decoration
Wuchuan, China

Fig1.5.6 Outdoor decoration/protection
Gothenburg, Sweden

1.5
TEXTILE IN ARCHITECTURAL DESIGN

IN AND OUT

In the past, textiles was one of the main building material because they were local materials with properties such as lightness and flexibility. Yurts, for example, have multiple layers of textiles that allow nomadic people to survive at -20°C as well as strong winds and sand. (Mauvieux, Reinberg& Touitou,2014) Nowaday, yurts still exist as hotels or hostels in the Xinjiang region of China (where temperatures reach over 30°C in the summer and down to -20°C in the winter) for tourists to experience the nomadic lifestyle and yurt living environment. Meanwhile, there are still some nomads who maintain their ancient way of life and live in yurts.

Before glass, textiles were widely used in windows because of their air permeability and transparency. Except from windows, the more widely known architectural application of textiles is outdoors structure, as textiles are wind-resistant and less susceptible to human damage.

In many of Chinese old towns, textile shelters can be found protruding from the buildings facade to provide shade and protection from the rain and sun in stores along the streets and alleys (Manufacture fibres are a better choice for improving the weather resistance of textiles). Due to the flexibility and easy to mount and dismount, many night market shops (e.g. Fig 1.5.4) use textiles as the main material for temporary construction. Nowadays, many outdoor squares/streets are decorated with textiles, which are also used to wrap facades (e.g. Fig 1.5.6) for the protection of passers-by during building renovations.

Compared to concrete, steel, wood, etc., textiles have advantages like lightness, easy to fold and easy to transport. But at the same time, because of its lightness and softness, it is difficult to build without the help of other materials (e.g. wood, steel). Take yurt as an example, before covering the skin with textiles or animal furs, a wood frame needs to be built, otherwise they cannot form a stable interior space.

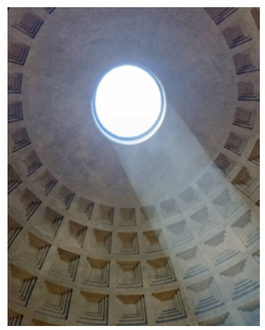
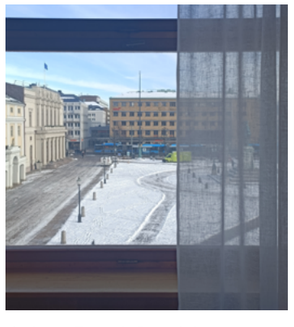


Fig 1.6.1 The Roman Pantheon
Roman, Italy

Fig 1.6.2 Landscape hollow window.
Suzhou, China

Fig 1.6.3 / Fig 1.6.4 New window in old-fashioned buildings. Wuhan/Guangzhou, China



Textile inside and outside the window. From left to right:
Fig 1.6.5 Residential housing in Wuchuan, China
Fig 1.6.6 Gothenburg city town in Sweden
Fig 1.6.7 The Ivar Aasen Centre in Norway

1.6
WINDOW IN ARCHITECTURAL DESIGN

Pierre von Meiss says that,"A window is a sign of life." He further adds that it is a wink to the passerby. (von Meiss. P, 1990)

WINDOW HISTORY

In early time, holes(windows) were made in closed dwellings for light and ventilation. One example is the Roman Pantheon, built in 113-125 AD (current building). Later, natural or artificial fibre were used to make window sashes that let in light and kept out the wind and rain. In the East, oil paper or textile was used, while in the West, glass was the main material for windows. (Britannica, 2023) Nowadays, glass is the main material for most windows due to its thermal insulation, heat resistance and transparency. But the window history tells us that textiles were once the main material for windows as well.

Oiled / Greased paper window

The oil makes the paper transparent and weather-resistant, so in ancient times it was often affixed to wooden window frames as a barrier between inside and outside. When oil is applied to paper, the grease fills all the fibre gaps and any light that hits the paper is not scattered but passes right through. (Goodwin. J, 2014).

Textile window

According to the Yuan Dynasty ***"Nongsang Series"*** explanation, that is, "summer and autumn ..... to paper paste window, because avoid flies cover all the air to and from the sky clear fomentation of heat disease, yin is wet white mould, yin and clear are not convenient; to textile paste window ..... cover flies off the air Wind .....". Here a word out the benefits of using textile, both to achieve the effect of ventilation and blocking the line of sight, but also to block mosquitoes.(Xu.G, 1562-1633)

Glass window

With the development of technology, glass window are gradually replacing the functions of paper/textile window due to their low cost and good properties. Glass window has the advantages of good insulation, heat resistance, corrosion resistance and high mechanical strength, which greatly improves the safety of the building, and is now widely used as building window filler.

Fig 1.6.8 Single glazed windows
Zhanjiang, China

Fig 1.6.9 Multi-glazed windows
Gothenburg, Sweden

Conclusion

Textile window VS Oiled paper window

When making textile using knitting and weaving methods, no matter how closely the yarns are laid, there will always be voids in between making it breathe. Paper itself is also breathable, but the oil/grease closes these voids while increasing tranparency of the paper and strengthening weather resistance. Textiles are tougher, softer and have better air ventilation than oiled paper, but rain resistance is one of the issues, which can be learnt from oiled paper.

Textile window VS Glass window

Glass is a non-renewable but recyclable material that causes a lot of wastewater pollution during the production process. (Dylan.D, 2022) Natural fiber are renewable and environmentally friendly heat insulation materials which do not cause a lot of pollution during textile process.(Karimah.A, 2021) Glass is tougher and different temperature zones are able to keep the room warmer by using different thicknesses of glass and also wind/rain/fire resistance. Textiles are airy and soft, flutter in the wind, are flexible and interact with people and the environment.

Inspiration

Textiles have unique advantages over oiled paper and glass. Softness, flexibility, lightness, breathable etc. Textiles are warmer and safer than glass, and can interact with people and the environment differently. Through the window history, I learnt how textiles were used in windows in ancient times. Later, I will explore the possibilities and effects of using textiles again in window design.

Fig 1.7.1 Park in Beijing.

Fig 1.7.2 Flower in Gothenburg.

Fig 1.7.3 Sea in Gothenburg.

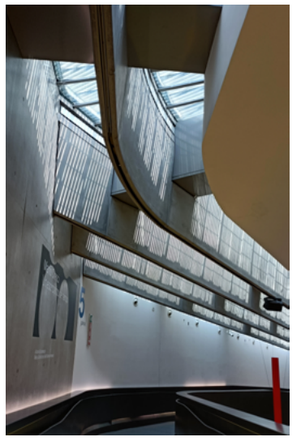


Fig 1.7.4 Museo nazionale delle arti del XXI secolo in Rome, Italy.

Fig 1.7.5 Mortensrud Kirke in Oslo, Norway.

Fig 1.7.6 Norwegian Glacier Museum in Fjaerland, Norway.

Fig 1.7.7 Light tower in Copenhagen, Denmark.

Fig 1.7.8 Colosseum in Rome, Italy

Fig 1.7.9 Albertina Museum Soravia Wing and Café in Vienna, Austria.

1.7
LIGHT&SHADOW IN ARCHITECTURAL DESIGN

NATURAL LIGHT&SHADOW

As shown in Fig 1.7.1 and 1.7.2, when sunlight encounters plant obstructions, it creates shadows on the projected objects. The shadows formed by trees on the road provide a resting place. When sunlight shines on plants, the overlapping shadows of leaves enhance the three-dimensional effect of the plants. As illustrated in Fig 1.8.3, sunlight shining on the sea has a similar effect, as the water moves, causing the sunlight to reflect differently and creating a sparkling effect. These conditions also exist in the building design.

Natural light in Architectural design

As shown in Fig 1.7.4 to 1.7.6, architectural projects create different spatial atmospheres through wisely facade/roof designs that influence the way light enters the building.

Peter Zumthor, in a description of the Kunsthaus Bregenz building, stated ‘the art museum stands in the light of Lake Constance. […] The spatial constellation of the slabs varies the orientation of the light, generates shadows and reflections. It tempers the mood of the light and gives depth to the room. The constantly fluctuating light creates the impression that the building is breathing’. （P.Zumthor, 1999)

Artificial light in Architectural design

Apart from natural light, artificial light is also an important element of building design. As shown in Fig 1.7.7, in coastal areas, lighthouses lit at night can guide ships to avoid danger. The Roman Colosseum in Fig 1.7.8 uses artificial light to make the building stand out at night. The Albertina Museum in Fig. 1.7.9 adds a huge Soravia wing to the roof, highlighting the entrance to the whole building and giving it a new lustre. The Soravia wing and three lighted advertising are particularly eye-catching at night. These three examples illustrate the importance of artificial lighting in public buildings, which, when used wisely, can bring more attention to the building.

Inspiration

By exploring the relationship between light&shadow and building, the design wants to create unique spatial effects using textiles and their properties in combination with light and wind. The space is ever-changing, breathable, and allows people to feel the changes in the outside environment.

Fig 1.8.1 / Fig 1.6.2 Screen made of white paper or textile

Fig 1.8.3 Wooden rods
Manipulate the roles

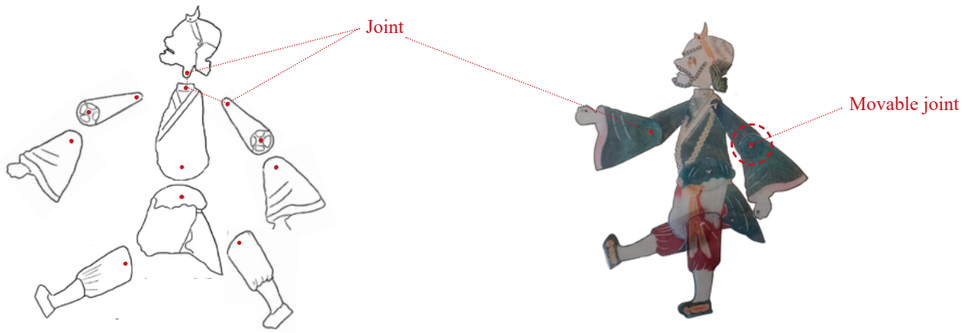


Fig 1.8.4 Famous Role in Chinese classic novel_*The Journey to the West*

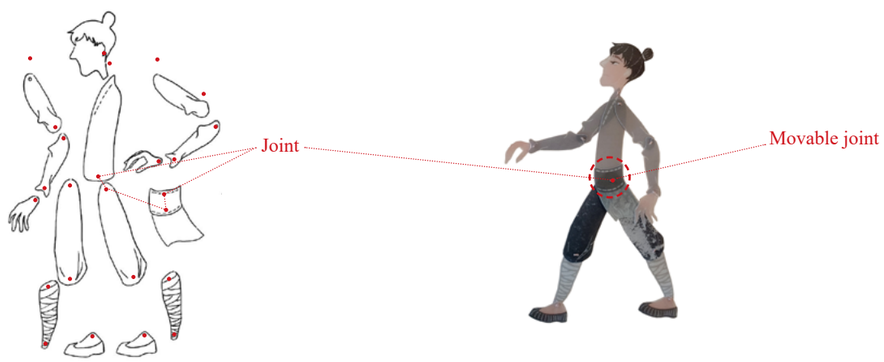


Fig 1.8.5 Classical Role used in Shadow play

1.8
TEXTILE DISPLAY SCREEN

SHADOW PUPPETS

Shadow play is a traditional folk theater in which characters made of animal skin or cardboard are used to perform stories. During the performance, artists manipulate the shadow puppets behind a white textile screen while narrating the story using locally popular tunes. The transparency of the textile and the effect of lighting work together, allowing colorful characters to appear vividly in front of the screen.(Shi.Y, Ying. F, Yu.J, 2013)

Screen and Light

At first, the screen for shadow play were made of white paper, but now they are mainly made of white textile, both of them are translucent. The entire performance team hide behind the white textile screen, which can be divided into the front, middle and back team. In the front team, the two main actors control the puppets close to the curtain and tell the story with their unique singing voices, while in the middle and back teams, an orchestra consisting of performers of various types of traditional Chinese musical instruments combines with lighting effects to interpret a story. With the development of technology, shadow lighting has evolved from the old oil lamps, steam lamps and incandescent lamps (at temperatures of 1900k-2900k) to the fluorescent tube lighting (at temperatures of 5500k-6000k) of today.(李治 , 2019).

Puppets

In the past, shadow figures were usually made from animal skin. However, becasuse the difficulty in obtaining materials and preserving the finished puppets, most of the shadow puppets can instead be made from materials such as PVC cardboard. In order to interpret the story and perform with sound and music,the puppets need to be disassembled into head, torso and limbs during the production process, then the actors can use the wooden rods to move the puppets back and forth from side to side in order to make the puppet performances vividly.

PLEINMUSEUM, 2004-2007

Pleinmuseum is a mobile 'pavilion' as a support for multiscreen video art in public space. The pavilion combines various technologies, such as hydraulics and computer-controlled to enable it to be opened and accessible to the public at sunset. A beamer installation realises one of the first 'video mappings' in the Netherlands. (Wolfgang.L, 2008)

With the help of hydraulics, the "mobile pavilion" become an open, flexible and approachable museum on a square in the city centre, a natural part of urban life. The mobile museum looks differently during the day and at night. During the day, the pavilion is closed, symbolised by the 'white cube', an example of a modernist museum. At night, the cube opens up through hydraulics, creating a dynamic architectural installation that embraces the space. The white walls are transformed into projection screens, which, like the skin of a chameleon, constantly take on a new appearance. (Wolfgang.L, 2008)

Inspiration

Inspired by the transparent textile screens of shadow puppetry and Pleinmuseum. The textile displays in this study will explore how to cooperate the transparental textiles and artificial light to make the curtain wall display different show in different festivals/needs. The textile design exploration will be more focused on exploring the artistic effect of applying it to the wall, then discuss if it can fulfil the basic function of window use.

2.

Site Background

- Wuchuan, Zhanjiang, Guangdong, China
- Meilu Cinema

Weather Analysis

- Temperature
- Wind
- Rainfall
- Sun

Connection

Location: old town of Meilu, Zhanjiang, China

21.345736, 110.377395

Fig 2.0.1 Site map.

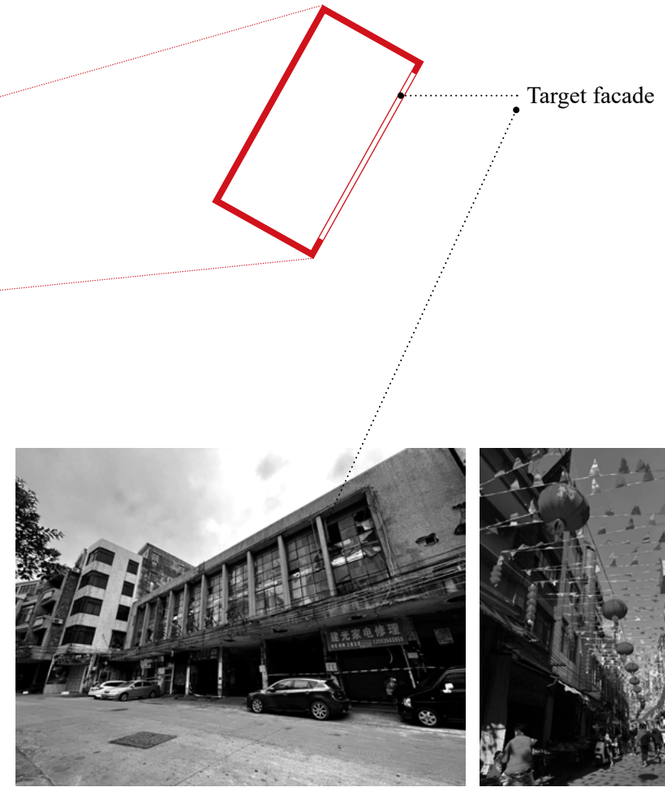


Fig 2.0.2 Meilu Cinema. Photograph. © Qiqi

Fig 2.0.3 Old town street Wuchuan, China

Located in the old town of a small city in southern China, where most of the buildings are brick or concrete and have more than 50 years history. This area have the best educational and medical institutions in Wuchuan City, as well as a cultural centre with local art groups such as lion dances, Piao Se and others. Even though the new city centre is booming, this area remains the busiest, most densely populated and most culturally active region.

