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Optimization of Sustainable House in Urban Area

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Abstract

The growth of time demands human to evolve needs. House as a primary needs is inseparable from the development of human life needs, especially in urban areas. The phenomenon of urban houses requires architects, developers, and even residents to be able to plan and collaborate in considering needs and limitations of land use. Humid tropical climate condition is a challenge for the planners or architects in creating indoor condition of the building that is eligible for dwelling. This paper aims to describe a simulation of interior arrangement to proving a design of efficient energy houses. The houses in urban areas are density houses with diverse environmental situations including density environmental housing and real estate. The identity of urban houses is characterized by inability to organize a dense interior space. Therefore, the requirements of comfortable and healthy dwelling are not fulfilled properly. The efforts to develop efficient energy, environmentally friendly and sustainable houses can be done through optimization approach of architectural design. The purpose of optimization is to find answers for possibilities of architectural design problems in order to obtain the best solution. The method of this research has been done by field observations to determine the pattern of spatial planning in several houses in Medan. In the process of model optimization, a possible improvement of existing dwelling model is designed through cyclical and analyzing planning, and alternative solutions that are sustainable and affect each other. The results of this analysis are expected to be a benchmark for local architects, researchers, and also residents in developing design optimizations, especially houses that have been built. This paper is a further research related to model developments of houses for urban community in Medan. Through an appropriate alternative interior arrangement, this research is expected to achieve the optimum design of houses based on the character of the urban environment without losing its identity as dwelling.

Keywords: sustainable; design; urban identity; optimization.

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1. Introduction

Medan is one of the five largest major cities in Indonesia. It can be clearly seen by the area and the rate of urban growth that is rapidly increasing. This rapid development is obviously viewed on the economy, population, and also the availability of facilities and infrastructures of the city. The developments in urban areas continue to grow sustainably and relentlessly. The growth of urban areas should be carefully managed and sustainable by considering factors of politic, economic, humanity, nature, and environment. The development activities, however, should be able to modify the situation of the city that is safe, comfortable, well-organized, as well as environmentally friendly to maintain the quality of the city.

The direction of development of Medan, recently, has followed modern economic and technological growth, the rate of population growth and urbanization pattern. This direction brings significant impacts on the ways of thinking and behaviors of society. As an example, the construction of urban facilities that is more increasing such as shop houses, shopping centers and entertainments, hotels, restaurants, housings, and offices causes a shift in the social life patterns and public mindsets, from conventional to modern. The increasing population of the city creates the conditions for an increasingly dense city and the growing demand for property. The problems are that the property development is often not able to accommodate aspirations of the community and is impressed to ignore applicable building regulations. House as the smallest environment of city is often affected by the increasing development of the city. On one side, houses are commonly located in dense and unhealthy environment, and on the other side, there are also other residential houses that have better environmental arrangements. Dwelling-settlement conditions should be a concern for policy makers of the city in which applicable regulations can be applied properly without neglecting human factors. It is due to all city residents have their own right to acquire a qualified life. In addition, the development of environmentally friendly and sustainable city is an effort to improve this condition.

The connection between architecture and sustainable concept is to create spaces of human life that are safe and support the physical and psychological developments of each human.[1] Based on viewpoint of tropical architects, the consideration of nature and environmental conditions has been discussed in the realm of architectures, particularly in Indonesia. Architecture in Indonesia should be planned by considering of ecology, utilization of natural resources, and environmentally friendly process during building operations. However, many architects ignore the sustainable rules in creating a built environment and also there is a lack of political policy in this field. It is related to low-level awareness of individual and government stakeholders on the issue of sustainability. Moreover, the arrangement of the city and region has not been integrated causing not to implement sustainable cities. Approaches of architectural design, nowadays, have been combined into several discussions- selection of the area, energy efficiency, water conservation, material resource efficiency, optimization and sustainability of design, and environmental quality in the building. Consequently, it is strongly needed to be done more intensive approaches to create built environments that are qualified, optimal in design, and sustainable, primarily on housing of the city with all existing problems.

2. Methodology

The method of this research has been done through observations in public housing. The objective of this study is to analyze the pattern of design in some houses in Medan. Because of limited discussion, this research only focuses on a house representing houses in settlement area of Medan city. Data is collected by study observations, documentations, sketches of houses and settlement areas, and also the data of potential land and local climate conditions. The obtained data is analyzed to identify positive and negative potentials in order to conclude any problems of the existing houses as a whole. The result will be emphasized by analytic description approach explained by sustainable ideas as an effort to optimize efficient energy and environmentally friendly house. In the process of model optimization, a possible improvement of existing dwelling model is designed through cyclical and analyzing planning, and alternative solutions that are sustainable and affect each other. The results of this analysis are expected to be a benchmark for local architects, researchers, and also residents in developing design optimizations, especially houses that have been built.

3. Literature

3.1. Sustainable terminology

Sustainable architecture can be defined as an environmentally friendly design.[2] In addition, the sustainable architectural design is also known as the design of "green", ecological, and environmental response.[3] It is not a new concept. The human purposes in constructing buildings are to fulfill the spatial aspects (room), visual (sight, including aesthetics), audio (hearing), and thermal (temperature).[4] There are three goals that should be fit by an architectural work (buildings). First, buildings must be a product of art work. Second, buildings should be able to provide comfort (mentally and physically) for the inhabitants. Last, buildings also need to be efficient on energy consumption. Buildings that are not able to accommodate activities of inhabitants with comfort will be added or reduced to provide more comfortable building. In terms of energy consumption, buildings that fail to save energy will be expensive in operational when it is related to the problems of the depletion of oil resources as the main source of energy of the current buildings.

According to Brundtland Report of PBB 1987, sustainable architecture is the development process (areas, cities, businesses, communities, etc) principled "development that meets the current needs and aspirations without compromising future generations to meet their own needs".[5] Meanwhile, the sustainable framework that is major and relates to architecture has been declared by the UIA (International Union of Architecture) on global architects congress in Copenhagen on December 7, 2009.[6] UIA suggests that buildings and construction industries have impacts on current climate change. Moreover, these impacts can be reduced by determining the system of built environment. In the congress, UIA has committed to reduce the impacts of damage through "sustainable by design strategy" programs.[7] This strategy focused on optimizing efficiency in design by using renewable and environmentally friendly energy. It also concerned on searching "healthy materials" in order to construct healthy buildings, ecologically and visually magnifying land use, as well as inspiring, convincing, and magnifying aesthetic impression.

Sustainable or environmentally friendly architectural approaches are to find ways in order to minimize the negative impacts on the environment and the building by improving efficiency and wisdom in the application of material, energy, and interior arrangement. Because of each step of human movement today will bring impacts on future generations, an awareness of environment should be applied to the design.[8]

3.2. Sustainable design

House is a design for the long-term viability of human life. Essentially, house is a crucial need that should be fulfilled. One way for a so-called sustainable design is an approach emphasizing the term "4-R"- reduce, reuse, recycle, and regenerate.[9]

Creating a sustainable design involves several aspects of complex planning and relates to energy. The most important issues in this design are heating, cooling, and lighting through energy transfer into or out of the building. The problems that can be viewed immediately and need special considerations are rising temperature of the earth (global warming), air pollution, and reduction of natural resources. The following are some demanding issues of design that can be maintained and be a priority for sustainable building:[10]

- Designing and building efficient energy houses
- Utilizing the existing buildings and its infrastructures that using open spaces
- Optimizing designs by using less space and more efficient materials
- Preserving and restoring local and biodiversity ecosystems
- Using building materials that are from efficient source and have smallest impact to the environment
- Designing buildings that are durable and easy to adapt
- Designing water-efficient buildings and outdoor-spaces. Producing safe and comfort interior designs
- Restoring, reusing, recycling waste and practicing the responsive environment behaviors
- Minimizing environmental impacts in residential and work-places surrounding

The term "sustainability" can be achieved by energy-efficient designs and buildings. In order to reach sustainable value in design, energy used by buildings must be renewable and non-polluting energy such as solar, wind, hydropower, biomass and geothermal energy. Furthermore, the selection of building materials should concern about the availability of natural resources that can be renewed and utilized by reuse and recycle approaches.

