The Characteristics of Secondary Skin Facade of Contemporary House by Indonesian Architects

Try Ramadhan¹, Nita Dwi Estika², Indah Widiastuti²

¹ Department of Architecture Engineering, Universitas Pendidikan Indonesia, Bandung-40154, Indonesia
² School of Architecture, Planning and Policy Development, Institut Teknologi Bandung, Bandung-40132, Indonesia

Corresponding email: tryramadhan@upi.edu

Abstract. In Indonesia, tropical climates force architects to elaborate their residential buildings’ design, especially those that need thermal comfort. As one of the thermal comfort strategies for indoor building, secondary skin technology is analyzed to examine various energy savings advantages. The secondary skin then becomes part of the building’s facade, which should blend into the architectural design itself and not become a separate component, unexplained or encoded, thus degrading the building’s architectural quality. Unfortunately, the study related to secondary skin building mostly only discusses the technical aspects. Therefore, it is necessary to study further the characteristics of the secondary skin in its context as a building facade. This paper will examine the secondary skin technology application in contemporary houses designed by several Andra Matin, Budi Pradono, Yu Sing, and Andy Rahman. This study shows that incorporating the secondary skin was quite varied, and they demonstrate a consistent local character display, advanced technology, and reflecting contextual issues. Each architect has its uniqueness in the design approach in using and exploring materials based on the design issues.

Keywords: Indonesian architect, contemporary house, secondary skin facade

1. Introduction

Historically, facade cladding features can be studied in relation to the development of the building's face and wall design treasures, both as a practical means separating interior and exterior, the architect's desire, and representation of image and identity. The history of modern architecture after the Cold War in the 1950s recognizes the concept of Le Corbusier's Briso-leil, which was first developed in Chandigarh and then spread to become one of the important styles in International Style architecture, especially in the Béton Brut style category. This influence has also arrived in Indonesia through various secondary skin designs of modern architecture, such as in the Bank Indonesia office building by F. Silaban in Jakarta. Robert Venturi's decorated shed also worked on a secondary skin distinctive to represent Postmodern architectural styles in the 1960-70s. The concept of decorated shed coating even leads to an even earlier reference to the Baroque era, namely the Palladian design method. The sequence links that Frank Gehry used in his early Deconstructivist work in the 1970s was also merely a cover for visual distraction. However, while Briso-Leil has a technical dimension to withstand solar radiation, its basic motivation remains aesthetically pleasing. Briso-leil's concepts and techniques become an
aesthetic solution that allows designers to design functional spaces and creative facades of buildings independently.

Nowadays, this facade cladding concept and features are popular with a new term, namely secondary skin (second building envelope). However, different from the previous period, this term has become one of construction and contemporary architecture terms, closely related to the thematic discourse on sustainability, air conditioning, and energy control problems. Secondary skin as part of the DSF (double skin facade) development is a building envelope exploration technology that develops on the idea of an exterior wall that can dynamically respond to various external conditions [1]. DSF is considered one solution to maintaining thermal comfort indoors due to excessive radiation exposure from the sun. The walls, usually one layer, are duplicated inside or outside, creating an air space that functions to circulate air in between [2]. Double skin facade systems have shown positive and negative impacts in their use, based on several studies, including environmental and economic aspects [3][4]. Thus, how about applying the secondary skin technology that has been widely practiced in houses in Indonesia?

1.1. Historical development of secondary skin

The building envelope concept stems from the old tradition of creating thermal supports with removable glass skins. This building envelope concept can adapt to exterior weather conditions, for example, storm windows in Central Europe [5]. In Indonesia, this old tradition can be found in the use of krepyak, a type of window with two shutters of glass and an opening that is grilles. The glass shutter is used to enter the sunlight, and the grilles shutter is used to circulate the air. These systems are probably the predecessors and prototypes of the current double-skin facade systems [5]. The evolution of double skin facades has a close relationship with the rapid development of modern manufacturing technology. The first application of DSF technology integrated into a building was carried out at a factory designed by Richard Steiff in Giengen, Germany, in 1903 using a secondary glass skin to improve building envelopes’ thermal insulation [5], [6].