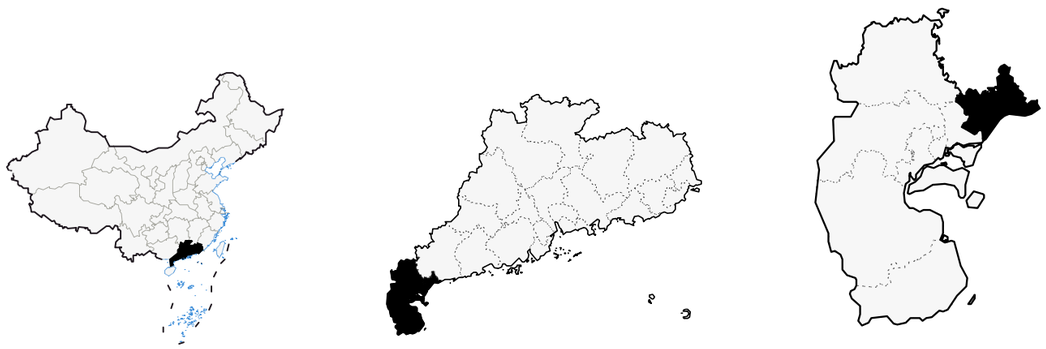
2.0
SITE BACKGROUND

WUCHUAN, ZHANJIANG, GUANGDONG, CHINA

Wuchuan is located in the southwest of Guangdong Province, China, between 21°15′ to 21°39′ north latitude and 110°28′ to 110°58′ east longitude. It is situated along the largest river in western Guangdong, the Jian River, and is a coastal city.

The total area of Wuchuan is 858.1 km². At the end of 2021, the permanent population of Wuchuan City was 910,600 according to the report from the offical website of Wuchuan City.

Wuchuan City belongs to the subtropical oceanic monsoon climate, with mild temperatures, long summers, short winters, abundant rainfall, and ample sunshine. The average annual temperature from 1979 to 2000 was 23.4°C, the temperature can be as high as 40℃ in summer, and occasionally lower than 10℃ in winter. The average annual sunshine hours are 1972.1, and the average annual precipitation is 1568.1 millimeters.



China - Guangdong　　Guangdong - Zhanjiang　　Zhanjiang - Wuchuan

Fig 2.0.4 Site map.

MEILU CINEMA

Time: 1972
Area: 1577m²
Location: Old town of Wuchuan
Structure/Material: Concrete-Steel, Glass

MEILU CINEMA

Meilu Cinema was initially built at the end of 1956. At first, it was a thatched shed occupying eight store spaces with seating consisting of benches. In 1972, to meet the demand for film projection, the cinema underwent further construction, transforming into a reinforced concrete structure with glass bricks and tiles, which is the present-day Meilu Cinema. Being Wuchuan's first cinema, Meilu Cinema was highly favored by the locals, especially during the years 1980-1993. In the end of the 20th century, with the advancement of technology, Meilu Cinema could no longer meet the demands for film projection and audience expectations, gradually falling into disuse. Now, after more than half a century, Meilu Cinema, occupying 1577 square meters, stands abandoned and deteriorating, having become a hazardous structure due to its age.

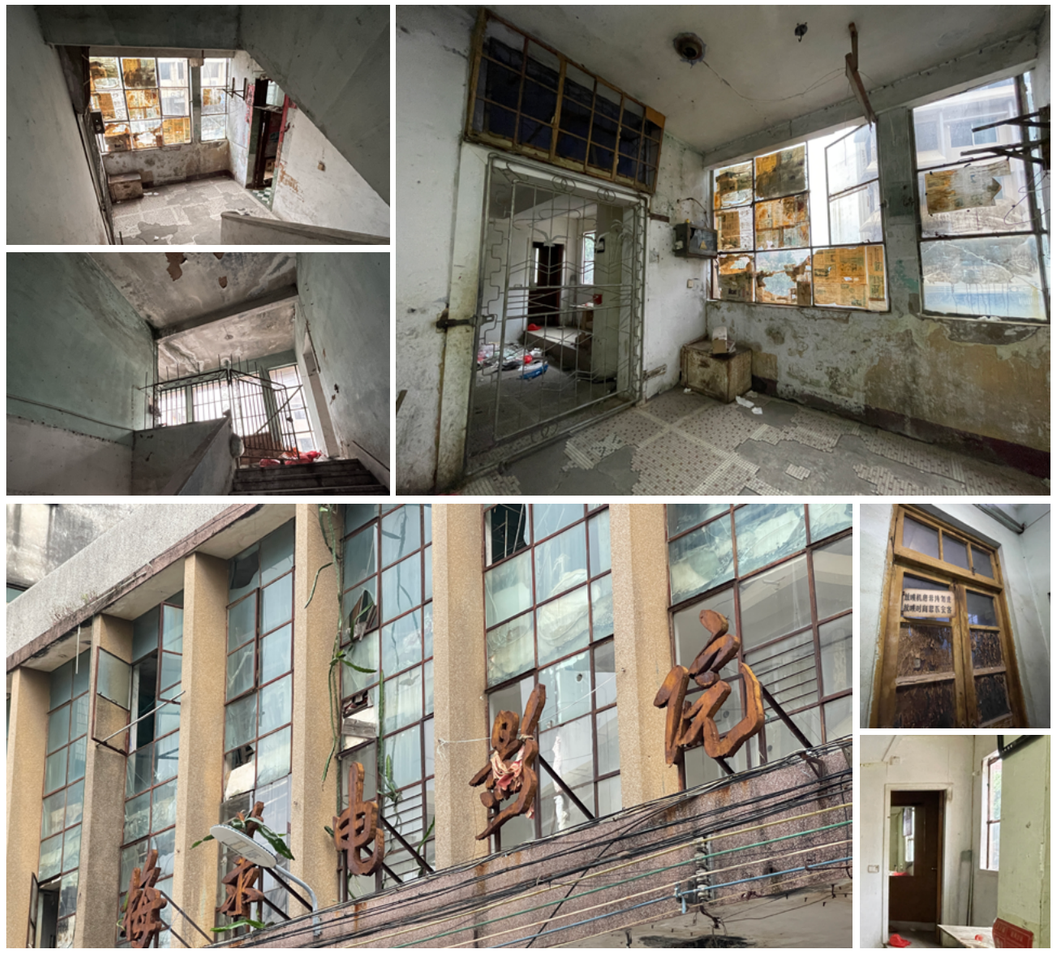


Fig 2.0.5 - 2.0.10　Meilu Cinema. Photograph. © Qiqi

2.1
WEATHER

As this design focuses on replacing glass with natural textiles as the main component of windows. Weather analyses such as temperature, wind, etc. need to be carried out for the city in which it is located to verify its feasibility. These datas are important for future testing of textiles for resistance to cold, wind and water.

TEMPERATURE

Datas from China Standard Weather Database (CSWD) and used Ladybug (plugin in grasshopper) to highlight in which period the temperature is lower than 10°C (Fig 2.1.2) and 20°C (Fig 2.1.1), and in which period it is higher than 30°C (Fig 2.1.3). This analysis is closely related to the insulation properties of textiles.

From the graphs (Fig 2.1.1~Fig 2.1.3), it can be seen in Zhanjiang only in the winter there will be less than 10°C and only last for a few days, and the midday period in winter are often higher than 20°C. From April to October, it is often above 30°C, especially from June to August the temperatures can reach 40°C. During summer time, air conditioning is usually used to lower the inner temperature.

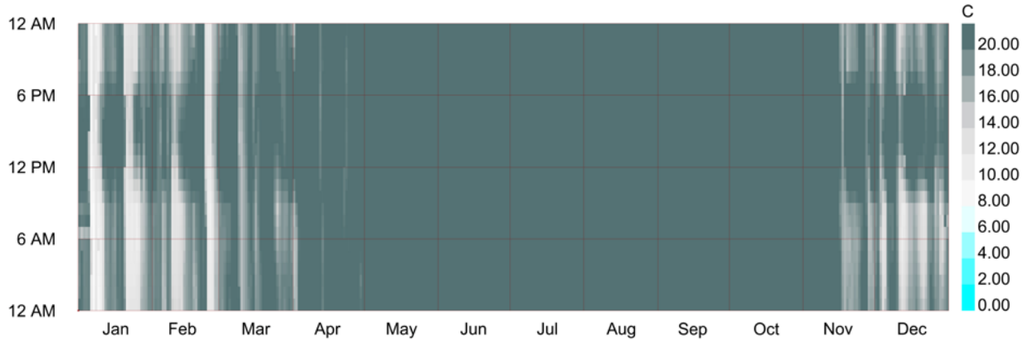


Fig 2.1.1 Temperature lower than 20°C

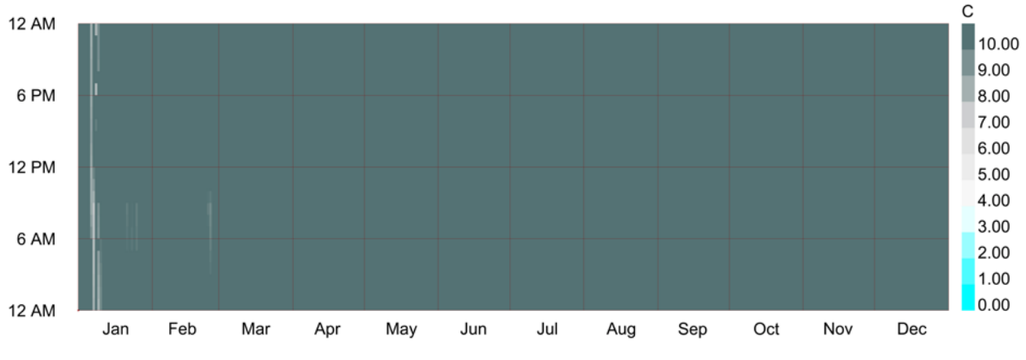


Fig 2.1.2 Temperature lower than 10°C

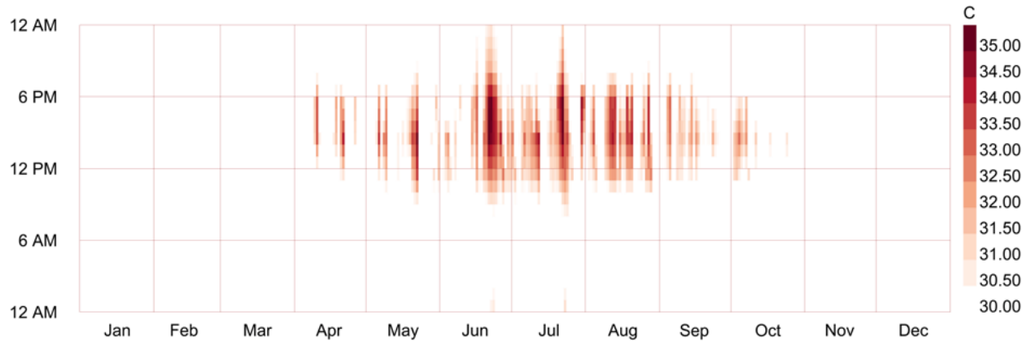


Fig 2.1.3 Temperature higher than 30°C

Dry Bulb Temperature(C)
1/1 to 12/31 between 0 and 23 @1
city: Zhangjiang

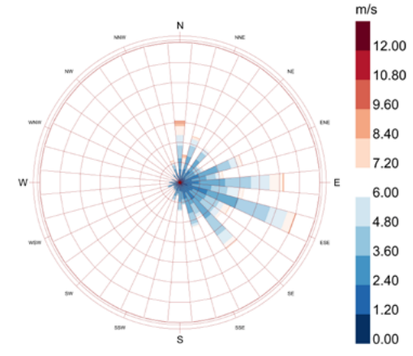
country: CHN
time-zone: 8.0

Conclusion: Most of the windows in this city are single glass and the walls do not require insulation layer. However, due to the hot summers and occasional cold weather in winter. Textile used in the window design need to take this into account.

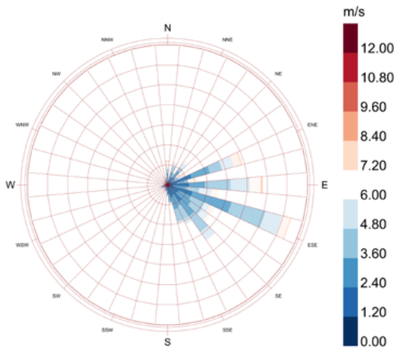
WIND

Datas from China Standard Weather Database (CSWD) and used Ladybug (plugin in grasshopper) to generate wind speed and direction graphs.

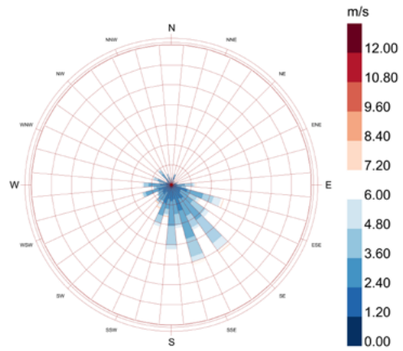
From the charts, the wind environment around the target building is favourable, with winds below 6m/s, but occasionally above 9m/s. The winds are mainly from the east, south and north, with strong winds coming mainly from the east and north. Apart from that, Zhanjiang is occasionally hit by typhoons from the southeast.



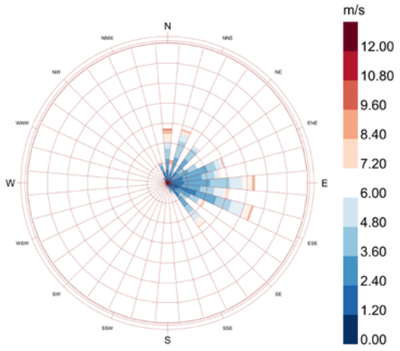
Wind Speed (m/s)
city: Zhangjiang
country: CHN
time-zone: 8.0
period: 1/1 to 12/31 between 0 and 23 @1
Calm for 1.8% of the time = 158 hours.
Each closed polyline shows frequency of 1.7% = 150 hours



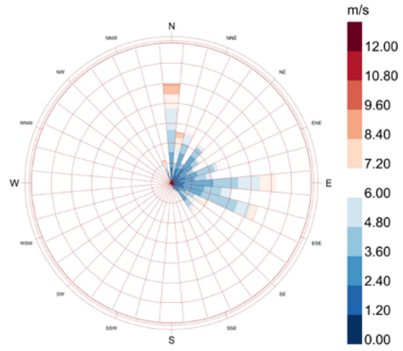
period: 3/1 to 5/31 between 0 and 23 @1
Calm for 0.36% of the time = 8 hours.
Each closed polyline shows frequency of 2.3% = 50 hours



period: 6/1 to 8/31 between 0 and 23 @1
Calm for 1.95% of the time = 43 hours.



period: 9/1 to 11/30 between 0 and 23 @1
Calm for 4.08% of the time = 89 hours.



period: 12/1 to 2/28 between 0 and 23 @1
Calm for 0.83% of the time = 18 hours.

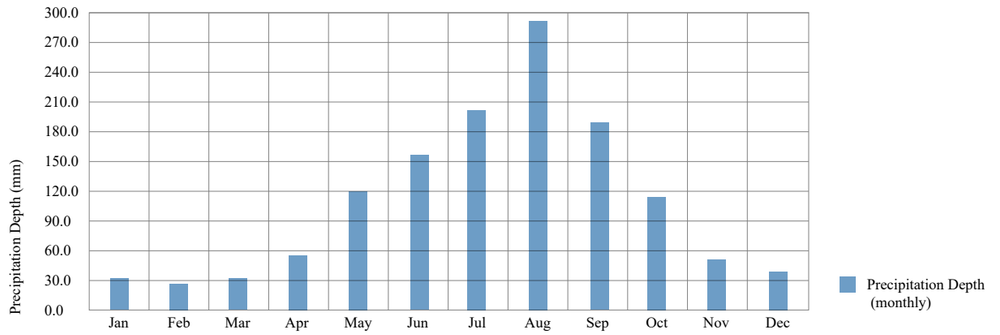
Fig 2.1.4 ~ 2.1.8 Wind direction diagrams

Conclusion: When the wind speed is below 6m/s, the wind is breezy and the wind speed has little effect on the textile windows. However, when a typhoon hits with wind speeds of up to 36 m/s or even higher, the use of textiles in windows requires further wind resistance testing or the addition of protective layers, which needs to be further studied.

RAINFALL

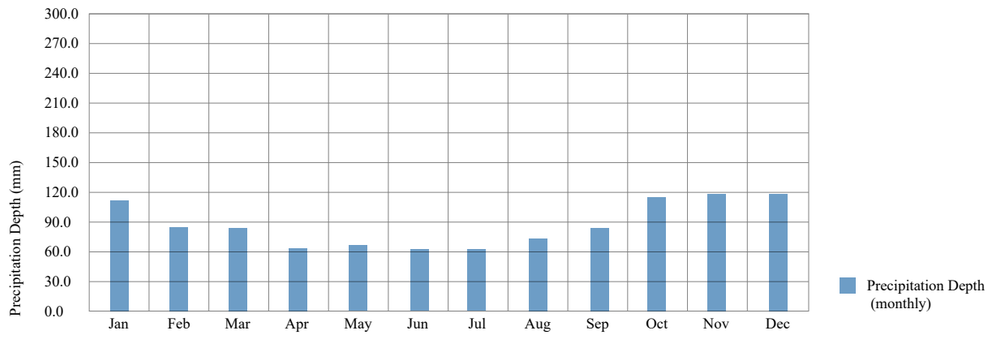
Datas from China Standard Weather Database (CSWD) and used Ladybug (plugin in grasshopper) to analyse rainfall in Zhanjiang, while rainfall chart in Gothenburg was used as a comparison group.

