Doctoral Dissertation

Study on Optimization of Visibility and Energy Efficiency of New “Sudare” for Building Façade

August
2017

Agus Hariyadi

Graduate School of Environmental Engineering
The University of Kitakyushu

JAPAN

Preface

All praise to Allah SWT. By his permission, this dissertation will be finished. It is hoped that it will give benefit to the community.

The research is about Sudare Façade, which functions not only to beautify a building but also to maintain the comfort of the occupants and to minimize energy consumption.

Enjoy…

August 7, 2017

Agus Hariyadi

Acknowledgment

To my family, my students, and my friends.

To the Department of Architecture and Planning, Faculty of Engineering, Universitas Gadjah Mada.

And to The Directorate General of Resources for Science, Technology and Higher Education Ministry of Research, Technology and Higher Education of the Republic of Indonesia.

Abstract

Sudare is a type of traditional Japanese blind made from bamboo. It has long been used in Japanese houses, especially during the summer. Its original function was to prevent direct solar radiation and to introduce natural ventilation. The characteristic form of Sudare allows one to look through it to see objects outside the house. As a shading device, Sudare can be implemented in hot areas where high energy demand for cooling is a problem.

Recently, Jakarta has implemented a new standard for new building construction intended to reduce the energy consumption of office buildings. This must meet the minimum Overall Thermal Transfer Value (OTTV) of 35 watt/m^2. In tropical countries, the most effective passive design strategy method is the use of shading devices. Dense shading can effectively reduce energy consumption, but it reduces visibility through openings.

The aim of this research is to identify an alternate mode of façade configuration using external horizontal blinds based on the Sudare form to meet the minimum requirements of the Indonesian National Standard (SNI), with greater efficiency in terms of cooling load to minimize energy consumption and maintain visual comfort. It will change architects’ mindset, influence the way they design new buildings and retrofit existing buildings, and encourage them to use shading devices as part of their designs. Ladybug and Honeybee inside the Grasshopper plugin of Rhinoceros 3D with the Energy plus engine will be used to simulate a standard building as baseline performance, and buildings that use different Sudare dimensions and spacers as shading devices parametrically.

Based on this study, the optimum form of Sudare blind, with a diameter of 10.01 mm and 5-mm spacers, has achieved a 5% reduction in OTTV and a 6% reduction in cooling load, as compared to the baseline building. The performance is close to that of tinted glass, with a solar heat gain coefficient of 0.2 and Tvis of 0.2. The visibility value of this configuration is 2.65, which is also close to the visibility of tinted glass, which has Tvis of 0.2 (2.92); privacy is 4.27, which is much better than that of tinted glass (3.38). It also gives better uniformity of daylight distribution, which improves visual performance and comfort.

Keywords: Sudare, horizontal shading, energy conservation, parametric analysis, energy efficiency, OTTV

Table of Content

Table of Figures

Table of Tables

Chapter 1 Introduction

1.1 Background

SUDARE, also called su (簾), misu (御簾), osu (小簾), or matchstick blinds, are blinds made from solid stems of bamboo (kanchiku 寒竹), the horsetail plant (tokusa 木賊), ditch reed (yoshi 葭), or bush clover (hagi 萩). The very slender stems of these plants are bound or plaited together with cord. Spaces are left between the stems so that light and air can pass through them easily, and so they can be rolled up when stored. Some have a decorative brocade binding and silk tassels hanging from the top. Sudare are used in tea ceremony houses (*chashitsu 茶室) designed in the sukiya style (*sukiya-zukuri 数寄屋造) and the shoin style (*shoin-zukuri 書院造). They are sometimes used to cover the ceiling of a rustic tea ceremony room (*souan 草庵) or above an alcove (*tokonoma 床の間). The blinds are sometimes used in place of translucent paper on sliding screens (*shouji 障子), which are known as Sudareshouji (簾障子) or *natsushouji (夏障子), because they are used during the summer months. The Sudare may be set vertically or horizontally into the shouji sliding panels. Other names for this type of Sudare are yoshishouji (葭障子)or Sudare (JAANUS n.d.).

Sudare are made of horizontal slats of decorative wood, bamboo, or other natural material woven together with simple string, colored yarn, or other decorative material to make nearly solid blinds. They can be either rolled or folded up out of the way when not in use. Yoshizu, a non-hanging type of Sudare, are made of vertical slats of common reed and used as screens.

Sudare are used in many Japanese homes to shield the verandah and other openings of the building from sunlight, rain, and insects. They are normally put up in spring and taken down again in autumn. Their light structure allows breezes to pass through, a benefit in the hot Japanese summers. Since the building materials are easy to find, Sudare can be made cheaply.

Elaborate Sudare for palaces and villas used high-quality bamboo, with expensive silk and gold embroidery worked in. Sometimes they featured paintings, most often on the inside; some Chinese screens had symbols painted on the outside as well.

Sudare protect the inhabitants of a building not only from the elements, but also from the eyes of outsiders. They are featured prominently in *The Tale of Genji*. During the Heian Era, a court lady would conceal herself behind a screen when speaking with a man outside her immediate family. She could peep through it and see her interlocutor, but because he had to remain at a distance from it, he could not see her. Only with her permission might he step closer and only she would ever raise the screen. Any unwarranted moves on the man's part were seen as a grave breach of etiquette and a threat against the lady's honor.

Sudare were also used during imperial audiences. Since looking directly at the *tennō* ("heavenly ruler") was forbidden, he would sit hidden behind a screen in the throne hall, with only his shoes showing. This practice fell out of use as imperial power declined.

Nowadays, Sudare still being used in all over Japan, especially during the summer, in traditional houses and some modern homes and commercial buildings (Figure 1-1). It is also easy to find in some supermarkets around Japan (Figure 1-2). The popularity of this local architectural wisdom is one reason to research it further and to develop it using modern materials. Its use for minimizing solar radiation is beneficial not only for Japan but for areas anywhere in the world that have problems with energy demands for cooling. One of the areas with this kind of problem is Jakarta, the capital of Indonesia.


たこ焼
豚骨だし入
たこ焼
1パック
8個入
200円


DAIWA

Figure 1-1 Some typical uses of Sudare

Figure 1-2 Sudare are easily found in supermarkets

In 2009, the president of Indonesia, Susilo Bambang Yudhoyono, declared the need to devise a policy to reduce the GHG emissions to 26% to 41% (with international support) by 2020 during the G20 Summit in Pittsburgh. To meet this goal, Indonesia has developed plans, policies, and actions to reduce GHG emissions (Environment & Indonesia 2014) (Sulistiyanto 2013). This task has taken to form of new renewable energy development and energy conservation implementation in all sectors.

Jakarta province supported the government plan by implementing Green Building Code No. 38 in 2012, which aims at meeting Jakarta's regulatory reform to achieve 30% CO2 reduction by 2030 (Sulistiyanto 2013). This regulation will be regularly reviewed to improve performance. According to this regulation, to receive a building permit, every new building project must meet the minimum standard of the Green Building Code.

It is estimated that, at present, buildings contribute as much as one-third of total global greenhouse gas emissions, primarily through the use of fossil fuels during their operational phase. The building sector contributes up to 30% of global annual greenhouse gas emissions and consumes up to 40% of all energy (UNEP-SBCI 2009). Architects will play a key role in minimizing the use of energy through environmentally-friendly building design. Their buildings must use less energy in the design, construction, and operational phases, even, and must include designs for retrofitting existing buildings. As part of the effort to reduce the greenhouse gas effect, some architects have joined the Green Building Council Indonesia (GBCI) and are collaborating with other engineers in the building industry to promote green building designs. GBCI is an independent organization established in 2009 by professionals in the design and construction industry who are concerned about green building practices. The focus of GBCI is to pursue the socialization and transformation of sustainable green principles, particularly in the building construction industry in Indonesia (GBCI 2017).

In organizing its activities, GBCI collaborates with all building stakeholders, including those in the professional, government and private sectors. GBCI has four main programs: market transformation, training and education, green building certification and stakeholder engagement.

1.2 Research Problem

In Jakarta, where most of the façades in office buildings are curtain glass wall, it is almost impossible to have the overall thermal transfer value less than 35 watt/m^2. The challenge in this situation is how to create a façade that can reduce cooling load, provide good outside views and visual comfort, and present a pleasing external image, comparable to that of a curtain glass wall façade.

1.3 Research Purpose

External shading is a passive design strategy that might overcome the problem of creating building façades that meet the Indonesia National Standard of OTTV less than 35 watt/m^2. The main purpose of this research is to find the best configuration of Sudare to use as external shading—one that provides good outside views and visual comfort, appealing external appearance, and minimum cooling load. Based on the result of this research, the shading system can be applied to existing buildings to meet the standard and improve energy performance. It also can be used in new construction to help create high-performance, energy-efficient buildings.

1.4 Research Novelty

There has been some research on visual comfort indices, but these are mostly concerned with glare, light amount, or light quality (Carlucci et al. 2015); the quality of the outside view as a visual comfort index has not been researched yet. In theory, with the shading control strategy, it is possible to optimize visual comfort and reduce the energy demand of office buildings as part of the optimization of a passive solar design strategy (Stevanović 2013) (Yun et al. 2014). From the perspective of architects, the optimizing strategy will be effective when they can simulate every strategy or combination of strategies and estimate the performance of buildings using some energy simulation software (Shi & Yang 2013). In this research, the visibility indices were built and applied to create façades that have better thermal performance to minimize energy consumption, and have better visual performance for daylight that considers the visibility and privacy of the occupants inside.

1.5 Research Structure

This dissertation was prepared within a research structure that consists of nine chapters (Figure 1-3). Each chapter represents a stage of a research—most of the results have already been published in scientific journals. The structure of this dissertation is as follows:

Chapter 1 Introduction, contains background of research, research problem, research purpose, and research structure.

Chapter 2 Sudare Blinds in Japan, describes the uses of Sudare in Japan, especially during the summer, and the effectiveness of Sudare as shading devices in reducing solar heat gain into a building.

Chapter 3 Building Façade and Its Challenge, describes building façade design in its current state all over the world and in Indonesia, specifically in Jakarta, as a case study, elaborates the climate condition and passive design strategy in Jakarta, Indonesia.

Chapter 4 Literature Study, contains information gathered from literature and field surveys of a bioclimatic approach in architecture, shading devices and formulation to calculate or simulate overall thermal transfer value (OTTV), visual comfort and solar energy used in building.

Chapter 5 Methodology, explains the parts of the two main phases of the research in detail.

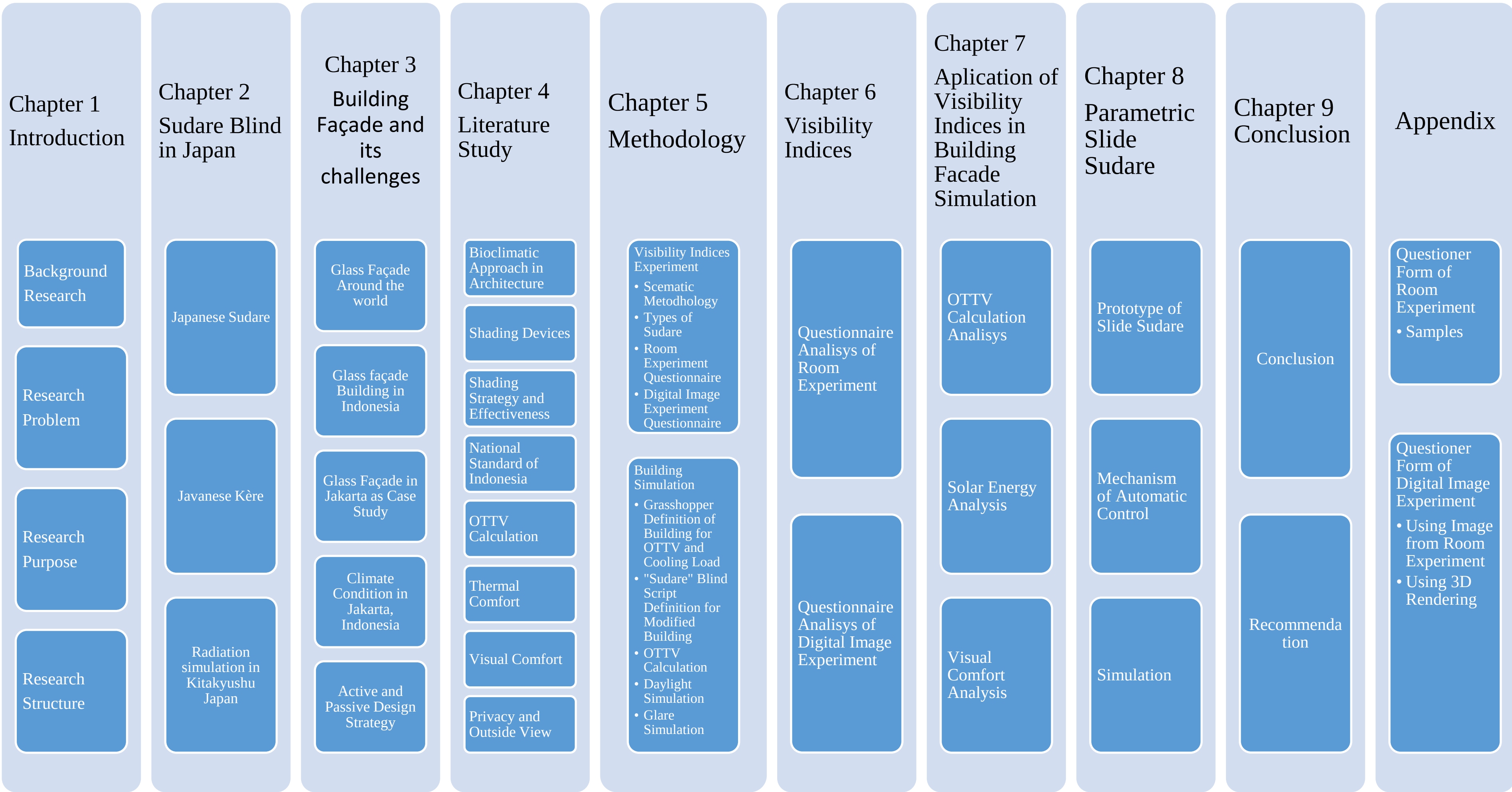
Chapter 6 Visibility Indices, describes the process of the first main phase of the research which used a three-part questionnaire. The first part used a room experiment and the second part used a digital image from the first experiment. The third part used a digital render from a Rhinoceros 3D model of the five types of Sudare façade.

Chapter 7 Application of Visibility Indices in Building Façade Simulation, describes the second main phase of the research, which used the simulation software Energy Plus as an energy simulation engine inside of the Grasshopper software, a plugin of Rhinoceros 3D software, to calculate OTTV and analyze the effect of different types of Sudare façade as external shading on solar energy consumption and visual comfort inside the building.

Chapter 8 Parametric Sliding Sudare, describes the making of a sliding Sudare prototype and simulation as parametric Sudare to increase the flexibility and control of Sudare.

Chapter 9 Conclusion, summarizes the research and makes recommendations for further research.

Research Structure



Source: Author, 2017

Figure 1-3 Research structure

Chapter 2 Sudare Blind in Japan

2.1 Sudare and Summer in Japan

In Japan, the winter cold can be overcome by simply putting on more clothing or turning on the heat. But in summer, the only ways to resist the heat and humidity are to block out the sun's rays and allow the unfettered passage of air. It is for this reason that Japanese architecture favors a minimum of walls and prefers furniture that can be easily moved to create an open-air style. In a traditional Japanese home, there is no clear demarcation between the interior and exterior. There is, instead, an intermediate area with various screen or blind devices to link inner components with outer, and bring nature almost indoors (Figure 2-1) (Yagi 1982).

Sudare is one type of screen or blind device that has been used as external shading and as an internal partition. Many traditional Japanese houses use Sudare as external shading to maintain thermal comfort in the summer; they protect the houses from direct solar radiation but still allow natural ventilation (Figure 2-1 no 1) This passive design strategy is effective for landed houses, the typical traditional Japanese house that has only one or two stories, sometimes with a yard around it, in a suburban area where the environment is still good and natural. Similar to some Islamic-architecture buildings, which use a traditional porous wall, Sudare can create a uniform distribution of illuminance in the interior, resulting in a more direct relationship with the external environment, and providing visual comfort (Ruggiero et al. 2009) (Sherif et al. 2012). As an internal partition, Sudare can divide a space into two or more separate areas with different functions and levels of privacy. On particularly bright days, people inside a room can sometimes see activities on the other side of the room or outside the house, although people outside the house cannot see the activities inside (Figure 2-1 no 2) (Yagi 1982). However, when the scenery is distracting, occupants only need to move farther away from the Sudare to solve the problem.

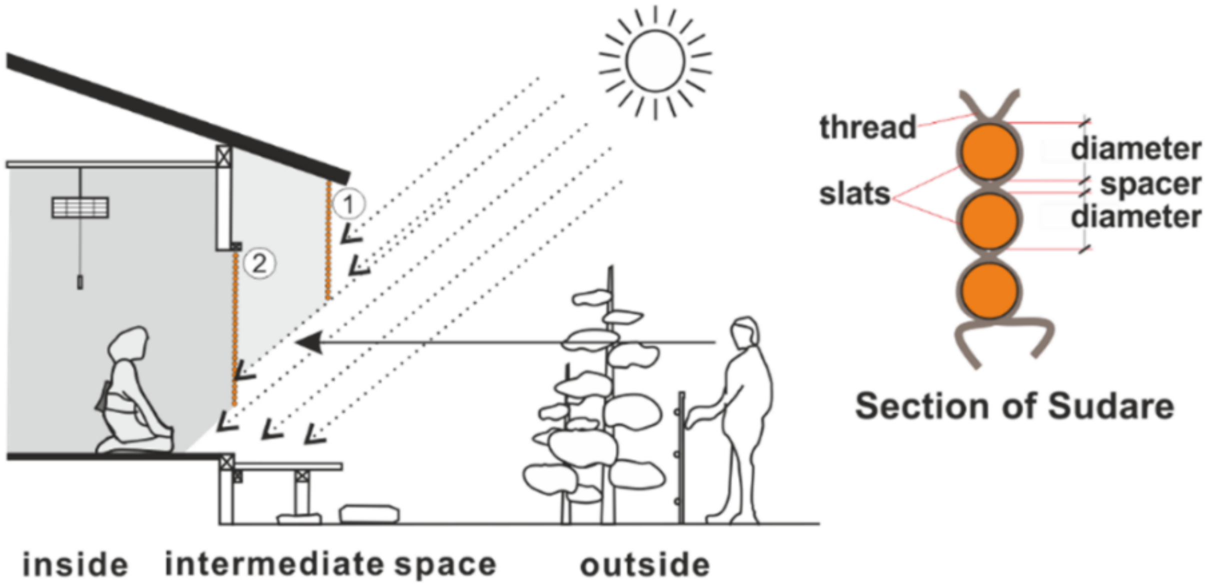


Figure 2-1 Sudare Japanese blind

Nowadays, Sudare still can be found in many places, such as shrines (Figure 2-2), where they are used as decoration or partitions connected to the outside; temples (Figure 2-3) as internal partitions that separate and/or connect two or more rooms; old Japanese houses (Figure 2-4) as external blind devices; and modern homes (Figure 2-5). Sudare have not been used in multi-story or high-rise buildings in Japan.

The materials from which Sudare are made range from pure bamboo slats (original Sudare) to plastic straws of varying diameters and colors.

Figure 2-2 Sudare in Dazaifu Tenman-gu Shrine, Fukuoka Japan

Figure 2-3 Sudare in Jogeji Temple, Yamaguchi Japan

Figure 2-4 Sudare in the old Japanese village of Gofukumotomachi, Saga Japan

Figure 2-5 Sudare in modern homes, Kitakyushu, Fukuoka Japan

2.2 Javanese Kère

Traditional screen or blind devices are not only found in Japan, but are also seen on the Indonesian island of Java. The name of this type of blind is Kère (Figure 2-6). This Javanese blind has differently shaped slats and more solid parts than the Sudare, so Sudare perform better in terms of visibility than Kère.

Photo: Alexander Rani S

Figure 2-6 Kère in a Javanese house, Indonesia

The original material used to make Kère is bamboo. For construction, the bamboo is first divided radially into many pieces of roughly the same size. The pieces are then arranged horizontally and connected with rope made from black sugar palm fiber. As with Sudare, the spacer width between slats is determined by the diameter of the rope (Figure 2-7).

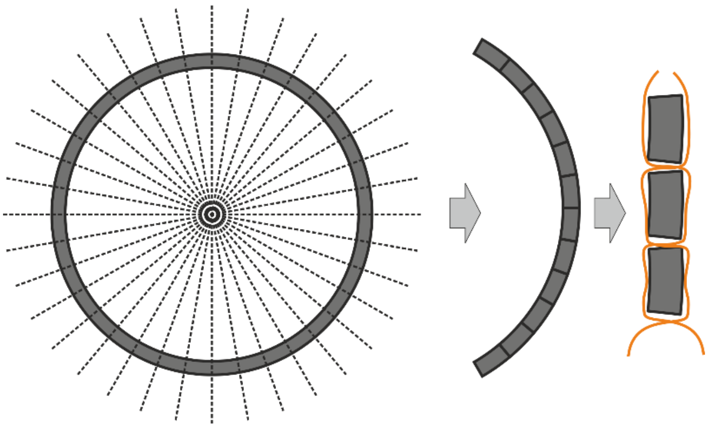


Figure 2-7 Process of making Kère

2.3 Simulation of Sudare in Kitakyushu Japan

Understanding the effect of Sudare as shading device during the summer time can be done by simulating a building model facing south with a full glass window façade. The location that was used for the simulation was Kitakyushu, Japan (Figure 2-8). The building was made based on a six tatami system with 2.8-m height. Summer in Japan lasts roughly from May 7 until August 8 every year, and this was used as the analysis time period in this simulation.

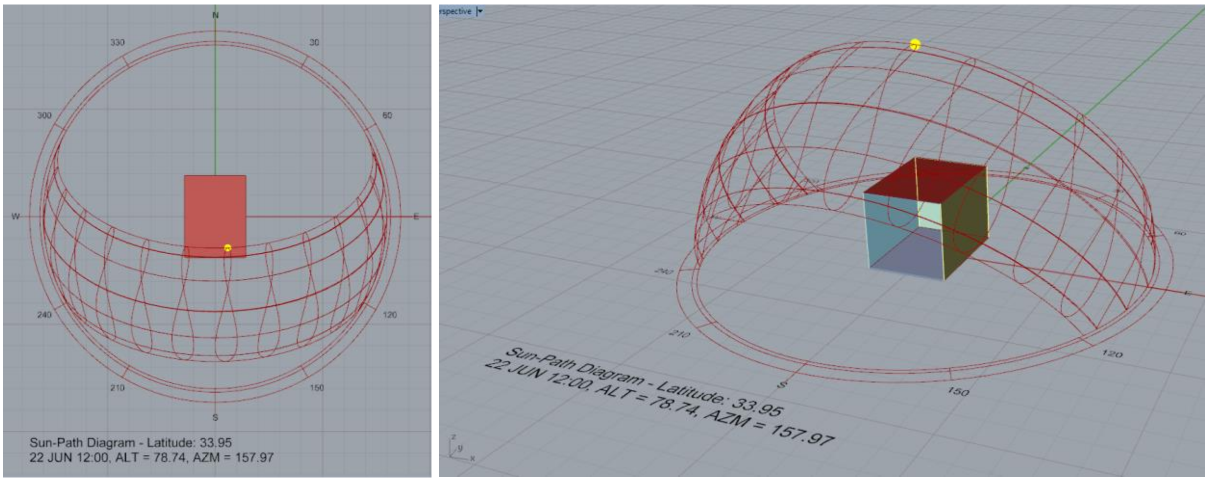
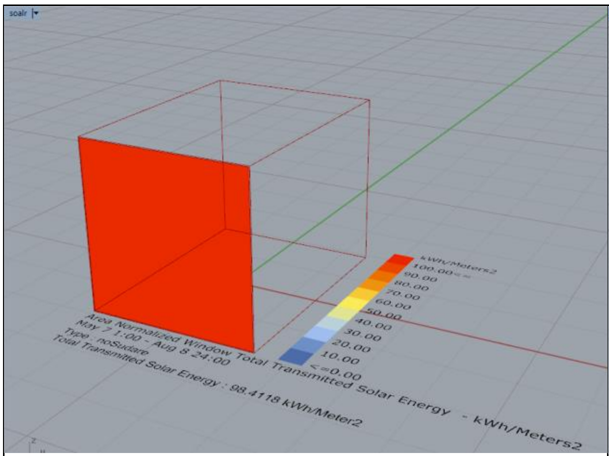
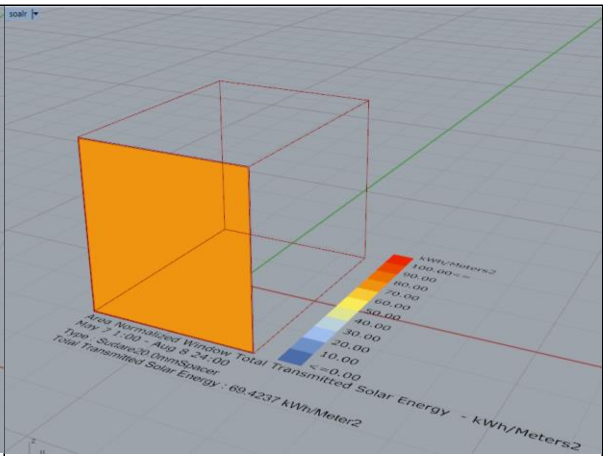
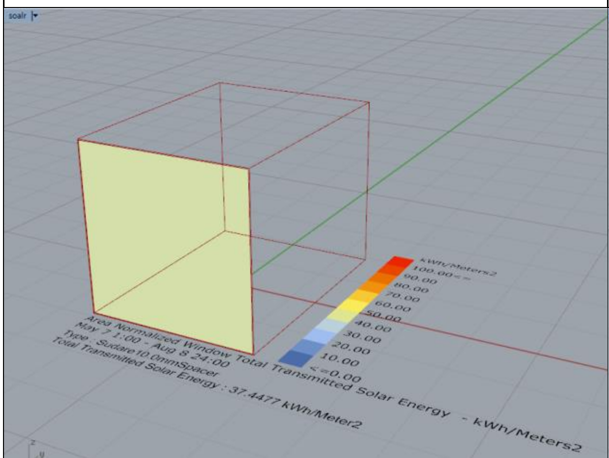
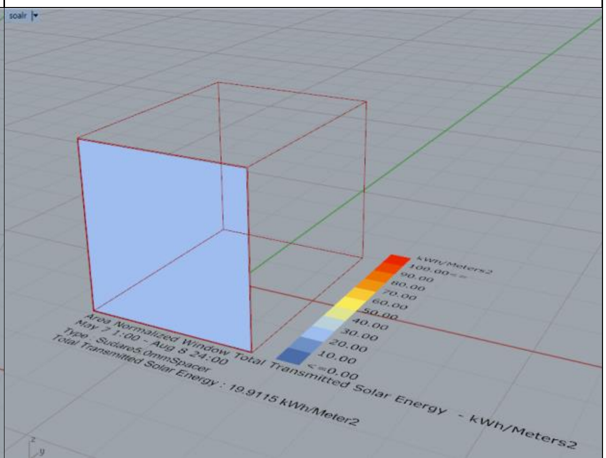
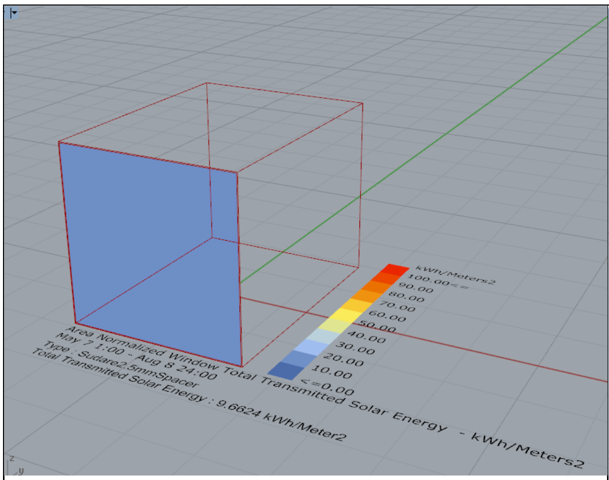


Figure 2-8 Sun-path diagram of Kitakyushu

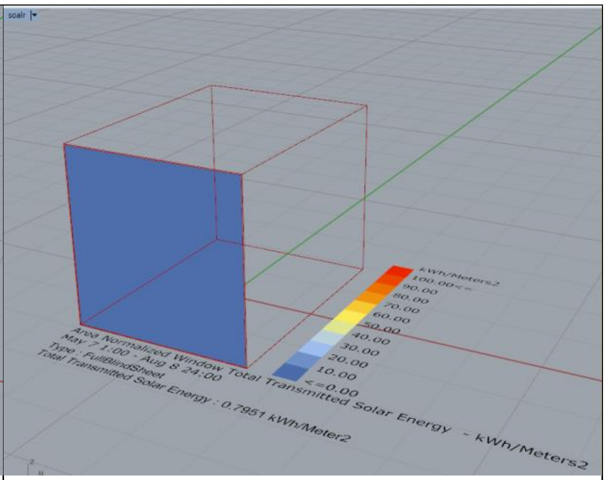
A radiation simulation was done to compare the effect of the Sudare façade on the building model in the summer time (Table 2-1). The summary can be seen in Table 2-2.

Table 2-1 Radiation simulation in six tatami building with Sudare façade

	
No Sudare, 98.41 kWh/m^2	Sudare 20 mm spacer, 69.42 kWh/m^2
	
Sudare 10 mm spacer, 37.44 kWh/m^2	Sudare 5 mm spacer, 19.91 kWh/m^2



Sudare 2.5 mm spacer, 9.66 kWh/m^2



Full block sheet, 0.79 kWh/m^2

Table 2-2 Summary of solar radiation analysis in a Japanese building

No	Type	Solar Radiation kWh/m^2	Efficiency
1	No Sudare	98.41	0%
2	20 mm spacer	69.42	29%
3	10 mm spacer	37.44	62%
4	5 mm spacer	19.91	80%
5	2.5 mm spacer	9.66	90%
6	Full block	0.79	99%

Based on the simulation above, Sudare can reduce the amount of solar radiation significantly. Compared to a glass window without Sudare shading that get 98.41 kWh/m^2 m^2 of solar radiation, the least amount of reduction is 29% (69.42 kWh/m^2). The most efficient way of reducing solar radiation is to block the windows entirely, which can eliminate up to 99% of solar radiation.

Chapter 3 Building Façade and Its Challenges

3.1 Glass Façade Around the World

Nowadays, people all over the world like to have buildings with a façade made of a curtain glass wall (Figure 3-1), regardless of climate. This is because a full glass façade improves the image or prestige of the building, making it easier to sell to clients. Another reason is because they want to have spectacular external view of the environment or of the city (Figure 3-2).

Source:(Payne n.d.)
Kanagawa Institute of Technology Glass Building, Japan

Source:(David Anderson n.d.)
Modern Houses in Camden, UK

Source: (Alan G Brake n.d.)
Commercial building in Portland, Oregon US

Source:(Summer Luu n.d.)
Neo Solar Power's Origami HQ, Taiwan

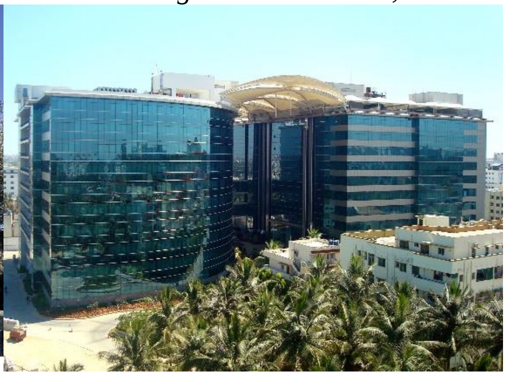
Source: Leonore Leibrock
The Sandcrawler Building, Singapore

Source: (Stephen Messenger n.d.)

School Building in Ponta Grossa, Brazil

Source: GPD 2015, Mick Eekhout

Octatube / TU Delft, Holand



Source: (Aliona n.d.)
Office buildings in Bangalore, India

Figure 3-1 Glass façade building around the world

Source: (Panaquip n.d.)

Source: (Brookfield n.d.)

Figure 3-2 View from inside curtain glass wall office

3.2 Glass Façade Building in Indonesia

In Indonesia, this same preference for glass façade exists in some major cities—there will always be at least two or three buildings with curtain glass wall façade (Figure 3-3). In buildings that rent office space, the owner wants to attract more clients with stylish, modern appearance. A full glass façade improves the image or prestige of the building, making it easier to sell to clients. Not only does this increase the cooling energy demand, but it also changes the microclimate around the buildings, which causes an urban heat island.

Source:(Tito Ari Pratama n.d.)

Saphir Square – Yogyakarta

Source: Oka Sudiatmika

Apartemen The Summit –Jakarta

Source: Oka Sudiatmika

Hotel Oval –Surabaya

Source: Oka Sudiatmika

IFC buildings –Jakarta

Source: Oka Sudiatmika

Hotel Santika Hayam Wuruk, Jakarta

Source: Oka Sudiatmika

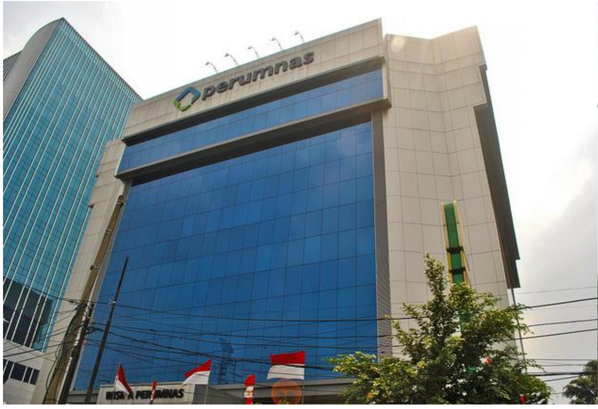
CIMB Niaga Building – Bandung

Source:(Deliana n.d.)

Senayan City Mall – Jakarta

Source:(Brahm n.d.)

Indonesia Convention Exhibition – Tangerang



Source: Oka Sudiatmika
Perumnas Building – Jakarta

Source: (Admin n.d.)
Ministry of Agriculture Building, Jakarta

Source: Oka Sudiatmika
Wisma Bumiputra –Bandung

Source: Oka Sudiatmika
Menara Satu building – Bekasi

Figure 3-3 Glass façade buildings in major cities of Indonesia

3.3 Glass Façade in Jakarta as Case Study

In Jakarta, these phenomena are more obvious. From single story building up to multi stories and hig-rise building have these kind of façade. There are more than 100 tall building in Indonesia where most of them are in Jakarta (Table 3-1). Most of the tall building have curtain glass wall as their façade (Figure 3-4). Even the highest building in Indonesia that completed in 2015 (Gama Tower) still using curtain glass wall, although it used very high performance glass.

Table 3-1 High-rise Building in Indonesia

Rank	Building	Province	Location	Height	Floors	Built	Notes
1	Gama Tower	DKI Jakarta	Jakarta	288 m	69	2016	
2	Wisma 46	DKI Jakarta	Jakarta	262 m	51	1996	Formerly the tallest

							building in Indonesia until 2016
3	Sahid Sudirman Center	DKI Jakarta	Jakarta	258 m	59	2015	
4	Raffles Jakarta	DKI Jakarta	Jakarta	253 m	49	2015	Tallest hotel in Indonesia
5	The Pakubuwono Signature	DKI Jakarta	Jakarta	252 m	50	2014	Tallest residential buiilding in Indonesia
6	Sinarmas MSIG Tower	DKI Jakarta	Jakarta	245 m	48	2015	
7	Menara BCA, Grand Indonesia	DKI Jakarta	Jakarta	230 m	56	2008	
8	Equity Tower	DKI Jakarta	Jakarta	220 m	44	2010	
9	Telkom Landmark Tower	DKI Jakarta	Jakarta	219 m	48	2016	
10	The Peak 1	DKI Jakarta	Jakarta	219 m	55	2006	
11	The Peak 2	DKI Jakarta	Jakarta	219 m	55	2006	
12	The Energy Tower	DKI Jakarta	Jakarta	217 m	40	2008	
13	Capital Place Office Tower	DKI Jakarta	Jakarta	215 m	47	2016	
14	Kempinski Residence, Grand Indonesia	DKI Jakarta	Jakarta	215 m	58	2008	
15	Bakrie Tower	DKI Jakarta	Jakarta	214 m	50	2009	
16	International Financial Centre Tower 2	DKI Jakarta	Jakarta	213 m	49	2016	
17	Sudirman Place	DKI Jakarta	Jakarta	213 m	52	2008	
18	Ritz-Carlton Jakarta Tower A	DKI Jakarta	Jakarta	212 m	48	2005	
18	Ritz-Carlton Jakarta Tower B	DKI Jakarta	Jakarta	212 m	48	2005	
20	The Tower	DKI Jakarta	Jakarta	212 m	50	2016	

21	Keraton at The Plaza Tower, Plaza Indonesia	DKI Jakarta	Jakarta	210 m	48	2009	
22	U-Residence Tower 2	Banten	Tangerang	209 m	59	2015	
23	Green Bay Pluit Tower J	DKI Jakarta	Jakarta	208 m	48	2015	
23	Green Bay Pluit Tower K	DKI Jakarta	Jakarta	208 m	48	2015	
23	Green Bay Pluit Tower L	DKI Jakarta	Jakarta	208 m	48	2015	
23	Green Bay Pluit Tower M	DKI Jakarta	Jakarta	208 m	48	2015	
27	The City Center	DKI Jakarta	Jakarta	208 m	47	2012	
28	Myhome Apartment	DKI Jakarta	Jakarta	207 m	49	2014	
29	Denpasar Residence 1, Kuningan City	DKI Jakarta	Jakarta	203 m	53	2012	
29	Denpasar Residence 2, Kuningan City	DKI Jakarta	Jakarta	203 m	53	2012	
31	Tunjungan Plaza 5	Jawa Timur	Surabaya	201 m	50	2015	Tallest building in Surabaya
32	The Plaza Office Tower, Plaza Indonesia	DKI Jakarta	Jakarta	200 m	42	2009	
33	Wisma Mulia	DKI Jakarta	Jakarta	195 m	54	2003	
34	Axa Tower Jakarta, Kuningan City	DKI Jakarta	Jakarta	195 m	45	2012	
35	UOB Plaza	DKI Jakarta	Jakarta	194 m	41	2012	
35	DBS Bank Tower	DKI Jakarta	Jakarta	194 m	37	2013	
37	The Ritz Kemang Village	DKI Jakarta	Jakarta	192 m	41	2012	
38	Ritz Carlton Hotel, One Pacific Place Tower	DKI Jakarta	Jakarta	190 m	38	2007	
39	Central Park Residence Tower 1	DKI Jakarta	Jakarta	188 m	49	2011	
39	Central Park Residence Tower 2	DKI Jakarta	Jakarta	188 m	49	2011	

39	Central Park Residence Tower 3	DKI Jakarta	Jakarta	188 m	49	2011	
42	Senopati Residence Tower 1	DKI Jakarta	Jakarta	188 m	43	2012	
42	Senopati Residence Tower 2	DKI Jakarta	Jakarta	188 m	43	2012	
44	Pacific Place Apartment 1	DKI Jakarta	Jakarta	180 m	32	2007	
44	Pacific Place Apartment 2	DKI Jakarta	Jakarta	180 m	32	2007	
45	Menara Palma 2	DKI Jakarta	Jakarta	181 m	34	2016	
47	The Orchard Satrio	DKI Jakarta	Jakarta	171 m	44	2016	
47	The Residence Satrio	DKI Jakarta	Jakarta	171 m	44	2016	
49	Kadin Tower	DKI Jakarta	Jakarta	169 m	37	1997	
50	Central Park Office Tower	DKI Jakarta	Jakarta	167 m	41	2011	
51	Skyloft	Jawa Timur	Surabaya	165 m	50	2016	
51	The Voila Apartment	Jawa Timur	Surabaya	165 m	50	2016	
53	Centennial Office Tower	DKI Jakarta	Jakarta	164 m	39	2015	
54	The Peak Tower 3	DKI Jakarta	Jakarta	163 m	37	2006	
54	The Peak Tower 4	DKI Jakarta	Jakarta	163 m	37	2006	
56	Amartapura I	Banten	Tangerang	163 m	52	1996	Tallest building in Tangerang
57	Menara Matahari	Banten	Tangerang	162 m	41	1996	
58	Equity Tower	DKI Jakarta	Jakarta	161 m	32	2012	
59	Plaza BII	DKI Jakarta	Jakarta	160 m	39	1997	
59	World Trade Center 2	DKI Jakarta	Jakarta	160 m	30	2012	
59	Oakwood Premier Cosmos	DKI Jakarta	Jakarta	160 m	45	2006	

62	Lacewood Tower	DKI Jakarta	Jakarta	159 m	37	2011	
63	Davinci Tower	DKI Jakarta	Jakarta	159 m	34	2003	
64	The St. Moritz Tower	DKI Jakarta	Jakarta	158 m	42	2016	
65	Sudirman Residence	DKI Jakarta	Jakarta	158 m	44	2009	
66	Amartapura II	Banten	Tangerang	158 m	41	1997	
67	Sampoerna Strategic Square A	DKI Jakarta	Jakarta	158 m	32	1997	
67	Sampoerna Strategic Square B	DKI Jakarta	Jakarta	158 m	32	1997	
69	U Residence I	Banten	Tangerang	157 m	41	2012	
70	Cyber2 Tower	DKI Jakarta	Jakarta	156 m	33	2009	
71	Batavia Tower	DKI Jakarta	Jakarta	155 m	32	1997	
72	Intercontinental Midplaza Jakarta Hotel	DKI Jakarta	Jakarta	155 m	37	1997	
73	Altira Office Park	DKI Jakarta	Jakarta	155 m	33	2015	
74	The Vue	East Java	Surabaya	153 m	38	2012	
74	The Via	East Java	Surabaya	153 m	38	2012	
76	Water Place Residence Tower E	East Java	Surabaya	153 m	38	2012	
76	Water Place Residence Tower B	East Java	Surabaya	153 m	38	2012	
76	Water Place Residence Tower A	East Java	Surabaya	153 m	38	2012	
79	First Capital Center	DKI Jakarta	Jakarta	152 m	37	1997	
80	Taman Anggrek I	DKI Jakarta	Jakarta	151 m	46	1998	
80	Taman Anggrek II	DKI Jakarta	Jakarta	151 m	46	1998	
80	Taman Anggrek III	DKI Jakarta	Jakarta	151 m	46	1998	
80	Taman Anggrek IV	DKI Jakarta	Jakarta	151 m	46	1998	
80	Taman Anggrek V	DKI Jakarta	Jakarta	151 m	46	1998	

80	Taman Anggrek VI	DKI Jakarta	Jakarta	151 m	46	1998	
80	Taman Anggrek VII	DKI Jakarta	Jakarta	151 m	46	1998	
80	Taman Anggrek VIII	DKI Jakarta	Jakarta	151 m	46	1998	
88	Aston Veranda	DKI Jakarta	Jakarta	150 m	39	2009	
89	Sudirman Plaza	DKI Jakarta	Jakarta	150 m	38	2007	
90	The City Tower	DKI Jakarta	Jakarta	150 m	32	2007	
90	The Pakubuwono House	DKI Jakarta	Jakarta	150 m	32	2015	
90	Parahyangan Residences	West Java	Bandung	150 m	35	2015	Tallest building in Bandung

Source : (GMBH n.d.)

Photo: M R Karim Reza

Gama Tower

Photo: M R Karim Reza

Astra Tower

Photo: Taman Renyah

Wisma 46

Photo: M R Karim Reza *Photo: Chris Woodrich* *Photo: 世書名付*

Menara BCA *Bakrie Tower* *Stock Exchange building*

Figure 3-4 Famous tower buildings in Jakarta

In new construction in some big cities near Jakarta (Bogor, Depok Tanggerang, Bekasi), usually known collectively as JABODETABEK, these practices are still common (Figure 3-5). Even when old buildings are retrofitted, often the job is merely a facelift—a full curtain glass wall is simply placed in front of the old façade (Figure 3-6). However, while this is good for the prestige or image of the owner, it is not good for the occupant. The workers in a building with full glass windows behave in a predictable, and energy-wasting, way. Most of the day, the windows are covered by vertical blinds on the inside of the building (Figure 3-7). This happens because the occupants who are near the windows feel uncomfortable due to the glare of the sun or the heat from solar radiation. This causes the interior to become darker, which then makes them turn on the electric lights. Consequently, they have no view of the outside and need more energy for both lighting and cooling, because the heat is already trapped between glass and blinds. This kind of design fails because of uncontrolled occupant behavior—something that should be accounted for at the design stage given knowledge of typical office activities (Xue et al. 2014). Another way to avoid this problem is to design an architectural façade that minimizes occupant intervention, for example outside shading devices.

Photo: Jatmika Adi S

Figure 3-5 New construction of an office buildings in Jakarta

Photo: Jatmika Adi S

Figure 3-6 Facelift of an old building with full curtain glass wall

Photo: Jatmika Adi S

Figure 3-7 Occupant behavior inside a building with a glass wall façade

To control the use of energy, the government of Indonesia has issued some standards for the performance of building façades. One of the standards to be followed when designing building façades concerns the overall thermal transfer value (OTTV), i.e., the average value of solar radiation through fenestration surfaces, conduction from glass material, and conduction from wall surfaces. In 2011, the government of Indonesia set the OTTV standard at 35 watt/m^2 (BSNI 2011b) (Paryudi et al. 2013), whereas before 2011 it had been 45 watt/m2 (BSNI 2000). The impact of this new standard has been a decrease in the cooling energy demand of buildings. The OTTV regulation has been adopted in other Asian countries, such as Singapore since 1979, and in 2004, Singapore adopted the Envelope Thermal Transfer Value (ETTV) (Building and Costraction Authority 2004), Malaysia since 1989, Thailand since 1992, Philippines since 1993 (Vijayalaxmi 2010); and Hong Kong since 1995 (Building Authority Hong Kong 1995) (Chan & Chow 2014). This regulation is appropriate for implementation in high-rise buildings, and most high-rise buildings in Jakarta are office buildings and mixed-use commercial and office buildings. This kind of building mostly uses energy for cooling and lighting systems. The amount of cooling energy used is influenced by the external gain from the building's envelope. The components that affect solar heat gain are glazing material, fenestration area, and orientation. As a result, this regulation has changed the way architects design the façade of buildings.

Façade design has become an important design element not only for controlling energy consumption, but also from a purely architectural standpoint. It is important to remember that the façade consumes a large portion of the construction and maintenance budget. Another consideration is that a significant function of a façade is to connect with the environment (Kolokotroni et al. 2004). Each element can be measured in terms of thermal and visual performance. A larger opening will increase the visual performance. It will, however, decrease the thermal performance and, in most cases, also causes glare.

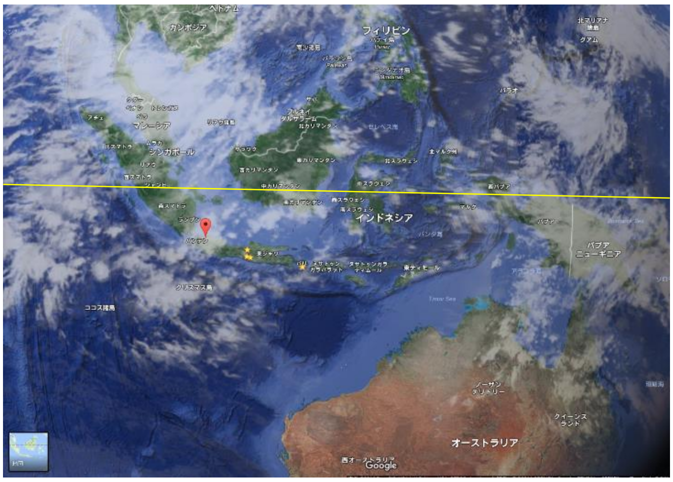
The choice of building shape also affects the behavior of the energy performance (Parasonis et al. 2012). It will also influence what materials are chosen and how the building is managed during construction and operation (Piroozfar & Farr 2013).

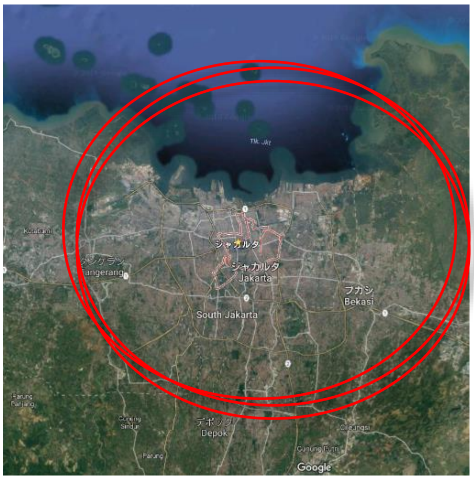
A more climate-sensitive design approach linked to the use of advanced control systems allows the building occupants to control their indoor environment while maximizing the contribution of ambient energy sources to the creation of a comfortable indoor environment. Under almost all circumstances it is necessary to provide some form of auxiliary heating, cooling, lighting or ventilation, since natural sources cannot always cover the requirements for thermal comfort, visual comfort, and IAQ (Indoor Air Quality) that are the prerequisite for a well-balanced, comfortable and healthy indoor environment.

3.4 Climate Condition in Jakarta, Indonesia

Indonesia is a part of the Asian continent. The latitude and longitude for cities in Indonesia are in the following range: Latitude from -10.1718 to 5.88969 and longitude from 95.31644 to 140.71813 (Figure 3-8). The DMS latitude and longitude coordinates for Jakarta are: 6°12'52.63"S, 106°50'42.47"E; or in decimal, -6.21462, 106.84513.

The climate of Indonesia is almost entirely tropical. The uniformly warm waters that make up 81% of Indonesia's area ensure that temperatures on land remain fairly constant, with the coastal plains averaging 28°C, the inland and mountain areas averaging 26°C, and the higher mountain regions, 23°C. Temperature varies little from season to season, and Indonesia experiences relatively little change in the length of daylight hours from one season to the next; the difference between the longest day and the shortest day of the year is only 48 minutes. The area's relative humidity ranges between 70% and 90%.





Source: google

Figure 3-8 Map of Indonesia and Jakarta

Data analysis from the weather file for Jakarta using Climate Consultant can describe the characteristic of the microclimate in Jakarta (figure 3-9).

WEATHER DATA SUMMARY	**LOCATION:** 409079_Jakarta, Downtown, - **Latitude/Longitude:** 6.204° South, 106.821° East, **Time Zone from Greenwich** 7 **Data Source:** Tmy2 - WMO Station Number, **Elevation** 10 m												
MONTHLY MEANS	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	
Global Horiz Radiation (Avg Hourly)	503	525	542	534	509	504	501	552	587	597	565	544	Wh/sq.m
Direct Normal Radiation (Avg Hourly)	402	428	467	491	523	552	546	563	559	542	490	458	Wh/sq.m
Diffuse Radiation (Avg Hourly)	215	207	198	183	161	143	143	154	176	192	206	211	Wh/sq.m
Global Horiz Radiation (Max Hourly)	1024	1048	1042	999	916	885	900	985	1042	1060	1028	1006	Wh/sq.m
Direct Normal Radiation (Max Hourly)	821	824	812	801	791	863	821	870	883	858	820	826	Wh/sq.m
Diffuse Radiation (Max Hourly)	518	528	525	484	372	389	386	375	478	512	502	506	Wh/sq.m
Global Horiz Radiation (Avg Daily Total)	6198	6415	6525	6341	5966	5874	5862	6519	7033	7259	6947	6721	Wh/sq.m
Direct Normal Radiation (Avg Daily Total)	4957	5227	5629	5825	6125	6431	6379	6648	6693	6583	6023	5669	Wh/sq.m
Diffuse Radiation (Avg Daily Total)	2652	2536	2389	2177	1895	1675	1672	1820	2109	2332	2533	2614	Wh/sq.m
Global Horiz Illumination (Avg Hourly)	32747	30551	47288	39773	47673	48737	53295	57728	59237	49647	42915	36904	lux
Direct Normal Illumination (Avg Hourly)	11067	7947	21786	15097	27937	35050	42746	44716	39776	24895	18032	14722	lux
Dry Bulb Temperature (Avg Monthly)	28	28	28	29	29	29	28	28	29	29	29	28	degrees C
Dew Point Temperature (Avg Monthly)	23	22	23	23	23	22	21	21	21	22	22	22	degrees C
Relative Humidity (Avg Monthly)	78	76	77	74	73	68	69	68	65	69	71	75	percent
Wind Direction (Monthly Mode)	300	290	240	180	190	50	120	20	40	50	240	230	degrees
Wind Speed (Avg Monthly)	2	3	2	2	2	2	3	3	3	2	2	3	m/s
Ground Temperature (Avg Monthly of 3 Depths)	28	28	28	28	28	28	27	27	27	27	27	27	degrees C

Figure 3-9 Summary of Jakarta weather data

From the summary above we can see that in this area the weather values are fairly constant: there is hot weather in all months. More detail about the climate can be seen in the following figures (Figure 3-10 to Figure 3-13).

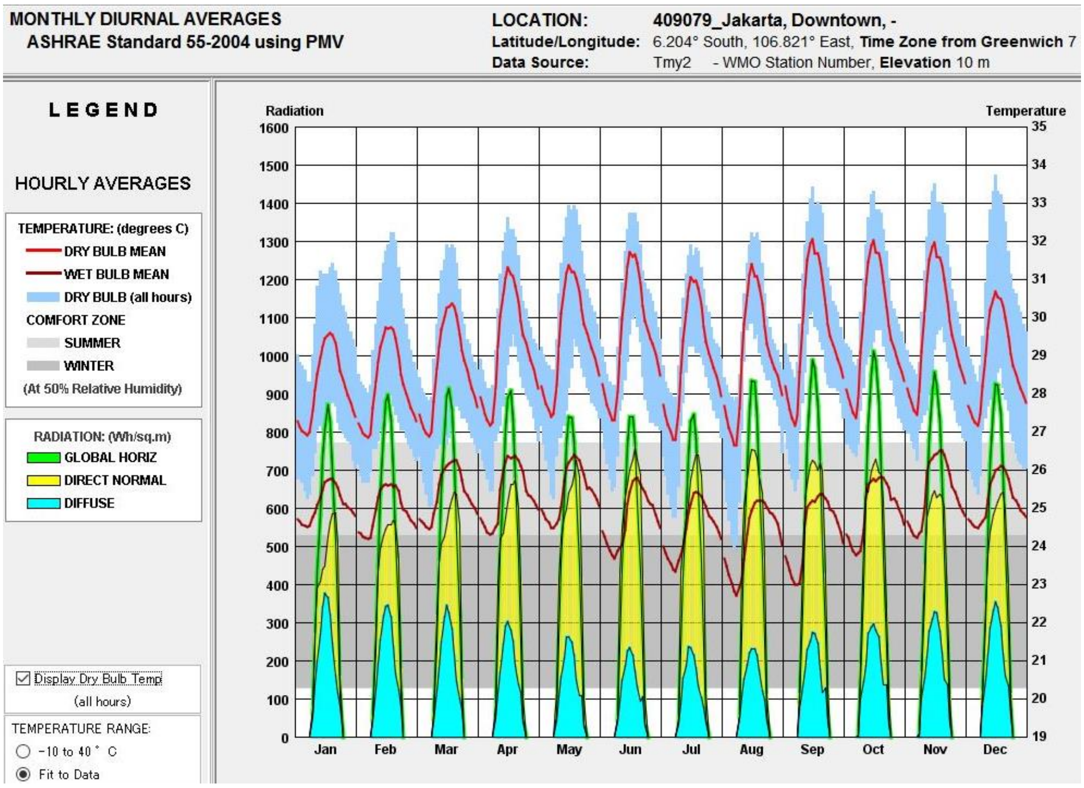


Figure 3-10 Monthly diurnal averages of Jakarta weather data

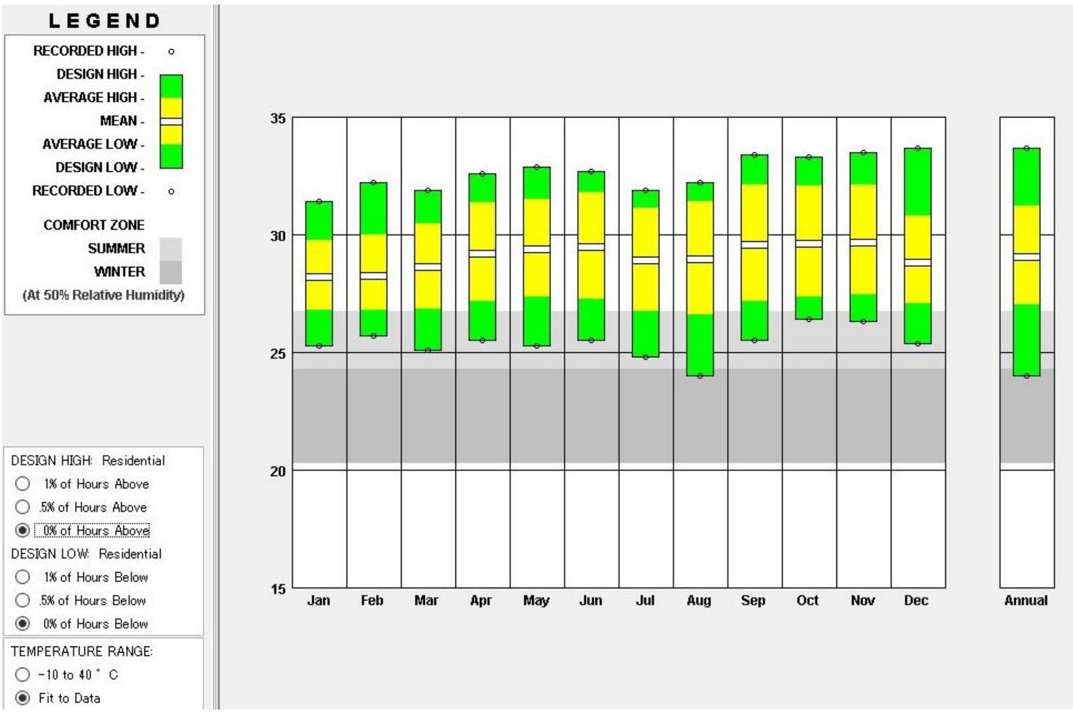


Figure 3-11 Average dry bulb temperature of Jakarta weather data

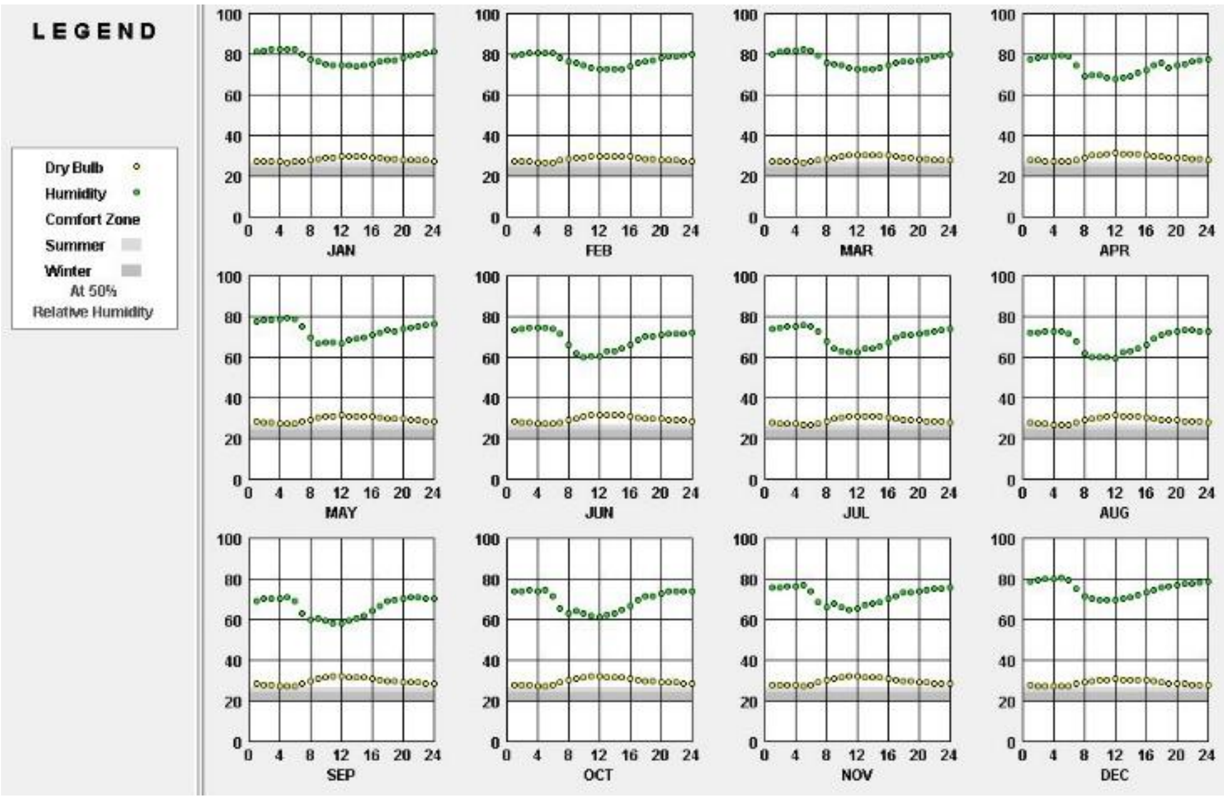


Figure 3-12 Dry bulb temperature and relative humidity of Jakarta weather data

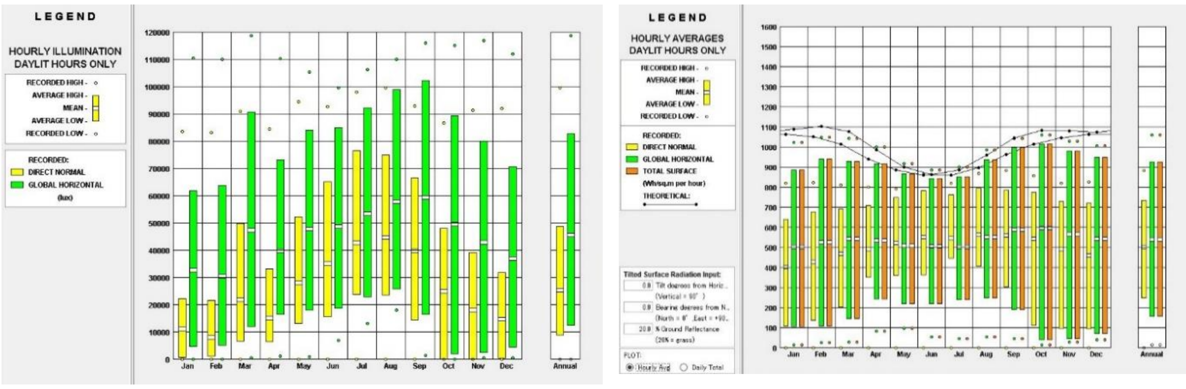


Figure 3-13 Illumination range of Jakarta weather data

Radiation data shows similar hourly patterns for each day. Most of the time the environmental conditions are above human comfort zones. This means that buildings must have some strategy for creating comfortable conditions inside. In the time table plot, more detail can be seen about the daily patterns from hour 0 to 24 (Figure 3-14). The wind speed does not have enough power to increase thermal comfort.

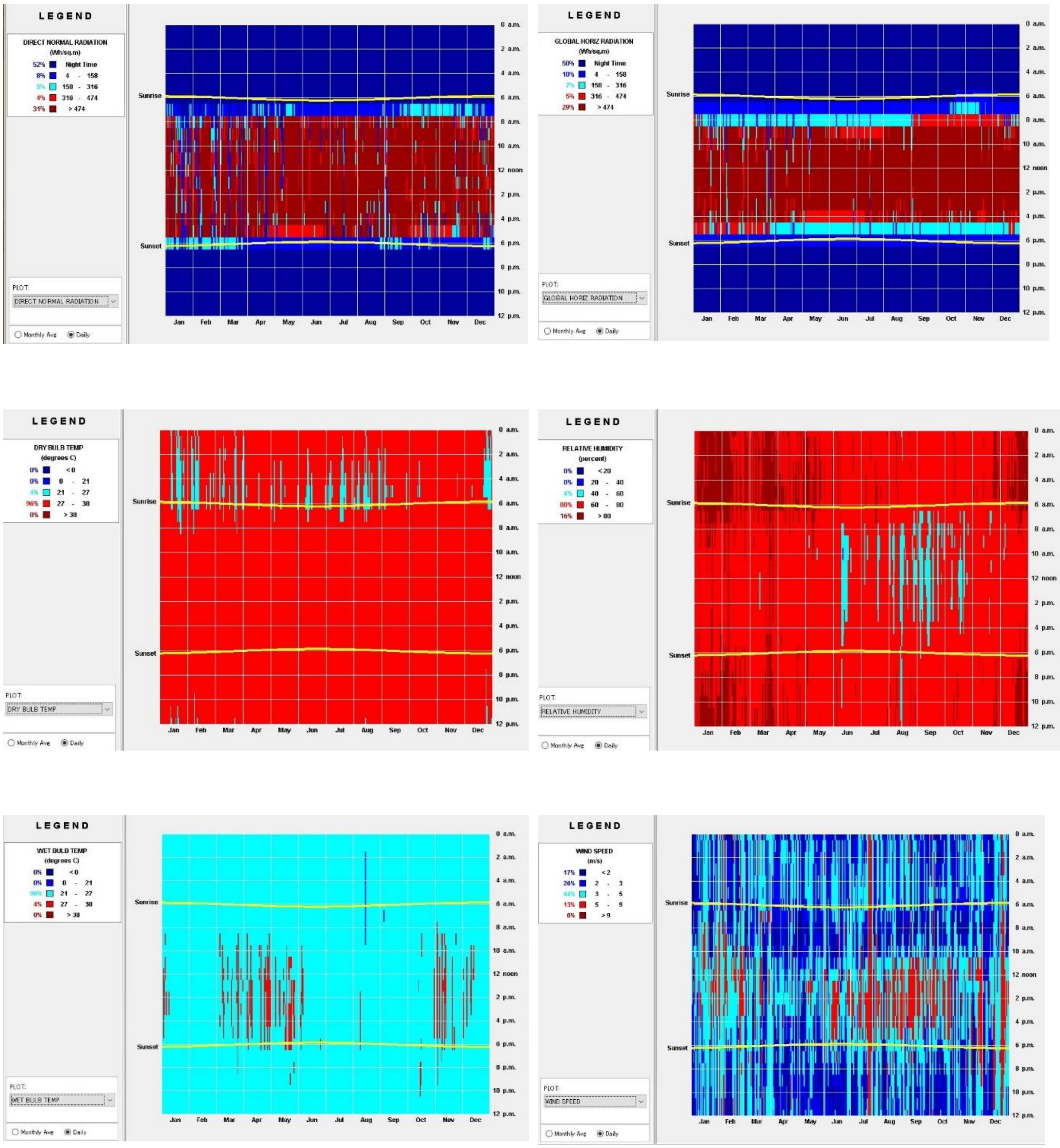


Figure 3-14 Time table plot of Jakarta weather file

3.5 Active and Passive Design Strategy

Based on the psychrometric chart, there are active and passive ways to solve the problem of comfort. In active strategy, cooling is the best way to get 98.9% comfortable hours in 24-hour mode; 100% comfort is achievable when office working hours only are counted (from 08:00 until 18:00). When using a passive design strategy, the most effective method is sun shading. Shading can create 34% comfortable hours in 24-hour mode; the value becomes 74.2% comfortable hours—a significant increase—when only considering office working hours (Figure 3-15 and Figure 3-16).

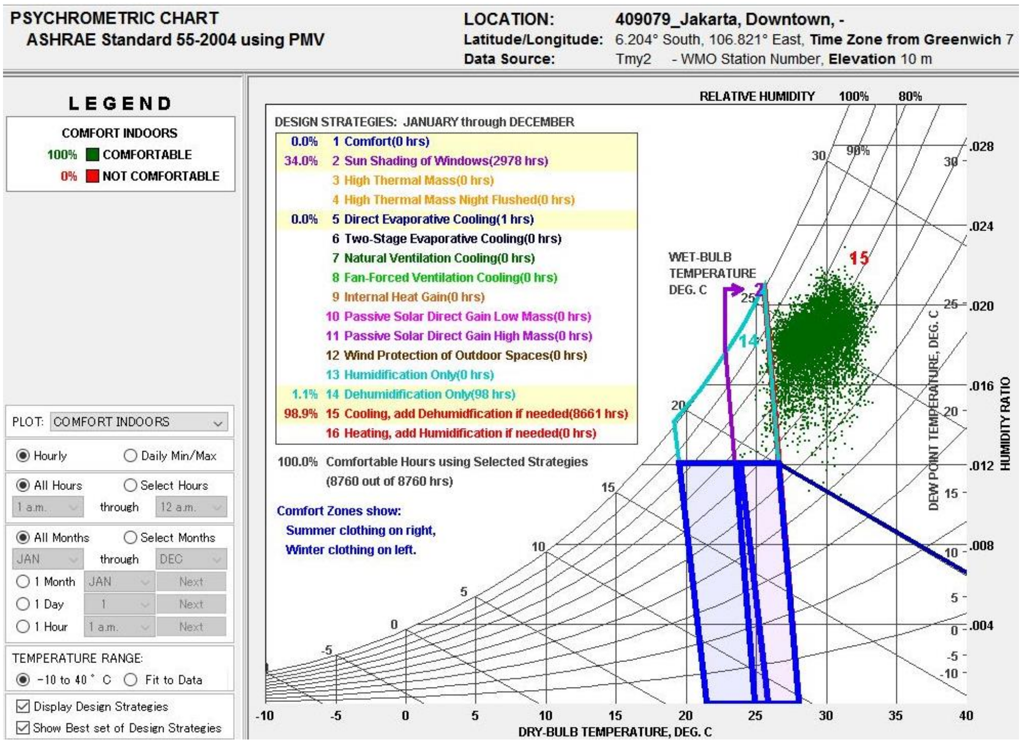


Figure 3-15 Psychrometric chart of passive and active design strategy based on Jakarta weather data (all hours)

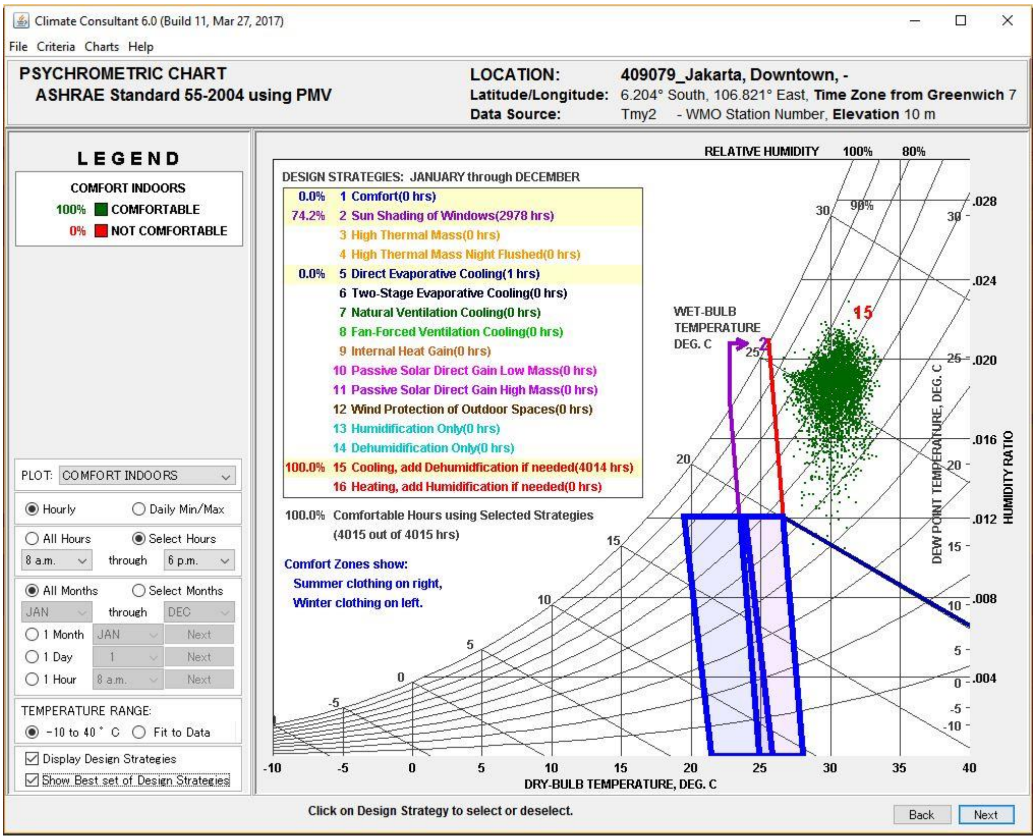
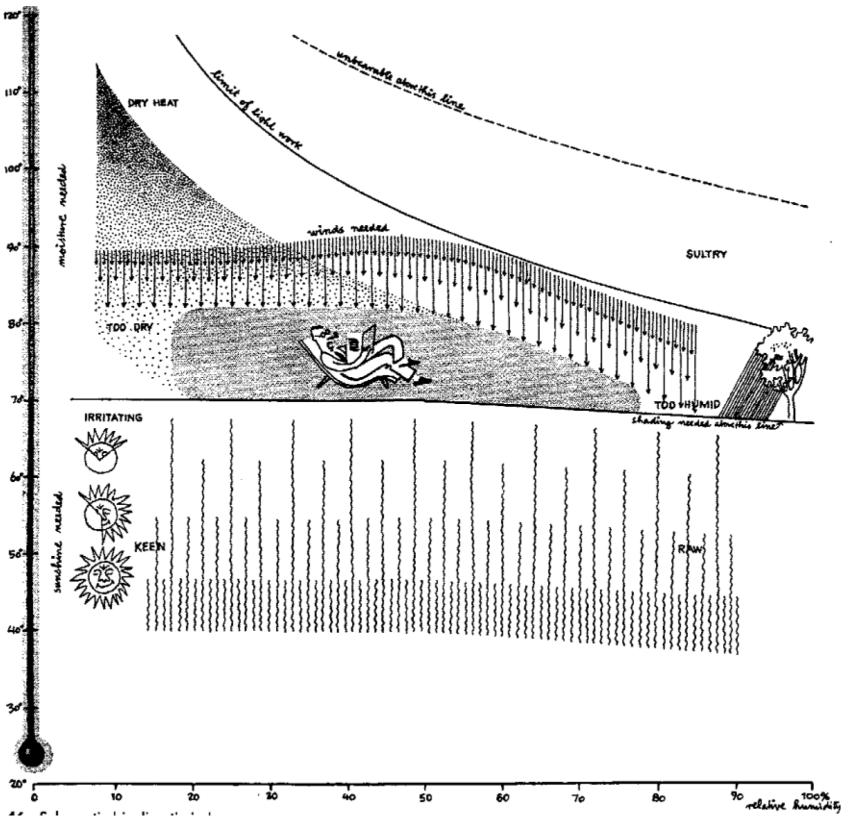


Figure 3-16 Psychrometric chart of passive and active design strategy based on Jakarta weather data (active hours)

Chapter 4 Literature Study

4.1 Bioclimatic Approach in Architecture

Microclimate is the main environmental factor that determines the configuration of a building. A simplified version of a bioclimatic chart shows the relationship of the various climatic elements to each other. Climatic needs for conditions outside the comfort zone are shown in a simple diagrammatic form (Figure 4-1). This is the initial step to understanding the site condition and finding the best strategy for overcoming the comfort problem in building design.