Modernist architects do many innovations of secondary skin facade. Le Corbusier developed the mur neutralizing or neutralizing wall in 1926-1933, which is an active facade using a glass material that is mechanically formed with air gaps [7]. Several exploratory works of the concepts developed by Le Corbusier got failure and success in their application. Still, this exploration became one of the principles of double skin facades that many architects use today. The discovery of the Trombe wall's passive design was the beginning of a modern double skin system that works with the concept of trapping hot air between the glass and the wall. The air will rise and produce a rotation that allows convection currents to flow (fluid). Cold air from the building is drawn to the bottom of the Trombe wall and back to the top of the building with a significant increase in temperature [8]. This technology is applied to houses built in 1973, covering the house with a wall of oil barrels filled with water that keeps the sun's heat during the day [9]. The wall is isolated from the inner space by a covering wall. Then at night, the exterior covering is closed, and the interior is opened so that the heat stored during the day can enter the room to warm [9].

In 1978, Richard Rogers expressed the importance of the responsive building to external conditions in the future. The key point is the facade's automatic adaptive ability to different weather conditions, called intelligence double-skin façade or adaptive building skin [5][10]. More recent architectural developments with technological and construction advances on double-skin facades influenced facade design evolution. A very interesting example is the kinetic approach that allows the facades to move automatically to optimize protection against radiation. An architecture student named Tyler Short offered this concept through the "Penumbra" concept [11]. This system technology idea provides dynamic and mechanical solutions through a system of devices that rotate independently to optimize sun protection and driven by a computer.

1.2. Building facade design as an identity maker

The building facade is the outermost part of the building that can be seen visually for the first time before entering the room inside. The following are some of the perceptions regarding the facade
according to several discourses. Rodriguez & D’alessandro state that the term ‘building skin’ is an envelope that protects and responds to indoor quality improvements [10]. Krier and Bryans assumed facades as the most important architectural elements for communicating the function and significance of a building [12], also reflects the values of the society that created it [13]. According to Elmoghazy and Affify, the purpose of using building facade patterns can be classified into three categories, which reflect the function of the building, the personality of the occupants, the character of an area, and other things such as socio-cultural factors, religion, art, and science [14]. The interrelationships of form, material, technique, texture in various patterns, and relationship with the environment are very important in designing elements of the facade of a building envelope that convey a message to the users and public that interact with it [15].

Facade as the outer layer of the building becomes the expression of the architect’s view of seeing life and the world. Facades provide an ‘identity’ that can be captured by creating a harmonious composition [12]. Identity becomes the logical base of architects in work, and architects have to craft their identity in their way. Creativity as the identity of the architect is creating and evoking architectural sensibility that the user can perceive. Architects’ work’s uniqueness informs their practical identity and communicates the flair and consistency in work that fosters a better architectural culture. [16]

Identity becomes a crucial architectural target that refers to function and context. These identities are captured from patterns that constitute the most common and reliable means of transfer and cultural expressions most common, such as response to the environment and structural demands. Therefore, the message dimension is considered the most significant and vital dimension in pattern making, the facade pattern [12], [14]. Various parties categorize patterns according to 2D shapes, 3D form, materials, techniques, and textures. This pattern becomes the representation of a symbol of identity that refers to a specific culture. This pattern appears to be a synergy of the facade pattern with the building ecology and plays an environmental role in controlling energy through its outer envelope [14]. How the architect’s identity was expressed through their secondary building facade design?

1.3. Implementation of secondary skin facades in Indonesia

Famous contemporary Indonesian architects such as Andra Matin, Budi Pradono, Yu Sing, and Andy Rahman already use secondary skin in their design work. Various studies have also been conducted on their works regarding the use of a secondary skin facade. Utami discusses the installation and maintenance of the secondary skin of the two ceramic roster houses by architect Andra Matin in the context of tropical areas [17]. Khaira and Nugroho examined the thermal comfort obtained from roster application on the facade of Kos Keputih by Andy Rahman [18]. Jati and Nugroho explored the adaptation of local ornaments or motifs as a secondary skin facade pattern [19] [20]. Moreover, Budiman compared the application of a secondary skin facade between Walter Gropius’ architecture (1925) and contemporary Indonesian architecture, which looks at the differences between the two but questions its originality and reflection on the past repetition [21]. The development of the secondary skin facade studied above is varied, related to originality, performance, or ornament adoption.

