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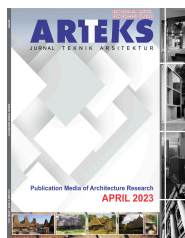
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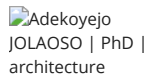


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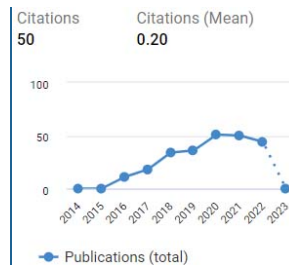
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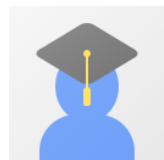


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Mapping of residential double skin façade design

Bramasta Putra Redyantanu 

Department of Architecture, Faculty of Civil Engineering and Planning,
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ARTICLE INFO	ABSTRACT
<p><i>Article history:</i> Received January 10, 2023 Received in revised form Jan. 30, 2023 Accepted February 11, 2023 Available online April 01, 2023</p> <p><i>Keywords:</i> Design strategies Double skin facade Mapping catalogue Residential design</p> <p>Corresponding author: Bramasta Putra Redyantanu Department of Architecture, Faculty of Civil Engineering and Planning, Petra Christian University, Indonesia Email: bramasta@petra.ac.id ORCID: https://orcid.org/0000-0003-0993-1234</p>	<p><i>This paper aims to trace and map the variety of Double Skin Façade (DSF) in residential designs in Indonesia. This response to issues regarding technology development, design strategy, and the role of DSF in buildings related to aesthetic, environmental, and materiality issues in design practice. A qualitative approach with a descriptive observation case study method was conducted on various modern residential architectural designs buildings in Indonesia to illustrate how designers positioned this double skin facade in their design. The connection between the DSF with tectonic, aesthetic, sustainability, and environmental issues is shown in this study. This paper set the study boundaries for exploring residential designs' typology because the limited scale project allowed the designer to have considerable flexibility and exploration of creativity. The residential architectural design also allows the role of the DSF to be integrated with a passive design strategy, compared to commercial or public building design. The findings suggest various strategies and design exploration mapping related to DSF design. The results show that it can form a new character for contemporary Indonesian architecture and become a catalogue of exploratory, strategic, and responsive design elements in its practices.</i></p>

Introduction

This study begins with the phenomena of the various double skin façade (DSF) design in Indonesia. Indonesia's humid tropical climate is one of the primary contexts in facade design. Designing architectural facade as the outer shell of the building, is one of the keys to achieving indoor comfort (Manubawa, Purwanto, and Ardiyanto 2020). DSF design exploration can reflect the design strategy of responsive architectural design.

Passive ventilation and natural lighting are keys to environmental sustainability (Fathia et al. 2020). Using a DSF as a ventilation system also supports better thermal comfort (Ahmed et al. 2016; Yazdi Bahri, Alier Forment, and Sanchez Riera 2021; Yazdizad, Rezaei, and Faizi 2014). The DSF acts as a filter for air and natural light to

circulate better indoors. Material, the opening direction, geometric composition, etc., are the design variables to achieve this comfort. The double-skin façade also has the potential to become a new visual identity that has a responsive impact on building performance.

Along with developing various technologies and materials, architectural DSF design is expanding with multiple techniques. Using a DSF is an alternative to exploring the façade design process (Zanghirella, Perino, and Serra 2011). The principle of using a double façade is to add geometrical instrument and material composition outside the main façade layer (Joe et al. 2014; Jankovic and Goia 2021). The development of materials commonly used in Indonesia, including brick, concrete, wood, and stone, which are natural materials, shifted to practical materials resulting from more varied industrial processing.

Industrial materials, synthetics, and fabrications can also influence DSF design variation.

The built design explorations related to this design element prompted this study to see how far Indonesian architect is developing their design strategy. The hypothesis of this study is suspect that the application of multiple DSF designs can reflect new design approaches that are adaptive, strategic, and responsive to tropical contexts. The mapping aims to see the diversity of tectonics, applications, and implementation of multiple technologies of the DSF that support future architectural design.