4. Discussion and results

4.1. Environmental conditions of dwelling

Environmental condition of dwelling in Medan is divided into two types- real estate and public housing. This study focuses on optimizing houses in public housing. The environmental condition of existing public housing generally consists of dense groups of houses in a settlement area. As shown in space organizations, existing dwelling has not considered the quality and viability of human life and other existed functions in this area. Poor drainage systems, the mangement of non independent water and household waste that do not apply reuse concept, and irregular height of buildings cause the disturbance of wind movement. Moreover, close-distances among the buildings cause irregular sunlight received by the building. Thus, the arrangement of existing dwelling needs to consider the factor of building heights, distance among buildings, and environmental utilization systems in achieving sustainable environmental quality.

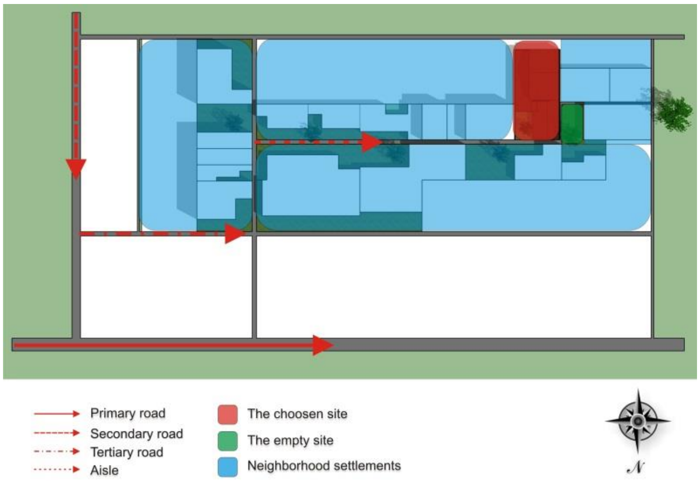

Fig. 1. The location of research object

4.2. The land use and the orientation of building mass

The location of the existing site is at crossroads, in which its position stands flanked by two routes of circulations. However, the density of the road is not being a problem for the site itself. Its position is one of positive values of site that can be utilized by building to optimize aeration and natural lighting. In terms of layout, the house has north-south orientation. This orientation is really favorable for the arrangements of space functions of the building, such as bedrooms. The bedroom would be better when it gains enough sunlight in the morning and afternoon and is being a cool site at night. Hence, the movement of the sun moving to the west direction and the eastern side have longer period in evaporating the hot air than western side of the building.

The settlement area is a group of single public houses. The average number of existing dwelling is single-storey buildings instead of double-storey buildings. Existing house is double-storey building, in which area of second floor is smaller than the first floor. Meanwhile, the buildings in surrounding have similar height, except for buildings that have more than one floor. The determination of building height will affect the movement of micro wind in the area and the angle of the sun fell on the building. For the example, the wind movement on the existing building is obstructed by dense housing that is without apart from each other. Because of its junction position, the building has an opportunity to gain direct wind blowing from the western side of the building. In order to optimize the wind movement and sunlight intensity into the site or building, it is required to design building mass that do not interact directly with neighboring buildings. It aims to avoid the obstruction of wind movement into or out of the buildings. In other words, the building is given "breathe" spaces.

The direct reflection of the sun on the eastern side of the building is blocked by other buildings. On the other side, the western side of the building does not have open-ventilation such as door and window as natural air and light circulations. The sunlight fell into the building is gained from the second floor with an approximate angle of more than 45^{o}. This light, however, is not able to accommodate spaces that require natural lighting on the first floor. As a result, it is necessary to draw the best solutions related to natural lighting and aeration.

In terms of land use, almost all houses in this settlement spend their land for the building. The building is massive form with 80% of site covered by the building and the rest of 20% used for natural or artificial open-green spaces. Open-green spaces are generally used for carport by giving pavement and are protected by a canopy, so that the sunlight can be reflected back to the air blowing hot and moist air into the room and environment. In terms of reducing humidity, greenery and water utilization- such as fish pond could be made. Plants and water are used as buffer or filter of the building towards dust and direct sunlight reflection. In addition, the more friendly pavements, like porous and not massive pavements could be designed. The porous pavements will help soil in case of water absorption. It helps to protect the sources of water absorption in environmental settlement and to minimize the overflow of excess water when rain falls.

Finally, the optimization by considering natural elements and climate conditions should be done to achieve sustainable spaces. Open-green space is not only as a buffer but also as a source of water infiltration to create microclimate environmental quality, good domestic environment, and the viability of existing support resources to remain sustainable.

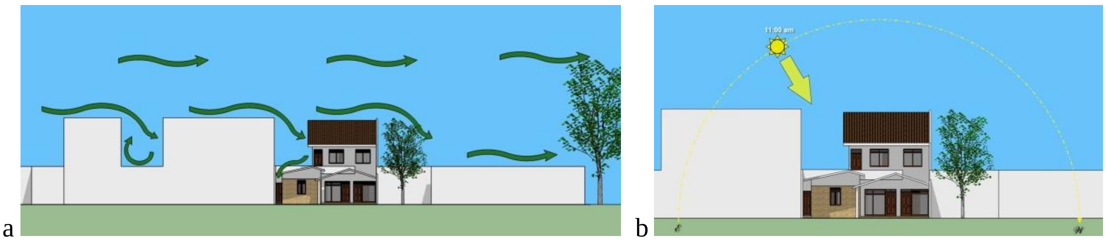

Fig. 2. (a) The wind movement through the environment; (b) Sun's orbit through the building

4.3. The space organization

The space layout of the building is supposed to be arranged to obtain the positive things and avoid negative things from outdoor space. Beneficial things involve sunlight and fresh air in the morning, while afternoon sunlight is the negative one. In reducing the negative aspects, other elements such as plants, windows, canopies, dual layers (double skin layer or double skin facade) should be added. Moreover, related to noise problems, space layout that its activities have a fairly high level of noise, such as public room, is better to be located in the front site of the building that is in contact to the outside area e.g. roads, while the spaces that require a privacy are placed on the sites that are protected from noises. For certain conditions, in terms of limited land, private areas that are in contact with public area could be protected by giving buffers- plants, trees, and parks.

The existing layout has not accommodated direct reflections of the sun and wind into the building. Excellent air circulation is not applied in the house because the lack of cross-ventilation systems causing air swirling in the building without any air exchanges. Besides having no cross-ventilation, it happens because close-distance of buildings and the height of eastern side of building that is taller that existing building. Because of this, the morning sun is not able to enter the building and the lighting is just obtained from the artificial lighting systems.

Consequently, this condition has not reflected the sustainable house in which the usage of electrical energy is quite high throughout the day.

In anticipating of high energy consumption, a solution should be drawn for the house. Reorganizing interior space, constructing appropriate cross-ventilation for air exchange, and utilizing the angle of space position as potential flows of natural light and air circulation are the example solutions.

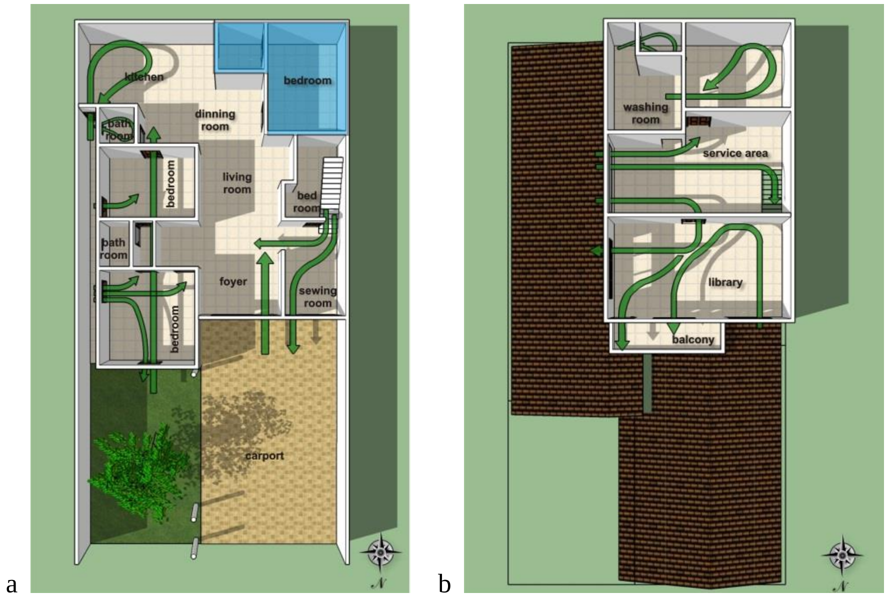

Fig. 3. (a) Existing layout on 1st floor; (b) 2nd floor

4.4. *The building's compliment and the material selection*

Design optimization of house is inseparable from the determination of the position and form of doors or windows, pavements, plants, and canopies. By existing, the design and the arrangement of doors or windows are not functioning properly. Doors or windows just define as decorative elements of the building. Sometimes windows that should be a path of air circulation are not widely open, because of indoor aeration system relying on air conditioning. Furthermore, the existing doors or windows are not supposed to be as an air and light ventilator because its design does not reflect an appropriate ventilator to accommodate air circulation and prevent dust. Besides there is no cross-ventilation of the building, dense settlements without any distances among buildings and irregular height of buildings inhibit the speed of wind entering the building. As a consequence, an optimization of the determining of doors or windows for achieving cross-ventilation is required by considering characteristics of local environments.