Previous studies related to secondary skin facade always discuss technical factors, such as evaluation, performance, and optimization factors [3]. The development of architectural knowledge should make this secondary skin study a functional technical study that integrates with the architectural design itself. Apart from playing a technical role, it seems that this skin’s existence also carries specific architectural messages and meanings in building design related to the architect’s ideas and ideas. The secondary skin should integrate with the architectural ideology of the building itself and not be a separate component. Thus, this research is not only intended to see various application conditions that are being carried out, but it can also be a reflection and raise the design development potential of secondary skin technology in Indonesian residential buildings in the future.

This study was compiled to examine the application of the secondary skin design of contemporary residential buildings by some of these architects concerning design strategies, characteristics, and intended architectural purpose. The four architects’ selection was based on differences in approach and design issues that became each architect’s peculiarities. These architects are also considered to be
sufficiently representative of Indonesia's contemporary architecture situation in the 2000s. This paper tries to expose the characteristics of shapes, materials, techniques, and textures that describe certain patterns on the secondary skin designed. The secondary skin pattern displayed on the building from various subsequent case studies is reviewed based on the intended architectural purposes, including the identity to be raised, the target to be aimed at, and the concept to be highlighted. This study can provide an up-to-date overview of the secondary skin application on the residential building facade designed by contemporary Indonesian architects.

2. Methodology

The approach used in this study is the descriptive qualitative method, by looking at the state of the research object through descriptions, definitions, or explanations of measurable or immeasurable analysis [22]. The data was collected by studying literature, books, magazines, and official websites related to architects and their works. Comparative analysis was also carried out to identify the characteristics of the secondary skins.

This research began by conducting a literature review related to the object studies, theories, and previous researches. In the second stage, each study object is grouped and descriptively deciphered according to the characteristics (form, material, technique, and texture that describe a certain pattern) and according to the building's intended architectural purposes (identity, target, and concept). In the third stage, all the case studies are analyzed comparatively to identify their general application. The fourth or final stage is to interpret theoretical views based on relevant theories and architect's ideas.

3. Discussion

3.1. Andra Matin

Andra Matin's building design is considered to have dynamic visual and spatial characters that build relationships between spatial aspects, land conditions, materials, and lighting in the building design. The architectural characters that usually emerge from Andra Matin's designs are the light expression and architectural formations that create a certain shadow illusion [23]. The exploration of light and shadow highlighting the experience of the space [24], and his interest is manifested by considering the lighting contrast/time tension aspect between day, afternoon, evening, and night [25].

Andra Matin's building designs discussed in this paper are AS Residence (Figure 1), I + L Residence (Figure 2), and MW House (Figure 3), see Table 1. These three buildings raise the issue of their different designs. AS Residence focuses on the private-communal relation issue, I + L Residence focuses on responding to the trees' presence, while the MW House responds to the land contours. These differences make the three buildings distinctly recognizable. Nevertheless, there is the same relationship between the three buildings. All three buildings show the application of a secondary skin, which produces a unique spatial effect. AS Residence produces evenly dim light, I + L Residence has strong and sharp shadow effects, and MW House, which gives a romantic impression. This shows that the secondary skin applied to the three buildings designed by Andra Matin can be recognized by controlling the color of light. The color controlling of the light becomes a visual character, one of Andra Matin's design identities.