Method

This study is a qualitative exploratory study based on case studies (Creswell 2018; Groat and Wang 2013). The research problem of this study is to map the various implementations of DSF, which can be read as responsive and contextual design strategies of Indonesian architects. Design practice can influence the development of knowledge equivalent to research (Verbeke 2013). The case study chosen is the architectural design of contemporary Indonesian residential within the past five years. This limit is determined to be able to see the latest developments in residential architecture, which tends to be a project with limited in scale size. It allows broader design exploration and creativity compared to large-scale commercial, public buildings.

This study tries to deliberate on DSFs mapping concept introduced by Jankovic (2021), reflected in architectural design practice, especially residential design in Indonesia. The study elements and variables of the mapping include ventilation system, geometry pattern, material tectonics, application technicality, and role in design (Mahmoudi and others 2021; Ramadhan, Estika, and Widiastuti 2021; Yazdizad, Rezaei, and Faizi 2014; Jankovic and Goia 2021). The mapping and the description are used to define the possibility of using DSF variation as a design catalogue and developing a particular design approach of architecture.

DSF exploration

The definition of a DSF system is several layers that cover the facade separated by air pores, with a shading system and airflow that can be controlled through the spaces between the facade

skins (Shameri et al. 2011; Boake et al. 2003). By implementing a DSF skin system, the innovation that can be obtained is maximizing the use of passive energy, especially ventilation, which can reduce active cooling loads, to achieve indoor thermal comfort (Zanghirella, Perino, and Serra 2011; Hosseini et al. 2019).

Another function of using this DSF is to create an intermediate space configured to separate the outer and inner areas that were initially directly connected. Its position is that this space can store heat, space cooling, and reduce noise from outside the building or acoustic comfort (Su, Li, and Xue 2017). From this understanding, the functions of multiple skins will tend to vary, and the most basic is thermal comfort and natural lighting. It has been proven quantitatively that the use of double skin is an alternative to achieving standard parameters of thermal comfort in tropical climates as a green building (Dewi et al. 2020).

Regarding the visual aesthetic factor, the use of DSF is used by many architects in Indonesia to explore their design character. From the generations of senior Indonesian architects to a more recent generation, at least once used a DSF in their project. These facts show that the implementation of the DSF technique has expanded, especially by Indonesian architect across generations. Facade design has become one of the most explored design instruments and gives a new character to Indonesian residential architecture nowadays (Misavan and Gultom 2014).

The creation of the DSF should be an inseparable part of the design approach and strategies, which cannot be seen as a partial element, but as an integrated element (Ramadhan, Estika, and Widiastuti 2021). The constituent elements are mostly divided into two categories, namely constructive elements, and surface elements (Dannapfel 2019). Constructive elements are typically composed of structural materials such as iron, aluminum, wood, etc. The surface can be composed of various materials, including bricks, metal plates, composite cement board (GRC), ceramics, bamboo, etc (Utami, Rizki, and Jatara 2015). The hypothesis is that DSF design variation can be a reflection of responsive and strategic design approach.

Result and discussion

This study's mapping will be divided into several categories, derived from the study by Jankovic (2021). The parameters and variables of DSF design strategy includes: Ventilation pattern, Geometric form, Material tectonics, Application technology and Role in design. From the results of this mapping, a matrix and diagram are produced to reflect the development of contextual design strategies related to contemporary residential Indonesian architecture. Another goal is that this study can become a catalogue that can assist designers in developing knowledge related to design (Karimah and Atmodiwirjo 2021).

Ventilation pattern: DSF as natural filter

a. No ventilation

This ventilation pattern places the DSF as forming the geometry of the building, where there is no purpose of ventilation conditioning to the space behind it. This type of design places a DSF as a massive wall covering the reverse area. This work by Gets Architects forms a multi-axis geometry through a double structural façade (figure 1).