The city where the target building is located rain a lot in the summer and is often accompanied by stormy weather that can even flood the streets.



Precipitation Depth (mm)
city: Zhangjiang
country: China

time-zone: 8.0
period: 1/1 to 12/31 between 0 and 23 @1



Precipitation Depth (mm)
city: Gothenburg
country: Sweden

time-zone: 2.0
period: 1/1 to 12/31 between 0 and 23 @1

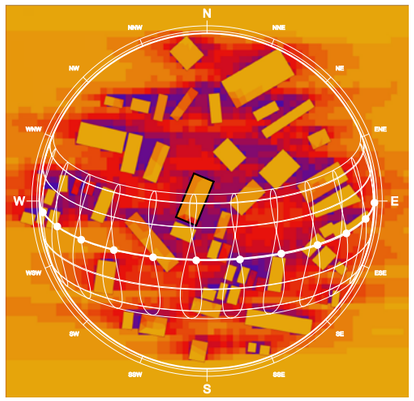
Fig 2.1.9 ~ 2.1.10 Zhanjiang & Gothenburg rainfall diagrams

Conclusion: Stormy weather often occurs in the summer and natural textiles are not waterproof, how to avoid rainwater entering the inner space needs to be taken into account in future research.

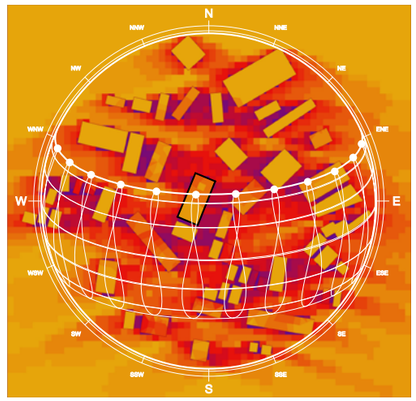
SUN

Datas from China Standard Weather Database (CSWD) and used Ladybug (plugin in grasshopper) to analyse direct sun hour and sun path on 3.21, 6.21, 9.22, 12.21.

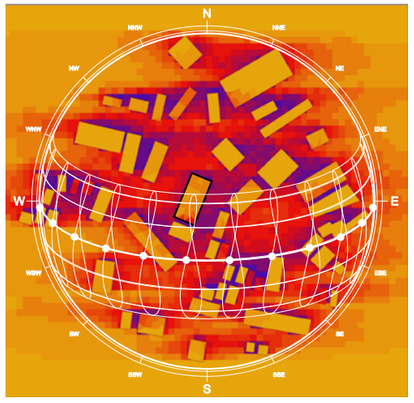
As can be seen from the graphs below, the front facade of the building (facing east) receives more than two hours of direct sunlight, even in winter. In summer it is more than four hours. The building is located in the tropics area and facing the road with no tall buildings to block the sunlight, a relatively high percentage of sunlight can enter into the building.



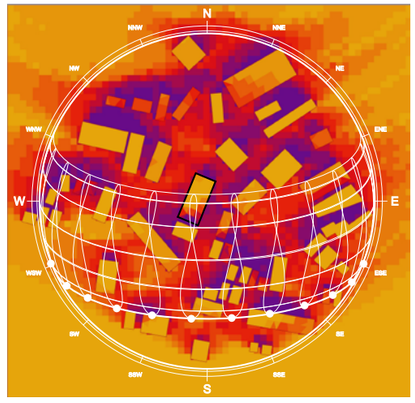
period: 3/21 between 0 and 23 @1



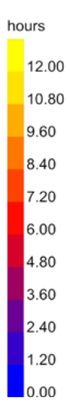
period: 6.21 between 0 and 23 @1



period: 9/22 between 0 and 23 @1



period: 12.21 between 0 and 23 @1



Direct sun hour (h)
city: Zhangjiang
country: China
time-zone: 8.0

Fig 2.1.11 ~ 2.1.14 Sun direction diagrams

Conclusion: Sunlight is an important factor in this thesis. The location, orientation and surroundings of the building are all closely related to the proportion of sunlight entering the building and how the textile windows behave in the sunlight.

2.2
CONNECTION

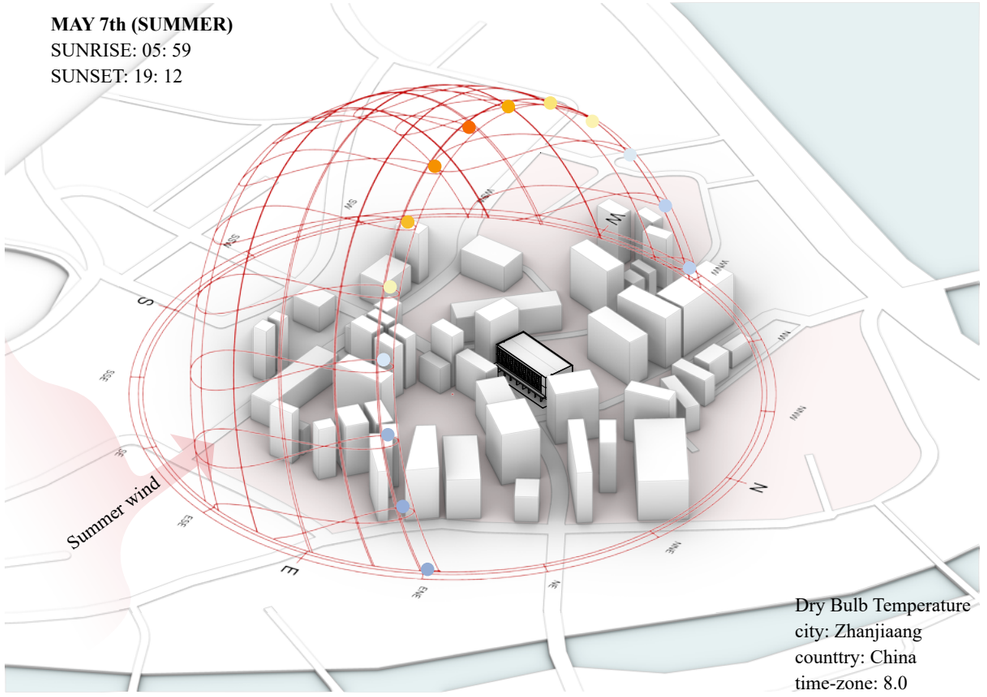
This chapter mainly focues on the site context, the history of the target building and a series weather analyses (temperature, wind, rainfall, sun path and direct sun hour) base on the location.

SITE - WEATHER - TEXTILE WINDOW DESIGN

The textile window experimental building is an old cinema located in the centre of the old town. The rich history and cultural heritage make this building an ideal place for textile window design experiments.

When designing textiles window for buildings and replacing the glass window. In practice, the performance of textile windows in terms of temperature, wind and rainfall needs to be considered. However, due to time and resource limitation, this thesis focuses on textile windows interacting with light in architectural spaces. The weather analyses in section 2.1 are more to understand the environmental impacts that the textile window will face, while weather resilience is left for possible future research. Textile yarns properties and selection can be found in section 1.4.

This design focuses on textiles and light, when applied to architecture, the sun will have a great impact on the effect of sunlight penetrating through the textiles into building. The analysis of sun path and direct sun hour in section 2.1 is intended to demonstrate the changes of sunlight over time around the target building.



Dry Bulb Temperature
city: Zhanjiaang
counttry: China
time-zone: 8.0

Fig 2.2.1 Weather analysis on site.

3.

List of experimental objects

Textile window

- Multiple layer of textile + **Light**
- Combinational logic

Testing methods

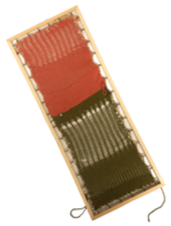
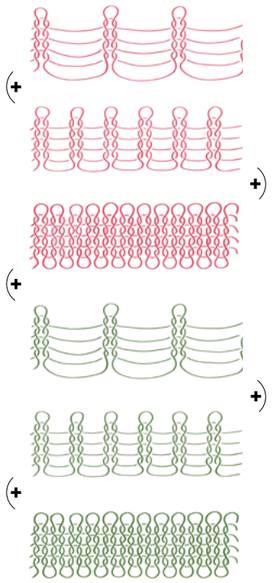
Light and Shadow Factors

- How does colour affect the transparency of textiles?
- What is the difference between sunlight and artificial light related to textile?
- How does the sparseness of textiles affect light and shadow?
- How do shadows differ on different materials?
- Conclusion

Connection

3.0
EXPERIMENTATION CATEGORY

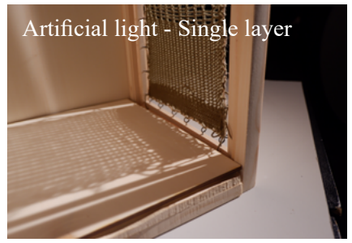
LIST OF EXPERIMENTAL OBJECTS

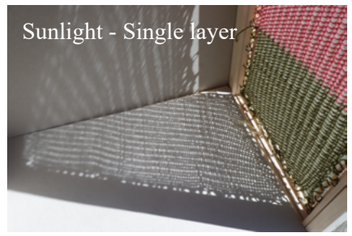
Colour	Name		*Sparseness*	Name	*Material*	Name	*Light*	
	Original white	100% Untreated cotton		Knitting from cotton yarns 		Grey paper Stable building material		Mimic: Sunlight G.Y.9.5/T25 220V-240V 650W
	Carrot yellow							
	Orange yellow	Stir in carrots, orange skins, grape skins, strawberries and pour into water, add 100% cotton fabric. Boil for half an hour and leave overnight.						
	Grape purple			Embroidery on white cotton woven textile		White transparent textile Moveable facade design		Mimic: Artificial light Internal LED ≤36V 5W 4000k Cool White 8000mAh
	Strawberry pink			Flower pounding on white cotton woven textile				

Tab 3.0.1 List of experimental subjects
*Sinece it is difficult to build a model suitable for observing changes in light and shadow in a short time. This model experiment is aim to provide a basis for later design and does not guarantee 100% simulation of natural light. As can be seen from the light comparison that the shadows cast by light through the textile and onto the projection are clearly visible in both artificial light and sunlight. In these experiments the artificial light source in Tab 3.0.1 will be used to simulate sunlight (light shining into the interior from the outside of the building).

LIGHT COMPARISON

A single window will be used in these expriments. Due to the recent rainy and windy weather, the simple 1:10 model is not stable. By comparing the shadows created on a sunny day in Gothenburg in 2024.6.4 and the effect of artificial lighting, the pictures are shown below.





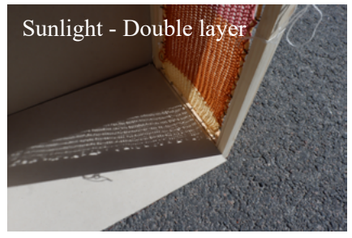


Fig 3.1.1~3.1.5 ***Layer 1.*** Solid-coloured transparent cotton textile from left - right. White - Grape - Strawberry - Orange - Carrot.

Fig 3.1.6/3.1.7 ***Layer 2.***
Knitting from 100% cotton yarns
Left: different density.
Right: different colour.

Fig 3.1.8/3.1.9 ***Layer 3.***
Patterns on transparent white cotton textile.
Left: embroider.
Right: flower pounding.

3.1
TEXTILE WINDOW

The beauty of architecture is in the details, in the way materials come together, in the play of light and shadow.

——Richard Rogers

3.1.1 MULTIPLE LAYERS OF TEXTILE + LIGHT

Layer 1 - Solid-coloured transparent textiles

The combination of solid-coloured transparent textiles and different lights can create a varied light shadow outcome. When light passes through other objects onto solid-coloured textiles, the colours of the other objects will show onto the solid-coloured textiles. When used individually, different coloured textiles create different spatial feeling when light shines from outside into the building.

Layer 2 - Colourful knitting textiles

Yarns can be knitted into textiles in a wide range of colours and patterns. In addition to showing colorful light and shadow effects on the first layer of transparent textiles. Research has shown that loose knitted structure can effectively reduce wind speed and high-energy eddies and address the need to improve wind comfort in urban areas. (Hörteborn.E, 2023)

Layer 3 - Colourful pattern textiles

Transparent solid-color textiles can be embroidered to reduce the void ratio of the textile, which may change the light and shadow effect on the first layer. Using plant flowers and leaves to print on solid-color textiles has less impact on the void ratio of the textile than embroidery. The third layer of textiles will be embroidered and flower pounding textiles, showing the differences in light and shadow.

Purpose

These different types of textiles will be arranged and combined to explore the relationship of spatial shading in different combinations. The exploration will be based on the four questions under Art of Light and shadow in Chapter 1.3. The aim is compare the similarities and differences of textiles in light under different conditions and to select the more striking combinations for later design.

Type 1 - Single layer

A1. Type 1 - Solid-coloured transparent textile

When only solid-coloured transparent textile is installed, it can be combined with other performing arts such as the two show in Fig 3.1.20/3.1.21. With no distractions of their own, the viewer standing/sitting in the street can clearly see the colours and movements of the characters and images.

Fig 3.1.10/3.1.11 Left: White Right: Strawberry

Feature: Transparent, Lightweight.
Scenario: Relevant arts festivals, nice weather (no rain, breezes, warm weather).

B1. Type 1 - Colourful knitting textile

Knitted textiles are soft and interactive, they can create different light and shadow effects in the architectural space depend on the density/pattern like the two show in Fig 3.1.24/3.1.25. Research has shown that knitted textiles can reduce the effect of wind on the environment. As the textile creasing with the wind, the shadows dance inside the building.

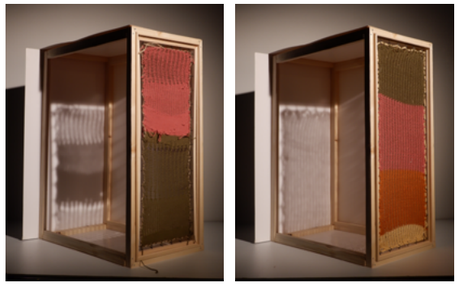


Fig 3.1.12/3.1.13 Left: Sparseness Right: Colour

Feature: Soft, Diverse, Interactive, Wind resistance.
Scenario: Arts festivals, good weather
(no rain, windy, warm weather).

C1. Type 1 - Colourful pattern textile

Embroidery changes the density of the textiles so that the pattern on the fabric can appear as a shadow on the floor/wall, whereas flower pounding has less of an effect. This can be seen in Fig 3.1.26/3.1.27.

Feature: Transparent, Interactive, Lightweight.
Scenario: Arts festivals, nice weather
(no rain, breezes, warm weather).

Fig 3.1.14/3.1.15 Left: Embroidery Right: Pounding

3.1.2 COMBINATION LOGIC

Type 2 - Double layers

A2. Solid-coloured transparent textile + Colourful knitting textile

Compared to using layer 2 alone, as shown in the Fig 3.1.12 and Fig 3.1.16, double layer reduces the proportion of sunlight hitting the building, which theoretically makes the space more comfortable for people in hot weather. Knitting textile also creates shadows on solid-coloured textiles, which can be change according to the wind and direction of light like Fig 3.1.18 ~ 3.1.19.

Fig 3.1.16 ~ Fig 3.1.19

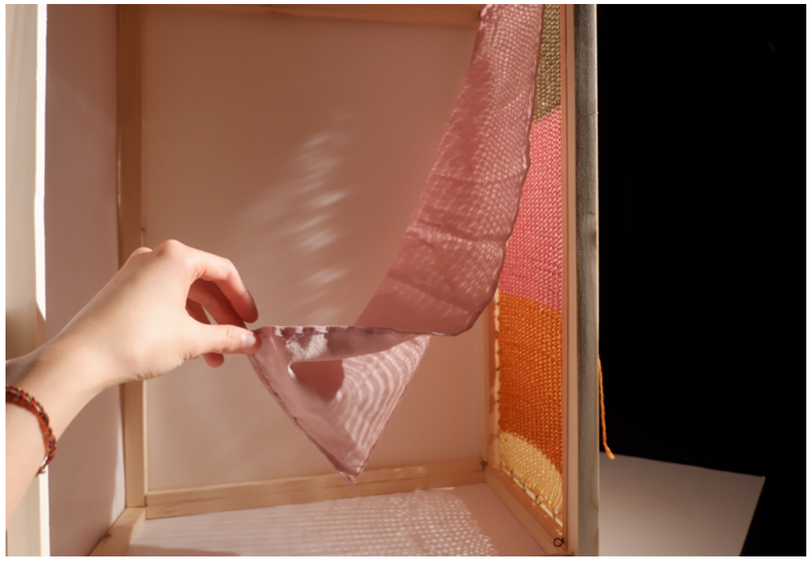
Feature: Shadow diversity, Interactive, Wind resistance.
Scenario: Arts festivals, good weather (no rain, windy, ≤ 32°C).