The secondary skin design of Andra Matin's work applied varies according to the shape, material, technique, and tectonic explorations of the architect. On the other hand, the similarity of characteristics can be seen through textures and colors, also shown through material use. In I + L Residence, the natural wood's texture, which is rough brown, is used to respond to the context, making it harmonious with the tree's texture and color. Overall, it appears that the processing and embodiment of the secondary skin can enhance context and function with adjustments of shape, material, technique, texture, and color. The processing and embodiment that is carried out indirectly show the capture of the architect's distinctive identity.

| Projects    | Characteristics | Architectural Purposes |
|-------------|-----------------|------------------------|
| AS Residence | Evenly dim light | Private-communal relation issue |
| I + L Residence | Strong and sharp shadow effects | Responding to the trees' presence |
| MW House | Romantic impression | Responding to the land contours |
3.2. Budi Pradono

Budi Pradono focuses on the sustainability and materiality aspects of the building design. Y. B. Mangunwijaya and Kenzo Tange became the figures that inspired him in choosing this approach [29]. Budi Pradono Architect (BPA) founded by Budi Pradono not only on sustainability issues but also on contemporary and urban context that make their work known to be functional and unique [30]. BPA's designs usually use simple geometries and can respond to environmental conditions [31]. Budi Pradono's design works discussed in this study are Pori-Pori House (Figure 4), Clay House (Figure 5), and Issi Villa (Figure 6), see Table 2. Conceptually and characteristically, these three buildings are different by using forms, material, technique, and textures to create excellence.

BPA's most identifiable works' architectural design goals are the functionality of the secondary skin designs realized through form, material, construction, technical, texture, and color, also related to the sensitivity of sustainability theme. The functionality was implemented through the first skin's flexibility as an open-close technique and the façade structure's dominance on the Pori-Pori House. The combination of open-close window glass and shading is effective in maintaining the comfort of space from thermal, visual (light), and noise pollution (audial) as well as other disturbances such as insects and the convenience to maintenance [32]. In another case, there is an adjustment of the secondary skin slide technique in Clay House in response to heat and glare due to the 180-degree view but still flexible.
Issi Villa is the most different from the others because it utilizes GRC material and white (reflective) perforated metal with a dynamic form.

Table 2. Budi Pradono's housing design patterns.

| Projects | Characteristics | Architectural Purposes |
|----------|------------------|------------------------|
| Pori-Pori House, South Jakarta (2007) | • **Form:** The arrangement of the dots on the horizontal dividing line forms slits like "pores".  
• **Material:** Bamboo and steel as secondary skin, while the first skin uses glass.  
• **Technical:** Joining bamboo pieces assembled without nails on a steel frame. The inside glass can be opened and closed. The inner glass can be closed to trap hot air in the center of the skin.  
• **Texture and color:** Combined color of natural bamboo and white on iron. | • **Identity:** Consideration of context and function is manifested in the use of a secondary skin in the form of a window that can be opened and closed (flexible). The flexibility is intended to protect the thermal aspects and prevent insects from entering the building. Besides, maintenance is made easier because almost all parts of the secondary skin are accessible.  
• **Target:** The facade structure technology that is responsive to the climate aspect uses a combination of natural fabric materials.  
• **Concept:** The secondary skin appears to have "pores" that allow the house to breathe. |
| Clay House, Lombok (2015) | • **Form:** Vertical arrangement of the perforated plane.  
• **Material:** Bamboo.  
• **Technical:** The bamboo layer is installed on the track rail to be moved or shifted horizontally.  
• **Texture and color:** Bamboo material covered with white paint. | • **Identity:** A combination of passive and mechanical design as a functional identity.  
• **Targets:** the secondary skin is placed in certain parts of the house in response to sunlight.  
• **Concept:** The building maximizes the 180-degree view, resulting in an area exposed to excessive sun. The secondary skin bamboo becomes the solution to this technical problem. |
| Issi Villa, Seminyak, Bali (2011) | • **Form:** Organic forms such as leaves.  
• **Material:** GRC and perforated metal sheet.  
• **Technical:** Permanently combined in attractive shape.  
• **Textures and colors:** Clean textures and bright colors. | • **Identity:** The function of this secondary skin provides privacy and identity.  
• **Target:** Respond to the sun on the west side and optimize it. The use of bright colors reflects heat well.  
• **Concept:** Creating a dynamic space so that the west side of the envelope will cast a different shadow based on natural light's arrival. The selection of material types is relatively new. |