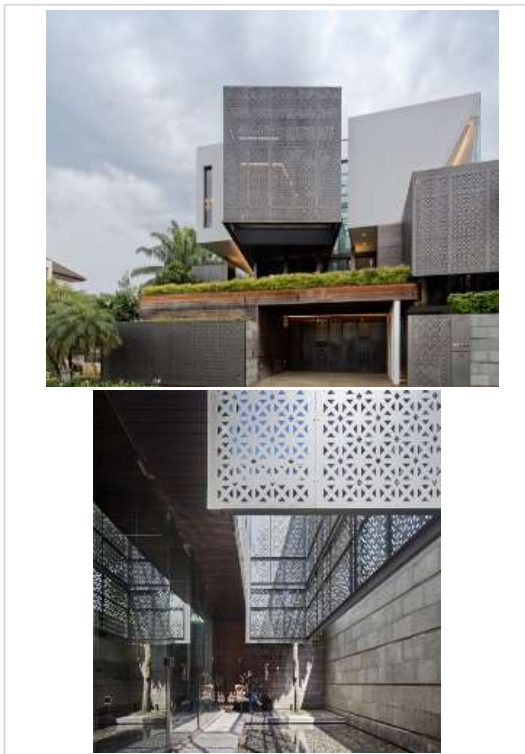


Figure 1. No ventilation secondary façade
Source: <https://www.archdaily.com/966914/>

b. Semi ventilated

This ventilation pattern places a DSF as the outer layer of the window behind it. The purpose of this ventilation is to condition ventilation and privacy so that the window ventilation behind it can be opened freely. This ventilation takes up part of the wall behind it. Elora House's work from Studio Bertiga uses bricks that cover part of the house's front façade (figure 2).



Figure 2. Semi ventilated secondary façade
Source: <https://www.archdaily.com/956863/>

c. Full ventilated

This ventilation pattern places the DSF as the 'primary' skin because there is no longer a wall but a whole opening behind it. So even though it is constructionally manifested as an additional structure outside the primary system, this facade is a single layer. It is commonly used for transitional and semi-public areas (terraces/balconies) in residential areas, such as in the Lumiere House by Studio Avana below (figure 3).



Figure 3. Fully ventilated system facade
Source: <https://www.archdaily.com/941186/>

Geometric shape: DSF as visual creativity

a. Repetition

This configuration is used by repeating the material linearly, both vertically and horizontally, to achieve a DSF facade configuration. An example of this repetition configuration is The Upstairs by Wahana Architects. The vertical repetition of the woods bar and line as the outermost part of the façade (figure 4).



Figure 4. Repetition composition of façade
Source: <https://www.archdaily.com/910498/>

b. Abstract

This configuration is used by abstractly arranging materials as patternless as the DSF layer of the facade. The application of the abstract composition can be seen in the work of HM House by Axial Studio. The roster block configuration is arranged irregularly, enhancing the abstract impression (figure 5).



Figure 5. Abstract pattern based façade
Source: <https://www.archdaily.com/887395>

c. Stacking

This configuration is commonly used by stacking materials such as bricks or rosters to obtain a composition similar to a bearing wall. The cavity created results from dividing the distance between the filler materials. An example of a work with a stacked system is *Rumah 12* by Studio Kita. The material used is concrete blocks which allow air and light to enter the interior of the building freely (figure 6).

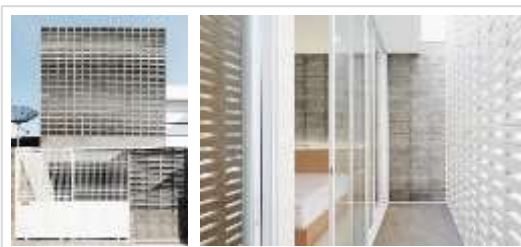


Figure 6. Stacking composition of façade material
Source: <https://www.archdaily.com/925070>

d. Wave

This configuration works like a knit/weave. Webbing seems to emerge from wavy arrangements that bind one another. The work that uses this principle is *Weave House* by Wahana Architects. You can see the woven impression from the outer part of the façade (figure 7).



Figure 7. Weave pattern of façade material
Source: <https://www.archdaily.com/952254>

e. Organic

This configuration works like a parametric system, where the movement of each element is conditioned according to specific parameters. In this case, an example is the work of *Rumah Sutorejo* by Dasquadrat. The rods are arranged with a particular slope to give the impression of moving as a whole (figure 8).