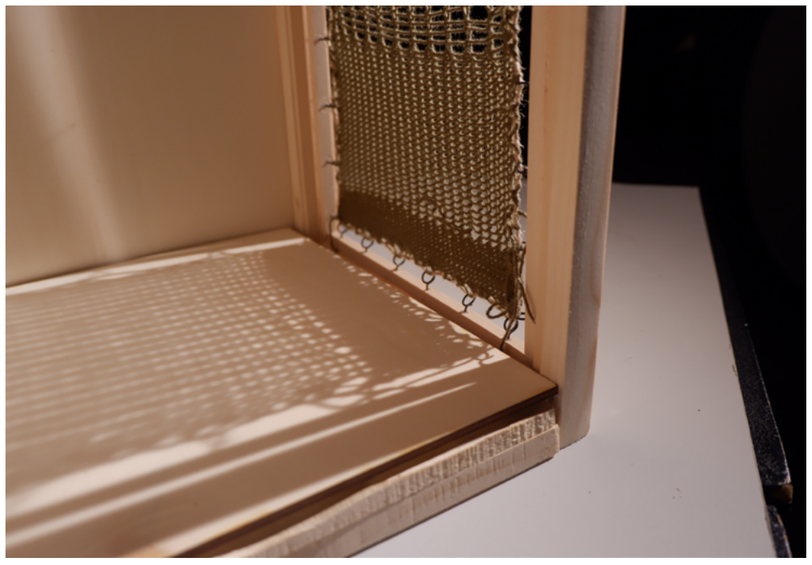
B2. Solid-coloured transparent textile + Colourful pattern textile

Transparent textiles with embroidery patterns create distinctive shadows when used alone. When used with solid-coloured transparent textiles, the shading pattern fades but adds a sense of mystery and interaction as shown in Fig 3.1.20 ~ Fig 3.1.22.

Fig 3.1.20 ~ Fig 3.1.22

Feature: Lightweight, Interactive.
Scenario: Arts festivals, good weather (no rain, breezes, ≤ 32°).





*Variable spatial shading in type 1/2.

Fig 3.2.1 Shadow play role

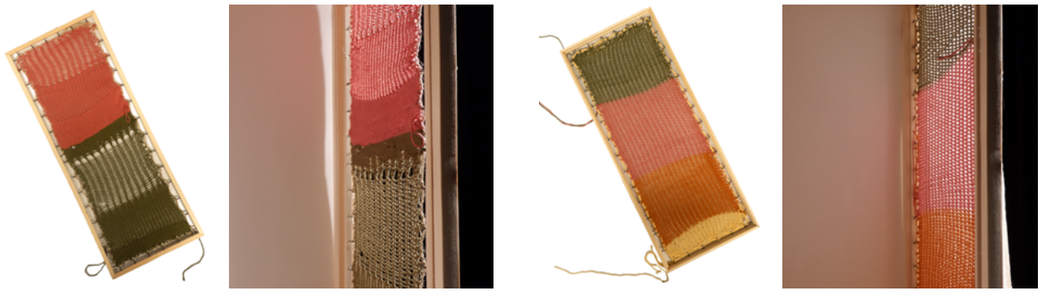


Fig 3.2.2 ~ 3.2.5 Different colour and density of knitting textile

Fig 3.2.6 ~ 3.2.9 Patterns made in different ways on textile

3.2
TESTING METHODS

In order to test the factors affecting the transmittance of textiles and to observe the art of light and shadow in different layer/textile combination, shadow puppets and colourful knitted and woven textiles were uesd for manual transmittance testing.

3.2.1 SHADOW PUPPETS

Shadow play is a traditional performance using brightly coloured costumes and decorations for the puppets, which are illuminated by lights and presented on a transparent white textile.

These experiments will explore the influence of colour and other factors on the transparency of textiles with the help of shadow puppets (Fig 3.2.1). In addition, the possibility of displaying shadow play performances on textile windows will be discussed later.

3.2.2 COLOURFUL KNITTING TEXTILE

The original colour of the fibre is usually white or pale yellow, but in the process of producing the fibre into yarns and textile, it can be dyed in many colours with simple treatments. In the process of knitting yarns into textile, the yarns can be arranged and combined to form a textile with different densities and patterns like.

These experiments will use knitted textiles to investigate how the colour and sparseness of textile influences the transparency of textile like Fig 3.2.2 ~ 3.2.5. It also will be assumed to be one of the layer of the textile windows in the later design.

3.2.3 COLOURFUL PATTERN TEXTILE

Textiles can be treated in a variety of ways and can be patterned by embroidery, printing and painting. Some methods change the sparsity of the textile, such as embroidery, while printing and painting have a lesser effect on the sparsity.

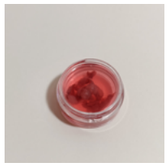
In these experiments, embroidery and fabrics printed with plants as shown in Fig 3.2.6 ~ Fig 3.2.9, they will be the third method of transparency testing. These fabrics will be used in the third layer of the textile window design to show the effect of the fabric's own colour in the light.

3.3.1
FACTORS - COLOUR

How **does colour affect the transparency of textiles?**

TEXTILE DISPLAY SCREEN

Solid-coloured transparent textiles will be used in the first layer of the textile window. These fabrics will be used as a media that can be combined with other layers of textiles to give different shades in the light. In this study, cotton were coloured with dyes made from carrot, orange peel, grape peel and strawberry to investigating the effect of combining different colours of transparent textiles with different objects.



Experiments	1.1	1.2	1.3	1.4
Main component	Water + Carrot	Water + Orange	Water + Grape	Water + Strawberry
Treatments	Stir in pieces / Boil for 0.5h / Add salt / Wait for one night			
Outcome				
Colouring level	(2)	(2)	(1)	(1)
Tranparency level	Botanical dyeing doesn't affect the transparency of the cloth much, except when two objects are the same colour.			

*Colouring / Tranparency level: High / Excellent (1) Medium / Good (2) Low / Moderate+Poor (3)
*All dyed textiles are cut from the same 100% white cotton transparent textile.

Tab 3.3.1 Experimental data on fabric dyeing.

3.3.1.1 WITH PUPPETS

Puppets

Puppets

Puppets under different colour transparent textile

Puppets with transparent material

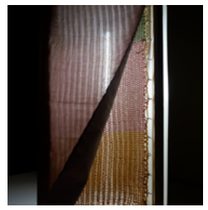
Puppets with opaque material

Results

Compare to white textiles, puppets under coloured textiles are affected by the colour of the textile, but are still clear. The transparency of the puppet itself will also have an effect.

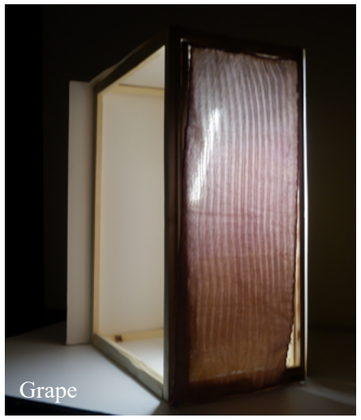
3.3.1.2 WITH KNITTING TEXTILE

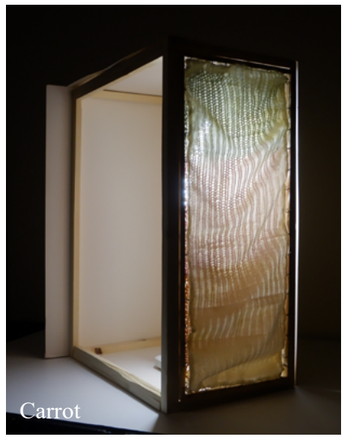
Colourful knitting textile



Outer layer ceasing with the wind

Textiles viewed through transparent textiles





Results

Knitting textiles made from yarns of different colours can be clearly observed under transparent textiles with colour variations, patterns. The closer a solid-coloured textile is to a colourful knitting textile, the clearer the colours and patterns.

3.3.1.3 WITH EMBROIDERY TEXTILE

Colourful embroidery textile

Single layer

+ White transparent textile

Textiles viewed through transparent textiles

Results

In contrast to colourful knitting textile, embroidered textile patterns and colours are not as easily observed, but this may also be a matter of proportion.

3.3.1.4 CONCLUSION

It can be seen from the experiment 3.3.1.1/3.3.1.2/3.3.1.3 that shadow puppets and coloured knitting textiles can clearly show their colours and patterns under solid-colour transparent textiles.

These outcomes can give guidance to later (Chapter 4) how to apply different textile combinations to the textile windows design. When solid-color transparent textile is used, it can become a display wall to display artistic expressions such as shadow puppets or knitting textile behind it.

3.3.2
FACTORS - LIGHT SOURCE

What **is the difference between sunlight (external) and artificial light (internal) related to textile?**

TEXTILE - HELP BUILDING CAPTURE THE LIGHT

Light is dynamic, visible and interactive, it is one of the most important elements in architectural design. Textiles are soft and flutter in the wind. When light shines through textiles into a building, the shadows change with time and weather. This chapter will explore the different light and shadow effects of light shining into architectural spaces from the outside through textiles and light illuminating textiles from the inside.

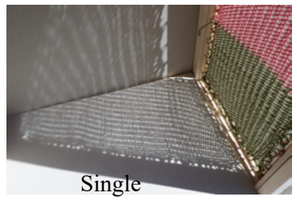
Single - Zoom in

Experiments	2.1	2.2
Objects	Sunlight / External	Artificial light / Internal
Light source	/	LED
milliampere Hour	/	8000mAh
Kelvins	/	4000k Cool White
Voltage	/	≤36V
Electric power	/	5W

*The objects - sunlight refers to the sunlight on a sunny day in Gothenburg on June 4, 2024, which is different from the venue in Chapter 4 .
*Experiment only records data under limited light sources, which does not mean that the light source intensity is close to the sunlight or artificial light in the real site.

Tab 3.3.2 Experimental data for lamps used.

3.3.2.1 DIFFERENT LIGHT SCENARIO

Light	Shadow differentiation			
Sunlight External Daytime	 Single	 Single	 Double	 Double
Artificial light Internal Nighttime	 Double	 Double	 Double	
Results	Sunny day, sunlight passes through the textiles creating shadows on both building space and the solid-coloured transparent textiles. At night, when light shines from inside onto the solid-coloured transparent textile, the object behind it becomes visible on itself and it becomes an architectural art display wall.			

3.3.2.2 CONCLUSION

Shadow is an optical phenomenon caused by light being blocked. Knitted textiles are lightweight and flexible, creating unique shadows in architectural spaces during the day that change with time and wind. Transparent textiles are light-transmissive. Whether they are shadow puppets or other light-transmitting materials, the colours and shapes are shown vividly.

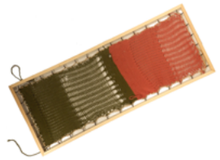
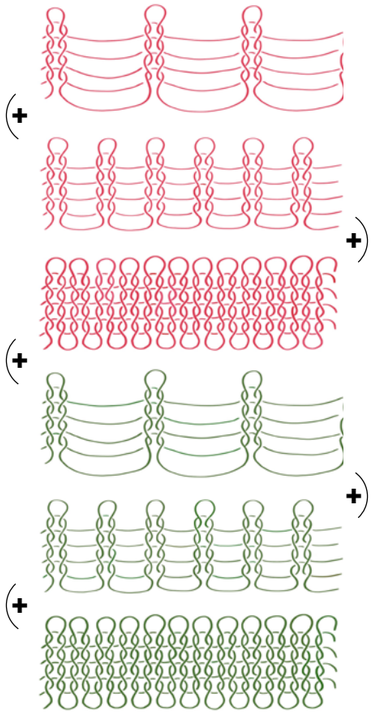
The purpose of these two is to explore the effects produced by textile windows during the day and night, and to inspire later designs.

3.3.3
FACTORS - SPARSENESS

How **does the sparseness of textiles affect light and shadow?**

TEXTILE - HELP BUILDING CAPTURE THE LIGHT

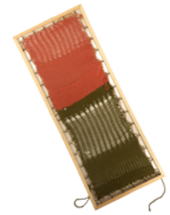
Knitting textile can be altered by changing the density of the knit to vary the size of the voids, resulting in different shadows. Embroidery textile can also be varied by changing the density of the textile so that the shadows of the embroidery pattern are revealed on the architectural space. In this chapter, the relationship between shadow and textile density is discussed and compare it to flower pounding textile.

			
Experiments	3.1	3.2	3.3
Types	Knitting	Embroidery	Flower pounding
Process		/	

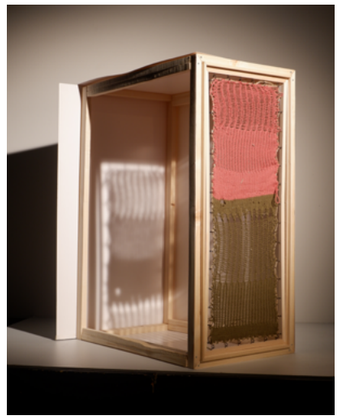
Tab 3.3.3 Objects for sparseness experiment.

3.3.3.1 KNITTING TEXTILE

Colourful knitting textile



Shadow related to knit method



Results

The shadows cast by light through the textile onto a fixed object (floor/wall) depend on the knitting density of the textile and the shadows move over time. When projected onto a movable object (light textile), the shadow will follow the fabric and flutter in the wind.

3.3.3.2 PATTERN TEXTILE

Colourful pattern textile	Shadow related to the density of textile
 Embroidery	 Single layer  Single layer  Single layer
 Flower pounding	 Double layer  Double layer
Results	As can be seen from the experiments, textiles produce special shadows on walls or other fabrics due to their own density when exposed to light.

3.3.3.3 CONCLUSION

Shadow clarity: Colourful knitting textile > Colourful Embroidery textile > Colourful Flower pounding textile.

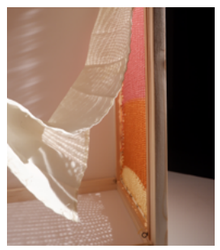
All three types of textiles are beautiful and unique. But in terms of this experiment on sparseness affecting the shape of shadows, knitted textiles are more clearly displayed in architectural spaces.The versatility of shadows in architectural spaces is increased when textiles are used to replace old glass window.

3.3.4
FACTORS - MATERIAL

How **do shadows differ on different materials?**

TEXTILE - HELP BUILDING CAPTURE THE LIGHT

Building materials vary from fixed/heavy materials such as concrete/brick/timber to movable/lightness materials like fabrics, etc. What is the difference between shadows on fixed/immovable building materials and on floating textiles?

		
Experiments	4.1	4.2
Simulated material	Grey paper Concrete	White transparent textile
Thickness	2mm	/
Distance	36.5cm	1~15cm
Shadow outcome		

*The textiles in this experiment were made using Experiment 3.1 knitting method in the sparseness experiment, where the different densities themselves will also affects the shadow.
*Except for white transparent textiles, the difference in distance to the projected object is negligible.

Tab 3.3.4 Experimental data for the simulation materials used.

3.3.4.1 WITH DIFFERENT MATERIALS

Material	Textile shadow on different material
Grey paper Mimic Concrete	 
Transparent textile	
Results	Shadows can show clearly on the immoveable material and will flutter with the wind on solid-coloured textiles. If the textile is transparent, the colours and patterns of the other layers of textile can be seen through it.

3.3.4.2 CONCLUSION

Light bocked by textile allow it create shadows in the architectural space as it passes through, which change according to changes in time (sun height and direction). Comparing the two types, knitted textiles have clearer shadows and better effects.The shadows are enriched by the lightweight nature of the textile and the help of the wind/sun.

The combination of knitting textiles and transparent textiles are outstanding and guide later designs.

3.3.5
FACTORS - CONCLUSIONS

Light is one of the most important elements of architectural design, textiles can help buildings capture light. It makes shadow more dynamic and enhance the interaction between people and buildings. Artistic performances can also be displayed on the facade through the relationship between light and textiles.

Experiment 1. Colour

Dyeing white transparent cotton fabric with natural dyes does not affect its transparency too much, but will creates a different spatial atmosphere when light shines through the different colours of the solid transparent fabric into the building.