The reflection of sunlight to the roof and open-green space will affect thermal conditions of the building. Anticipations could be done by selecting the roof and pavement materials to reduce heat and to construct roof vents allowing air inside. Other consideration is to make pavement elements on open-green space more natural and environmentally friendly. In case of pavements, its shapes actually should be capable of absorbing water, for example grass and porous paving blocks. Making a fish pond is a way to involve water elements in the land. Beside of absorbing heat and keeping humidity, these techniques will create micro environment that is fresher, comfortable, and environmentally friendly.

Open-green spaces at existing conditions are covered by more than 50% of open-green spaces with massive pavement and greenery in plant containers. The function of open-space changes to be a carport caused by the building does not have special space for storing vehicles. If the massive pavement is more dominant than green-space, it will cause the decreasing of load-bearing capacity of soil and the lack of source of water infiltration. Hence, the unmanaged environment that cannot be handled continuously will lead to the environmental degradation, occupancy comfortless, and the reducing of aesthetics value.

In material selections, the existing building has not considered the continuity factors of natural resources as building materials. The selection of doors or windows, paints, roof covers and frames, floor coverings is a major concern in designing sustainable dwellings. Reuse concept can be applied in materials of doors or windows, roof covers and frames, and floor coverings. Reusing waste materials into new materials will be more economical for building cost. Meanwhile, the remained materials of construction work can be reutilized as building materials such as pavement, fencing, and others aiming to reduce construction waste wisely as sustainable efforts.

5. Conclusion

The optimization of sustainable design of dwellings should be able to save energy that will actually serve comfort, more humane, and has a pleasant aesthetic sense. In terms of financing and building operation of post occupancy, this building has cost less than conventional buildings. The design of efficient energy buildings will produce a building that minimizes the needs of expensive, polluted, and non recyclable energy.

Decisions on the design process that prioritize sustainable factors can affect the environmental controlling, and the aesthetic shape as well as the value of the building. Through sustainable design of houses, buildings could be responsible, friendly to the environment, and potentially aesthetics.

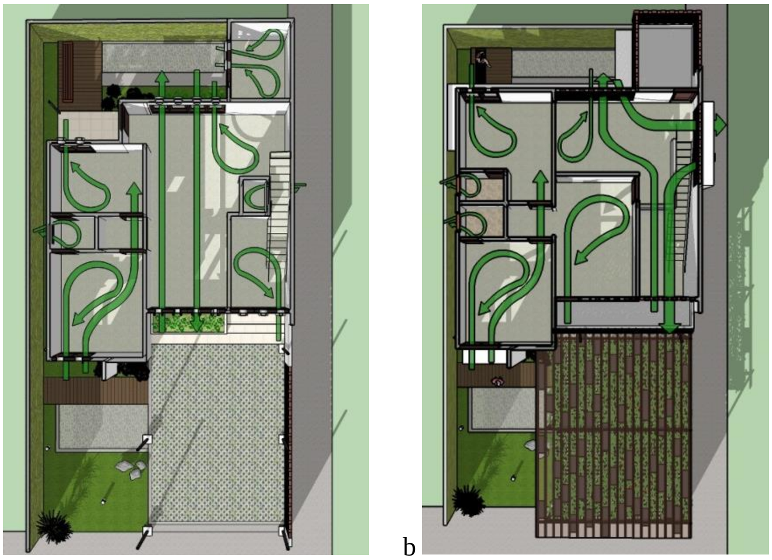

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Fig. 4. (a) The optimization in layout arrangement and the ventilation setting on 1st floor; (b) 2nd floor

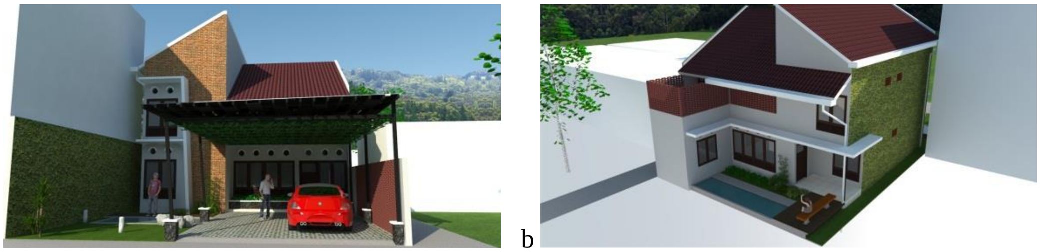

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Fig. 5. (a) The optimization of house design at front view; (b) Back view

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Energy-efficient building retrofit – Engineered transparency

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Abstract

Due to its energy consumption, the building sector plays a crucial role in the implementation of climate protection goals in Germany. In addition to the construction of energy efficient new buildings is the energetic refurbishment of existing buildings of particular importance in this process. A particular focus has to be placed on the transparent components of the building envelope, given that structural changes here do not only affect energy loss due to transmission, but also affect solar energy gains. Thus, structural measures on these components have an impact on the thermal protection in both winter and summer. This situation is exacerbated in the case of historical buildings and architectural monuments, because alterations of the building envelope are coupled with strict conditions. This article describes the energetic enhancement of two construction forms of transparent building envelopes on the example of the two World Heritage Sites Bauhaus Dessau and Siedlung Schillerpark Berlin. In addition to the description of constructional peculiarities, especially the potential solutions for an energetic and historically appropriate retrofitting of the sensitive building constructions are presented. As a result, notably slim façade profiles were developed. With a new thermal break they match the original appearance. In Siedlung Schillerpark Berlin, the energy demand could be reduced by integrating the box-type windows into the ventilation concept. At the same time, thermal comfort was increased.

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Keywords: Façade; Glass; Retrofit

1. Introduction

The Energy Concept 2050 of the Federal Republic of Germany aims for a sustainable energy supply in Germany. By 2050, CO_2 emissions are to be reduced by 80% compared to 1990 levels. Furthermore, the primary energy consumption in 2050 shall decrease by 50% compared to 2008 and the share of electricity from renewable energy in

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gross electricity consumption should amount to 80% [1]. In fulfilling these ambitious goals, the building sector plays an important role, as it alone accounts for about 40% of the energy consumption in Germany [2]. Residential buildings from the periods 1919 to 1948 and 1949 to 1978 together account for about 51% of the housing stock in Germany. Moreover, these buildings also have the highest energy demand. Here, potential savings of 50% (period 1919-1948) to 65% (period 1949-1978) could be achieved [3].

These figures show that the energy efficiency of existing buildings is an essential element for reducing the total energy demand of the Federal Republic of Germany. Choosing the right restoration measures for the historic materials and building structures is of crucial importance in order to improve the energy efficiency of a building and to avoid structural damage. This requires a careful surveying of the building stock and of the building construction typical for the respective building period. Energetically sustainable and damage-free adaptation measures can be developed only if typical constructions and their flaws are known.

This paper describes the constructional peculiarities of transparent building envelopes from the previously described building periods using the example of the two World Heritage Sites Bauhaus Dessau and Siedlung Schillerpark Berlin. Transparent parts of the building envelope require special attention, as they affect both the energy loss through transmission and the energy gains from solar radiation. In addition, alterations to the building envelope have a particularly strong impact on the external appearance. Regarding architectural monuments, such alterations are to be considered particularly carefully, which again makes the actual restoration task difficult but not impossible. A number of successful energetic refurbishments in the field of heritage buildings can be found in literature [4 to 7].