Reference: author's work

3.3. Yu Sing

Yu Sing is an architect who always strives to apply environmentally friendly concepts by utilizing the local potential and using recycled materials. Yu Sing's attention to the local aspect is manifested through a design process that uses the local architectural elements to transform building compositions [36]. Since 2005, Yu Sing has responded to low-cost housing issues to provide services to the lower class [37]. All at once shows Yu Sing's sensitivity, which is implied not only on environmental issues
but also on environmental issues and humanity. Yu Sing's building designs discussed in this study are Betang House (Figure 7), Puri Cinere House (Figure 8), and Nias House (Figure 9 & 10), see Table 3. Puri Cinere and Nias Houses have similar characteristics; both use vertical bamboo material with simple techniques to be easily replaced. It is closely related to context identity achievement because bamboo material is widely available near the house's location.

It is different from Betang House; the design involved the recycling used wood material with a transformed form of the Akar Betaut pattern typical of the Dayak Kalimantan tribe. The similarity of the three designs is the character assimilation of modernity and locality. This study shows that the secondary skin gives the identity of the context at the residential building scale. The eco-friendly concept is also felt in the secondary skin's design as the distinctive identity of the three works by Yu Sing.

Table 3. Yu Sing's housing design patterns.

| Projects                  | Characteristics                                                                 | Architectural Purposes                                                                 |
|---------------------------|----------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| Rumah Betang, Kalimantan  | Form: Vertical arrangement and adding Akar Betaut pattern.                       | Identity: Context can be felt with an Akar Betaut pattern inspired by the Bornean Dayak  |
|                           | Material: wood.                                                                   | ethnic pattern, which means unity and integrity of humankind. [39]. This pattern is also   |
|                           | Technical: Vertical wood (from the bottom to the top of the building) is arranged | becoming a strong element with the appearance of a shadow effect in space.              |
|                           | tightly enough and connected with horizontal wood attached to the building        | Target: Respond to environmental conditions by using wood materials.                   |
|                           | structure.                                                                        | Concept: The concept's consistency is seen in the bamboo material, made as natural as   |
|                           | Texture and color: Natural blackish-brown wood color.                             | possible according to the building's finishing materials.                              |
| Puri Cinere House, 2010   | Form: The vertical arrangement is tight enough to the second floor's height, and  | Identity: Context considerations are dominant with the use of bamboos, which are        |
|                           | the thickness of the bamboo looks various.                                        | constructed with simple constructions that can be easily replaced for maintenance.      |
|                           | Material: Bamboo.                                                                  | Target: The response to the hot sun and the simplicity of the structure can also be      |
|                           | Technical: Bamboo has been soaked with termite then repellently polished.        | captured.                                                                             |
|                           | Texture and color: Natural bamboo.                                                | Concept: The concept's consistency is seen in the bamboo material, made as natural as   |
| Nias house                | Form: Vertical and horizontal arrangements that are tightly gapped.               | possible according to the building's finishing materials.                              |
|                           | Material: Wood and bamboo.                                                        |                                                                                       |
|                           | Technical: Horizontal wooden planks on the facade. The secondary skin bamboos     |                                                                                       |
|                           | cover some parts of the building mass. The building's center has bamboo material, |                                                                                       |
|                           | which is used as the secondary skin after glass material.                         |                                                                                       |
|                           | Texture and color: Natural bamboo and wood.                                       |                                                                                       |
|                           | Identity: The context of bamboo planting, which technically can replace bamboo    |                                                                                       |
|                           | material, is rotten due to the outside environment.                               |                                                                                       |
|                           | Target: Environmental response with the use of bamboo material and climate        |                                                                                       |
|                           | response on the facade.                                                           |                                                                                       |
|                           | Concept: The building mass, covered by a secondary skin, is located between      |                                                                                       |
|                           | other masses and plays a divider or transition area.                              |                                                                                       |

Reference: author's work
3.4. Andy Rahman

Andy Rahman's architectural works bring back local elements through perceptions and materiality in the design and construction process. Collaboration between craftsmen and architects can realize a strong element of materiality in building design [42]. The local aspects are also applied to the interior building designed [43]. If we look further, the depth process of design and development ideas chosen by Andy Rahman is part of his awareness of the social condition, environment, natural resources, and the history and meaning of Indonesian identity.