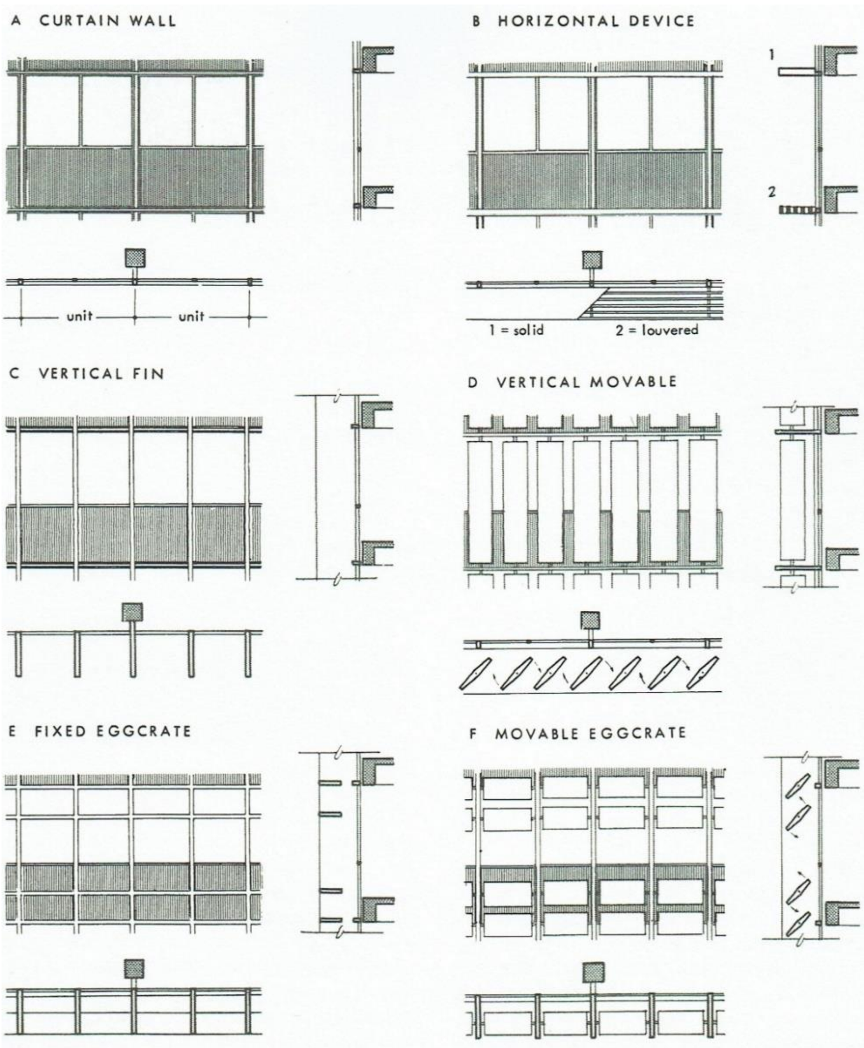


Source :(Olgyay 1963)

Figure 4-1 Thermal comfort diagram

4.2 Shading Devices

“The windows account for the greatest amounts of heat entering the building and therefore shading them, offers the greatest protections” (Olgyay 1963). Thus, it is crucial to shade the windows of our buildings when the outdoor temperature is above the shaded line in the thermal comfort diagram above (Figure 4-1). The window should be well protected from the sun to reduce radiation. Shading devices can be inside the building in the form of blinds, rollers and curtains, or outside in the form of fins and overhangs. The former devices are placed behind the glass and can only reflect part of the radiation, while the most of the heat is absorbed, convected, and reradiated into the room. Outside shading devices actually shade the window from direct radiation, therefore preventing a large part of the heat from getting in. Hence, the location of these outside shading devices is crucial. The ability to keep radiation out is at its highest when shading devices are in front of the glazing surface; lower when they are on the glazing surface; and at their lowest when they are behind the glazing surface. Common types of shading devise include vertical shading, horizontal shading, and a combination of vertical and horizontal shading called egg crate (Figure 4-2).

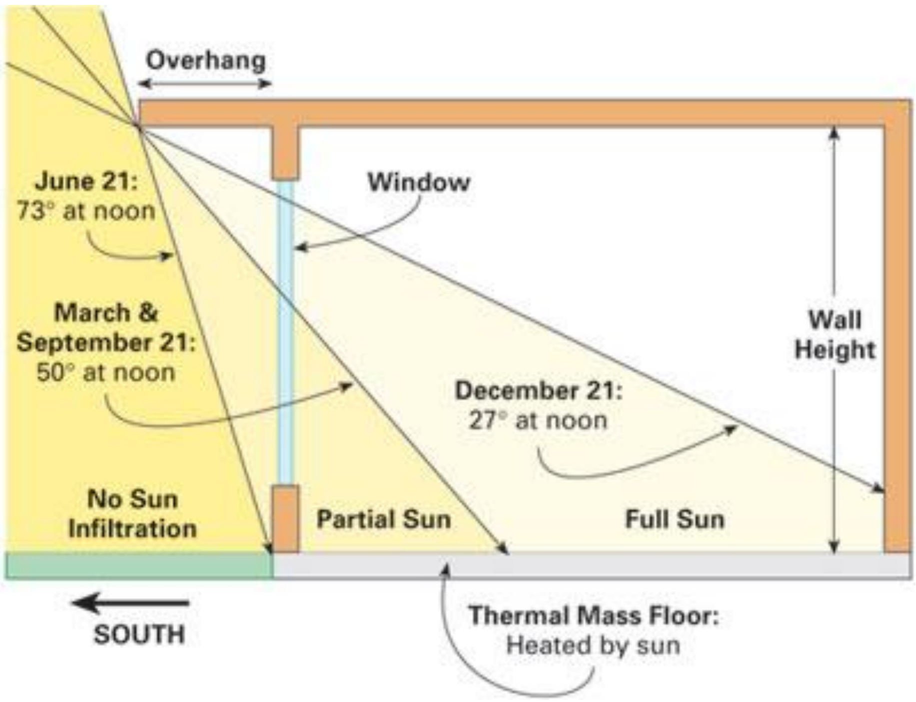


Source :(Olgyay 1963)

Figure 4-2 Types of shading devices

4.2.1 Horizontal Shading Devices - Overhangs

These devices are placed horizontally in front of the window in various ways. Their shape, type, depth and height all differ, depending on the sun conditions. A window overhang is (usually) a horizontal surface that juts out over a window to shade it from the sun. This is desirable for reducing glare or solar heat gain during warm seasons. In temperate climates, where there are warm and cool seasons due to the tilt of the earth's axis of rotation in relation to the plane of its orbit, it is often desirable to shade a window during hot summer months but allow sunlight to shine through a window in the winter to help warm a building. Because the sun is higher in the sky in the summer than it is in the winter, it is possible for a fixed overhang to accomplish both summer shading and winter sunlight admission.

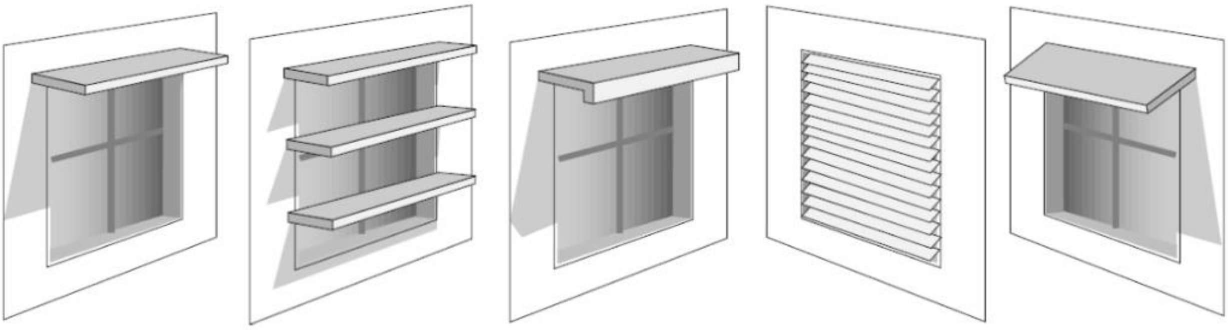


Source : *(Parmar 2015)*

Figure 4-3 Overhang shading device

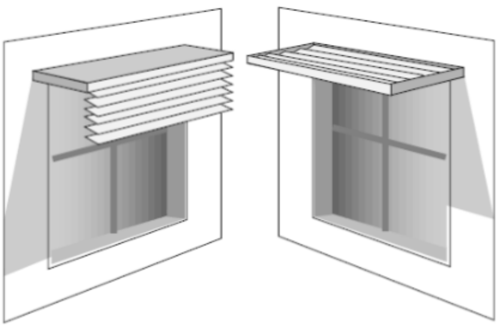
As this diagram illustrates, the basic concept is that an overhang can be positioned to totally allow low winter sun in the entire window while completely shading the entire window from summer sun (Figure 4-3). The design calculation is performed over a certain period of mid-summer and a certain period of mid-winter, typically a month or two on either side of the two solstices. The calculation is also performed only for a certain period during the day, typically near solar noon since that is when it's most important to increase solar gain in the winter and reduce gain in the summer (because the sun is most intense then). In fact, it is not usually possible to design a horizontal overhang that works in the early morning or late afternoon because the sun is low in the sky in both the summer and winter.

Depend on the situation and location, horizontal shadings are the most popular types of shading (Figure 4-4). Some shading use the combination of horizontal shading in horizontal form or vertical form (Figure 4-5).



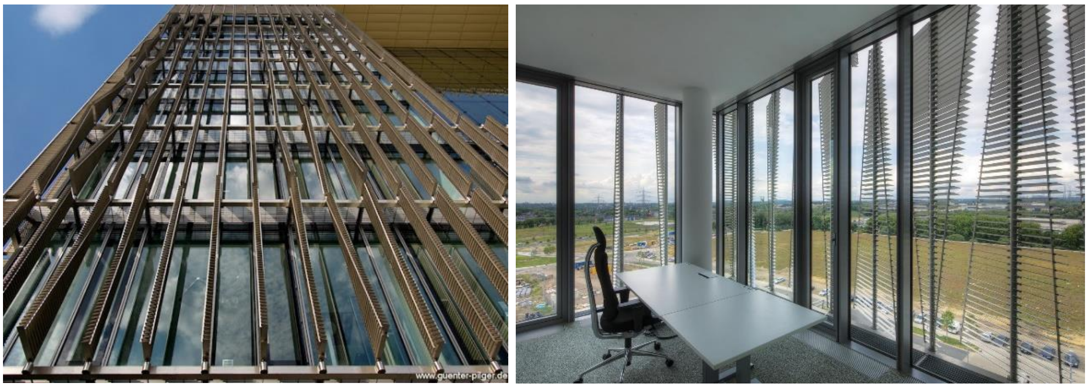
Source: (O’Connor et al. 1997)

Figure 4-4 Horizontal shading types



Source: (O’Connor et al. 1997)

Source: (Andrew Michler n.d.)

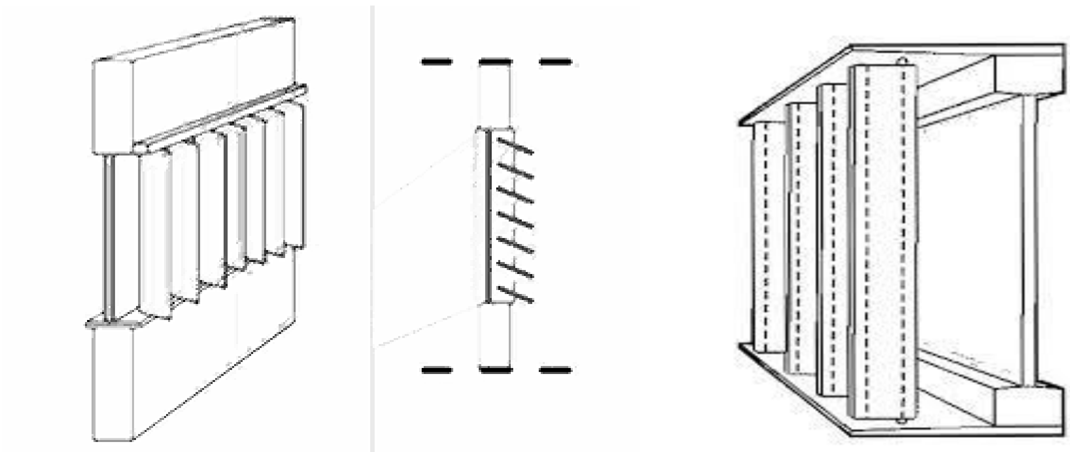


Source: *(Ignacio Fernández Solla 2010)*

Figure 4-5 Louver in dropped edge (left) or solid overhang (right)

4.2.2 Vertical Shading Devices

The vertical exterior louver and egg-crate solar shading devices are primarily useful for eastern and western exposures. These devices also improve the insulation value of glass in winter months by acting as a windbreak (Figure 4-6).



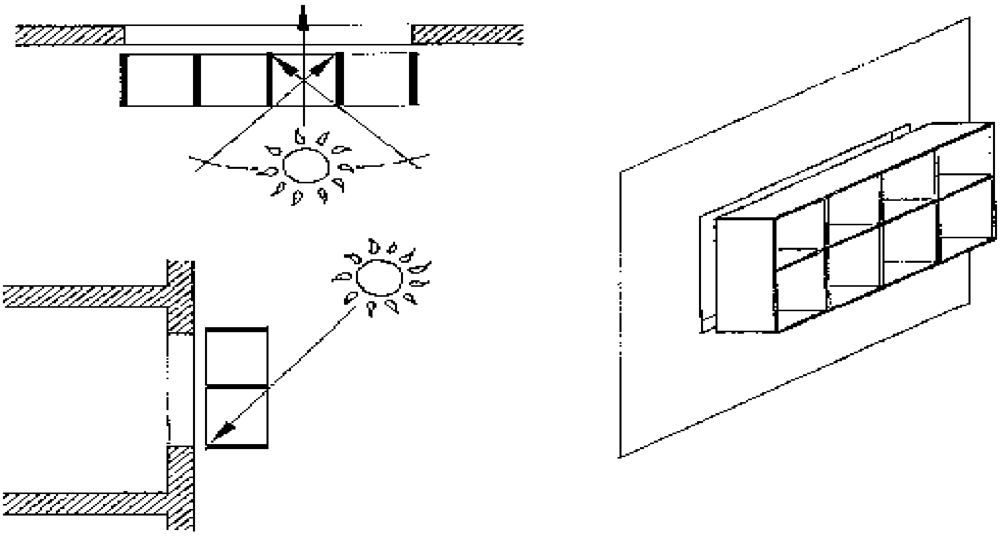
Source: (Kumar 2016)

Figure 4-6 Vertical shading types

Vertical elements can also be designed to vary angle according to the sun's position. Moveable, vertical louvres can provide shading coefficients from 0.15 to 0.10. Due to problems from icing, they are not practical in cold regions. On cloudy days, a photocell-powered control device can set moveable louvres to the perpendicular position shown below for maximum light penetration. Indoor louvres with integral tubing for removing or putting heat as required, is also an option.

4.2.3 Egg-crate

The egg-crate solar shading device is a combination of vertical and horizontal shading elements (Figure 4-7). They are more commonly used in hpt climate regions because of their high shading efficiencies (e. S.C <= 0.10). The horizontal elements control ground glare from reflected solar rays. The device works well on walls



Source : (Kumar 2016)

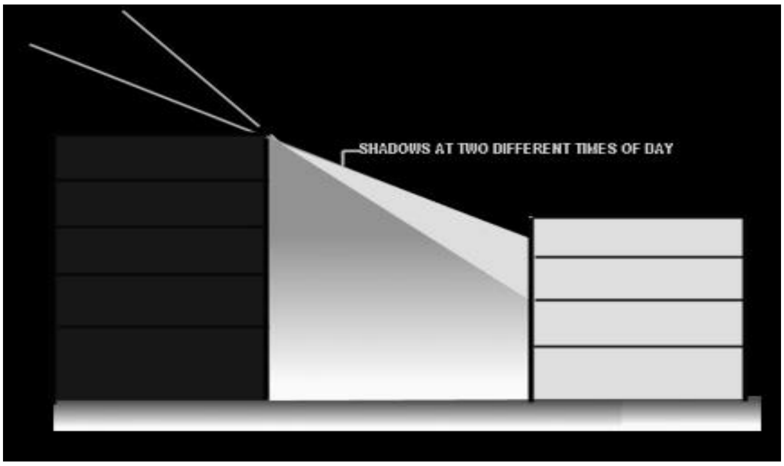
Figure 4-7 Egg-crate shading types

4.2.4 Shading from Surroundings

Buildings can provide useful shade for nearby structures. For example, a planned building located at 40 degrees north latitude will be shaded as shown below (Figure 4-8) on the afternoon of July 23. This may or may not be beneficial. A building may be designed with the best intentions, but if the buildings around it are not kept in mind the building might become totally shaded and cold at certain times of the day. In the same way, trees and vegetation can be used to provide shade, and the effect on a building must be kept in mind.

4.2.4.1 Shading from Buildings

Surrounding buildings in the location of design building can also act as shading by using its shadow that fall in design building’s façade (Figure 4-8).

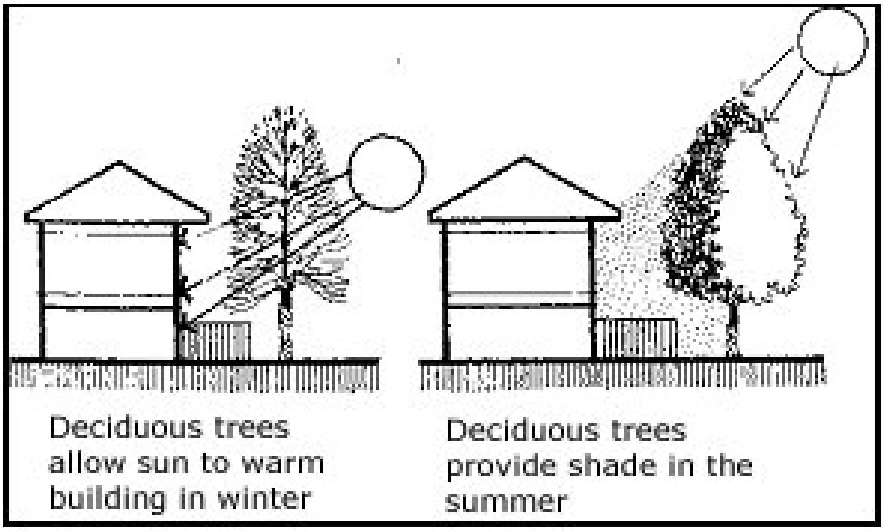


Source : (Kumar 2016)

Figure 4-8 Shade from other buildings

4.2.4.2 Shading from Vegetation

Vegetation is, in fact, a powerful tool in shading, as well as in reducing solar radiation, wind, and precipitation. Trees located strategically can save up to 30% of a building's total energy requirement. Trees and vegetation can be used to provide shade where it is seasonally beneficial (Figure 4-9). In hot places, plants and trees planted in front of a window will not only reduce solar radiation, but the evaporation process also helps to cool the air. In winter, properly placed trees and shrubs can shield your home from cold winds, reducing heat loss by 10 to 30%.



Source : (Kumar 2016)

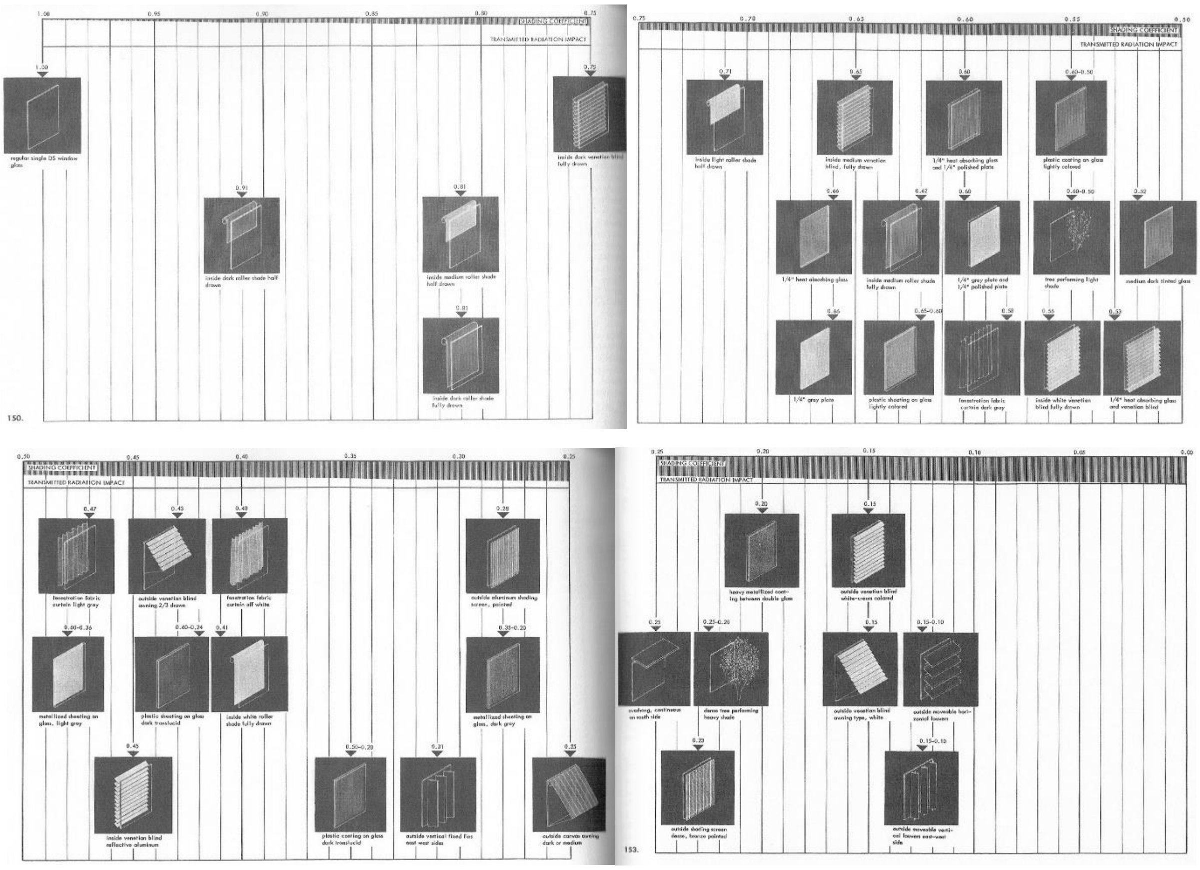
Figure 4-9 Shading from vegetation

Identifying the right tree type for a particular building requires the following steps:

- Identifying the "solar window," which is how much sun the building receives given its placement on the lot. For example, the Pacific Northwest climate, the ideal solar window is 90 degrees east and about 50 degrees west of true south.
- The building should be kept clear for winter warmth and light. If there is need to plant trees inside the solar window, minimize the impact by planting deciduous, "solar friendly" trees that have open crowns in the winter, leaf late spring and drop their leaves early in the fall (for example: redbud, green ash, and honey locust.). Tall, high crowned trees planted close to the building are the best. Palm trees are often chosen for this. Vines are also a common choice for this purpose. When properly placed, mature trees have shading coefficients (S.C) from 0.25 to 0.20.
- Outside the solar window, conifers or deciduous trees with dense winter crowns should be planted to protect from the cold winter wind. Deciduous trees may be preferable on the west side because they'll give more light in the winter.

4.3 Shading Strategy and Effectiveness

The effectiveness of window glass at protecting against the sun depends on several factors: (A) the reflectivity of the applied shading material and its color coating; (B) the location of the shade protection, which influences the reradiation and convection of heat; (C) the specific arrangement of the applied shading method.(Figure 4-10) (Olgyay 1963).



Source :(Olgyay 1963)

Figure 4-10 Efficiency of various shading methods

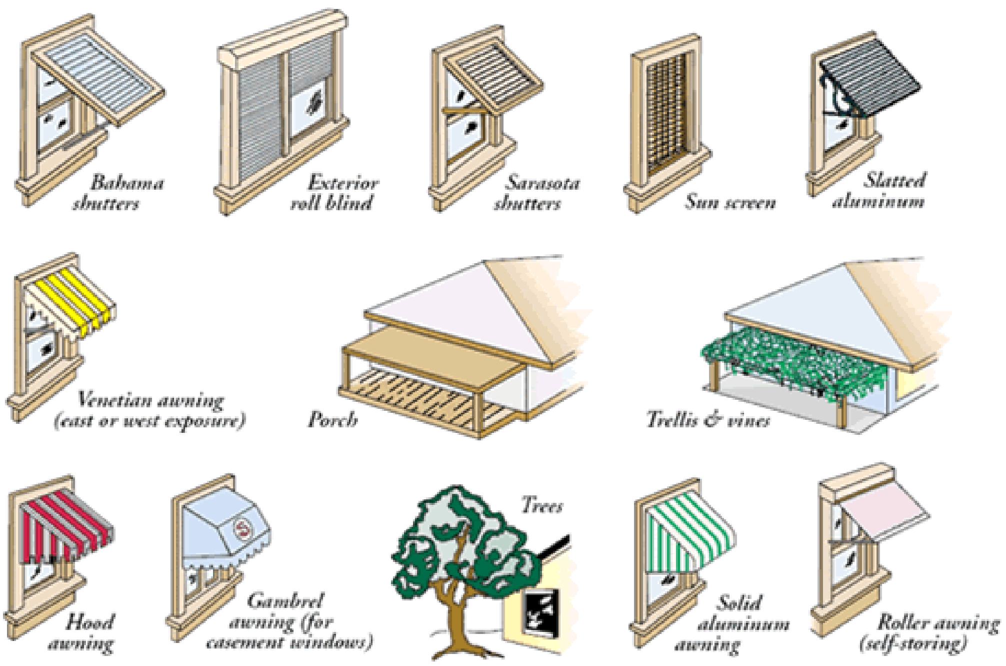
A detail summary of the shading effectiveness:

- Venetian blinds with an off-white color give 20% more shade protection than dark-colored ones; aluminum blinds offer an additional 10% more protection. With roller shades, the effect is more pronounced: off-white shades give 40% more protection than the dark ones. With inside curtains the difference is not so great: light-colored curtains are 18% more effective than dark one.
- As an overall rule, one could conclude that effectiveness increases by about 35% when using outside shade protection instead of inside shade protection.
- Various method of shading can be listed based on increased shading coefficient:
  - Inside Venetian blinds
  - Inside roller shades
  - Tinted glass
  - Insulating curtain

- Outside shade screen
- Outside metal blind
- Coating on glass surface
- Trees
- Outside awning
- Outside fixed shading device
- Outside movable shading device

In general, it is best to block the sun before it reaches the window. The variety of shading strategies shown below are effective at accomplishing that goal (Figure 4 -11)

.



Souce :(Florida Solar Energy Center n.d.)

Figure 4-11 Shading Strategy

4.4 National Standard of Indonesia

There are several National Standard of Indonesia (SNI) codes that must be followed when designing a building. One of the standard codes contains rules for interior illuminance: SNI 03-6197-2000 (*Konservasi energi pada sistem pencahayaan*). In this standard, the minimum illuminance for office buildings is between 100 lux to 750 lux, depending on the type of work done in the room (Table 4-1).

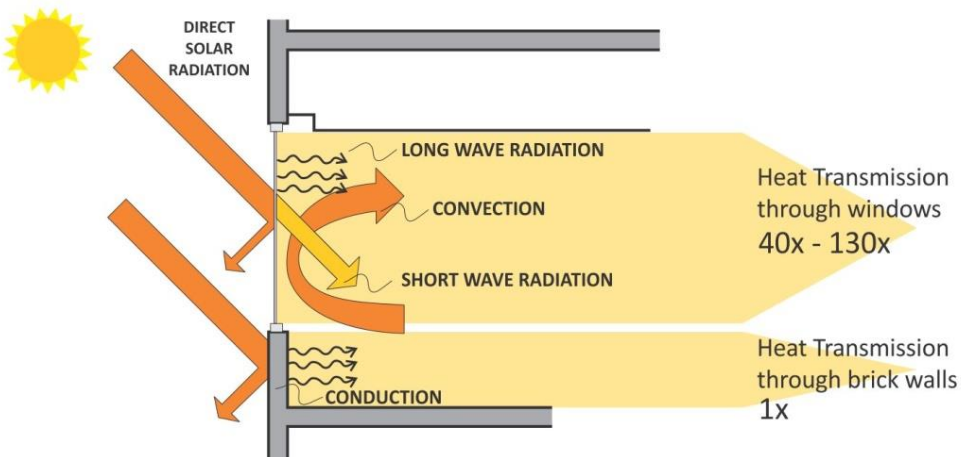
Table 4-1 Illuminance levels for office buildings

Room Function	Illuminance Level (Lux)
Receptionist room	300
Director office	350
Work space	350
Computer room	350
Meeting room	300
Drawing room	750
Archive storage	150
Active archive room	300
Emergency stair	150
Parking space	100

There is also a national standard that regulates the amount of daylight in the building. Another National Standard of Indonesia regulates the OTTV: SNI 03-6389-2011. In this standard, the maximal value for OTTV is 35 W/m^2. Details about the calculation of OTTV will be described in the following sub-chapter.

4.5 OTTV Calculation

Overall thermal transfer value (OTTV) calculation determines the average heat gain into a building through the building envelope. It consists of three major components: conduction through opaque walls, conduction through window glass, and solar radiation through window glass. (Figure 4-12).



Source:*(Suryabrata 2014)*

Figure 4-12 Thermal transfer through building envelope

The general form of the OTTV equation for external walls is:

$$OTTVi = \frac{Qwc + Qqc + Qsol}{Ai}$$

$$OTTVi = \frac{(Aw \times Uw \times TDeq) + (Af \times Uf \times DT) + (Af \times SC \times SF)}{Ai}$$

$$OTTVi = (1 - WWR) \times Uw \times TDeq + WWR \times Uf \times DT + WWR \times SC \times SF$$

where *OTTVi* = overall thermal transfer value of the external wall (W/m^2)

Qwc = heat conduction through opaque walls (W)

Qgc = heat conduction through window glass (W)

Qsol = solar radiation through window glass (W)

Aw = area of opaque wall (m^2)

Uw = U-value of opaque wall (W/m^2.K)

TDeq = equivalent temperature difference (K)

Af = area of fenestration (m^2)

Uf = U-value of fenestration (W/m^2.K)

DT = temperature difference between interior and exterior (K)

SC = shading coefficient of fenestration (dimensionless) = SCwin x SSF

SCwin = shading coefficient of window glass (dimensionless)

SSF = solar shade factor of external shading devices (dimensionless)

SF = solar factor of fenestration (W/m^2) solar factor (W/m^2), depends on building orientation (130 for North (N), 113 for North East (NE),112 for East (E), 97 for South East(SE), 97 for South (S), 176 for South West (SW), 243 for West (W), 211 for North West (NW) for Jakarta.

Ai = gross area of the walls (m^2) = Aw+ Af

WWR = window-to-wall ratio (gross wall area) = Af/ Ai

For calculating the OTTV of whole façade, the equation is:

$$OTTVi = \frac{(Ao1 \times OTTV\ 1) + (Ao2 \times OTTV\ 2) + \cdots + (Aoi \times OTTV\ i)}{Ao1 + Ao2 + \cdots + Aoi}$$

$$= \frac{\sum (Ao \times OTTV)}{\sum Ao}$$

where Aoi = area of all façade (m^2)

Based on the equation, window-to-wall ratio and type of glass become the major factors that determine OTTV value. The biggest limitation of the OTTV method is that it only deals with the building envelope and does not consider other aspects of building design (such as lighting and air conditioning) and the coordination of building systems to optimize their combined performance. The use of OTTV as the only control parameter is inadequate and cannot ensure that energy is used efficiently in the building (Yik & Chan 1995). Unless other energy codes are implemented, the effect of the OTTV standard on ‘real ’energy savings is questionable, although it helps to increase concern and awareness of energy efficiency matters.

Although the OTTV approach has made code compliance simple for conventional building designs, it has tended to restrict designers from innovation and more challenging work. If alternative paths for code compliance are not provided, innovative designs that exceed the OTTV limits but can achieve a higher overall efficiency will be excluded and discouraged. For example, designs employing daylighting to reduce energy consumption of electric lights will be restricted (Hui 1997).

4.6 Thermal Comfort

Energy-efficient buildings are only effective when the occupants of the buildings are comfortable. If they are not comfortable, they will use alternative means of heating or cooling a space, such as space heaters or window-mounted air conditioners, that could be substantially worse than typical heating, ventilation and air conditioning (HVAC) systems.

Thermal comfort is difficult to measure because it is highly subjective. It depends on the air temperature, humidity, radiant temperature, air velocity, metabolic rates, and clothing. Each individual experiences these sensations a bit differently based on his or her physiology and mental state.

Thermal comfort is defined as the sensation of complete physical and mental well-being that is influenced by personal variables (activity and clothing) and environmental variables (air temperature, mean radiant temperature, air velocity, and air humidity).

To define the environmental variables: Temperature is the average air temperature from the floor to the height of 1.1 m. This is the dominant environmental factor, as it determines convective heat dissipation. The mean radiant temperature (MRT) is the average temperature of surrounding surfaces, which includes the effect of the incidental solar radiation. Air velocity has an effect on convective heat loss from the body: air at greater velocities will seem cooler. Air humidity has an effect on latent heat losses and has a particularly important impact in environments that are both warm and humid. Medium humidities (RH 30% to 65%) do not have much effect, but high humidities restrict evaporation from skin and in respiration, and thus curb the dissipation mechanism. Very low humidities lead to drying of the mucous membranes (mouth, throat) and skin, causing discomfort.

Thermal comfort is calculated as a heat transfer energy balance. Heat transfer through radiation, convection, and conduction are balanced against the occupant’s metabolic rate. The heat transfer occurs between the environment and the human body, which has an area of 19 ft^2 (1.81 m^2). If the amount of heat leaving the occupant is greater than the heat entering the occupant, the thermal perception is one of “cold.” If the heat entering the occupant is greater than the heat leaving the occupant, the thermal perception is one of “warm” or “hot.”

A method of describing thermal comfort was developed by Ole Fanger. It is referred to as Predicted Mean Vote (PMV) (Table 4-2) and Predicted Percentage of Dissatisfied (PPD).

Table 4-2 Predicted mean vote sensation scale

Value	Sensation
-3	Cold
-2	Cool
-1	Slightly cool
0	Neutral
1	Slightly warm
2	Warm
3	Hot

The recommended acceptable PMV range for thermal comfort from ASHRAE 55 is between -0.5 and +0.5 for an interior space. Predicted Percentage of Dissatisfied (PPD) predicts the percentage of occupants who will be dissatisfied with the thermal conditions. It is a function of PMV, given that as PMV moves further from 0, or neutral, PPD increases. The maximum number of people who can be dissatisfied with their comfort conditions is, of course, 100%. The recommended acceptable PPD range for thermal comfort from ASHRAE 55 is less than 10% persons dissatisfied for an interior space. Since PPD is a function of PMV, it can be defined as:

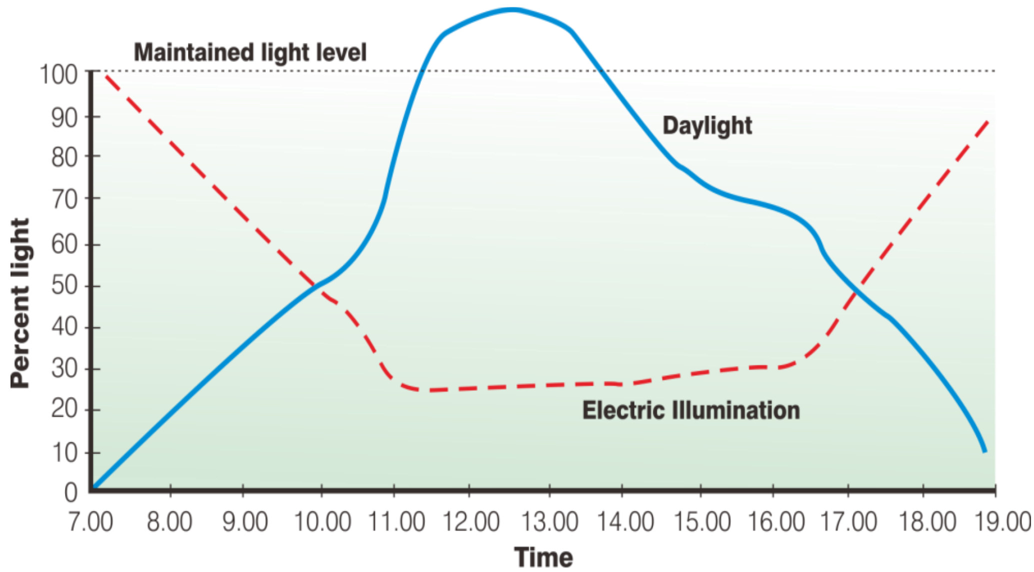
$$PPD = 100 - 95e^{[-(0.3353PMV^4 + 0.2179PMV^2)]}$$

4.7 Visual Comfort

Maintaining visual comfort means ensuring that people have enough light for their activities, that the light has the right quality and balance, and that people have good views. Good lighting helps create a happy and productive environment. Natural light does this much better than electric lighting. Having good views and sightlines gives people a sense of control of their environment and provides a sense of well-being.

Daylighting design strategies like high or clerestory windows, light shelves, and well-placed skylights can help distribute sunlight inside a space. When you do need to use artificial lights, you can reduce energy use by using efficient fluorescents or LEDs with daylighting dimming controls, effective fixtures, and good lighting design. Good controls can automatically balance natural and artificial lighting. Most lights should have occupancy sensors.

In the guidelines given by Jakarta, there are some steps for optimizing daylighting that should be considered when designing a building (Territory & Corporation n.d.). The most significant and logical way of reducing lighting energy is to use naturally available daylight as much as possible (Figure 4-13).



Source: (Territory & Corporation n.d.)

Figure 4-13 Electric lighting and daylight integration in a well-balanced lighting system

Daylighting used in concert with existing lighting-control technologies can save up to 50% of the energy used for lighting in offices (Figueiro et al. 2002). A well daylit building not only looks more vibrant and spacious but also has been shown to increase worker productivity and health. Two recent studies have shown that significant positive impacts of daylighting include increased retail sales and higher student test scores (Heschong et al. 2002).

In a study, it was shown that people in windowed offices spent significantly more time (15%) on work-related tasks than people in interior offices without windows (Figueiro et al. 2002).

Optimum benefits of daylighting can be achieved in two distinct steps: daylight design and daylighting control. Good lighting is well-distributed, is not too dim or too strong, and uses minimal energy. Lighting is often measured either by the amount of light falling on a surface (illuminance - lux) or the amount of light reflecting from a surface (luminance- cd). Good visual comfort also generally means that as much of this light as possible is natural light. Humans are hard-wired to like the sun's light, and, of course, it saves energy.

A metric called useful daylight illuminance (UDI) is used to determine the percentage of each point in the area that has an illuminance value of between 100 to 2000 lux, which is considered as useful daylight for interiors (Nabil & Mardaljevic 2005) (Nabil & Mardaljevic 2006) (Cantin et al. 2011). This range was selected because in the operation of the building, daylight must be combined with artificial light when the illuminance level is below 100 lux—the lowest useful value—and values above the maximum threshold (2000 lux) will -produce harmful glare. UDI also has a more realistic and informative daylight metric using climate-based data (Rasmussen et al. 2015). The UDI metric has a range from less than 100 lux, between 100 to 500 lux, between 500 to 2000 lux, and higher than 2000 lux. The definition of each stage is as follows:

- Daylight illuminances of less than 100 lux are generally considered insufficient to be either the sole source of illumination or to contribute significantly to artificial lighting.
- Daylight illuminances in the range of 100 to 500 lux are considered effective either as the sole source of illumination or in conjunction with artificial lighting.
- Daylight illuminances in the range of 500-2000 lux are often perceived either as desirable or at least tolerable.

- Daylight illuminances higher than 2000 lux are likely to produce visual or thermal discomfort, or both.

Another issue to be considered with daylight is the possibility of glare. Measuring the glare index can determine the effectiveness of shading devices. The metric that is used to measure glare is Daylight Glare Probability (DGP). DGP is the percentage of people disturbed due to the level of vertical eye illuminance. The simple linear formula is DGP(s) =6.22*10-5 * Ev+0.184 where Ev is the vertical eye illuminance (Wienold & Christoffersen 2006). The DGP(s) scheme works primarily for work spaces where contrasts do not pose a problem, e.g., offices where a large window takes up much of the view. This means DGPs apply for buildings with curtain glass wall façades. The full version of DGP has a component that considers contrasts. The default threshold of 30% people disturbed corresponds to a vertical eye illuminance of 2,500 lux. The DGPs are defined as four levels of glare: Imperceptible Glare, when the DGP is less than 0.35; Perceptible Glare, when the DGP is equal to or between 0.4 and 0.35; Disturbing Glare, when the DGP is more than or equal to 0.40 but less than 0.45; and Intolerable Glare, when the DGP is more than or equal to 0.45 (Wienold & Christoffersen 2006).

4.8 Privacy and Outside View

View refers to the ability for building occupants to see landscape, objects, and people outside the building. For many occupants, the outlooks from their space or public areas are a major factor in their enjoyment of the site, and it can add considerably to the ambience of a building. In addition, views of nature and of social spaces have been shown to improve worker productivity, student test scores, and people's health.

View is measured by drawing a line of sight from a location in the building to any exterior windows; if the line of sight to an exterior window is unbroken, that location has a view. The line of sight must be drawn at the appropriate height for occupants; for instance, typical office workers or students are usually sitting, with an eye level assumed to be 42 in. (1.1m) above floor level by some building rating systems (Caroline 2008).

In Jakarta, one of the organizations that certify buildings is Green Building Council Indonesia (GBCI). In the “Indoor Heath and Comfort” section of the certification for new buildings, one of the points is outside view (IHC-4). The IHC section of the Greenship (Green Building Code from GBCI) can be seen in Table 4-3.

Table 4-3 Indoor Health and Comfort section of Greenship Certification

Criteria and category		Maximum point	Explanation
IHC P	Outdoor Air Introduction	P	1 prerequisite; 7 criteria credits
IHC 1	CO2 Monitoring	1	
IHC 2	Environmental Tobacco Smoke Control	2	
IHC 3	Chemical Pollutant	3	
IHC 4	Outside View	1	
IHC 5	Visual Comfort	1	
IHC 6	Thermal Comfort	1	
IHC 7	Acoustic Level	1	
Total		10	9.9 %

For occupants, comfort also means privacy—an important factor that needs to be considered. This is especially true for Eastern cultures.

There are no metrics to measure visibility and privacy that have been published yet, therefore, a point of this research is to try to make indices that can be used to judge the levels of visibility and privacy. The details of the indices will be explained in chapters 6 and 7.

Chapter 5 Research Methodology

5.1 Visibility Indices Experiment

This research examines the effect of different illuminance levels on the visibility value of two rooms separated by Sudare, based on observer perception of five different types of traditional Japanese Sudare.

5.1.1 Schematic Methodology

An experiment room was used to set up a controllable illuminance-level condition by using a room that had been isolated from outside light. Basically, one room was divided into two different zone-rooms, on one side of which was the observer, and on the other was an object, or a person to act as an object, to be seen by the observer, who sat at a table. Both sides had LED lamps with a remote that could be used to change the illuminance level, measured at the height of the work plane (0.8 m above the floor). The distance between observer and Sudare blind was the same as the distance between the object and Sudare blind. An LED lamp was placed above the observer and above the object. By using this method, we could make sure that both rooms had the same variable value of illuminance level. To measure the illuminance level, we used a light meter (Figure 5-2 (d)) that was placed above the table, under the LED lamp. A Sudare blind (our setup allowed us to put each type of Sudare in place as needed) was placed in the middle of the room, separating the room into an observer room and an object room. The schematic detail is shown in Figure 5-1.

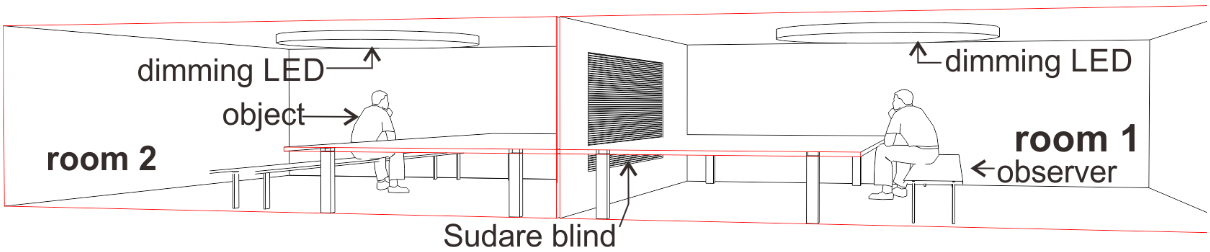


Figure 5-1 Schematic of experiment room

5.1.2 Type of Sudare

In this research, five types of Sudare were used to examine the effects of their differing physical characteristics of Sudare. The differences between each Sudare were the diameter of slats, the space between slats, and the level of whiteness, as shown in Figure 5-2 (a). The diameter and spacer for each type of Sudare was measured with a digital distance measurement device (Figure 5-2 (c)); whiteness level was measured with the Reple application from

Panasonic (Figure 5-2 (b)). The whiteness level was the result of the reflectance and absorbance value of the Sudare to the same light source when being measured.

Source: Apple store

Figure 5-2 Object and tools of research

(a) Section of Sudare; (b) Reple application; (c) Digital measurement; (d) Light meter

In Table 5-1, we describe the physical characteristics of each Sudare. Only Type A Sudare (white, big) was made from plastic straw slats, whereas the other types were made from bamboo slats. Type B (light brown, medium) and Type C (dark brown, medium) Sudare had similar characteristics, being made of small bamboo with some small differences in diameter, but were of different colors. Type D (ivory, medium small) and Type E (mocha, small) Sudare were made from solid bamboo. The comparison between the Sudare’s solid part and spacer part can be calculated to determine the void percentage ratio of the Sudare, which was called Void to Blind Ratio (VBR)

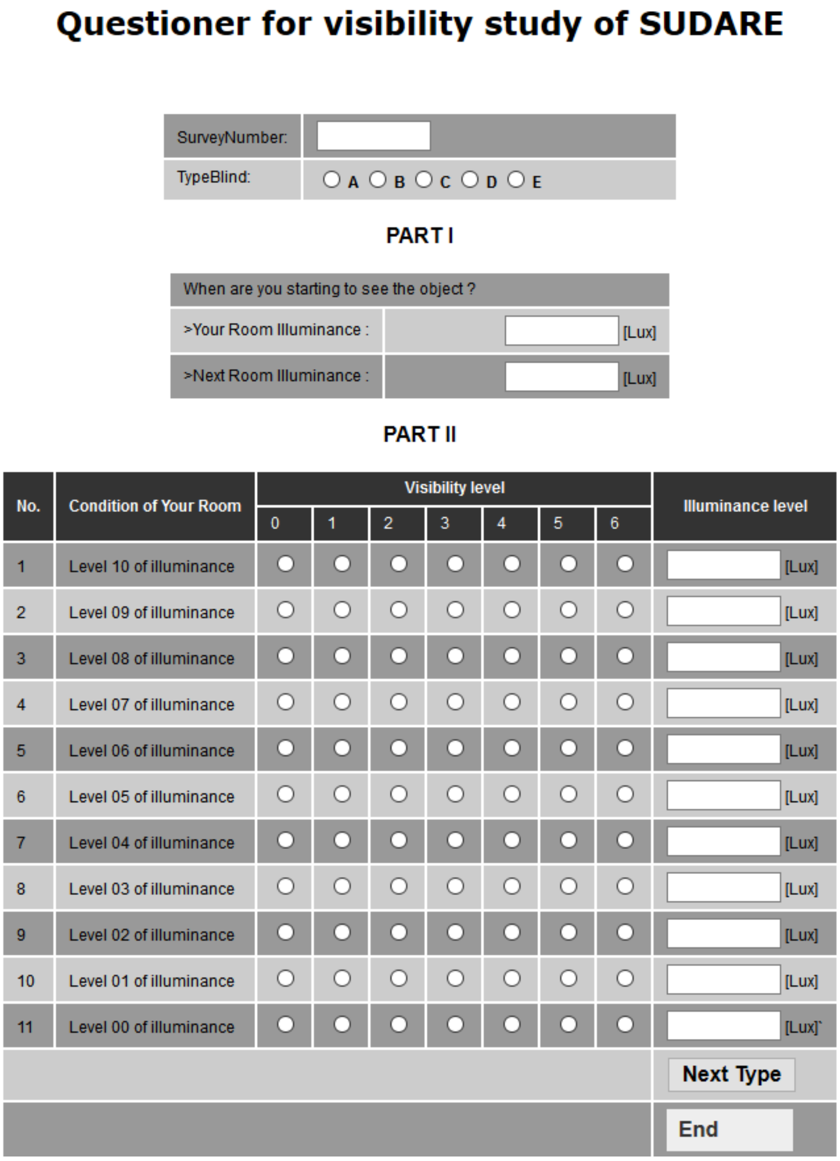
Table 5-1 Physical characteristics of Sudare

Type	Diameter Ø [mm]		Spacer [mm]		VBR [%]	Whiteness Level [lux]	
A		4.09		1.51	24%	 755	755

B		2.42		1.31	33%		363
C		2.42		1.31	33%		196
D		2.47		1.01	27%		467
E		1.18		0.64	34%		419

5.1.3 Questionnaire of Room Experiment

Data were collected using questionnaires completed by 121 students and teachers of Kitakyushu University who acted as observers for each type of Sudare. There are two parts in this questionnaire (Figure 5-3): The purpose of Part I was to examine the condition in which observers in room 1 started to see objects in room 2 when room 1 was at the maximum illuminance level, around 900 lux; The purpose of Part II was to examine the level of visibility with changing illuminance levels in room 1 (observer room), from a maximum illuminance level of between 838 to 876 lux to a minimum level of between 20 to 31 lux, while room 2 (object room) was at the maximum level of illuminance, around 900 lux. Eleven levels of illuminance, from maximum to minimum, are shown in Table 5-2, and samples of the condition of each experiment can be seen in Table 5-3. The full 11 conditions can be seen in Appendix 1. Samples of the answers to the questionnaire can be seen in Appendix 2.



Questioner for visibility study of SUDARE

SurveyNumber:	
TypeBlind:	A B C D E

PART I

When are you starting to see the object ?	
>Your Room Illuminance :	[Lux]
>Next Room Illuminance :	[Lux]

PART II

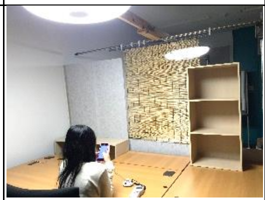
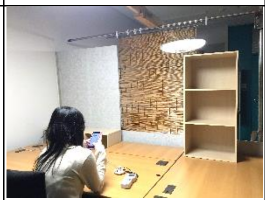
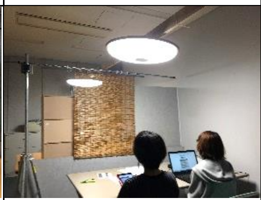
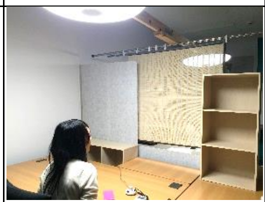
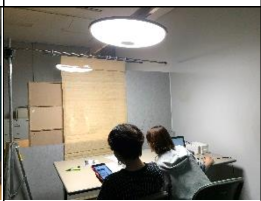
No.	Condition of Your Room	Visibility level							Illuminance level
		0	1	2	3	4	5	6	
1	Level 10 of illuminance								[Lux]
2	Level 09 of illuminance								[Lux]
3	Level 08 of illuminance								[Lux]
4	Level 07 of illuminance								[Lux]
5	Level 06 of illuminance								[Lux]
6	Level 05 of illuminance								[Lux]
7	Level 04 of illuminance								[Lux]
8	Level 03 of illuminance								[Lux]
9	Level 02 of illuminance								[Lux]
10	Level 01 of illuminance								[Lux]
11	Level 00 of illuminance								[Lux]
									Next Type
									End

Figure 5-3 Questionnaire sheet

Table 5-2 Illuminance value of 11 brightness conditions

Type	Level 10 [lux]	Level 09 [lux]	Level 08 [lux]	Level 07 [lux]	Level 06 [lux]	Level 05 [lux]	Level 04 [lux]	Level 03 [lux]	Level 02 [lux]	Level 01 [lux]	Level 00 [lux]
A	876	780	696	605	514	429	344	273	204	108	31
B	854	761	677	589	501	416	335	265	198	104	29
C	838	750	668	581	493	409	330	259	191	97	24
D	860	764	679	592	502	416	334	263	192	98	25
E	859	762	679	591	502	416	334	264	194	98	24
Average	857.4	763.4	679.8	591.6	502.4	417.2	335.4	264.8	195.8	101	26.6

Table 5-3 Experiment room condition

Type	Room 2	Room 1	Level 10 (Room 2)	Level 00 (Room 2)
A				
B				
C				
D				
E				

In this experiment, observers had to judge each condition with a value between 0 and 6. The meaning of each value can be seen in Table 5-4.

Table 5-4 Meaning of judgment value

Value	Meaning
0	Cannot see object
1	Recognize silhouette (a dark shape seen against a light surface) of the object
2	Recognize silhouette and color of the object
3	Recognize the object and color but these are not really clear
4	Recognize and start to see the object and color but cannot pick out detail
5	Can see the object and color and pick out some detail
6	Can see the object clearly (identify the detail and color)

5.1.4 Questionnaire of Digital Image Experiment

The next step was to re-run the experiment using digital images of each level for the five types of Sudare from the previous experiment, using computer display interaction. Data were collected from 211 respondents. The scale in the questionnaire was changed from 7 levels to 11 levels to give wider flexibility than in the previous experiment (Figure 5-4). The meaning of each value can be seen in Table 5-5. The scale figure guidelines were placed beside each image to give the respondents the same feeling of comparison when deciding on the level of visibility. This step was taken to validate and improve the accuracy of the previous experiment. Using this method, respondents could be anyone who had a computer that was connected to the internet. The complete questionnaire sheet is shown in Appendix 2. To compare the value with the first scale (7 levels), the second scale (11 levels) need to be converted using the remap component from the Grasshopper script (Figure 5-5).

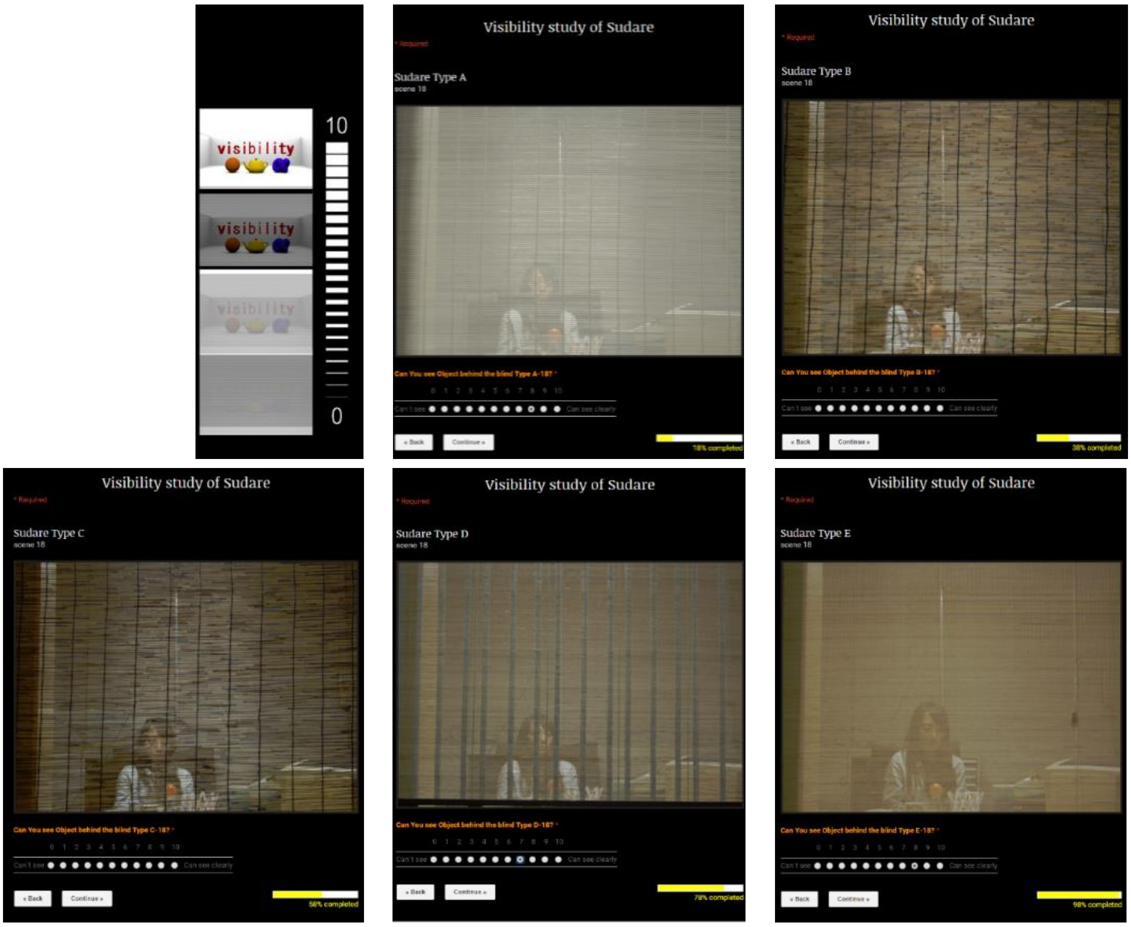


Figure 5-4 Digital images experiment

Table 5-5 Meaning of judgment value

Value	Meaning
0	Cannot see object
1	Recognize silhouette (a dark shape seen against a light surface) of the object
2	Recognize silhouette and simple color of the object
3	Recognize silhouette and color of the object
4	Recognize the object and color but these are not really clear
5	Recognize the object and color more better but still not too clear
6	Recognize and start to see the object and color but cannot pick out detail
7	Recognize and start to see the object and color and start to pick small detail
8	Can see the object and color and pick out small detail
9	Can see the object and color more clear and pick out some detail
10	Can see the object clearly (identify the detail and color)

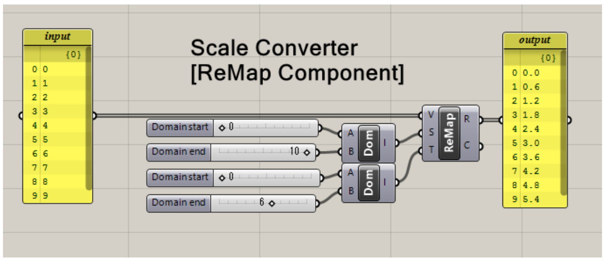


Figure 5-5 Scale converter component

5.2 Building Simulation

The research was carried out in four steps. The first was finding configurations of fenestration area, or window to wall ratio (WWR), that would meet the Indonesian National Standard (SNI) using different types of glass material with different solar heat gain coefficients (SHGC), without using any shading device as in a normal building. The second was modifying our model of a normal building by adding Sudare in front of each window as a shading device, then analyzing the improvement of the OTTV value and the impact on cooling load. The third was finding the visibility perception of the modified model that meets the new standard of OTTV 35 watt/m^2 using a questionnaire from the rendered images of clear glass and tinted glass of the normal building and the modified building. The fourth step was analyzing the daylight and glare performance. Daylight was simulated using the climate-based sky to evaluate the annual daylight for UDI 100 to 2000 (percentage of time during the active occupancy hours that the test point receives between 100 and 2000 lux of visual comfort inside the room) (Chien & Tseng 2014). Daylight glare probability was measured to evaluate the visual comfort of the building as regards the glare factor when the sun was in the lowest position for this location (June 22). The simulation for the daylight distribution was made using the intermediate standard CIE sky on the same day that the daylight distribution and glare probability were evaluated.

5.2.1 Generating a 3D Simulation Model for OTTV and Cooling Load Simulation

The model geometry for the simulation was made using Grasshopper parametric software in Rhinoceros 3D. Ladybug and Honeybee, two Grasshopper open-source plugins, helped to explore and evaluate the environmental performance. Ladybug imported the standard EnergyPlus weather files (.EPW) into Grasshopper and provided a variety of 3D interactive graphics to support the decision-making process during the initial stages of design. Honeybee connected Grasshopper's visual programming environment to four validated simulation engines—specifically, EnergyPlus, Radiance, Daysim, and OpenStudio—which evaluated building energy consumption, comfort, and daylight (Sadeghipour Roudsari M., Pak M., 2013). These plugins were used to prepare the simulation data for Energy Plus to get the OTTV value and cooling load. The visualization of the 3D modelling base on the Grasshopper definition can be seen in the Rhinoceros 3D screen (Figure 5-6), while the full Grasshopper definition can be seen in Figure 5-7.

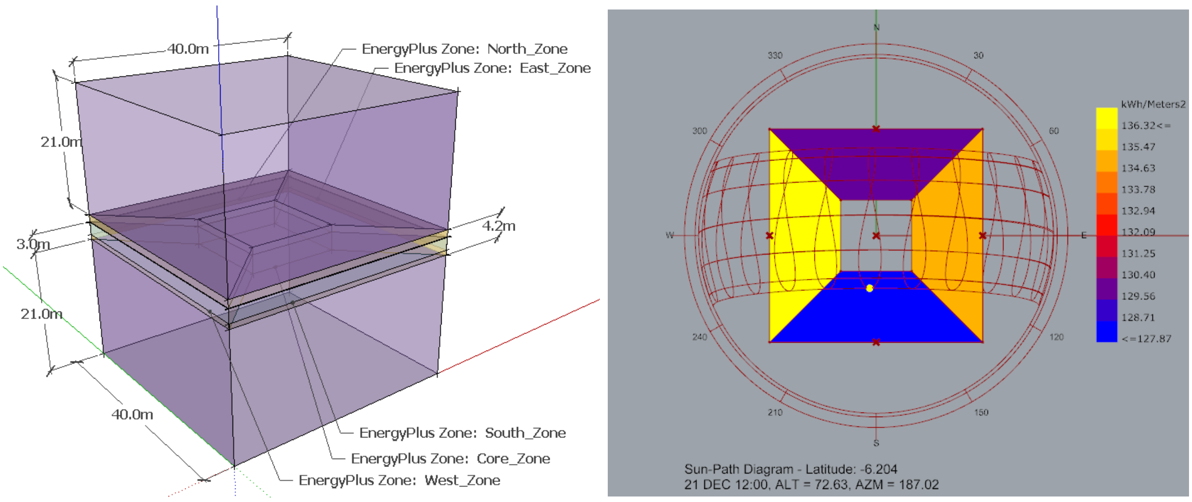


Figure 5-6 Grasshopper definition for parametric simulation in Grasshopper Rhinoceros 3D to Energy Plus from Ladybug and Honeybee plugins

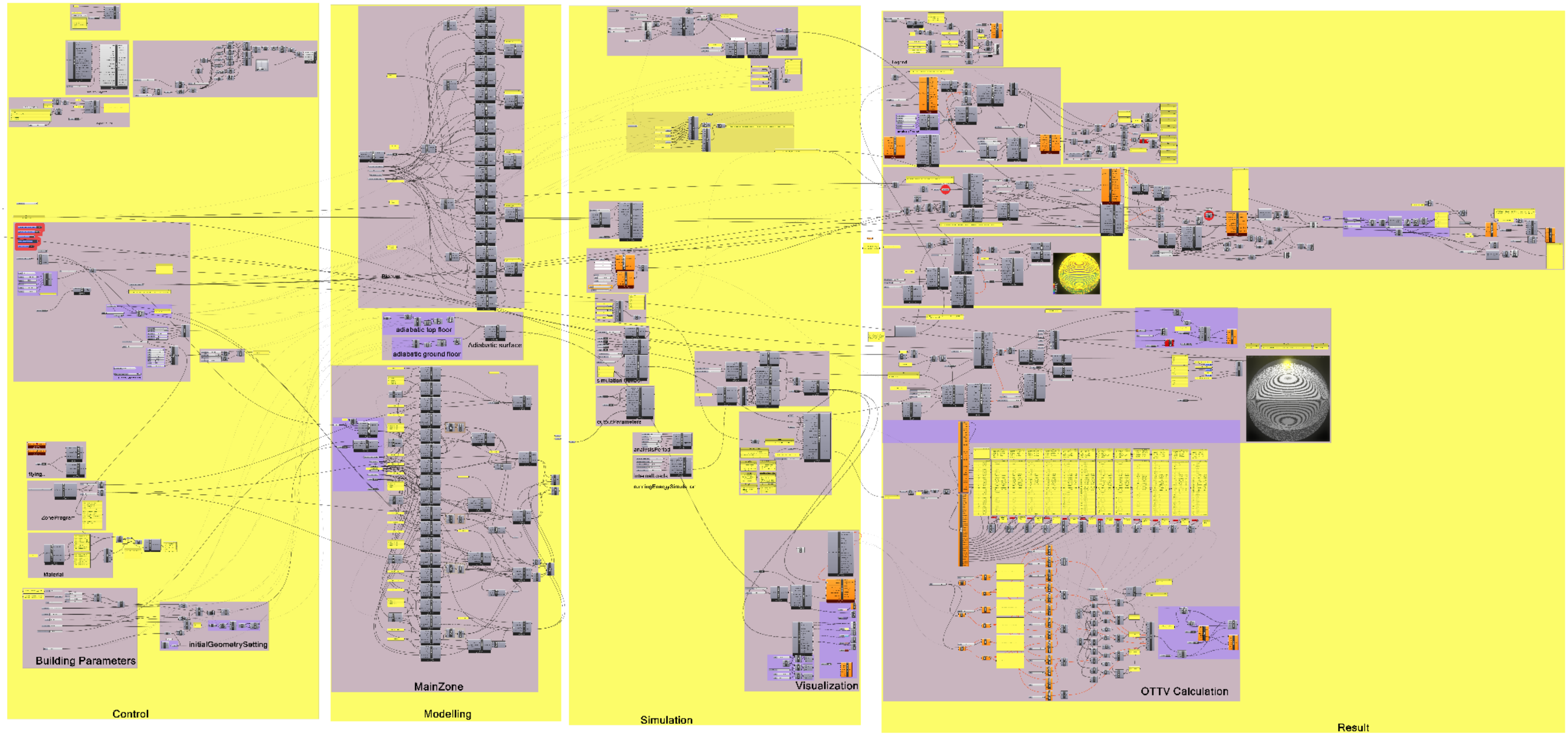


Figure 5-7 Grasshopper definitions for parametric simulation

The following (Table 5-6) is the building assumption for EnergyPlus 8.4 inside Ladybug and Honeybee.

Table 5-6 Building assumption

Building type	: Office
Weather data (.epw)	: JakartaDowntown.epw
Building Orientation	: 0°
Typical floor area	: 1,600 m^2
Floor to floor height	: 4.2 m
Floor to ceiling height	: 3.0 m
WWR	: 10% - 70%
Number of floors	: 11
Number of zones	: 5
Simulated floor	: 6 of 11
Simulation period	: Jan 1 to Dec 31
External Wall	: Plaster (15 mm) – Hebel block (100 mm) - Plaster (15 mm) U-value (wall) – with film: 1.039 W/m^2-K
HVAC System	: Ideal Load
Indoor Illuminance level	: 300 lux (based on Indonesia National Standard for office building (BSNI 2011a))
Opening glass types	: showed in Table 5-7.

Table 5-7 Glass types

Type	Name of Glass	U factor	SC	SHGC	Rel. Ht. Gain	Tvis
		W/m^2-K			W/m^2	
1	Glass Company A, Silver 20 OSW-SREX, NFRC ID 278	5.895	0.230	0.200	187	0.177
2	Glass Company A, 4 Mil Quantum/Silver/Quantum 10, NFRC ID 263	5.987	0.346	0.301	260	0.103
3	Glass Company B, NFRC ID 1112	5.687	0.461	0.401	331	0.090
4	Glass Company C, Panasap Dark Blue 8.0, NFRC ID 1200	5.744	0.579	0.504	406	0.494

5	Glass Company C, Panasap Dark Blue 5.0, NFRC ID 1246	5.848	0.692	0.602	477	0.624
6	Glass Company C, Indoflot Clear 15.0, NFRC ID 1219	5.515	0.816	0.710	554	0.833
7	Glass Company D, SentryGlas® Plus, NFRC ID 1123	5.657	0.920	0.801	621	0.887
8	Glass Company E, Clearvision 8, NFRC ID 4336	5.745	1.036	0.901	694	0.911

Source: WINDOW6.3

5.2.2 Simplification of Model for Modified Building Simulation

In this step, the 3D model from the first step was used with the addition of a Sudare layer in front of the windows. Due to the limitation of Energy Plus in recognizing minimum surface dimensions in modeling, it cannot recognize a surface less than or equal to 10 mm. The minimum diameter of the solid parts of the Sudare that could be used in the research is thus 10.01 mm. There were four types of Sudare with solid parts that had the same diameter but different-size spacers, of 20 mm, 10 mm, 5 mm, and 2.5 mm.

Two hundred twenty-four simulations were run. If the model used the full shape of a Sudare, it required around two hours for one simulation. The Sudare model was then simplified and compared with the results of the full shape and simplified model to choose a similar value to the OTTV and cooling load. Two types of simplified model were compared with the original full-shape geometry (circle shape) for the OTTV and cooling load in each direction. The result shows that the cross shape has a close value to the original full-shape model (Figure 5-8). In this step, the WWR for the model was 70% with clear glass SHGC 0.7. This would show the maximum result effect of the Sudare as a shading device.

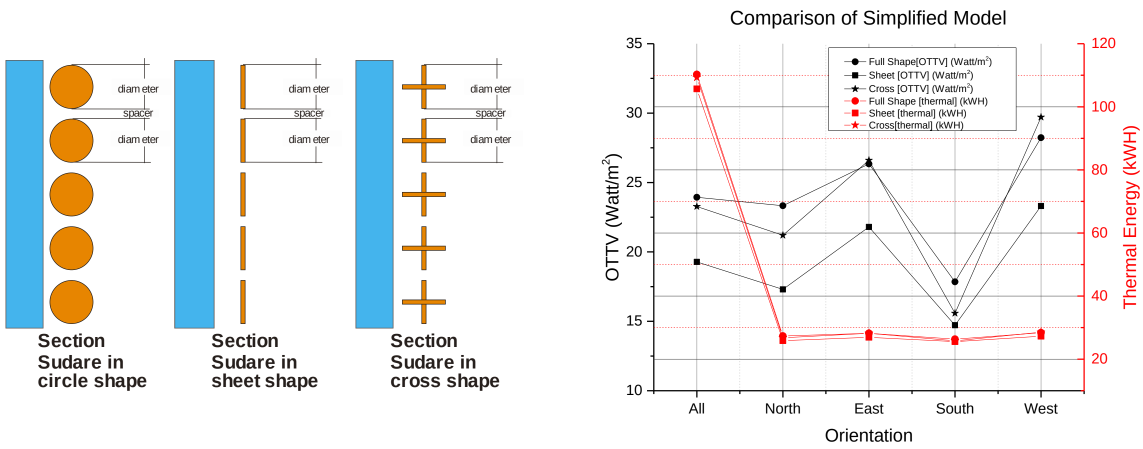


Figure 5-8 Comparison of OTTV and cooling load between two types of simplified-geometry Sudare and full-shape Sudare

5.2.3 Questionnaire for Rendering of Modified Building Model

After simulating the normal and modified model with Energy Plus, all configurations of the model were rendered using Autodesk 3DS Max. The rendering capability of 3ds Max can represent the real-world scene and has been validated in the Experimental Validation of Autodesk® 3ds Max® research (Reinhart & Breton 2009). The setup condition for each configuration was decided using the previous experiment condition to get the visibility value using the questionnaire (Figure 5-9). The sequence of illuminance for the outside varies from 0 lux to 1000 lux while that of the inside was maintained at 1000 lux. After the outside illuminance level reaches 1000 lux, the inside illuminance will gradually change from 1000 lux to 0 lux. Using this method, the visibility level and privacy level can be measured. From the inside to the outside, the aim was to get a high value of visibility. Meanwhile, from outside to inside, the aim was to get less visibility, which means high privacy. The collecting data process was done with a limited number of sequences using the same method of digital image experiment seen in the room experiment (Figure 5-10). The complete sequence can be seen in Appendix 3.