After an extensive survey, consisting of file search and onsite investigations in both cases, constructional improvement measures were elaborated. In addition to reducing the energy consumption, they also include increasing the thermal comfort and reducing the damage potential, for example through condensation. The quantification of energy savings was carried out with the aid of dynamic thermal building simulation software, dynamic hygrothermal component simulations and CFD simulations. This approach goes beyond the usual scope of methods used in retrofitting projects.

2. Single glazing with steel profiles

2.1. Initial state

Since 1870, rolled-steel sections in the form of T-profiles and L-profiles have been fabricated in Germany. These gradually replaced forged and cast iron as the preferential material of window frames. The rapid development of further types of profiles result that in 1905 complex composite window constructions with several hinges and seal levels were possible [8]. In design terms, there was the advantage of a thin frame and thin sash bars [9]. A disadvantage of these constructions is the high thermal conductivity of steel, resulting in high heat losses and low surface temperatures on the inside of the window frame by low outside temperatures. As part of the refurbishment measures at the Bauhaus in Dessau, the opportunity arose to draw up an energy-optimized and authentic restoration solution for these types of windows.

With regard to the high level of occupancy, heating loads and rising energy prices, operation costs of the Bauhaus building in Dessau are constantly rising. Consequently, the first ideas for an energetic enhancement of the building came up in 2009. The main focus has been placed on the preservation of the original appearance and the quality of the monument. Apart from the financial aspect of the high facility costs, the thermal comfort shall be improved. Because of the low temperatures on the inner surface of the single glazing, some users complained about strong drafts in the rooms. Very soon it became obvious that only the development of a comprehensive concept can protect the value of the monument.

Fig. 1. Bauhaus building Dessau, © Winfried Brenne Architects

The complex of buildings of the Bauhaus in Dessau consists of five main parts which were built within one year (1925/1926) and inaugurated in December 1926. Figure 1 gives an overview of the Bauhaus building.

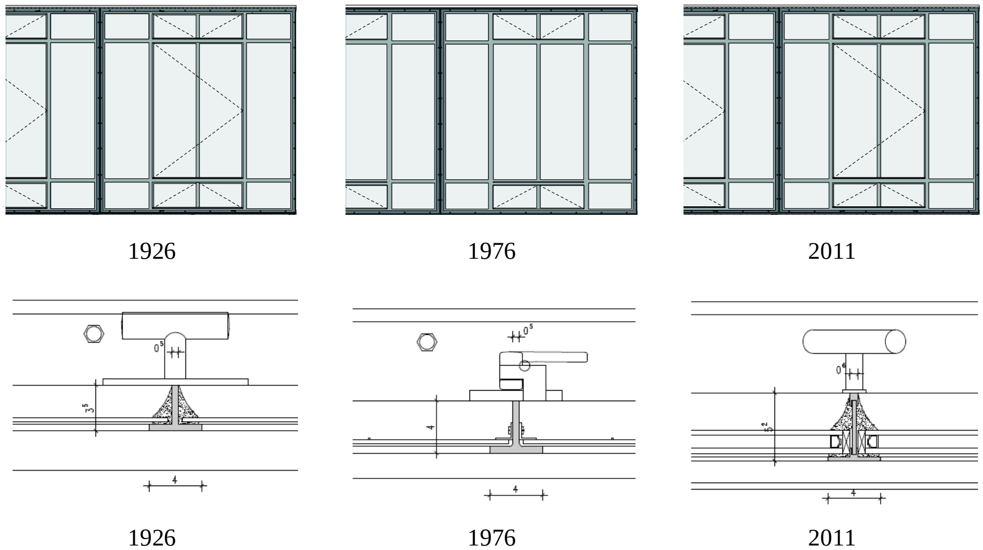

Fig. 2. Historical and modern glazing of the north wing, © Winfried Brenne Architects

The north wing shows continuous strip windows that were put in front of the façade. It was used as a commercial vocational school. The atelier building includes a perforated façade to the east and the west of the building. All window constructions of the Bauhaus building originally consisted of hot-rolled steel profiles with single glazing. Currently, the old windows are still present in some areas only. The window elements of the strip windows and the window constructions of the live-in studios have the same appearance as the original windows, but the shape of the profiles has been simplified. Furthermore, the number of opening casements was reduced and the opening function modified. Figure 2 shows the views and sectional drawings of windows of the north wing from the beginning (1926), after the first refurbishment (1976) and after the current refurbishment (2011). The most important change between 1926 and 2011 is the modification of the single glazing into insulated glazing while restoring the opening functions which were changed in 1976.

2.2. Variety of solutions

To determine the areas with the highest energy losses, more than one energetic concept has been developed. After the implementation of a selection process, the company TRANSSOLAR Energietechnik GmbH from Stuttgart worked out a comprehensive energetic concept in 2011. The aim was the analysis of heating and cooling systems, utilization of the buildings, behaviour of the users, power consumption and options for power generation instead of a major intervention in the construction. In this way, it was possible to show various potentials in saving and optimizing the energy consumption. Because of the high amount of glazing, the designers expected the highest saving potential in these fields. Therefore, the glazing was divided into three categories – preserve, examine, change.

In a first step, the designers wanted to change the windows which were declared as changeable to insulating glass. After a few steps of simulation, they noticed that this method would be very inefficient. Due to the high amount of leakages and no thermal break of the steel profiles, the designers expected only a small benefit. Therefore, an energetic improvement and a technical approval of the steel profiles were necessary. In further investigations, it became clear that the original windows consisted of crystal plate glass. This glazing has a high transparency and creates – depending upon lighting conditions and viewing direction – laminar reflections. Since this glass is no longer produced today, it is important to find a suitable replacement.

Because of the status as an architectural monument, the solid areas of the façade and the original substructure of the strip windows in the north wing of the north façade cannot be refurbished with regards to energetic properties. This would require building physics studies for critical areas.

2.3. Practical implementation

Because of the status as an architectural monument, the Bauhaus building in Dessau allows only minimal structural modifications. To use the energetic advantages of new insulation, a thermal break of the steel profiles was required. Very soon it became clear that profiles with a sufficiently fine sash and frame were not available on the market. In cooperation with the company MHB from the Netherlands, a suitable thermally broken profile had been developed. Based on the existing product SL30-ISO®, designers found a solution which enabled an energetic optimization as well as the reflection of the original shape. In order to receive a technical approval, the Technische Universität Dresden carried out several examinations in its testing facilities. As a result, the product CLASSIC-ISO® was developed [10]. It consists of hot-rolled flat steel with laser-welded U-profiles and a thermally broken bar of fiber reinforced plastic. The width of the bars and their location for the thermal break are variable. The variability allows the development of different profiles with different specifications, based on one system. The CLASSIC-ISO® system allows sightlines of 30 mm for frames and 51 mm for the sash. Depending on the glazing, the whole window element can reach a U_W-value of 1.2 W/(m²K). Figure 3 shows drawings of the original profiles and of a prototype of a profile which has been tested in the testing facilities of the Technische Universität Dresden.

The sealing of the stationary glass elements is fastened by puttying. In the area of the sash, three integrated strip seals guarantee the sealing. Visible drainage does not exist.

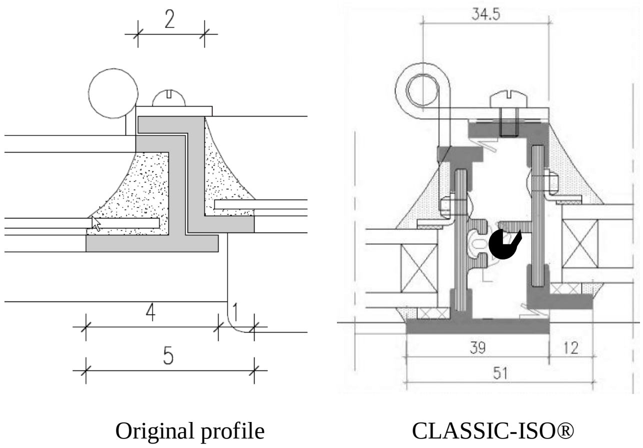

Fig. 3. Original and new steel profiles, © Winfried Brenne Architects

Another issue was choosing a new glass for the windows. It should reach the same high level of quality in flatness and reflective characteristics as the original crystal plate glass. Modern insulating glass often includes coating systems based on metal oxides to improve the energetic properties. After several tests with different glasses from different manufacturers in test façades, the designers realized that the reflective behaviour of the original glass could not be reached with the different coating systems. Therefore, neither a thermal insulation coating nor a solar control coating could be used. As there are no external shading devices in the original state, the latter would have been the only possibility to improve the protection against summer overheating, as a measure of climate adaptation. Consequently, two-piece laminated insulating glass units made of uncoated white glass reduced in iron oxide with a krypton-filled gap were used. In contrast to insulating glass with coating, which has a U-value of U_g = 1.1 W/(m²K) to 1.6 W/(m²K), this glass has a considerably higher U_g-value of 2.6 W/(m²K).