Experiment 2. Light Source

As external light travels through the textile to reach the architectural space, the shadow of the textile will show in the building. Due to the lightness of the textile, the shadows will change with the help of the wind.

When light emanates from the building, the colours and patterns of the knitted textiles/patterned textiles can be clearly seen through the transparent solid-coloured textiles. Thanks to the transparency of the textiles, other artistic performances, such as shadow play, can be show on the textile facade of the building.

Experiment 3. Sparseness

Knitted textiles can change the shadow shape by controlling the knitting density. The lightness, flexibility, colourfulness, transparency and opacity of textiles can be combined with architectural design to create unique, interactive spaces.

Experiment 4. Material

The light and shadow of a textile is not only influenced by its own properties, but also has a different outcome on different material media. When the shadow acts on both the light textile and the architectural space, the shadow is variable.

3.4
CONNECTION

CONNECTION

As can be seen in the previous chapters, the toughness, touch and feel of textiles vary depending on the raw material. Yarns also come in a wide variety of colors, and 100% white cotton transparent textile by woving can take on a wealth of colors with a simple treatment of vegetable dyes, as shown in Fig 3.4.1 and in the experiment section 3.3.

From this chapter experiments, different solid-colors transparent textiles produce different effects in different combinations even in different colour of them.

During the day, if it is placed on the outside of the knitted fabric, it reduces light penetration like Fig 3.4.2/3.4.3 and is suitable for high temperatures and high UV environmental conditions. If placed on the inside of a knitted fabric, the shadows created by sunlight hitting a building will not only create shadows in the architectural space, but also on the solid-colored transparent fabric as shown in Fig 3.4.6. The difference between the two is that the latter is subject to less wind interference, as the knitted fabric reduces wind penetration.

At night, by placing it on the outside of the puppets or the knitted fabrics as shown in Fig 3.4.4/3.4.5, the colors and patterns of both the translucent puppets and the colourful knitting textile are clearly visible when light hits the fabric walls from inside the building.

INSPIRATION

When applied to an actual building facade, the ideal effect is to be able to demonstrate the diversity of textiles as shown in the 1:20 model Chapter 4, Section 4.2.3. What stands out in the combination experiments in this chapter are the combinations of solid-coloured transparent textiles with shadow play or colorful knitted textiles and the different architectural spatial sensations during the day and night. Chapter 4 - Applying textiles to actual window design (replacing existing glass windows) will focus on these two combinations.

Fig 3.4.1 Solid-coloured transparent textile
+ Light from outside

Fig 3.4.2 Colourful knitting textile
+ Light from outside

Fig 3.4.3 Solid-coloured transparent textile
+ Colourful knitting textile
+ Light from outside

Fig 3.4.4 Solid-coloured transparent textile
+ Puppets
+ Light from inside

Fig 3.4.5 Solid-coloured transparent textile
+ Colourful knitting textile
+ Light from inside

Fig 3.4.6 Colourful knitting textile
+ Solid-coloured transparent textile
+ Light from outside

4.