Figure 8. Organic composition on façade
Source: <https://www.arsitag.com/sutorejo-house>

f. Perforated

This configuration utilizes regular holes in the material, which is generally plane. An example of the work is the *HOS House* by MONO STUDIO. This work uses a perforated pattern on the aluminum panel, the primary material. Holes like this can be adjusted to the design of the architect (figure 9).



Figure 9. Perforated pattern and façade form
Source: <https://www.archdaily.com/951495>

Material Tectonics: DSF as craftsmanship

a. Tectonics of transparency

Solid: The material is solid, meaning there is no transparency in it. An open impression is obtained by arranging materials at a certain distance so that holes appear between them. An example of a work with this type of material is Andyrahman's *Omah Boto* which use brick as primary material (figure 10).



Figure 10. Solid tectonics of material
Source: <https://www.archdaily.com/921631>

Transparent: The materials are transparent, where transparency can be at a high level or slightly opaque. The choice of material can be in the form of field material or block material. Various transparent materials include glass, polycarbonate, plastic, and so on. An example of a work using a transparent material, which is a glass block as a DSF, is RAD+ar's Refraction House (figure 11).



Figure 11. Transparent material of façade
Source: <https://www.archdaily.com/921631>

b. Tectonics of material configuration

Panel system: The character of this material is modular and thin. Its use usually needs to be supported by an additional framework as a basis for construction. The choice of this material is diverse, including steel panels, composite cement panels, PVC plastic panels, aluminum panels, etc. Using it as is or perforated with laser cut or CNC techniques is also possible. An example of the work is the 3500 mm house by Ago Architect, with the DSF material being polycarbonate panels (figure 12).



Figure 12. Panel system of façade
Source: <https://www.archdaily.com/921631>

Strip system : Strip or line-based material is generally a material with extended properties, such as iron bamboo wood, which is then arranged horizontally and vertically with a repetition system. An example of a work made of stem material is Parhuis House by Aaksen Studio. The material used is wood with a vertical configuration (figure 13).



Figure 13. Façade system with repetitive strip
Source: <https://www.archdaily.com/959889>

Block system : Block material is a material whose unit is in the form of small units. These units can be arranged in such a way as to obtain a particular configuration. Examples of this material are concrete, bricks, roster, and so on. An example of a block material is SH house by StudioKas (figure 14).



Figure 14. Block system on façade
Source: <https://www.archdaily.com/787057>

c. Tectonics of material source

Natural: The variety of materials sourced from nature includes bamboo, wood, stone, rattan, etc. This material is generally used with minimal processing so that the original shape of the material is still maintained. An example of a work with natural materials as a DSF is Wahana Architect's House in Nursery which utilizes bamboo stems as its material (figure 15).



Figure 15. Natural material (bamboo) of façade
Source: <https://www.archdaily.com/109391>

Industrial : Artificial or industrial materials are all materials that have been processed at the factory. Examples are PVC material, plastic, metal, aluminum, etc. An example of a work with fabricated materials is Ivan Priatman's JJ House which utilizes wire mesh as the outer shell of the building (figure 16).



Figure 16. Natural material (bamboo) of façade
Source: <https://www.archdaily.com/109391>

d. Tectonics of material texture

Material has texture as a visual image as well as forming its character. Based on the surface, second-skin materials such as aluminum, glass, polycarbonate, and so on can be smooth textured. However, the texture can also be rough, such as brick, rooster, adobe, wood, rattan, etc (figure 17 and 18).



Figure 17. Smooth surface on facade texture
Source: <https://www.archdaily.com/940497>



Figure 18. Rough surface on facade texture
Source: <https://www.archdaily.com/965874>

Application and technology: DSF as technological integration

a. Kynetic system

This technology is a mechanical technology that supports the facade to be moved as needed. This movement adjusts the intensity of environmental variables related to indoor comforts, such as the intensity of sunlight, wind, and visual comfort, such as the degree of privacy. An example of a recent work that uses both kinetic facades is Andramatin's Awrawikara House. The opening and closing mechanisms are combined with rattan woven material so that the space behind the facade can be conditioned according to the occupants' needs at certain times and conditions (figure 19).

especially useful in the exterior aspects of the building, while in the interior, beauty can radiate because of the light that falls. It is conditioned by design because the light penetrates through the gaps of the panels of the DSF. The impression varies, can form shadows, strengthen the color in the interior (figure 23).