Fig. 4. Bauhaus building during renovation, © Winfried Brenne Architects

Areas which are not refurbished because of their status as an architectural monument have to be investigated with a focus on building physics. As a result, the original steel substructure of the strip windows in the north wing was not thermally broken. Therefore, an electrical trace heating in form of heating tapes has been added. These measures could not prevent the condensation of water at reveals and walls during extreme temperature and humidity conditions. So, the users had been introduced to proper ventilation behaviour. In some areas, electronic humidity controls had been installed. These systems emit a signal, which triggers the ventilation. Figure 4 shows the refurbishment of the steel substructure of the strip windows at the north wing.

3. Box-type windows

3.1. Initial state

Box-type windows are common in Europe and have been used since the 19th century. They consist of two independent window frames, which can be operated individually and have separate closing setups. The window frames are usually made of wood, but their wood thicknesses and profiles vary regionally. Approximately 50 million box-type windows are currently installed in Germany. Because of the two glazing units, they reach a U-value of U_w = 2.8 to 3.0 W/(m² K) [11]. The example of restoration measures for an apartment in the residential estate "Siedlung Schillerpark Berlin" demonstrates the handling of box-type windows and their potential. In the considered apartment, the window areas of the balconies consist of two layers of single glazing, which are divided by a 50 cm wide space. This type of glazing is also called "Blumenfenster" (flower window) and has a high priority for the energetic enhancement as well as for the status as a monument.

The Siedlung Schillerpark Berlin, which was built in the 1920s and 1950s by the architects Bruno Taut and Hans Hoffmann, belongs to UNESCO World Cultural Heritage together with five other estates of the "Berliner Moderne". The estate is composed of six construction stages. The first three sections were built between 1924 and 1930, sections four to six in the years between 1954 and 1959. The apartment blocks of the construction stages five and six possess plastered façades and were designed as 2½ - room flats. After World War II, the buildings were built with a high level of transparency. Figure 5 shows the façade to the backyard which is almost completely glazed. On the one hand, the Blumenfenster is a major part of the monument and, on the other hand, it is critical for the energetic performance of the building. The remaining windows are composite windows consisting of two panes.

Fig. 5. Balconies with the Blumenfenster, © Winfried Brenne Architects

3.2. Variety of Solutions

For the development of an energetic concept for the residential estate "Siedlung Schillerpark Berlin", the designers, in cooperation with the Technische Universität Dresden, used both experiences of refurbishments of similar buildings and modern simulation software, like dynamic thermal building simulation software, dynamic hygrothermal component simulations and CFD simulations. Two concepts were investigated.

For concept A, the external pane of the Blumenfenster is replaced by an insulating glass. The single glazing of the inner pane will not be changed. The cantilevering ceilings intersect the new insulation layer. To prevent flanking heat transmission, an additional insulation below and above the ceilings is necessary, which is placed in the space between the two layers of the Blumenfenster. In addition to the insulation of opaque envelope components, the ventilation concept is a major component of the draft. A ventilation system is installed in the bathroom. Due to the incipient vacuum and air vents, air flows through the flower window into the room. The incoming air is preheated by solar radiation in the space in between the two windows and then proceeds into the interior. In combination with all other measures, the simulated reduction of the heating demand was 59 % compared to the initial state.

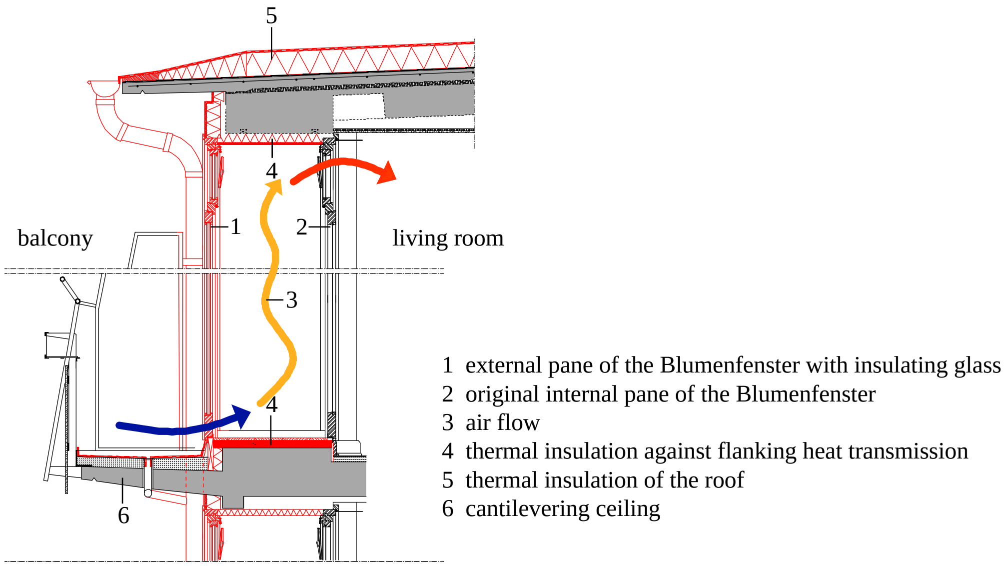

Fig. 6. Design of a flower window with corresponding ventilation scheme, © Winfried Brenne Architects

Concept B is a standard-concept according to the guidelines of the current building regulations (EnEV). In addition to the insulation of opaque envelope components, all windows are replaced by triple glazing. The inner pane of the Blumenfenster is completely removed. This would cause the positive effect of a bigger floor area. To prevent a discomfort caused by cold air downdrafts, the position of the radiators in living rooms and bedrooms has to be changed. This causes a large intervention in the substance of the monument. The ventilation concept is realized as classic window ventilation, which creates a few disadvantages: firstly, uncontrolled air and humidity conditions would be created and, secondly, no positive effects of heat recovery would be gained.

Overall, the amount of energy saved in concept B is nearly the same as in concept A. Figure 7 shows the consumption of heating energy of the building in the initial state as well as the simulated heating loads for the initial state and for concepts A and B. Furthermore, the simulation shows that the thermal bridge grows in result of reducing the inner pane of the Blumenfenster. The refurbishment could reduce the heating load by a factor of more than two and consequently save a large fraction of greenhouse gas emissions.

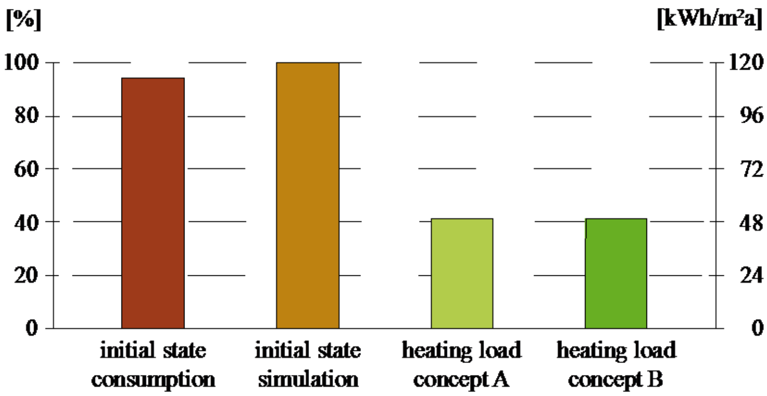

Fig. 7. Consumption of heating energy and heating loads, © Technische Universität Dresden, Institute of Building Construction

3.3. Practical implementation

Simulations showed that concept A is advantageous for the thermal comfort in the rooms. The risk of radiation asymmetry due to differences of temperature of the surfaces decreases. The PMV-value as an index of comfort is in the uncritical range of -0.3 to + 0.3. Based on the results of the simulation and under the aspect of the status as an architectural monument, the designers developed a refurbishment concept. This concept is based on an altered concept A which contains ideas of concept B for special areas.