Original Building

Design Exploration

Design Concept

After Building

Aerial View

Exploded section

Renders

Models

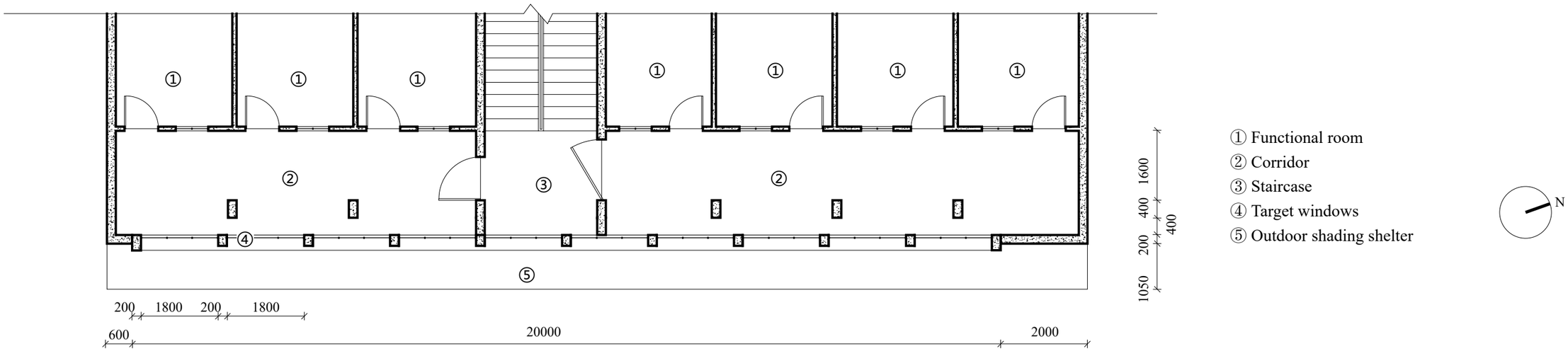
1:1 real sense model

1:100 part model

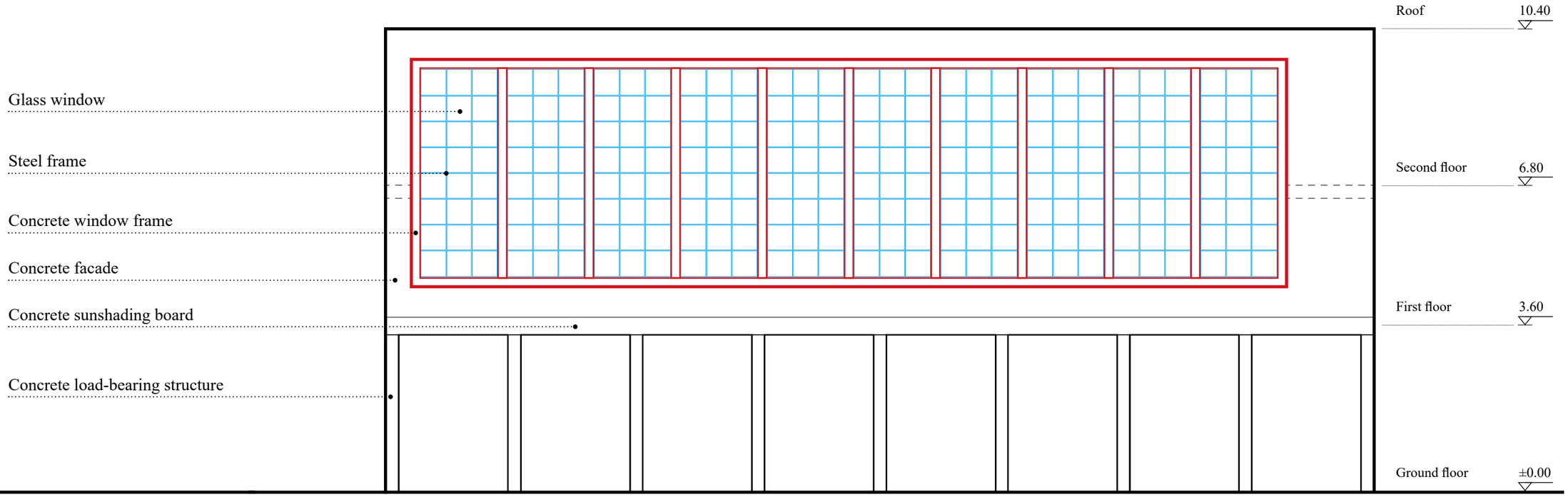
1:20 material model

1:10 texting model

4.0
ORIGINAL BUILDING

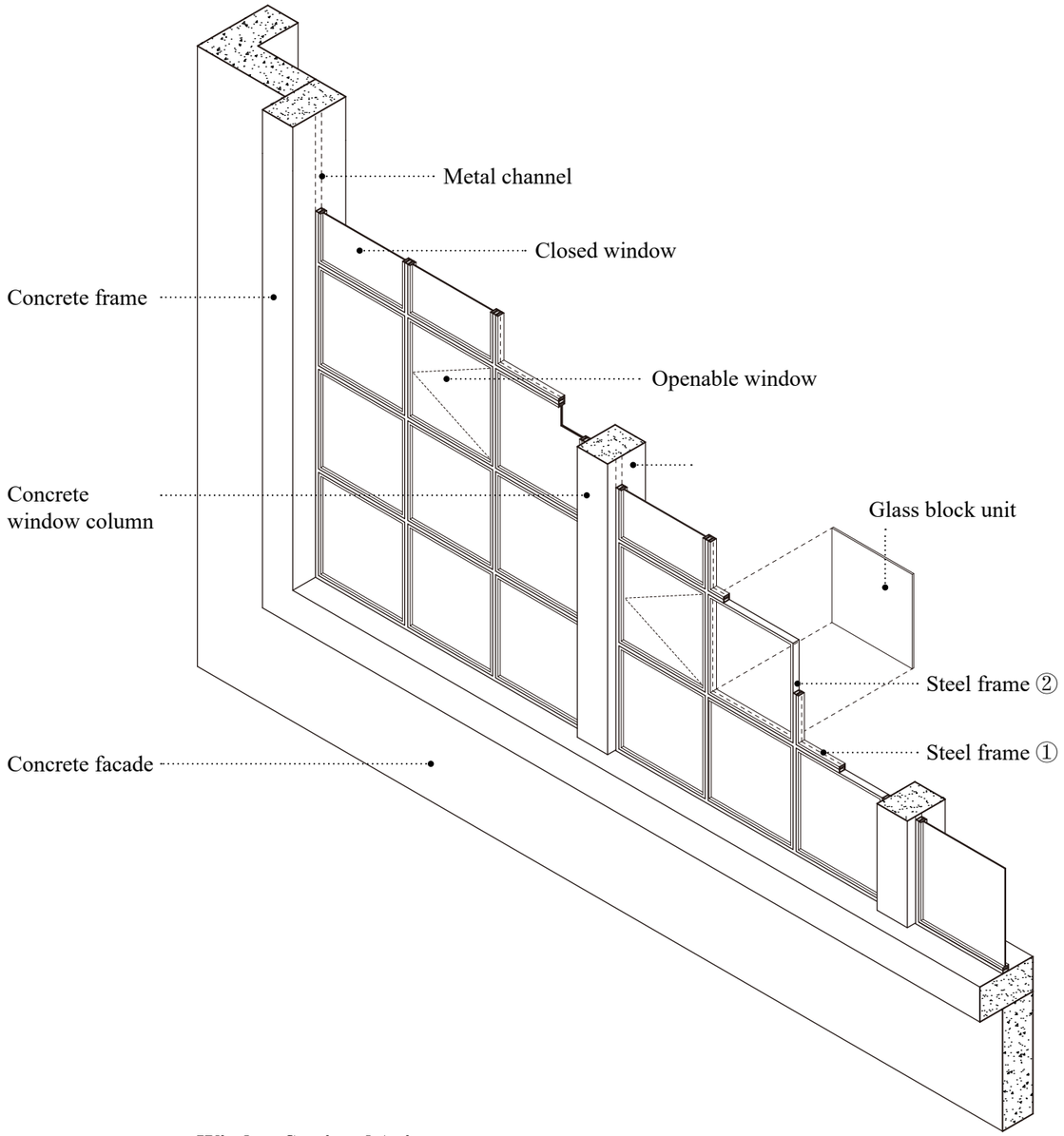


First floor plan 1:100

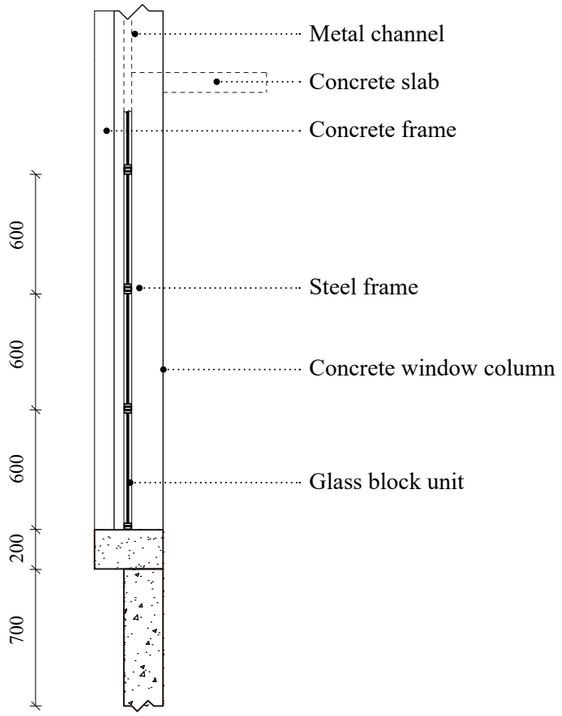


Front Facade Elevation 1:100

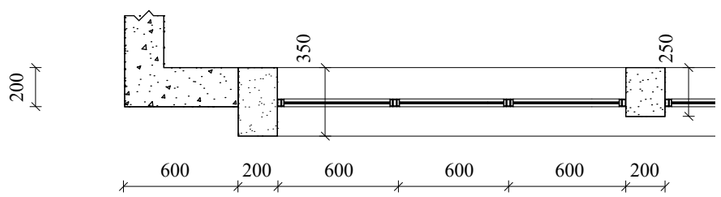
DETAILS



Window Sectional Axis



Window Detail Section

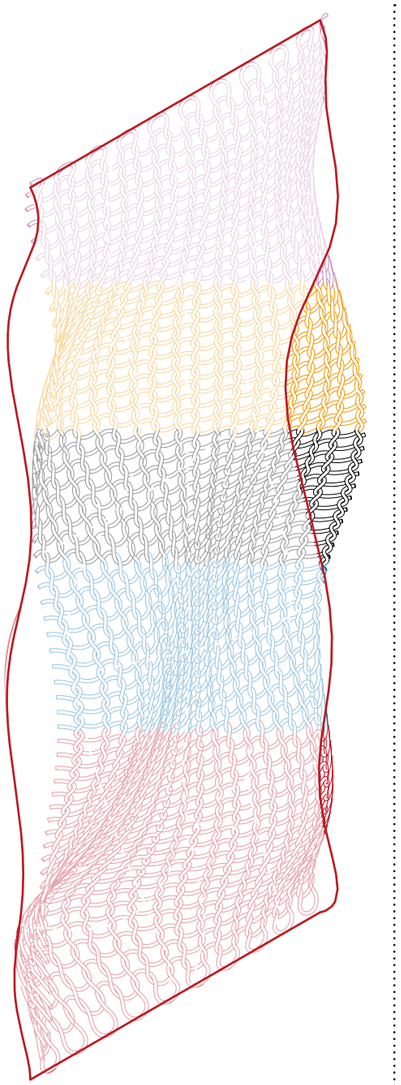


Window Detail Plan

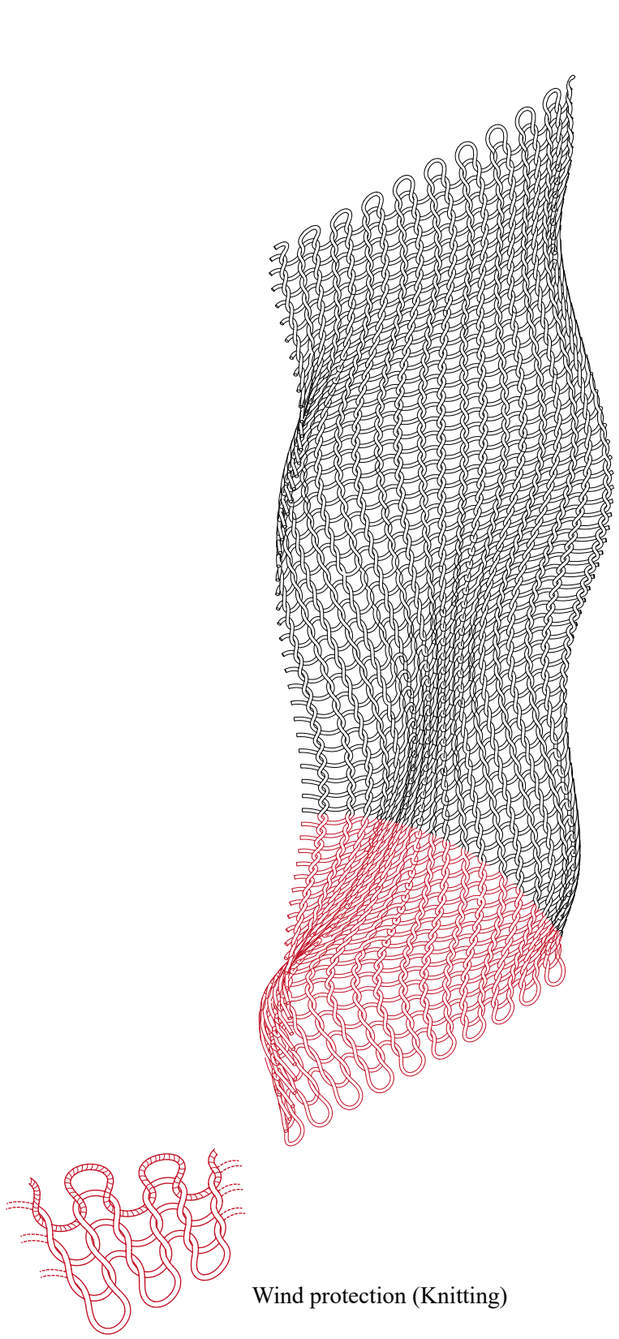
4.1
DESIGN EXPLORATION

4.1.1 CONCEPT - COMBINATION MODE 1

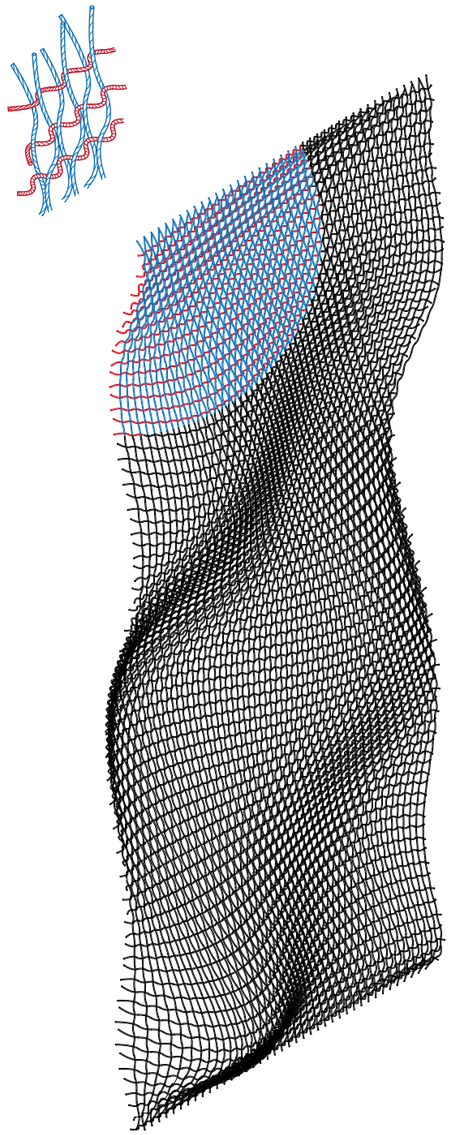
The combination of transparent solid-coloured textiles and knitted textiles in rich colours and shapes is a special combination. As can be seen from the experiments in the chapter 3, textiles under the light are able to show an unique shadow in the architectural space and on the textile facade, where the shadows are movable with the help of the wind.



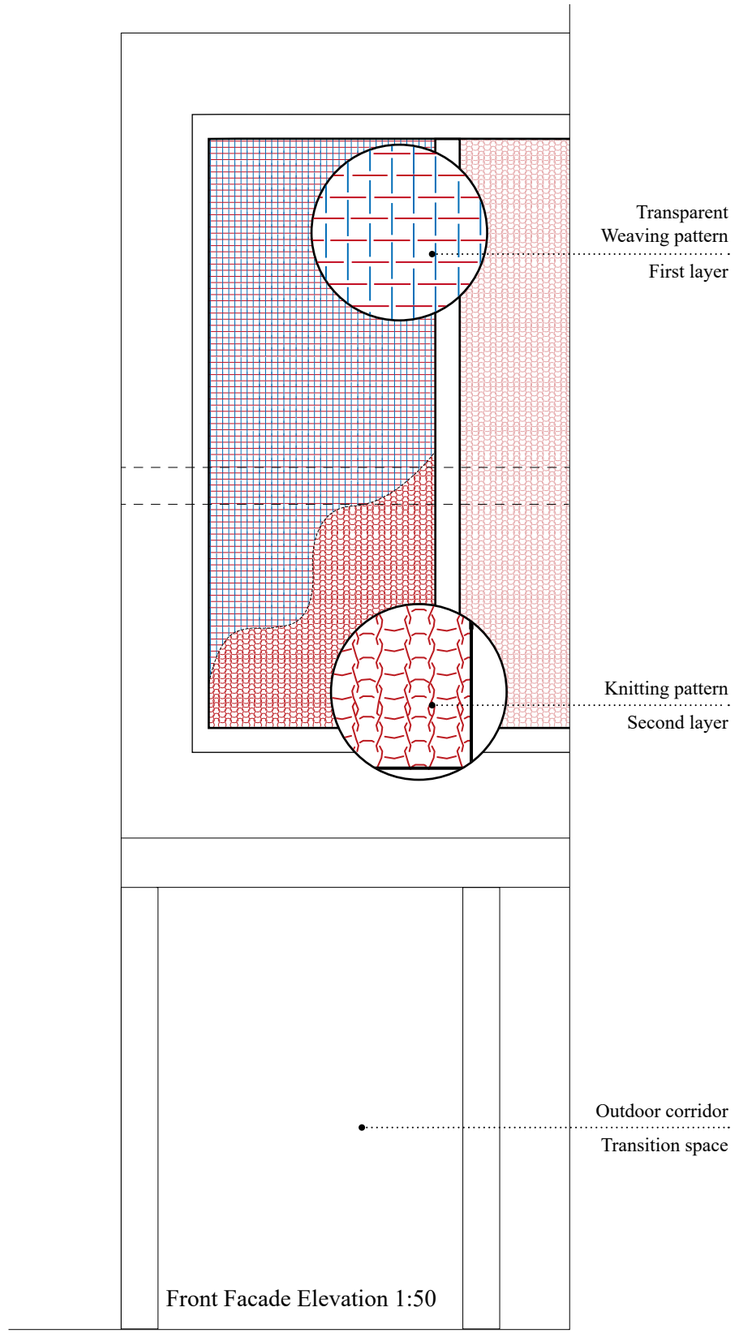
Creasing with the wind



Wind protection (Knitting)



Translucent textile (Weaving)



Front Facade Elevation 1:50

4.1.1 CONCEPT - COMBINATION MODE 2

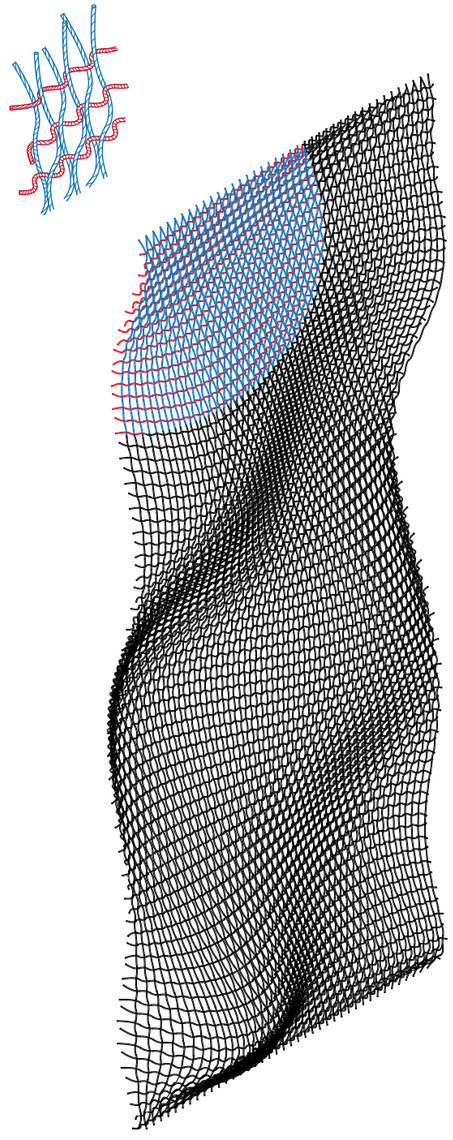
The original building was an old cinema, the first permanently built cinema in the county but has been abandoned for a long time. Although this design only uses the front facade of the building as a test site for the textile windows, it is hoped that the renovation will allow the building to be seen by the public again as an arts/entertainment venue.

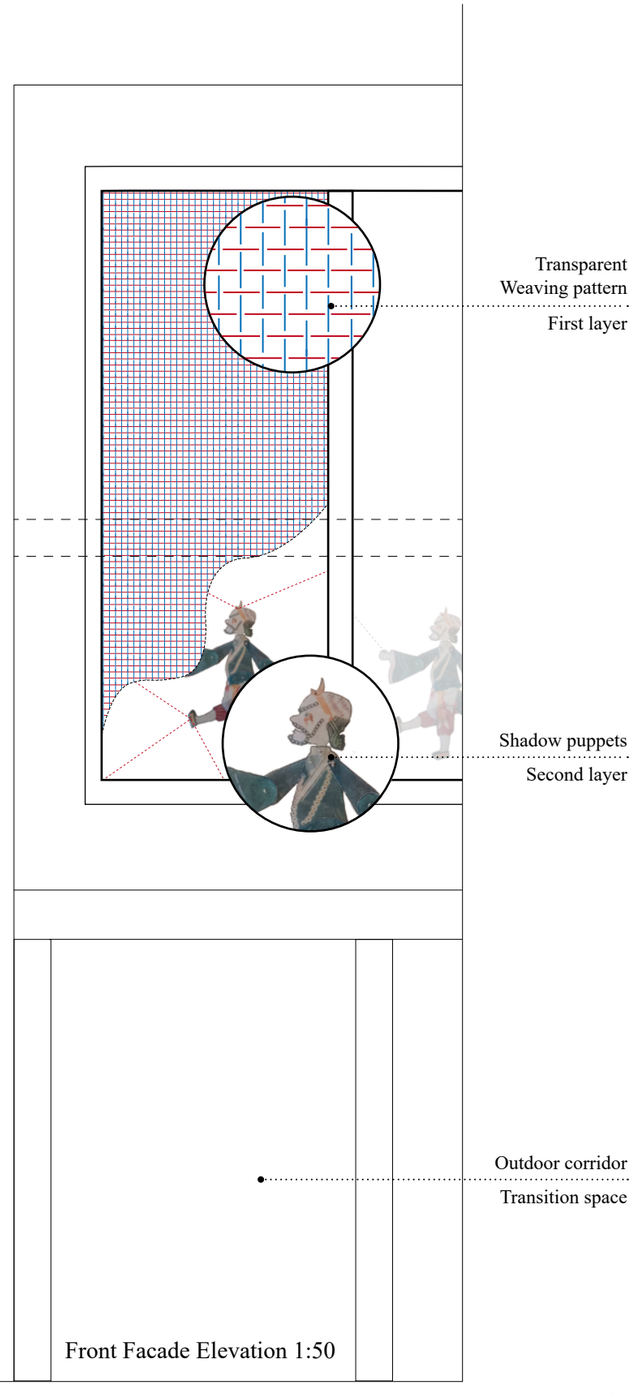
The transparent nature of the textiles allows for art to be performed behind the windows at night when the weather is good, making the building a place to interact with people.

Art performance

Shadow puppets (As an art perform example)

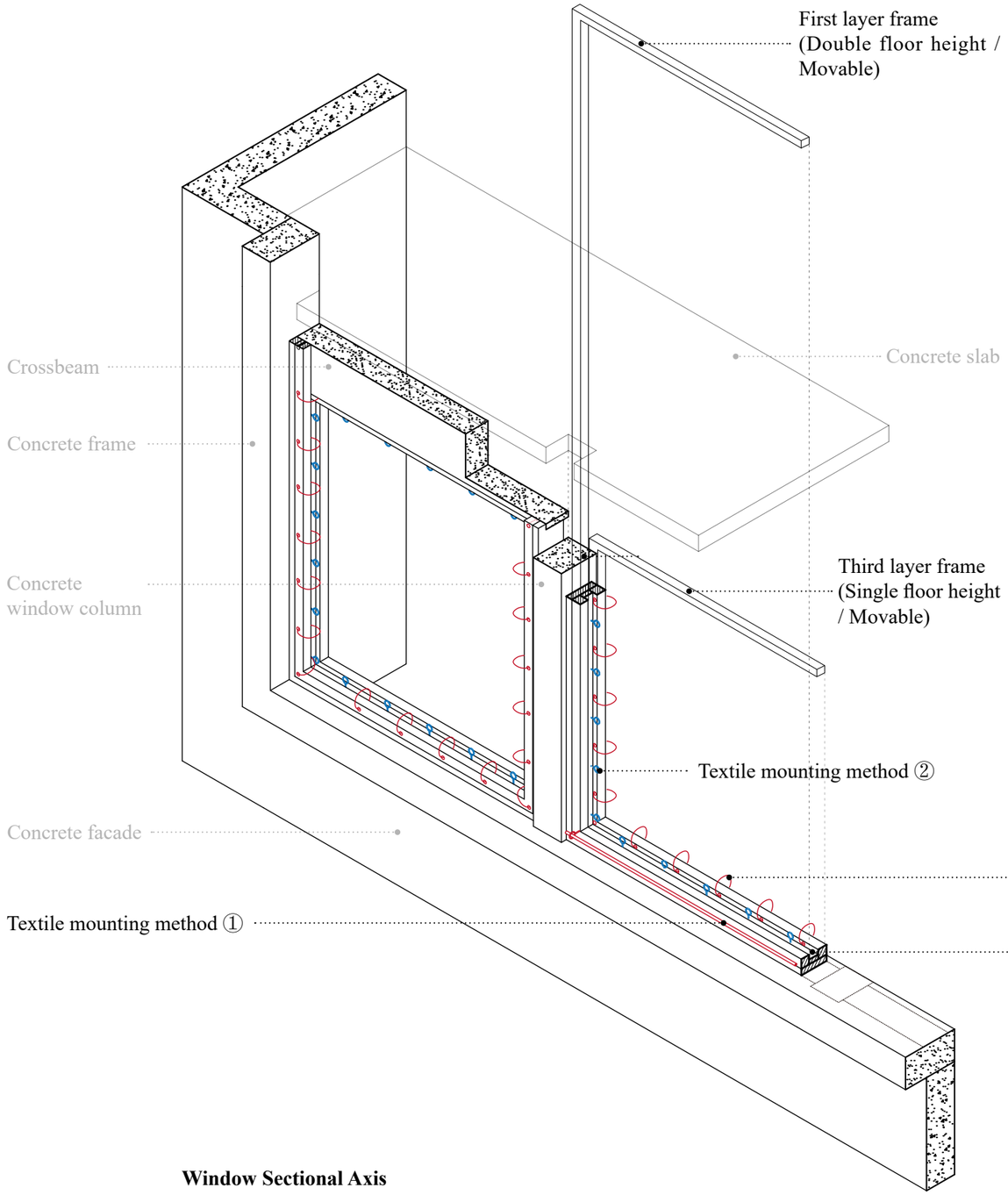
Translucent textile (Weaving)