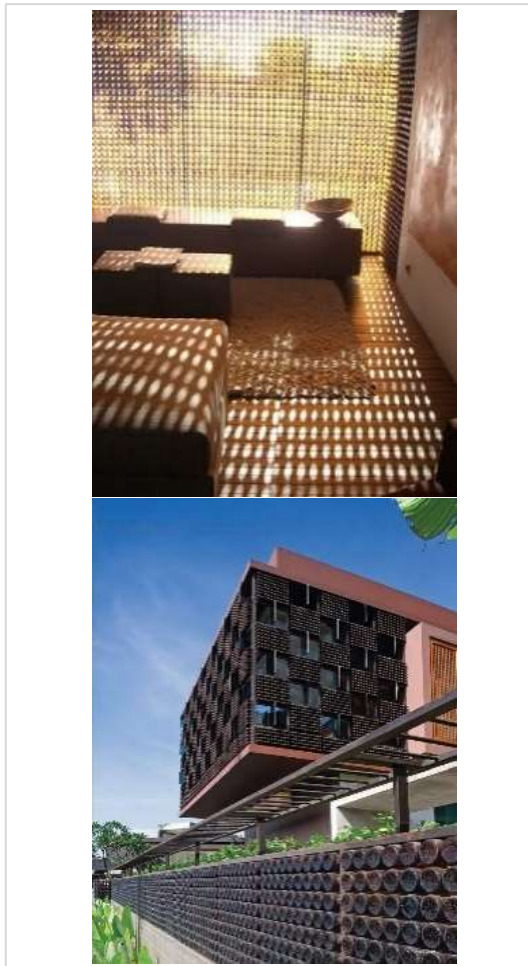


Figure 23. Color and spatial ambience formed by secondary façade
Source: <https://www.archdaily.com/964603>

c. Spatial experience (privacy and identity)

DSFs can also strongly define a building's identity (Viovetta, Santosa, and Iyati 2017). The inner space experience is also formed with the DSF, especially the spaces directly adjacent to the large openings behind the DSF. The area will simultaneously have personal feelings and privacy and remain open with sufficient distance in the DSF. One of the works of the FFFAAARRR, a boarding house in the Haji Baun

area of Lebak Bulus, utilizes bricks to shape the character of the building from the exterior powerfully. The building looks solid with the dominance of brick material, but from the inside, you get a good level of privacy while still considering ventilation and natural lighting (figure 24).



Figure 24. Facade as experience instrument
Source: <https://www.archdaily.com/985237/>

Based on the various explorations of multiple facades in residential architecture above, a categorization diagram can be produced as follows (figure 25):

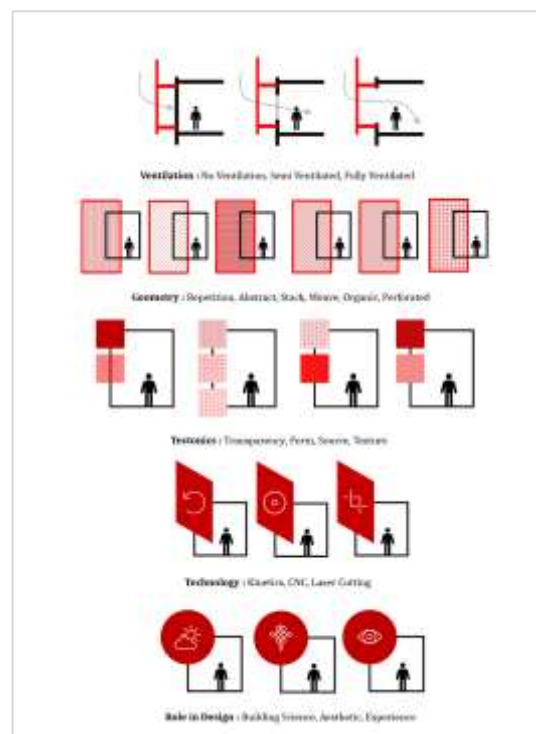


Figure 25. Diagram of categorization catalogue

Based on the possible uses, DSFs in buildings can be mapped with the following possible matrix (figure 26):