All opaque areas with insulation receive a mineral plaster, which imitates the original plaster in its visual effect. To preserve the appearance, a variable thickness of insulation around the building was used. Thus, the windows can be placed into the layer of insulation and the original depth of the reveals can be preserved. The façade with the balconies is isolated with high-quality and expensive “Resol” hard foam with a thickness of 8 cm. This minimizes the change of the building geometry. In this area, the ends of the balustrades and the partition walls have to be shortened in the thickness of the insulated composite system. The Blumenfenster remain in their original state. Only the outer pane is replaced by insulated glazing. Figure 8 shows the view of the balconies before and after the refurbishment. The major difference is the color of the parapets, which was changed back to the original color.

Before refurbishment

After refurbishment

Fig 8. Comparison – Blumenfenster before and after energy-oriented renovation, © Winfried Brenne Architects

To realize the ventilation concept, apertures were installed in the frame of the outer pane of the Blumenfenster. Thus, the outside air is heated in the space between the two layers of the Blumenfenster, flows into the room and is removed through the chimney. Using dynamic hygrothermal component simulations, it could be shown that the flanking insulation in the inner space of the flower window is sufficient so as not to fall below the temperature of 12.6 °C, which is critical for mould growth, on the inner surface of the flower window (Fig. 9). Condensation in the cooler areas between the two panes of the flower window is not expected due to the air flow directed through the ventilation system. Only for the event of failure of the ventilation system, recoil valves are provided on the inner pane of the flower window to prevent warm air from the living area from getting into the inner space of the flower window.

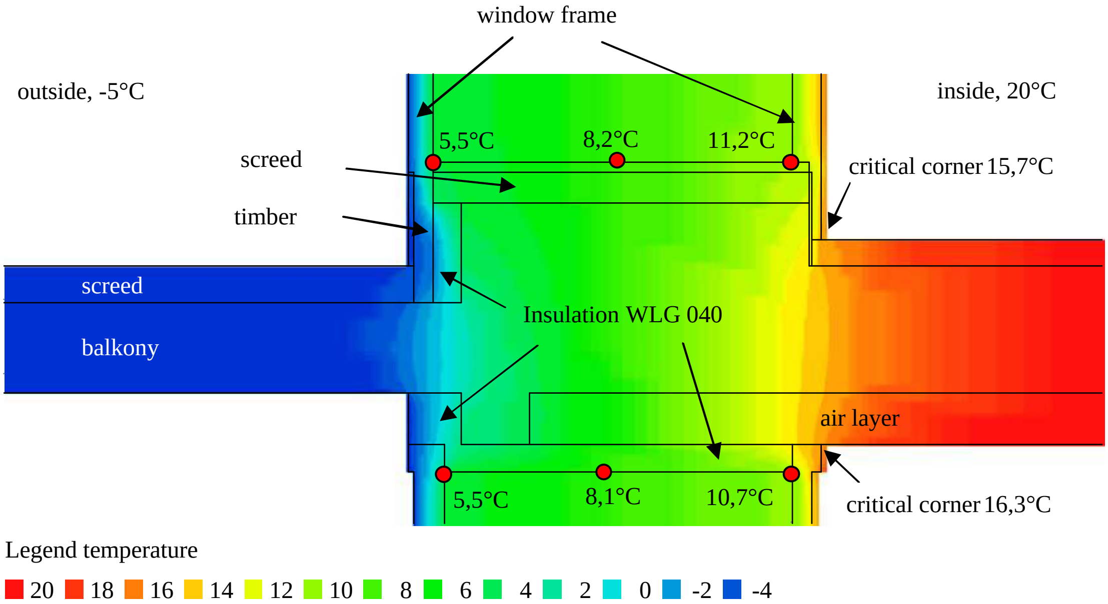

Fig. 9. Simulation of heat distribution in the continuous balcony slab, © Technische Universität Dresden, Institut für Bauklimatik

During the refurbishment of the Siedlung Schillerpark Berlin, one flat was modified to the refurbishment concept under supervision of the Technische Universität Dresden. Especially the ventilation concept was under investigation because it has a great influence on the thermal behaviour of the building. With the help of a blower-door test, the air flow inside the flat was investigated. The emphasis was primarily placed on the inflow in the area of the Blumenfenster. A measurement of the flow velocity confirmed a slow and evenly inflow of the air. The maximum measured air speed was inside the comfort conditions, which protects the users from unpleasant drafts. The measurements confirmed the efficiency of the ventilation system and the simulation results from the Technische Universität Dresden.

4. Conclusions

The two examples considered have shown that a reasonable energetic refurbishment of transparent components in the building envelope should be integrated into a comprehensive renovation concept and should be developed in an integrated design process involving both users and systems engineering. However, it can also be seen that meeting current energy standards is associated with major interventions, which often cannot be fully implemented, especially in the field of listed heritage buildings. In these cases, we recommend an early involvement of the respective historic monuments protection authorities in order to outline the framework for planners and architects and to search for alternative solutions at an early stage.

To conclude, the measures on the steel windows with single glazing in combination with all other measures led to a simulation result of 39 % in energy saving at the north wing and 66 % at the eastern façade of the Bauhaus building Dessau. It is a fact that there are little energy savings in the north wing in contrast to the eastern façade due to uninsulated areas and the electrical trace heating. All participants agreed that an architectural monument with the status of a world cultural heritage cannot be compared to a new building in terms of energy saving. So, the energetic refurbishment will take second seat behind heritage preservation. The designers accepted a glazing with a U-value of U_g = 2.6 W/(m²K). In comparison to the original windows with a U-value of U_W = 5.88 W/(m²K), this still means a huge improvement of the indoor climate and user satisfaction. The presented solution is a good compromise between heritage protection and energy savings, which lead to reduced greenhouse gas emissions and therefore contribute to climate change mitigation. Obtained results and technical solutions during this refurbishment represent a progress in the refurbishment of steel windows for buildings of the International Style.

The refurbishment concept for the apartment in Siedlung Schillerpark Berlin has shown the potential of box-type windows when they are integrated into the ventilation concept. In addition to a notional reduction of the heating demand by 60 %, the risk of air draft could be reduced and thus the thermal comfort was increased. Furthermore, the requirements of heritage protection were met. Subsequent measurements have shown that the ventilation concept is working and contributing to a pleasant room climate.

As part of this interdisciplinary planning team, the institute of building construction was primarily concerned with the constructional implementation of transparent building envelopes. At the Bauhaus building Dessau, this was mainly issuing a technical approval for the thermally broken steel profiles. Regarding Siedlung Schillerpark Berlin, the implementation of the ventilation concept and the inspection of structural damage was coordinated.

In addition to the presented structural measures, the effects of climate change with inconsistent environmental conditions are recommended to be considered for future projects. This may vary depending on the geographic location and the considered building [12].

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Urban farming construction model on the vertical building envelope to support the green buildings development in Sleman, Indonesia

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Abstract

The purpose of this paper is to analyze the construction model of urban farming on vertical building envelopes to support the green building development in Sleman Regency, Special District Yogyakarta Province, Indonesia. The construction of vertical buildings in Sleman district is growing rapidly together with the increasing demand for the provision of housing and public facilities. The rapid physical development in Sleman has caused the reduction of green land such as green open space (RTH), agricultural land and rice fields. These developments potentially threaten food security in Sleman district. Urban farming is a method of agricultural activities to reduce the problems of agricultural land limitation in urban areas, like Sleman district. The construction design model of urban farming on the vertical building envelope is one aspect of green building that will support the efforts in vertical farming processes. This showed that the method did not require any horizontally ground space but effectively used the vertical space on the building envelope, including wall and building roof features and construction. In fact, the urban farming construction method will not only contribute to productive agricultural activities, but also support the greening of the urban area as well as reduce the crisis of agricultural land issues. The urban farming construction model of the vertical building facade includes the urban farming construction on the roof, wall, and balcony.

Peer-review under responsibility of the organizing committee of SCESCM 2016.

Keywords: urban farming, vertical farming, building envelope, Sleman

1. Introduction

Green roofs, walls and facades are turning into common in many cities across the world. The growing numbers of urbanism are realizing the potential of these living systems to increase the quality of their built environment to provide social,

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aesthetic, environmental and economic benefits [1]. The building envelope constitutes all the building elements that separate the indoors from the outdoors. Building envelopes components include the walls, foundations, roof, windows and doors [2].