Andy Rahman’s designs that are discussed in this study are Rumah Berongga (Figure 11), Folding House (Figure 12), and Omah Boto (Figure 13), see Table 4. The purpose and architectural characteristics of these three buildings are different. Rumah Berongga responds to air circulation issues, Folding House responds to privacy areas, while Omah Boto deals with elements of craftsmanship. This difference brings an impact on the characteristics of the building facade. The most prominent thing is the application of the open-close technique to the Folding House and the response of the facade structure to Omah Boto. This study shows that the secondary skin can be applied based on different architectural goals. The secondary skin is used to keep thermal comfort and is also used as a visual response (private). In the newest case, craftsmanship becomes the mainstay of the concept of secondary skin exploration in Indonesia's buildings (see figure 13).

Table 4. Andy Rahman's housing design patterns.

| Projects             | Characteristics                                                                 | Architectural Purposes                                      |
|----------------------|--------------------------------------------------------------------------------|-------------------------------------------------------------|
| Rumah Berongga, Surabaya (2014) | ● **Form:** Random pattern of wind cavities.                                         | ● **Identity:** There is a transformation from traditional architecture that creates a balanced composition. Functionally, there are rosters on the side of the building, so they have good air circulation. |
|                      | ● **Material:** Roster concrete, called krawangan.                                    |                                                            |
|                      | ● **Technical:** Roster and openings dominate the four sides of the house's walls because the house has 80 cm wide from the other house. |                                                            |
|                      | ● **Texture and color:** Natural concrete roster.                                      |                                                            |
|                      | ![Figure 11. Rumah Berongga](source: www.andyrahmanarchitect.com)                    |                                                            |
| Folding House, Sidoarjo (2012) | ● **Form:** Vertical arrangement divided by segmented horizontal frames.            | ● **Identity:** This technology displays a different facade when it is open or closed. |
|                      | ● **Material:** Wood.                                                                | ● **Target:** Environmental targets related to sunshine were not found to be a major consideration. |
|                      | ● **Technical:** The wooden lattice is attached to the frame to be opened and closed by a folding system. | ● **Concept:** The combination of passive and mechanical design becomes a concept to answer the less exposed problems, especially on the balcony. The uniqueness of the facades of residential buildings can be shown. |
|                      | ● **Texture and color:** Natural wood.                                               |                                                            |
| ![Figure 12. The facade of Folding House](source: www.andyrahmanarchitect.com) | ![Figure 12. The facade of Folding House](source: www.andyrahmanarchitect.com) |                                                            |
Omah Boto, Sidoarjo (2018)

● **Form:** Arrangement of bricks with gaps and massive breaks throughout the facade surface.
● **Material:** Brick.
● **Technical:** The bricks are made to form a hollow pattern connected by vertical iron frames on almost all parts of the facade.
● **Texture and color:** Natural brick.

● **Identity:** Context can be captured from brick material on the facade and iconic to the surrounding environment.
● **Target:** In addition to environmental targets related to climate response, an explored structural response from steel reinforce technology for brick was also explored.
● **Concept:** In this building, the elements of craftsmanship, ideas, and facade exploration are very dominant in the construction process.

Reference: author's work

The characteristics of the secondary skin of 12 residential case studies designed by the four architects are further organized into Table 5 to trace variations in the use of forms, materials, techniques, textures, and colors. The discussion is divided based on these four characteristics (see Table 5).