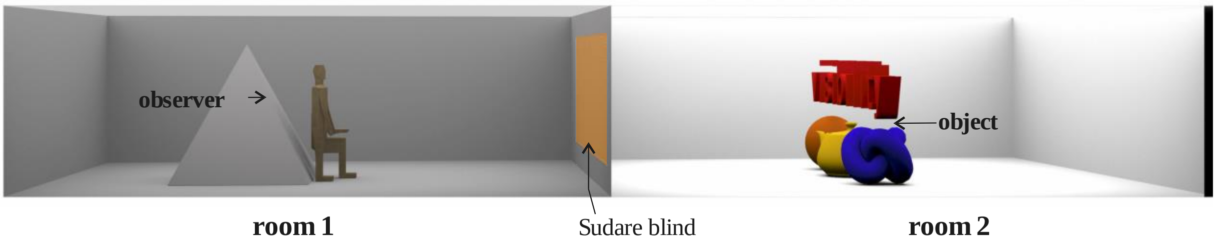
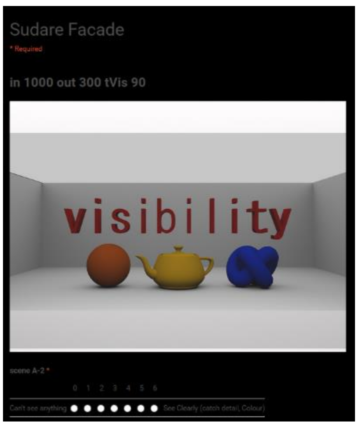


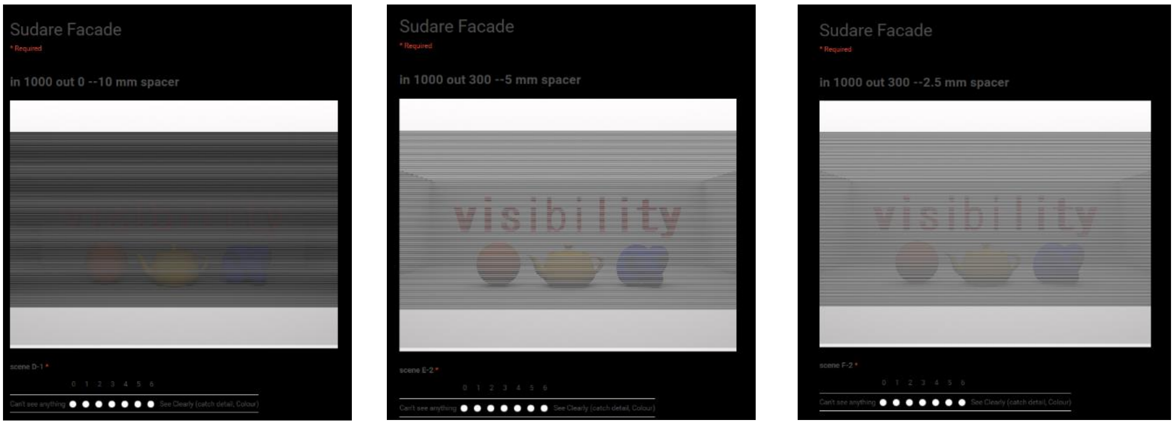
Figure 5-9 Setup room for visibility visualization using 3DS Max render



Clear Glass (TVis 90)

Tint Glass (TVis 20)

Sudare with 20 mm spacer



Sudare with 10 mm spacer | Sudare with 5 mm spacer | Sudare with 2.5 mm spacer

Figure 5-10 Digital rendering images experiment

5.2.4 Daylight Simulation

Daylight simulations were created within Honeybee, using the Daysim engine, and using the 3D model utilized in the first and second steps to maintain the consistency of model properties (Figure 5-11). Ten points away from window were created to record the illuminance level based on the climate-based sky that was created from the weather file. The simulations were done in four zones based on the orientation of the windows (North, East, South, West). Each result was plotted on a graph for the different types of façade configurations.

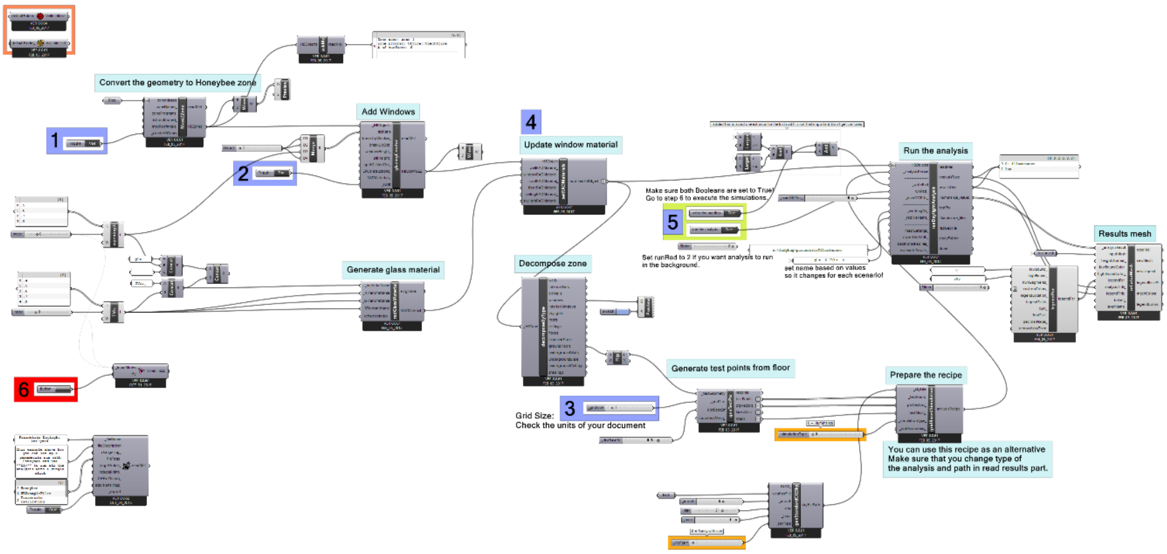


Figure 5-11 Daylight simulation Grasshopper script definition

5.2.5 Glare Simulation

Glare simulations were also created within Honeybee, using the Radiance engine, and using the 3D model utilized in the first and second steps to maintain the consistency of model properties. The result of the radiance simulation was luminance file in the HDRI image generated from fish eye camera lens type within the 3D modelling which can show the daylight glare probability (DGP) value (Figure 5-12). In the glare evaluation, simulations were carried out at five points for each orientation. The points were considered as a fish-eye lens camera facing the window at a distances of 1 m, 2.5 m, 4 m, 5.5 m, and 7 m.

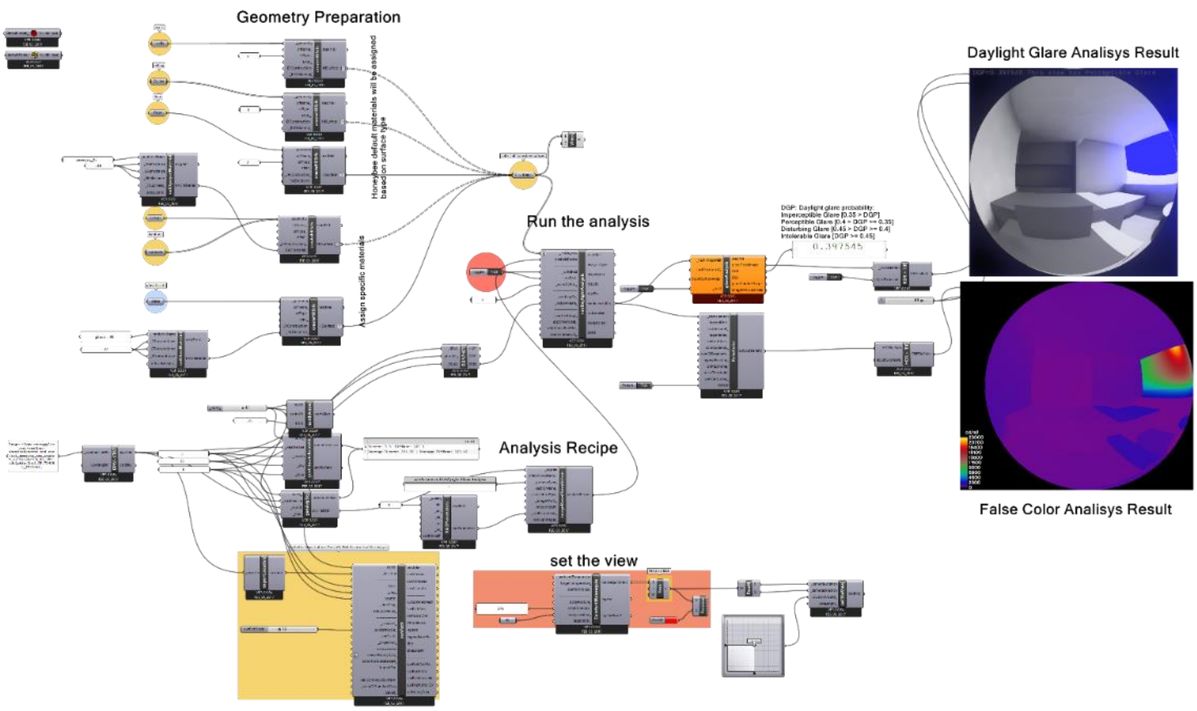


Figure 5-12 Glare simulation Grasshopper script definition

Chapter 6 Visibility Indices

6.1 Room Experiment

Data from the experiments have been compiled and the average level of illuminance at which respondents started to see objects can be seen in Table 6-1. Although the source of LED light was at the same level, the value of illuminance in the working table area was different because of the difference in the absorbance and reflectance material of the Sudare. The illuminance ratio between the observer room and the object room is calculated by dividing the illuminance value of the object room (I2) by the illuminance value of the observer room (I1). The smaller the illuminance value of the object room, the smaller the illuminance ratio.

Table 6-1 Average value of illuminance ratio (I2/I1) for each Sudare

Sudare type	Image	Room 1 (I1) [Observer]	Room 2 (I2) [Object]	I2/I1
type A (white big)		849.24	204.16	0.24
type B (light brown medium)		834.89	237.65	0.28
type C (dark brown medium)		824.93	152.55	0.18
type D (ivory medium small)		844.54	233.48	0.27
type E (mocha small)		840.95	181.19	0.21

The aim of this first part is to know the minimum condition of room 2 (object room) in which the observer starts to recognize the object. In this result, type C (dark brown medium) Sudare has the lowest illuminance ratio (0.18), which means it has the lowest illuminance level needed for the observer to start to see the object in the object room. Type C Sudare has the lowest whiteness (196 lux) of all the types.

In the second part of the questionnaire, the illuminance ratios increased, starting from 1, whereas the illuminance level between the observer room and the object room is the same. The distribution visibility value can be seen in Table 6-2.

Table 6-2 Illuminance ratio in each brightness illuminance level condition

Type	Level	10	09	08	07	06	05	04	03	02	01	00
type A	visibility	4.40	4.50	4.64	4.67	4.78	4.79	4.89	5.10	5.17	5.44	5.52
	I2/I1	1.00	1.12	1.26	1.45	1.70	2.04	2.55	3.21	4.30	8.15	87.58
type B	visibility	3.90	4.03	4.22	4.35	4.55	4.76	4.94	5.17	5.41	5.54	5.58
	I2/I1	1.00	1.12	1.26	1.45	1.71	2.05	2.55	3.23	4.32	8.19	85.44
type C	visibility	4.37	4.51	4.66	4.81	4.95	5.14	5.26	5.43	5.58	5.70	5.76
	I2/I1	1.00	1.12	1.25	1.44	1.70	2.05	2.54	3.24	4.39	8.60	83.78
type D	visibility	3.63	3.73	3.88	4.16	4.36	4.60	4.85	5.14	5.33	5.54	5.63
	I2/I1	1.00	1.13	1.27	1.45	1.71	2.07	2.58	3.28	4.47	8.77	86.04
type E	visibility	3.98	4.17	4.26	4.42	4.69	4.90	5.17	5.36	5.51	5.76	5.86
	I2/I1	1.00	1.13	1.26	1.45	1.71	2.06	2.57	3.25	4.43	8.78	85.92

From the visibility value of all configurations in the physical experiment step, it seems that observers give quite a high value of visibility with small different range. However, comparing each type of Sudare, there are variations that allow us to analyze the effect of different conditions of the environment.

Based on the average distribution of visibility value for each Sudare type at every step of illuminance level, all showed a value increase because of the decrease in the illuminance level in room 1 (observer room), as seen in Figure 6-1 and Table 6-2. Comparing the Sudare types based on diameter and spacer, a wider diameter and spacer did not always have a higher visibility value, and Type A Sudare (bigger diameter and wider spacer), with 24% VBR, had a higher value from level 10 to level 6, but after level 5, Type E Sudare (smaller diameter and narrower spacer), with 34% VBR, had a higher value than Type A Sudare. This means that in the lower illuminance ratio, Sudare with a large scale and a smaller VBR have a better visibility value, whereas in a high illuminance ratio, Sudare with a small scale and a bigger VBR have a better visibility value. This also happens if we compare Type A Sudare with Type D and Type B Sudare, which have nearly the same whiteness level. In Figure 6-2 (a) and Figure 6-2 (b), we can see that a smaller scale will result in a wider band range of visibility values from level 10 to level 0 condition. This result is also an indication that the scale of Sudare has to be analyzed in more detail in later research.

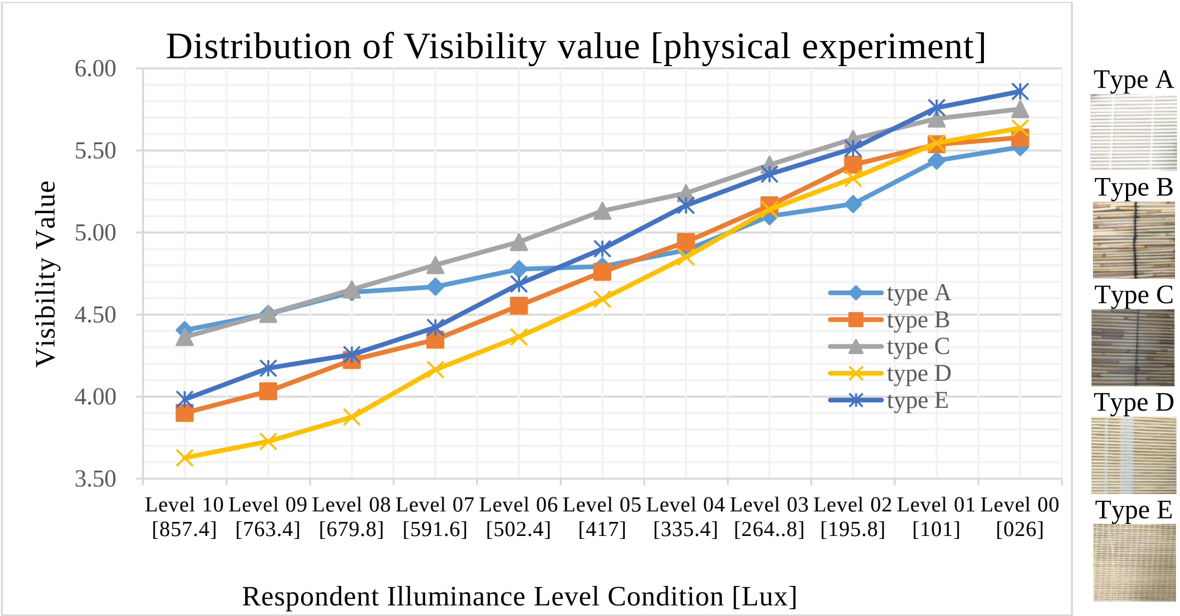
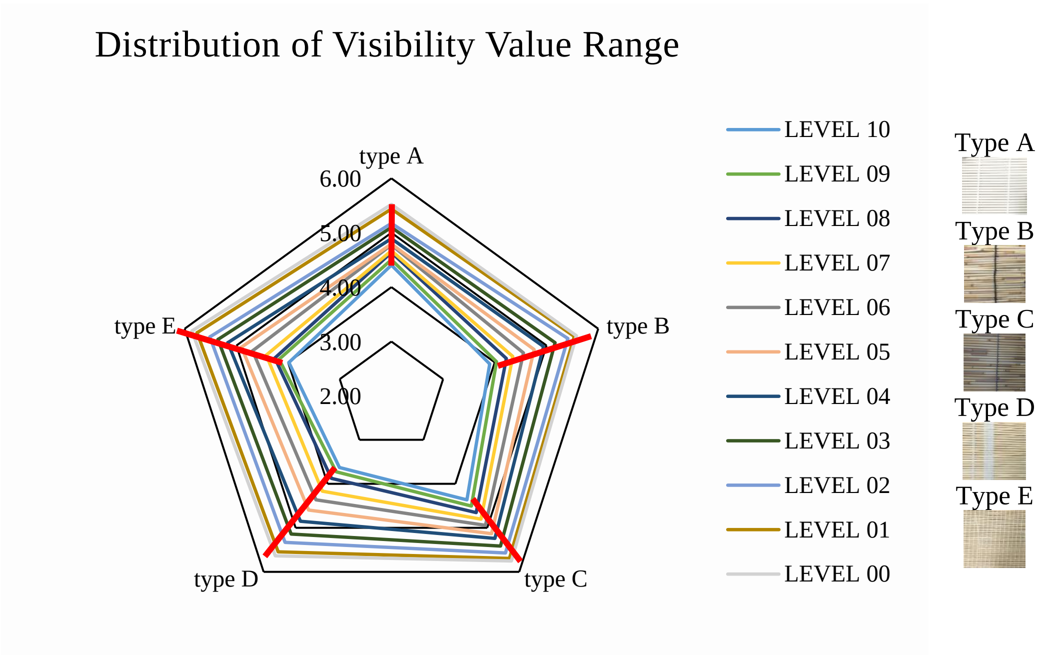
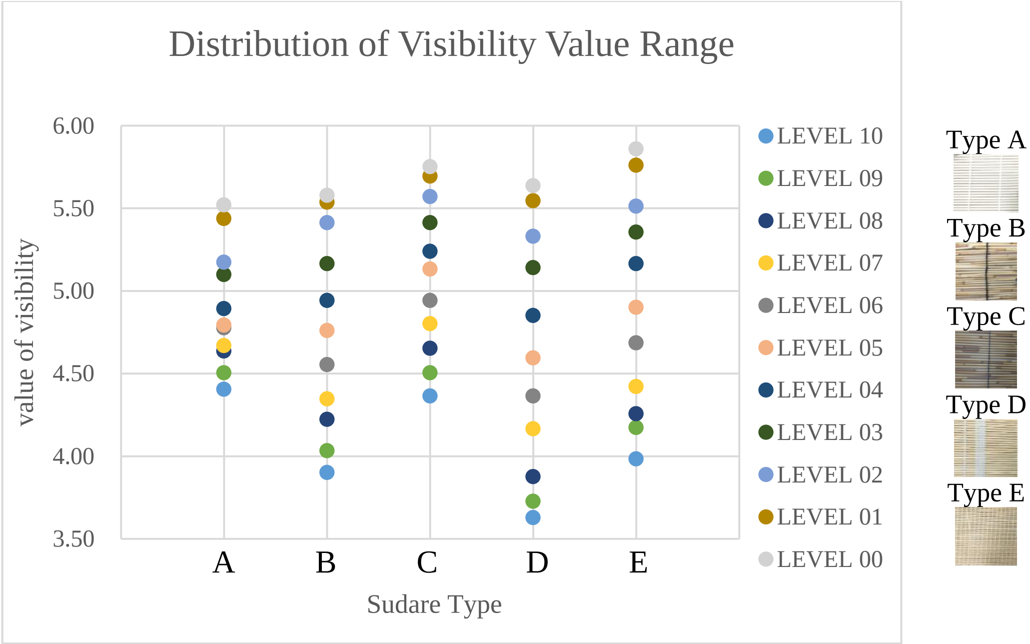


Figure 6-1 Average distribution value for each type of Sudare in every illuminance level condition

Comparing Type B (light brown, medium) and Type C (dark brown, medium) Sudare, these types have similar characteristics of diameter and spacer with different whiteness levels. Sudare with lower whiteness levels (Type C Sudare with a whiteness level of 196 lux) have a higher value of visibility at every level than those with a higher whiteness levels (Type B Sudare with whiteness level of 363 lux).



(a)



(b)

Figure 6-2 Distribution of visibility value

6.2 Digital Image Experiment

The next step was re-run the experiment using images from the previous experiment for 211 respondents. There were 106 questions divided into six parts. The first part was about respondent data (Figure 6-3).

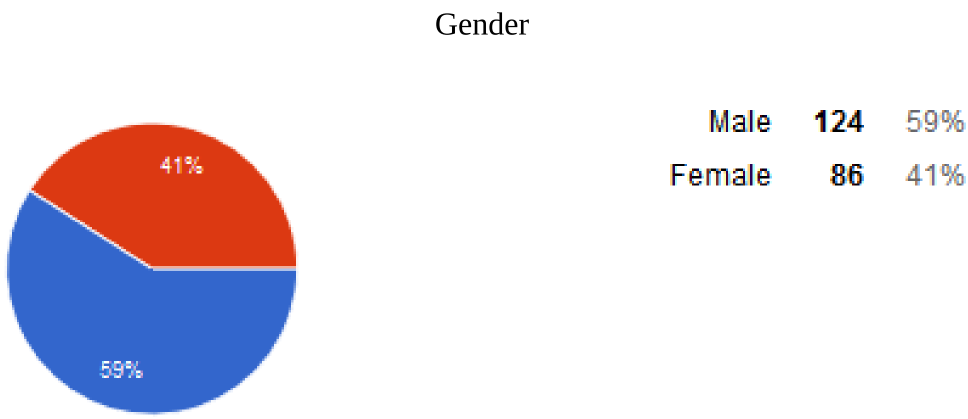
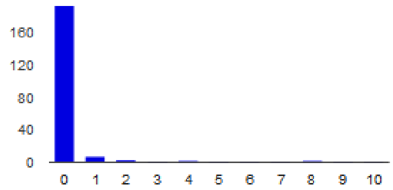
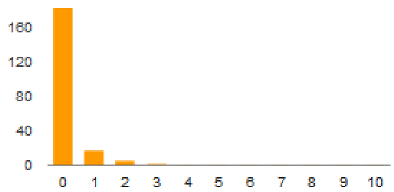
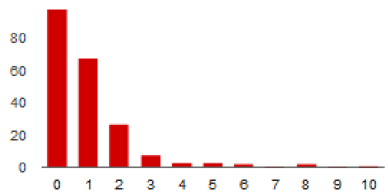
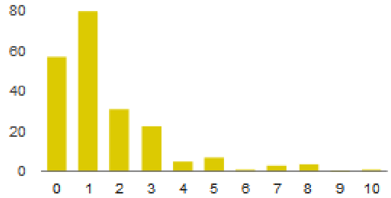
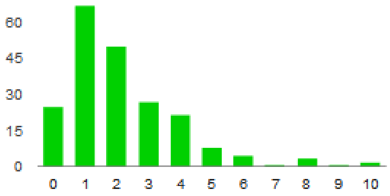
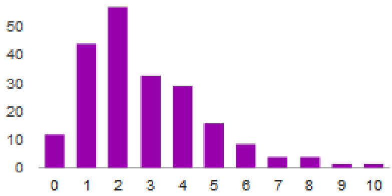
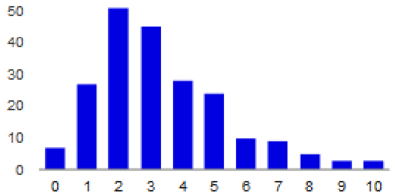
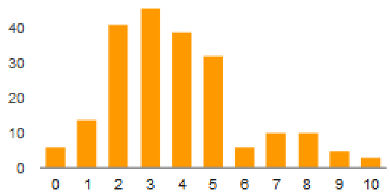
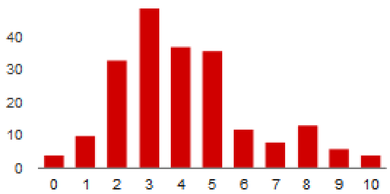


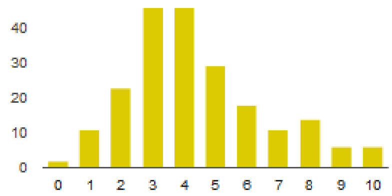
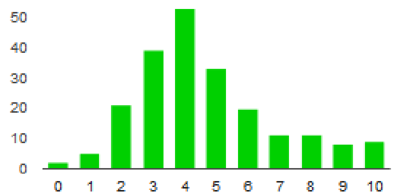
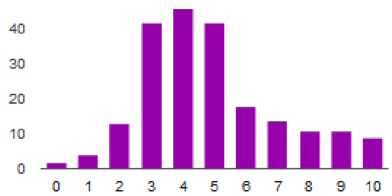
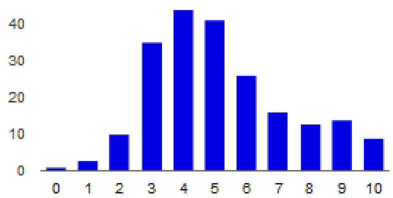
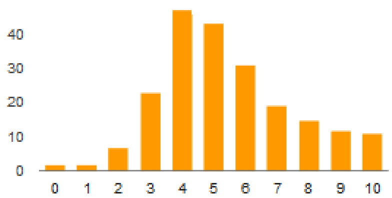
Figure 6-3 Respondent distribution

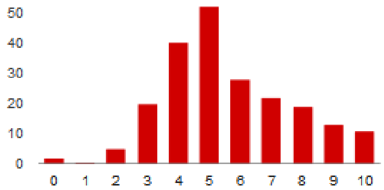
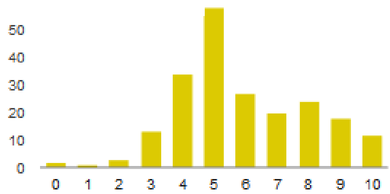
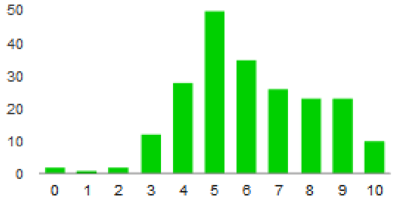
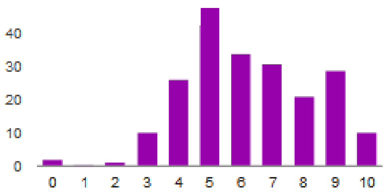
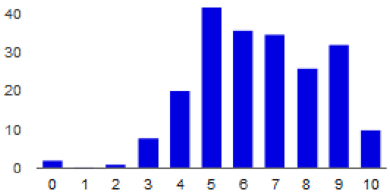
The second part was 21 questions about the visibility value in different illuminance conditions with Sudare Type A (white, big). The complete data can be seen in Table 6-3.

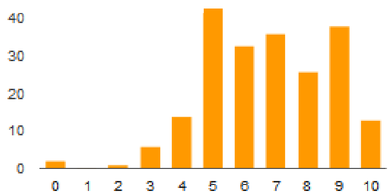
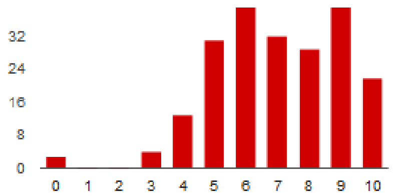
Table 6-3 Data questionnaire of Sudare Type A

No	Question	Graphic of data distribution
1	Can you see object behind the blind Type A-00?	 Can't see: 0 194 91.5% 1 8 3.8% 2 3 1.4% 3 1 0.5% 4 2 0.9% 5 0 0% 6 0 0% 7 1 0.5% 8 2 0.9% 9 0 0% Can see clearly: 10 1 0.5%
2	Can you see object behind the blind Type A-01?	 Can't see: 0 183 86.3% 1 18 8.5% 2 6 2.8% 3 2 0.9% 4 1 0.5% 5 0 0% 6 0 0% 7 0 0% 8 1 0.5% 9 0 0% Can see clearly: 10 1 0.5%
3	Can you see object behind the blind Type A-02?	 Can't see: 0 98 46.2% 1 68 32.1% 2 27 12.7% 3 8 3.8% 4 3 1.4% 5 3 1.4% 6 2 0.9% 7 0 0% 8 2 0.9% 9 0 0% Can see clearly: 10 1 0.5%
4	Can you see object behind the blind Type A-03?	 Can't see: 0 57 26.9% 1 80 37.7% 2 31 14.6% 3 23 10.8% 4 5 2.4% 5 7 3.3% 6 1 0.5% 7 3 1.4% 8 4 1.9% 9 0 0% Can see clearly: 10 1 0.5%

5	Can you see object behind the blind Type A-04?	 Can't see: 0 25 11.8% 1 67 31.6% 2 50 23.6% 3 27 12.7% 4 22 10.4% 5 8 3.8% 6 5 2.4% 7 1 0.5% 8 4 1.9% 9 1 0.5% Can see clearly: 10 2 0.9%
6	Can you see object behind the blind Type A-05?	 Can't see: 0 12 5.7% 1 44 20.8% 2 57 26.9% 3 33 15.6% 4 29 13.7% 5 16 7.5% 6 9 4.2% 7 4 1.9% 8 4 1.9% 9 2 0.9% Can see clearly: 10 2 0.9%
7	Can you see object behind the blind Type A-06?	 Can't see: 0 7 3.3% 1 27 12.7% 2 51 24.1% 3 45 21.2% 4 28 13.2% 5 24 11.3% 6 10 4.7% 7 9 4.2% 8 5 2.4% 9 3 1.4% Can see clearly: 10 3 1.4%
8	Can you see object behind the blind Type A-07?	 Can't see: 0 6 2.8% 1 14 6.6% 2 41 19.3% 3 46 21.7% 4 39 18.4% 5 32 15.1% 6 6 2.8% 7 10 4.7% 8 10 4.7% 9 5 2.4% Can see clearly: 10 3 1.4%
9	Can you see object behind the blind Type A-08?	 Can't see: 0 4 1.9% 1 10 4.7% 2 33 15.6% 3 49 23.1% 4 37 17.5% 5 36 17% 6 12 5.7% 7 8 3.8% 8 13 6.1% 9 6 2.8% Can see clearly: 10 4 1.9%

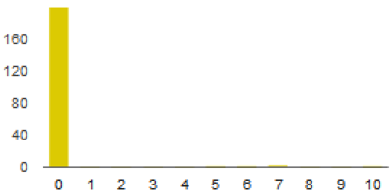
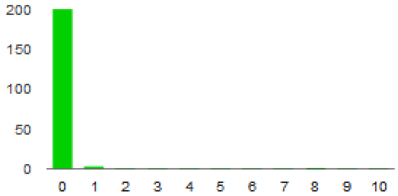
10	Can you see object behind the blind Type A-09?	 Can`t see: 0 2 0.9% 1 11 5.2% 2 23 10.8% 3 46 21.7% 4 46 21.7% 5 29 13.7% 6 18 8.5% 7 11 5.2% 8 14 6.6% 9 6 2.8% Can see clearly: 10 6 2.8%
11	Can you see object behind the blind Type A-10?	 Can`t see: 0 2 0.9% 1 5 2.4% 2 21 9.9% 3 39 18.4% 4 53 25% 5 33 15.6% 6 20 9.4% 7 11 5.2% 8 11 5.2% 9 8 3.8% Can see clearly: 10 9 4.2%
12	Can you see object behind the blind Type A-11?	 Can`t see: 0 2 0.9% 1 4 1.9% 2 13 6.1% 3 42 19.8% 4 46 21.7% 5 42 19.8% 6 18 8.5% 7 14 6.6% 8 11 5.2% 9 11 5.2% Can see clearly: 10 9 4.2%
13	Can you see object behind the blind Type A-12?	 Can`t see: 0 1 0.5% 1 3 1.4% 2 10 4.7% 3 35 16.5% 4 44 20.8% 5 41 19.3% 6 26 12.3% 7 16 7.5% 8 13 6.1% 9 14 6.6% Can see clearly: 10 9 4.2%
14	Can you see object behind the blind Type A-13?	 Can`t see: 0 2 0.9% 1 2 0.9% 2 7 3.3% 3 23 10.8% 4 47 22.2% 5 43 20.3% 6 31 14.6% 7 19 9% 8 15 7.1% 9 12 5.7% Can see clearly: 10 11 5.2%

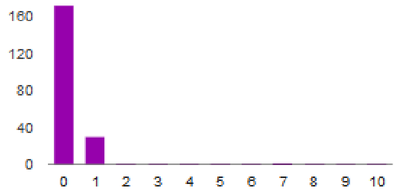
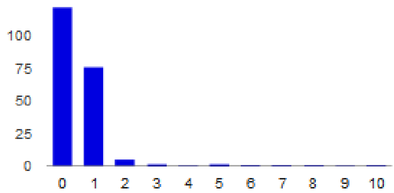
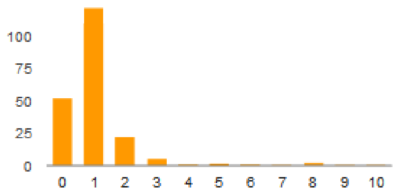
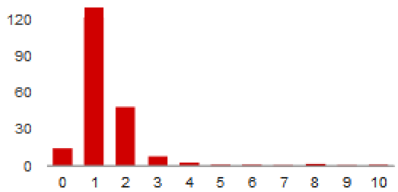
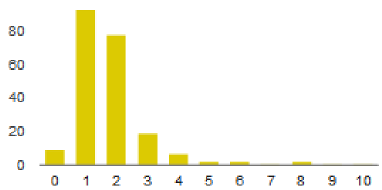
15	Can you see object behind the blind Type A-14?	 	Can`t see: 0 **2** 0.9% 1 **0** 0% 2 **5** 2.4% 3 **20** 9.4% 4 **40** 18.9% 5 **52** 24.5% 6 **28** 13.2% 7 **22** 10.4% 8 **19** 9% 9 **13** 6.1% Can see clearly: 10 **11** 5.2%
16	Can you see object behind the blind Type A-15?	 	Can`t see: 0 **2** 0.9% 1 **1** 0.5% 2 **3** 1.4% 3 **13** 6.1% 4 **34** 16% 5 **58** 27.4% 6 **27** 12.7% 7 **20** 9.4% 8 **24** 11.3% 9 **18** 8.5% Can see clearly: 10 **12** 5.7%
17	Can you see object behind the blind Type A-16?	 	Can`t see: 0 **2** 0.9% 1 **1** 0.5% 2 **2** 0.9% 3 **12** 5.7% 4 **28** 13.2% 5 **50** 23.6% 6 **35** 16.5% 7 **26** 12.3% 8 **23** 10.8% 9 **23** 10.8% Can see clearly: 10 **10** 4.7%
18	Can you see object behind the blind Type A-17?	 	Can`t see: 0 **2** 0.9% 1 **0** 0% 2 **1** 0.5% 3 **10** 4.7% 4 **26** 12.3% 5 **48** 22.6% 6 **34** 16% 7 **31** 14.6% 8 **21** 9.9% 9 **29** 13.7% Can see clearly: 10 **10** 4.7%
19	Can you see object behind the blind Type A-18?	 	Can`t see: 0 **2** 0.9% 1 **0** 0% 2 **1** 0.5% 3 **8** 3.8% 4 **20** 9.4% 5 **42** 19.8% 6 **36** 17% 7 **35** 16.5% 8 **26** 12.3% 9 **32** 15.1% Can see clearly: 10 **10** 4.7%

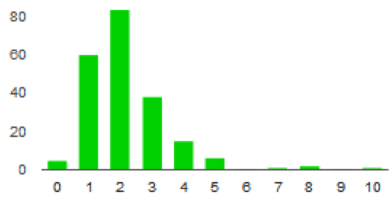
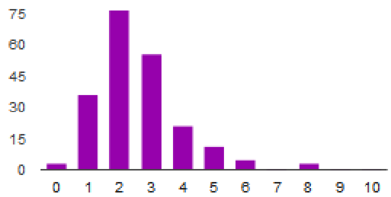
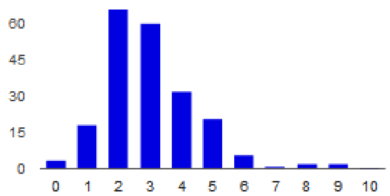
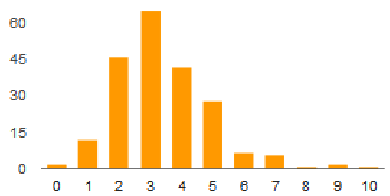
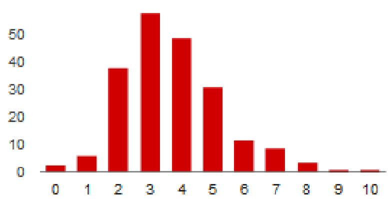
20	Can you see object behind the blind Type A-19?	 Can`t see: 0 **2** 0.9% 1 **0** 0% 2 **1** 0.5% 3 **6** 2.8% 4 **14** 6.6% 5 **43** 20.3% 6 **33** 15.6% 7 **36** 17% 8 **26** 12.3% 9 **38** 17.9% Can see clearly: 10 **13** 6.1%
21	Can you see object behind the blind Type A-20?	 Can`t see: 0 **3** 1.4% 1 **0** 0% 2 **0** 0% 3 **4** 1.9% 4 **13** 6.1% 5 **31** 14.6% 6 **39** 18.4% 7 **32** 15.1% 8 **29** 13.7% 9 **39** 18.4% Can see clearly: 10 **22** 10.4%

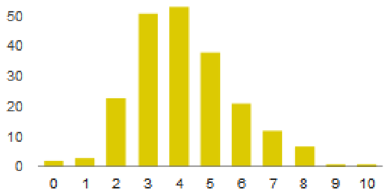
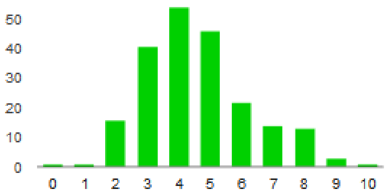
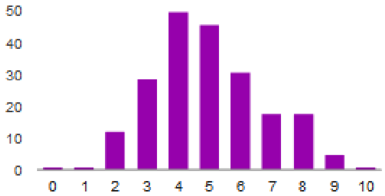
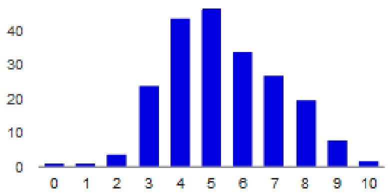
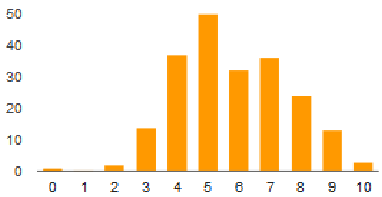
The third part was 21 questions about the visibility value in different illuminance conditions with Sudare Type B (light brown, medium). The complete data can be seen in Table 6-4.

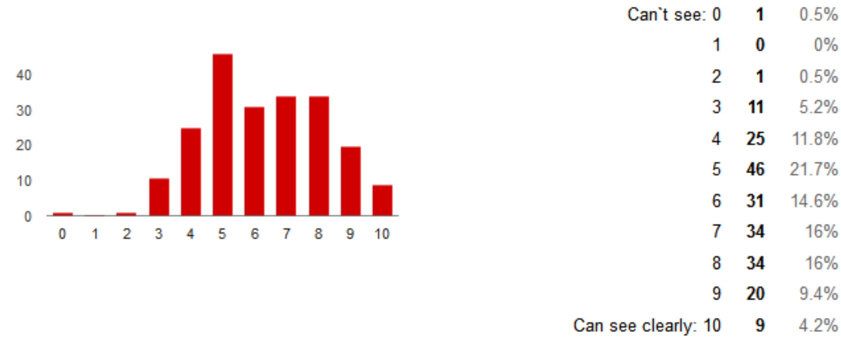
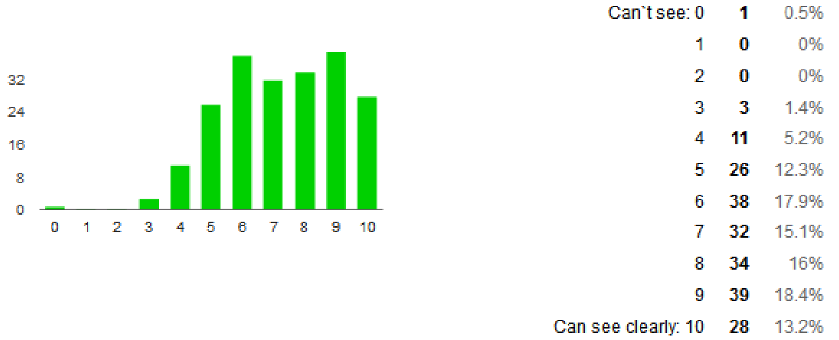
Table 6-4 Data questionnaire of Sudare Type B

No	Question	Graphic of data distribution
1	Can you see object behind the blind Type B-00?	 Can`t see: 0 **199** 93.9% 1 **1** 0.5% 2 **0** 0% 3 **1** 0.5% 4 **0** 0% 5 **2** 0.9% 6 **2** 0.9% 7 **3** 1.4% 8 **1** 0.5% 9 **1** 0.5% Can see clearly: 10 **2** 0.9%
2	Can you see object behind the blind Type B-01?	 Can`t see: 0 **201** 94.8% 1 **5** 2.4% 2 **0** 0% 3 **1** 0.5% 4 **0** 0% 5 **1** 0.5% 6 **1** 0.5% 7 **0** 0% 8 **2** 0.9% 9 **0** 0% Can see clearly: 10 **1** 0.5%

3	Can you see object behind the blind Type B-02?		Can`t see: 0 172 81.1% 1 31 14.6% 2 1 0.5% 3 1 0.5% 4 1 0.5% 5 1 0.5% 6 1 0.5% 7 2 0.9% 8 1 0.5% 9 0 0% Can see clearly: 10 1 0.5%
4	Can you see object behind the blind Type B-03?		Can`t see: 0 122 57.5% 1 76 35.8% 2 6 2.8% 3 2 0.9% 4 0 0% 5 2 0.9% 6 1 0.5% 7 1 0.5% 8 1 0.5% 9 0 0% Can see clearly: 10 1 0.5%
5	Can you see object behind the blind Type B-04?		Can`t see: 0 53 25% 1 123 58% 2 23 10.8% 3 6 2.8% 4 1 0.5% 5 2 0.9% 6 1 0.5% 7 0 0% 8 3 1.4% 9 0 0% Can see clearly: 10 0 0%
6	Can you see object behind the blind Type B-05?		Can`t see: 0 15 7.1% 1 131 61.8% 2 49 23.1% 3 9 4.2% 4 3 1.4% 5 1 0.5% 6 1 0.5% 7 0 0% 8 2 0.9% 9 0 0% Can see clearly: 10 1 0.5%
7	Can you see object behind the blind Type B-06?		Can`t see: 0 9 4.2% 1 93 43.9% 2 78 36.8% 3 19 9% 4 7 3.3% 5 2 0.9% 6 2 0.9% 7 0 0% 8 2 0.9% 9 0 0% Can see clearly: 10 0 0%

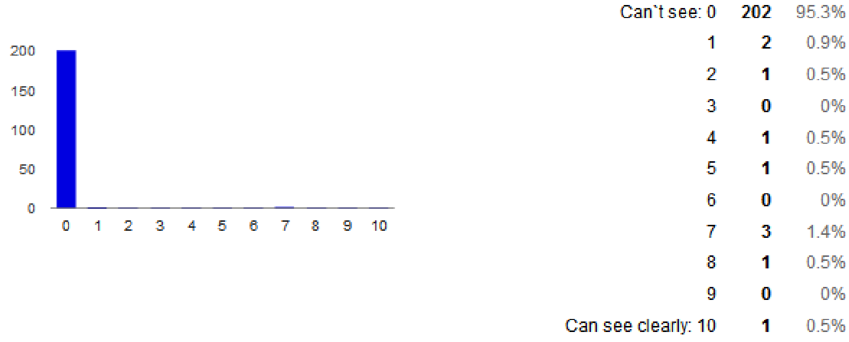
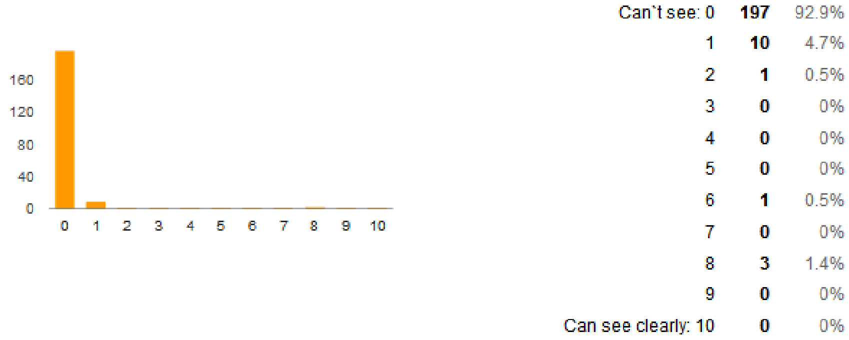
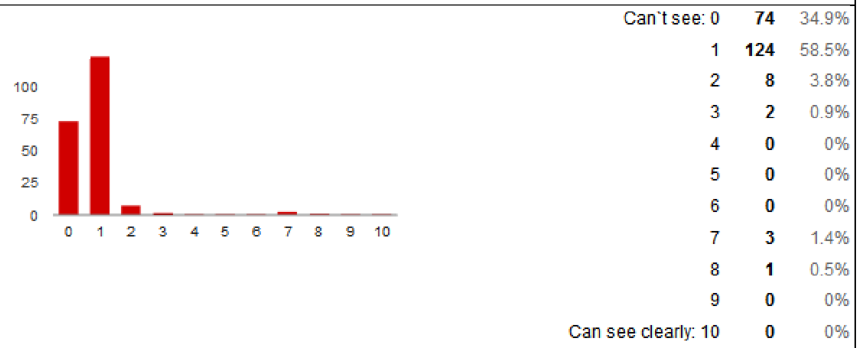
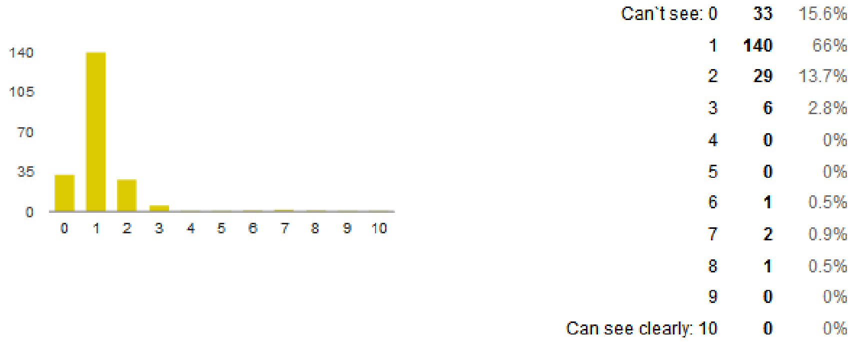
8	Can you see object behind the blind Type B-07?	 Can`t see: 0 **5** 2.4% 1 **60** 28.3% 2 **84** 39.6% 3 **38** 17.9% 4 **15** 7.1% 5 **6** 2.8% 6 **0** 0% 7 **1** 0.5% 8 **2** 0.9% 9 **0** 0% Can see clearly: 10 **1** 0.5%
9	Can you see object behind the blind Type B-08?	 Can`t see: 0 **3** 1.4% 1 **36** 17% 2 **77** 36.3% 3 **56** 26.4% 4 **21** 9.9% 5 **11** 5.2% 6 **5** 2.4% 7 **0** 0% 8 **3** 1.4% 9 **0** 0% Can see clearly: 10 **0** 0%
10	Can you see object behind the blind Type B-09?	 Can`t see: 0 **4** 1.9% 1 **18** 8.5% 2 **66** 31.1% 3 **60** 28.3% 4 **32** 15.1% 5 **21** 9.9% 6 **6** 2.8% 7 **1** 0.5% 8 **2** 0.9% 9 **2** 0.9% Can see clearly: 10 **0** 0%
11	Can you see object behind the blind Type B-10?	 Can`t see: 0 **2** 0.9% 1 **12** 5.7% 2 **46** 21.7% 3 **65** 30.7% 4 **42** 19.8% 5 **28** 13.2% 6 **7** 3.3% 7 **6** 2.8% 8 **1** 0.5% 9 **2** 0.9% Can see clearly: 10 **1** 0.5%
12	Can you see object behind the blind Type B-11?	 Can`t see: 0 **3** 1.4% 1 **6** 2.8% 2 **38** 17.9% 3 **58** 27.4% 4 **49** 23.1% 5 **31** 14.6% 6 **12** 5.7% 7 **9** 4.2% 8 **4** 1.9% 9 **1** 0.5% Can see clearly: 10 **1** 0.5%

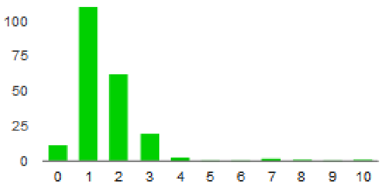
13	Can you see object behind the blind Type B-12?		Can`t see: 0 **2** 0.9% 1 **3** 1.4% 2 **23** 10.8% 3 **51** 24.1% 4 **53** 25% 5 **38** 17.9% 6 **21** 9.9% 7 **12** 5.7% 8 **7** 3.3% 9 **1** 0.5% Can see clearly: 10 **1** 0.5%
14	Can you see object behind the blind Type B-13?		Can`t see: 0 **1** 0.5% 1 **1** 0.5% 2 **16** 7.5% 3 **41** 19.3% 4 **54** 25.5% 5 **46** 21.7% 6 **22** 10.4% 7 **14** 6.6% 8 **13** 6.1% 9 **3** 1.4% Can see clearly: 10 **1** 0.5%
15	Can you see object behind the blind Type B-14?		Can`t see: 0 **1** 0.5% 1 **1** 0.5% 2 **12** 5.7% 3 **29** 13.7% 4 **50** 23.6% 5 **46** 21.7% 6 **31** 14.6% 7 **18** 8.5% 8 **18** 8.5% 9 **5** 2.4% Can see clearly: 10 **1** 0.5%
16	Can you see object behind the blind Type B-15?		Can`t see: 0 **1** 0.5% 1 **1** 0.5% 2 **4** 1.9% 3 **24** 11.3% 4 **44** 20.8% 5 **47** 22.2% 6 **34** 16% 7 **27** 12.7% 8 **20** 9.4% 9 **8** 3.8% Can see clearly: 10 **2** 0.9%
17	Can you see object behind the blind Type B-16?		Can`t see: 0 **1** 0.5% 1 **0** 0% 2 **2** 0.9% 3 **14** 6.6% 4 **37** 17.5% 5 **50** 23.6% 6 **32** 15.1% 7 **36** 17% 8 **24** 11.3% 9 **13** 6.1% Can see clearly: 10 **3** 1.4%

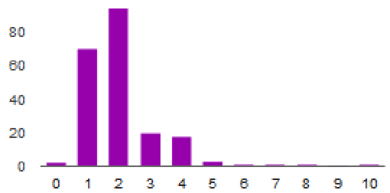
<table>
<tr><td>18</td><td>Can you see object behind the blind Type B-17?</td><td>
</td></tr>
<tr><td>19</td><td>Can you see object behind the blind Type B-18?</td><td>
</td></tr>
<tr><td>20</td><td>Can you see object behind the blind Type B-19?</td><td>
</td></tr>
<tr><td>21</td><td>Can you see object behind the blind Type B-20?</td><td>
</td></tr>
</table>

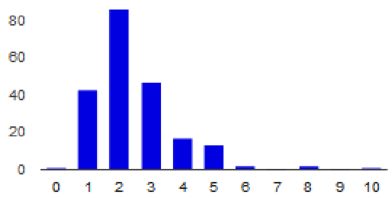
The fourth part was 21 questions about the visibility value in different illuminance conditions with Sudare Type C (dark brown, medium). The complete data can be seen in Table 6-5.

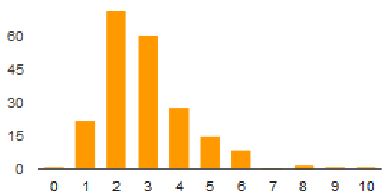
Table 6-5 Data questionnaire of Sudare Type C

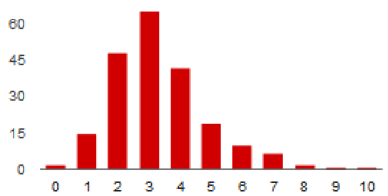
No	Question	Graphic of data distribution
1	Can you see object behind the blind Type C-00?	
2	Can you see object behind the blind Type C-01?	
3	Can you see object behind the blind Type C-02?	
4	Can you see object behind the blind Type C-03?	

<table>
<tr><td>5</td><td>Can you see object behind the blind Type C-04?</td><td>


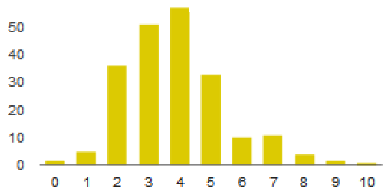
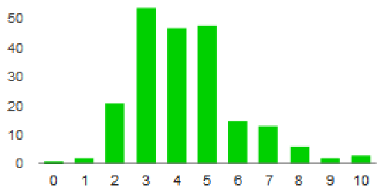
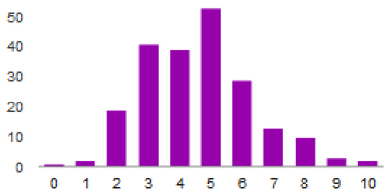
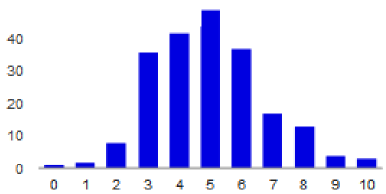
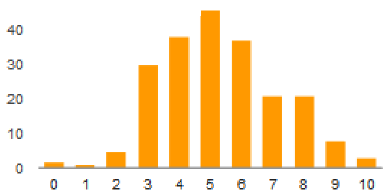
Can`t see: 0 12 5.7%
1 111 52.4%
2 62 29.2%
3 20 9.4%
4 3 1.4%
5 0 0%
6 0 0%
7 2 0.9%
8 1 0.5%
9 0 0%
Can see clearly: 10 1 0.5%</td></tr>
<tr><td>6</td><td>Can you see object behind the blind Type C-05?</td><td>


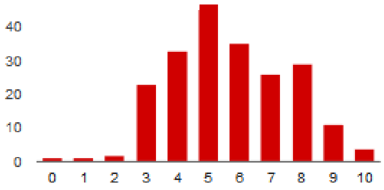
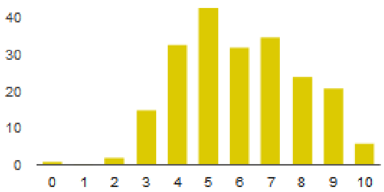
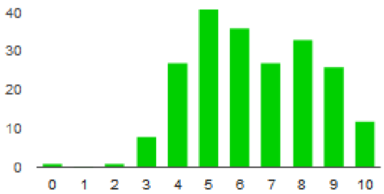
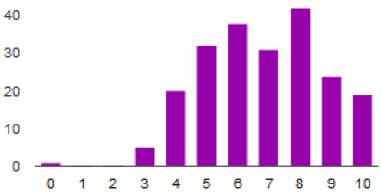
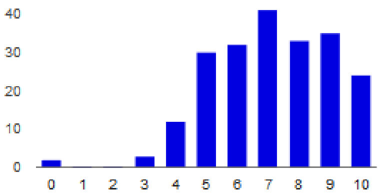
Can`t see: 0 2 0.9%
1 70 33%
2 95 44.8%
3 20 9.4%
4 18 8.5%
5 3 1.4%
6 1 0.5%
7 1 0.5%
8 1 0.5%
9 0 0%
Can see clearly: 10 1 0.5%</td></tr>
<tr><td>7</td><td>Can you see object behind the blind Type C-06?</td><td>


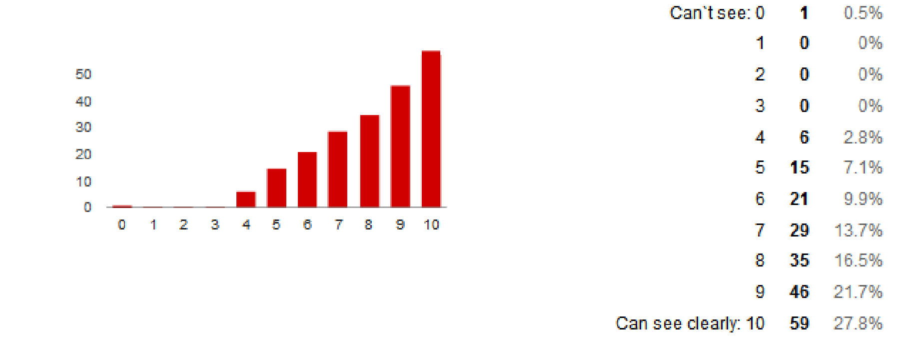
Can`t see: 0 1 0.5%
1 43 20.3%
2 86 40.6%
3 47 22.2%
4 17 8%
5 13 6.1%
6 2 0.9%
7 0 0%
8 2 0.9%
9 0 0%
Can see clearly: 10 1 0.5%</td></tr>
<tr><td>8</td><td>Can you see object behind the blind Type C-07?</td><td>


Can`t see: 0 1 0.5%
1 22 10.4%
2 72 34%
3 61 28.8%
4 28 13.2%
5 15 7.1%
6 9 4.2%
7 0 0%
8 2 0.9%
9 1 0.5%
Can see clearly: 10 1 0.5%</td></tr>
<tr><td>9</td><td>Can you see object behind the blind Type C-08?</td><td>


Can`t see: 0 2 0.9%
1 15 7.1%
2 48 22.6%
3 65 30.7%
4 42 19.8%
5 19 9%
6 10 4.7%
7 7 3.3%
8 2 0.9%
9 1 0.5%
Can see clearly: 10 1 0.5%</td></tr>
</table>

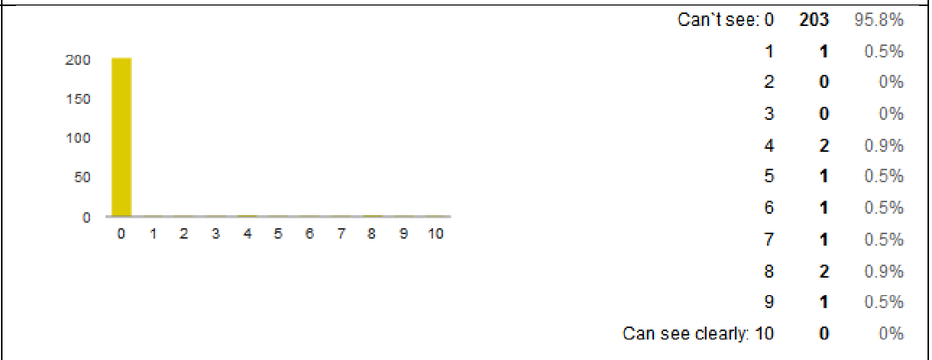
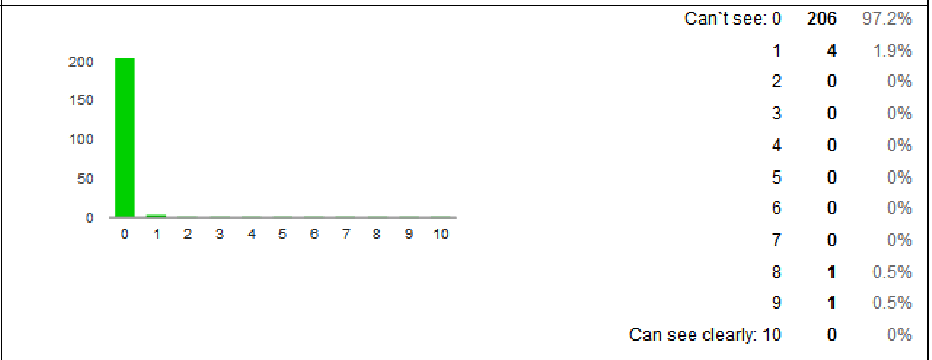
10	Can you see object behind the blind Type C-09?		Can`t see: 0 **2** 0.9% 1 **5** 2.4% 2 **36** 17% 3 **51** 24.1% 4 **57** 26.9% 5 **33** 15.6% 6 **10** 4.7% 7 **11** 5.2% 8 **4** 1.9% 9 **2** 0.9% Can see clearly: 10 **1** 0.5%
11	Can you see object behind the blind Type C-10?		Can`t see: 0 **1** 0.5% 1 **2** 0.9% 2 **21** 9.9% 3 **54** 25.5% 4 **47** 22.2% 5 **48** 22.6% 6 **15** 7.1% 7 **13** 6.1% 8 **6** 2.8% 9 **2** 0.9% Can see clearly: 10 **3** 1.4%
12	Can you see object behind the blind Type C-11?		Can`t see: 0 **1** 0.5% 1 **2** 0.9% 2 **19** 9% 3 **41** 19.3% 4 **39** 18.4% 5 **53** 25% 6 **29** 13.7% 7 **13** 6.1% 8 **10** 4.7% 9 **3** 1.4% Can see clearly: 10 **2** 0.9%
13	Can you see object behind the blind Type C-12?		Can`t see: 0 **1** 0.5% 1 **2** 0.9% 2 **8** 3.8% 3 **36** 17% 4 **42** 19.8% 5 **49** 23.1% 6 **37** 17.5% 7 **17** 8% 8 **13** 6.1% 9 **4** 1.9% Can see clearly: 10 **3** 1.4%
14	Can you see object behind the blind Type C-13?		Can`t see: 0 **2** 0.9% 1 **1** 0.5% 2 **5** 2.4% 3 **30** 14.2% 4 **38** 17.9% 5 **46** 21.7% 6 **37** 17.5% 7 **21** 9.9% 8 **21** 9.9% 9 **8** 3.8% Can see clearly: 10 **3** 1.4%

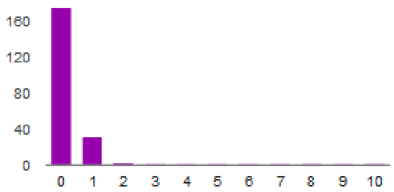
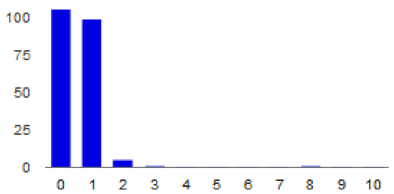
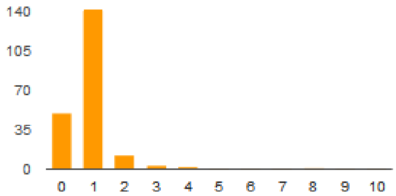
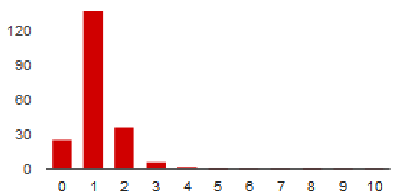
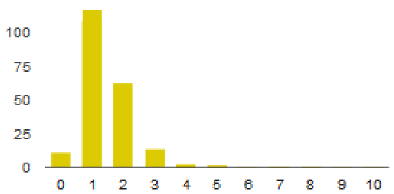
15	Can you see object behind the blind Type C-14?		Can`t see: 0 **1** 0.5% 1 **1** 0.5% 2 **2** 0.9% 3 **23** 10.8% 4 **33** 15.6% 5 **47** 22.2% 6 **35** 16.5% 7 **26** 12.3% 8 **29** 13.7% 9 **11** 5.2% Can see clearly: 10 **4** 1.9%
16	Can you see object behind the blind Type C-15?		Can`t see: 0 **1** 0.5% 1 **0** 0% 2 **2** 0.9% 3 **15** 7.1% 4 **33** 15.6% 5 **43** 20.3% 6 **32** 15.1% 7 **35** 16.5% 8 **24** 11.3% 9 **21** 9.9% Can see clearly: 10 **6** 2.8%
17	Can you see object behind the blind Type C-16?		Can`t see: 0 **1** 0.5% 1 **0** 0% 2 **1** 0.5% 3 **8** 3.8% 4 **27** 12.7% 5 **41** 19.3% 6 **36** 17% 7 **27** 12.7% 8 **33** 15.6% 9 **26** 12.3% Can see clearly: 10 **12** 5.7%
18	Can you see object behind the blind Type C-17?		Can`t see: 0 **1** 0.5% 1 **0** 0% 2 **0** 0% 3 **5** 2.4% 4 **20** 9.4% 5 **32** 15.1% 6 **38** 17.9% 7 **31** 14.6% 8 **42** 19.8% 9 **24** 11.3% Can see clearly: 10 **19** 9%
19	Can you see object behind the blind Type C-18?		Can`t see: 0 **2** 0.9% 1 **0** 0% 2 **0** 0% 3 **3** 1.4% 4 **12** 5.7% 5 **30** 14.2% 6 **32** 15.1% 7 **41** 19.3% 8 **33** 15.6% 9 **35** 16.5% Can see clearly: 10 **24** 11.3%

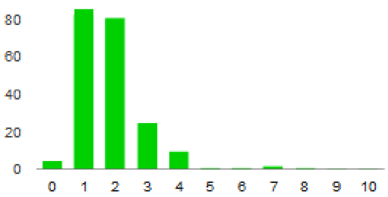
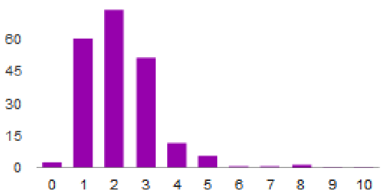
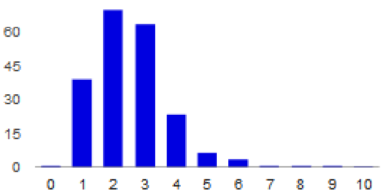
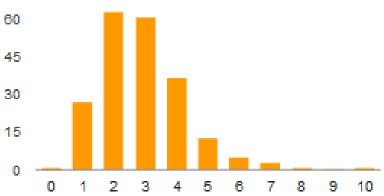
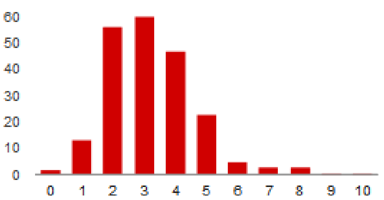
20	Can you see object behind the blind Type C-19?	
21	Can you see object behind the blind Type C-20?	

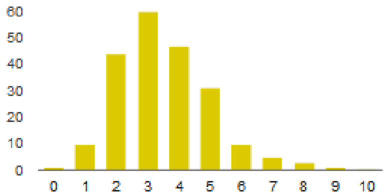
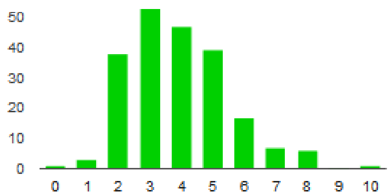
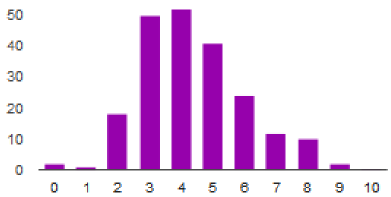
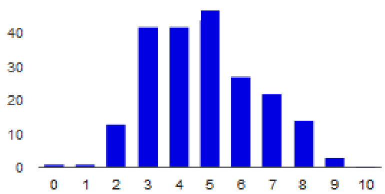
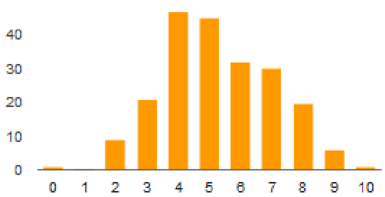
The sixth part was 21 questions about the visibility value in different illuminance conditions with Sudare Type D (ivory medium small). The complete data can be seen in Table 6-6.

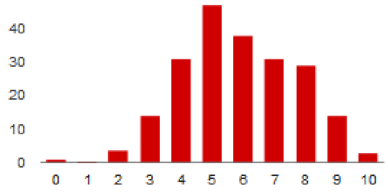
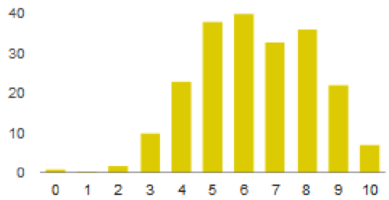
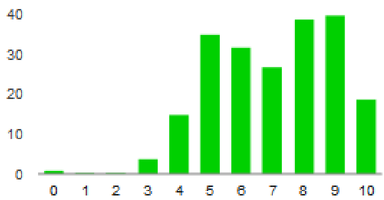
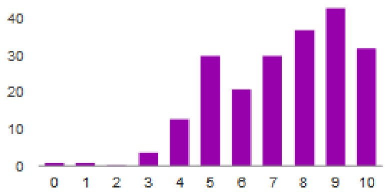
Table 6-6 Data questionnaire of Sudare type D

No	Question	Graphic of data distribution
1	Can you see object behind the blind Type D-00?	
2	Can you see object behind the blind Type D-01?	