1.1. Population Growth in Sleman and Increasing Vertical Building Development

The development of Sleman regency is increasing as shown in the increase of its developmental growth later on trigerring the raising quantity of new comers leading to the increase of population growth. In 2008 the quantity of people in Sleman was 31.09%. Until 2010, Yogyakarta's population grew once more to 31,62% population and kept growing in 2013 as noted as 31,76%. The population growth in Sleman was the effect from Yogyakarta province unable to accommodate the population for the increase of economic, social and governmental activities. The increase of population growth in cities every year causes an increasing demand for the needs of residence and facilities, which have to be accommodated [3]. However, as population grown and lands are limited, the land cost is high. Therefore, vertical building is deemed as the most efficient solution for the limited land and the today high land price and it starts to be applied in Sleman.

1.2. Sleman Agriculture Land Use Issues and Food Security Issues

The way to prevent the productive land such as *urban farming* could really be applied because this method is a farming style in city areas, which is identic to the limited land. The rarely productive land for farming does not affect the farming activities in city [4] [5]. Moreover, it can help city urbanization, land crisis and contributes in food problems. Urban farming also holds an important role to improve air quality in the city [1]. The shrinkage of agricultural land occurred due to the effect of growth and uneven population distribution in 2008-2013 [6].

In the period of 2008-2013 the agricultural land in Sleman reduced about 365 Ha. It then brought an effect on the sustainability of regional food. Food production in Sleman during 2010 was 168.158 tons of rice, and then it reduced about 8% from production in 2009 [6]. The phenomenon was caused by the weakness of government regulation that was unable to control the change of agricultural land utilization. The Government of Yogyakarta only could protect land that is appropriate with regulation. It is mentioned that it is only about 35.000 Ha of total productive agricultural land in Yogyakarta that can be protected. Hence, the innovation of development is needed to protect the food security [7].

1.3. Lack of Implementation of Building Vertical Urban Farming

The assembly of vertical greening on the wall and balcony is still limited only in ornamental plant. Fig 1 shows that balcony is equipped of ornamental plant and some walls are just left as an empty space. Meanwhile, the center picture indicates the domination of the wall and minimization of opening does not make any use of vacant land as a growing plant media that can be used to reduce heat and to absorb the air.

Fig. 1. Limited vertical farming and vegetation in most buildings in Yogyakarta

The purpose of this paper is to identify the model of urban farming on the vertical building envelope as a basic of green building design in Sleman. The objective of this study is to analyze the urban farming construction in some building elements including roof and wall. The wall elements cover some parts of wall including wall, balcony/terrace, and window.

2. Urban Farming Construction

The urban farming in the building facade will refer to the green facade approach. A green facade is created by growing climbing plants up and across the facade of a building, either from plants grown in garden beds at its base, or by container planting installed at different levels across the building those are roof and wall elements (see Fig.2) [1].

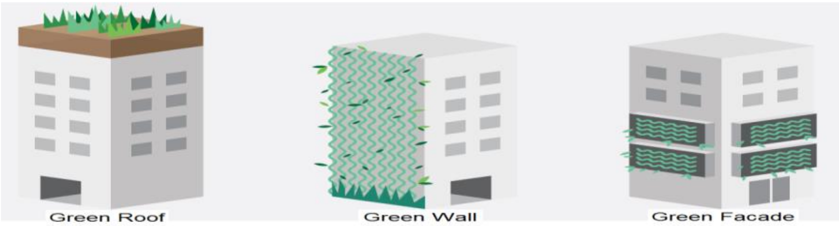
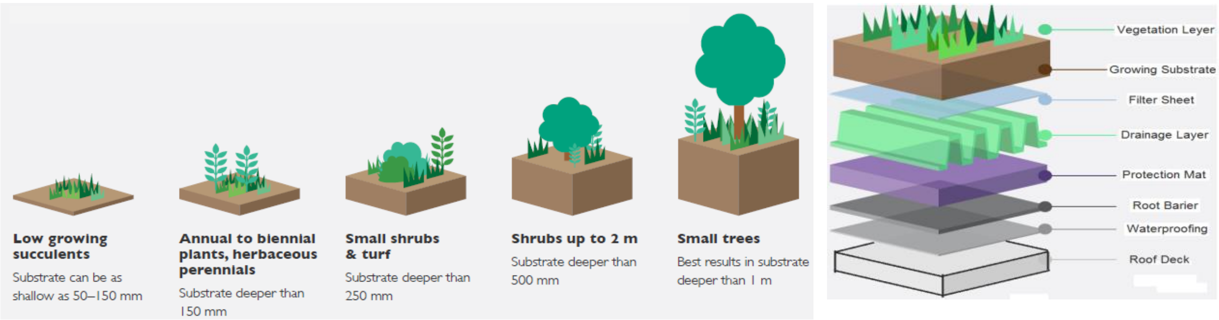


Fig. 2. Schematic model of Green Roof, Green Wall, and Green Facade

2.1. Green Roof Construction

Green roof constitutes a vegetated landscape built up from a series of layers that are installed on a roof surface as ‘loose laid’ or modular installed layer by layer on the roof or as pre-prepared layers in trays. Vegetation on green roofs is established in a growing medium that may range in depth from 50 mm to more than a meter depending upon the weight capacity of the building’s roof and the aims of the design [1][8]. Green roofs are built up as a series of layers, each of which performs a specific function. The most typical build-up is shown in Fig. 3 [1]



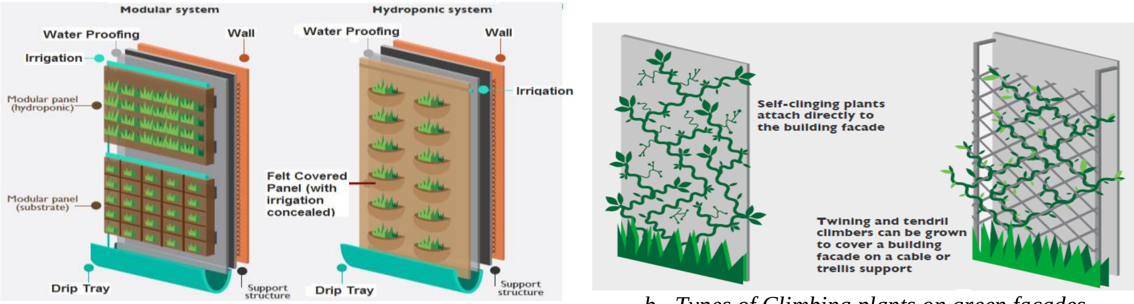
a. The substrate depth on a green roof influences the plant types

b. Layer of Green Roof

Fig 3. Substrate Typology and Green Roof Layers

2.2. Green Wall Construction

A green wall is comprised of plants grown in supported vertical systems that are generally attached to an internal or external wall, although in some cases can be freestanding. Like many green roofs, green walls incorporate vegetation, growing medium, irrigation and drainage into a single system [1]. The construction model and scheme of urban farming can be seen on Fig. 4.



a. Types of green wall configurations *b. Types of Climbing plants on green facades*

Fig. 4 Typology of Green Wall and Green Facades Construction Schemes

2.3. Green Facade Construction

A green facade is created by growing climbing plants up and across the facade of a building, either from plants grown in garden beds at its base or by container planting installed at different levels across the building. Climbing plants can attach directly to the surface of a building, or they can be supported on an independent structure of the building. The use of climbers that anchor themselves to a structure by twining stems or twining tendrils enables a green facade to be installed in front of solid walls or some other structure, to create a partition, privacy screen or sunshade. The degree of density of the facade coverage can be managed to suit the required function [1][8][9]

3. Vertical Urban Farming Case Study and Construction Models

Greenhost Boutique Hotel, located on Jalan Prawirotaman II No. 629, Brontokusuman, Mergangsan, Yogyakarta, Special District of Yogyakarta, is optimistic if the social and environmental changes that occur at this time are also accompanied by the emergence of a passion for innovation and better habits. The increasing number of people living in the city requires people to farm in the city. Climate change and environmental degradation make people choose more wisely production methods and reduce energy consumption. In addition, health problems require people to behave and eat healthy foods. All these principles are applied to each element in Greenhost Boutique Hotel, including rooms and the products used, building design, food, and service [10]. The roof utilization as a plant medium can be applied by various methods, such as pot placing on the flat roof as well as on the slopping roof.