### Table 5. Comparison of the design characteristics of the secondary skin technology in 12 case studies.

| Architects  | Project           | Form                                                                 | Material              | Technique                                      | Texture and Color                      |
|-------------|-------------------|----------------------------------------------------------------------|-----------------------|------------------------------------------------|----------------------------------------|
| Andra Matin | US Residence      | Composition of rest with a small gap and envelops the entire building| Roster concrete (experimental) | The composition made seen like floating above the ground | Natural rough, dark ash                |
| I + L Residence | Vertical gaps in the horizontal plane | Wood | Arranged along the corridor of one of the building masses | Natural wood, rough brown aligned with the trees in the |
| MW House area | Arrangement of stack motifs perforated around one building mass | concrete | Roster covering ramp and first glass skin | Natural concrete, Dark gray, contrast |
| Budi Pradono | Pori-Pori House   | Bamboo arrangement with perforated breaks in the dominant horizontal dividing line of all facades | bamboo on the steel frame | Combining bamboo pieces assembled on a steel frame. Glass inside can be opened. | Natural bamboo on white iron          |
| Clay House | Vertical patterned with holes in the break | bamboo | There is a track rail that allows the bamboo to be shifted horizontally | Clean, soft, bright color (white) |                                      |
| Issi Villa | Organic such as slit leaves | GRC and perforated metal sheet | Created in an attractive form | Clean, soft, bright color (white). |                                      |
| Yu Sing | Rumah Betang | Vertical with slits and root pattern. | Re-used | Vertical wood connected to horizontal wood attached to the building structure | Natural wood, dark brown |
1. **Forms.** The forms used in secondary skin are generally a combination of vertical, horizontal, regular, and random stacks. The form exploration is related to the selected material. The special form of the secondary skin is found in Issi Villa's work (Budi Pradono), which applies an organic form, and the Betang House (Yu Sing), which transforms the *akar betaut* pattern.

2. **Materials.** Materials commonly used in the secondary skin include a concrete roster, wood, and bamboo. Meanwhile, the experimental material used was the brick at Omah Boto (Andy Rahman). Materials that tend to be new and different from other buildings are used in Issi Villa (Budi Pradono) with the combination of GRC material and perforated metal sheets.

3. **Techniques.** The most widely secondary skin technique used is arrangement and stacking. Mechanical techniques have also begun to be applied, such as the Clay House (Budi Pradono) sliding system and the folding system at the Folding House (Andy Rahman). The response of the facade structure caused by secondary skin dominance also influences the technique. This can be seen in the AS Residence (Andra Matin), which seems to float, the Pori-Pori House (Budi Pradono), which uses a steel frame, and Omah Boto (Andy Rahman), which adds reinforcement with vertical iron. Other techniques relate to pre-construction, such as bamboo processing in Yu Sing's building design.

4. **Texture and color.** All of the case studies show that natural texture and color are dominant for the secondary skin. Natural textures and colors also reinforce concept and context.

Based on the study, the technology that was applied does not advance by using adaptive automation. It may also relate to the effectiveness of technology on cost efficiency for site residential buildings. Although the performance of these technologies' application should be examined further, it can be seen from the 12 case studies by four architects that they provide solutions that tend to be a reiteration. The secondary skin's intended architectural purposes in the 12 residential case studies designed by these four architects are further tabulated into Table 6 to trace the similarities and differences. The discussion is then divided based on these three goals (see Table 6).
Table 6. Comparison of the architectural purpose of the secondary skin on the 12-case study.

| Architect       | Project          | Identity                      | Target                                      | Conceptual                                                                 |
|-----------------|------------------|-------------------------------|---------------------------------------------|-----------------------------------------------------------------------------|
| Andra Matin     | AS Residence     | Context and function          | Environmental and structure                 | Creating a private, intimate, and simple geometric. Dip light.              |
|                 | I + L Residence  | Context                       | Environmental                               | Linkages tightly between land, buildings, and shading effects.              |
|                 | MW House         | Function                      | Environmental                               | The romantic impression of light and shadow.                                |
| Budi Pradono    | Pori-Pori House  | Context and function          | Environmental and structure                 | "Pores” that allow the house to breathe.                                    |
|                 | Clay House       | Function                      | Environmental                               | The secondary skin becomes heat response due to maximizing the 180-degree view. |
|                 | Issi Villa       | Function                      | Environmental                               | Creating a dynamic space to produce different shadows every time, as well as material innovation. |
| Yu Sing         | Rumah Betang     | Context                       | Environmental                               | Representing the transformation of traditional architectural concepts.       |
|                 | Rumah Puri Cinere| Context                       | Environmental                               | The consistency of the natural concept in material finishing.              |
|                 | Rumah Nias       | Context                       | Environmental                               | Traditional Nias houses as well as being a divider or transition area of the two main masses. |
| Andy Rahman     | Rumah Berongga   | Context and function          | Environmental                               | Hollow is inspired by village architecture and maintains privacy.          |
|                 | Folding House    | Function                      | Environmental is not the main consideration | Combined passive and mechanical design as a solution to privacy constraints. |
|                 | Omah Boto        | Context                       | Environmental and structure                 | Craftsmanship                                                              |