3	Can you see object behind the blind Type D-02?	 Can`t see: 0 **177** 83.5% 1 **31** 14.6% 2 **2** 0.9% 3 **0** 0% 4 **0** 0% 5 **0** 0% 6 **0** 0% 7 **0** 0% 8 **1** 0.5% 9 **0** 0% Can see clearly: 10 **1** 0.5%
4	Can you see object behind the blind Type D-03?	 Can`t see: 0 **106** 50% 1 **99** 46.7% 2 **5** 2.4% 3 **1** 0.5% 4 **0** 0% 5 **0** 0% 6 **0** 0% 7 **0** 0% 8 **1** 0.5% 9 **0** 0% Can see clearly: 10 **0** 0%
5	Can you see object behind the blind Type D-04?	 Can`t see: 0 **50** 23.6% 1 **143** 67.5% 2 **13** 6.1% 3 **3** 1.4% 4 **2** 0.9% 5 **0** 0% 6 **0** 0% 7 **0** 0% 8 **1** 0.5% 9 **0** 0% Can see clearly: 10 **0** 0%
6	Can you see object behind the blind Type D-05?	 Can`t see: 0 **26** 12.3% 1 **138** 65.1% 2 **37** 17.5% 3 **7** 3.3% 4 **2** 0.9% 5 **1** 0.5% 6 **0** 0% 7 **0** 0% 8 **1** 0.5% 9 **0** 0% Can see clearly: 10 **0** 0%
7	Can you see object behind the blind Type D-06?	 Can`t see: 0 **11** 5.2% 1 **117** 55.2% 2 **63** 29.7% 3 **14** 6.6% 4 **3** 1.4% 5 **2** 0.9% 6 **0** 0% 7 **1** 0.5% 8 **1** 0.5% 9 **0** 0% Can see clearly: 10 **0** 0%

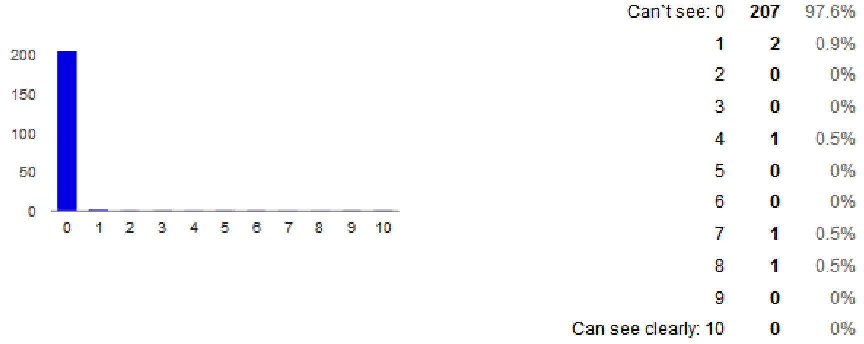
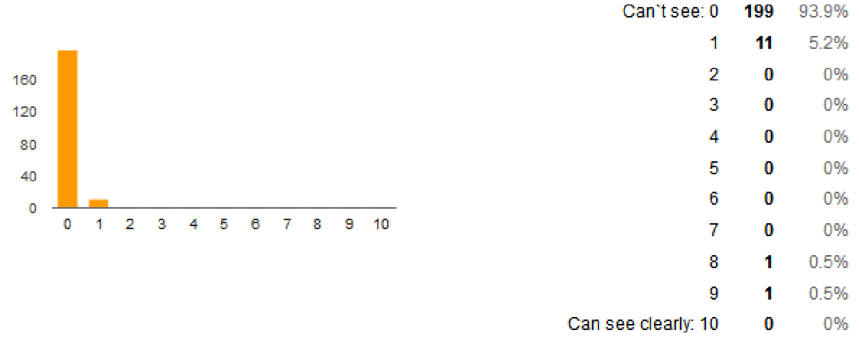
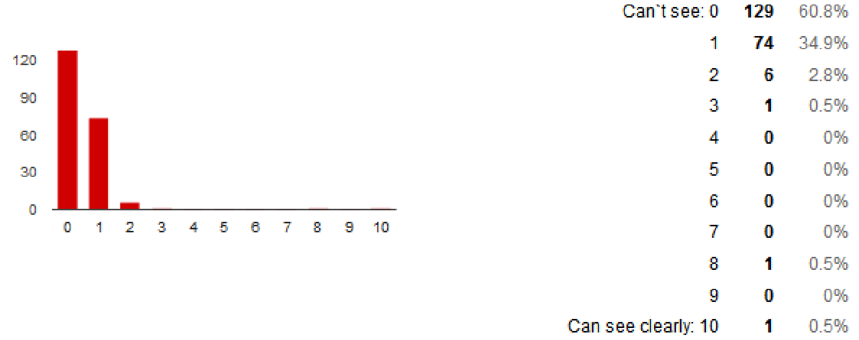
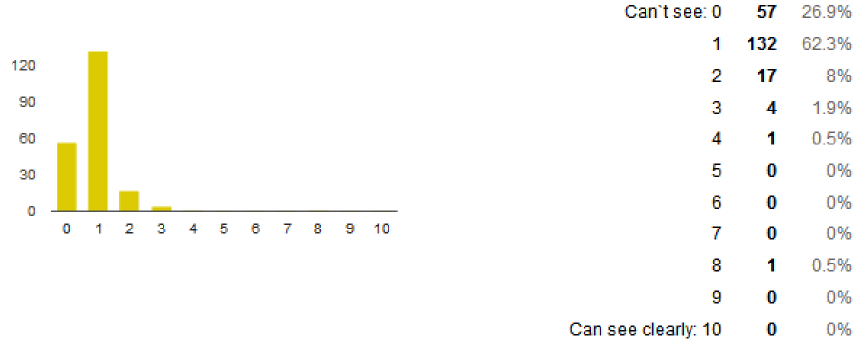
8	Can you see object behind the blind Type D-07?		Can`t see: 0 **5** 2.4% 1 **86** 40.6% 2 **81** 38.2% 3 **25** 11.8% 4 **10** 4.7% 5 **1** 0.5% 6 **1** 0.5% 7 **2** 0.9% 8 **1** 0.5% 9 **0** 0% Can see clearly: 10 **0** 0%
9	Can you see object behind the blind Type D-08?		Can`t see: 0 **3** 1.4% 1 **61** 28.8% 2 **74** 34.9% 3 **52** 24.5% 4 **12** 5.7% 5 **6** 2.8% 6 **1** 0.5% 7 **1** 0.5% 8 **2** 0.9% 9 **0** 0% Can see clearly: 10 **0** 0%
10	Can you see object behind the blind Type D-09?		Can`t see: 0 **1** 0.5% 1 **39** 18.4% 2 **70** 33% 3 **64** 30.2% 4 **24** 11.3% 5 **7** 3.3% 6 **4** 1.9% 7 **1** 0.5% 8 **1** 0.5% 9 **1** 0.5% Can see clearly: 10 **0** 0%
11	Can you see object behind the blind Type D-10?		Can`t see: 0 **1** 0.5% 1 **27** 12.7% 2 **63** 29.7% 3 **61** 28.8% 4 **37** 17.5% 5 **13** 6.1% 6 **5** 2.4% 7 **3** 1.4% 8 **1** 0.5% 9 **0** 0% Can see clearly: 10 **1** 0.5%
12	Can you see object behind the blind Type D-11?		Can`t see: 0 **2** 0.9% 1 **13** 6.1% 2 **56** 26.4% 3 **60** 28.3% 4 **47** 22.2% 5 **23** 10.8% 6 **5** 2.4% 7 **3** 1.4% 8 **3** 1.4% 9 **0** 0% Can see clearly: 10 **0** 0%

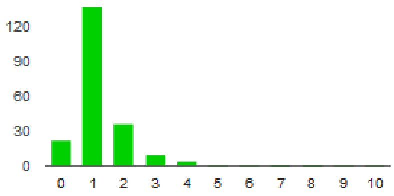
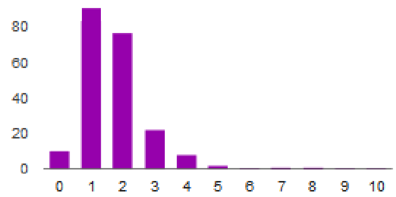
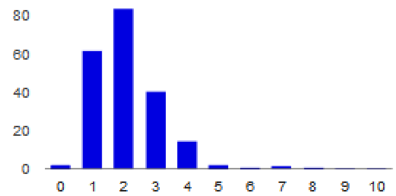
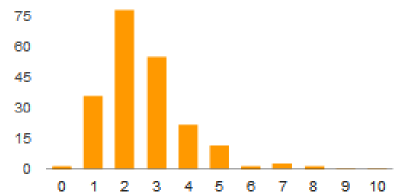
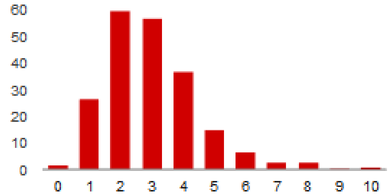
13	Can you see object behind the blind Type D-12?		Can`t see: 0 **1** 0.5% 1 **10** 4.7% 2 **44** 20.8% 3 **60** 28.3% 4 **47** 22.2% 5 **31** 14.6% 6 **10** 4.7% 7 **5** 2.4% 8 **3** 1.4% 9 **1** 0.5% Can see clearly: 10 **0** 0%
14	Can you see object behind the blind Type D-13?		Can`t see: 0 **1** 0.5% 1 **3** 1.4% 2 **38** 17.9% 3 **53** 25% 4 **47** 22.2% 5 **39** 18.4% 6 **17** 8% 7 **7** 3.3% 8 **6** 2.8% 9 **0** 0% Can see clearly: 10 **1** 0.5%
15	Can you see object behind the blind Type D-14?		Can`t see: 0 **2** 0.9% 1 **1** 0.5% 2 **18** 8.5% 3 **50** 23.6% 4 **52** 24.5% 5 **41** 19.3% 6 **24** 11.3% 7 **12** 5.7% 8 **10** 4.7% 9 **2** 0.9% Can see clearly: 10 **0** 0%
16	Can you see object behind the blind Type D-15?		Can`t see: 0 **1** 0.5% 1 **1** 0.5% 2 **13** 6.1% 3 **42** 19.8% 4 **42** 19.8% 5 **47** 22.2% 6 **27** 12.7% 7 **22** 10.4% 8 **14** 6.6% 9 **3** 1.4% Can see clearly: 10 **0** 0%
17	Can you see object behind the blind Type D-16?		Can`t see: 0 **1** 0.5% 1 **0** 0% 2 **9** 4.2% 3 **21** 9.9% 4 **47** 22.2% 5 **45** 21.2% 6 **32** 15.1% 7 **30** 14.2% 8 **20** 9.4% 9 **6** 2.8% Can see clearly: 10 **1** 0.5%

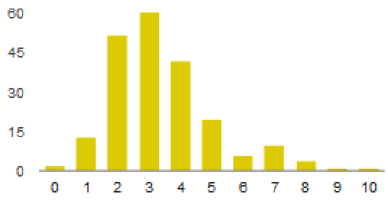
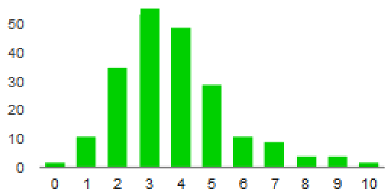
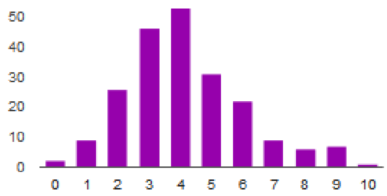
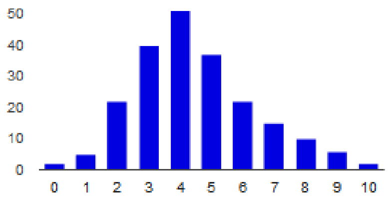
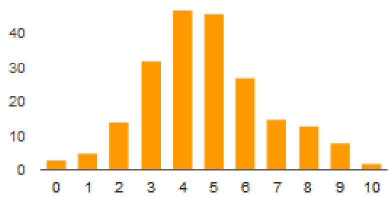
18	Can you see object behind the blind Type D-17?	 Can`t see: 0 **1** 0.5% 1 **0** 0% 2 **4** 1.9% 3 **14** 6.6% 4 **31** 14.6% 5 **47** 22.2% 6 **38** 17.9% 7 **31** 14.6% 8 **29** 13.7% 9 **14** 6.6% Can see clearly: 10 **3** 1.4%
19	Can you see object behind the blind Type D-18?	 Can`t see: 0 **1** 0.5% 1 **0** 0% 2 **2** 0.9% 3 **10** 4.7% 4 **23** 10.8% 5 **38** 17.9% 6 **40** 18.9% 7 **33** 15.6% 8 **36** 17% 9 **22** 10.4% Can see clearly: 10 **7** 3.3%
20	Can you see object behind the blind Type D-19?	 Can`t see: 0 **1** 0.5% 1 **0** 0% 2 **0** 0% 3 **4** 1.9% 4 **15** 7.1% 5 **35** 16.5% 6 **32** 15.1% 7 **27** 12.7% 8 **39** 18.4% 9 **40** 18.9% Can see clearly: 10 **19** 9%
21	Can you see object behind the blind Type D-20?	 Can`t see: 0 **1** 0.5% 1 **1** 0.5% 2 **0** 0% 3 **4** 1.9% 4 **13** 6.1% 5 **30** 14.2% 6 **21** 9.9% 7 **30** 14.2% 8 **37** 17.5% 9 **43** 20.3% Can see clearly: 10 **32** 15.1%

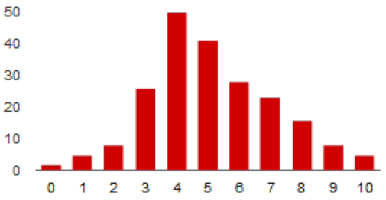
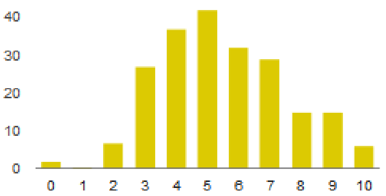
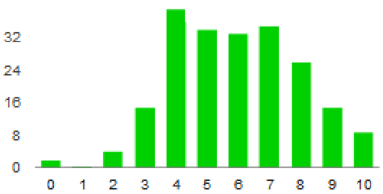
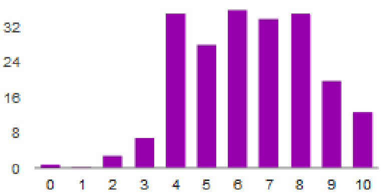
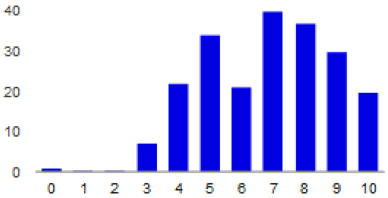
The seventh part was 21 questions about the visibility value in different illuminance conditions with Sudare type E (mocha, small). The complete data can be seen in Table 6-7.

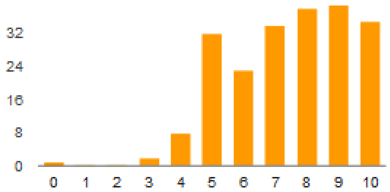
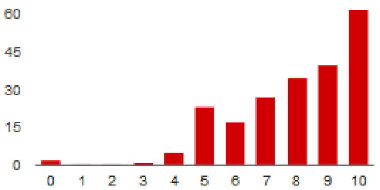
Table 6-7 Data questionnaire of Sudare Type E

No	Question	Graphic of data distribution
1	Can you see object behind the blind Type E-00?	
2	Can you see object behind the blind Type E-01?	
3	Can you see object behind the blind Type E-02?	
4	Can you see object behind the blind Type E-03?	

5	Can you see object behind the blind Type E-04?	 Can`t see: 0 — 22 — 10.4% 1 — 137 — 64.6% 2 — 37 — 17.5% 3 — 10 — 4.7% 4 — 4 — 1.9% 5 — 0 — 0% 6 — 0 — 0% 7 — 1 — 0.5% 8 — 1 — 0.5% 9 — 0 — 0% Can see clearly: 10 — 0 — 0%
6	Can you see object behind the blind Type E-05?	 Can`t see: 0 — 10 — 4.7% 1 — 91 — 42.9% 2 — 77 — 36.3% 3 — 22 — 10.4% 4 — 8 — 3.8% 5 — 2 — 0.9% 6 — 0 — 0% 7 — 1 — 0.5% 8 — 1 — 0.5% 9 — 0 — 0% Can see clearly: 10 — 0 — 0%
7	Can you see object behind the blind Type E-06?	 Can`t see: 0 — 3 — 1.4% 1 — 62 — 29.2% 2 — 84 — 39.6% 3 — 41 — 19.3% 4 — 15 — 7.1% 5 — 3 — 1.4% 6 — 1 — 0.5% 7 — 2 — 0.9% 8 — 1 — 0.5% 9 — 0 — 0% Can see clearly: 10 — 0 — 0%
8	Can you see object behind the blind Type E-07?	 Can`t see: 0 — 2 — 0.9% 1 — 36 — 17% 2 — 78 — 36.8% 3 — 55 — 25.9% 4 — 22 — 10.4% 5 — 12 — 5.7% 6 — 2 — 0.9% 7 — 3 — 1.4% 8 — 2 — 0.9% 9 — 0 — 0% Can see clearly: 10 — 0 — 0%
9	Can you see object behind the blind Type E-08?	 Can`t see: 0 — 2 — 0.9% 1 — 27 — 12.7% 2 — 60 — 28.3% 3 — 57 — 26.9% 4 — 37 — 17.5% 5 — 15 — 7.1% 6 — 7 — 3.3% 7 — 3 — 1.4% 8 — 3 — 1.4% 9 — 0 — 0% Can see clearly: 10 — 1 — 0.5%

10	Can you see object behind the blind Type E-09?		Can't see: 0 — 2 — 0.9% 1 — 13 — 6.1% 2 — 52 — 24.5% 3 — 61 — 28.8% 4 — 42 — 19.8% 5 — 20 — 9.4% 6 — 6 — 2.8% 7 — 10 — 4.7% 8 — 4 — 1.9% 9 — 1 — 0.5% Can see clearly: 10 — 1 — 0.5%
11	Can you see object behind the blind Type E-10?		Can't see: 0 — 2 — 0.9% 1 — 11 — 5.2% 2 — 35 — 16.5% 3 — 56 — 26.4% 4 — 49 — 23.1% 5 — 29 — 13.7% 6 — 11 — 5.2% 7 — 9 — 4.2% 8 — 4 — 1.9% 9 — 4 — 1.9% Can see clearly: 10 — 2 — 0.9%
12	Can you see object behind the blind Type E-11?		Can't see: 0 — 2 — 0.9% 1 — 9 — 4.2% 2 — 26 — 12.3% 3 — 46 — 21.7% 4 — 53 — 25% 5 — 31 — 14.6% 6 — 22 — 10.4% 7 — 9 — 4.2% 8 — 6 — 2.8% 9 — 7 — 3.3% Can see clearly: 10 — 1 — 0.5%
13	Can you see object behind the blind Type E-12?		Can't see: 0 — 2 — 0.9% 1 — 5 — 2.4% 2 — 22 — 10.4% 3 — 40 — 18.9% 4 — 51 — 24.1% 5 — 37 — 17.5% 6 — 22 — 10.4% 7 — 15 — 7.1% 8 — 10 — 4.7% 9 — 6 — 2.8% Can see clearly: 10 — 2 — 0.9%
14	Can you see object behind the blind Type E-13?		Can't see: 0 — 3 — 1.4% 1 — 5 — 2.4% 2 — 14 — 6.6% 3 — 32 — 15.1% 4 — 47 — 22.2% 5 — 46 — 21.7% 6 — 27 — 12.7% 7 — 15 — 7.1% 8 — 13 — 6.1% 9 — 8 — 3.8% Can see clearly: 10 — 2 — 0.9%

15	Can you see object behind the blind Type E-14?		Can`t see: 0 — 2 — 0.9% 1 — 5 — 2.4% 2 — 8 — 3.8% 3 — 26 — 12.3% 4 — 50 — 23.6% 5 — 41 — 19.3% 6 — 28 — 13.2% 7 — 23 — 10.8% 8 — 16 — 7.5% 9 — 8 — 3.8% Can see clearly: 10 — 5 — 2.4%
16	Can you see object behind the blind Type E-15?		Can`t see: 0 — 2 — 0.9% 1 — 0 — 0% 2 — 7 — 3.3% 3 — 27 — 12.7% 4 — 37 — 17.5% 5 — 42 — 19.8% 6 — 32 — 15.1% 7 — 29 — 13.7% 8 — 15 — 7.1% 9 — 15 — 7.1% Can see clearly: 10 — 6 — 2.8%
17	Can you see object behind the blind Type E-16?		Can`t see: 0 — 2 — 0.9% 1 — 0 — 0% 2 — 4 — 1.9% 3 — 15 — 7.1% 4 — 39 — 18.4% 5 — 34 — 16% 6 — 33 — 15.6% 7 — 35 — 16.5% 8 — 26 — 12.3% 9 — 15 — 7.1% Can see clearly: 10 — 9 — 4.2%
18	Can you see object behind the blind Type E-17?		Can`t see: 0 — 1 — 0.5% 1 — 0 — 0% 2 — 3 — 1.4% 3 — 7 — 3.3% 4 — 35 — 16.5% 5 — 28 — 13.2% 6 — 36 — 17% 7 — 34 — 16% 8 — 35 — 16.5% 9 — 20 — 9.4% Can see clearly: 10 — 13 — 6.1%
19	Can you see object behind the blind Type E-18?		Can`t see: 0 — 1 — 0.5% 1 — 0 — 0% 2 — 0 — 0% 3 — 7 — 3.3% 4 — 22 — 10.4% 5 — 34 — 16% 6 — 21 — 9.9% 7 — 40 — 18.9% 8 — 37 — 17.5% 9 — 30 — 14.2% Can see clearly: 10 — 20 — 9.4%

20	Can you see object behind the blind Type E-19?	 Can`t see: 0 1 0.5% 1 0 0% 2 0 0% 3 2 0.9% 4 8 3.8% 5 32 15.1% 6 23 10.8% 7 34 16% 8 38 17.9% 9 39 18.4% Can see clearly: 10 35 16.5%
21	Can you see object behind the blind Type E-20?	 Can`t see: 0 2 0.9% 1 0 0% 2 0 0% 3 1 0.5% 4 5 2.4% 5 23 10.8% 6 17 8% 7 27 12.7% 8 35 16.5% 9 40 18.9% Can see clearly: 10 62 29.2%

In this experiment, the respondents not only gave responses to two steps of the experiment, i.e., when they started to see the object and another 10 different conditions, but they also gave responses to 21 further conditions, as shown in Figure 6-4. With this method, the distribution figure shows the gradual changes from the minimum visibility level (cannot see anything) to the maximum level, based on their perception.

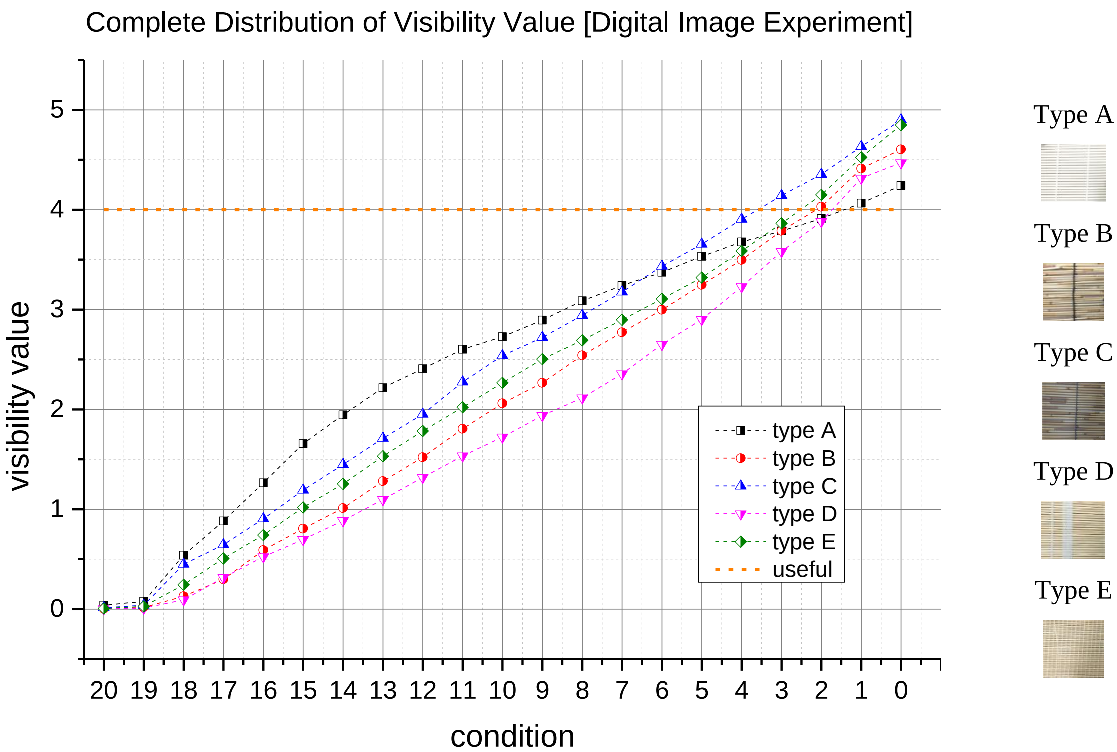


Figure 6-4 Complete of visibility value distribution from digital images experiment

The standard environment condition for analyzing the possibilities of Sudare to be used on façade design can be seen in Figure 6-5. The results of the visibility value when the inside illuminance levels were below 1000 lux were below 3, which means there is a low visibility value from outside and high privacy from inside. The value is still under 3 when the illuminance level was the same as the outside. When the outside illuminance was 300 lux and the inside 1000 lux, the visibility value was near 4, which means high visibility. This also means when the observer was inside the room with 300 lux illuminance and the object was outside with 1000 lux illuminance or, more likely, in daytime where the outside value of illuminance level is always more than 5,000 lux, and usually 10,000 lux or more, the visibility value will also be high. A high visibility value of between 4 and 6 can be achieved when the illuminance ratio is more than 4.30.

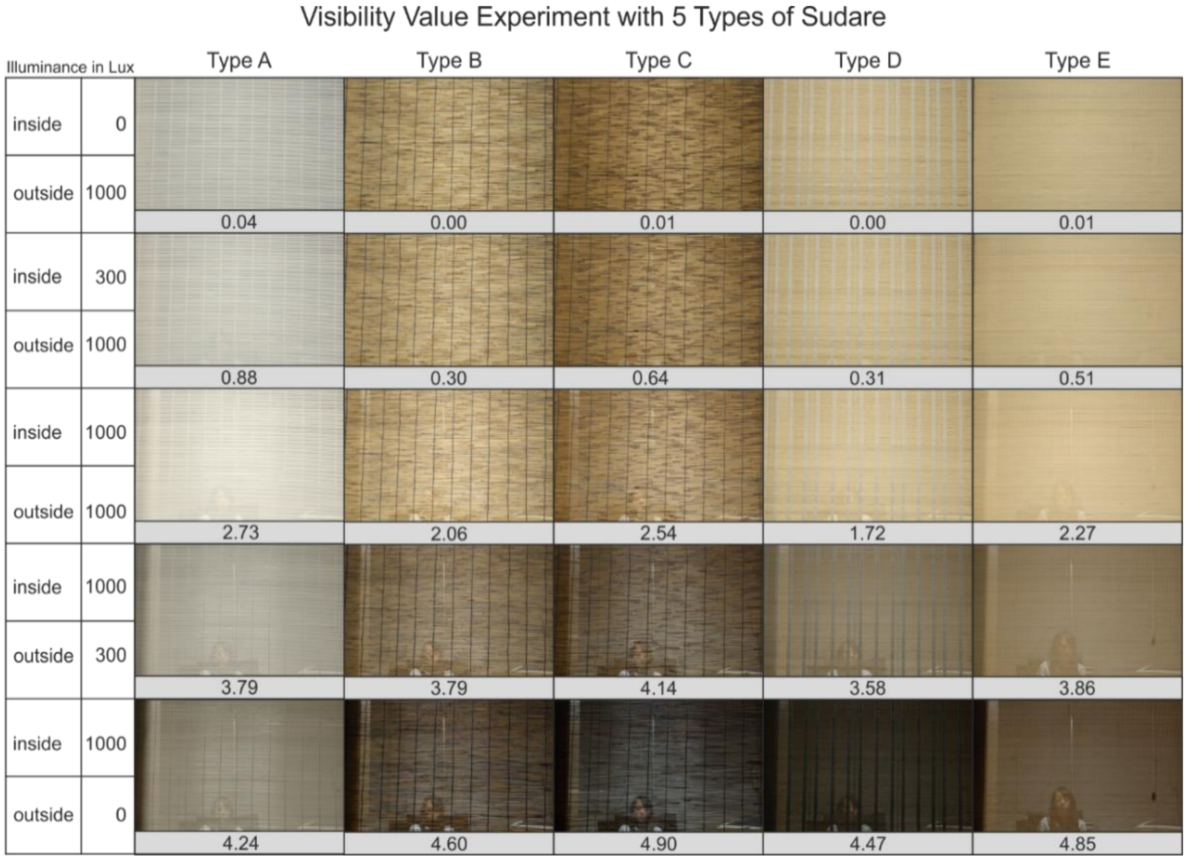


Figure 6-5 Visibility value distribution of digital image experiment

A comparison of the visibility value distribution of the physical experiment with the normalized value of the digital image shows the same trend in Figure 6-6. The maximum and minimum visibility values of the digital images experiment are lower than physical experiment.

This condition is more realistic because of the number of steps in 21 different conditions. In condition level 10, the illuminance value between inside and outside was the same. This is the minimum condition that will happen when using Sudare as an external blind, and when the inside illuminance is higher than that outside, the effect of the visibility will be the opposite (in night-time).

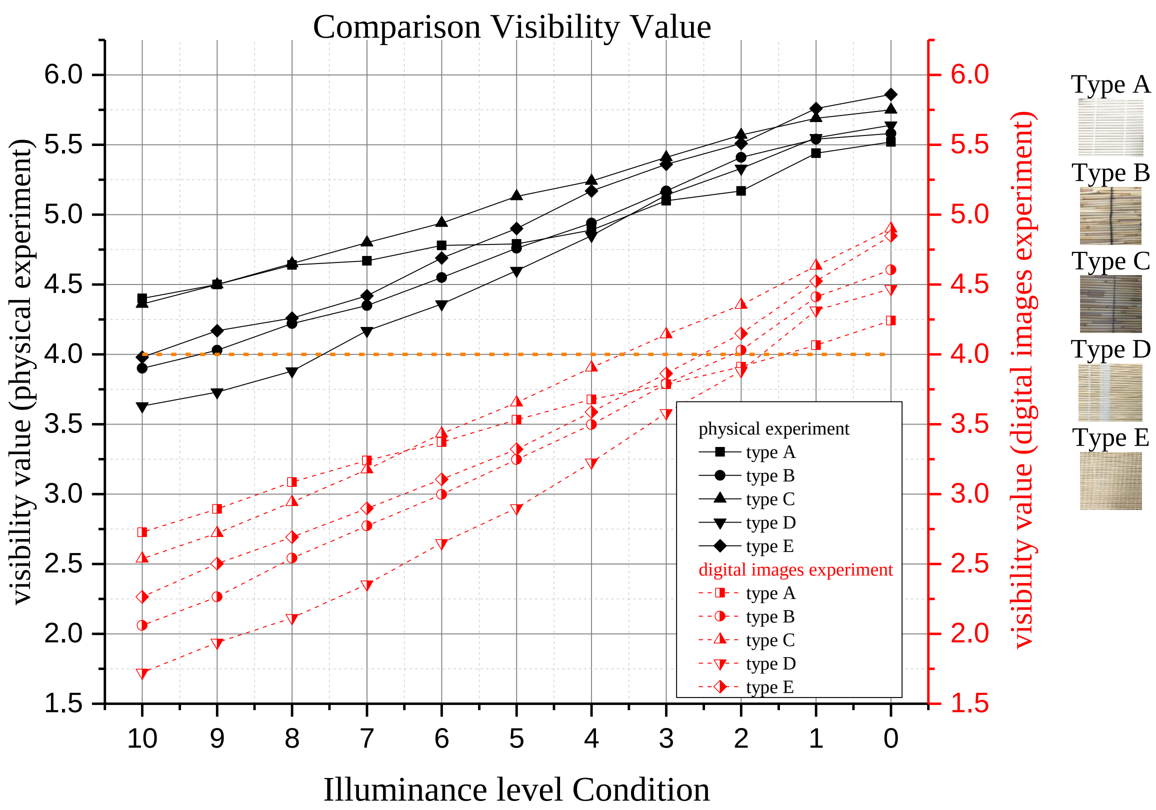


Figure 6-6 Comparison of visibility value distribution

A visibility value of between 0 and 2 is considered low, which means only the object's silhouette is seen, but the object is not recognized. However, the level of privacy is considered high. A visibility of between 2 and 4 is considered medium, which means that not only is an object's silhouette is seen, but the object and its color can be recognized, although they are not clear. This means that the level of privacy is also medium. Finally, a visibility value between 4 and 6 is considered high and useful for occupants to see outside, but, for privacy, it is considered to be low because people can see what is happening inside.

In this research, the configuration of the Sudare was fixed, which means the diameter of the slats and the spacer between slats could not be changed. For this reason, the results could not identify the optimum configuration of Sudare to be used as a building façade.

6.3 Section Conclusion

Based on the analysis of the questionnaire data comparing physical and digital experiments, the ratio of illuminance is the main factor that affects the value of visibility. The combination of whiteness factor, scale, and the ratio between the Sudare's diameter and spacer have a correlation with the distribution band of the visibility value. In a low illuminance ratio, a bigger scale has better visibility value but in high illuminance, a small scale has a better visibility value. A high visibility value can be achieved when the illuminance ratio is more than 4.30. A wider band range will offer more flexibility for controlling the view and can be achieved with the small ratio of Sudare.

6.4 Section Recommendation

The comparison of the visibility value distribution of the physical experiment and the normalized value of the digital image shows the same trend. The maximum and minimum visibility values of the digital image experiment are lower than those of the physical experiment. This condition is more realistic because of the number of steps in 21 different conditions.

In real conditions, the visibility value of Sudare will improve when using outdoor illuminance as an object room because the illuminance level is always more than 1000 lux, while the standard interior illuminance will be 300 lux.

The next research to undertake is to investigate more deeply the optimal configuration of Sudare and the minimum ratio of illuminance at which observers can see through a Sudare blind, using more precise and uniform material within the same ratio, but with different scales. This research has a high potential to be implemented in façade design with a parametric approach: changing the spacer of the Sudare according to the environment illuminance value.

Simulating cooling load with the different types of Sudare is also possible, to compare the effect of each type on the amount of energy reduction for the building (Hariyadi et al. 2017). By controlling the environmental energy input on the building envelope, energy savings can be achieved (Tagliabue et al. 2012)(Hariyadi et al. 2015).

Chapter 7 Application of Visibility Indices in Building Façade Simulation

The simulation experiment was divided into four steps. Each step will be discussed in detail.

7.1 OTTV and Cooling Load in Different Glasses

In this first step, the results of the OTTV calculation values for the normal building show the position and effect for each different condition of fenestration area, between 10% to 70% of the window to wall ratio (WWR) with different SHGC values between 0.2 and 0.9. They show that with SHGC values between 0.2 and 0.9, the standard OTTV 35 watt/m2 could only be achieved with WWR 20% (Figure 7-1).

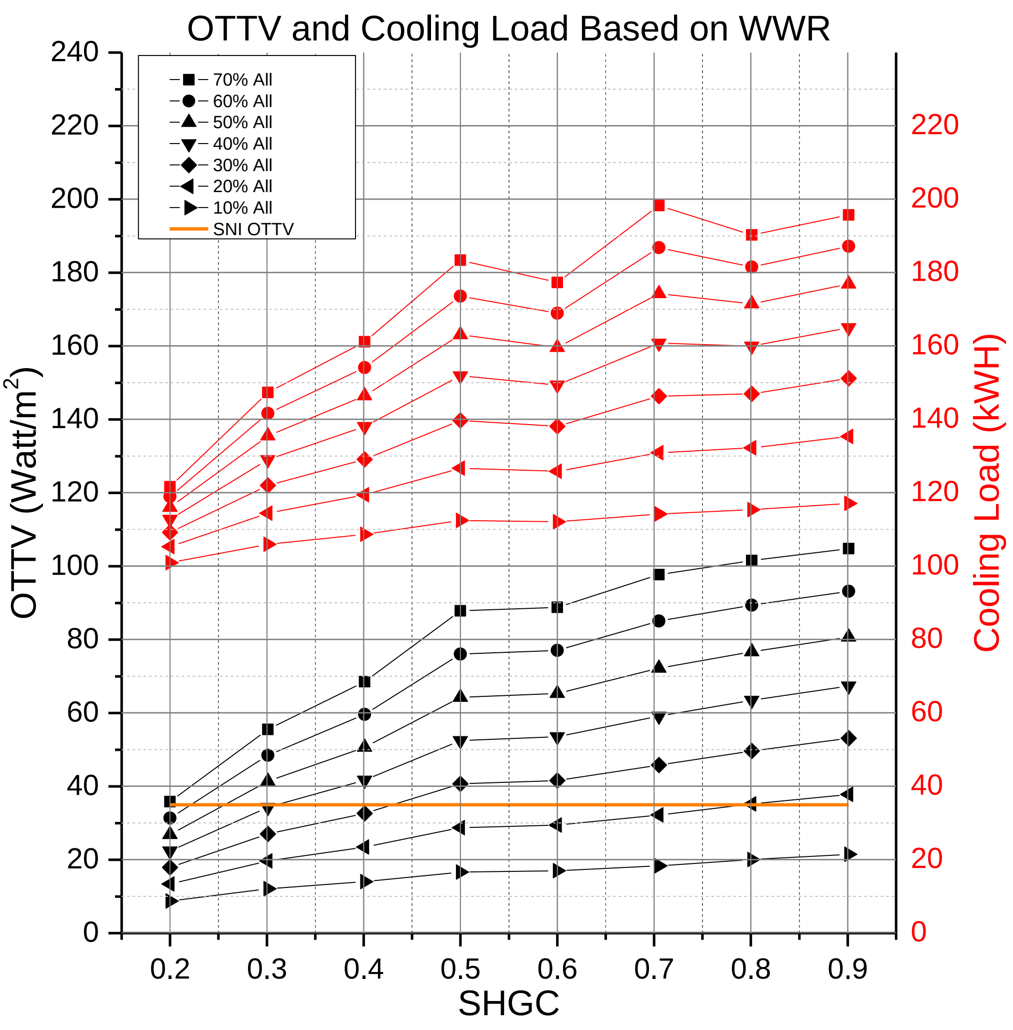
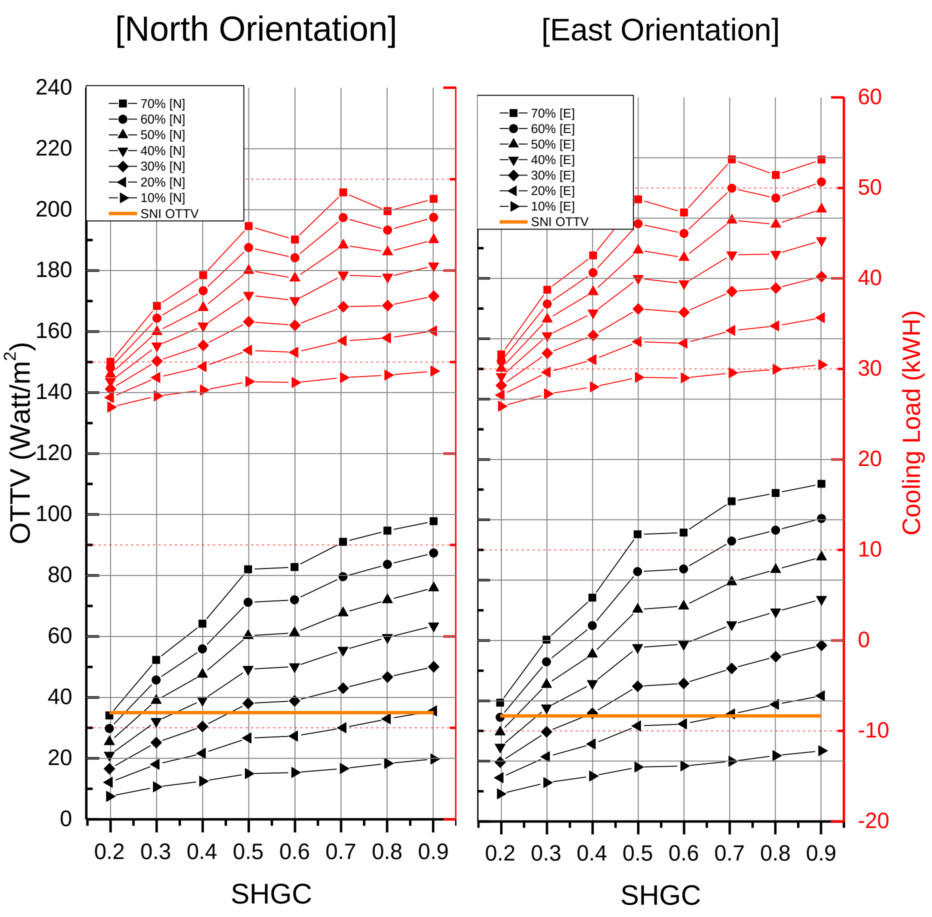


Figure 7-1 Comparison of OTTV and cooling load with different SHGC glass

Using this WWR, the cooling load is between 105 and 135 kWh/m2 annually. The cooling load for OTTV 35 watt/m2 (using WWR 22.05% with SHGC 0.7) is 134.16 kWh/m2 annually, used as the baseline building.

In the breakdown of each orientation using 20% WWR, only the north and south sides have OTTV less than 35 watt/m2. Meanwhile, the highest OTTV is in the west orientation, at 48.26 watt/m2. Although it is possible to meet the standard using a combination of different WWR in each window orientation by minimizing the openings to the east and, especially, to the west (Figure 7-2), it would be very difficult for architects to develop the necessary creativity as regards façade openings.



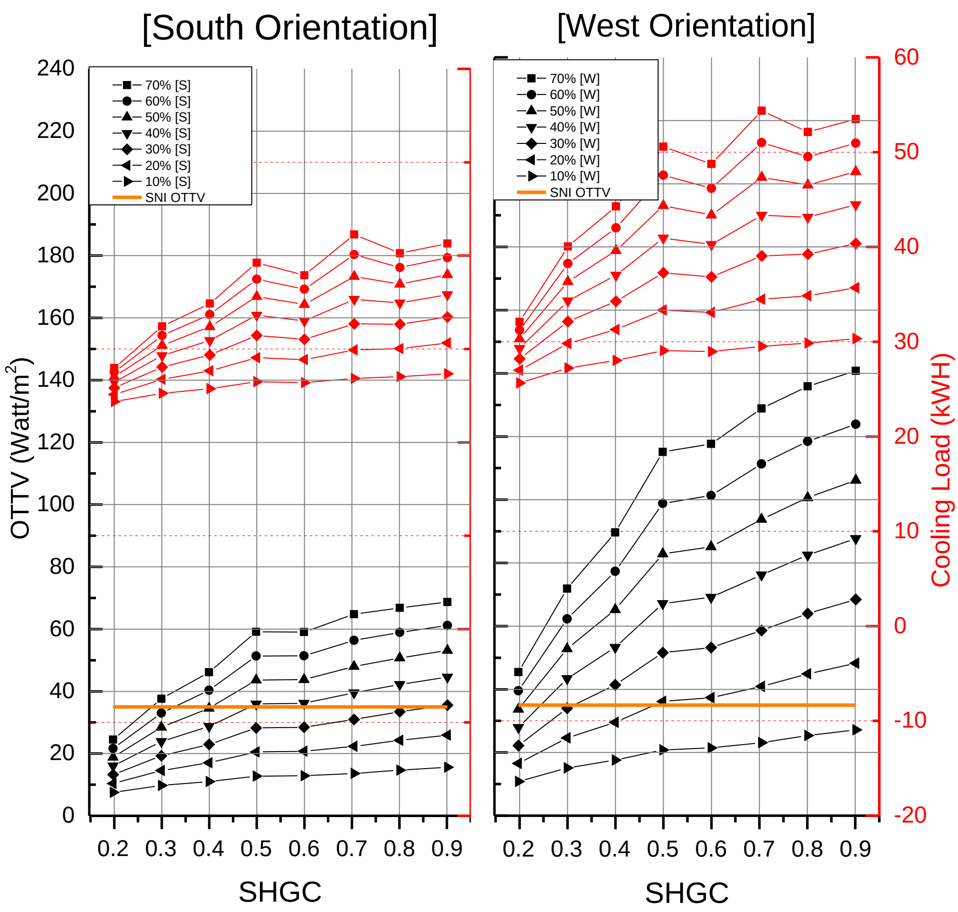


Figure 7-2 Breakdown of OTTV and cooling load of normal building in four orientations

7.2 OTTV and Cooling Load in Modified Building Façade

In the second step, by comparing the OTTV value of the modified building with that of the normal building, it can be seen that Sudare as shading devices can reduce OTTV significantly (Figure 7-3). The effectiveness of Sudare increases with the decrease of the spacer, but the amount of material for the Sudare also increases

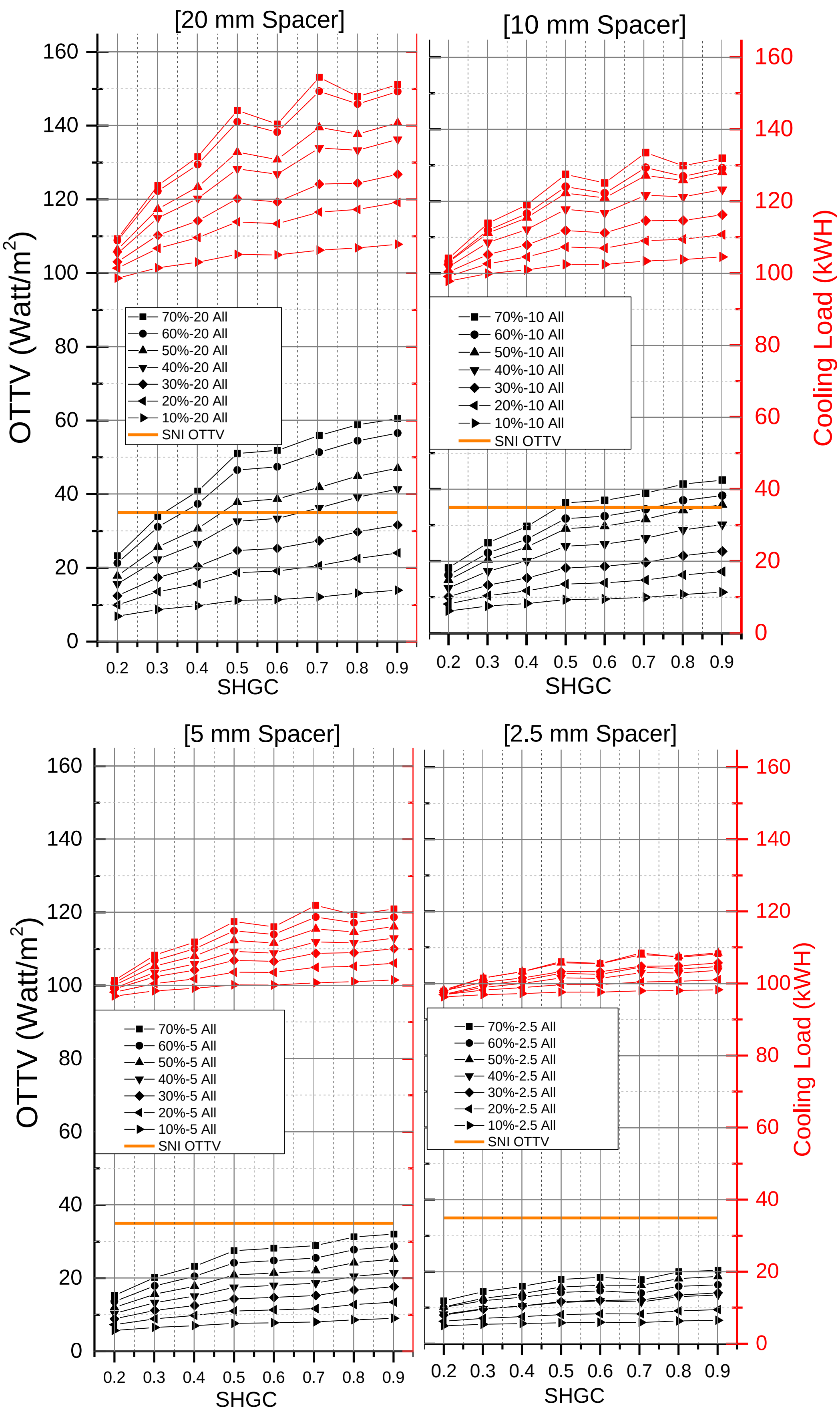
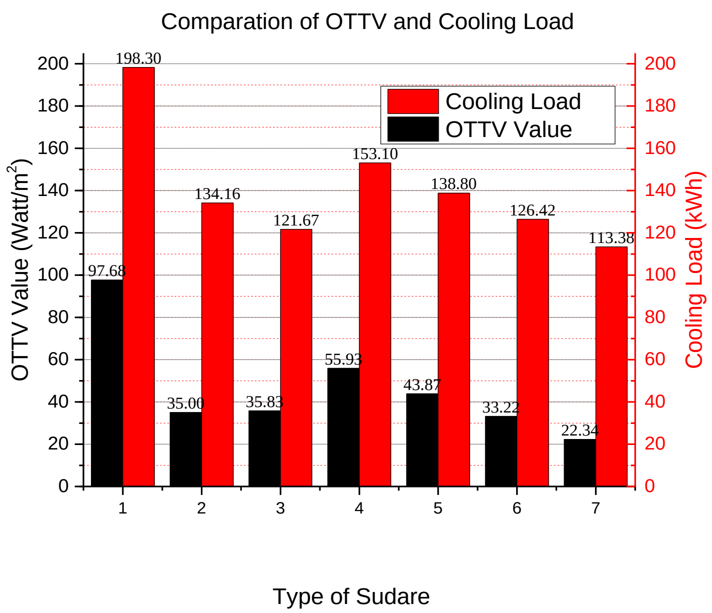


Figure 7-3 OTTV and cooling load of four types of modified building

The comparison of a baseline building with clear glass material with SHGC 0.7 (WWR 22.05%), with a building using tinted glass (SHGC 0.2) and the five types of Sudare is analyzed in (Figure 6-4) and later in Table 6-3. An OTTV of below 35 watt/m2 can be achieved by a Sudare with a 5-mm spacer (33.22 watt/m2) by decreasing 5% of OTTV from the baseline building, and with 126.417 kWh cooling load or 6% less cooling load than the baseline building. It can also be achieved by a Sudare with a 2.5-mm spacer with an OTTV of 22.34 watt/m2, 36% lower than the baseline, and with 113.38 kWh cooling load, or 15% less than the baseline building.

Compared to the tinted glass with SHGC 0.2, a Sudare with a 5-mm spacer has better OTTV. Although the cooling load is still above that of tinted glass windows, the difference is not great. A Sudare with a 2.5-mm spacer has a much better OTTV and cooling load value than tinted glass (Figure 7-4).



Type of Sudare	
1	No Sudare, Clear Glass SHGC 0.7 T vis 0.8
2	Baseline
3	No Sudare, Tint Glass SHGC 0.2 T vis 0.2
4	20 mm spacer
5	10 mm spacer
6	5 mm spacer
7	2.5 spacer

Figure 7-4 Comparison of OTTV and cooling load of buildings

7.3 Visibility Perception

After comparing the results, the next step is to review the visibility value using the questionnaire from the rendering image. The respondents filled in the questionnaire using a Google form, ticking each image on a scale from 0, indicating they could not see anything, to 6, indicating they could see the object clearly. The respondents in this survey were 35 Japanese university students and 40 Indonesian university students chosen randomly from undergraduate and graduate students of the architecture departments of their schools (Table 7-1). They are also among the respondents for the previous experiment so they already understood the scale.

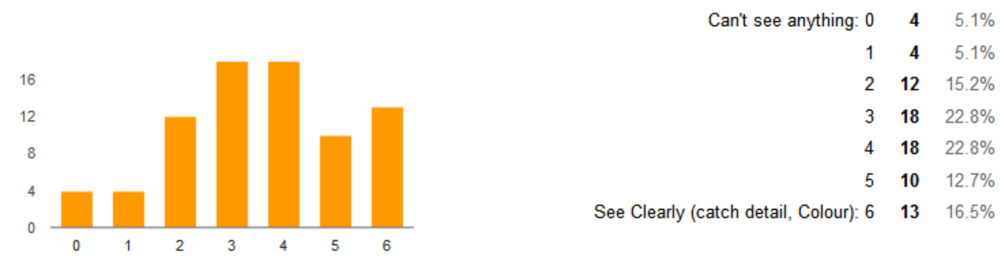
The Japanese university architecture students were chosen because of their familiarity with Sudare, having worked in studio rooms that are similar to offices. They will also be working in offices soon after they graduate. The reason for Indonesian students being chosen is that, like the Japanese students, they are familiar with Kère. The graduate students already had experience in working in offices because they had already worked before they continued their graduate study as master’s or doctoral students. The architecture department students are familiar with the images and visuals so they have better individual judgment than other students.

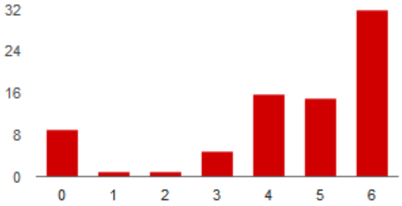
Table 7-1 Number of visibility questionnaire respondents

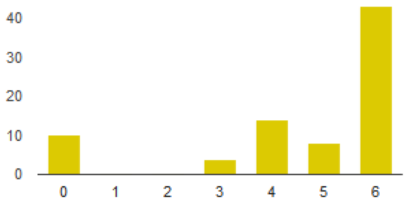
No	Nationality	Gender		Age	
		Male	Female	< 22 (undergraduate)	> 22 (graduate)
1	Japanese	21	14	17	18
2	Indonesian	14	26	30	10
Total		32	43	47	28

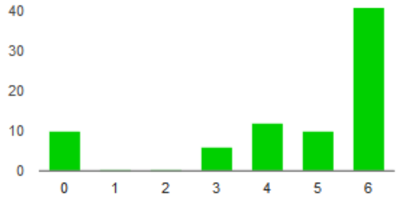
Five conditions were compared. Conditions 1 and 2 were used to test the visibility value from outside to inside, i.e., privacy for the inside, where the illuminance of the outside was higher than the illuminance inside in the daytime. Compared to the normal conditions (type I and type II), tinted glass (type III) and Sudare (type IV-type VII) have a low visibility value, which means they have a high privacy value. Condition 3 was to test the visibility and privacy when the illuminance levels inside and outside were the same. Conditions 4 and 5 were to test the visibility value from inside to outside. A Sudare with a 20-mm spacer has a better visibility value than tinted glass and other sizes of spacers. Sudare with 10-mm and 5-mm spacers have a visibility value close to that of tinted glass. The complete data can be seen in Table 7-2.

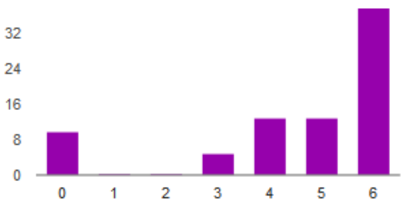
Table 7-2 Data questionnaire of rendering image

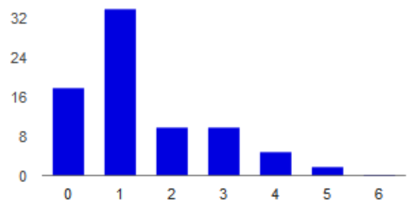
No	Condition	Graphic of data distribution
1	in 1000 out 0 tVis 90 scene A-1	

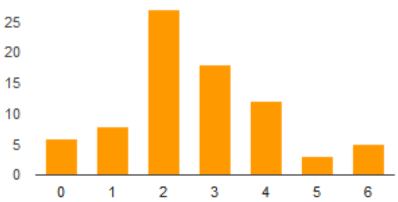
<table>
<tr><td>2</td><td>in 1000
out 300
tVis 90
scene A-2</td><td>

Can't see anything: 0 | 9 | 11.4%
1 | 1 | 1.3%
2 | 1 | 1.3%
3 | 5 | 6.3%
4 | 16 | 20.3%
5 | 15 | 19%
See Clearly (catch detail, Colour): 6 | 32 | 40.5%</td></tr>
<tr><td>3</td><td>in 1000
out 1000
tVis 90
scene A-3</td><td>

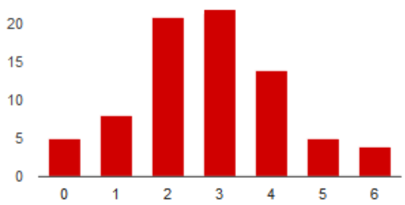
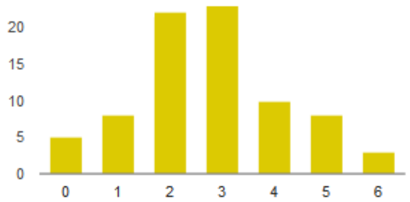
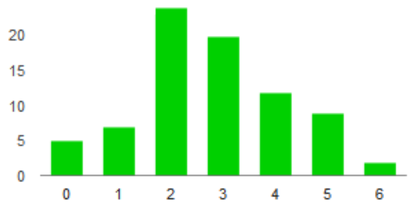
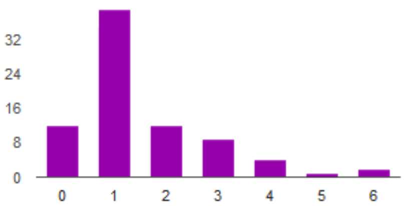
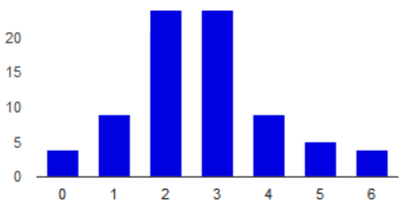
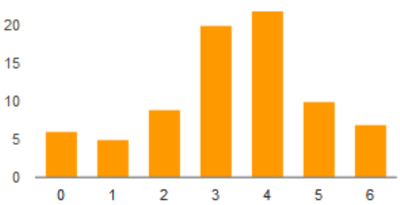
Can't see anything: 0 | 10 | 12.7%
1 | 0 | 0%
2 | 0 | 0%
3 | 4 | 5.1%
4 | 14 | 17.7%
5 | 8 | 10.1%
See Clearly (catch detail, Colour): 6 | 43 | 54.4%</td></tr>
<tr><td>4</td><td>in 300
out 1000
tVis 90
scene A-4</td><td>

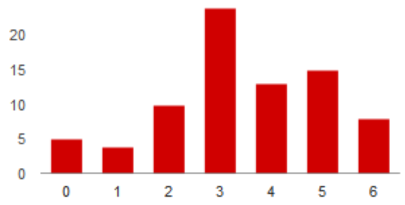
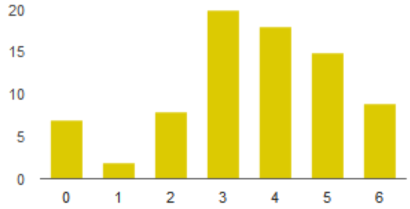
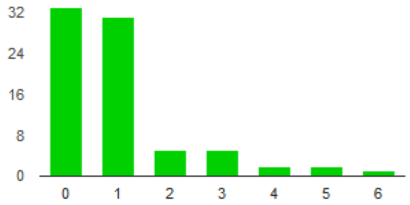
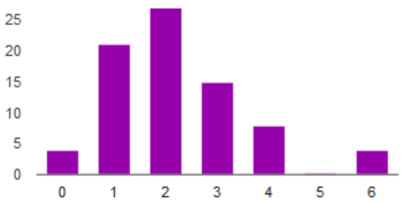
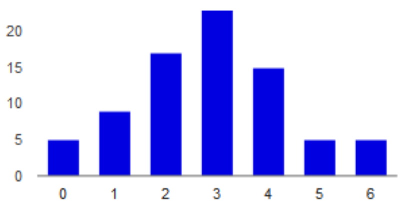
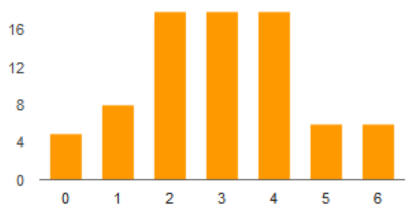
Can't see anything: 0 | 10 | 12.7%
1 | 0 | 0%
2 | 0 | 0%
3 | 6 | 7.6%
4 | 12 | 15.2%
5 | 10 | 12.7%
See Clearly (catch detail, Colour): 6 | 41 | 51.9%</td></tr>
<tr><td>5</td><td>in 0
out 1000
tVis 90
scene A-5</td><td>

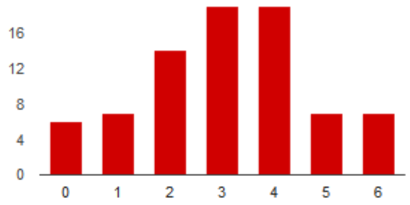
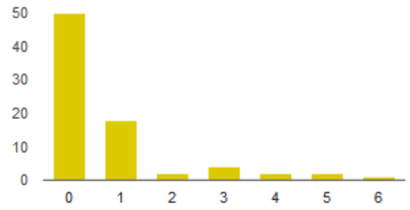
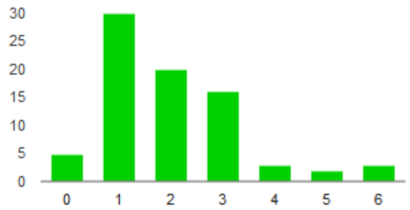
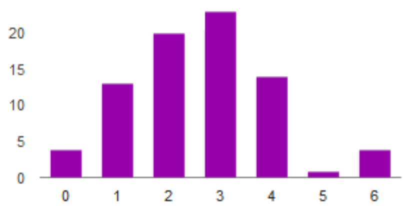
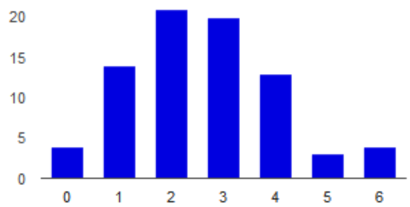
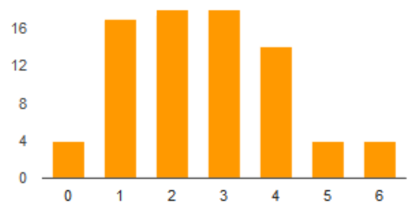
Can't see anything: 0 | 10 | 12.7%
1 | 0 | 0%
2 | 0 | 0%
3 | 5 | 6.3%
4 | 13 | 16.5%
5 | 13 | 16.5%
See Clearly (catch detail, Colour): 6 | 38 | 48.1%</td></tr>
<tr><td>6</td><td>in 1000
out 0
tVis 20
scene B-1</td><td>

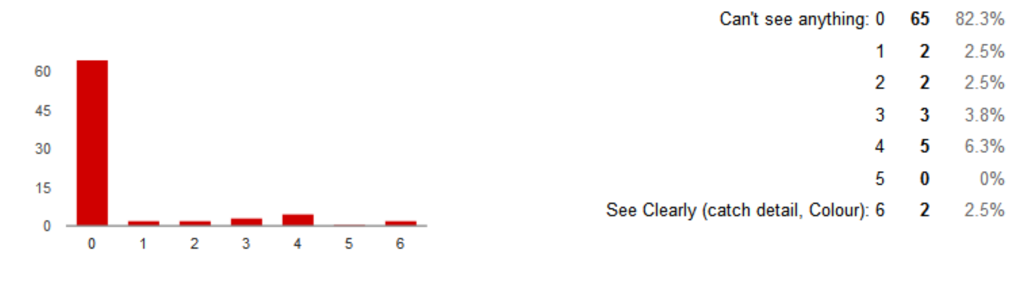
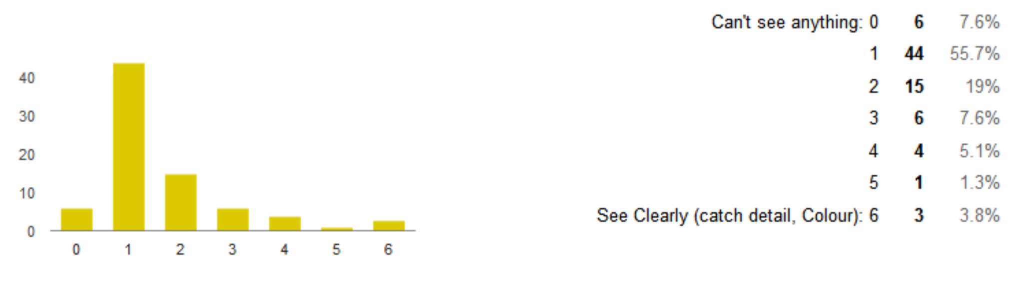
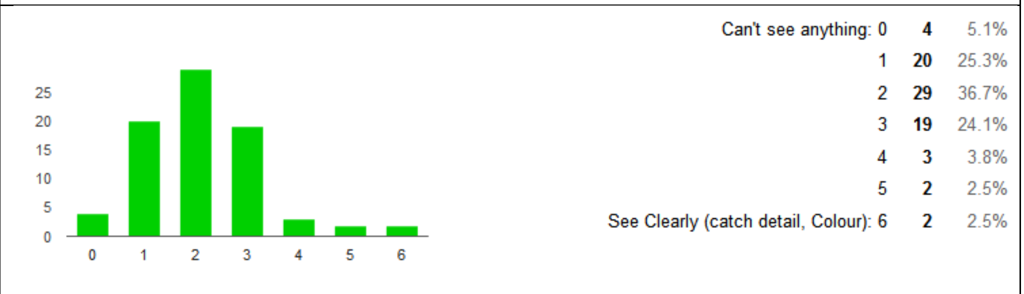
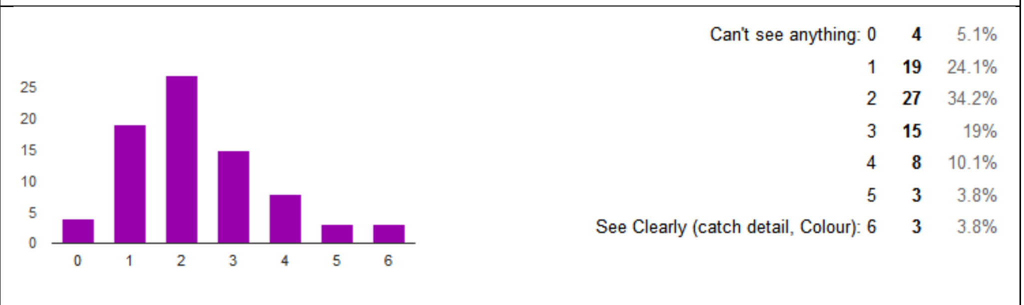
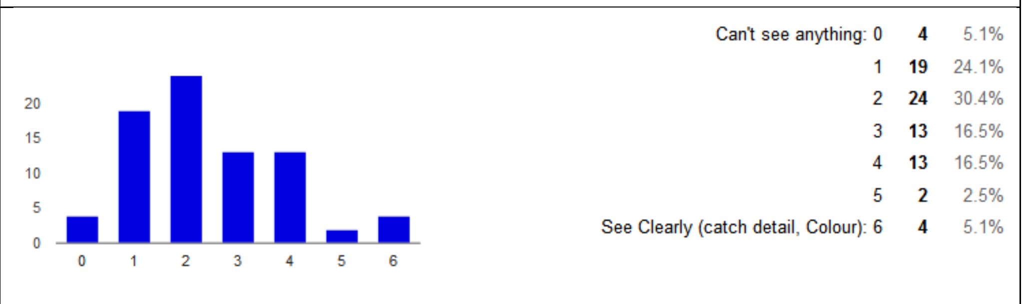
Can't see anything: 0 | 18 | 22.8%
1 | 34 | 43%
2 | 10 | 12.7%
3 | 10 | 12.7%
4 | 5 | 6.3%
5 | 2 | 2.5%
See Clearly (catch detail, Colour): 6 | 0 | 0%</td></tr>
<tr><td>7</td><td>in 1000
out 300
tVis 20
scene B-2</td><td>

Can't see anything: 0 | 6 | 7.6%
1 | 8 | 10.1%
2 | 27 | 34.2%
3 | 18 | 22.8%
4 | 12 | 15.2%
5 | 3 | 3.8%
See Clearly (catch detail, Colour): 6 | 5 | 6.3%</td></tr>
</table>

8	in 1000 out 1000 tVis 20 scene B-3		Can't see anything: 0 — 5 — 6.3% 1 — 8 — 10.1% 2 — 21 — 26.6% 3 — 22 — 27.8% 4 — 14 — 17.7% 5 — 5 — 6.3% See Clearly (catch detail, Colour): 6 — 4 — 5.1%
9	in 300 out 1000 tVis 20 scene B-4		Can't see anything: 0 — 5 — 6.3% 1 — 8 — 10.1% 2 — 22 — 27.8% 3 — 23 — 29.1% 4 — 10 — 12.7% 5 — 8 — 10.1% See Clearly (catch detail, Colour): 6 — 3 — 3.8%
10	in 0 out 1000 tVis 20 scene B-5		Can't see anything: 0 — 5 — 6.3% 1 — 7 — 8.9% 2 — 24 — 30.4% 3 — 20 — 25.3% 4 — 12 — 15.2% 5 — 9 — 11.4% See Clearly (catch detail, Colour): 6 — 2 — 2.5%
11	in 1000 out 0 20 mm spacer scene C-1		Can't see anything: 0 — 12 — 15.2% 1 — 39 — 49.4% 2 — 12 — 15.2% 3 — 9 — 11.4% 4 — 4 — 5.1% 5 — 1 — 1.3% See Clearly (catch detail, Colour): 6 — 2 — 2.5%
12	in 1000 out 300 20 mm spacer scene C-2		Can't see anything: 0 — 4 — 5.1% 1 — 9 — 11.4% 2 — 24 — 30.4% 3 — 24 — 30.4% 4 — 9 — 11.4% 5 — 5 — 6.3% See Clearly (catch detail, Colour): 6 — 4 — 5.1%
13	in 1000 out 1000 20 mm spacer scene C-3		Can't see anything: 0 — 6 — 7.6% 1 — 5 — 6.3% 2 — 9 — 11.4% 3 — 20 — 25.3% 4 — 22 — 27.8% 5 — 10 — 12.7% See Clearly (catch detail, Colour): 6 — 7 — 8.9%

14	in 300 out 1000 20 mm spacer scene C-4	 Can't see anything: 0 — 5 — 6.3% 1 — 4 — 5.1% 2 — 10 — 12.7% 3 — 24 — 30.4% 4 — 13 — 16.5% 5 — 15 — 19% See Clearly (catch detail, Colour): 6 — 8 — 10.1%
15	in 0 out 1000 20 mm spacer scene C-5	 Can't see anything: 0 — 7 — 8.9% 1 — 2 — 2.5% 2 — 8 — 10.1% 3 — 20 — 25.3% 4 — 18 — 22.8% 5 — 15 — 19% See Clearly (catch detail, Colour): 6 — 9 — 11.4%
16	in 1000 out 0 10 mm spacer scene D-1	 Can't see anything: 0 — 33 — 41.8% 1 — 31 — 39.2% 2 — 5 — 6.3% 3 — 5 — 6.3% 4 — 2 — 2.5% 5 — 2 — 2.5% See Clearly (catch detail, Colour): 6 — 1 — 1.3%
17	in 1000 out 300 10 mm spacer scene D-2	 Can't see anything: 0 — 4 — 5.1% 1 — 21 — 26.6% 2 — 27 — 34.2% 3 — 15 — 19% 4 — 8 — 10.1% 5 — 0 — 0% See Clearly (catch detail, Colour): 6 — 4 — 5.1%
18	in 1000 out 1000 10 mm spacer scene D-3	 Can't see anything: 0 — 5 — 6.3% 1 — 9 — 11.4% 2 — 17 — 21.5% 3 — 23 — 29.1% 4 — 15 — 19% 5 — 5 — 6.3% See Clearly (catch detail, Colour): 6 — 5 — 6.3%
19	in 300 out 1000 10 mm spacer scene D-4	 Can't see anything: 0 — 5 — 6.3% 1 — 8 — 10.1% 2 — 18 — 22.8% 3 — 18 — 22.8% 4 — 18 — 22.8% 5 — 6 — 7.6% See Clearly (catch detail, Colour): 6 — 6 — 7.6%

20	in 0 out 1000 10 mm spacer scene D-5	 Can't see anything: 0 — 6 — 7.6% 1 — 7 — 8.9% 2 — 14 — 17.7% 3 — 19 — 24.1% 4 — 19 — 24.1% 5 — 7 — 8.9% See Clearly (catch detail, Colour): 6 — 7 — 8.9%
21	in 1000 out 0 5 mm spacer scene E-1	 Can't see anything: 0 — 50 — 63.3% 1 — 18 — 22.8% 2 — 2 — 2.5% 3 — 4 — 5.1% 4 — 2 — 2.5% 5 — 2 — 2.5% See Clearly (catch detail, Colour): 6 — 1 — 1.3%
22	in 1000 out 300 5 mm spacer scene E-2	 Can't see anything: 0 — 5 — 6.3% 1 — 30 — 38% 2 — 20 — 25.3% 3 — 16 — 20.3% 4 — 3 — 3.8% 5 — 2 — 2.5% See Clearly (catch detail, Colour): 6 — 3 — 3.8%
23	in 1000 out 1000 5 mm spacer scene E-3	 Can't see anything: 0 — 4 — 5.1% 1 — 13 — 16.5% 2 — 20 — 25.3% 3 — 23 — 29.1% 4 — 14 — 17.7% 5 — 1 — 1.3% See Clearly (catch detail, Colour): 6 — 4 — 5.1%
24	in 300 out 1000 5 mm spacer scene E-4	 Can't see anything: 0 — 4 — 5.1% 1 — 14 — 17.7% 2 — 21 — 26.6% 3 — 20 — 25.3% 4 — 13 — 16.5% 5 — 3 — 3.8% See Clearly (catch detail, Colour): 6 — 4 — 5.1%
25	in 0 out 1000 5 mm spacer scene E-5	 Can't see anything: 0 — 4 — 5.1% 1 — 17 — 21.5% 2 — 18 — 22.8% 3 — 18 — 22.8% 4 — 14 — 17.7% 5 — 4 — 5.1% See Clearly (catch detail, Colour): 6 — 4 — 5.1%

<table>
<tr><td>26</td><td>in 1000
out 0
2.5 mm
spacer
scene F-1</td><td>
</td></tr>
<tr><td>27</td><td>in 1000
out 300
2.5 mm
spacer
scene F-2</td><td>
</td></tr>
<tr><td>28</td><td>in 1000
out 1000
2.5 mm
spacer
scene F-3</td><td>
</td></tr>
<tr><td>29</td><td>in 300
out 1000
2.5 mm
spacer
scene F-4</td><td>
</td></tr>
<tr><td>30</td><td>in 0
out 1000
2.5 mm
spacer
scene F-5</td><td>
</td></tr>
</table>

This value will be better in real-life applications, where the illuminance level will increase outside; this means that this type of Sudare has the potential to be implemented (Figure 7-5). The privacy index is calculated from the respondents' answers about visibility value. It is the opposite of the visibility index, which means that if the respondent's answer was 0, the privacy index was 6 and if the respondent's answer was 6, the privacy index was 0. The calculation also uses the opposite condition with visibility: When calculating visibility (indoor 300 lux), it used the result in condition 4 of figure 21 and privacy is 6 minus visibility value in condition 2 of Figure 7-5 and Figure 7-6.

The result of the rendering image experiment is of lower value than that of the previous experiment using a real Sudare blind. This is because the diameter scale of the Sudare was bigger than that of the real Sudare, which was noted in the previous experiment. A smaller-diameter Sudare has a better visibility value even with the same ratio between its diameter and its spacer.