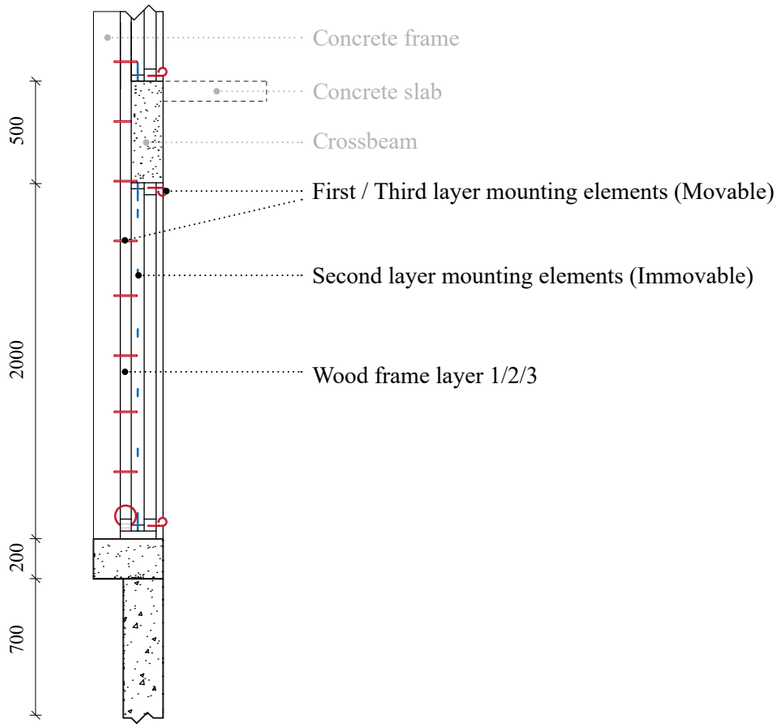


Front Facade Elevation 1:50

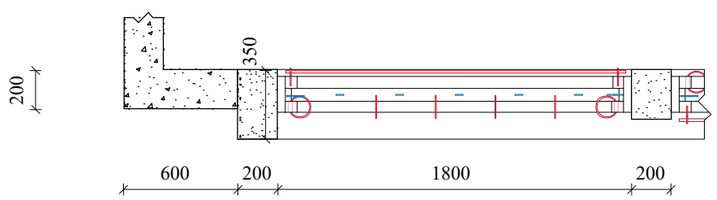
4.1.2 AFTER BUILDING - DETAILS



Window Sectional Axis



Window Detail Section



Window Detail Plan

4.1.2 AFTER BUILDING - LAYERS

Textile mounting frame ①

Textile mounting method ①

①

First Layer

Textile mounting frame ③

Textile mounting method ③

Textile mounting frame ③

②

Second Layer

③

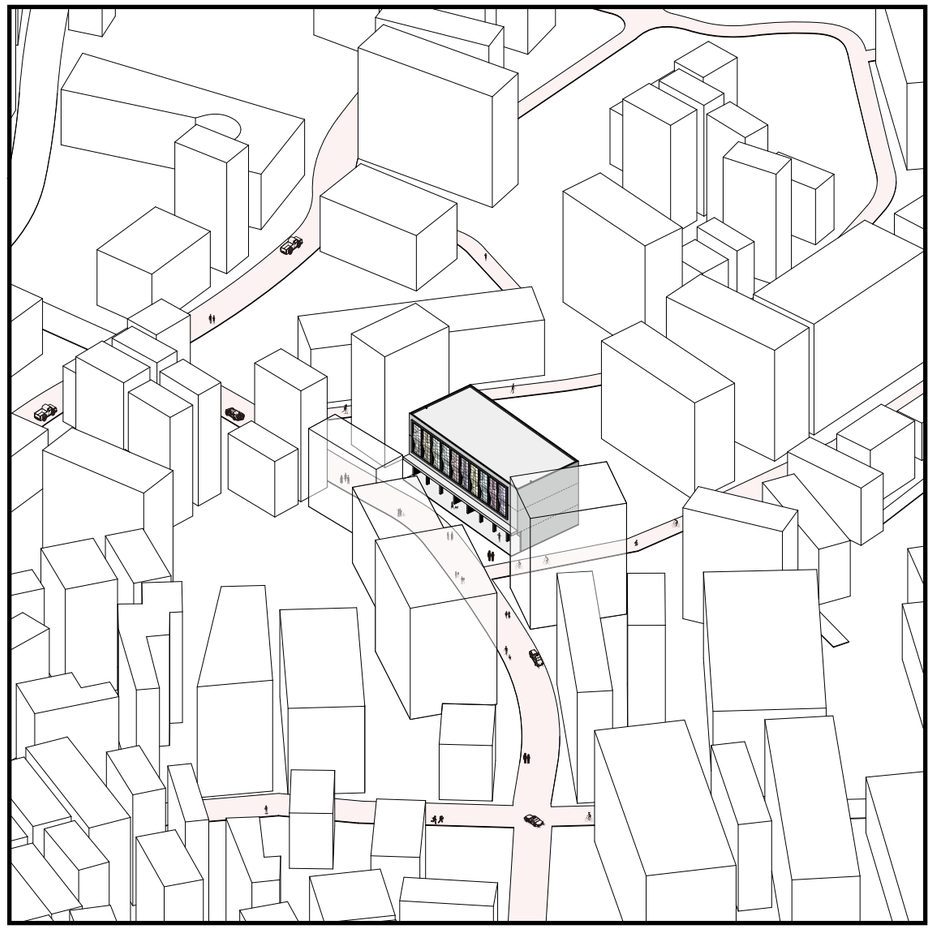
Metal joint

Textile joint

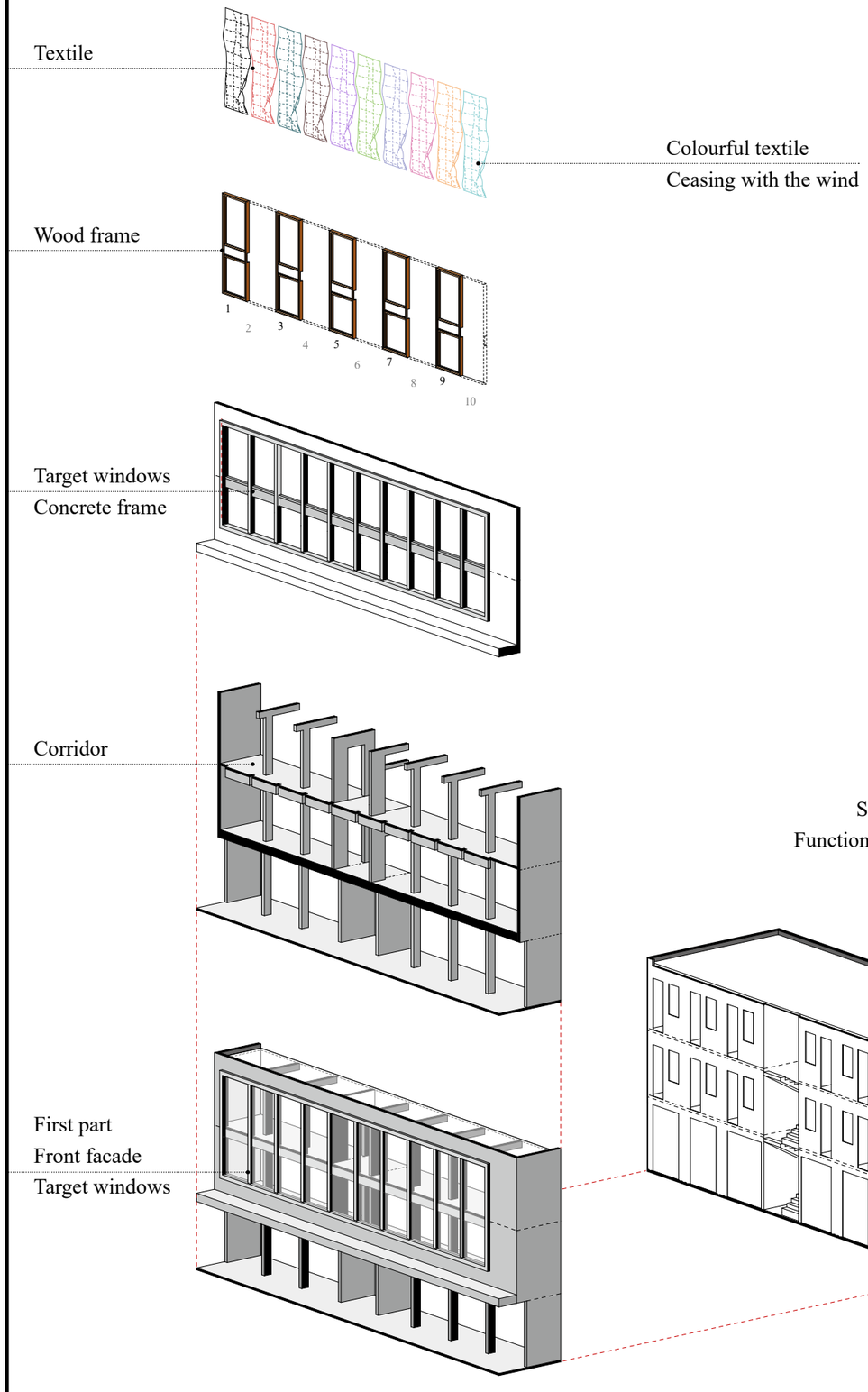
Holes without joint

Third Layer

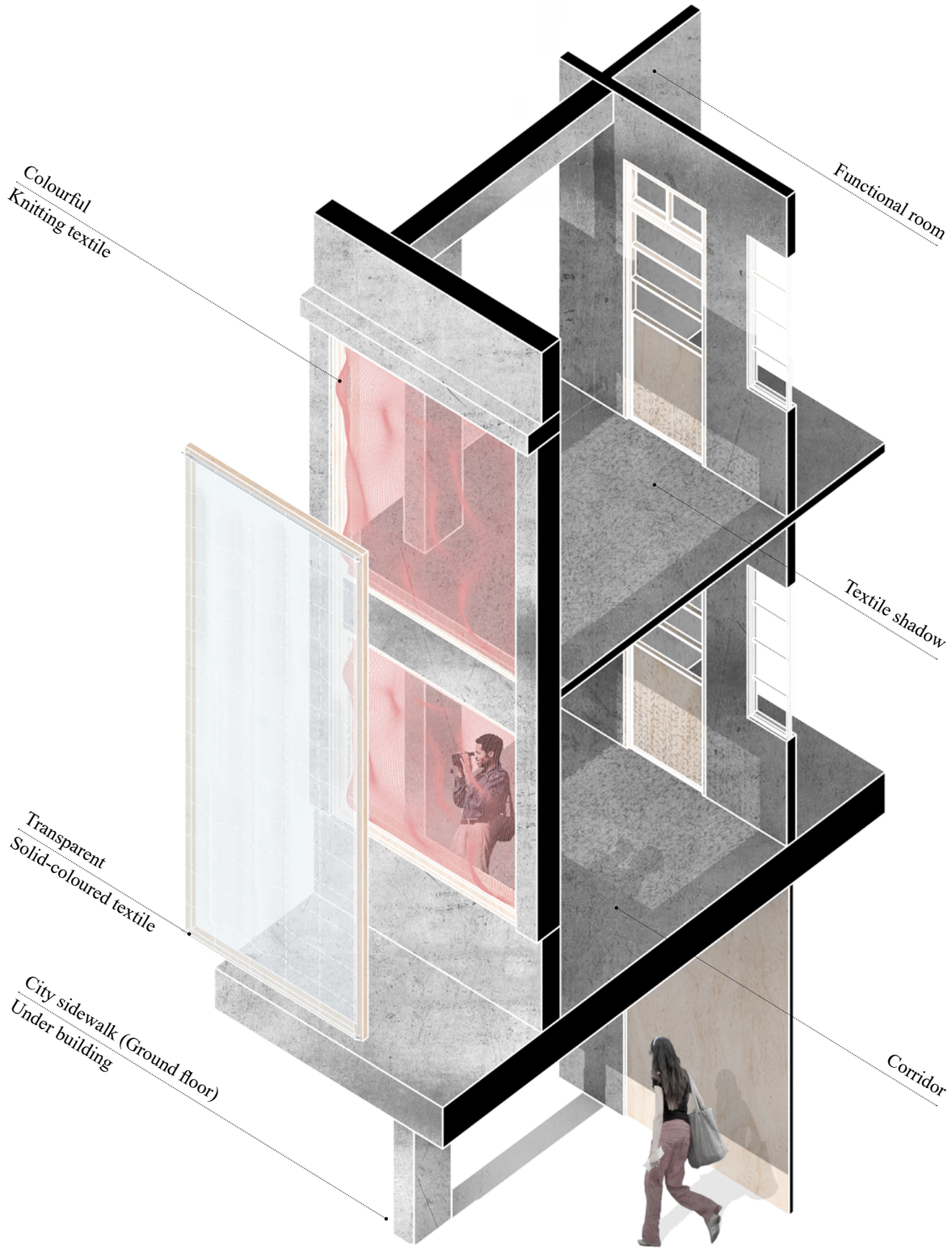
4.1.3 AERIAL VIEW



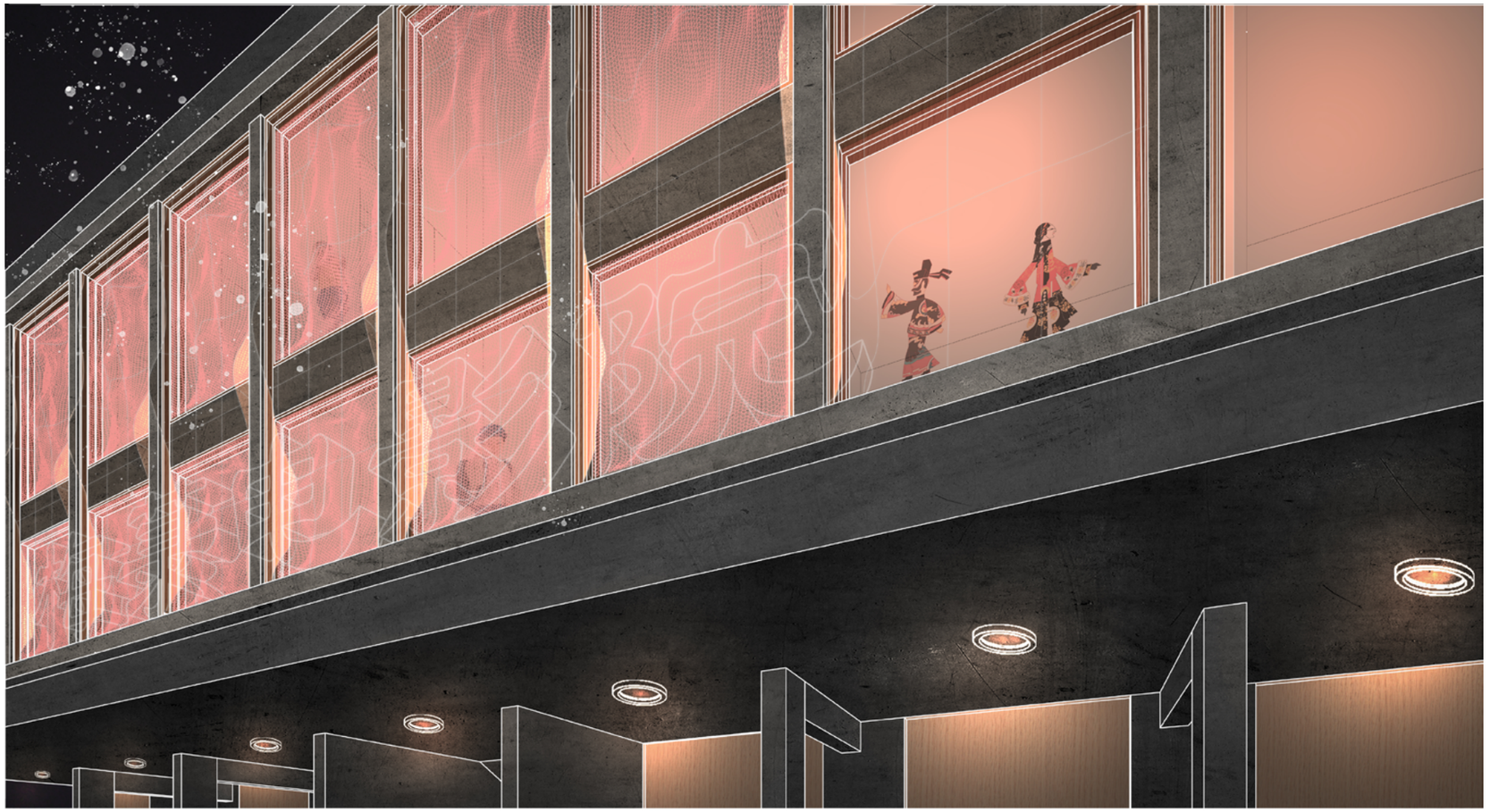
4.1.4 EXPLODED SECTION



4.1.5 RENDERS


Colourful
Knitting textile
Functional room
Textile shadow
Transparent
Solid-coloured textile
City sidewalk (Ground floor)
Under building
Corridor


華豪电影院



4.2
MODELS

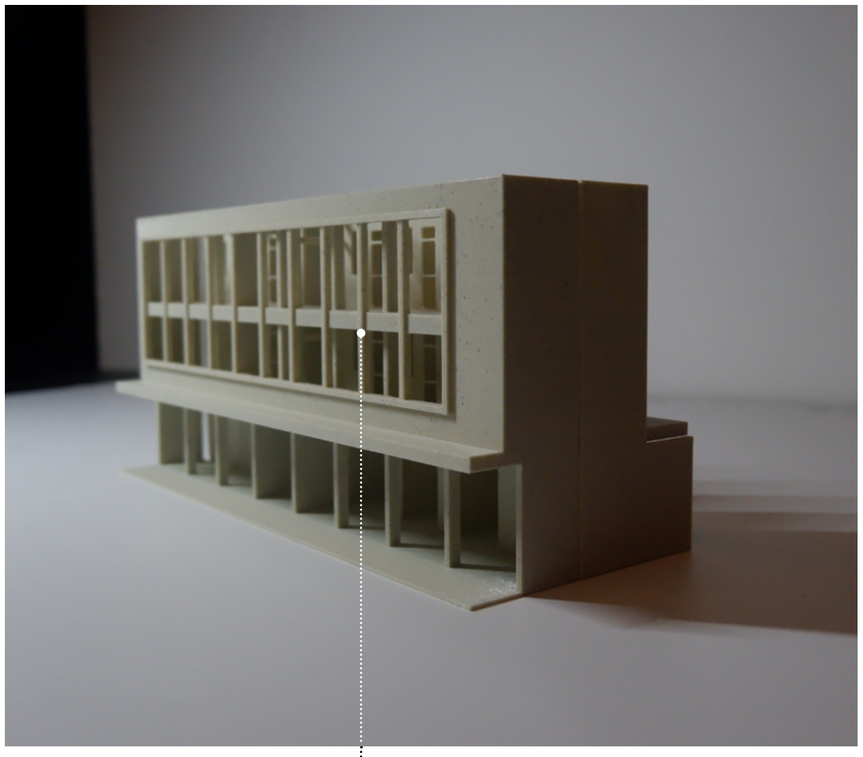
4.2.1 *1:1 REAL SENSE MODEL*

*This is part of a textile window approximately 1m x 1m, hung at a height of 1 metre above the ground. Light shines on the textiles from one side, having shadows in the architectural space, and people can interact with the textiles and the shadows of the architectural space.