The Greenhost hotel is implementing the urban farming that has been installed in constructional manner on the roof, wall, and facade. In this hotel, the application of urban farming mostly uses the Nutrient Film Technique (NFT) system with a number of perforated pipes, and the nutrient is channeled by using pomp and timer to manage the time enabling it to run automatically [11]. The planting, treatment until harvesting methods are very easy to be done just like the general way of planting However, the green roof of the Greenhost hotel is not only constructed on the flat roof but also tilted or slopping roof. As slopping or tilted roof is mostly used in Sleman and most regions in Indonesia, urban farming on the roof element is better to applicate the urban farming construction for slopping/tilted roof (see Fig. 6). Though the use of tilted roof as a planting medium is less popular in the society nowadays; it can be applied by the following methods. Lettuce is recommended to be planted at a distance of 12.5 cm.

3.1. Green Roof of Urban Farming Construction

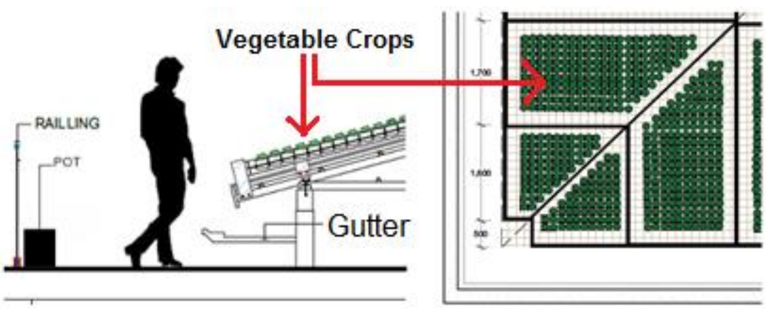


Fig. 6. Urban farming installation construction on the roof.

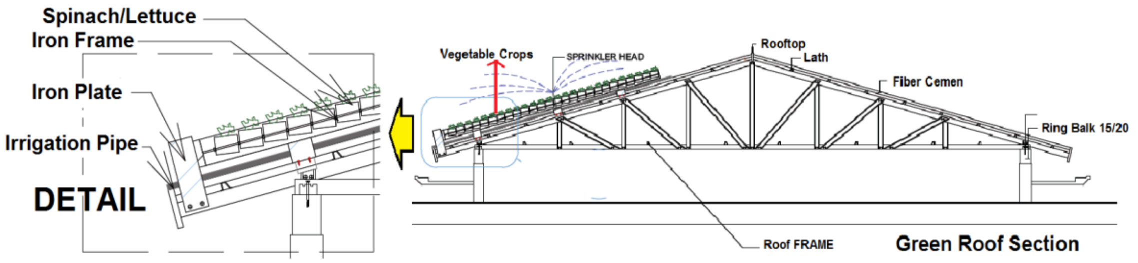


Fig. 7 - Urban farming application and the detail construction

The roof slope is designed to about 15^0 to make the roof save to be stepped onto and make it easy to do planting, vegetation treatment until harvesting. The simple construction uses the frame as a place to put the plant pots on the roof with fiber cement as roof materials. The space giving to the plant is used to give circulation for the plant harvesting as well as plant treatment (See Fig.7). The irrigation system on the roof uses electrically automatic system by applying the sprinkler (Cook, 2015).

3.2. Urban Farming on the Wall and Facade Construction Model

The utilization of plain wall can be used as green wall with a simple construction so that it saves the cost and structure. In Greenhost hotel, the wall is used to put the pot by using the welded iron construction. The use of simple construction such as welded iron can be used as cantilever media of the pot. Here, harvesting and treatment can be done easily. The vegetables planted on the high places can be harvested by using ladder to help. Lettuce and basil in this case are the recommended plants. Moreover, the distance between plants in the construction below can be adjusted to the plant size, which will be used because it is flexible and as needed.

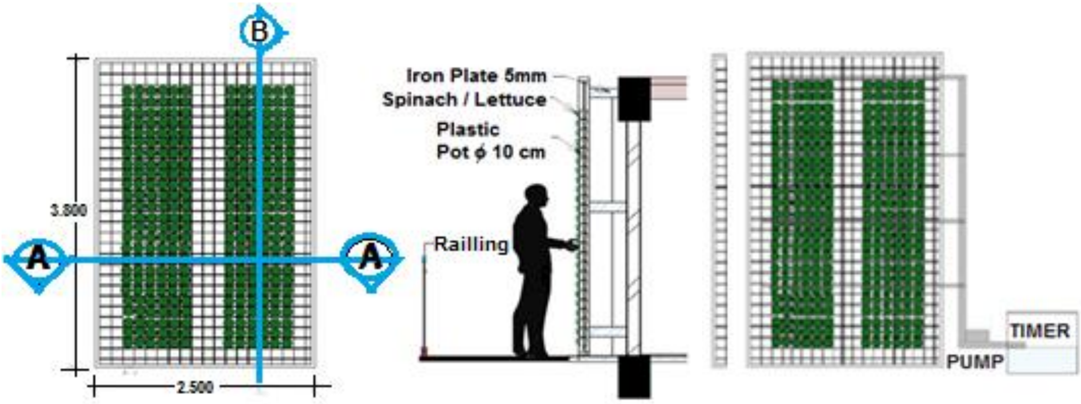
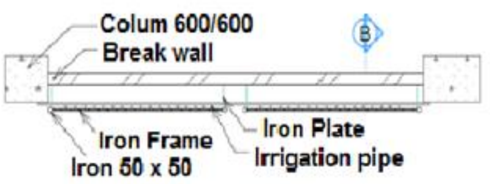


Fig. 8 - Urban Farming Application on the wall: (a) Elevation, (b) Section, and (c) Irrigation system

a. Irrigation system



The irrigation system in the wall uses an automatic watering with timer and pomp. The water is channeled through a pipeline and distributed to every row of the plant. The pot is made of plastic with many small holes to provide a way for water to flow to the rock wool plant media, and to every plant.

Fig. 9 - Urban Farming Application on the Wall Plan

b. Urban Farming on the Balcony

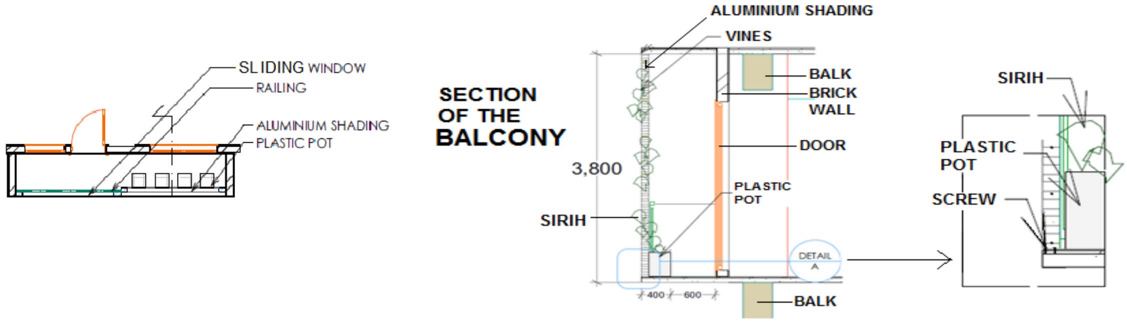


Fig.10 – Balcony Plan and the Balcony Section (a) Section of pot placing on the balcony

The utilization of balcony as a medium for planting as well as for making use of the less productive room is right. Those are the urban farming application on the balcony. Equal to the planting in the roof, planting in the railing uses NFT irrigation model arranged vertically and horizontally. The size can be adjusted with the building length. While the building facades is planted by decorated vegetation that is *lee kwan yew* plant. The other alternative of balcony utilization is giving crawled plants on the shading. The plants can be *srikaya* or other spreading plants.

The harvesting system is very flexible for being located on the balcony and easily to be controlled. Furthermore, the pot is in located lower enabling it to be reached by anyone. The recommended plant is spreading plant like the *srikaya* fruit in which this plant can also be used as sun screen.

4. Conclusion

In Sleman District and Yogyakarta, most buildings are lacking of the implementation of urban farming. The application of urban farming is not limited to the roof or balcony, but it can be done vertically on a wall. The used construction is simple to be applied on building roof, wall, and facade. The model of urban farming are the selected form and materials in accordance to the space provided. More research on urban farming construction models should be conducted not only in university context but also in the government and the agriculture community context. This will encourage more urban agricultures in our cities and regions.

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