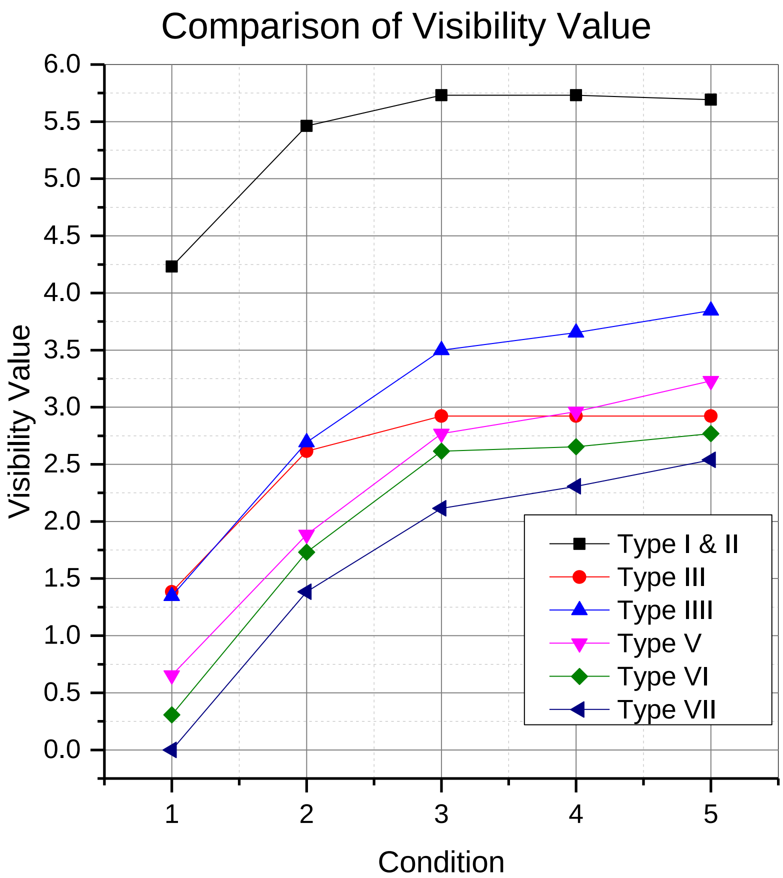


Figure 7-5 Visibility perception of rendering image

Visibility Value Experiment Comparison for Glass and Sudare

Lux	1 inside 0 / outside 1000	2 inside 300 / outside 1000	3 inside 1000 / outside 1000	4 inside 1000 / outside 300	5 inside 1000 / outside 0
Type I Type II No Sudare Clear Glass T vis 0.8 — visibility level	4.23	5.46	5.73	5.73	5.69
Type III No Sudare Tint Glass T vis 0.2 — visibility level	1.38	2.62	2.92	2.92	2.92
Type IV Sudare Ø 10.01 mm Spacer 20 mm Clear Glass T vis 0.8 — visibility level	1.35	2.69	3.50	3.65	3.85
Type V Sudare Ø 10.01 mm Spacer 10 mm Clear Glass T vis 0.8 — visibility level	0.65	1.88	2.77	2.96	3.23
Type VI Sudare Ø 10.01 mm Spacer 5 mm Clear Glass T vis 0.8 — visibility level	0.31	1.73	2.62	2.65	2.77
Type VII Sudare Ø 10.01 mm Spacer 2.5 mm Clear Glass T vis 0.8 — visibility level	0	1.38	2.12	2.31	2.54

Figure 7-6 Detail of visibility perception from rendering image

7.4 Daylight and Glare

In this study, daylight performance was simulated using climate-based sky for annual daylight performance. Using climate-based sky means that the calculation would consider the sky condition in the weather file for simulation. A useful daylight illuminance (UDI) metric was used to determine the percentage of each point in the area that has an illuminance value of between 100 lux to 2000 lux, which is considered to be a useful amount of daylight for the interior (Nabil & Mardaljevic 2005) (Nabil & Mardaljevic 2006) (Cantin et al. 2011). This range was selected because in the operation of the building, daylight must be combined with artificial light when the illuminance level is below 100 lux—the lowest useful level, and values above the maximum threshold (2000 lux) are harmful and will produce glare (Figure 7-7). This metric also has a more realistic and informative daylight metric using climate-based data (Rasmussen et al. 2015).

From the simulation data, it can be seen that the baseline building has 59.07 % area with UDI of 100 lux to 2000 lux. While clear-glass windows only have 27.17 %, only the area some distance from the window has a good value, because most of the time the values are very high, especially near the windows. The Sudare façade with 20-mm and 10-mm spacers also has a value below the baseline building, with 40.95 % and 56.36%. The tinted glass and Sudare façades with 5-mm and 2.5-mm spacers have better values than the baseline building in all orientations, having 90.11 %, 81.24 %, and 88.24 % respectively (Table 7- 3).

Distribution of daylight was simulated using a standard CIE sky (intermediate without sun), which is the common condition in Jakarta. The simulation day was June 22 at 12 PM, the lowest position of the sun in the year, which represents the worst-case scenario in this location (Figure 6-8). From the simulation data, it can be seen that the range of illuminance from minimum to maximum is high for a façade without Sudare, even for the baseline building, which has WWR 0.2205, especially for the northern orientation. This is understandable due to the position of the sun in the current situation. Buildings with Sudare have a more uniform distribution of test points from near the window to the inside of the room (Figure 7-8 and Figure 7-9).

Table 7-3 Useful Daylight Illuminance

No	Type	criteria	>=60%				
		orientation	North	East	South	West	ALL
1	No Sudare, Clear	UDI 100-2000 [%]	28.00	28.00	33.18	19.50	27.17

	Glass SHGC 0.7 Tvis 0.8	Efficiency [%]	-53.82	-52.94	-47.25	-63.36	-54.00
2	**Baseline**	**UDI 100-2000 [%]**	**60.64**	**59.50**	**62.91**	**53.23**	**59.07**
3	No Sudare, Tinted Glass SHGC 0.2 Tvis 0.2	UDI 100-2000 [%]	89.45	85.50	100	85.50	90.11
		Efficiency [%]	47.53	43.70	58.96	60.63	52.56
4	20-mm spacer	UDI 100-2000 [%]	42.27	40.36	48.00	33.18	40.95
		Efficiency [%]	-30.28	-32.16	-23.70	-37.66	-30.67
5	10-mm spacer	UDI 100-2000 [%]	58.45	59.50	59.50	48.00	56.36
		Efficiency [%]	-3.60	0.00	-5.42	-9.82	-4.58
6	5-mm spacer	UDI 100-2000 [%]	78.14	80.68	98.68	67.45	81.24
		Efficiency [%]	28.86	35.60	56.86	26.73	37.53
7	2.5-mm spacer	UDI 100-2000 [%]	89.73	89.14	86.82	87.45	88.28
		Efficiency [%]	47.98	49.81	38.01	64.30	49.46

In the glare evaluation, simulations were carried out at five points for each orientation. The points were considered as a fish-eye camera lens facing the window at distances of 1 m, 2.5 m, 4 m, 5.5 m, and 7 m. Each point was simulated to find the daylight glare probability (DGP). The DGPs were defined as four levels of glare: Imperceptible Glare, when the DGP is less than 0.35; Perceptible Glare, when the DGP is equal to or between 0.4 and 0.35; Disturbing Glare, when the DGP is more than or equal to 0.40 but less than 0.45; and Intolerable Glare, when the DGP is more than or equal to 0.45 (Figure 7-10). Sudare with 5-mm and 2.5-mm spacers have similar glare conditions to tinted glass, and perform even better in northern orientation when positioned near the window. The key to glare reduction is uniformity of daylight distribution inside the building, which sometimes means, even with lower illuminance than the standard, that the occupants can see better and feel more comfortable. The complete glare analysis image can be seen in Table 7-4 for North orientation, Table 7-5 for East orientation, Table 7-6 for South orientation, and Table 7-7 for West orientation.

The summary of the simulation can be used to evaluate the efficiency of the Sudare façade compared to that of the baseline building and the tinted glass façade (Table 7-8). The full clear-glass-façade simulation result can be used to describe the common practice of office buildings and show the potential energy savings that can be achieved when the building standard is used in practice. Also, the comparison of visibility and privacy values for each type of Sudare with a daylight and glare evaluation is useful to analyze the visual performance and visual comfort of occupants inside the building.

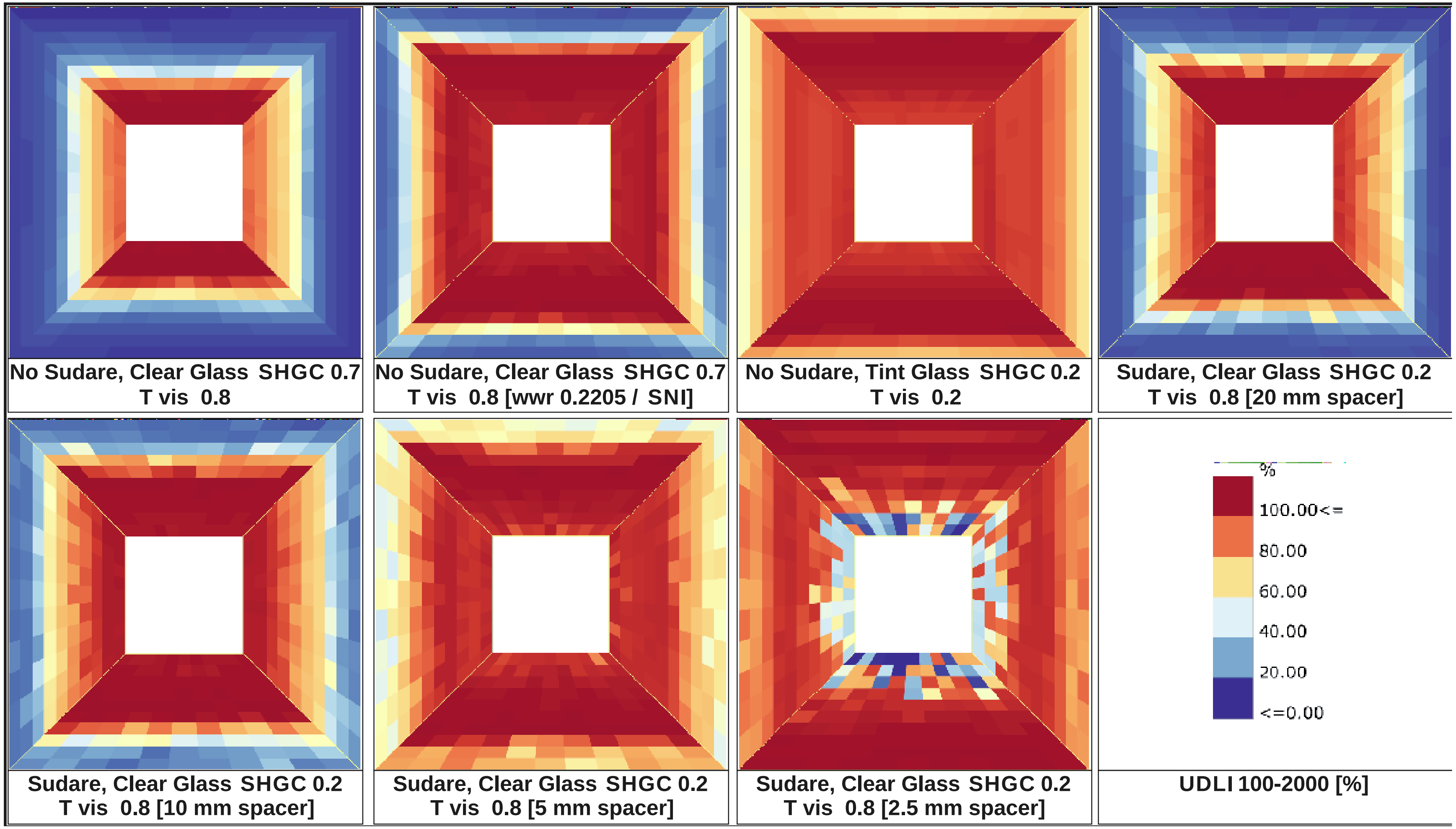


Figure 7-7 UDLI 100-2000 simulation

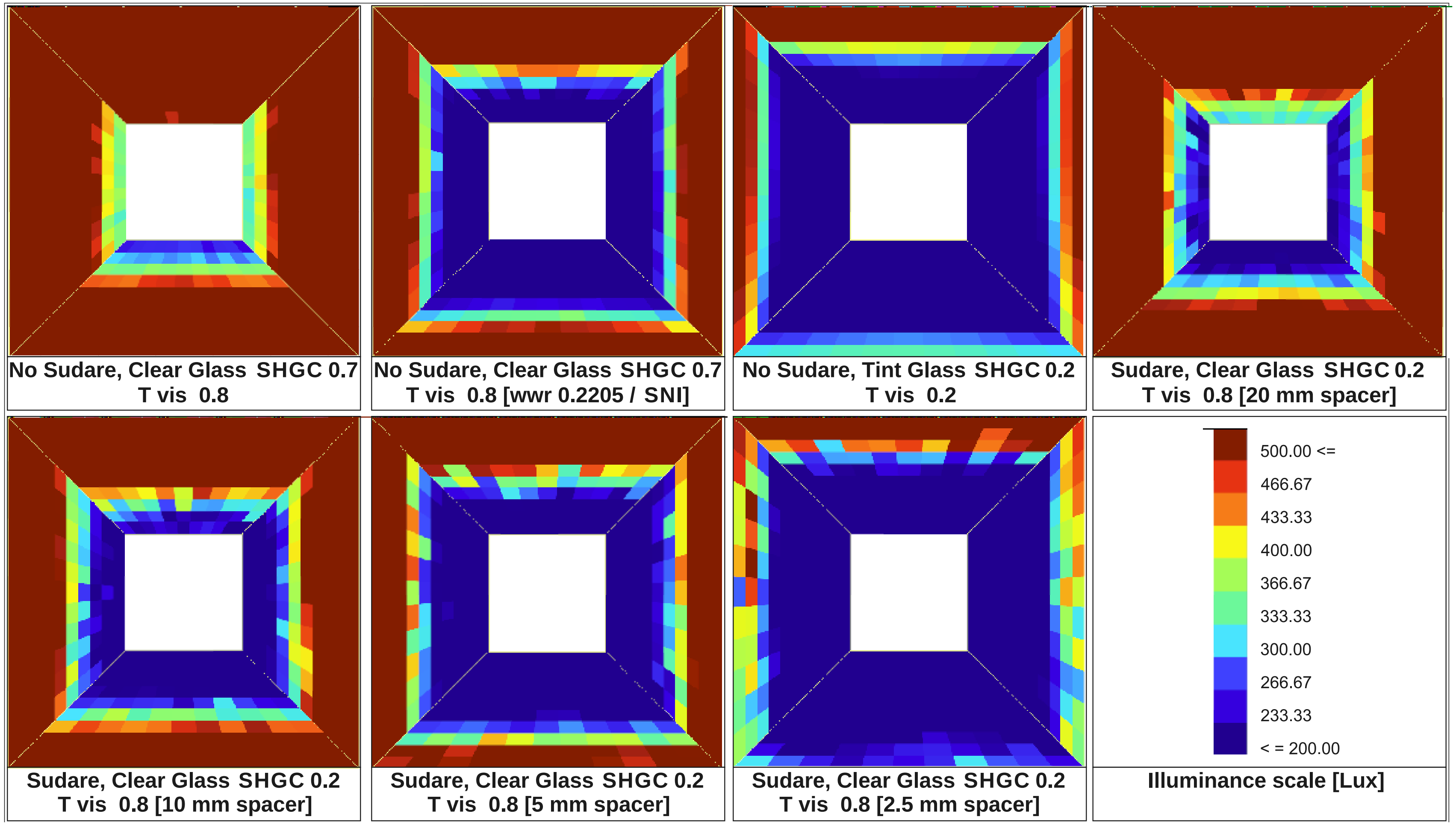


Figure 7-8 Illuminance distribution simulation

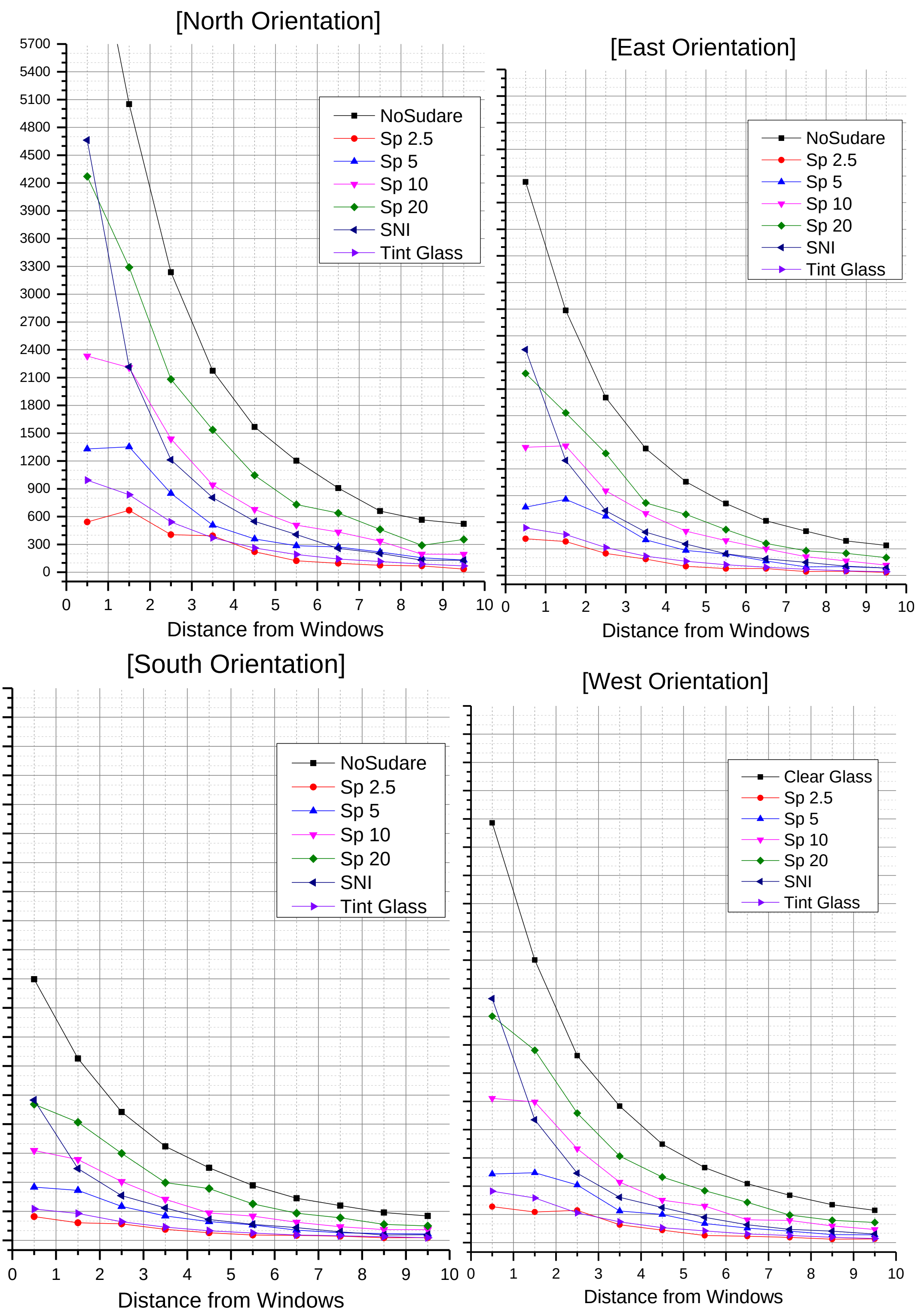
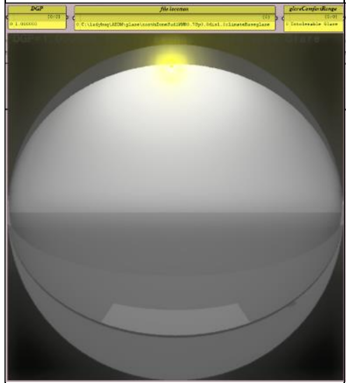
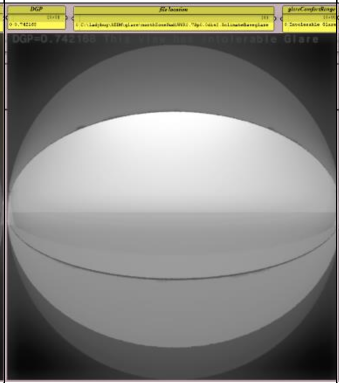
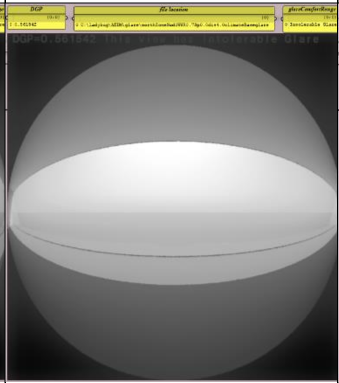
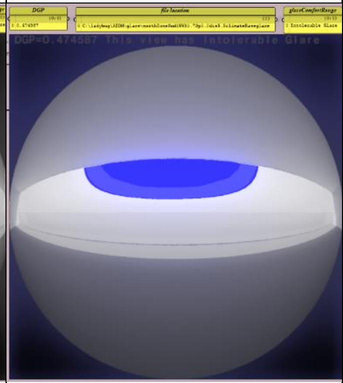
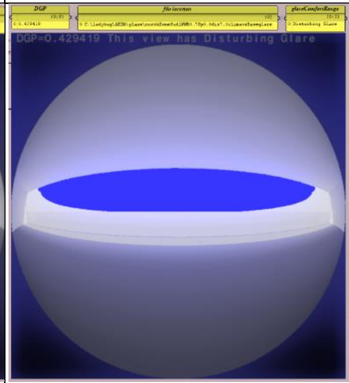
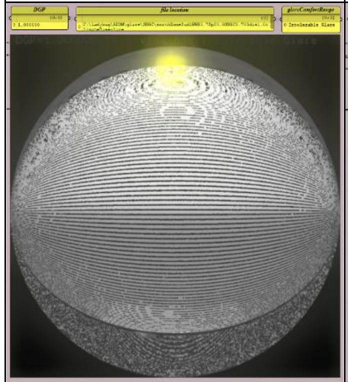
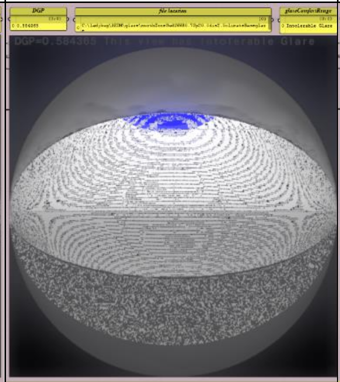
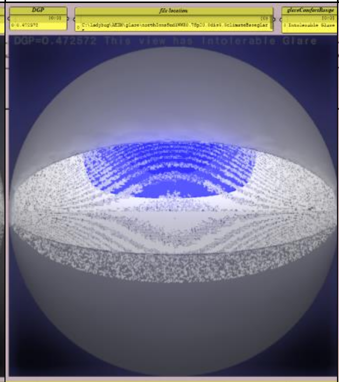
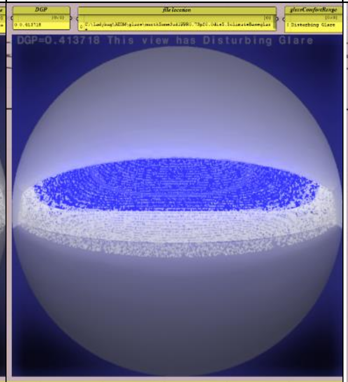
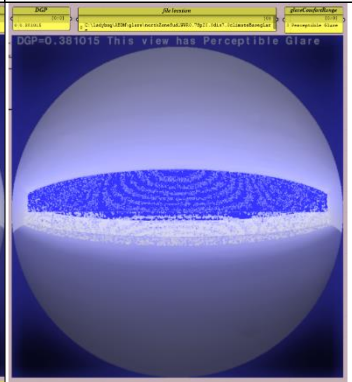
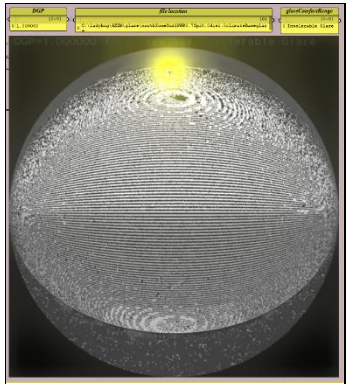
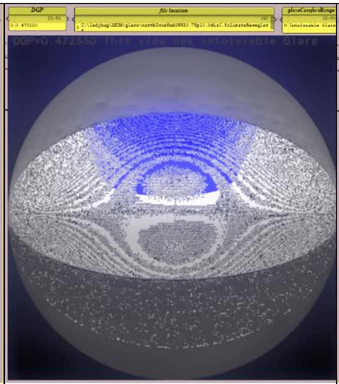
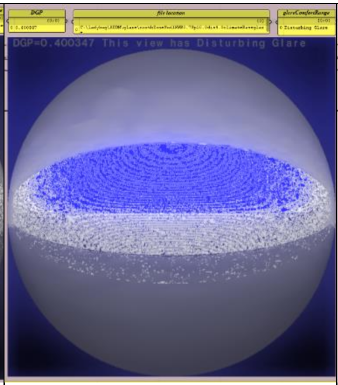
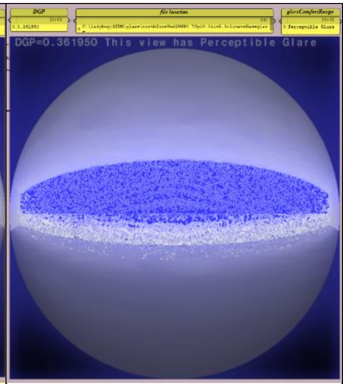
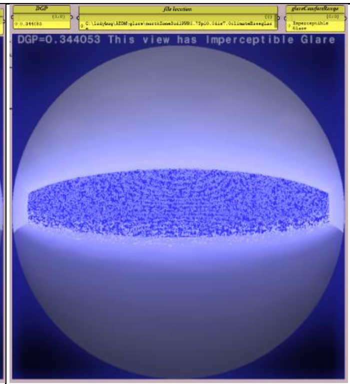
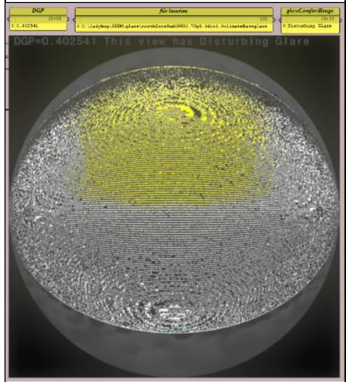
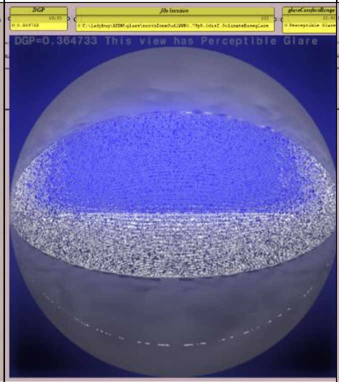
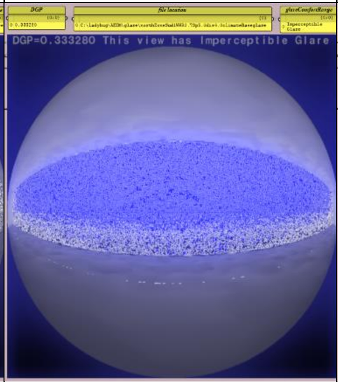
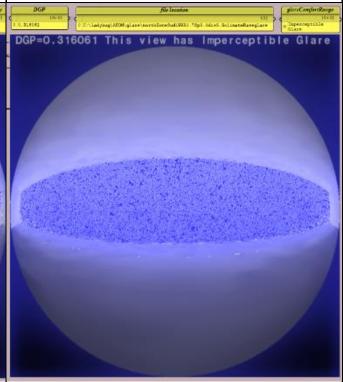
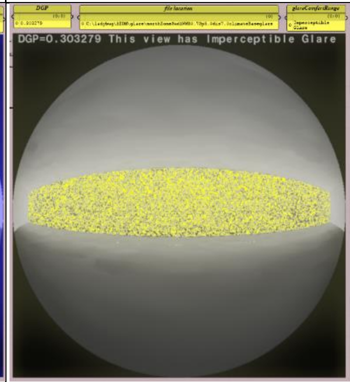


Figure 7-9 Illuminance distribution away from windows

Table 7-4 Glare comfort range simulation result (North)

Distance from window (m)					Type
1	2.5	4	5.5	7	
					No Sudare
DGP = 1 (Intolerable Glare)	DGP = 0.74 (Intolerable Glare)	DGP = 0.56 (Intolerable Glare)	DGP = 0.47 (Intolerable Glare)	DGP = 0.42 (Disturbing Glare)	
					Sudare, Spacer 20 mm
DGP = 1 (Intolerable Glare)	DGP = 0.58 (Intolerable Glare)	DGP = 0.56 (Intolerable Glare)	DGP = 0.41 (Disturbing Glare)	DGP = 0.38 (Perceptible Glare)	

					Sudare, Spacer 10 mm
DGP = 1 (Intolerable Glare)	DGP = 0.47 (Intolerable Glare)	DGP = 0.40 (Disturbing Glare)	DGP = 0.36 (Perceptible Glare)	DGP = 0.34 (Imperceptible Glare)	
					Sudare, Spacer 5 mm
DGP = 0.40 (Disturbing Glare)	DGP = 0.36 (Perceptible Glare)	DGP = 0.33 (Imperceptible Glare)	DGP = 0.31 (Imperceptible Glare)	DGP = 0.30 (Imperceptible Glare)	

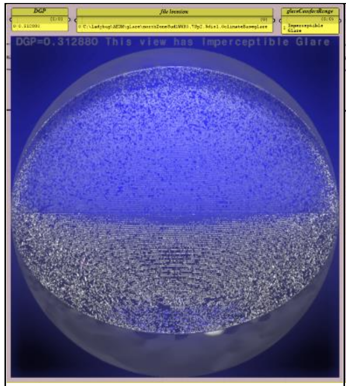
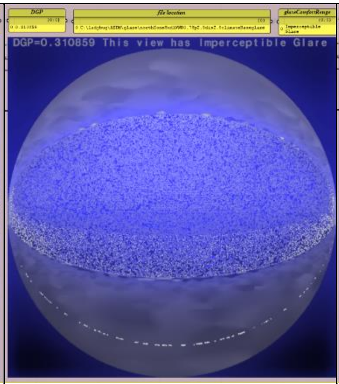
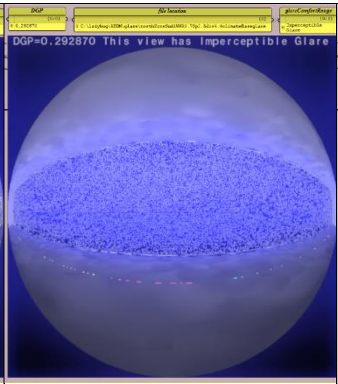
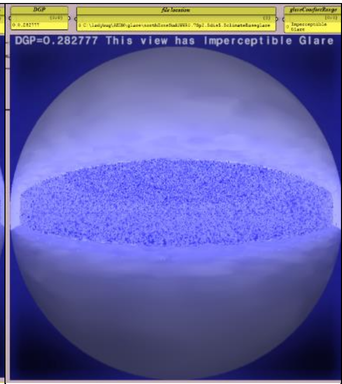
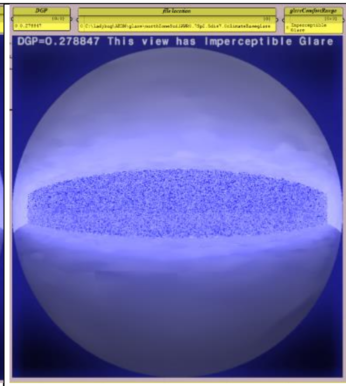
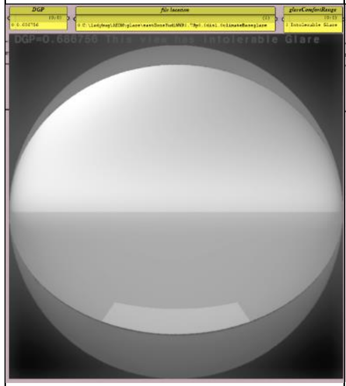
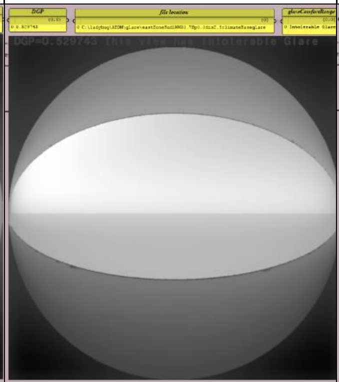
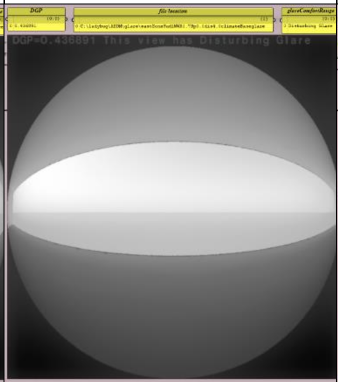
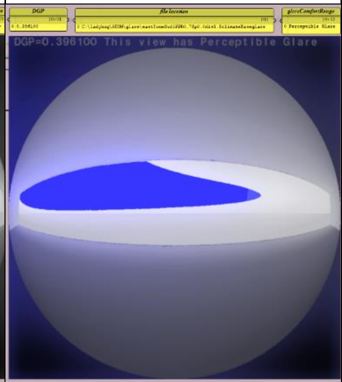
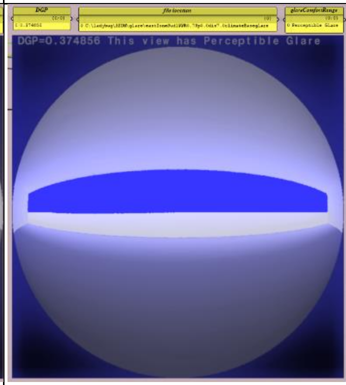
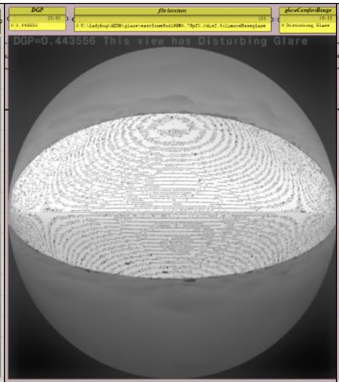
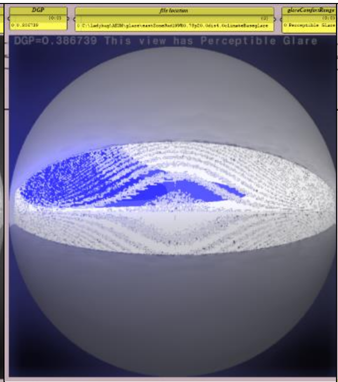
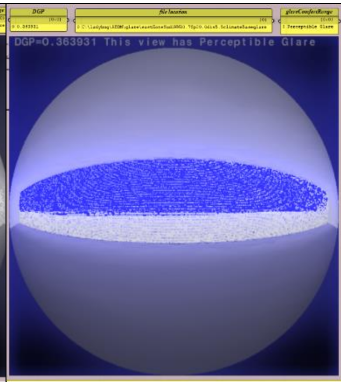
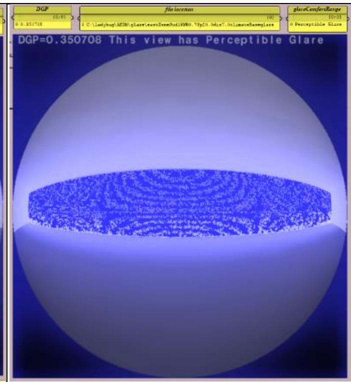
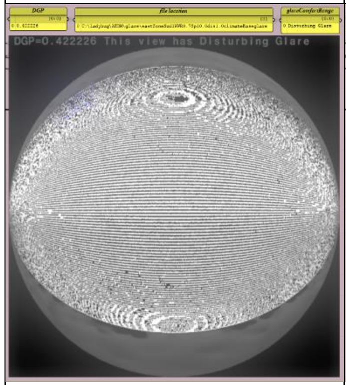
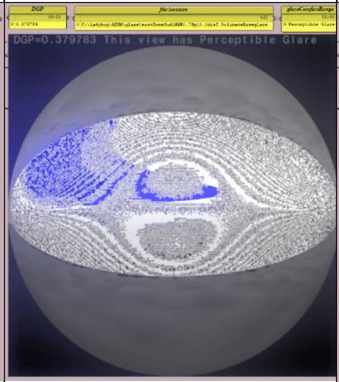
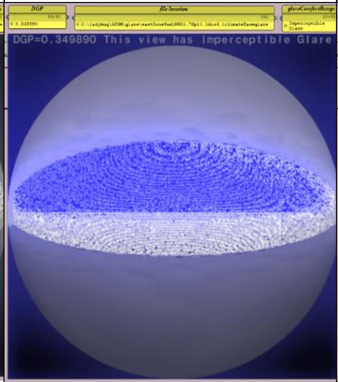
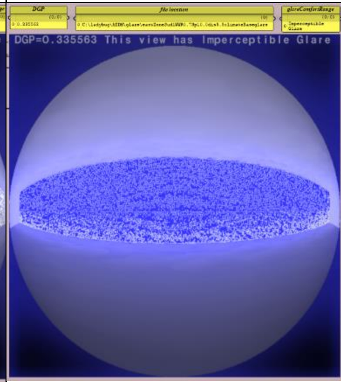
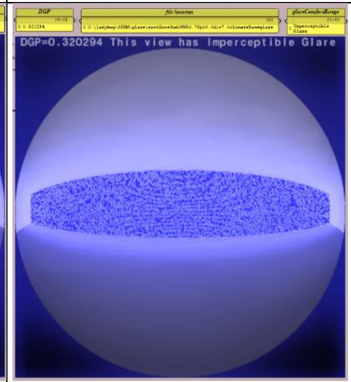
					Sudare, Spacer 2.5 mm
DGP = 0.31 (Imperceptible Glare)	DGP = 0.31 (Imperceptible Glare)	DGP = 0.29 (Imperceptible Glare)	DGP = 0.28 (Imperceptible Glare)	DGP = 0.27 (Imperceptible Glare)	

Table 7-5 Glare comfort range simulation result (East)

Distance from window (m)					Type
1	2.5	4	5.5	7	
					No Sudare
DGP = 0.68 (Intolerable Glare)	DGP = 0.52 (Intolerable Glare)	DGP = 0.43 (Disturbing Glare)	DGP = 0.39 (Perceptible Glare)	DGP = 0.37 (Perceptible Glare)	

					Sudare, Spacer 20 mm
DGP = 0.52 (Intolerable Glare)	DGP = 0.44 (Disturbing Glare)	DGP = 0.38 (Perceptible Glare)	DGP = 0.36 (Perceptible Glare)	DGP = 0.35 (Perceptible Glare)	
					Sudare, Spacer 10 mm
DGP = 0.42 (Disturbing Glare)	DGP = 0.37 (Perceptible Glare)	DGP = 0.34 (Imperceptible Glare)	DGP = 0.33 (Imperceptible Glare)	DGP = 0.32 (Imperceptible Glare)	

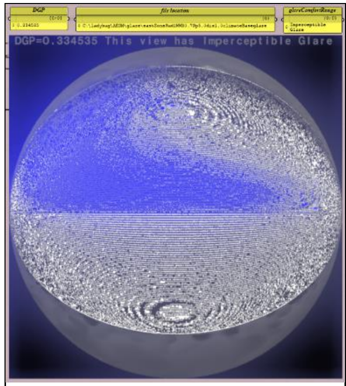
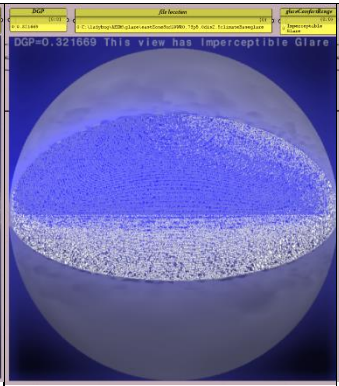
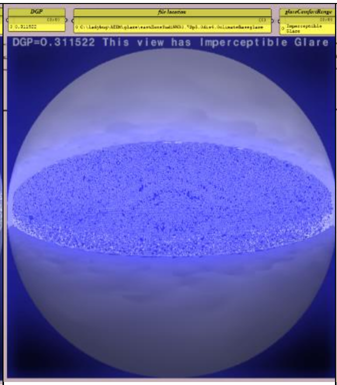
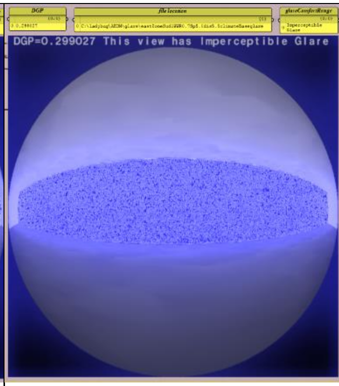
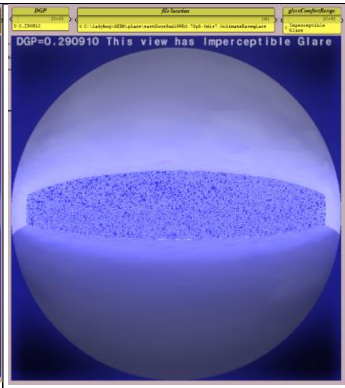
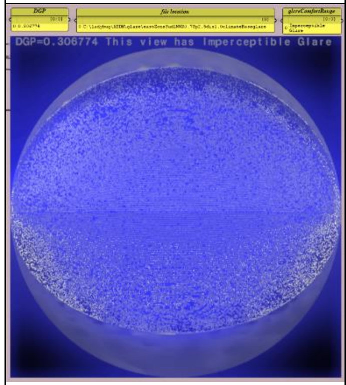
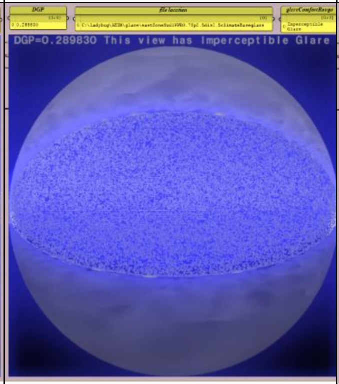
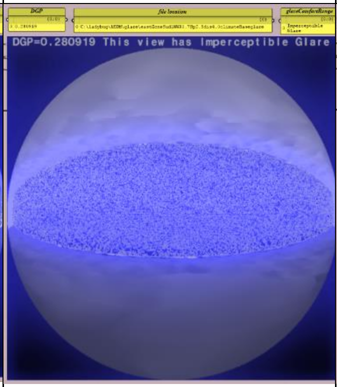
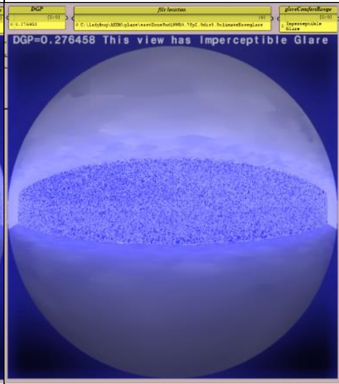
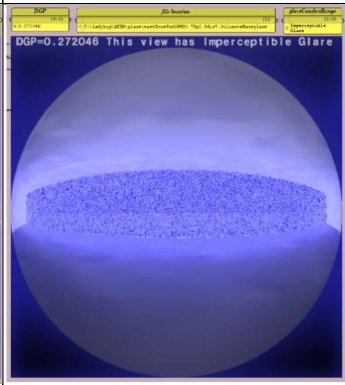
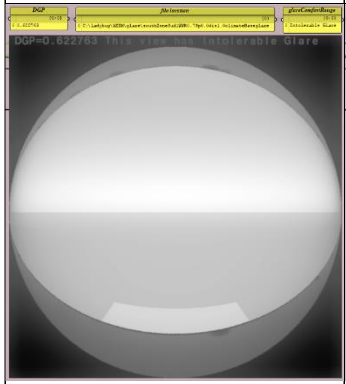
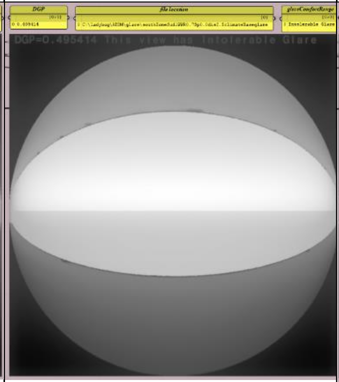
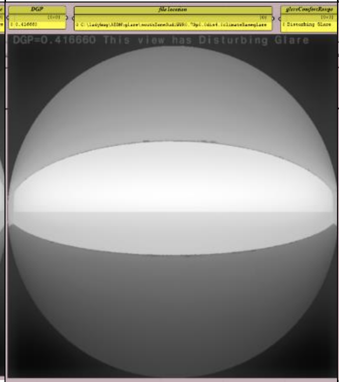
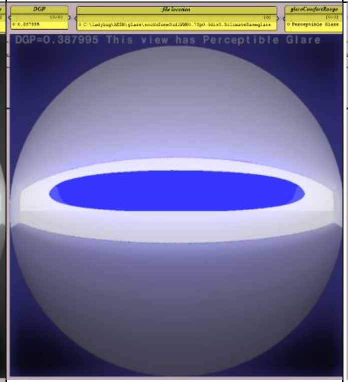
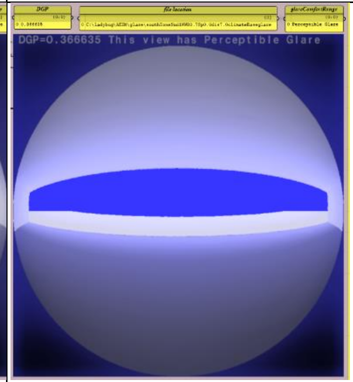
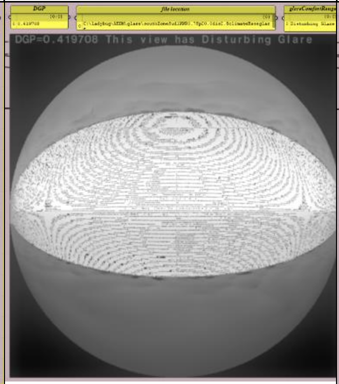
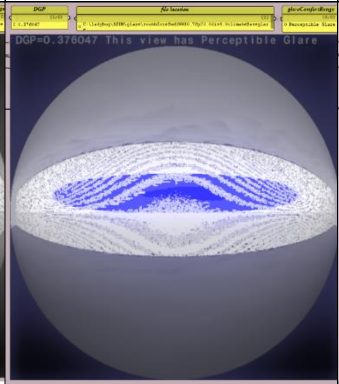
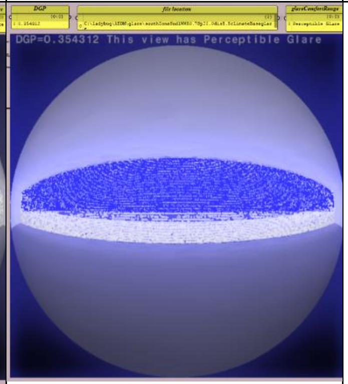
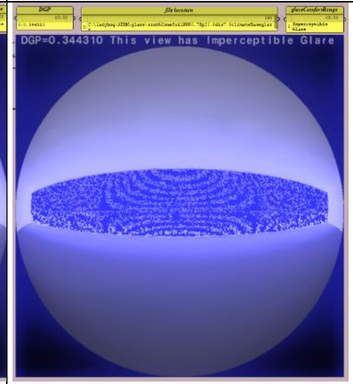
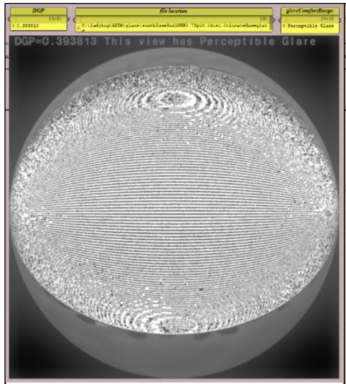
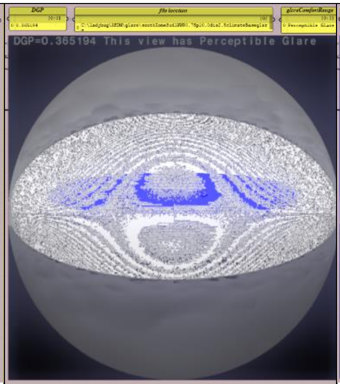
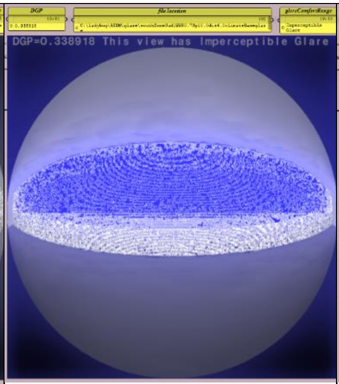
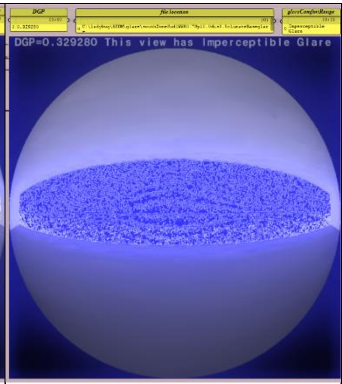
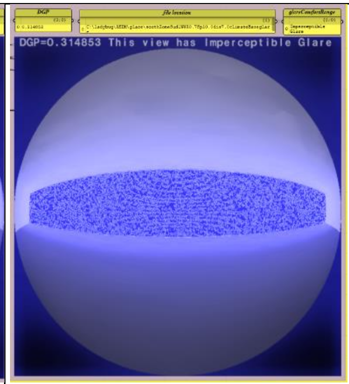
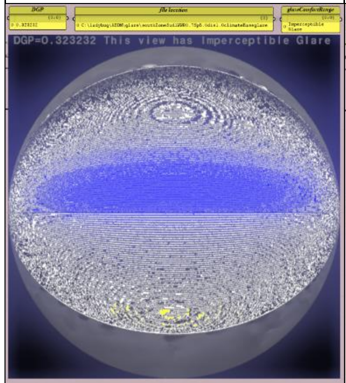
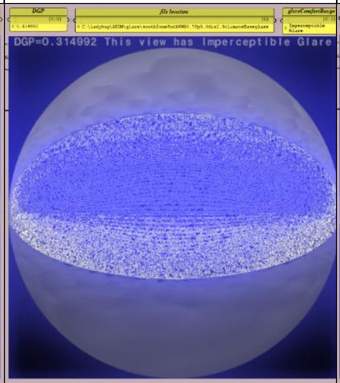
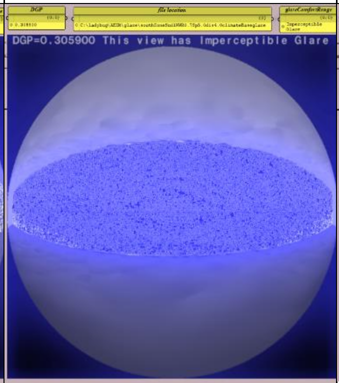
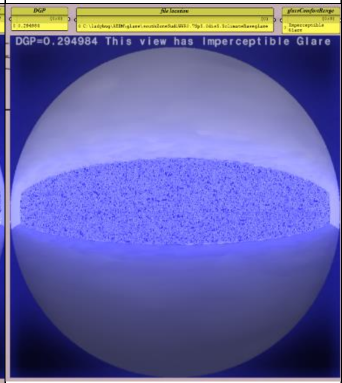
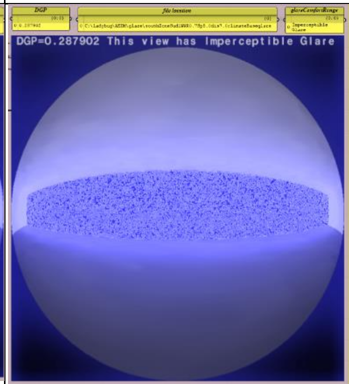
					Sudare, Spacer 5 mm
DGP = 0.33 (Imperceptible Glare)	DGP = 0.32 (Imperceptible Glare)	DGP = 0.31 (Imperceptible Glare)	DGP = 0.29 (Imperceptible Glare)	DGP = 0.29 (Imperceptible Glare)	
					Sudare, Spacer 2.5 mm
DGP = 0.30 (Imperceptible Glare)	DGP = 0.28 (Imperceptible Glare)	DGP = 0.28 (Imperceptible Glare)	DGP = 0.27 (Imperceptible Glare)	DGP = 0.27 (Imperceptible Glare)	

Table 7-6 Glare comfort range simulation result (South)

Distance from window (m)					Type
1	2.5	4	5.5	7	
					No Sudare
DGP = 0.62 (Intolerable Glare)	DGP = 0.49 (Intolerable Glare)	DGP = 0.41 (Disturbing Glare)	DGP = 0.38 (Perceptible Glare)	DGP = 0.36 (Perceptible Glare)	
					Sudare, Spacer 20 mm
DGP = 0.47 (Intolerable Glare)	DGP = 0.41 (Disturbing Glare)	DGP = 0.37 (Perceptible Glare)	DGP = 0.35 (Perceptible Glare)	DGP = 0.34 (Imperceptible Glare)	

<table>
<tr>
<td>
</td>
<td>
</td>
<td>
</td>
<td>
</td>
<td>
</td>
<td rowspan="2">Sudare, Spacer 10 mm</td>
</tr>
<tr>
<td>DGP = 0.39 (Perceptible Glare)</td>
<td>DGP = 0.36 (Perceptible Glare)</td>
<td>DGP = 0.33 (Imperceptible Glare)</td>
<td>DGP = 0.32 (Imperceptible Glare)</td>
<td>DGP = 0.31 (Imperceptible Glare)</td>
</tr>
<tr>
<td>
</td>
<td>
</td>
<td>
</td>
<td>
</td>
<td>
</td>
<td rowspan="2">Sudare, Spacer 5 mm</td>
</tr>
<tr>
<td>DGP = 0.32 (Imperceptible Glare)</td>
<td>DGP = 0.31 (Imperceptible Glare)</td>
<td>DGP = 0.30 (Imperceptible Glare)</td>
<td>DGP = 0.29 (Imperceptible Glare)</td>
<td>DGP = 0.28 (Imperceptible Glare)</td>
</tr>
</table>

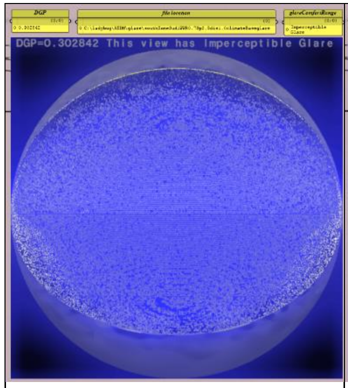
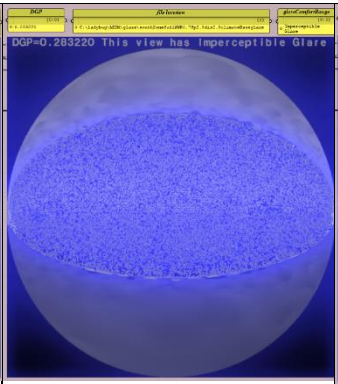
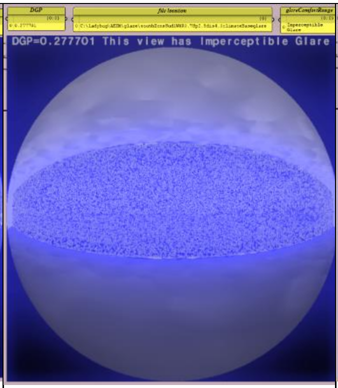
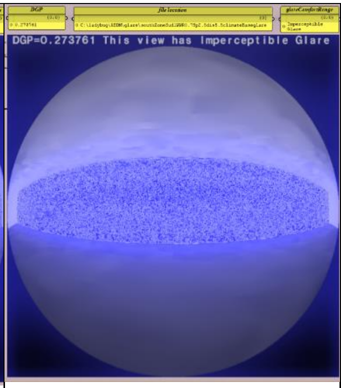
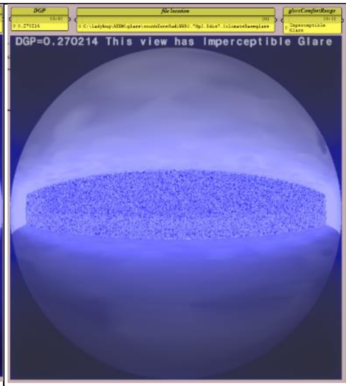
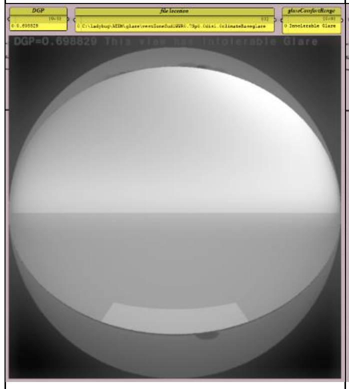
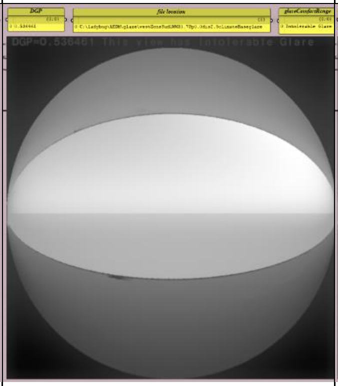
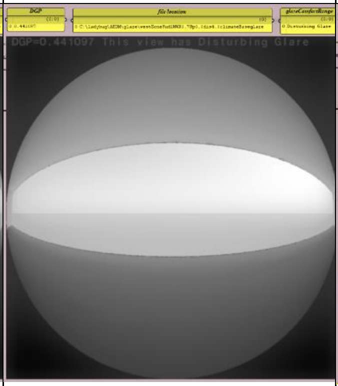
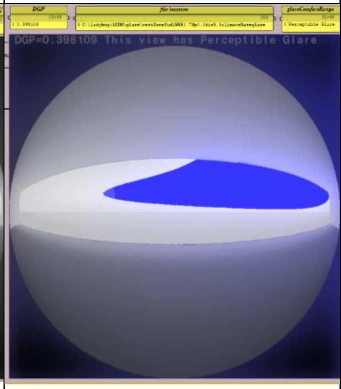
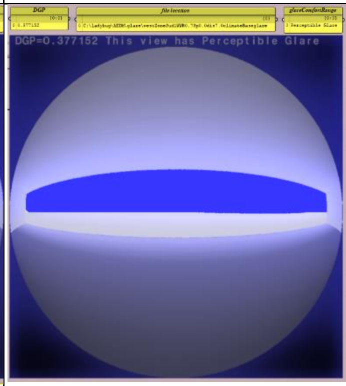
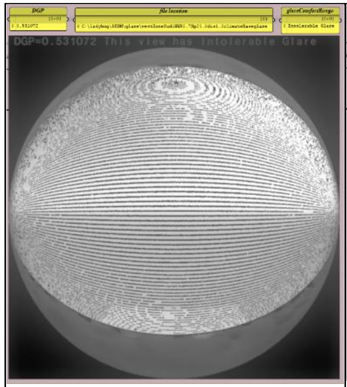
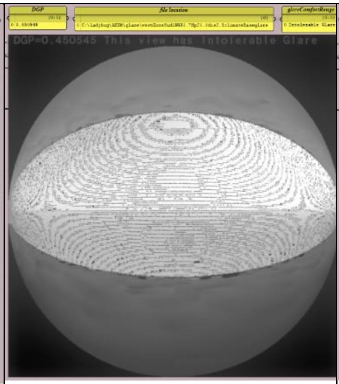
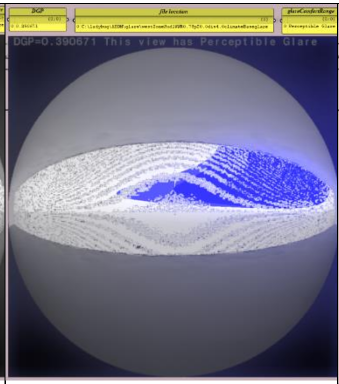
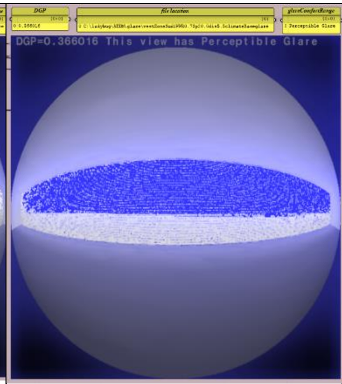
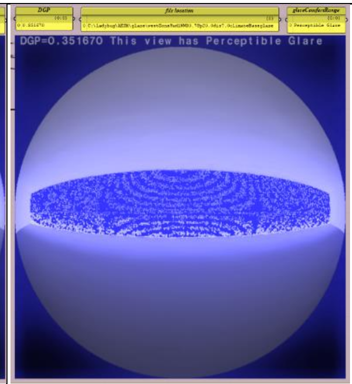
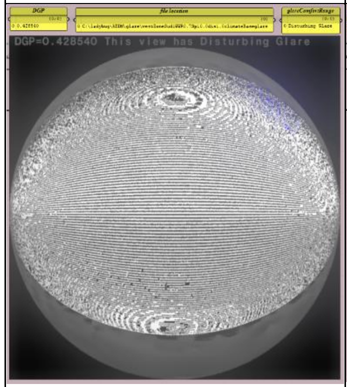
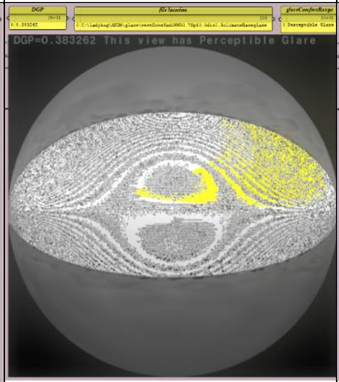
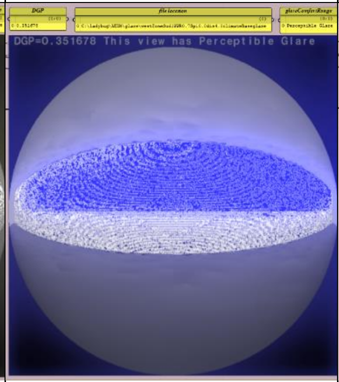
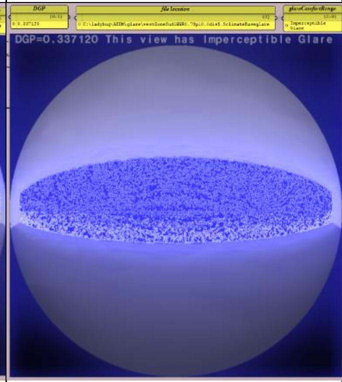
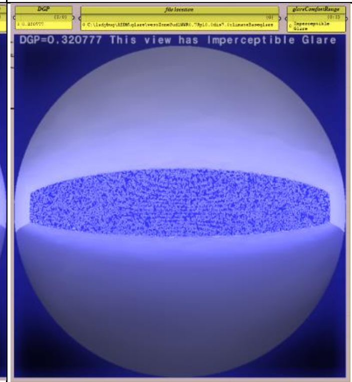
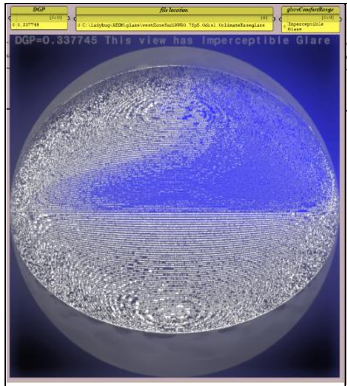
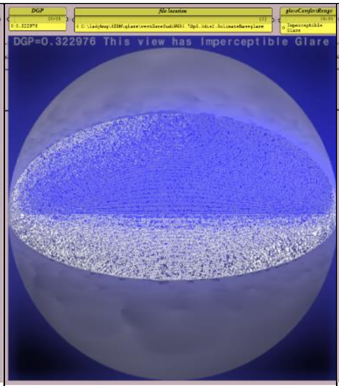
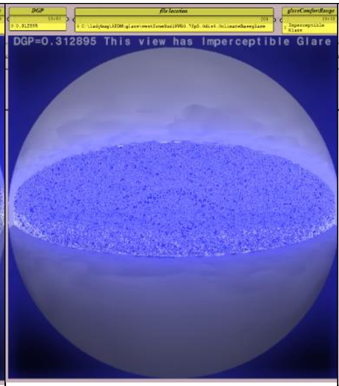
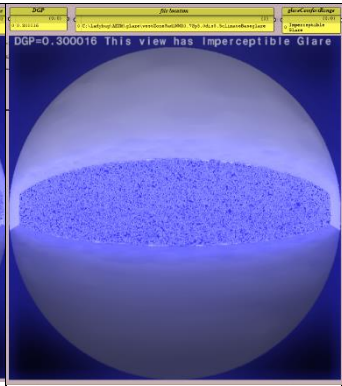
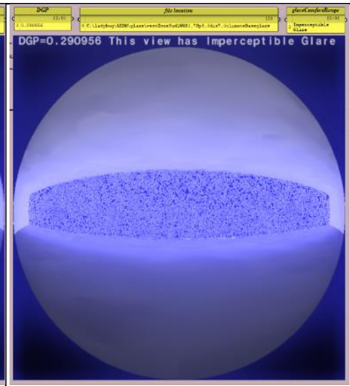
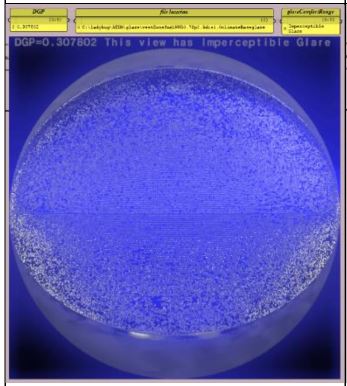
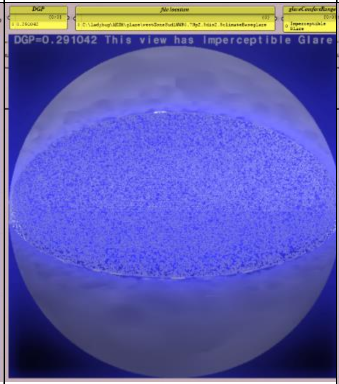
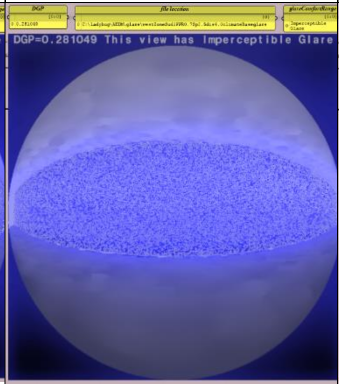
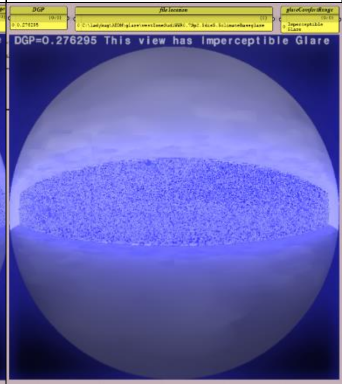
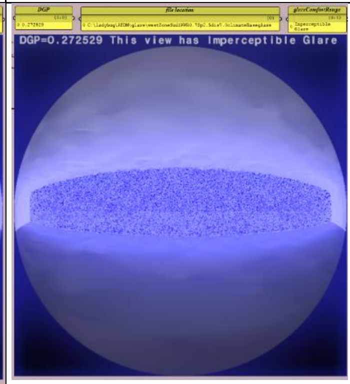
					Sudare, Spacer 2.5 mm
DGP = 0.30 (Imperceptible Glare)	DGP = 0.28 (Imperceptible Glare)	DGP = 0.28 (Imperceptible Glare)	DGP = 0.27 (Imperceptible Glare)	DGP = 0.27 (Imperceptible Glare)	

Table 7-7 Glare comfort range simulation result (West)

Distance from window (m)					Type
1	2.5	4	5.5	7	
					No Sudare
DGP = 0.69 (Intolerable Glare)	DGP = 0.53 (Intolerable Glare)	DGP = 0.44 (Disturbing Glare)	DGP = 0.39 (Perceptible Glare)	DGP = 0.37 (Perceptible Glare)	

					Sudare, Spacer 20 mm
DGP = 0.53 (Intolerable Glare)	DGP = 0.45 (Intolerable Glare)	DGP = 0.39 (Perceptible Glare)	DGP = 0.36 (Perceptible Glare)	DGP = 0.35 (Perceptible Glare)	
					Sudare, Spacer 10 mm
DGP = 0.42 (Disturbing Glare)	DGP = 0.38 (Perceptible Glare)	DGP = 0.35 (Perceptible Glare)	DGP = 0.33 (Imperceptible Glare)	DGP = 0.32 (Imperceptible Glare)	

					Sudare, Spacer 5 mm
DGP = 0.33 (Imperceptible Glare)	DGP = 0.32 (Imperceptible Glare)	DGP = 0.31 (Imperceptible Glare)	DGP = 0.30 (Imperceptible Glare)	DGP = 0.29 (Imperceptible Glare)	
					Sudare, Spacer 2.5 mm
DGP = 0.30 (Imperceptible Glare)	DGP = 0.29 (Imperceptible Glare)	DGP = 0.28 (Imperceptible Glare)	DGP = 0.27 (Imperceptible Glare)	DGP = 0.27 (Imperceptible Glare)	

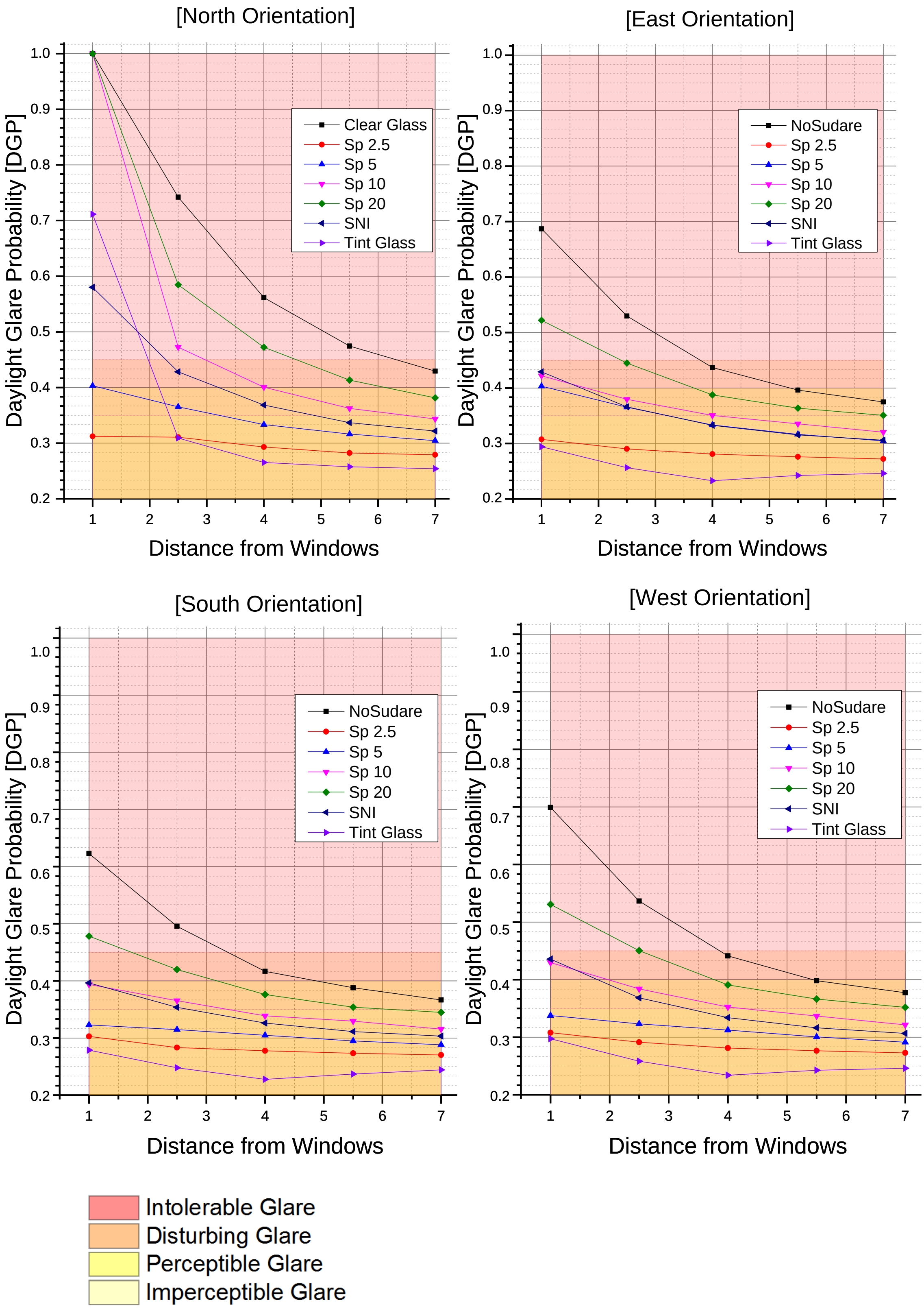


Figure 7-10 Daylight glare probability looking at the window

Table 7-8 Efficiency value comparison of modified model

No	Type	Volume of Sudare material [m^3]	OTTV Value [Watt / m^2]	Efficiency [%]	Cooling load [kWh]	Efficiency [%]	Visibility (indoor 300) lux	Privacy	UDI 100-2000 [%]	Efficiency [%]	DGP 2.5 m	State
1	No Sudare, Clear Glass SHGC 0.7 Tvis 0.8	0.00	97.68	-179	198.30	-48	5.73	0.54	27.17	-54	0.58	InG
2	Baseline	0.00	35	0	134.16	0	5.73	0.54	59.07	0	0.38	PG
3	No Sudare, tinted glass SHGC 0.2 Tvis 0.2	0.00	35.83	-2	121.67	9	2.92	3.38	90.11	52.56	0.27	ImG
4	20-mm spacer	0.93	55.93	-60	153.10	-14	3.65	3.31	40.95	-30.67	0.47	InG
5	10-mm spacer	1.40	43.87	-25	138.80	-3	2.96	4.12	56.36	-4.58	0.40	DG
6	5-mm spacer	1.86	33.22	5	126.42	6	2.65	4.27	81.24	37.53	0.34	ImG
7	2.5-mm spacer	2.23	22.34	36	113.38	15	2.77	4.62	88.28	49.46	0.29	ImG

ImG: Imperceptible Glare
PG: Perceptible Glare
DG: Disturbing Glare
InG: Intolerable Glare

7.5 Section Conclusion

Based on the results of this analysis, the geometry of Sudare shows effectiveness in reducing the OTTV and cooling load value while maintaining the visual qualities of view and the privacy of occupants inside. This condition gives more flexibility and creativity for architects to design building façades. Minimum fenestration areas to achieve OTTV 35 watt/m2 have increased significantly, from 20% when using glass with SHGC 0.2 to 70% when using normal clear glass (SHGC 0.7) with Sudare of 10.01-mm diameter and 5-mm spacers. In terms of efficiency, this configuration decreases 5% of OTTV and 6% of cooling load compared to the baseline building, and better OTTV than, and a close cooling load value to, tinted glass. The visibility value of this configuration is 2.65, close to the visibility of tinted glass with Tvis 0.2 (2.92); the privacy is 4.27, much better than that of tinted glass (3.38). This condition will be better in a real-life application where the illuminance difference is much higher between the inside and outside than the maximum illuminance condition of the experiment room. The Sudare façade can also improve the uniformity of the daylight, which causes an improvement in visual performance and the comfort of occupants.