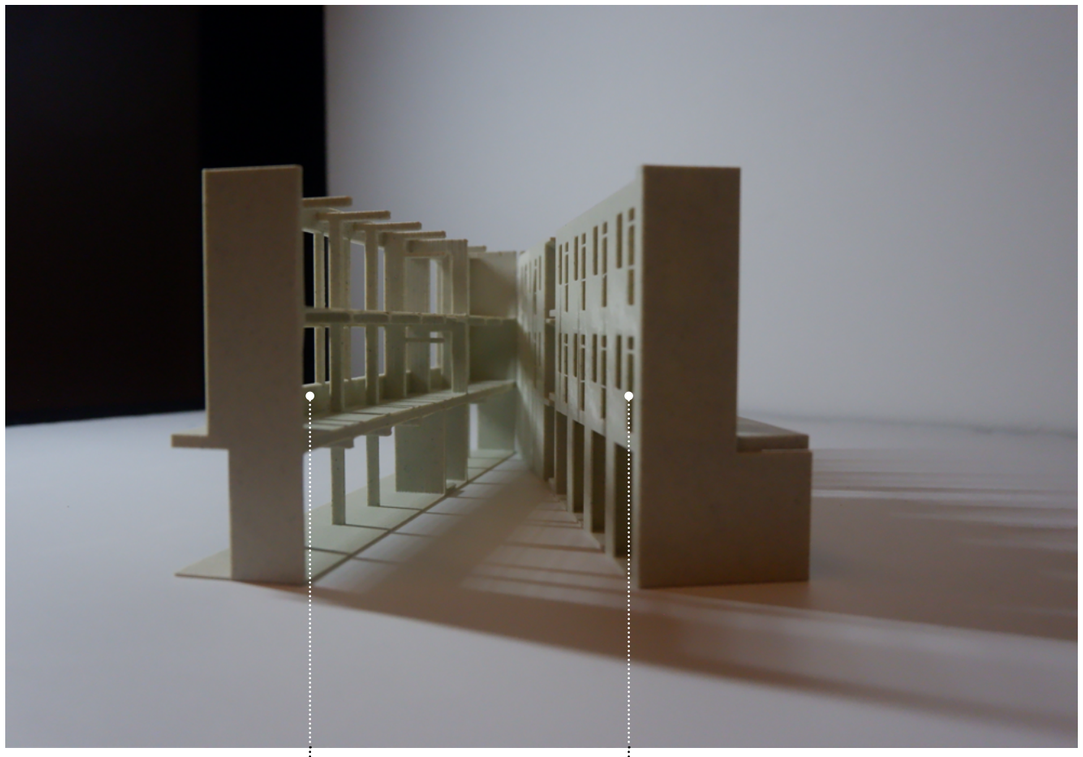
Classification according to raw material of yarns: 100% Cottoon - Pink/Green/Orange.
100% Acrylic - Blue.
65% Acrylic 35% Polyester - Dark green.
50% Merino wool 50% Acrylic.

4.2.2 *1:100 PART SECTIONAL MODEL*

*The purpose of the partial model is to show the architectural space behind the facade of the building where the shadow of textile windows will be visible. A gallery of approx. 2 m between the outer facade and the function rooms is the best place for the textile light art.

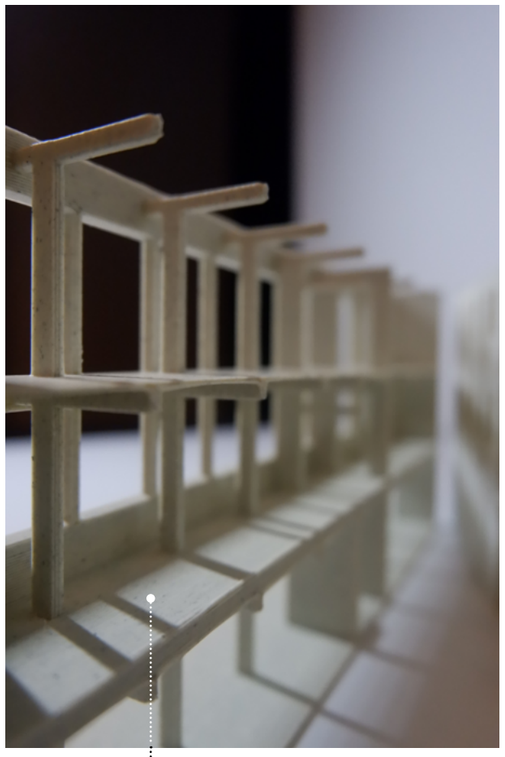


Textile target windows



Corridor
Shadow stage

Second facade
Function rooms



Corridor
Shadow stage

4.2.3 *1:20 PROCESS MODEL - Display of experimental materials*

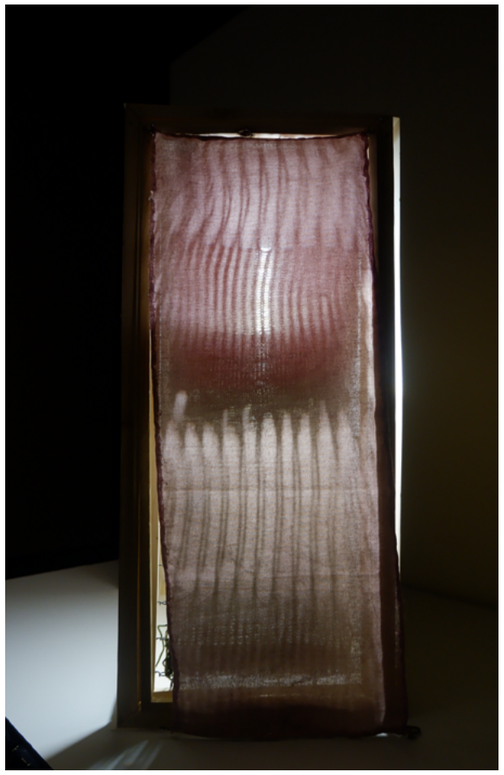
*Showcasing the diversity of textile designs on the windows on the front facade of the target building (simulating the concrete wall of the old building, as well as the new timber frames), while contrasting with the existing windows. From the photographs, the artistic performances behide the solid-coloured textiles are visible in the light when they are combined with other textiles or artistic performances.

*Ideally, this textile window has different types and combinations of textile windows as shown in this model. In order to maintain the flexibility of the textile, the wooden window frames are easily removable, which means that the textile windows can vary from week to week.

* Daytime, old glass window and single layer of textile windows.
* Nighttime with the light, puppets and textile behide solid-coloured transparent textile can be clearly seen. Double-layered textiles, except on the far right.

4.2.4 *1:10 SHADOW TEXTING MODEL*

*This is a test model for testing the light and shadow effects produced by different textile combinations. This 1:10 model will show how three layers of textiles can be flexibly assembled and disassembled on a window using a wooden frame.



5.

Findings

Reflection

5.0
REFLECTION

The use of textiles in architectural design is an ongoing study, and a large number of research is validating the ability of textiles to replace or even outperform other materials.

This thesis explored the possibility of textiles replacing glass as the main material for architectural window design, mainly focus on the unique artistic performance (light and shadow) that textiles show in building facade. It aims to give people a sense of using textiles in architectural design, a daily used material that is often overlooked for use in architectural design.

These experiments show countless possibilities. Such as, different colors of transparent textiles can create different spatial atmospheres under the light, and the proportion of light transmission into buildings can be controlled by changing the density of knitted textiles. For instance, at night, lighting can illuminate textile windows to allow people to see the art behind them through the transparent fabric, transforming them into art showcase designs instantly. Furthermore, integrating textiles into architectural design can turn disadvantages into advantages by combining with wind and light, thus creating an ever-changing architectural space,etc.

Further research is needed to validate the feasibility of using textiles instead of glass for window design. Due to limitations in time, manpower, and resources, this experiment did not physically apply textiles to actual building windows and observe their specific outcome within architectural spaces under the influence of wind and light.

The design concept derived from simulating lighting effects using a scale model and analyzing urban weather conditions to assess the potential of textiles for real construction. However, it's important to clarify that this research did not focus on the environmental resistance capabilities of textiles, nor did it involve data analyzing how textiles withstand high temperatures, rainy weather, or provide fire and theft protection, which would require significant time. That's why further research experiments are needed.

Due to the emergence of numerous materials, many previous building materials such as paper, textiles, straw, and others have been overlooked. This thesis proposes a reapplication of textiles in architectural design and the art of light and shadow in different combinations and be applied in various scenarios in architecture. In summary, this paper gives a new approach to modern architectural facade design using textiles. The diverse spatial effects and application scenarios of different textiles are particularly intriguing, adding vitality to architectural spaces.

5.1
FINDINGS

This chapter summarises the key findings in relation to the research questions.

RESEARCH QUESTIONS

1. How do external/natural and internal/artificial light combined with the properties of textiles themselves, affect the light and shadow effects of textiles in the setting of textile windows?

The variations in light and shadow effects created by different textiles largely depend on the objects being projected and the viewer's perspective. For instance, light from outside will pass through textiles and create shadows on the building space or other textiles. Because the lightweight textiles will sway and flutter in the wind, the shadows they also move accordingly. After dark, light shines from the building to the textile windows. Due to the transparency of the textiles, people standing on the street can clearly see the colors, shapes of the knitted textiles, or the performances of artistic figures behind them, such as shadow puppets.

Furthermore, the density of the textile itself has a great influence on the shadow. When there is no gaps between the threads, light is unable to pass through, resulting in a dark shadow. This means that the patterns and designs of the textile can be displayed as shadow in architectural spaces by changing the knitting method.

2. How can textiles be used in an architectural design for an exterior curtain wall that serves both as a wall and a window?

Due to the soft and lightweight of textiles, they require sturdy materials like wood or steel to be fixed onto buildings, like the yurts. Additionally, because some textiles are transparent while others are opaque, designers can control visibility through windows by adjusting the density of knitting or adding layer.

Since weather resistance of textiles was not the mians focus of this study, extensive research in this area was not conducted. But in this research location, the functional rooms and textile windows of the target building are seperated by an enclosed corridor with a reinforced concrete structure. Which reduces discomfort due to weather conditions. Furthermore, existing research indicated that textiles can improve urban wind environments and can be waterproof after treatment like paper.

In general, textiles are more versatile and flexible compared to other materials. However, there is still a long way to go before they can be built as a building wall or a window.

Bibliograpgy

Krüger, S. (2009). Textile architecture = Textile Architektur. Jovis.

Kadolph, S. J. (2014). Textiles (11. ed. ; international edition). Pearson Education Limited.

Fridh, K., Zetterblom, M., & Femenias, P. (2019). Sound absorbing textile surfaces in the urban landscape - -- collaborative research in textile and architectural design. Urban materiality.

Erica Hörteborn. (2023). Knitted architecture and wind. Designing loosely fitted architectural textiles for interaction with wind

Liu, Yige & Hua, Hao & Li, Biao. (2022). Exploration and design of knitted composites for architectural application: The MeiTing project. Frontiers of Architectural Research. 11. 10.1016/j.foar.2022.01.004.

Awais, Habib, et al. "Effect of fabric architecture on the shear and impact properties of natural fibre reinforced composites." Composites Part B: Engineering 195 (2020): 108069.

Nawab, Y., Hussain, T., Ashraf, M., Rasheed, A., Ahmad, S., Ali, Z., & Abdulbasit. (2016). Textile Engineering : An Introduction (1st ed.). Walter de Gruyter GmbH.

Mauvieux B, Reinberg A, Touitou Y. The yurt: a mobile home of nomadic populations dwelling in the Mongolian steppe is still used both as a sun clock and a calendar. Chronobiol Int. 2014 Mar;31(2):151-6. doi: 10.3109/07420528.2014.874801. Epub 2014 Jan 8. PMID: 24400857.

Jianwei Yang, Yezhen Zhao, Yi Wang, Zhen Liu. Research on the Development Path of Shaanxi Shadow Play Industry Driven by Design Creativity. The Frontiers of Society, Science and Technology (2023) Vol. 5, Issue 6: 84-90. https://doi.org/10.25236/FSST.2023.050613.

Li, T., Cao, W. Research on a method of creating digital shadow puppets based on parameterized templates. Multimed Tools Appl 80, 20403–20422 (2021). https://doi.org/10.1007/s11042-021-10726-1

Ying, Xu. “Inheritance and innovation of Chinese shadow puppetry art in digital media art teaching in colleges and universities.” International Journal of New Developments in Education (2022): n. pag.

Shi, Y., Ying, F., Yu, J. (2013). Enjoying of Traditional Chinese Shadow Play – A Cross-Culture Study. In: Pan, Z., Cheok, A.D., Müller, W., Liarokapis, F. (eds) Transactions on Edutainment IX. Lecture Notes in Computer Science, vol 7544. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-37042-7_19

Z. Yan, Z. Jia, Y. Chen and H. Ding, "The Interactive Narration of Chinese Shadow Play," 2016 International Conference on Virtual Reality and Visualization (ICVRV), Hangzhou, China, 2016, pp. 341-345, doi: 10.1109/ICVRV.2016.63.

Intangible Heritage-Piying, N.: http://baby.sina.com.cn/edu/08/3101/1840104616.shtml

Rewatkar, K. P., & Rewatkar, P. K. (2016). Window as an Element of Architecture. Journal of Civil Engineering and Environmental Technology, 3(5), 465-471.

Haojun Wang. (2021) Inheritance and Update of Chinese Traditional Windows in Landscape Architecture. E3S Web Conf., 308 (2021) 02024

Britannica, T. Editors of Encyclopaedia (2023, December 17). window. Encyclopedia Britannica. https://www.britannica.com/technology/window

Goodwin, Jane (July 1, 2014). "Little House Science: Greased Paper Windows". Steve Spangler Science. Retrieved 17 August 2016.

Scherer, Annie Locke. (2019). Concrete Form[ing]work: Designing and Simulating Parametrically-Patterned Fabric Formwork for Cast Concrete. 759-768. 10.5151/proceedings-ecaadesigradi2019_193.

Fridh, Kristina & Zetterblom, Margareta & Femenias, Paula. (2019). Sound absorbing textile surfaces in the urban landscape - collaborative research in textile and architectural design. 10.6084/m9.figshare.9943259.v1.

von Meiss, P. (1990). Elements of Architecture: From Form to Place (1st ed.). Routledge. https://doi.org/10.4324/9781315024691

李治 . (2019). 从皮影戏《 人鱼姑娘》 谈皮影灯光创作发展历程 . 艺海 , (6), 21-23.

Xu, Guangqi (1562-1633).A complete collection on agriculture. Persistent Link: https://nrs.lib.harvard.edu/urn-3:fhcl:27725248

Azizatul Karimah, Muhammad Rasyidur Ridho, Sasa Sofyan Munawar, Danang Sudarwoko Adi, Ismadi, Ratih Damayanti, Bambang Subiyanto, Widya Fatriasari, Ahmad Fudholi. (2021)A review on natural fibers for development of eco-friendly bio-composite: characteristics, and utilizations.

P. Zumthor, Kunsthaus Bregenz, Ostfildern-Ruit 1999, p. 13, 14.

CONTACT

XIAOFEI DENG

+46 0793500217 / +86 13265970095
freyadxf@outlook.com

EDUCATION

Master // 2022-2024
Chalmers university of technology
The Oslo School of Architecture and Design // Exchange program

Bechelor // 2015-2019
Guangzhou university

EMPLOYMENT

UDA Architecture // 2021
Architecture Designer

GZLI Design // 2019-2021
Architecture Designer