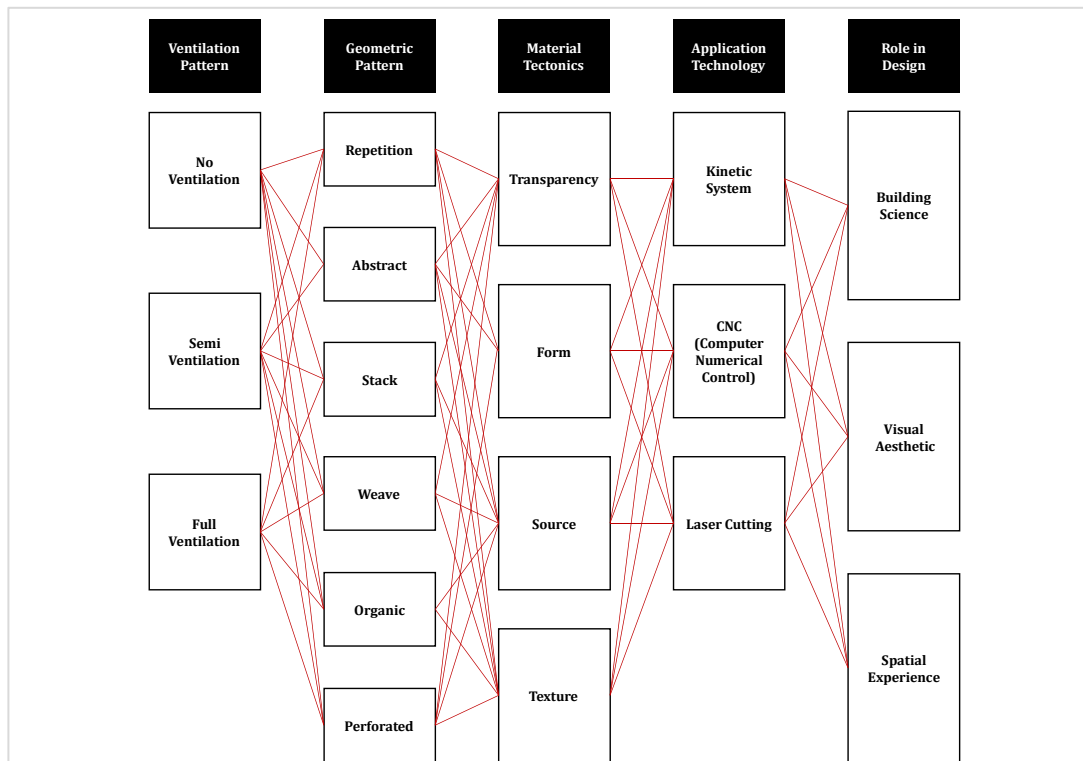


Figure 26. Matrix of DSF design possibility

Conclusion

The use of the DSF has many benefits, both externally (identity, aesthetics) and internally (comfort, environmental science, privacy, etc). The range of materials and configurations applied in design is vast, so the designer can define the characteristics of solving the design problem with the most contextual choices. This study presents the categorization and the possibility of using a variation of DSF. It also demonstrates that it can reflect the designer's thinking in achieving a particular goal in the design process, such as performative and responsive design.

The possibility for the future is that more technologies can be utilized to support the application of this DSF. Using and implementing the DSF in architectural design is considered very contextual to the humid tropical climate conditions because environmental parameters can be adjusted to achieve better spatial comfort. In addition, the discourse on this DSF system has broad dynamic potential due to the development of technology, construction engineering, creativity in design processing, and material tectonic developments.

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