.

Chapter 8 Parametric Sliding Sudare

8.1 Prototype of Sliding Sudare

The improvement of control from the previous experiment was done based on the idea that different spacer sizes in the Sudare would improve the visibility level. This parametric spacer still had to minimize the movement of the solid part of the Sudare and while being practical to build for the implementation. The other limitation that needed to be considered was the similarity of improved model to the original Sudare. The model should be small in diameter but still be controlled easily and parametrically. One idea that finally achieved the criteria was the use of a sliding door typical of many traditional Japanese houses, so the improved model was called Sliding Sudare (Figure 8-1).

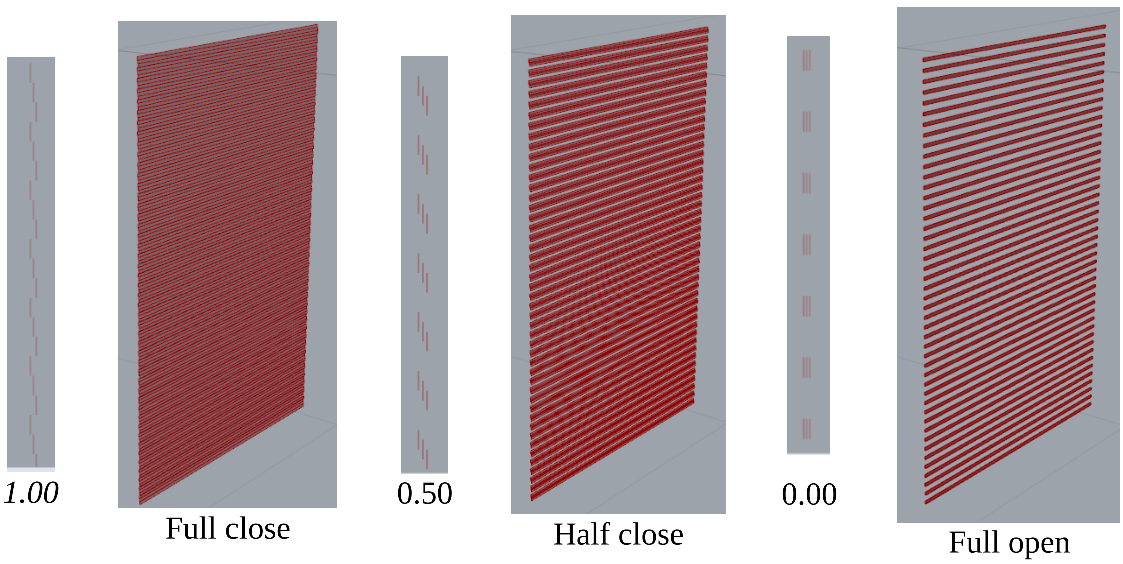
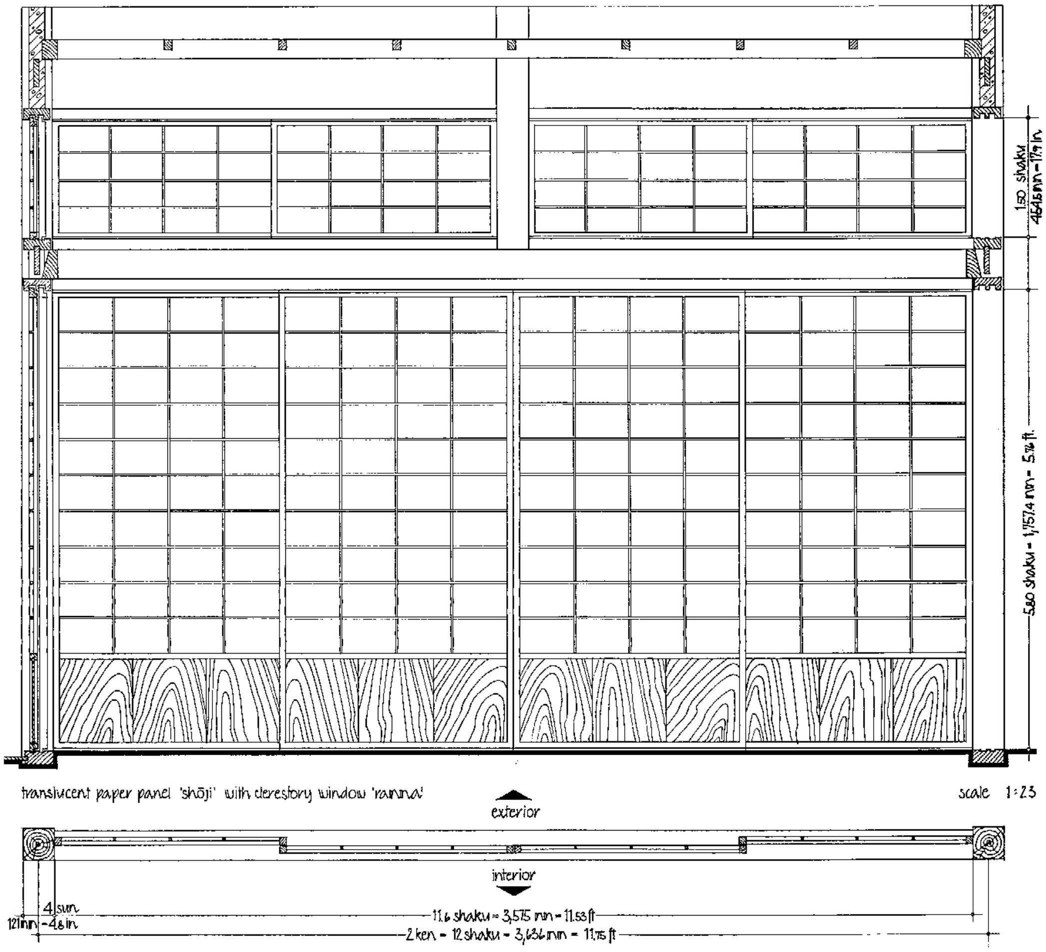


Figure 8-1 Sliding Sudare model

In traditional Japanese sliding doors or windows, there are only two layers, even with four door panels (Figure 8-2) (Engel 1985). The modification from two layers to three was done to increase the distance flexibility of the void or spacer which becomes three times that of the solid width but still maintains the thinness of all layers.



Source: Engel,1985

Figure 8-2 Japanese sliding door

8.1.1 Grasshopper definition of Sliding Sudare

The first step was to simulate and develop a model using Grasshopper software (Figure 8-3). By using this parametric software, the model can be easily changed parametrically in the 3D model world.

The prototype was made using a 3D printer because of the ease of customization and the fact that it could be built based on 3D data from Rhinoceros 3D. The model will be built to scale, but in a smaller size due to the limitations on the maximum printing size of the 3D printer. In this experiment, the model was built with dimensions of 150 mm width and 200 mm height.

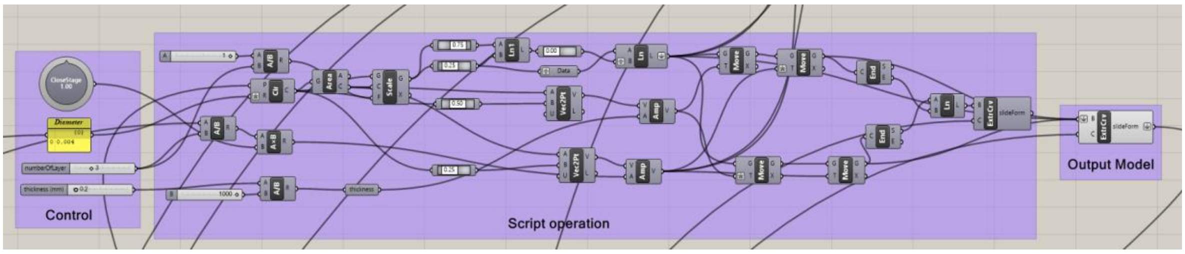


Figure 8-3 Sliding Sudare Grasshopper script definition

8.1.2 3D Print of Sliding Sudare

After designing the basic model of the sliding Sudare, the next operation using Grasshopper script, was to make the offside object of each layer for the frame (Figure 8-4). The intention of the frame was to hold each slat in the same layer because it would be very hard to maintain the distance of each slat using rope or different material than the slat material (Figure 8-5).

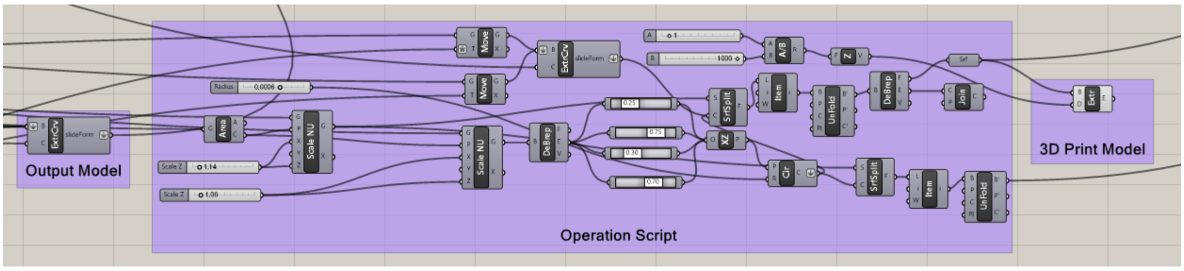


Figure 8-4 Grasshopper script for making 3D print model

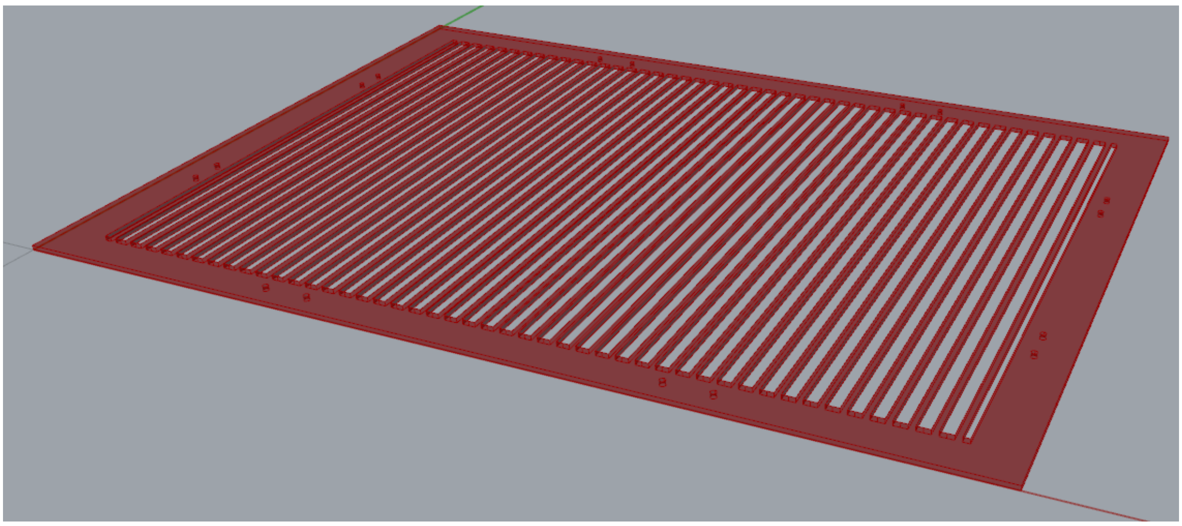


Figure 8-5 3D model in Rhinoceros 3D

The next step was to print the 3D model using Rhinoceros 3D using MakerBot: one piece for the middle layer, and two more for front layer and back layer (Figure 8-6). MarkerBot is a 3D printing machine that uses PLA plastic to print with a layer-by-layer method (MakerBot n.d.).

Figure 8-6 3D Printing process

After printing all three pieces of the model, they were put together using rubber rope on the outer part of the sliding Sudare. This rubber rope had two functions: first, it joins the three layers together; second it can be used as the moving mechanism of the sliding Sudare itself (Figure 8-7).

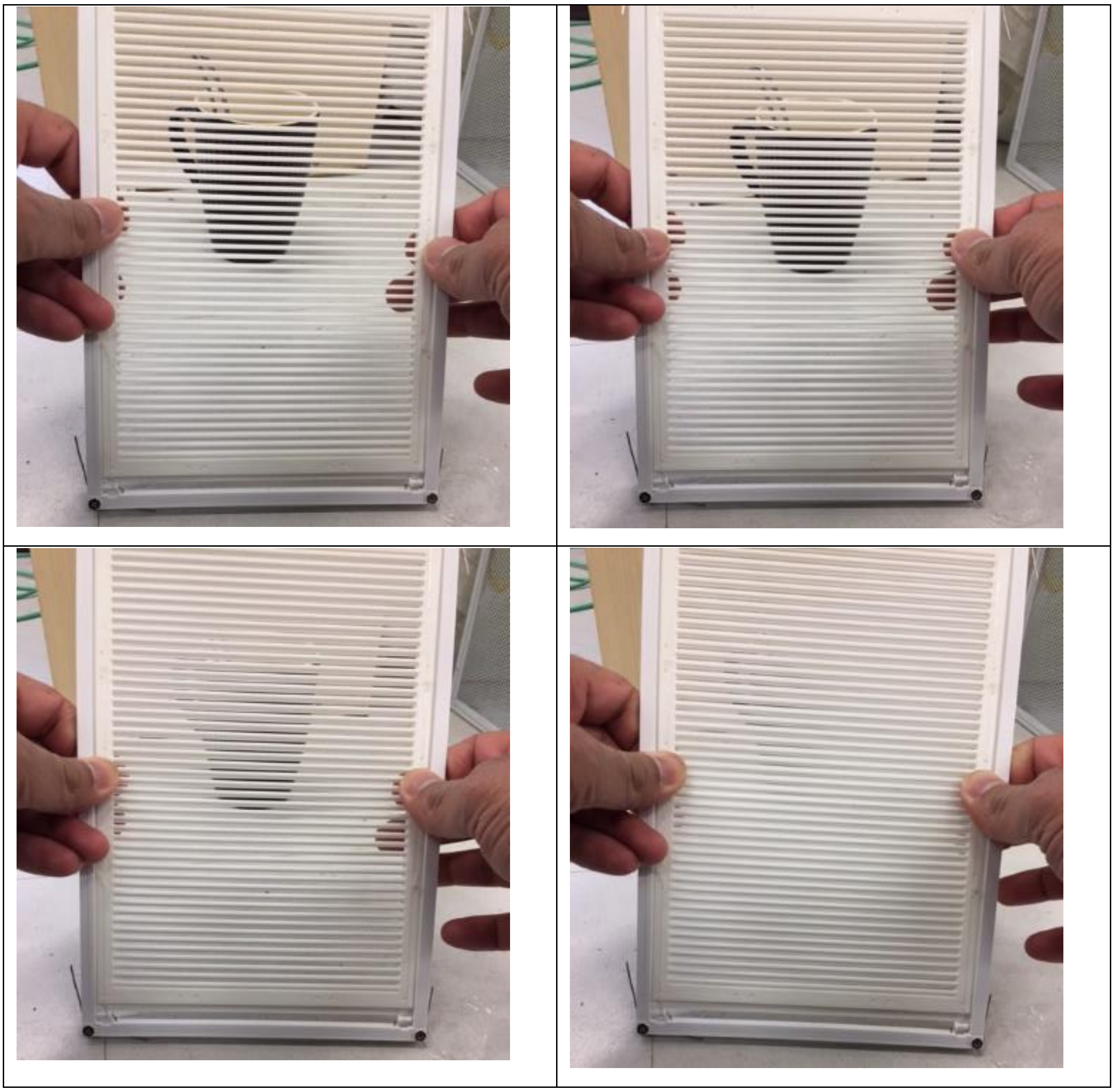


Figure 8-7 Sliding Sudare model (3D Print)

8.2 Sliding Sudare Kinetic Façade

The prototype model is a very promising development pointing to the next area of research: building a responsive kinetic façade that can be changed based on the environment.

Recent research on kinetic façade has shown the ability to optimize the façade function in minimizing energy consumption of building (Radhi et al. 2013).

The idea is to use an illuminance sensor to determine how much to open or close the sliding Sudare. Based on the previous research result, with higher illuminance, which occurs at the same time as peak sun shine or peak solar radiation, smaller voids will still allow high visibility. Minimizing the voids will also maximize the shading capabilities of the sliding Sudare. The sensor will activate a microcontroller to switch on a motor to move the front layer, which will generate movement in the back layer. The middle layer will not move because this layer is the main component that connects to the frame and attaches to the window frame (Figure 8-8).

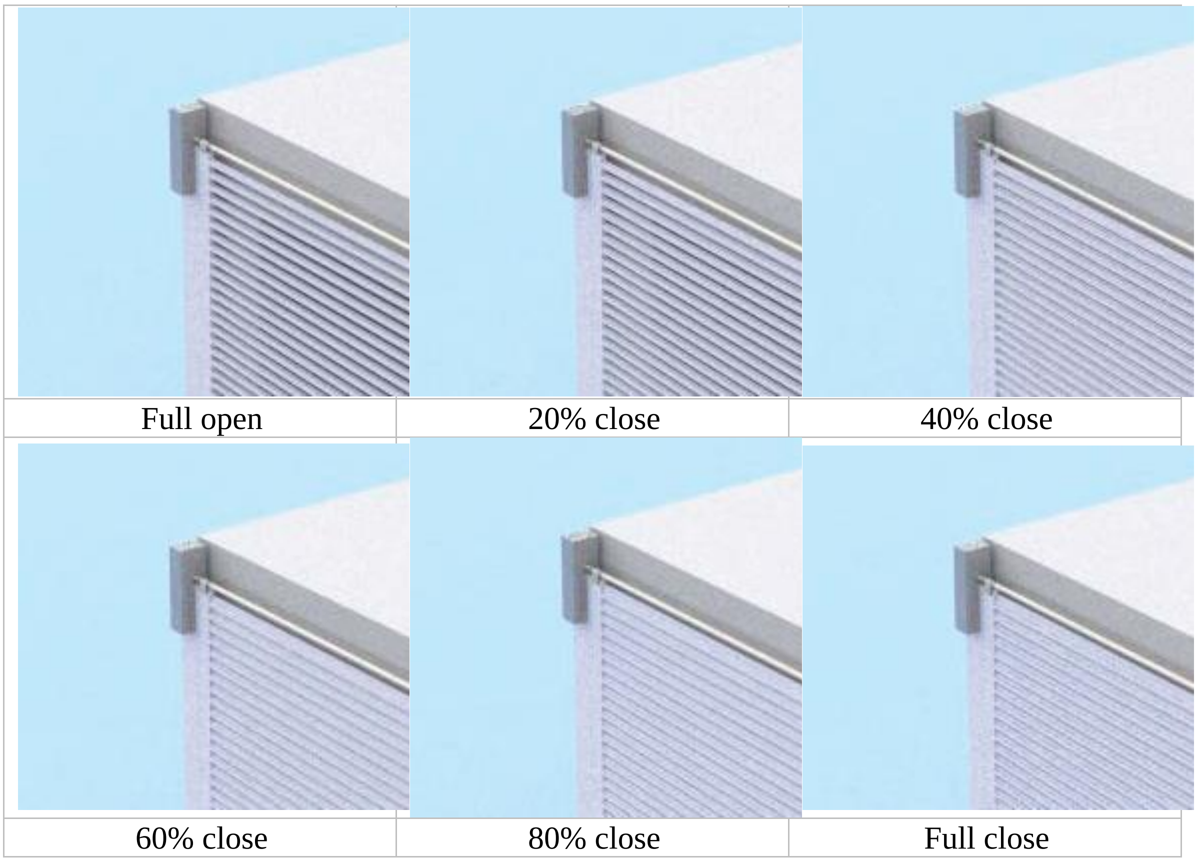
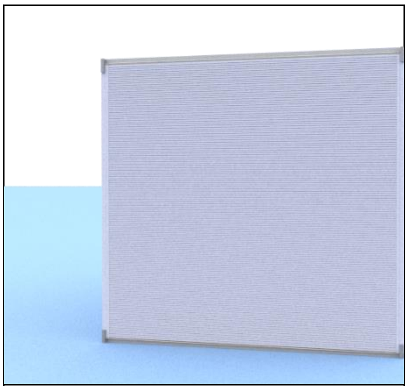
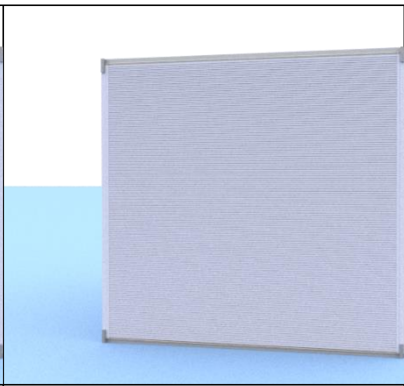
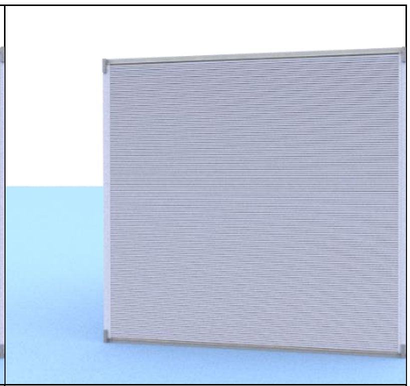
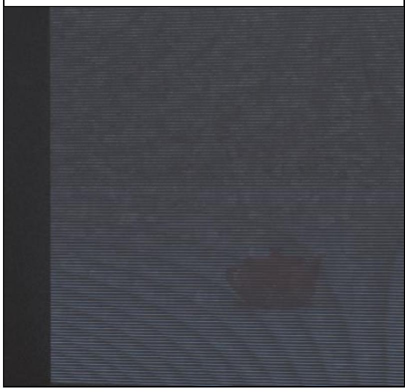
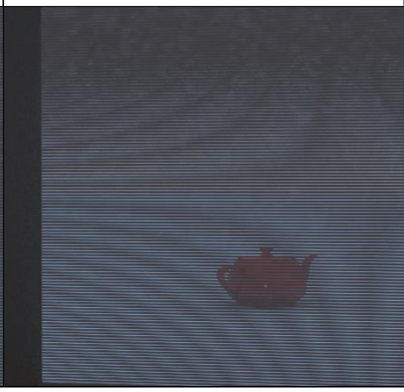


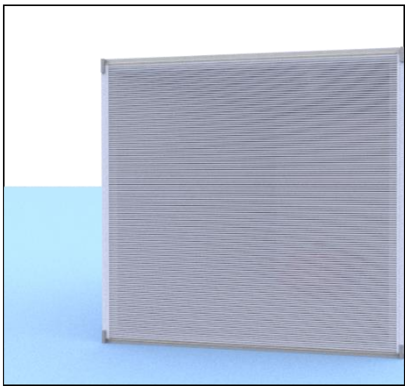
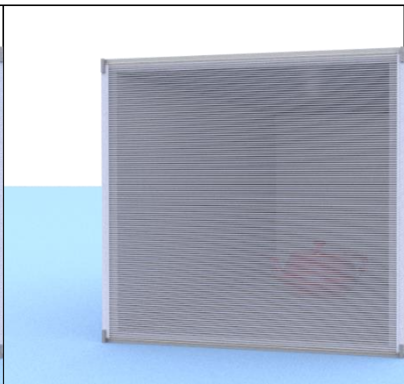
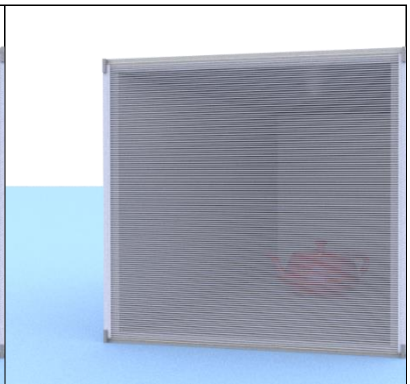
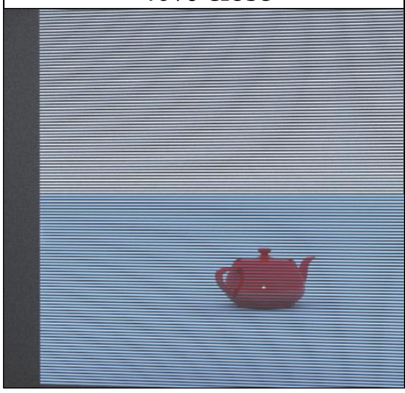
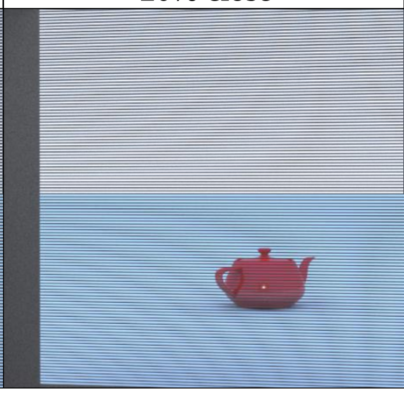
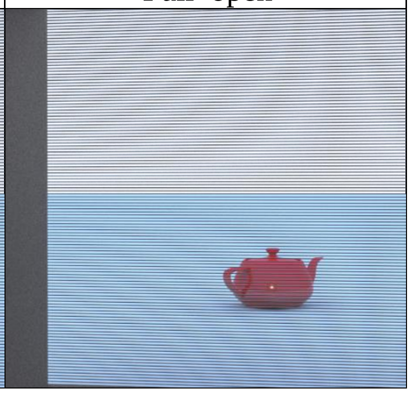
Figure 8-8 open-close mechanism

8.3 Visual image of Sliding Sudare Kinetic Façade

A rendered image of the both side view using the same setting shows the capability of the façade to maximize the amount of shade and maintain visibility for the occupants from inside to outside (Table 8-1). Compared to a full-glass window without shading devices, people from outside still could not see clearly inside until the full open condition. While from inside to outside, occupants could see silhouettes of the object in front of the window, even with full close condition

Table 8-1 Rendering image for visibility perception

		
Full close	80% close	60% close
		

		
40% close	20% close	Full open
		

8.4 Prototype model of Sliding Sudare

The function of making prototype was to measure the feasibility and evaluate the "actual feel" of the object design. This process also important to improve the design by solving or minimizing problem that may occur in the product.

Using the 3D print object result of the three layer Sliding Sudare, then it being assembly in the frame and tested for the kinetic mechanism (Figure 8-9).

Figure 8-9 Complete prototype model

The frame was the interface between the window and window frame for the sliding Sudare, and was also a place to hang the roller for pulley. Nylon string was used to connect and pull the front layer and back layer of the sliding Sudare, controlled by a lever inside the window (Figure 8-10).

(a) (b) (c)

Figure 8-10 Detail mechanism (a) front roller attach to Sudare frame (b) back roller attach to window (c) lever attach to window inside

The prototype model was tested for parametric operation using the lever switch to change the spacer of the sliding Sudare (Figure 8-11). The result showed the ability of the sliding Sudare to function as intended. I t also proved that the design could be developed further to create a practical, full-size model.

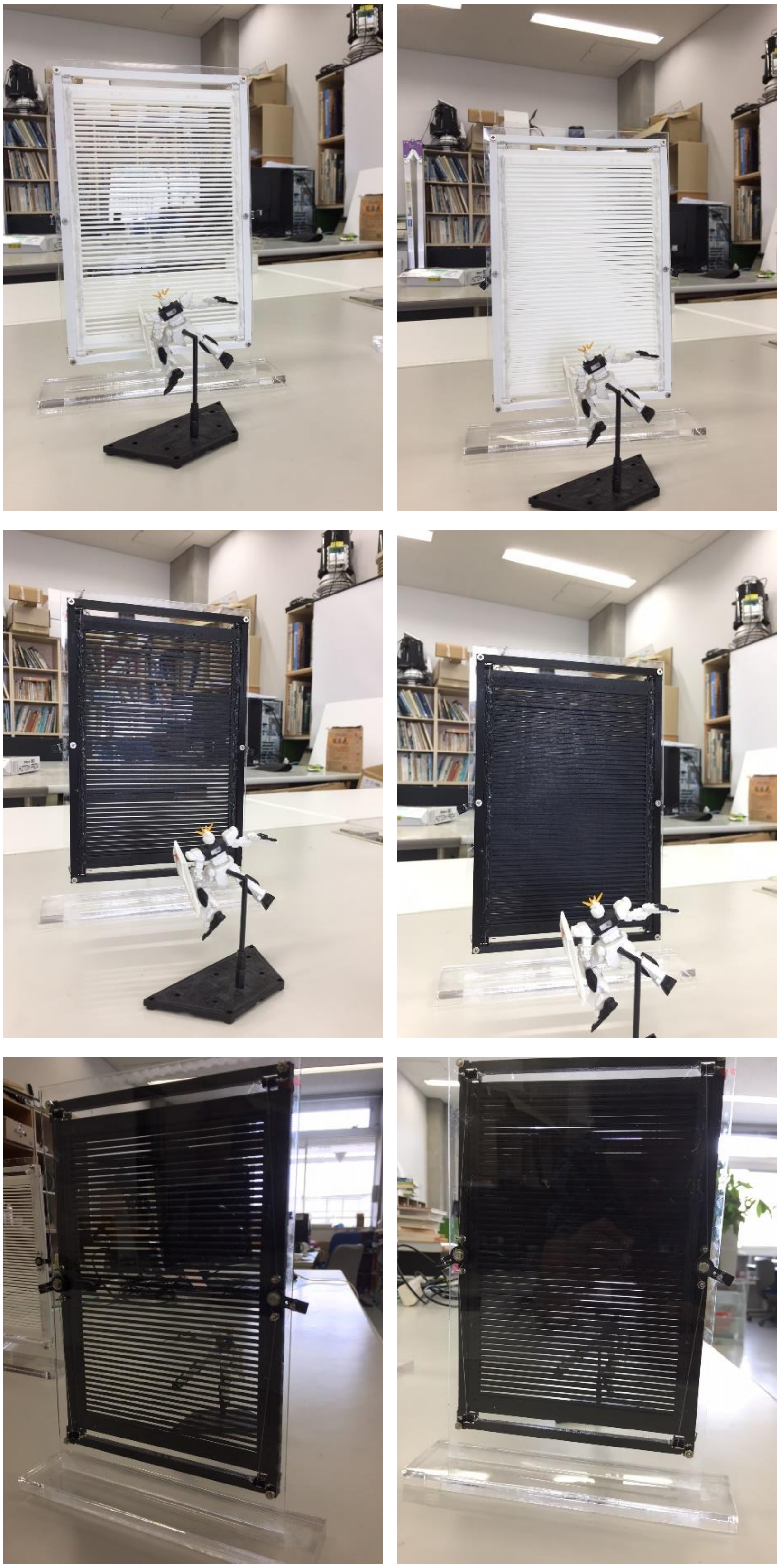
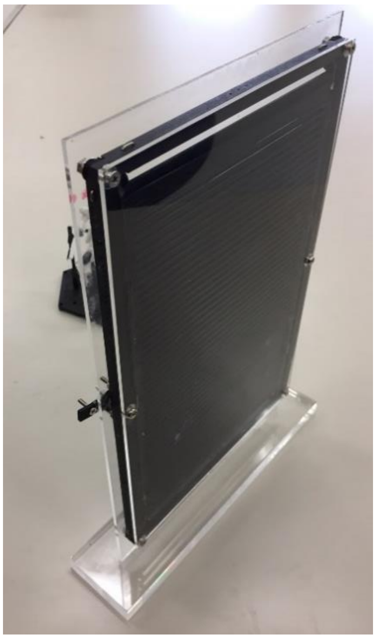


Figure 8-11 Parametric operation of sliding Sudare

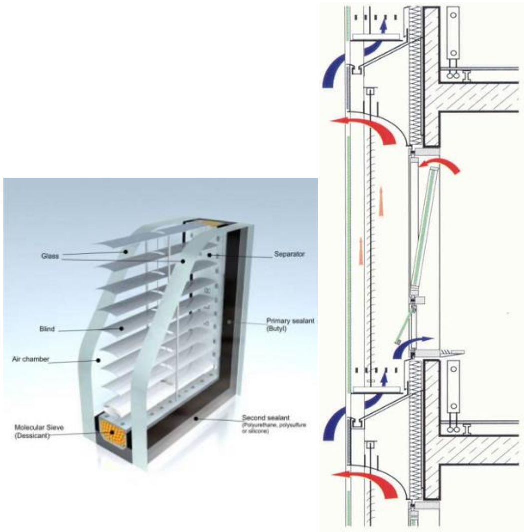
8.5 Technical Implementation

Based on the previous prototype of the sliding Sudare, the outside shading implementation may work well on single-story or low-rise buildings, but for high-rise buildings, there are other considerations that must be calculated. The effects of wind must be overcome. One technology that is already available is an integral blind inside double glass system (Pearce n.d.) (Figure 8-12). In addition to protecting against the wind, using this technology has additional benefits: It might require no additional maintenance—something outside Sudare would certainly need—and it would also improve thermal performance by using insulating glass with gas, which has maximum thickness for an optimal result (15 mm space for air and 16mm for argon).



Front view

Back view



Similar system

Figure 8-12 Double glass with Sliding Sudare inside system and double façade system

8.6 Automatic Responsive System

Automatic responsive system works based on the changing conditions of illuminance and/or solar radiation of the outdoor environment. An illuminance sensor was placed outdoors to measure the illuminance level and send the value to the microcontroller (Arduino). Based on the value of the illuminance meter, the Arduino will control the servo to rotate and move the sliding Sudare and change its open/close position (Figure 8-13). The movement of the sliding Sudare can be further controlled by using a timer to schedule the changes.

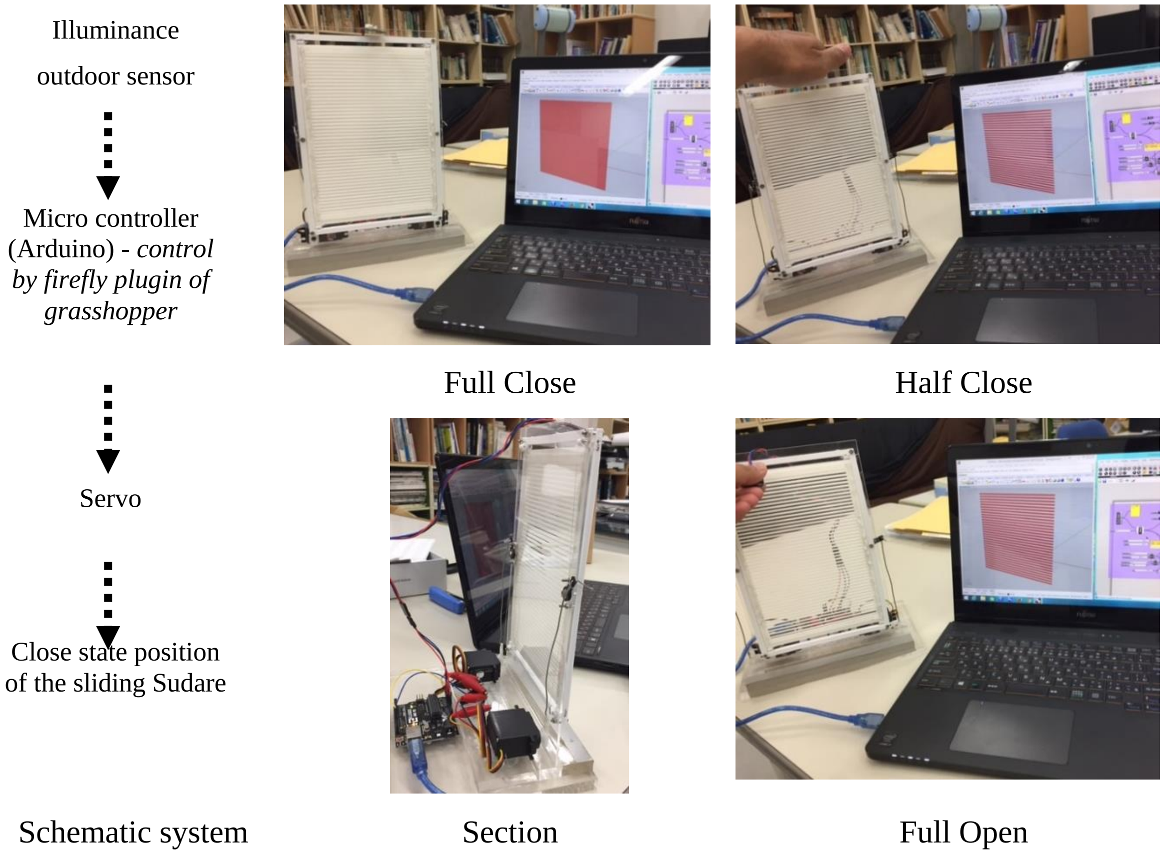


Figure 8-13 Automatic sliding Sudare system

8.7 Simulation

The next steps in this research were to simulate the thermal performance and visual comfort of the sliding Sudare system. The steps of the simulation were the same as those of the previous Sudare system. This was done to analyze the maximum and minimum of the thermal and visual performance of the sliding Sudare system. The simulation was done using Jakarta weather data location with a north-facing facade due to the significance of the orientation in this location (Figure 8-14).

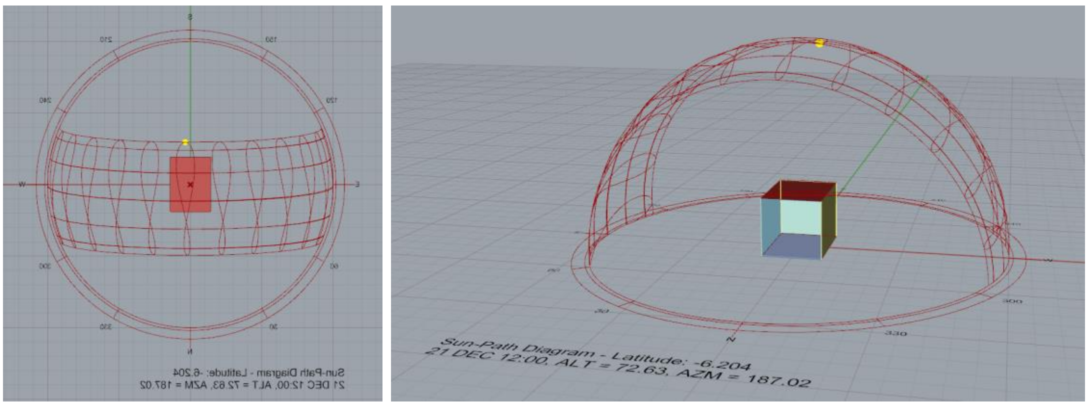
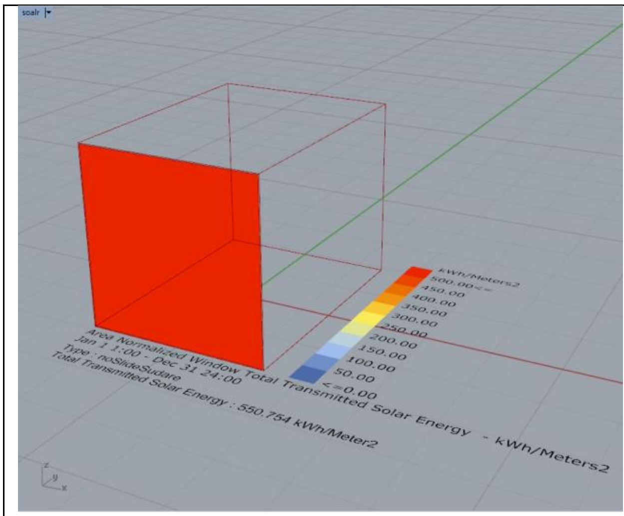


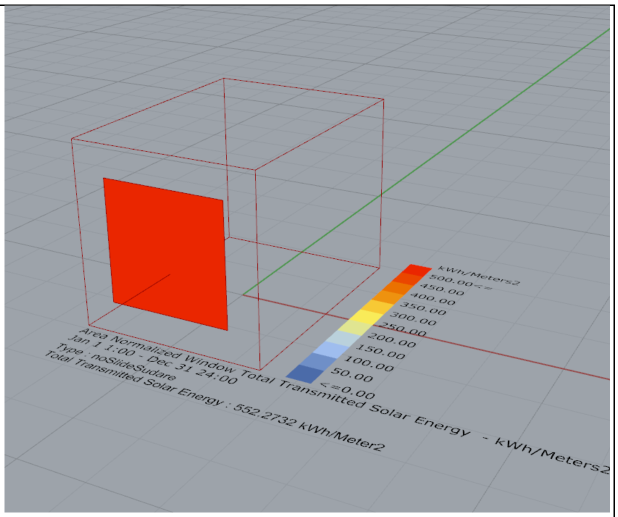
Figure 8-14 Sliding Sudare simulation in six tatami building with Jakarta weather file

In the solar radiation simulation, the sliding Sudare reduced the OTTV of 18 Watt/m^2 when in the full close mode, and reached the minimum OTTV for the Indonesian standard when in the 60% to 80% closed mode (Table 8-2) (Figure 8-15).

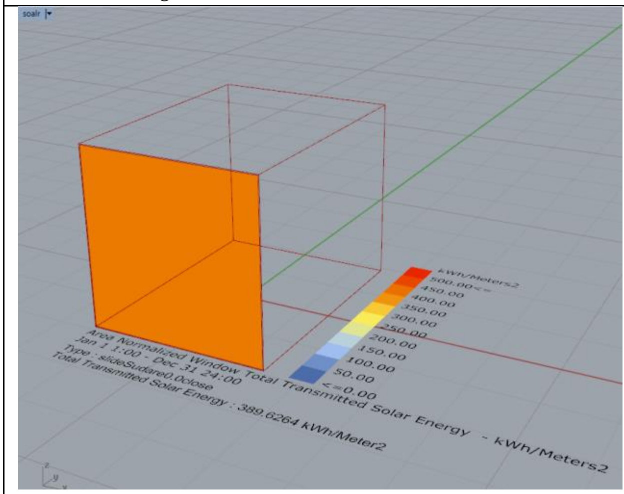
Table 8-2 Solar Radiation Simulation of Sliding Sudare in Jakarta

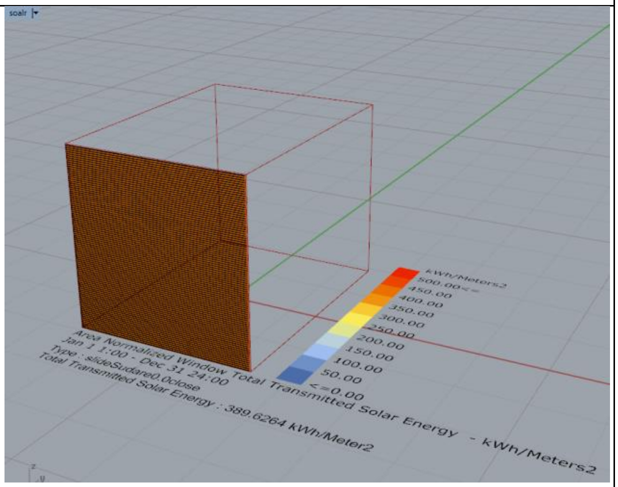


No Sliding Sudare, 550.75 kWh/m^2,OTTV 147 Watt/m^2

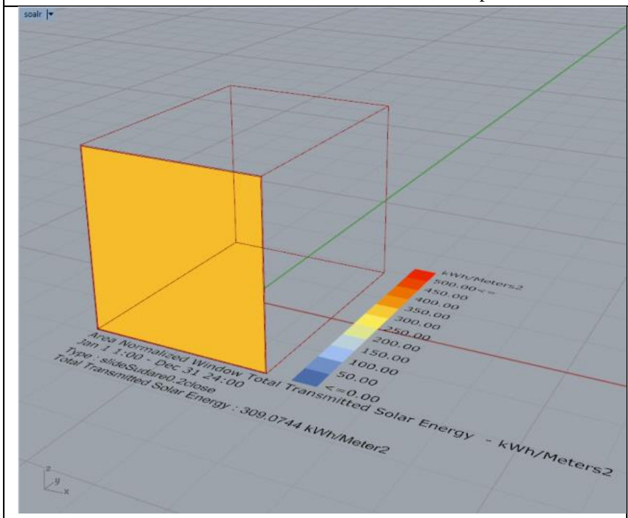


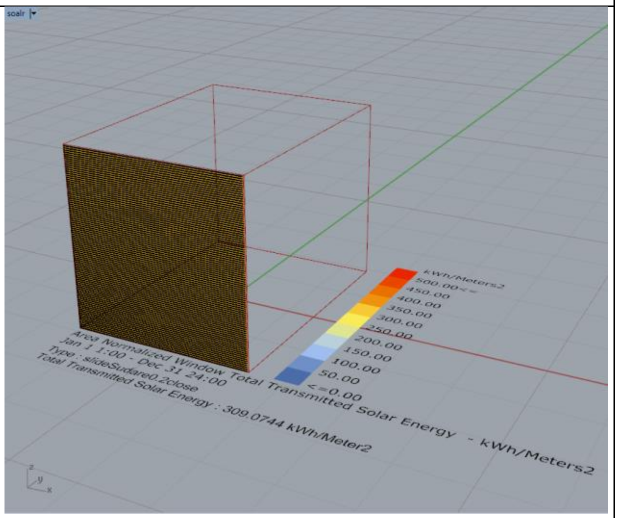
SNI, 552.27 kWh/m^2,OTTV 35 Watt/m^2



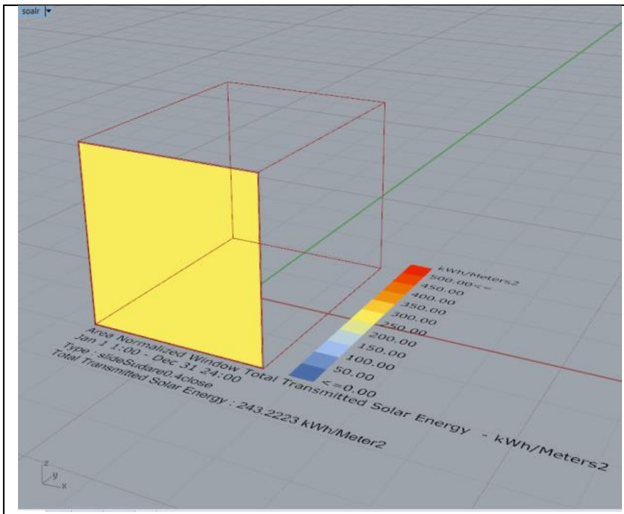


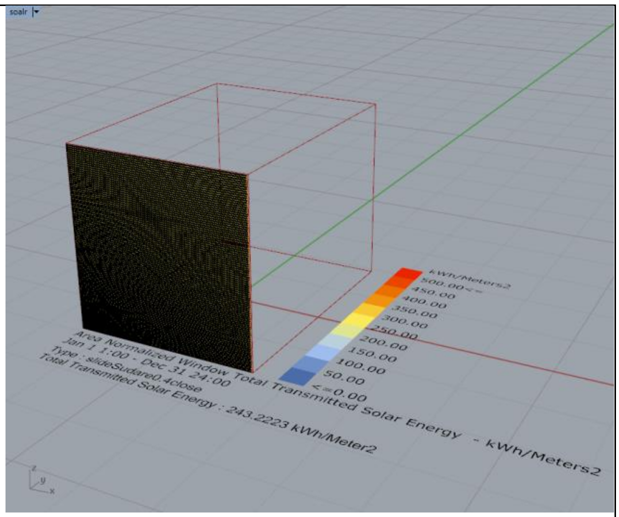
Full Open, 389.63 kWh/m^2,OTTV 108 Watt/m^2



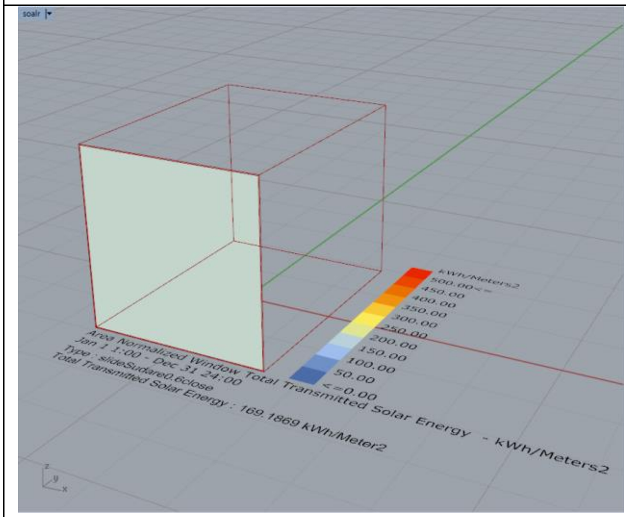


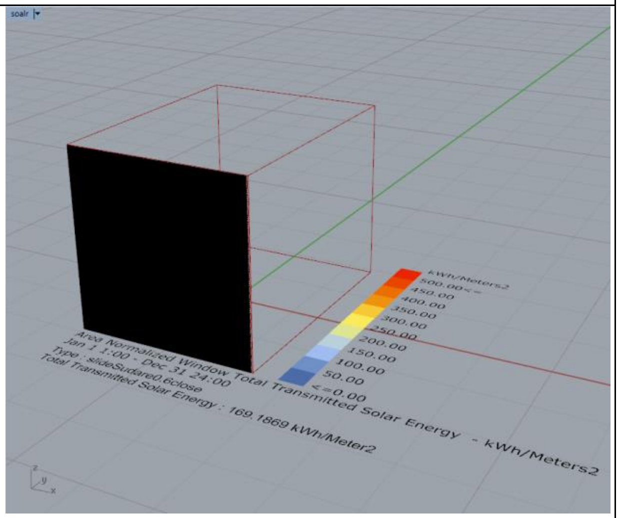
20% Close, 309.07 kWh/m^2,OTTV 88.06 watt/m^2



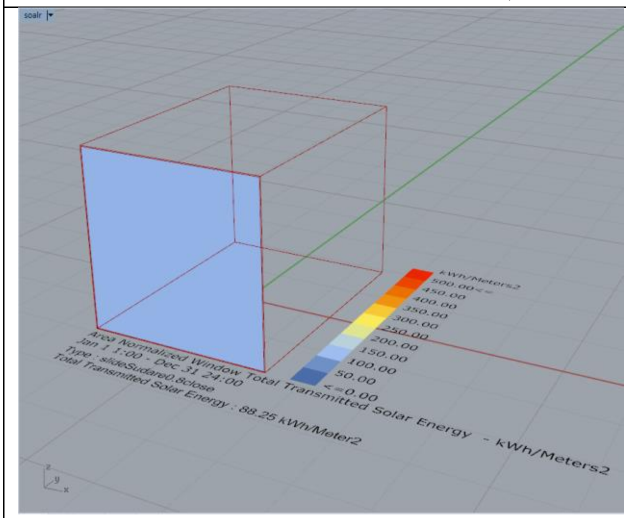


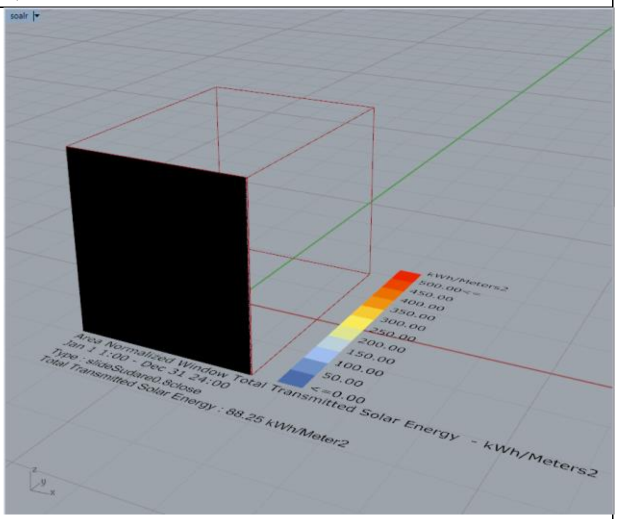
40% Close, 243.22 kWh/m^2,OTTV 71 watt/m^2



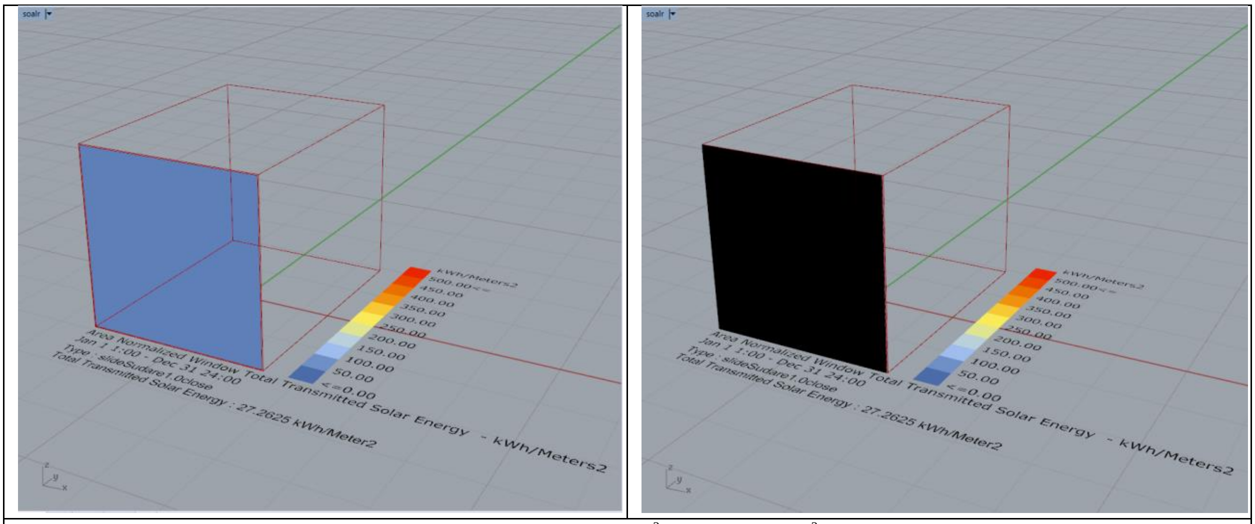


60% Close, 169.19 kWh/m^2,OTTV 53.56 watt/m^2

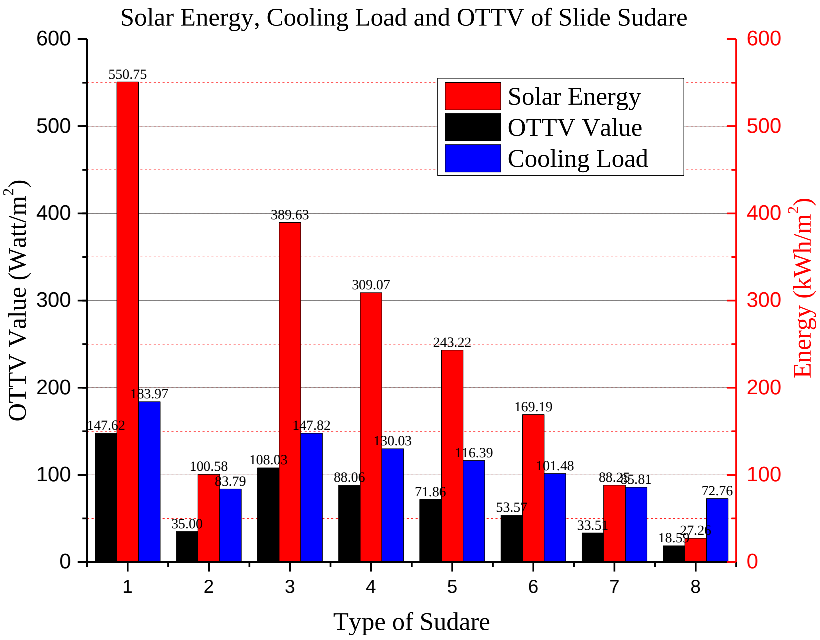




80% Close, 88.25 kWh/m^2,OTTV 33.5 watt/m^2



Full Close, 27.26 kWh/m^2,OTTV 18 watt/m^2

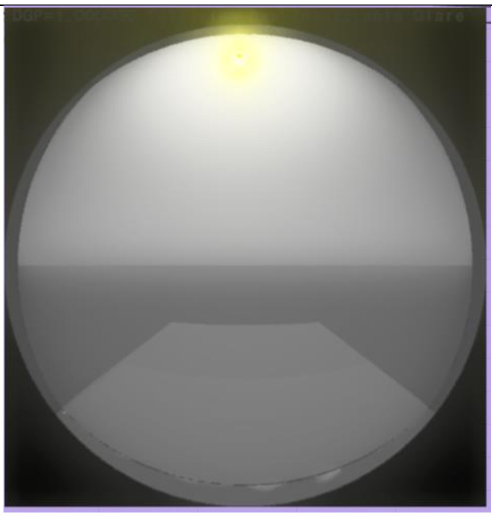
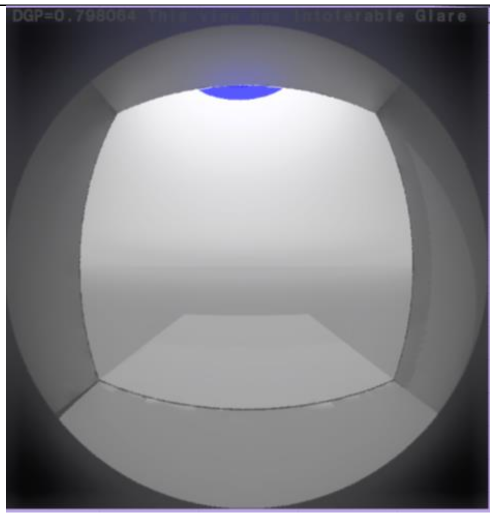
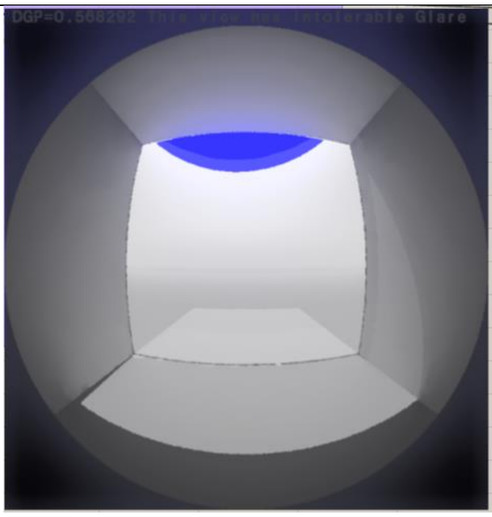
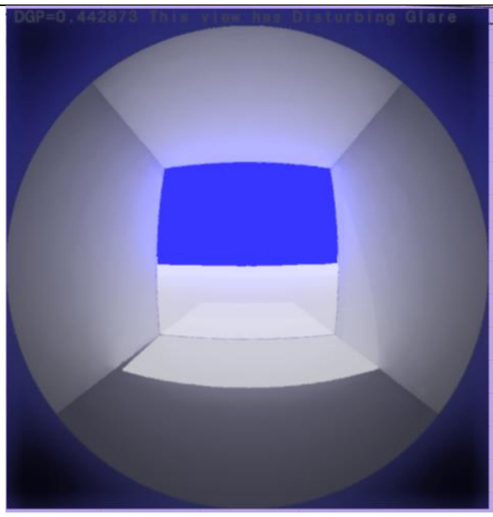
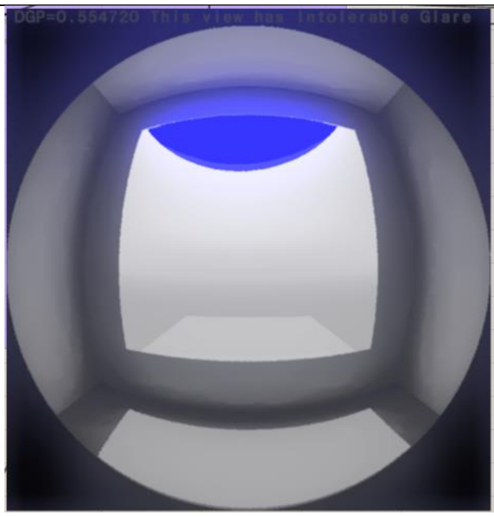


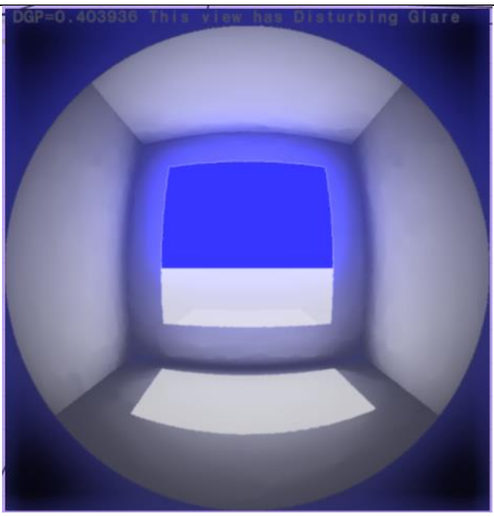
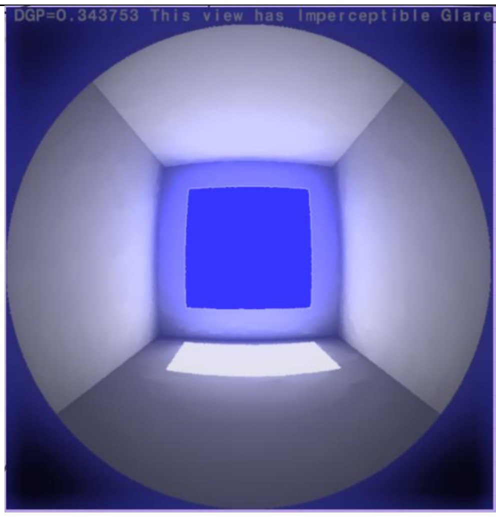
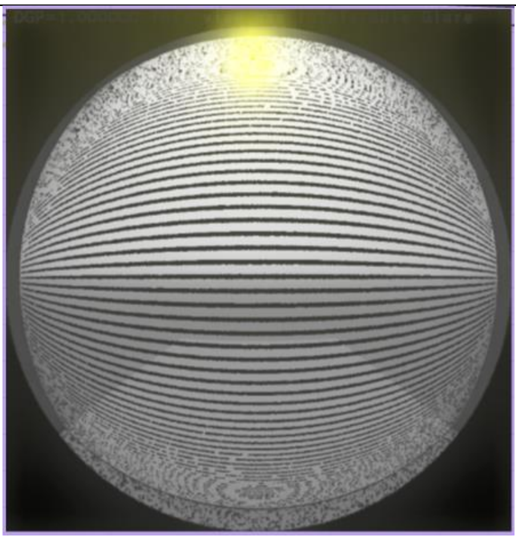
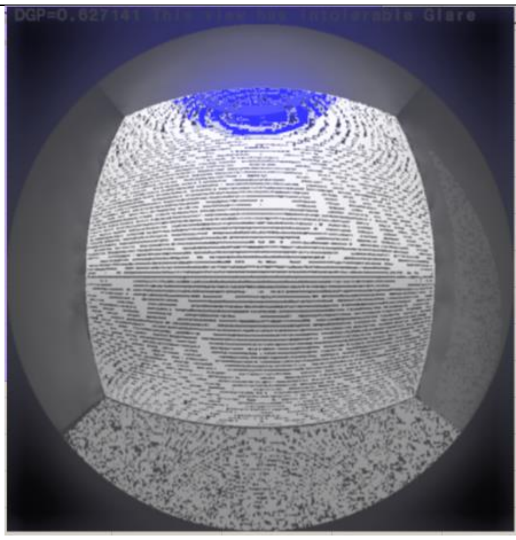
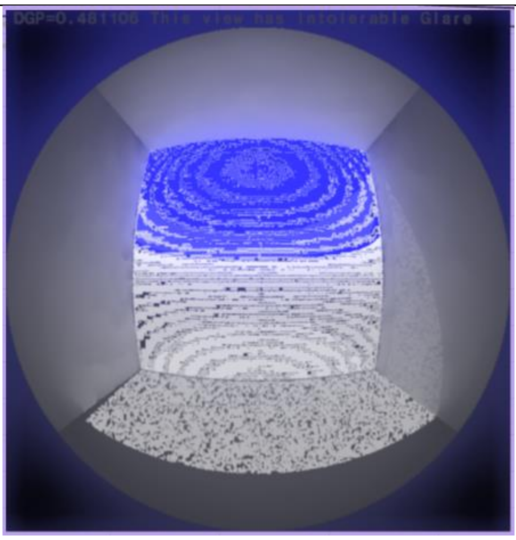
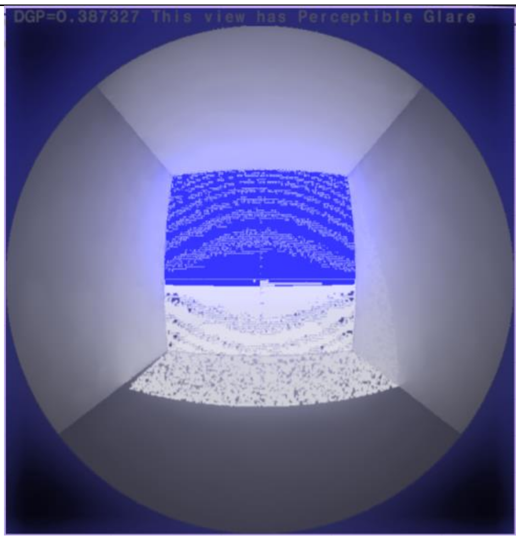
Type of Slide Sudare	
1	No Slide Sudare
2	No Slide Sudare, SNI
3	Slide Sudare Full Open
4	Slide Sudare 20% Close
5	Slide Sudare 40% Close
6	Slide Sudare 60% Close
7	Slide Sudare 80% Close
8	Slide Sudare Full Close

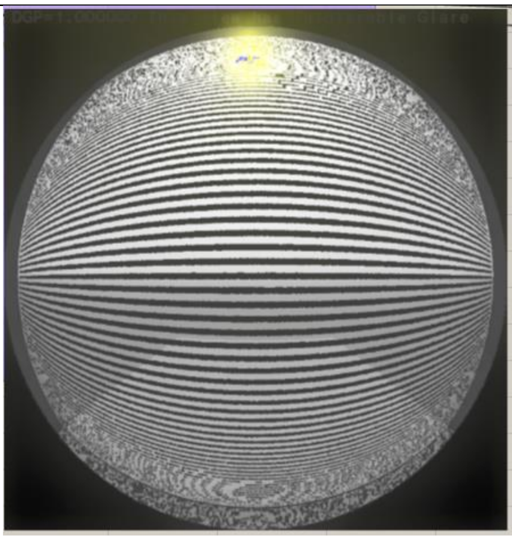
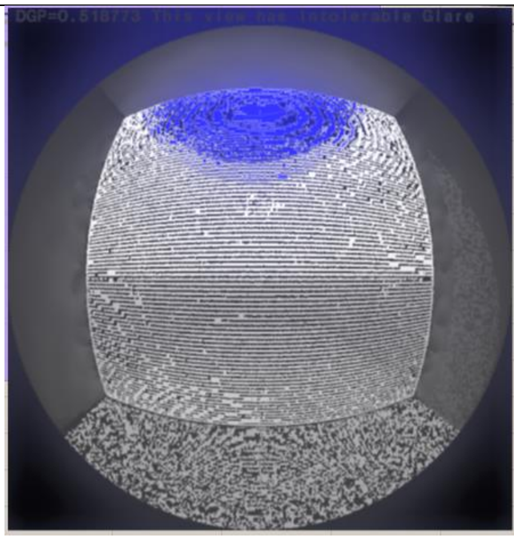
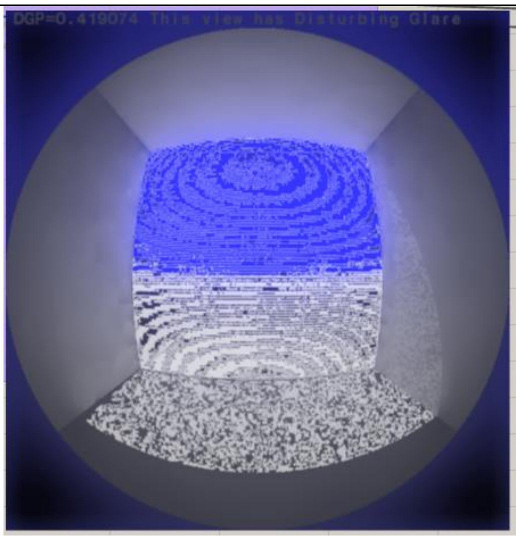
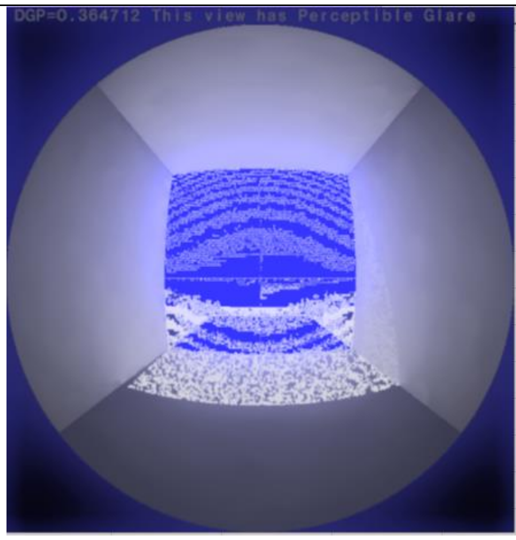
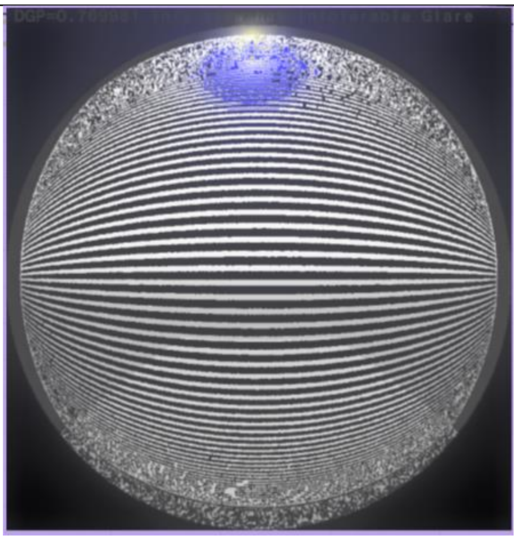
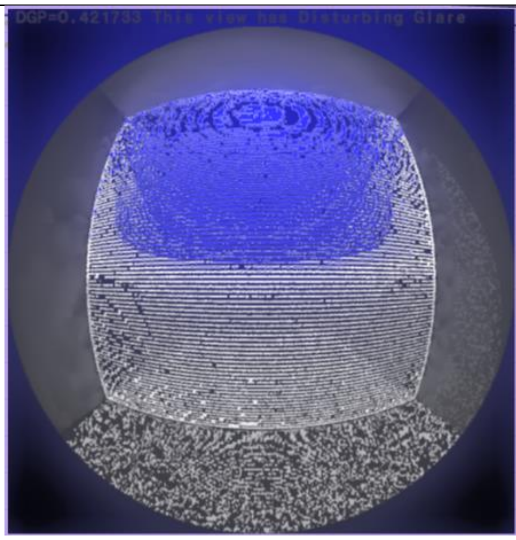
Figure 8-15 Thermal performance of sliding Sudare

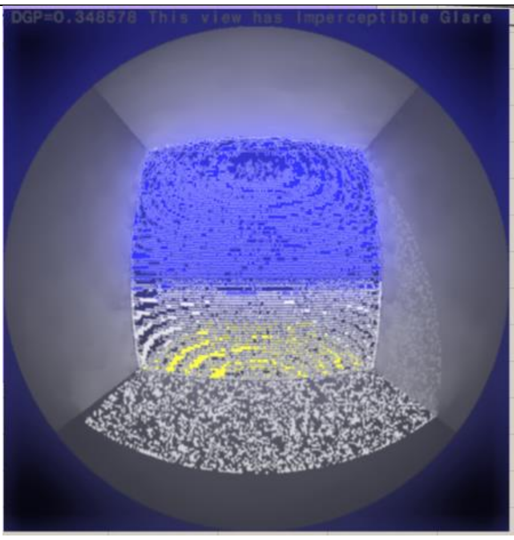
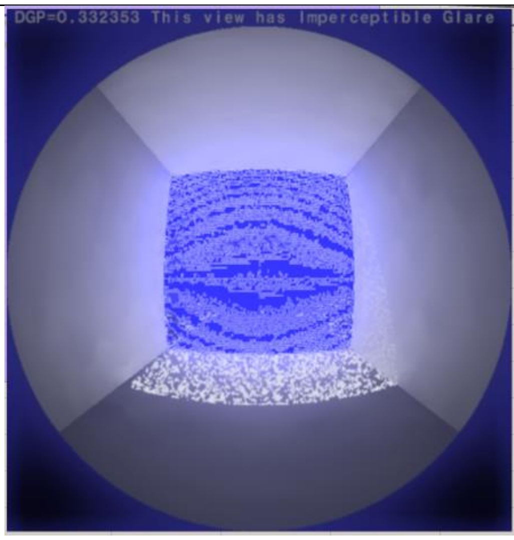
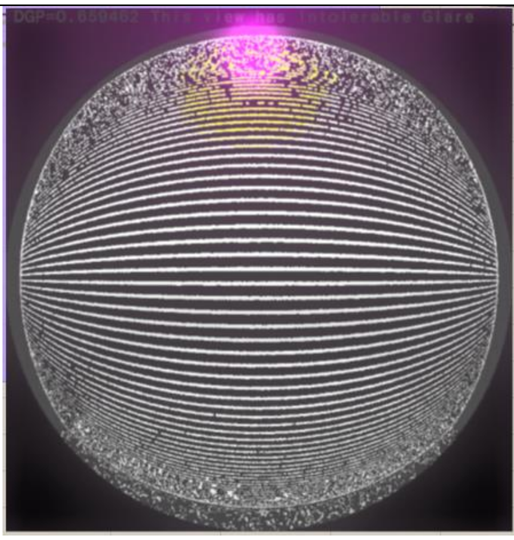
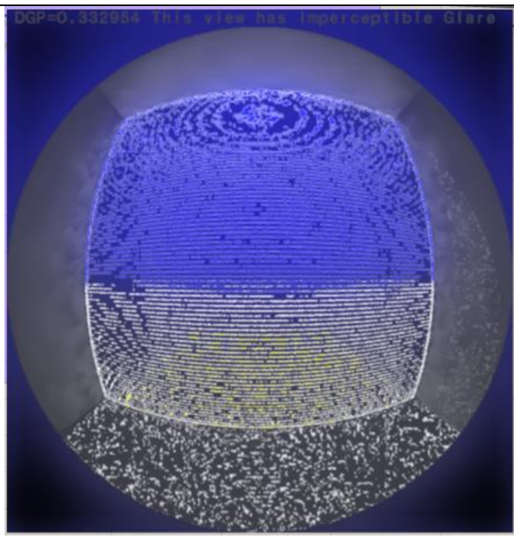
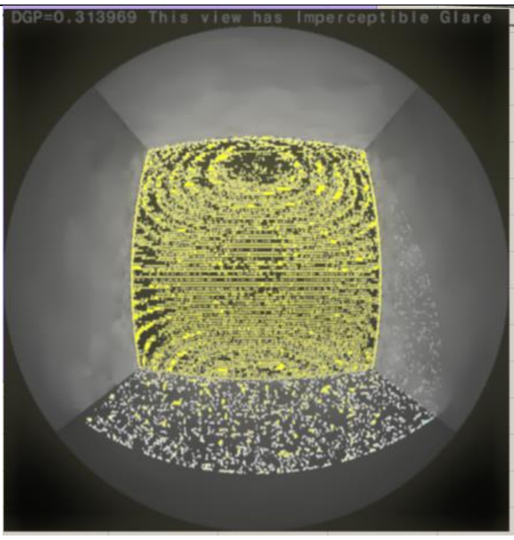
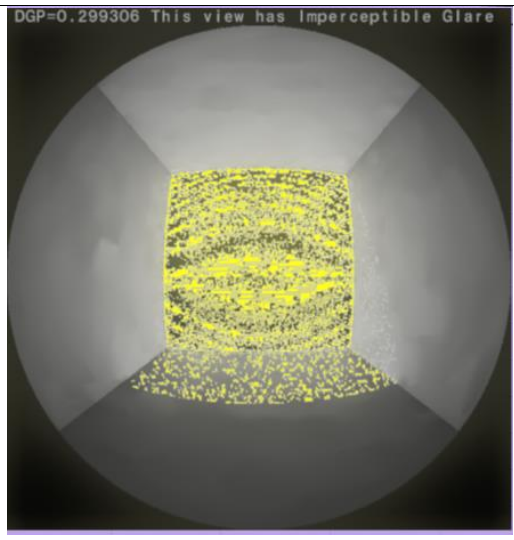
Daylight simulation shows the ability of sliding Sudare to increase the uniformity of light inside a building, which reduces or even eliminates the glare that occurs most of the time in the normal façade for this case study (Table 8-3 and Table 8-4)(Figure 8-15).

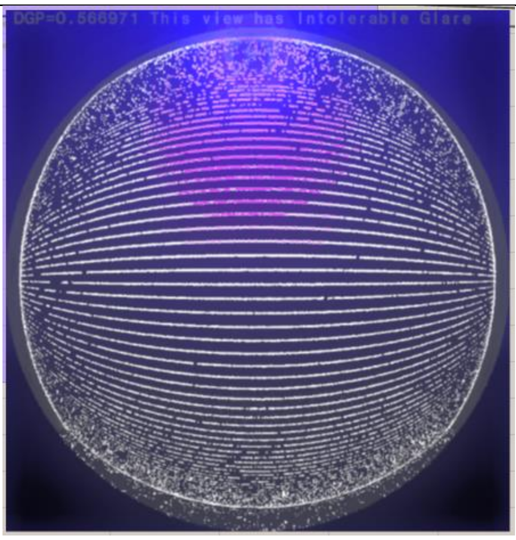
Table 8-3 Daylight glare probability simulation of sliding Sudare in Jakarta

	
No Sliding Sudare, 0.5 m, 1 (intolerable glare)	No Sliding Sudare, 1.5 m, 0.798 (intolerable glare)
	
No Sliding Sudare, 2.5 m, 0.568 (intolerable glare)	No Sliding Sudare, 3.5 m, 0.443 (disturbing glare)
	
SNI, 0.5 m, 1 (intolerable glare)	SNI, 1.5 m, 0.555 (intolerable glare)

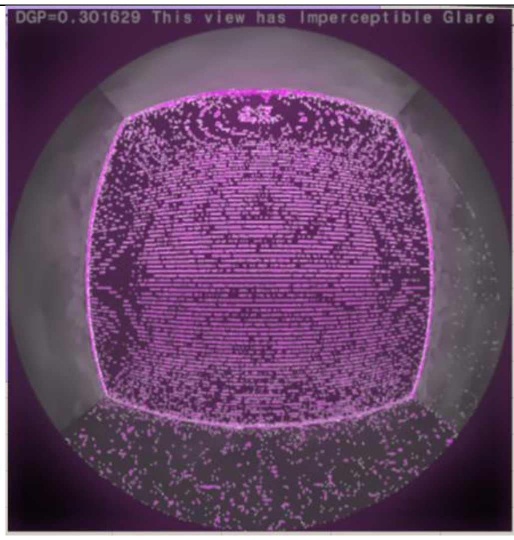
	
SNI,2.5 m, 0.404 (Disturbing glare)	SNI, 3.5 m, 0.344 (imperceptible glare)
	
Full Open, 0.5 m, 1(intolerable glare)	Full Open, 1.5 m, 0.627 (intolerable glare)
	
Full Open, 2.5 m, 0.481 (intolerable glare)	Full Open, 1.5 m, 0.387 (perceptible glare)

	
20% Close, 0.5 m, 1 (intolerable glare)	20% Close, 1.5 m, 0.518 (intolerable glare)
	
20% Close, 2.5 m, 0.419 (disturbing glare)	20% Close, 3.5 m, 0.365 (perceptible glare)
	
40% Close, 0.5 m, 0.769 (intolerable glare)	40% Close, 1.5 m, 0.422 (disturbing glare)

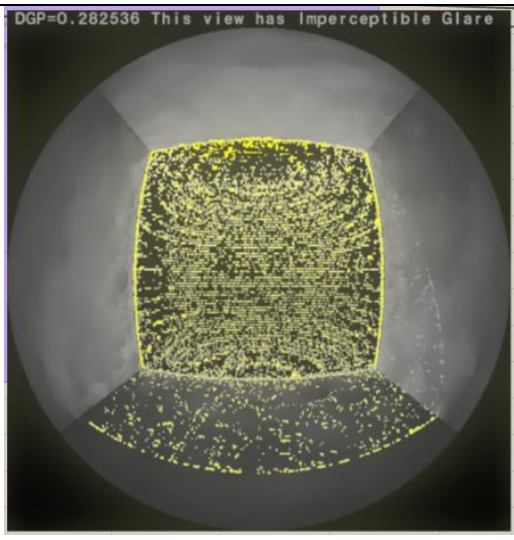
	
40% Close, 2.5 m, 0.348 (imperceptible glare)	40% Close,3.5 m, 0.332 (imperceptible glare)
	
60% Close, 0.5 m, 0.659 (intolerable glare)	60% Close, 1.5 m, 0.333 (imperceptible glare)
	
60% Close, 2.5 m, 0.314 (imperceptible glare)	60% Close, 3.5 m, 0.299 (imperceptible glare)



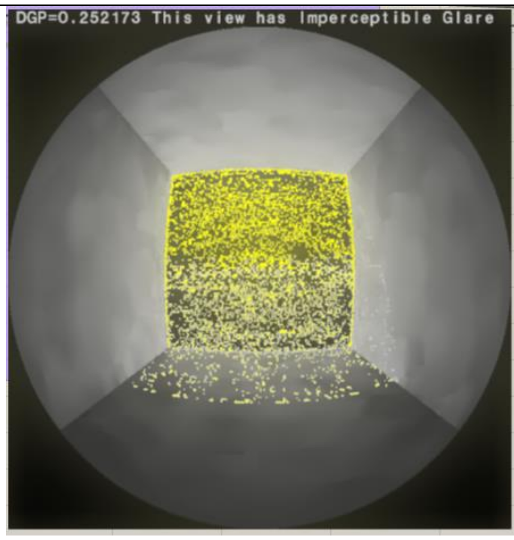
80% Close, 0.5 m, 0.567 (intolerable glare)



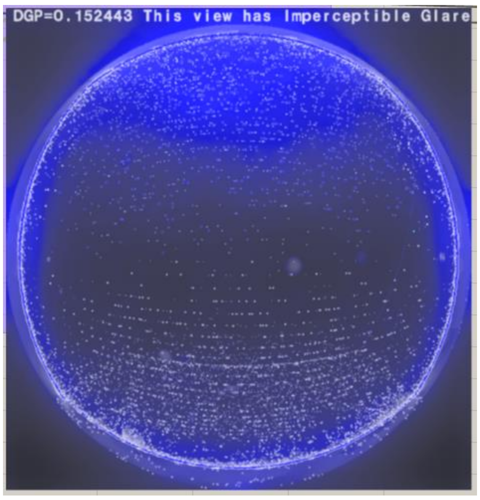
80% Close, 1.5 m, 0.302 (imperceptible glare)



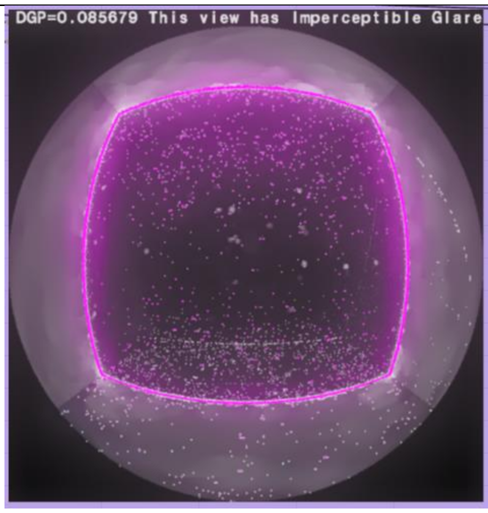
80% Close, 2.5 m, 0.283 (imperceptible glare)



80% Close, 3.5 m, 0.252 (imperceptible glare)



Full Close, 0.5 m, 0.152 (imperceptible glare)



Full Close, 1.5 m, 0.086 (imperceptible glare)

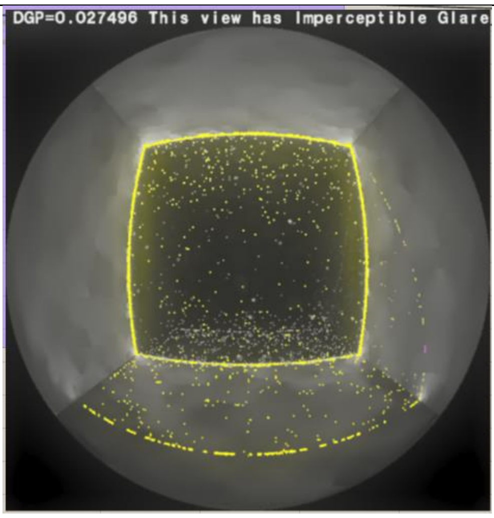
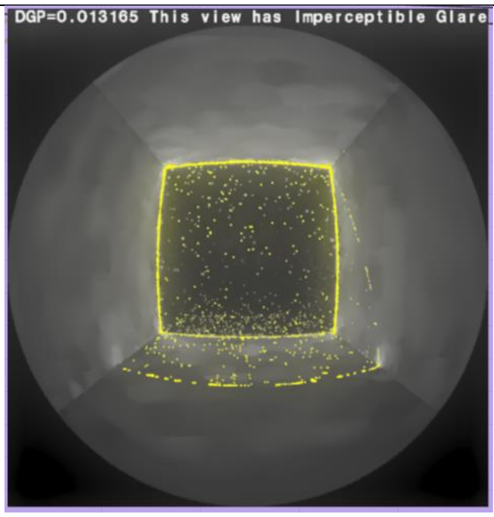
	
Full Close, 2.5 m, 1 (imperceptible glare)	Full Close, 3.5 m, 1 (imperceptible glare)

Table 8-4 Summary of daylight glare probability simulation

Type	Distance from Window			
	0.5	1.5	2.5	3.5
No Sudare	InG	InG	InG	DG
SNI	InG	InG	DG	ImG
Sliding Sudare Full Open	InG	InG	InG	PG
Sliding Sudare 20% Close	InG	InG	DG	PG
Sliding Sudare 40% Close	InG	DG	ImG	ImG
Sliding Sudare 60% Close	InG	ImG	ImG	ImG
Sliding Sudare 80% Close	InG	ImG	ImG	ImG
Sliding Sudare Full Close	ImG	ImG	ImG	ImG

ImG: Imperceptible Glare
PG: Perceptible Glare
DG: Disturbing Glare
InG: Intolerable Glare

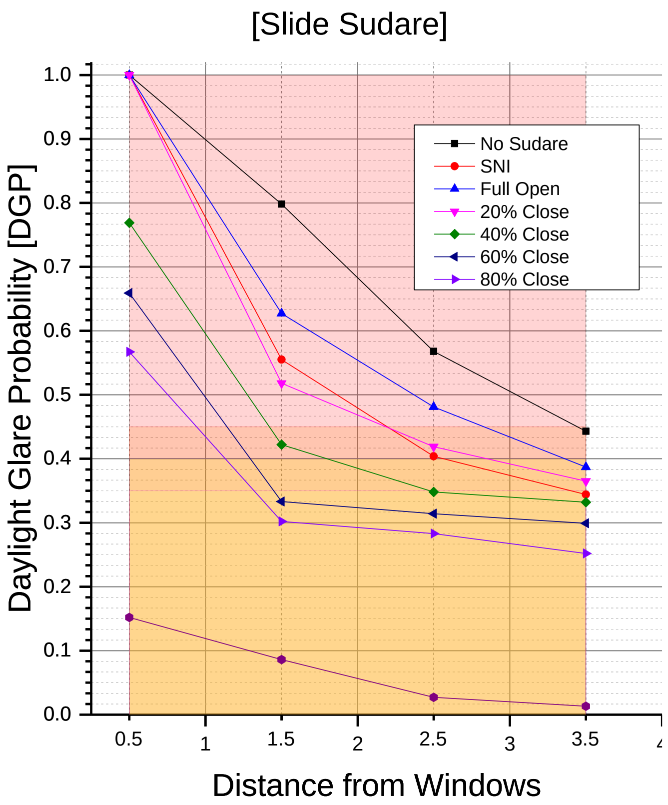
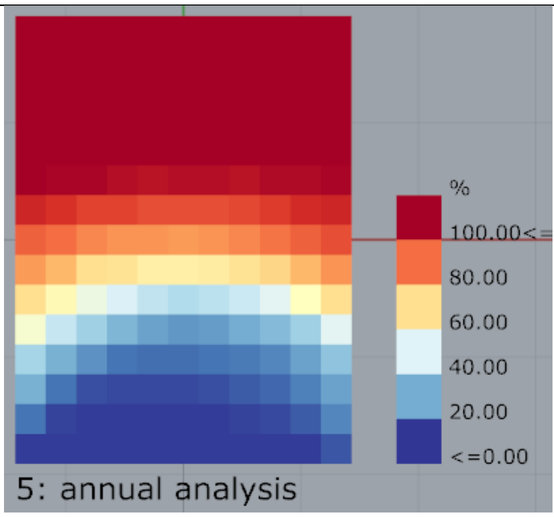
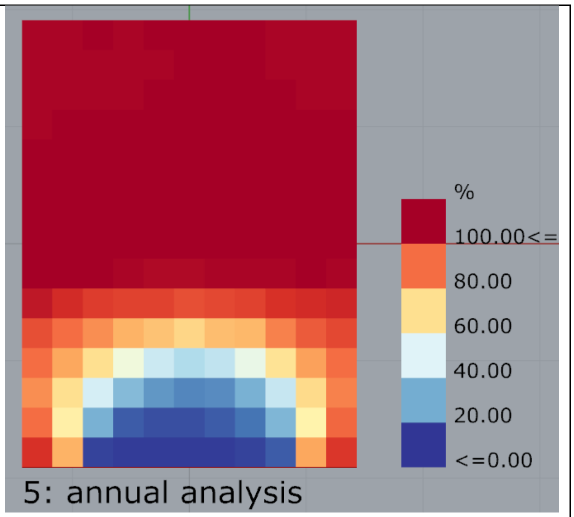
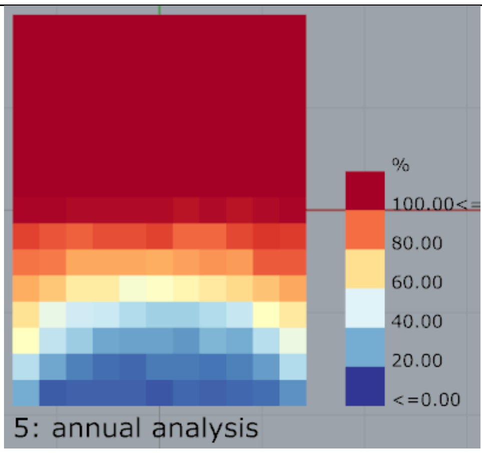


Figure 8-16 Daylight glare probability of sliding Sudare distribution

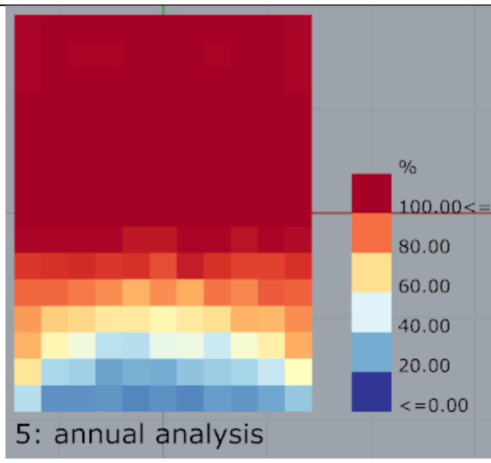
In the UDI simulation, from 20% closed to 60% closed mode has better UDLI value than the baseline Indonesia standard, but for 80% or full closed mode, the sliding Sudare have lower UDLI value than the standard (Table 8-5).

Table 8-5 Useful daylight illuminance simulation of sliding Sudare in Jakarta

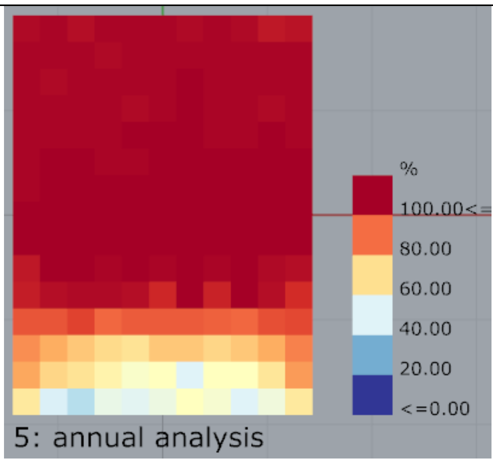
<table>
<tr><td>
</td><td>
</td></tr>
<tr><td>No Sliding Sudare, UDLI 100-2000: 61.7%</td><td>SNI,UDLI 100-2000, 81.13%</td></tr>
</table>



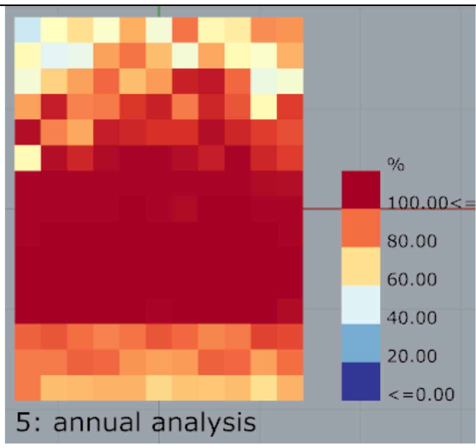
Full Open, UDLI 100-2000: 73.9%



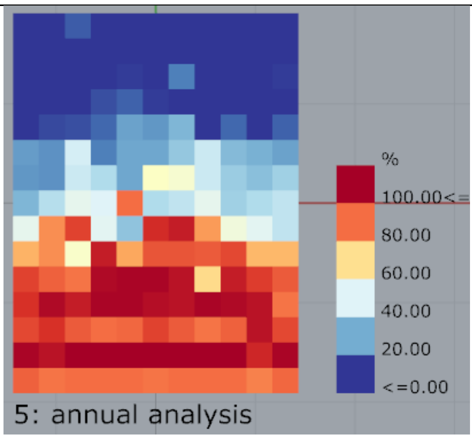
20% Close, UDLI 100-2000: 81.56%



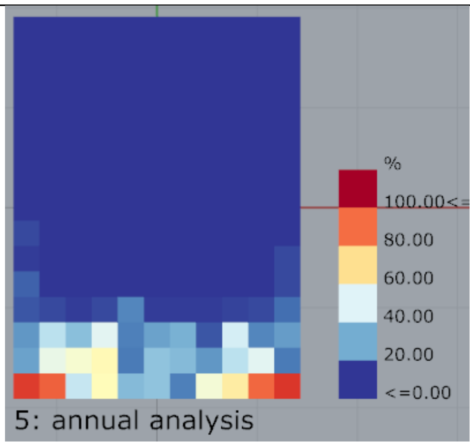
40% Close, UDLI 100-2000: 89.32%



60% Close, UDLI 100-2000: 84.75%



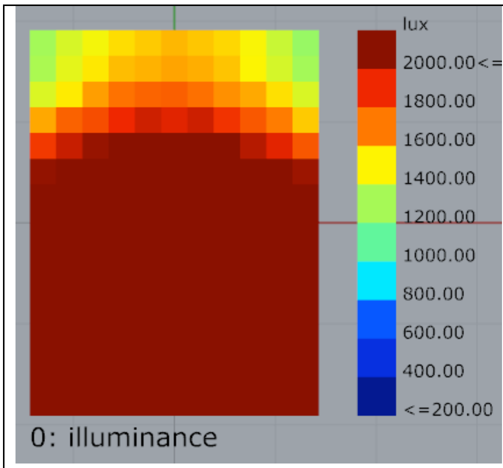
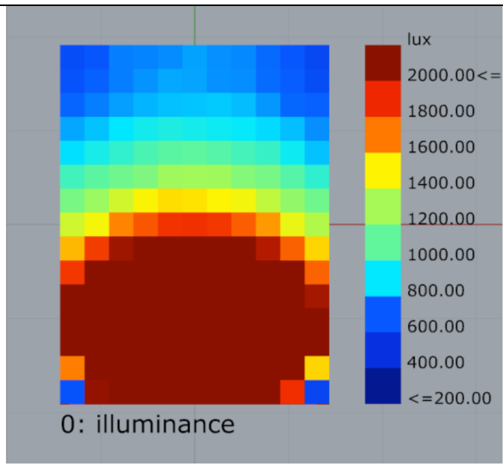
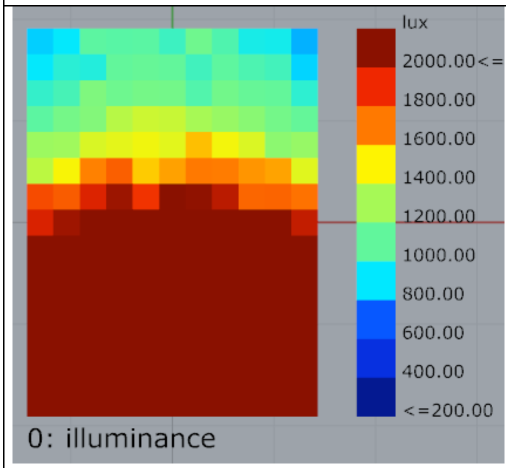
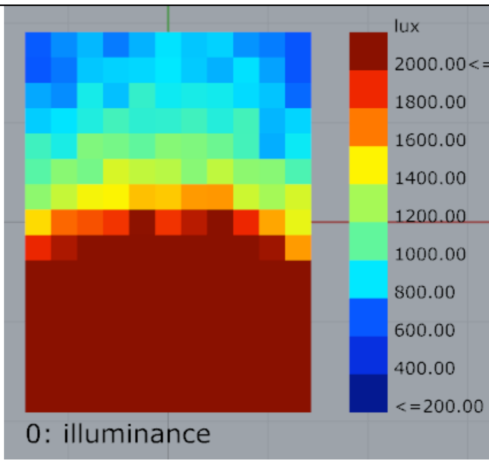
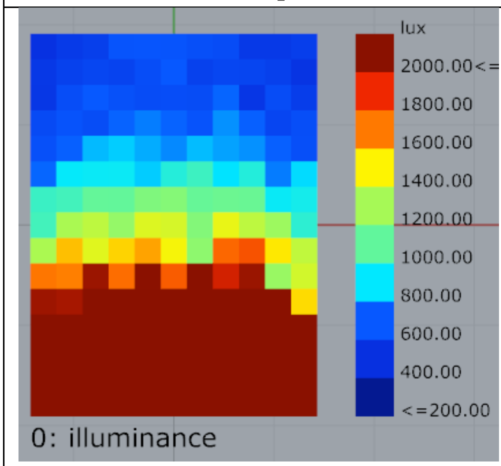
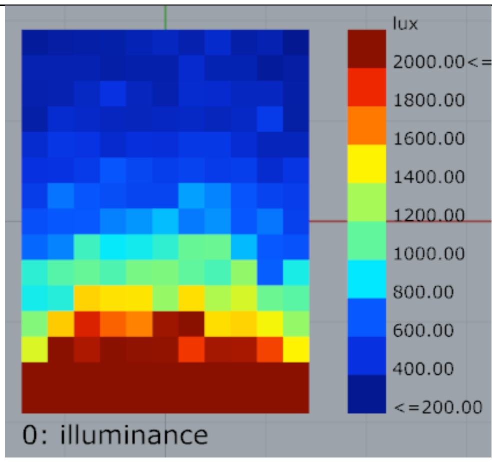
80% Close, UDLI 100-2000: 45.40%

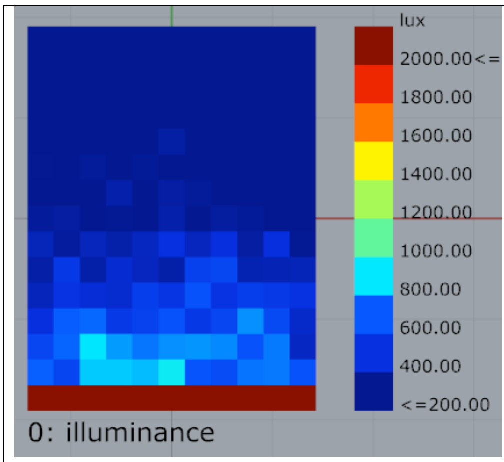


Full Close, UDLI 100-2000: 7.30%

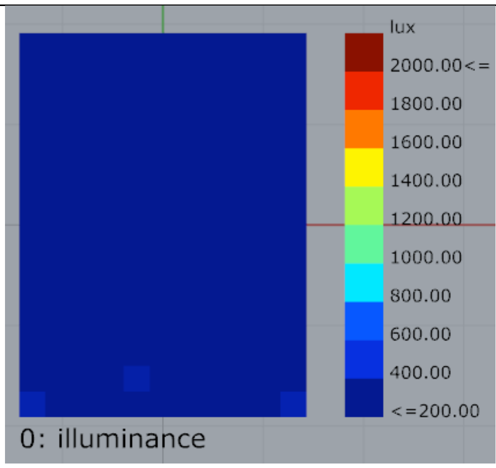
The daylight distribution simulation also confirms the ability of sliding Sudare to make more uniform illuminance levels inside a building, which also caused better DGP as previously mentioned in this chapter (Table 8-6).

Table 8-6 Daylight illuminance distribution simulation of sliding Sudare in Jakarta

	
No Sliding Sudare	SNI
	
Full Open	20% Close
	
40% Close	60% Close



80% Close



Full Close

8.8 Section Conclusion

Sliding Sudare have optimum result when in the area of 80% closed mode, which already has minimum OTTV requirement. Compared to the normal full glass window, the effectiveness of 80% closed mode is 77% better; although when compared to baseline standard it is only 4% better. For cooling load, the 80% closed mode also has 17% better efficiency compared to the baseline building, and 45% better efficiency when compare to the normal full glass window.

For visual comfort, sliding Sudare can improve daylight distribution and reduce daylight glare probability compared to the baseline and normal buildings. But in the useful daylight illuminance, only the 20% to 60% closed mode has better UDLI value than the standard baseline building.

Chapter 9 Conclusion

9.1 Conclusion

Visibility indices can be used as measuring tools to evaluate the level of visibility and privacy of building façade. Although the value of the room experiment and the digital image experiment are slightly different, the tendencies of both methods are the same for each type of Sudare. The room experiment is of higher value because of the ability of the respondents to change position when giving a judgement of the visibility value for each condition.

The application of visibility indices in the rendered image experiment have shown the effectiveness of this tool to evaluate the different types of Sudare compared to tinted glass or clear glass window façades.

From the prototype model, it can be concluded that sliding Sudare have great potential to be implemented as external shading in low-rise buildings and as part of the integrated sliding Sudare inside double glass system.

Parametric sliding Sudare, which can adapt to the environment using an automatic responsive system, can improve the effectiveness of thermal performance and visual comfort of the building façade.

Traditional Japanese Sudare blinds have great potential to be implemented as external shading devices that will improve the shading capability of glass building façades while maintaining the ability for occupants to see outside from inside. As external shading, due to the position of the shading devices, Sudare can block almost all of the solar radiation, depending on the width of the spacer and the distance from the window to the wall.

9.2 Recommendation

Visibility indices need to be developed further with numerical and statistical analysis so that the effects of Sudare can be easily implemented into the building simulation system without the need of the questionnaire, which took so much time in the design process.

The implementation of Sudare blinds in a true model of low-rise and high-rise buildings should consider material and structural aspects. It will be impossible to use natural materials as external shading devices in high-rise buildings would create durability and maintenance problems. In Indonesia, the humidity is high every day—approximately 80% relative humidity. The outdoor temperature is also high—approximately 27oC to 34oC. The fluctuation of the material conditions would cause natural materials to break easily. Metal would be the best choice for making the blinds. Investigating the thermal behavior of metal materials is essential. Research on metal sheets for perforated and non-perforated materials, and on various colors has been carried out, comparing galvanized steel sheets and anodized aluminum sheets. The results indicate that galvanized steel sheets reached temperatures between 4oC and 5oC higher than the anodized aluminum, and black-painted sheets performed with temperatures between 6oC and 8oC higher than white lacquer-coated sheets (Blanco et al. 2014). Another result regarding the material and color of perforated metals shows that galvanized steel, closely followed by white aluminum, is considered the most appropriate combination (Blanco et al. 2016). Modification of the Sudare form would also be necessary to improve strength and increase the possibility of its being implemented outside window glass.

In real-world conditions where the environment always changes dynamically, and considering the prototype and the simulation results, sliding Sudare have great potential to be researched more deeply. If implemented as a full-size model with a responsive façade system, based on the environmental condition, the result can be optimal.

This research also shows the possibilities for development and implementation in landed house systems using the traditional materials of Sudare, which would preserve the traditional value.

Bibliography

Admin, Kementan Akan Gelar Rakernas Pembangunan Pertanian 2013. Available at: http://www.pertanian.go.id/eplanning/berita-148-kementan-akan-gelar-rakernas-pembangunan-pertanian-2013.html [Accessed July 21, 2017].

Alan G Brake, Glass facade reveals timber structure of Portland office building. Available at: https://www.dezeen.com/2015/11/29/framework-building-portland-timber-structure-glass-facade-works-partnership-architecture/ [Accessed July 24, 2017].

Aliona, Office buildings in Bangalore wallpapers and images - wallpapers, pictures, photos. Available at: http://www.zastavki.com/eng/World/India/wallpaper-68547.htm [Accessed July 24, 2017].

Andrew Michler, Daylit Austrian Kindergarten is a Bright, Open Space That Blends With the Outdoors | Inhabitat - Green Design, Innovation, Architecture, Green Building. Available at: http://inhabitat.com/daylit-austrian-kindergarten-mixes-with-the-out-doors/ [Accessed June 7, 2017].

Blanco, J.M. et al., 2016. Energy assessment and optimization of perforated metal sheet double skin façades through Design Builder; A case study in Spain. *Energy and Buildings*, 111, pp.326–336. Available at: http://www.sciencedirect.com/science/article/pii/S0378778815304175 [Accessed January 10, 2016].

Blanco, J.M. et al., 2014. Investigating the thermal behavior of double-skin perforated sheet façades: Part A: Model characterization and validation procedure. *Building and Environment*, 82, pp.50–62.

Brahm, Business Travel | Indonesian Travel Blog with a Social touch. Available at: https://www.istania.net/blog/tag/business-travel/ [Accessed July 31, 2017].

Brookfield, Principal Place - Gallery. Available at: http://www.principalplace.co.uk/gallery [Accessed July 24, 2017].

BSNI, 2011a. *SNI 03-6197-2011 Konservasi Energi pada Sistem Pencahayaan*, Badan Standarisasi Nasional Indonesia.

BSNI, 2000. *SNI 03-6389-2000 Konservasi energi selubung bangunan pada bangunan gedung. 1.*, Badan Standarisasi Nasional Indonesia.

BSNI, 2011b. *SNI 03-6389-2011 Konservasi energi selubung bangunan pada bangunan gedung. 1.*, Badan Standarisasi Nasional Indonesia.

Building and Costraction Authority, 2004. *Guidelines on Envelope Thermal Transfer Value for Buildings*, BCA Singapore.

Building Authority Hongkong, 1995. *Code of Practice for Overall Thermal Transfer Value in Buildings*, Building Authority Hongkong.

Cantin, F. et al., 2011. Daylighting metrics based on illuminance , distribution , glare and directivity. *Lighting Research & Technology*, 43, pp.291–307.

Carlucci, S. et al., 2015. A review of indices for assessing visual comfort with a view to their use in optimization processes to support building integrated design. *Renewable and Sustainable Energy Reviews*, 47, pp.1016–1033. Available at: http://www.sciencedirect.com/science/article/pii/S1364032115002154 [Accessed April 16, 2015].

Caroline, C., 2008. *Leadership in Energy and Environmental design (LEED),*

Chan, A.L.S. & Chow, T.T., 2014. Calculation of overall thermal transfer value (OTTV) for commercial buildings constructed with naturally ventilated double skin façade in subtropical Hong Kong. *Energy and Buildings*, 69, pp.14–21. Available at: http://www.sciencedirect.com/science/article/pii/S0378778813006464 [Accessed November 2, 2014].

Chien, S. cheng & Tseng, K.J., 2014. Assessment of climate-based daylight performance in tropical office buildings: A case study. *International Journal of Low-Carbon Technologies*, 9(2), pp.100–108.

David Anderson, Modern London Houses. Available at: http://daveanderson.me.uk/houses/london.html [Accessed July 24, 2017].

Deliana, Jadi, Kota Jakarta Ada di Mana? – Kita dan Kota. Available at: https://kitadankota.wordpress.com/2014/06/05/jadi-kota-jakarta-ada-di-mana/ [Accessed July 31, 2017].

Engel, H., 1985. *Measure and Construction of the Japanese House*, TUTTLE.

Environment, M. of & Indonesia, U., 2014. *Indonesia National Assessment Report on Building* *and Energy Sector Policies for Climate Mitigation*,

Figueiro, M.G. et al., 2002. Daylight and Productivity – A Field Study. *ACEEE Summer Study on Energy Efficiency in Buildings*, pp.69–78.

Florida Solar Energy Center, Window Orientation and Shading. Available at: http://www.fsec.ucf.edu/en/consumer/buildings/homes/windows/shading.htm [Accessed June 7, 2017].

GBCI, 2017. Green Building Council Indonesia. Available at: http://gbcindonesia.org/ [Accessed May 11, 2017].

GMBH, E., Jakarta | Statistics | EMPORIS. Available at: https://www.emporis.com/statistics/tallest-buildings/city/100259/jakarta-indonesia [Accessed July 6, 2017].

Hariyadi, A. et al., 2015. Performance Based Façade Design Study of Department of Public Affair Building Complex in Jakarta Indonesia. *Journal of Asian Urban Environment*, pp.7–12.

Hariyadi, A., Fukuda, H. & Ma, Q., 2017. The Effectiveness of the Parametric Design “Sudare” Blind as External Shading for Energy Efficiency and Visibility Quality in Jakarta. *Architectural Engineering and Design Management*.

Heschong, L., Wright, R.L. & Okura, S., 2002. Daylighting Impacts on Human Performance in School. *Journal of the Illuminating Engineering Society*, 31(2), pp.101–114. Available at: http://www.tandfonline.com/doi/abs/10.1080/00994480.2002.10748396.

Hui, S.C.M., 1997. Overall Thermal Transfer Value (OTTV): How to Improve Its Control in Hong Kong. *Proceedings of the One-day Symposium on Building, ENergy and Environment*, (October), pp.12-1-11.

Ignacio Fernández Solla, 2010. Façades Confidential: ThyssenKrupp Quarter facades: a giant’s gentle skin. Available at: http://facadesconfidential.blogspot.jp/2010/12/thyssenkrupp-quarter-facades-giants.html [Accessed June 7, 2017].

JAANUS, JAANUS / Sudare 簾 . Available at: http://www.aisf.or.jp/~jaanus/deta/s/Sudare.htm [Accessed June 26, 2017].

Kolokotroni, M. et al., 2004. Environmental impact analysis for typical office facades. *Building*

Research & Information, 32(1), pp.2–16.

Kumar, R., 2016. Sun Shading Devices.

MakerBot, MakerBot Replicator Desktop 3D Printer - User Manual. Available at: http://download.makerbot.com/replicator/MB_Replicator_UserManual.pdf.

Nabil, A. & Mardaljevic, J., 2005. Useful daylight illuminance: a new paradigm for assessing daylight in buildings. *Lighting Research and Technology*, 37(1), pp.41–59.

Nabil, A. & Mardaljevic, J., 2006. Useful daylight illuminances: A replacement for daylight factors. *Energy and Buildings*, 38(7), pp.905–913.

O'Connor, J. et al., 1997. *Envelope & Room Decisions: Tips for Daylighting with windows*,

Olgyay, V., 1963. *Design with Climate: Bioclimatic Approach to Architectural Regionalism new and expanded edition* 2015th ed., Princeton University Press.

Panaquip, Free photo: Window, Panama, View, Office - Free Image on Pixabay - 959542. Available at: https://pixabay.com/en/window-panama-view-office-959542/ [Accessed July 25, 2017].

Parasonis, J., Keizikas, A. & Kalibatiene, D., 2012. The relationship between the shape of a building and its energy performance. *Architectural Engineering and Design Management*, 8(January 2014), pp.246–256.

Parmar, R.S., 2015. Solar Control &Shading Devices.

Paryudi, I., Fenz, S. & Tjoa, A.M., 2013. Study on Indonesian Overall Thermal Transfer Value (OTTV) Standard. *Int. J. of Thermal & Environmental Engineering*, 6(2), pp.49–54. Available at: http://iasks.org/sites/default/files/1-2-vol6.pdf.

Payne, S., Kanagawa Institute of Technology Glass Building 2 - TheCoolist. Available at: http://www.thecoolist.com/kanagawa-institute-of-technologys-glass-building/kanagawa-institute-of-technology-glass-building-2/ [Accessed July 24, 2017].

Pearce, M., Residential Double Glazing Blind System Blind System. Available at: https://www.kjmgroup.co.uk/files/downloads/Integral Blind System brochure.pdf [Accessed July 11, 2017].

Piroozfar, P. (Amir E.. & Farr, E.R.P., 2013. Visual perception and the choice of systemised building façades. *Architectural Engineering and Design Management*, 2007(September), pp.1–17. Available at: http://www.tandfonline.com/doi/abs/10.1080/17452007.2013.775103.

Radhi, H., Sharples, S. & Fikiry, F., 2013. Will multi-facade systems reduce cooling energy in fully glazed buildings? A scoping study of UAE buildings. *Energy and Buildings*, 56, pp.179–188. Available at: http://www.sciencedirect.com/science/article/pii/S0378778812004343 [Accessed May 4, 2016].

Rasmussen, H.F., Vangeloglou, E. & Mårbjerg, M., 2015. Evaluation of Daylight in Buildings in the Future. , (October), pp.35–40.

Reinhart, C. & Breton, P.F., 2009. *Experimental Validation of Autodesk ® 3ds Max ®*,

Ruggiero, F., Florensa, R.S. & Dimundo, A., 2009. Re-interpretation of traditional architecture for visual comfort. *Building and Environment*, 44(9), pp.1886–1891. Available at: http://www.sciencedirect.com/science/article/pii/S0360132309000110 [Accessed April 30, 2016].

Sherif, A., Sabry, H. & Rakha, T., 2012. External perforated Solar Screens for daylighting in residential desert buildings: Identification of minimum perforation percentages. *Solar Energy*, 86(6), pp.1929–1940.

Shi, X. & Yang, W., 2013. Performance-driven architectural design and optimization technique from a perspective of architects. *Automation in Construction*, 32, pp.125–135. Available at: http://www.sciencedirect.com/science/article/pii/S0926580513000253 [Accessed October 29, 2015].

Stephen Messenger, New School Building Mistakenly Features a See-Through Restroom - Brazbeat. Available at: http://brazbeat.com/115/new-school-building-mistakenly-features-see-through-restroom/ [Accessed July 25, 2017].

Stevanović, S., 2013. Optimization of passive solar design strategies: A review. *Renewable and Sustainable Energy Reviews*, 25, pp.177–196. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84878120151&partnerID=tZOtx3y1 [Accessed October 8, 2015].

Sulistiyanto, T., 2013. Indonesia ' s Experience in Assessing Green Building Performance. , (March).

Summer Luu, Folding Glass Buildings : Neo Solar Power Corporation. Available at: https://www.trendhunter.com/trends/neo-solar-power-corporation [Accessed July 24, 2017].

Suryabrata, J.A., 2014. Principles and Applications Energy efficient Design.

Tagliabue, L.C., Buzzetti, M. & Arosio, B., 2012. Energy Saving Through the Sun: Analysis of Visual Comfort and Energy Consumption in Office Space. *Energy Procedia*, 30, pp.693–703. Available at: http://linkinghub.elsevier.com/retrieve/pii/S1876610212015950 [Accessed August 9, 2016].

Territory, G. of the P. of J.C.S. & Corporation, I.F., *JAKARTA GREEN BUILDING USER GUIDE LIGHTING*,

Tito Ari Pratama, Inspirasi Indonesia: Daftar pusat perbelanjaan Modern (Mall) di Yogyakarta. Available at: http://myindonesians.blogspot.jp/2014/11/daftar-pusat-perbelanjaan-modern-mall.html [Accessed July 31, 2017].

UNEP-SBCI, 2009. *Buildings and Climate Change*,

Vijayalaxmi, J., 2010. Concept of Overall Thermal Transfer Value (OTTV) in Design of Building Envelope to Achieve Energy Efficiency. *International Journal of Thermal and Environmental Engineering*, 1(2), pp.75–80.

Wienold, J. & Christoffersen, J., 2006. Evaluation methods and development of a new glare prediction model for daylight environments with the use of CCD cameras. *Energy and Buildings*, 38(7), pp.743–757. Available at: http://www.sciencedirect.com/science/article/pii/S0378778806000715 [Accessed May 25, 2017].

Xue, P., Mak, C.M. & Cheung, H.D., 2014. The effects of daylighting and human behavior on luminous comfort in residential buildings: A questionnaire survey. *Building and Environment*, 81, pp.51–59. Available at: http://www.sciencedirect.com/science/article/pii/S0360132314001978 [Accessed November 5, 2015].

Yagi, K., 1982. *A Japanese Touch for Your Home* First., New York: Kodansha International.

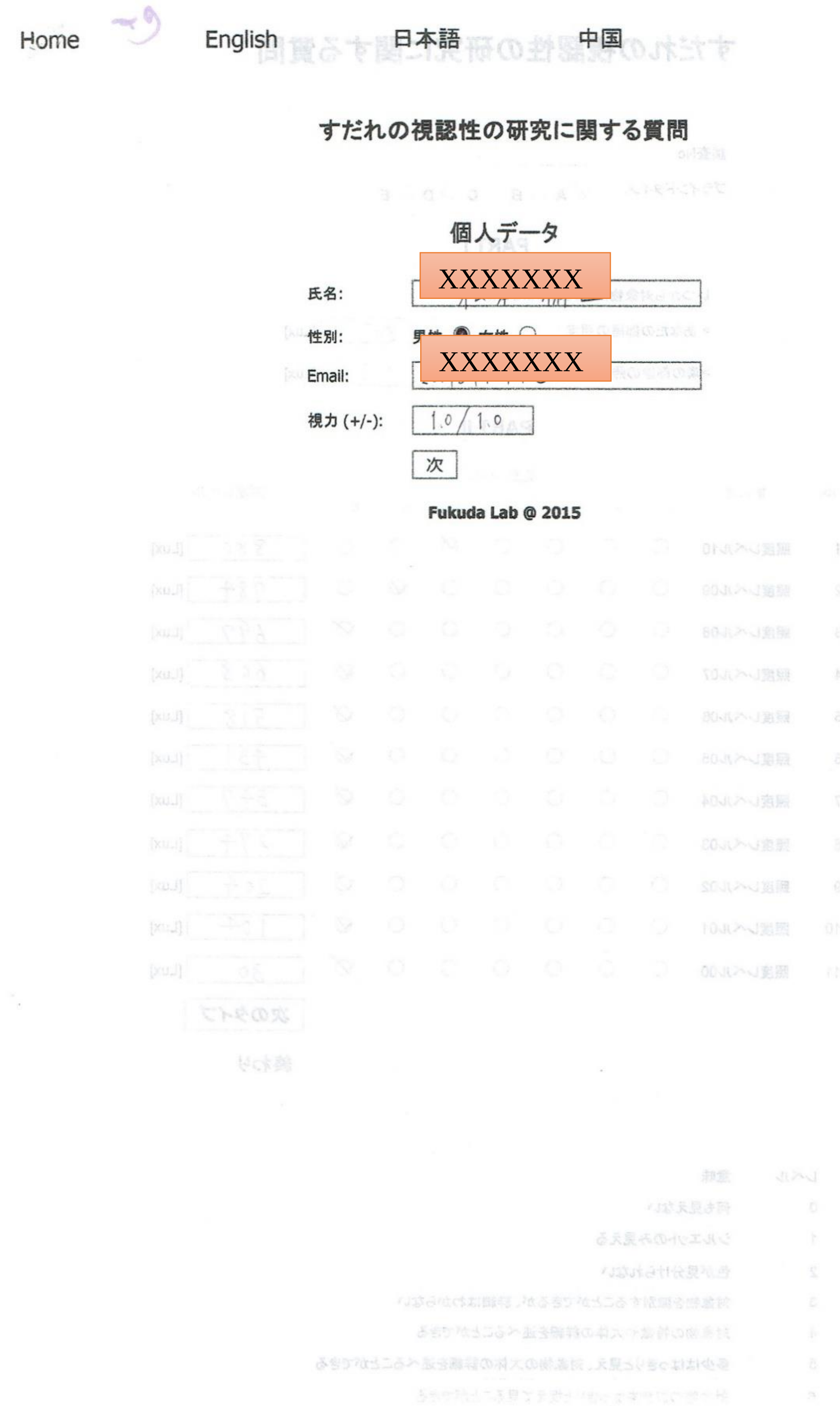
Yik, F.W.H. & Chan, K.T., 1995. Energy Performance Criteria for Commercial Buildings in

Hong Kong: An Alternative to OTTV. *HKIE Transactions*, 2(1), pp.17–22. Available at: http://www.tandfonline.com/doi/abs/10.1080/1023697X.1995.10667676.

Yun, G., Yoon, K.C. & Kim, K.S., 2014. The influence of shading control strategies on the visual comfort and energy demand of office buildings. *Energy and Buildings*, 84, pp.70–85. Available at: http://www.sciencedirect.com/science/article/pii/S0378778814005787 [Accessed November 13, 2015].

Appendix 1 Room Experiment Questionnaire

Respondent personal data


Home English 日本語 中国

すだれの視認性の研究に関する質問

個人データ

氏名: XXXXXXX

性別:

Email: XXXXXXX

視力 (+/-): 1.0 / 1.0

次

Fukuda Lab @ 2015

Sudare Type A (sample response)

すだれの視認性の研究に関する質問

調査No [ ]

ブラインドタイプ: ✓A ○B ○C ○D ○E

PART I

いつから対象物が見え始めましたか？

\> あなたの部屋の照度： 855 [Lux]

\>隣の部屋の照度： 145 [Lux]

PART II

No.	室条件	視認レベル 0	1	2	3	4	5	6	照度レベル
1	照度レベル10	○	○	○	○	✓	○	○	880 [Lux]
2	照度レベル09	○	○	○	○	○	✓	○	784 [Lux]
3	照度レベル08	○	○	○	○	○	○	✓	697 [Lux]
4	照度レベル07	○	○	○	○	○	○	✓	608 [Lux]
5	照度レベル06	○	○	○	○	○	○	✓	518 [Lux]
6	照度レベル05	○	○	○	○	○	○	✓	431 [Lux]
7	照度レベル04	○	○	○	○	○	○	✓	347 [Lux]
8	照度レベル03	○	○	○	○	○	○	✓	274 [Lux]
9	照度レベル02	○	○	○	○	○	○	✓	204 [Lux]
10	照度レベル01	○	○	○	○	○	○	✓	104 [Lux]
11	照度レベル00	○	○	○	○	○	○	✓	30 [Lux]

次のタイプ

終わり

レベル	意味
0	何も見えない
1	シルエットのみ見える
2	色が見分けられない
3	対象物を識別することができるが、詳細はわからない
4	対象物の特徴や大体の詳細を述べることができる
5	多少ははっきりと見え、対象物の大体の詳細を述べることができる
6	対象物の詳細をはっきりと捉えて見ることができる

Sudare Type B (sample response)

すだれの視認性の研究に関する質問

調査No [ ]

ブラインドタイプ: ○ A ☑ B ○ C ○ D ○ E

PART I

いつから対象物が見え始めましたか？

> あなたの部屋の照度： 851 [Lux]

>隣の部屋の照度： 315 [Lux]

PART II

No.	室条件	視認レベル 0	1	2	3	4	5	6	照度レベル
1	照度レベル10	○	○	○	○	☑	○	○	867 [Lux]
2	照度レベル09	○	○	○	○	○	☑	○	771 [Lux]
3	照度レベル08	○	○	○	○	○	☑	○	686 [Lux]
4	照度レベル07	○	○	○	○	○	☑	○	598 [Lux]
5	照度レベル06	○	○	○	○	○	☑	○	508 [Lux]
6	照度レベル05	○	○	○	○	○	☑	○	422 [Lux]
7	照度レベル04	○	○	○	○	○	○	☑	340 [Lux]
8	照度レベル03	○	○	○	○	○	○	☑	268 [Lux]
9	照度レベル02	○	○	○	○	○	○	☑	198 [Lux]
10	照度レベル01	○	○	○	○	○	○	☑	100 [Lux]
11	照度レベル00	○	○	○	○	○	○	☑	28 [Lux]

次のタイプ

終わり

レベル	意味
0	何も見えない
1	シルエットのみ見える
2	色が見分けられない
3	対象物を識別することができるが、詳細はわからない
4	対象物の特徴や大体の詳細を述べることができる
5	多少ははっきりと見え、対象物の大体の詳細を述べることができる
6	対象物の詳細をはっきりと捉えて見ることができる

Sudare Type C (sample response)

すだれの視認性の研究に関する質問

調査No [ ]

ブラインドタイプ: ○ A ○ B ☑ C ○ D ○ E

PART I

いつから対象物が見え始めましたか？

> あなたの部屋の照度： 840 [Lux]

>隣の部屋の照度： 180 [Lux]

PART II

No.	室条件	視認レベル 0	1	2	3	4	5	6	照度レベル
1	照度レベル10	○	○	○	○	✓	○	○	857 [Lux]
2	照度レベル09	○	○	○	○	○	✓	○	762 [Lux]
3	照度レベル08	○	○	○	○	○	✓	○	678 [Lux]
4	照度レベル07	○	○	○	○	○	○	✓	591 [Lux]
5	照度レベル06	○	○	○	○	○	○	✓	501 [Lux]
6	照度レベル05	○	○	○	○	○	○	✓	416 [Lux]
7	照度レベル04	○	○	○	○	○	○	✓	333 [Lux]
8	照度レベル03	○	○	○	○	○	○	✓	262 [Lux]
9	照度レベル02	○	○	○	○	○	○	✓	193 [Lux]
10	照度レベル01	○	○	○	○	○	○	✓	96 [Lux]
11	照度レベル00	○	○	○	○	○	○	✓	23 [Lux]

次のタイプ

終わり

レベル	意味
0	何も見えない
1	シルエットのみ見える
2	色が見分けられない
3	対象物を識別することができるが、詳細はわからない
4	対象物の特徴や大体の詳細を述べることができる
5	多少ははっきりと見え、対象物の大体の詳細を述べることができる
6	対象物の詳細をはっきりと捉えて見ることができる

Sudare Type D (sample response)

すだれの視認性の研究に関する質問

調査No [ ]

ブラインドタイプ: ○A ○B ○C ✓D ○E

PART I

いつから対象物が見え始めましたか？

> あなたの部屋の照度： 855 [Lux]

>隣の部屋の照度： 178 [Lux]

PART II

No.	室条件	視認レベル 0	1	2	3	4	5	6	照度レベル
1	照度レベル10	○	○	○	○	✓	○	○	871 [Lux]
2	照度レベル09	○	○	○	○	✓	○	○	775 [Lux]
3	照度レベル08	○	○	○	○	✓	○	○	688 [Lux]
4	照度レベル07	○	○	○	○	○	✓	○	600 [Lux]
5	照度レベル06	○	○	○	○	○	✓	○	509 [Lux]
6	照度レベル05	○	○	○	○	○	✓	○	422 [Lux]
7	照度レベル04	○	○	○	○	○	○	✓	339 [Lux]
8	照度レベル03	○	○	○	○	○	○	✓	266 [Lux]
9	照度レベル02	○	○	○	○	○	○	✓	196 [Lux]
10	照度レベル01	○	○	○	○	○	○	✓	97 [Lux]
11	照度レベル00	○	○	○	○	○	○	✓	24 [Lux]

次のタイプ

終わり

レベル	意味
0	何も見えない
1	シルエットのみ見える
2	色が見分けられない
3	対象物を識別することができるが、詳細はわからない
4	対象物の特徴や大体の詳細を述べることができる
5	多少ははっきりと見え、対象物の大体の詳細を述べることができる
6	対象物の詳細をはっきりと捉えて見ることができる

Sudare Type E (sample response)

すだれの視認性の研究に関する質問

調査No [ ]

ブラインドタイプ: ○A ○B ○C ○D ✓E

PART I

いつから対象物が見え始めましたか？

> あなたの部屋の照度： 855 [Lux]

>隣の部屋の照度： 179 [Lux]

PART II

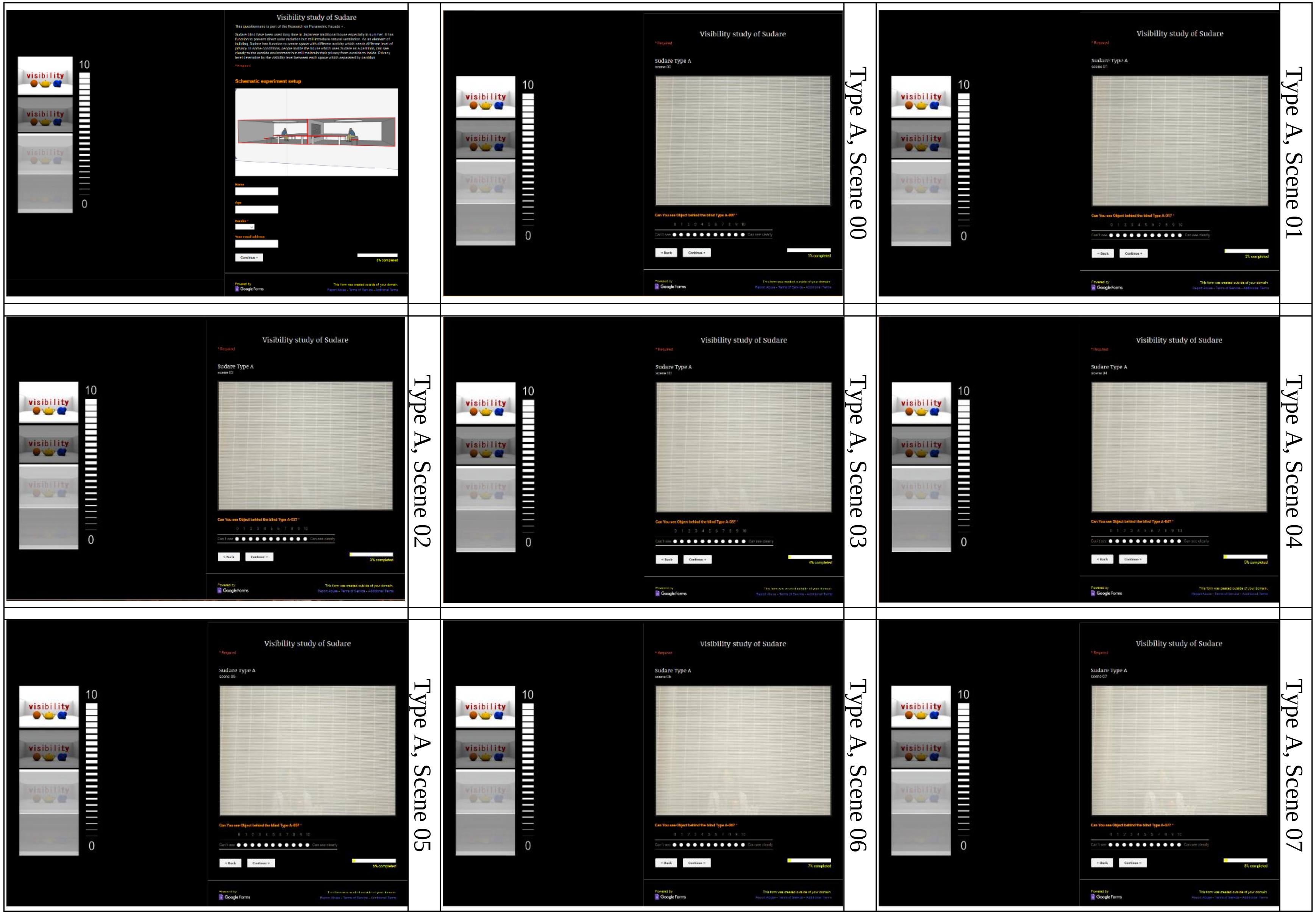
No.	室条件	視認レベル 0	1	2	3	4	5	6	照度レベル
1	照度レベル10	○	○	○	○	○	✓	○	873 [Lux]
2	照度レベル09	○	○	○	○	○	✓	○	776 [Lux]
3	照度レベル08	○	○	○	○	○	✓	○	689 [Lux]
4	照度レベル07	○	○	○	○	○	✓	○	601 [Lux]
5	照度レベル06	○	○	○	○	○	○	✓	510 [Lux]
6	照度レベル05	○	○	○	○	○	○	✓	423 [Lux]
7	照度レベル04	○	○	○	○	○	○	✓	339 [Lux]
8	照度レベル03	○	○	○	○	○	○	✓	266 [Lux]
9	照度レベル02	○	○	○	○	○	○	✓	196 [Lux]
10	照度レベル01	○	○	○	○	○	○	✓	97 [Lux]
11	照度レベル00	○	○	○	○	○	○	✓	23 [Lux]

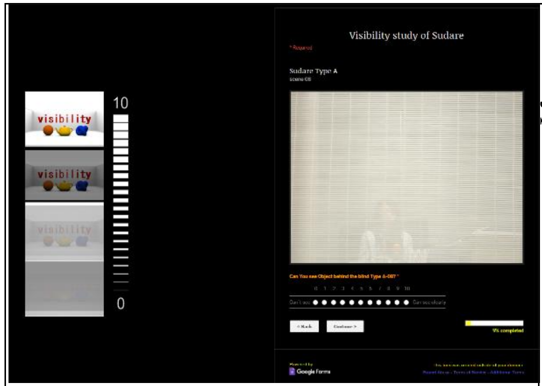
次のタイプ

終わり

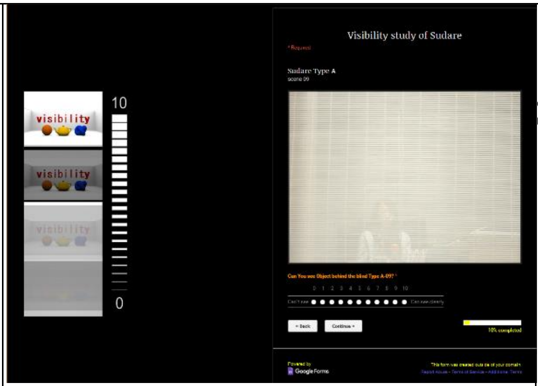
レベル	意味
0	何も見えない
1	シルエットのみ見える
2	色が見分けられない
3	対象物を識別することができるが、詳細はわからない
4	対象物の特徴や大体の詳細を述べることができる
5	多少ははっきりと見え、対象物の大体の詳細を述べることができる
6	対象物の詳細をはっきりと捉えて見ることができる

Appendix 2 Digital Image Questionnaire

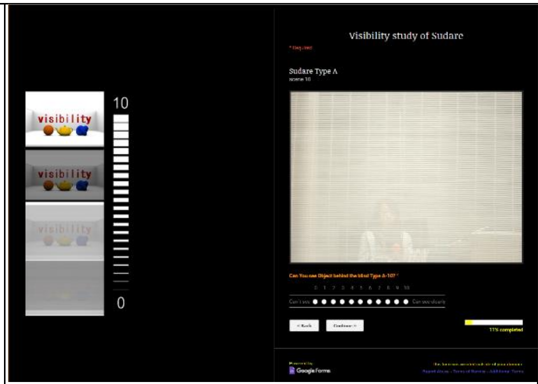

Visibility study of Sudare
Type A, Scene 00
Type A, Scene 01
Type A, Scene 02
Type A, Scene 03
Type A, Scene 04
Type A, Scene 05
Type A, Scene 06
Type A, Scene 07



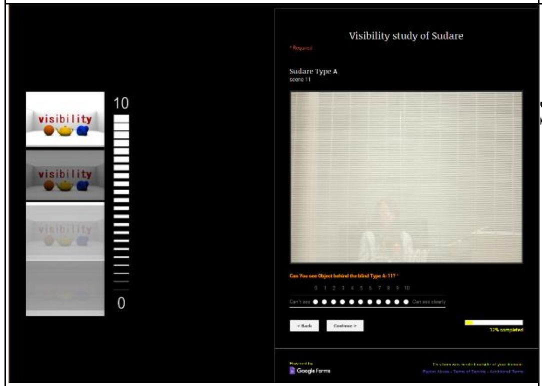
Type A, Scene 08



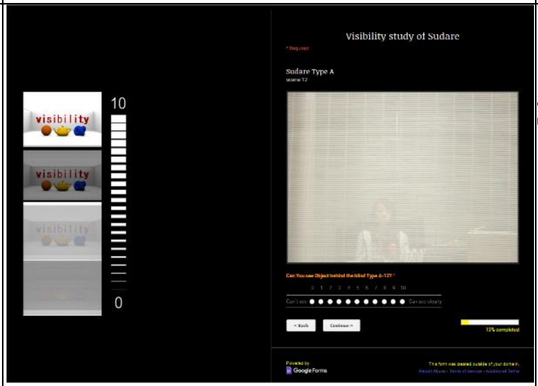
Type A, Scene 09



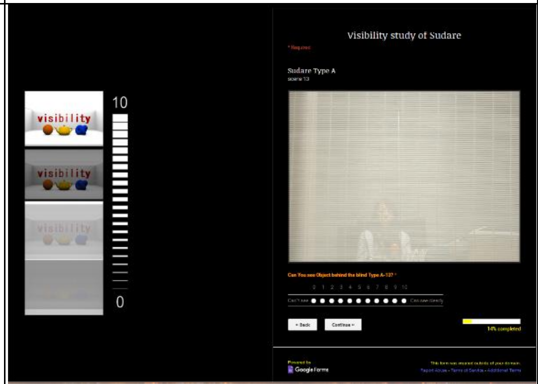
Type A, Scene 10



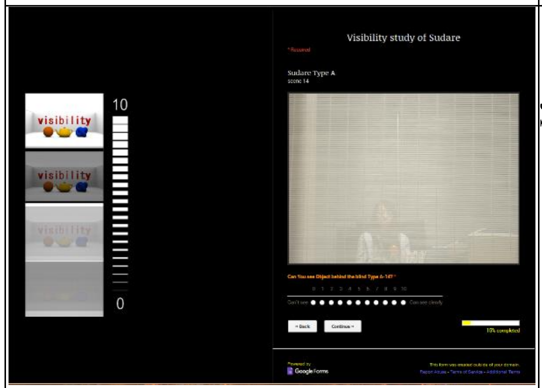
Type A, Scene 11



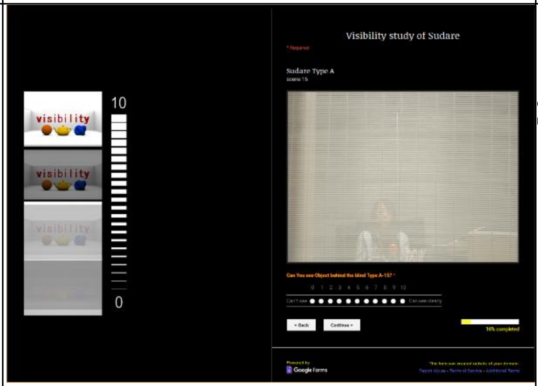
Type A, Scene 12



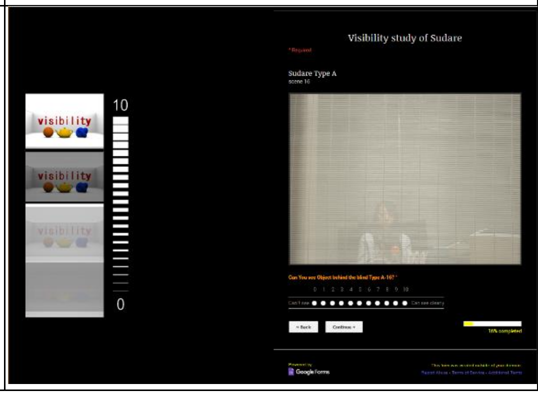
Type A, Scene 13



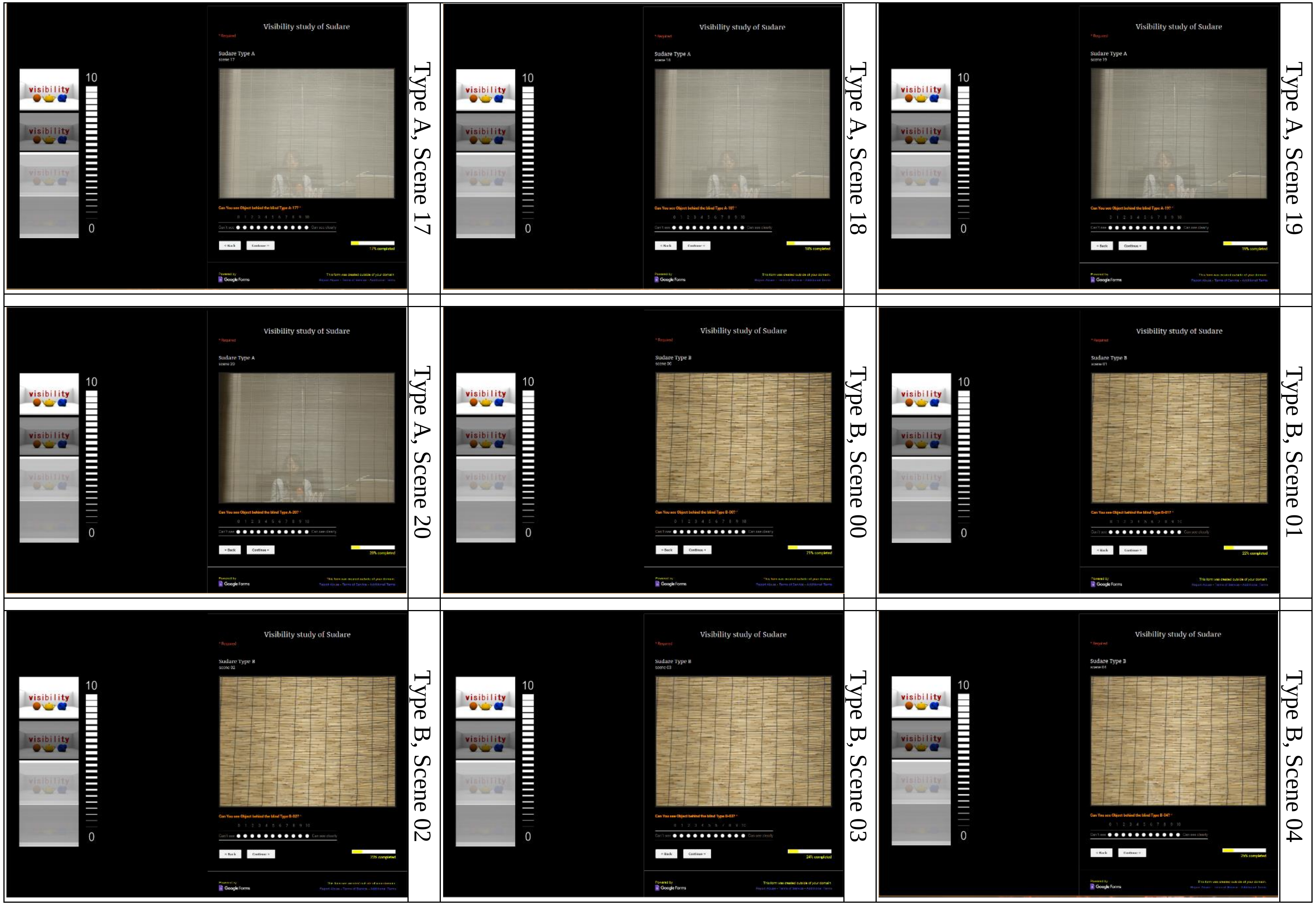
Type A, Scene 14

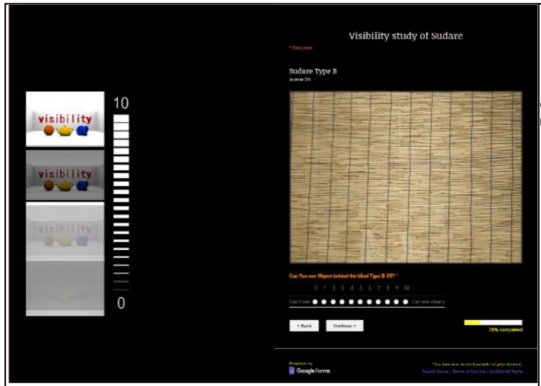


Type A, Scene 15

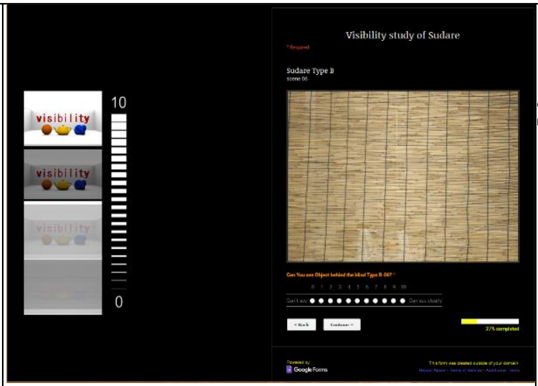


Type A, Scene 16

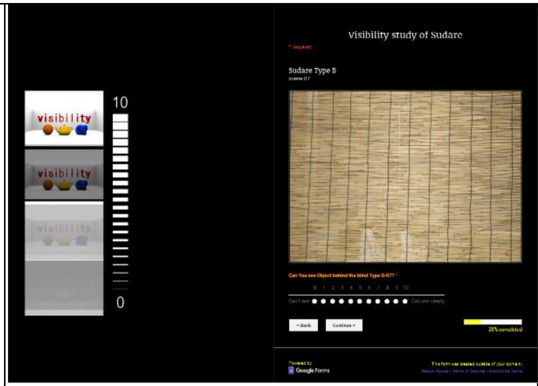

Type A, Scene 17
Type A, Scene 18
Type A, Scene 19
Type A, Scene 20
Type B, Scene 00
Type B, Scene 01
Type B, Scene 02
Type B, Scene 03
Type B, Scene 04
Visibility study of Sudare
visibility
10
0



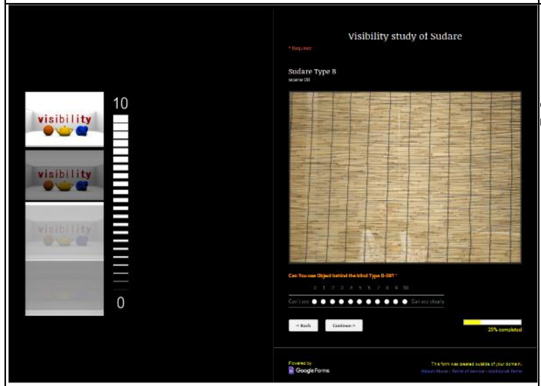
Type B, Scene 05



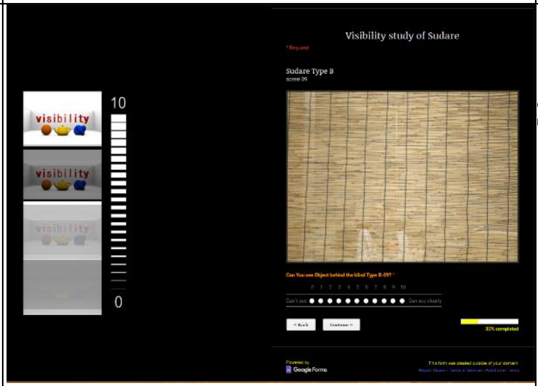
Type B, Scene 06



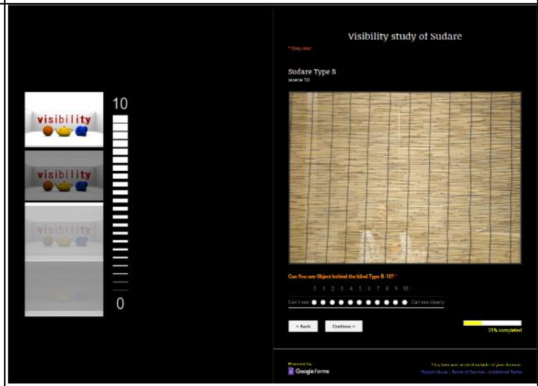
Type B, Scene 07



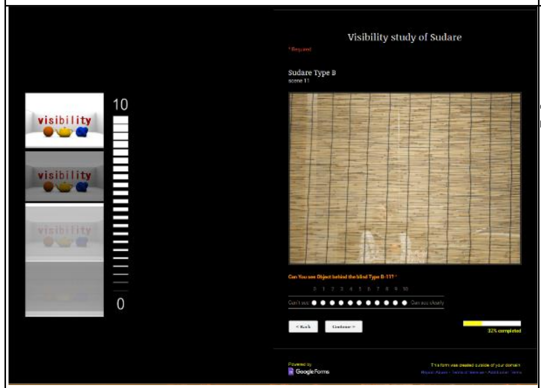
Type B, Scene 08



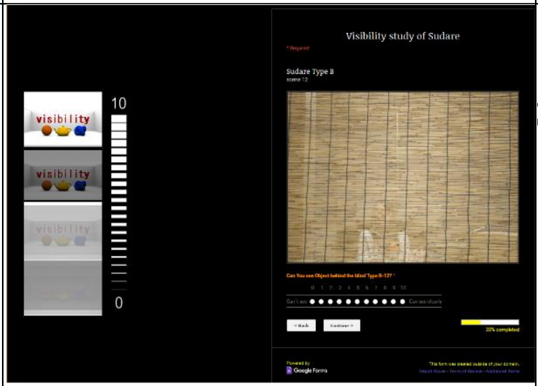
Type B, Scene 09



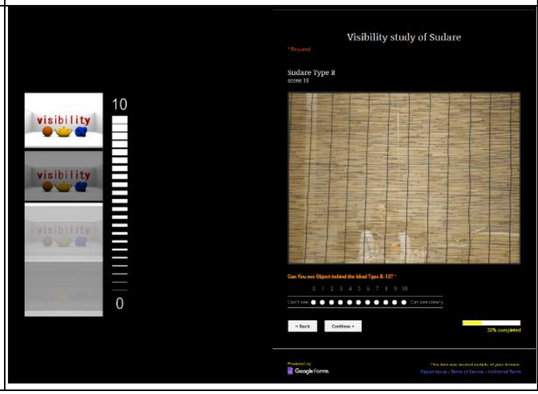
Type B, Scene 10



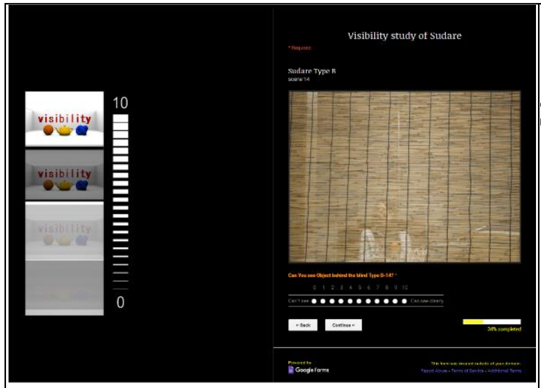
Type B, Scene 11



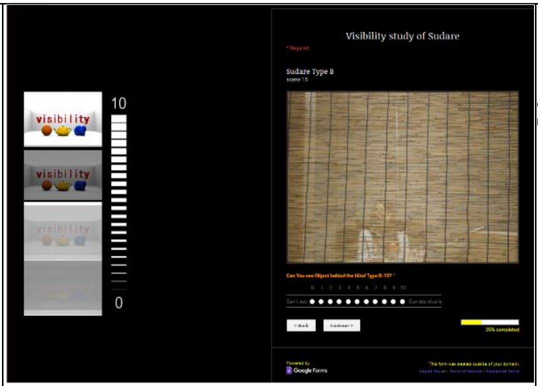
Type B, Scene 12



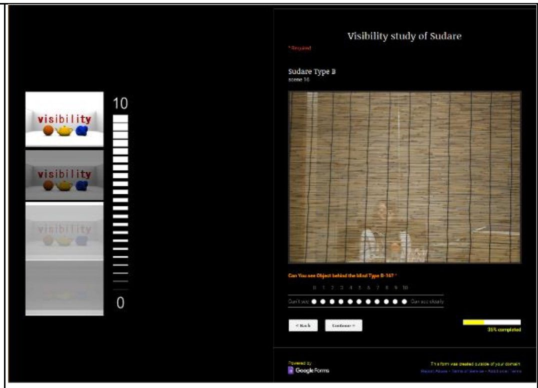
Type B, Scene 13



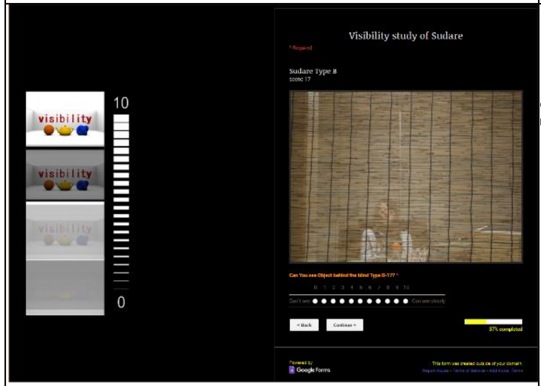
Type B, Scene 14



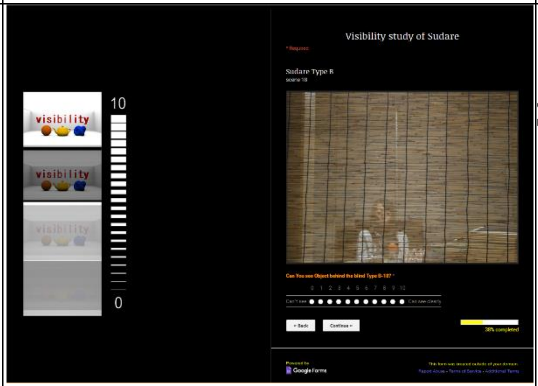
Type B, Scene 15



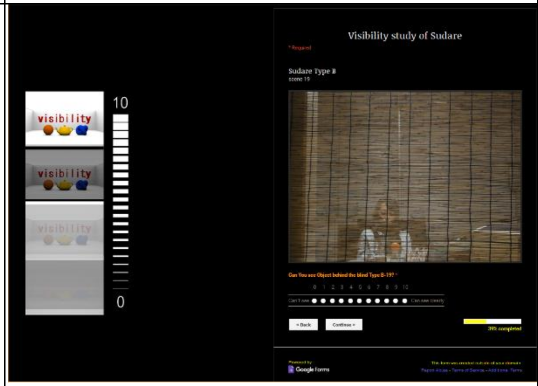
Type B, Scene 16



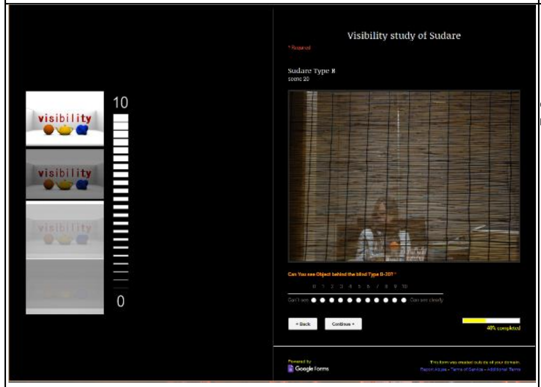
Type B, Scene 17



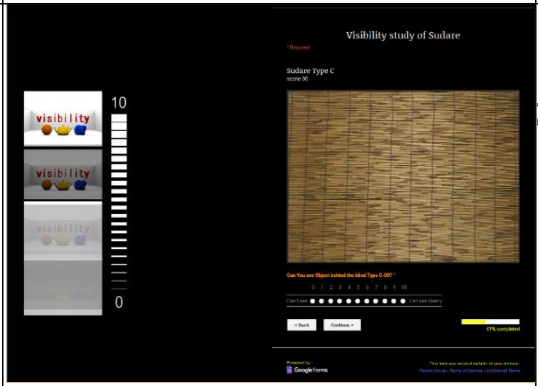
Type B, Scene 18



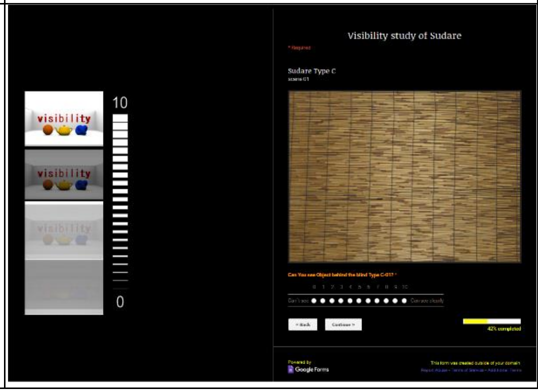
Type B, Scene 19



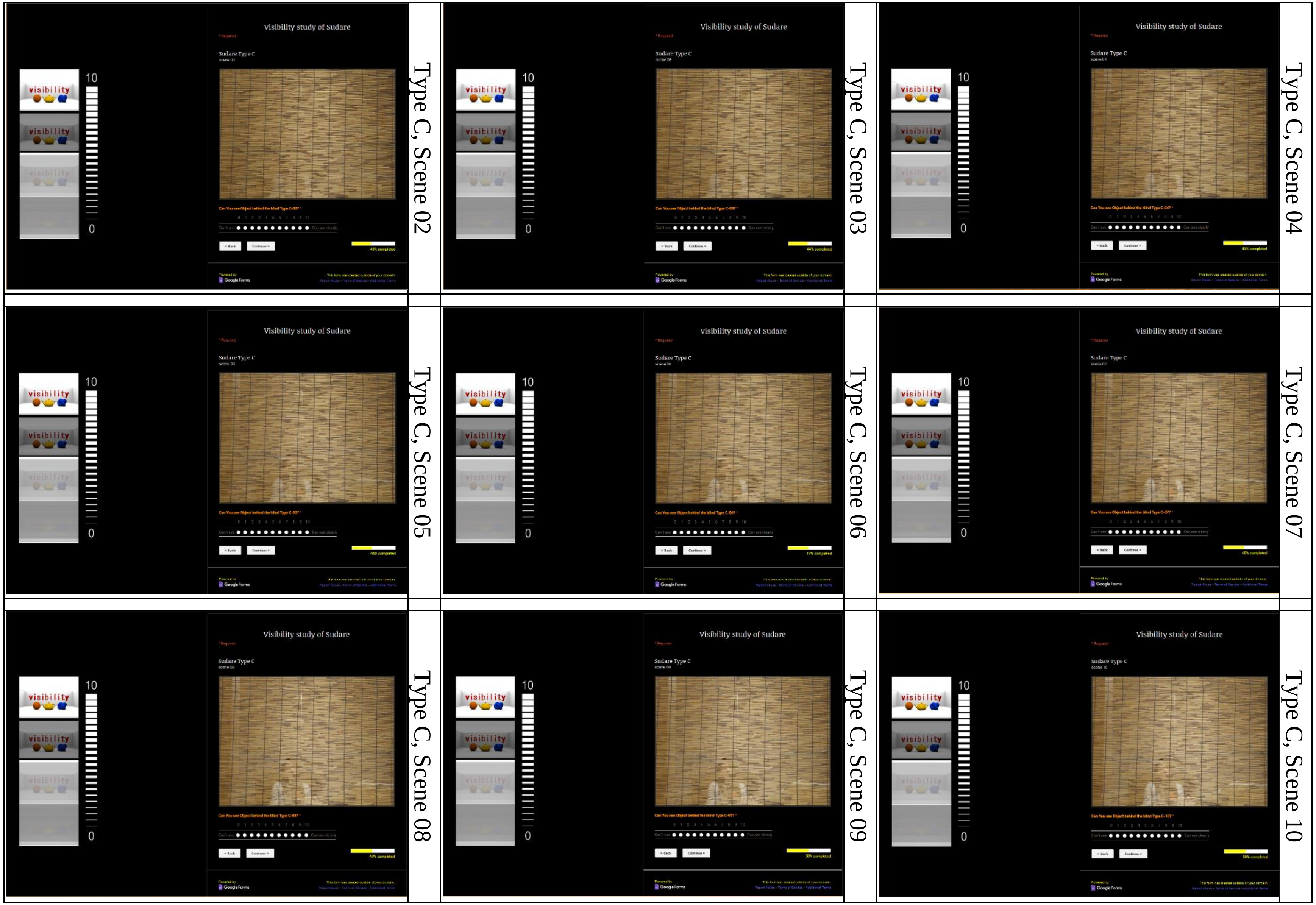
Type B, Scene 20

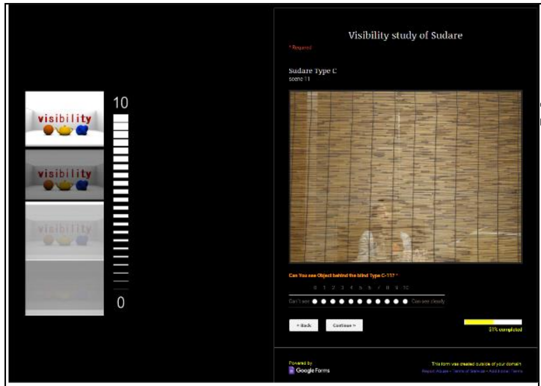


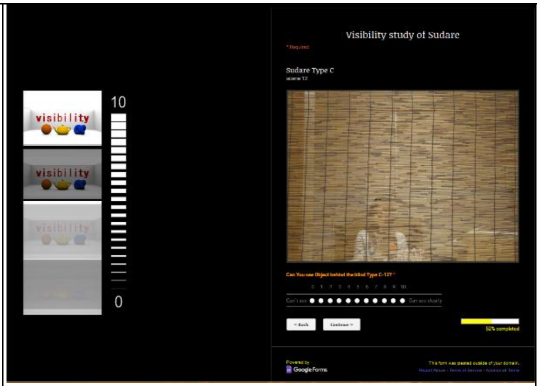
Type C, Scene 00

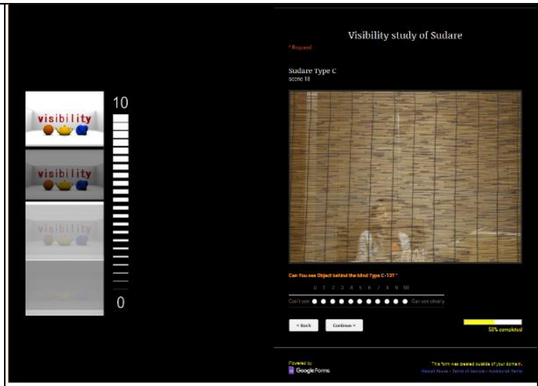


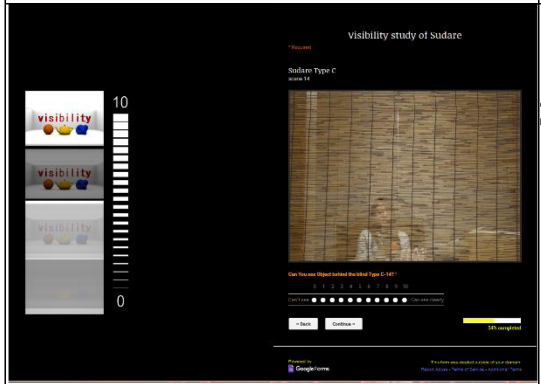
Type C, Scene 01

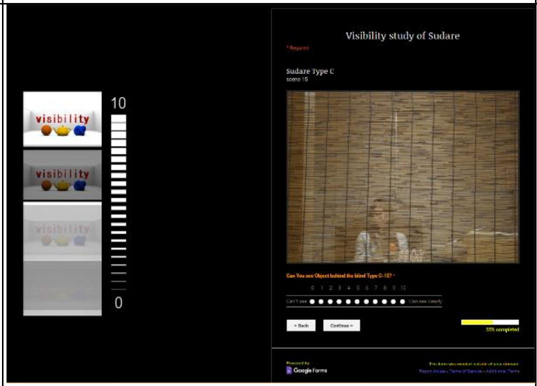

Visibility study of Sudare
Sudare Type C
visibility
10
0
Type C, Scene 02
Type C, Scene 03
Type C, Scene 04
Type C, Scene 05
Type C, Scene 06
Type C, Scene 07
Type C, Scene 08
Type C, Scene 09
Type C, Scene 10

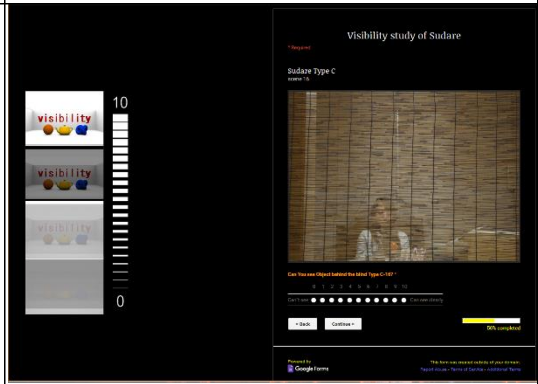

Type C, Scene 11

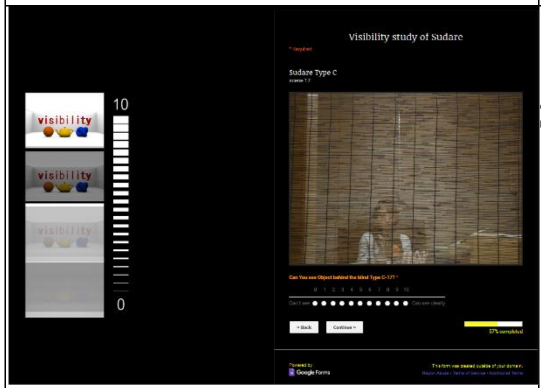

Type C, Scene 12

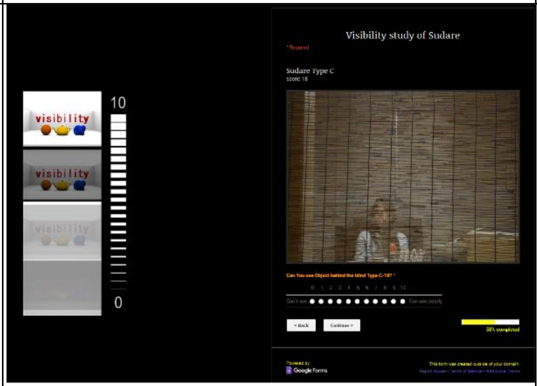

Type C, Scene 13

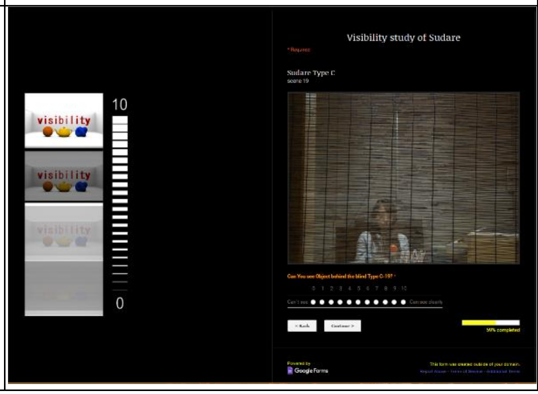

Type C, Scene 14

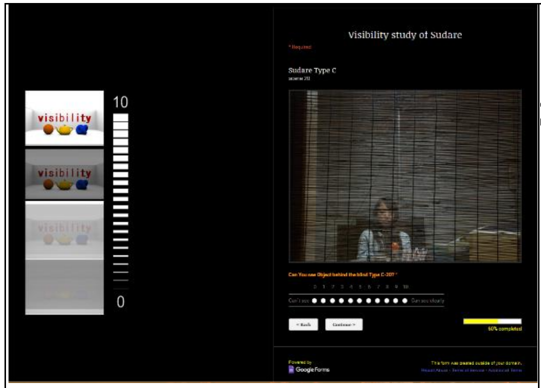

Type C, Scene 15


Type C, Scene 16

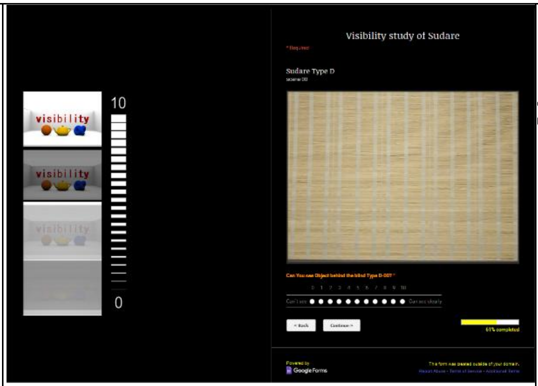

Type C, Scene 17


Type C, Scene 18

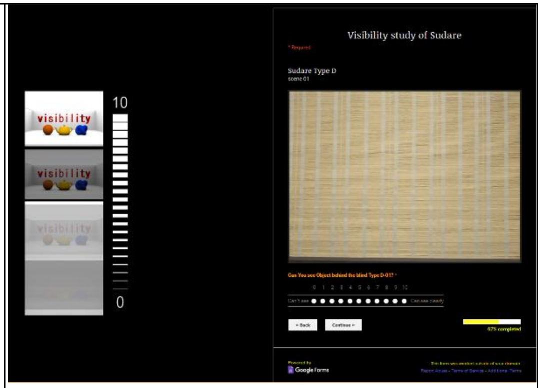

Type C, Scene 19



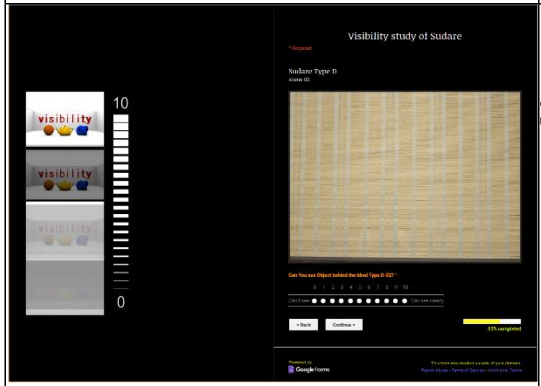
Type C, Scene 20



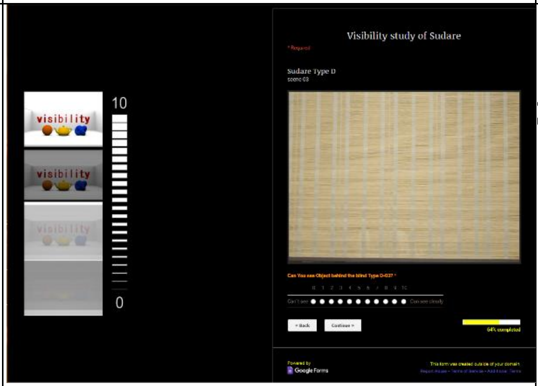
Type D, Scene 00



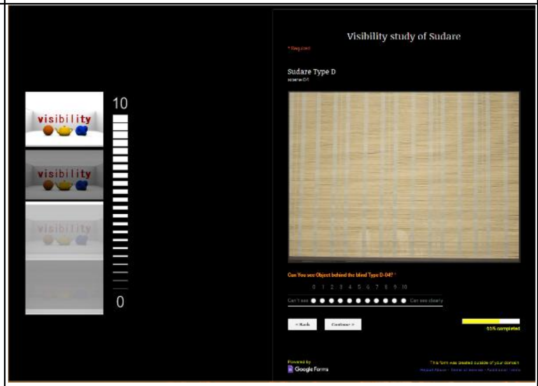
Type D, Scene 01



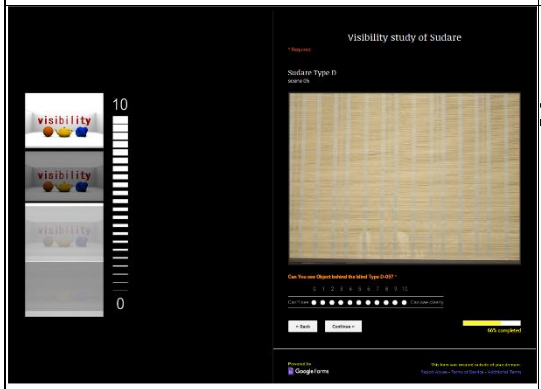
Type D, Scene 02



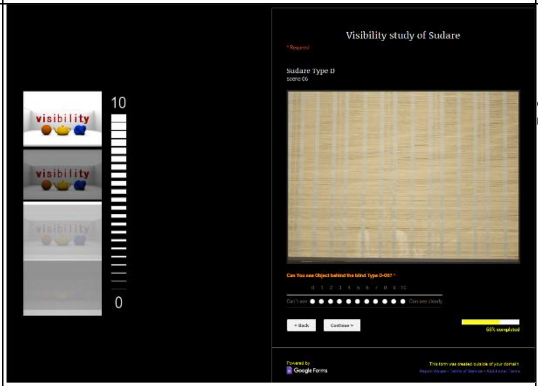
Type D, Scene 03



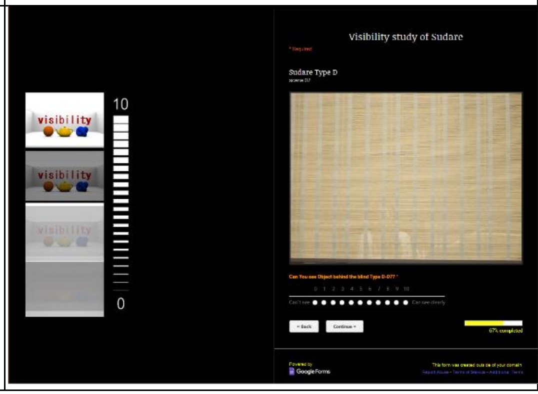
Type D, Scene 04



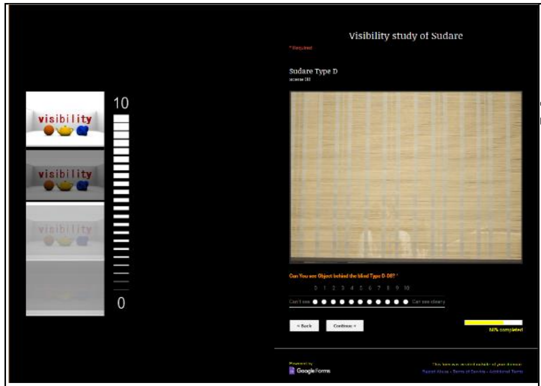
Type D, Scene 05



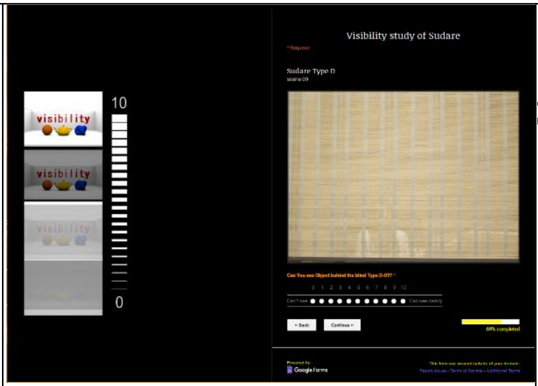
Type D, Scene 06



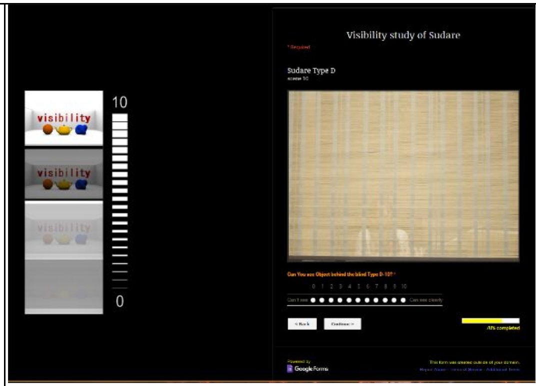
Type D, Scene 07



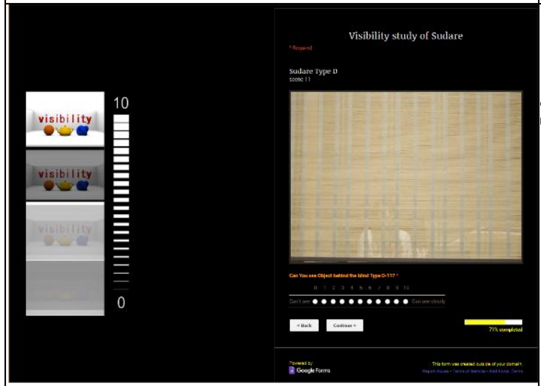
Type D, Scene 08



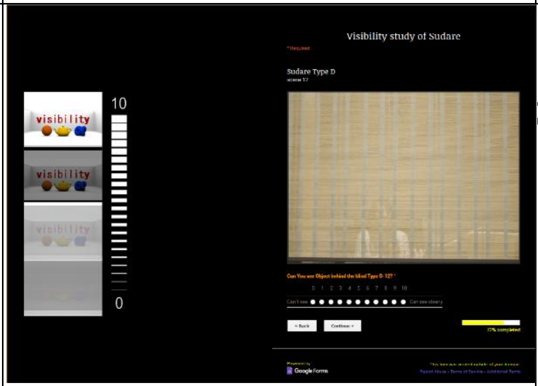
Type D, Scene 09



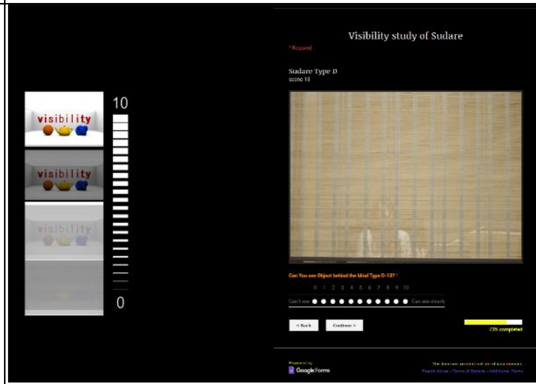
Type D, Scene 10



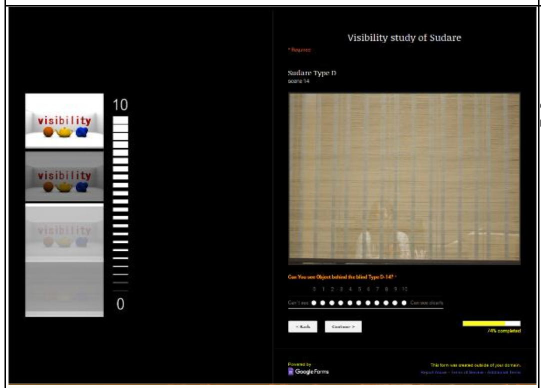
Type D, Scene 11



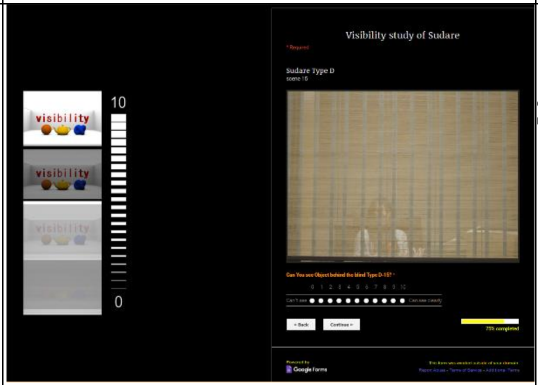
Type D, Scene 12



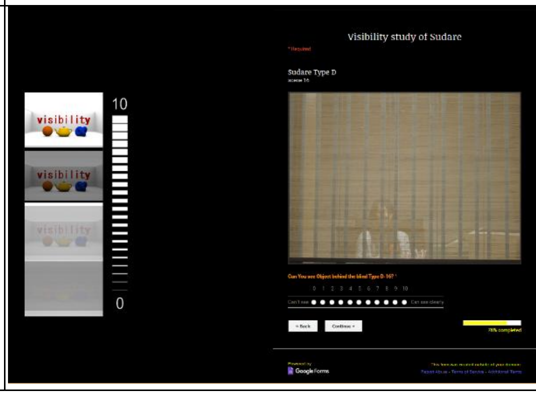
Type D, Scene 13



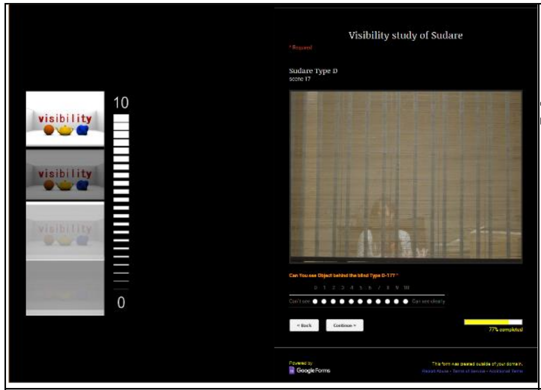
Type D, Scene 14



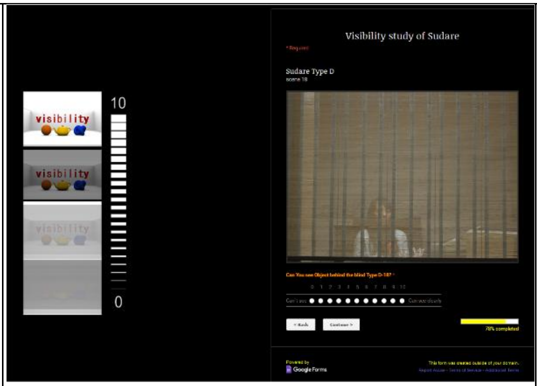
Type D, Scene 15



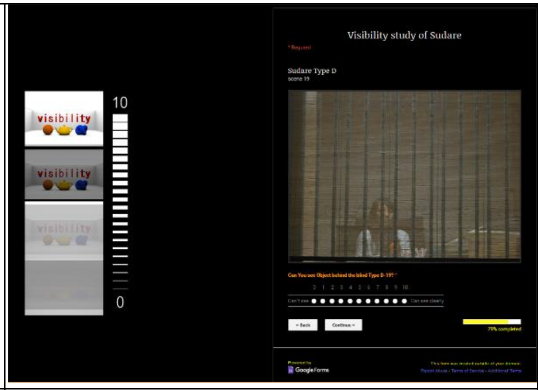
Type D, Scene 16



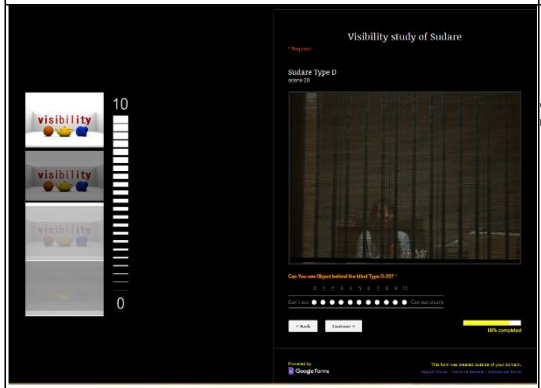
Type D, Scene 17



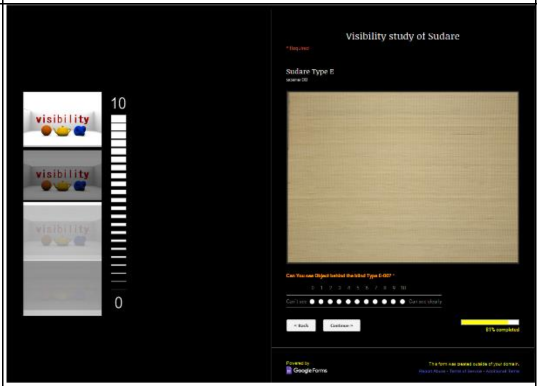
Type D, Scene 18



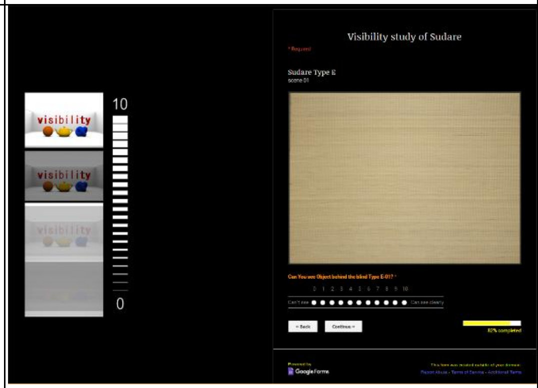
Type D, Scene 19



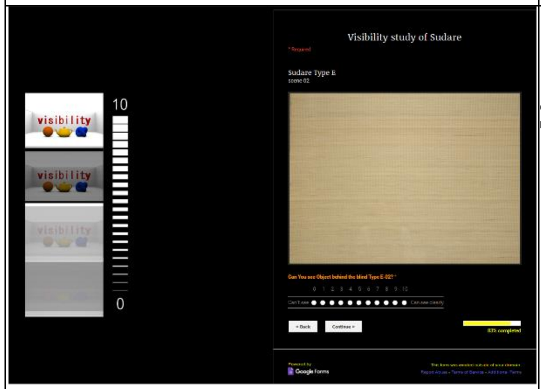
Type D, Scene 20



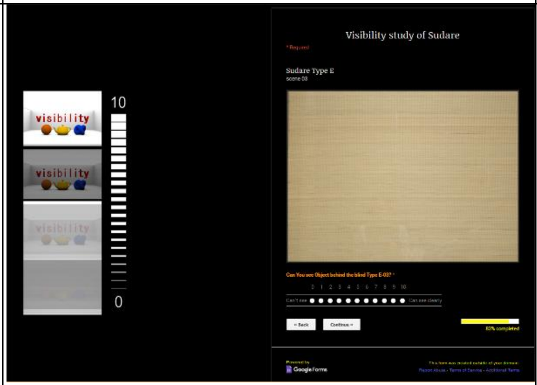
Type E, Scene 00



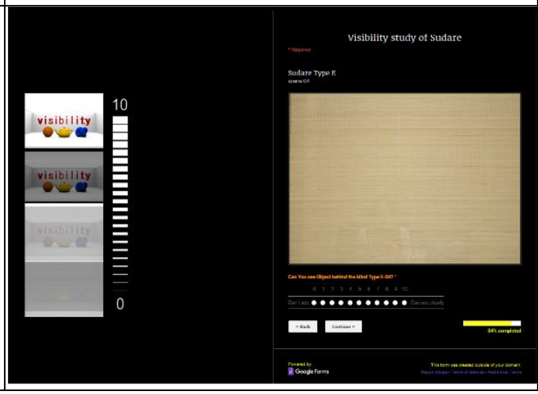
Type E, Scene 01



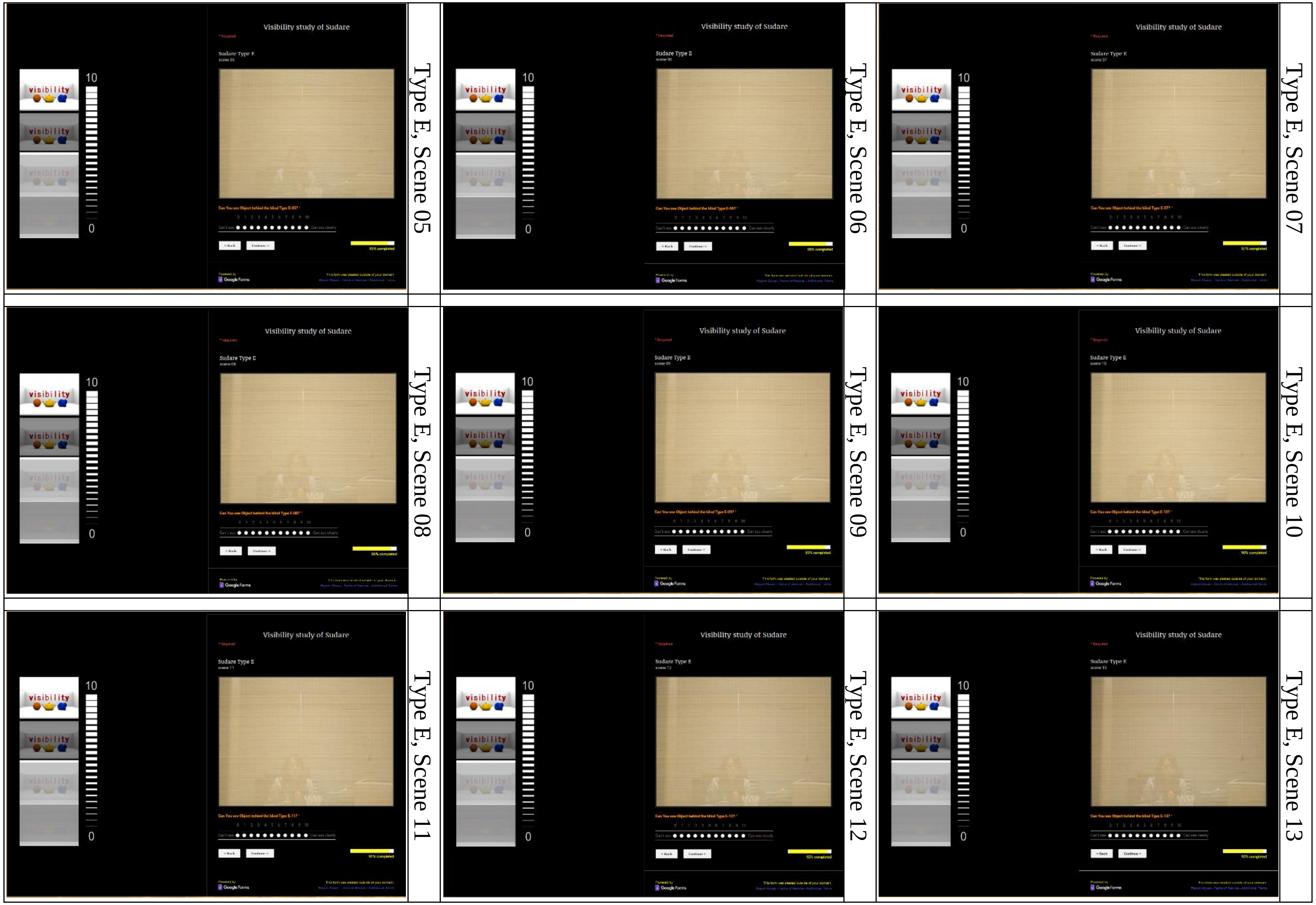
Type E, Scene 02

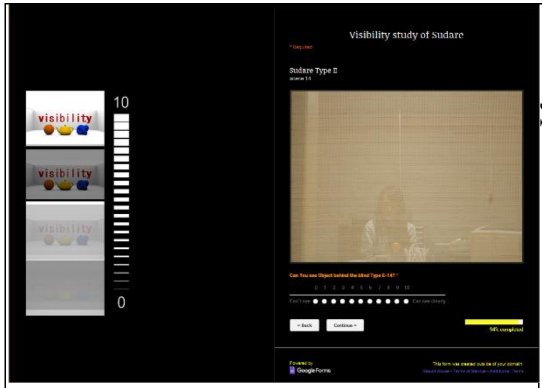


Type E, Scene 03

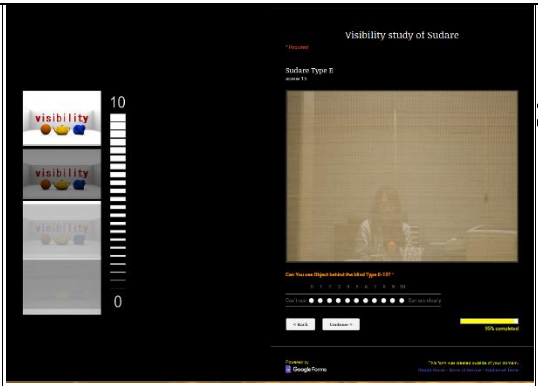


Type E, Scene 04

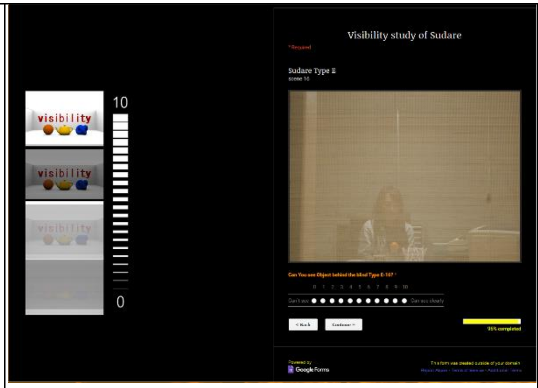

Type E, Scene 05
Type E, Scene 06
Type E, Scene 07
Type E, Scene 08
Type E, Scene 09
Type E, Scene 10
Type E, Scene 11
Type E, Scene 12
Type E, Scene 13
Visibility study of Sudare
visibility
10
0



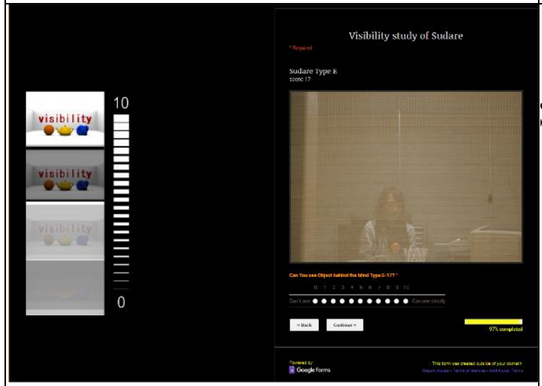
Type E, Scene 14



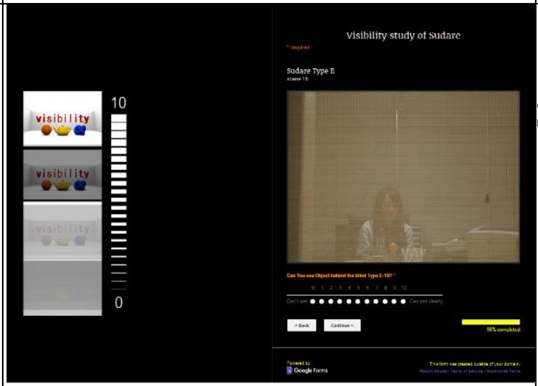
Type E, Scene 15



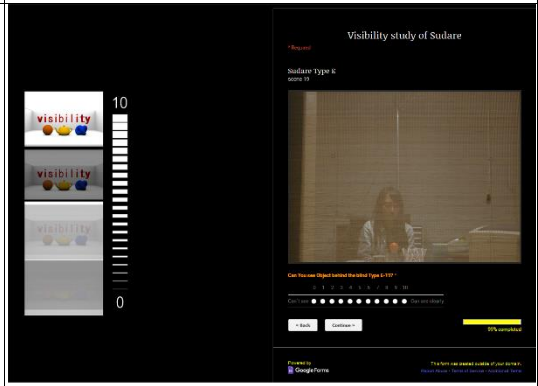
Type E, Scene 16



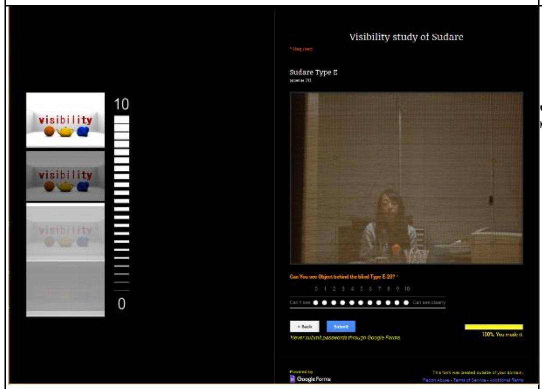
Type E, Scene 17



Type E, Scene 18

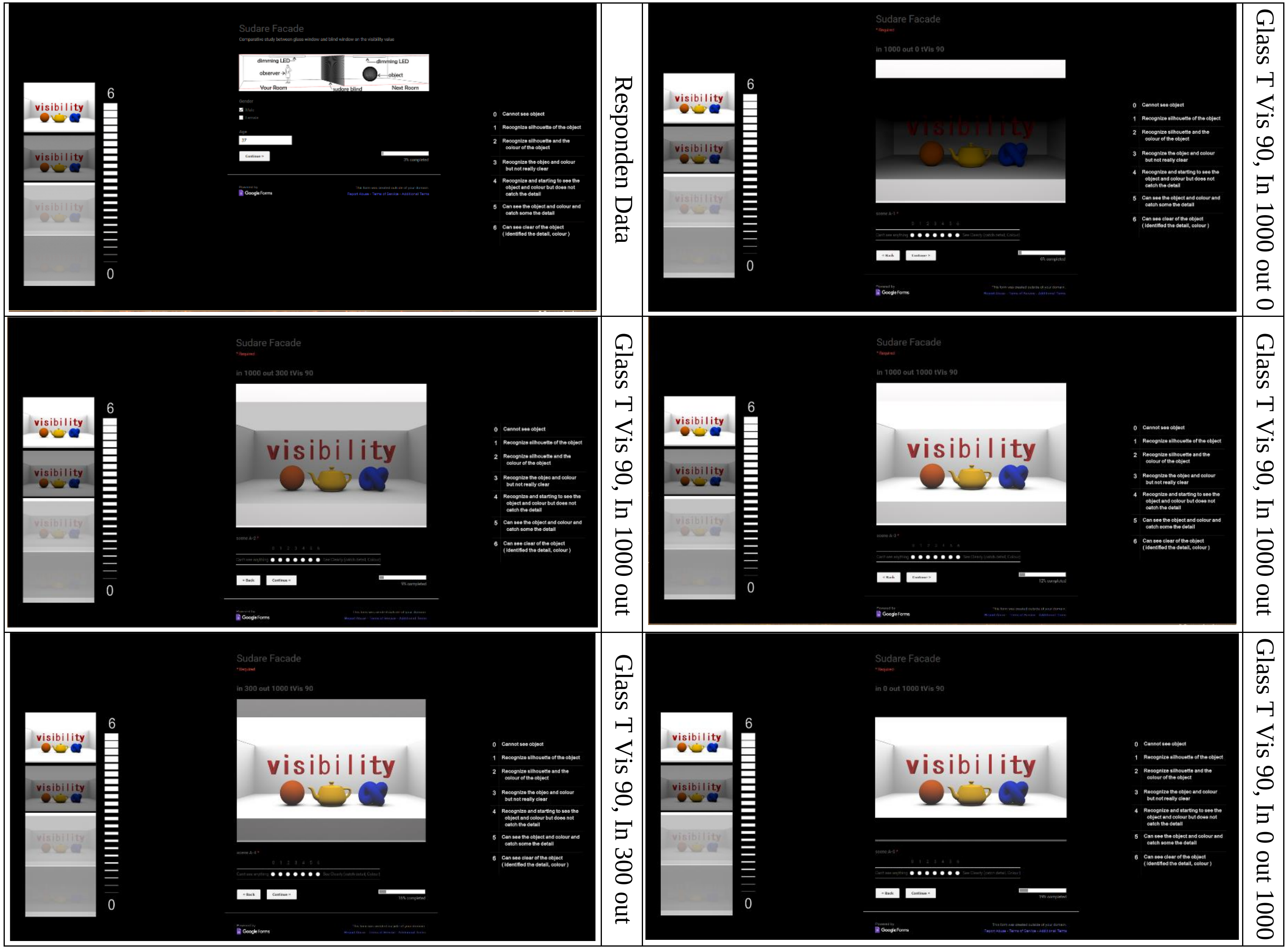


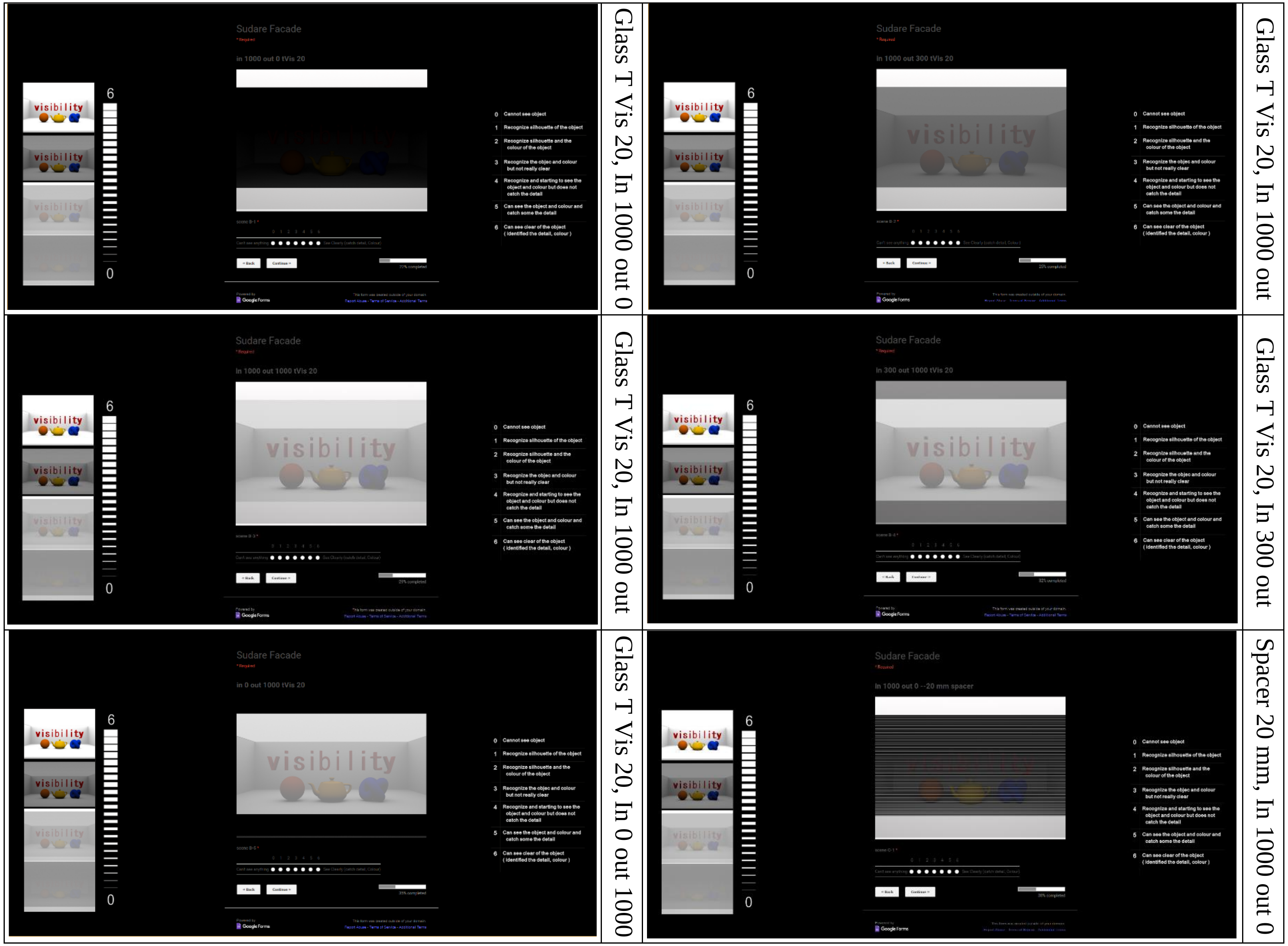
Type E, Scene 19

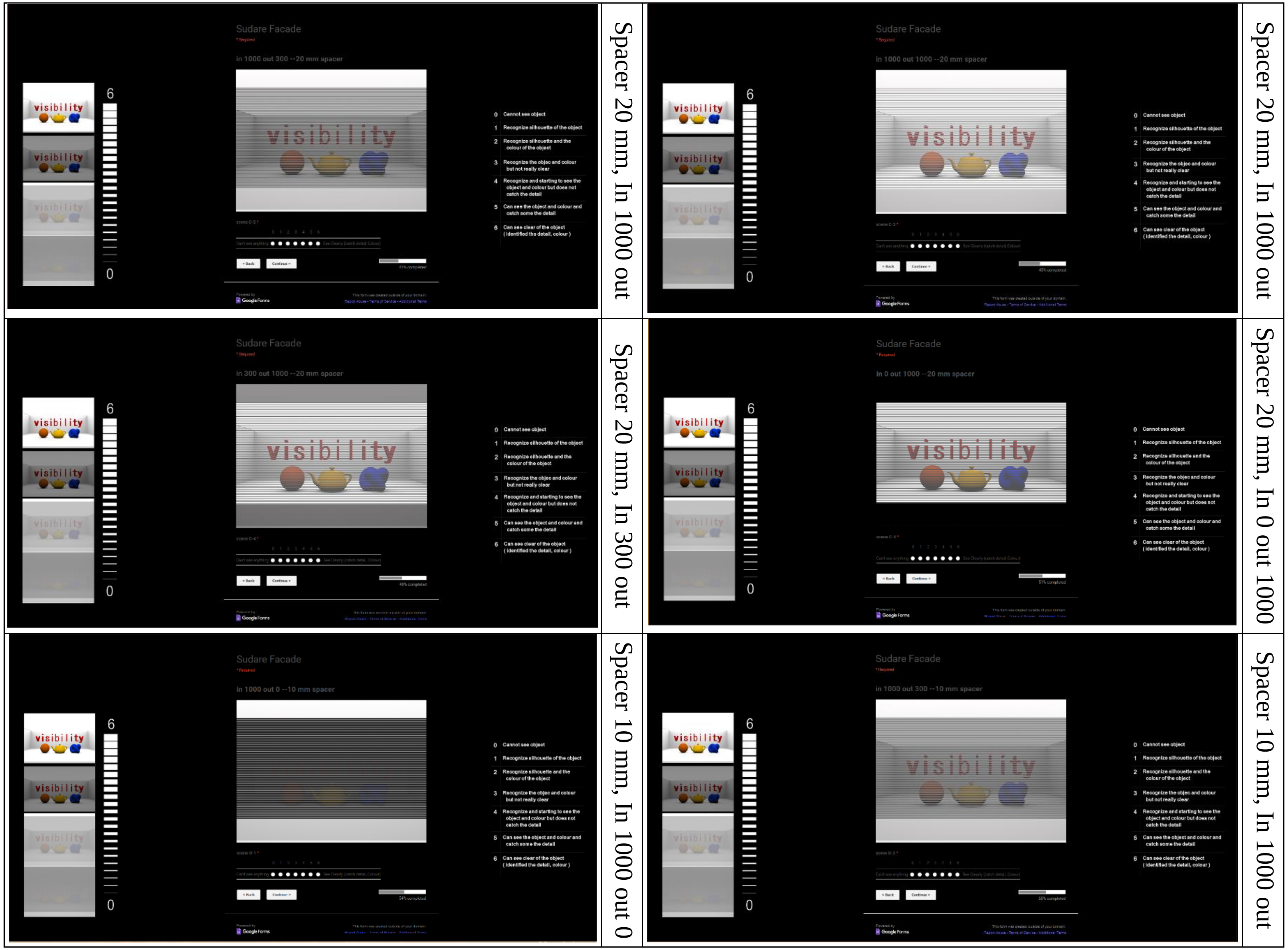


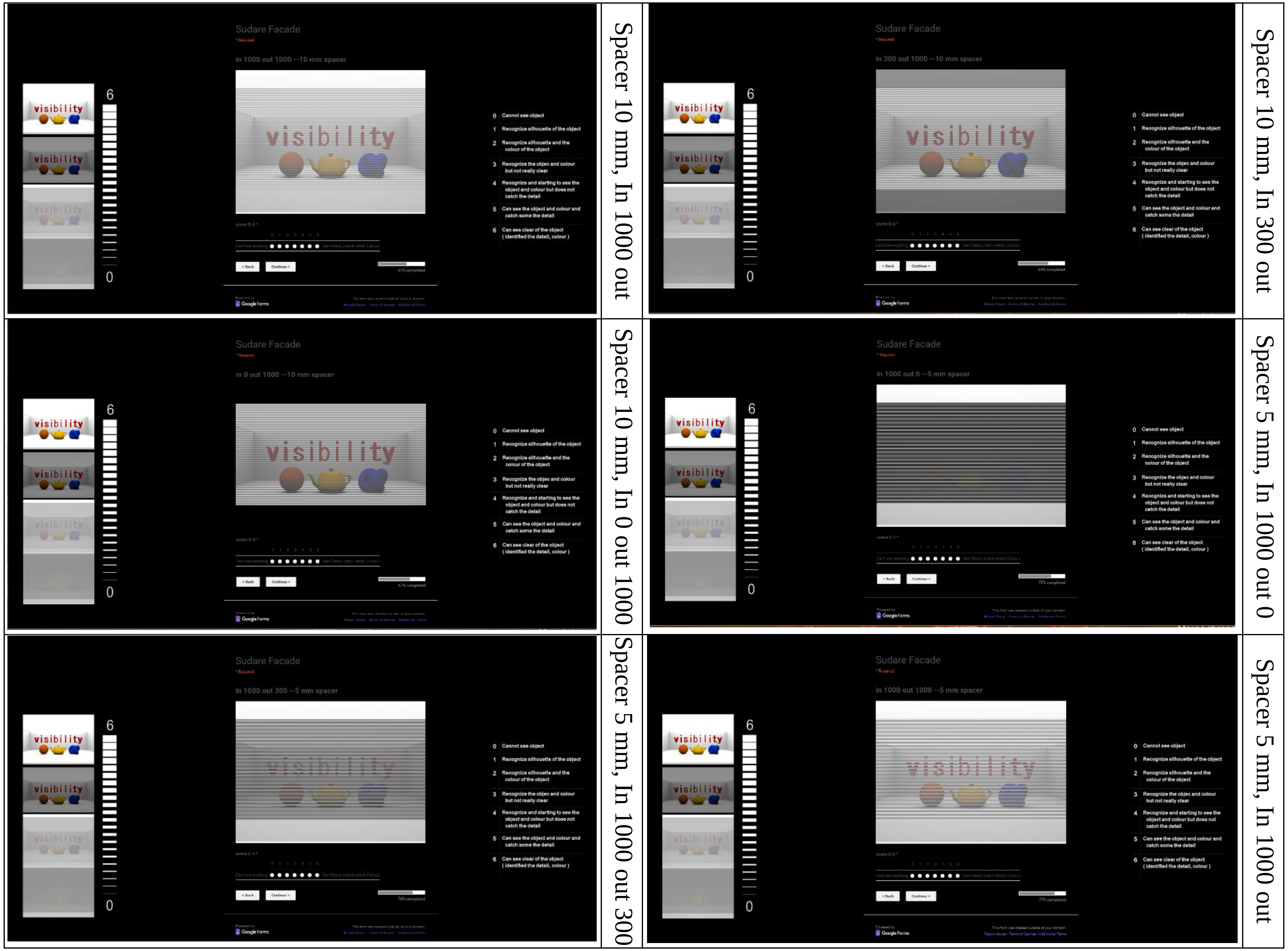
Type E, Scene 20

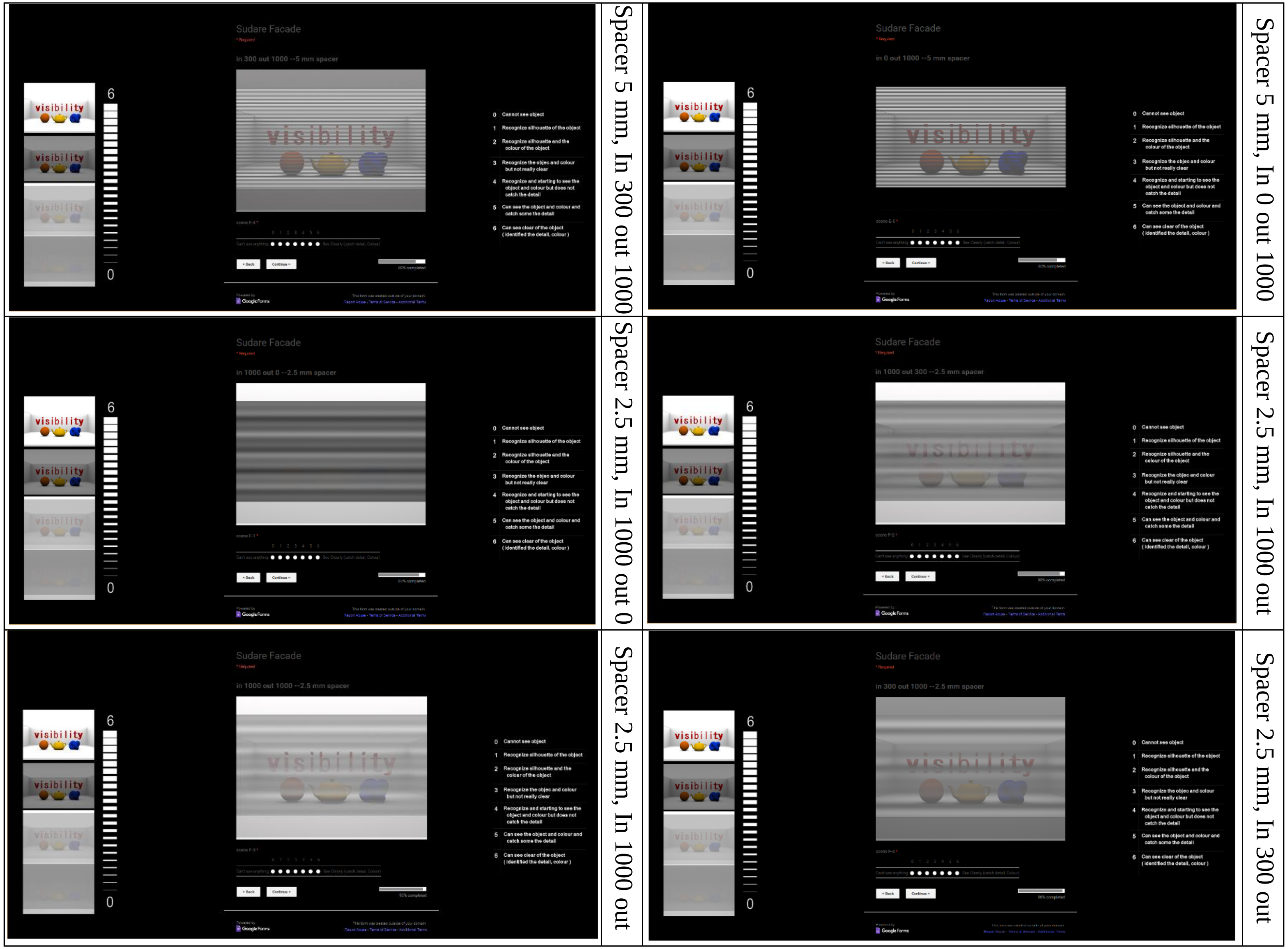
Appendix 3 Digital Rendering Image Questionnaire


Responden Data
Glass T Vis 90, In 1000 out 0
Glass T Vis 90, In 1000 out 300
Glass T Vis 90, In 1000 out 1000
Glass T Vis 90, In 300 out 1000
Glass T Vis 90, In 0 out 1000
Sudare Facade
visibility


Glass T Vis 20, In 1000 out 0
Glass T Vis 20, In 1000 out
Glass T Vis 20, In 1000 out
Glass T Vis 20, In 300 out
Glass T Vis 20, In 0 out 1000
Spacer 20 mm, In 1000 out 0
Sudare Facade
In 1000 out 0 tVis 20
In 1000 out 300 tVis 20
In 1000 out 1000 tVis 20
In 300 out 1000 tVis 20
in 0 out 1000 tVis 20
In 1000 out 0 --20 mm spacer
visibility
6
0


Sudare Facade
in 1000 out 300 --20 mm spacer
Spacer 20 mm, In 1000 out
Sudare Facade
in 1000 out 1000 --20 mm spacer
Spacer 20 mm, In 1000 out
Sudare Facade
in 300 out 1000 --20 mm spacer
Spacer 20 mm, In 300 out
Sudare Facade
in 0 out 1000 --20 mm spacer
Spacer 20 mm, In 0 out 1000
Sudare Facade
in 1000 out 0 --10 mm spacer
Spacer 10 mm, In 1000 out 0
Sudare Facade
in 1000 out 300 --10 mm spacer
Spacer 10 mm, In 1000 out
visibility
6
0
0 Cannot see object
1 Recognize silhouette of the object
2 Recognize silhouette and the colour of the object
3 Recognize the objec and colour but not really clear
4 Recognize and starting to see the object and colour but does not catch the detail
5 Can see the object and colour and catch some the detail
6 Can see clear of the object (identified the detail, colour)


Sudare Facade
in 1000 out 1000 --10 mm spacer
Spacer 10 mm, In 1000 out
Sudare Facade
in 300 out 1000 --10 mm spacer
Spacer 10 mm, In 300 out
Sudare Facade
in 0 out 1000 --10 mm spacer
Spacer 10 mm, In 0 out 1000
Sudare Facade
in 1000 out 0 --5 mm spacer
Spacer 5 mm, In 1000 out 0
Sudare Facade
in 1000 out 300 --5 mm spacer
Spacer 5 mm, In 1000 out 300
Sudare Facade
in 1000 out 1000 --5 mm spacer
Spacer 5 mm, In 1000 out
visibility
6
0
0 Cannot see object
1 Recognize silhouette of the object
2 Recognize silhouette and the colour of the object
3 Recognize the objec and colour but not really clear
4 Recognize and starting to see the object and colour but does not catch the detail
5 Can see the object and colour and catch some the detail
6 Can see clear of the object (identified the detail, colour)


Sudare Facade
in 300 out 1000 --5 mm spacer
Spacer 5 mm, In 300 out 1000
Sudare Facade
in 0 out 1000 --5 mm spacer
Spacer 5 mm, In 0 out 1000
Sudare Facade
in 1000 out 0 --2.5 mm spacer
Spacer 2.5 mm, In 1000 out 0
Sudare Facade
in 1000 out 300 --2.5 mm spacer
Spacer 2.5 mm, In 1000 out
Sudare Facade
in 1000 out 1000 --2.5 mm spacer
Spacer 2.5 mm, In 1000 out
Sudare Facade
in 300 out 1000 --2.5 mm spacer
Spacer 2.5 mm, In 300 out

	Spacer 2.5 mm, In 0 out 1000		