Reference: author's work

Table 5 and Table 6 capture interesting findings, especially on the material and color, identity, and target relatively repetitive to each architect. The secondary skin's main target is related to environmental responses, but apart from that, the structural response has already begun to be applied in several case studies. This structural response usually arises from the predominance of the secondary skin facade applied to the design. Table 6 presents the architects' degree of identity-based on the calculation of Context (C) and Function (F).

Budi Pradono's identity (C:1 and F: 3) strongly elaborate the design's functional aspect to achieve the futuristic goal of sustainability. The dominance of white material color shows the contrast but still maintains harmony with the surroundings. Andra Matin and Andry Rahman's identity (C:2 and F:2) show the combination of contextual and functional aspects. Andra Matin's focus is to create the ambiance and atmosphere of space by using the dark grey material color to highlight the space formed by light creation. This color selection is a special feature of Andra Matin's works as the inner will of the architect to create his identity, while the use of natural colors is more intended to respond to the context of the
site. The texture and color of Andy Rahman's work present as the application of elaboration of material creation's craftsmanship. Yu Sing’s identity (C:3) relates to the context applied by less intervention of the material used, but try to appreciate and accommodate the material characteristics. The natural color of the material is maintained, and this action as the understanding of establishment the building is to keep the soul with surroundings.

The secondary skin facade implies the identity of the architect to the building, besides providing thermal comfort. Each architect has their uniqueness in using and exploring materials based on the design issues raised in each design. On the other hand, apart from the technical aspects, the secondary skin has also become a medium for architects' exploration, creating a spatial atmosphere through daylighting. This is in line with Jahya [48], who has revealed that the application of facades continues to experience innovation in both form and function and the existence of this secondary skin.

Based on the case studies reviewed, the application of this secondary skin technology does not appear to have experienced a significant development when compared to the literature review conducted regarding the recent technology that has been developed. The secondary skin exploration that began to occur was only in several aspects, such as the controller's technical aspects, the knitting methodology's methodological aspects, the structural, technical aspects, and the technical maintenance aspects. The exploration of the secondary skin technology seems inseparable from the exploration of the facade. Secondary skin application is a little more emphasis on the facade elements. Therefore, beautifying the secondary skin as part of the facade element is certainly important. Technology and construction need to be considered because they are the second most important parameter of the ten parameters of implementing green architecture or the existing concept of sustainability [49][50]. Therefore, the sustainability approach is closely related to technological exploration and construction. The secondary skin technology on building facades to achieve sustainability and the medium of conveying messages shows that this technology is a strategic entity in architectural design. An understanding of sustainability that is faced with the increasing diversity of human needs to be answered with the development of the technology [51].

4. Conclusion

World architecture, including Indonesia, recognizes the concept of facade cladding, which has evolved historically. Baroque and Postmodern architecture treats the facade cladding as a play of visual communication. Modern architecture and International Style treats the facade cladding as an embodiment of art as well as a glare response. Modern architecture and International Style treats the facade cladding as an embodiment of art as well as a glare remover. In the 2000s, this trend emerged as a new popular term - secondary skin, as Indonesian architects practiced.

The use of a secondary skin, which is part of the facade with various characteristics, also gives a new identity to the housing. In this case, the secondary skin provides thermal comfort and can give a specific identity in the architectural work. This study shows that the secondary skin can strengthen context and function by adjusting the form, material, technique, texture, and color. On the other hand, the secondary skin indirectly gives a picture of the architect's unique identity. It can be seen from Andra Matin's work, which gives an identity of modernity, materiality, and the play of light effects. Yu Sing's work provides an assimilation identity that is balanced between nature, modernity, and locality. Likewise, Budi Pradono and Andy Rahman's works provide an identity that is almost the same as exploring more innovative technological ideas but still reflects on locality.

The secondary skin can be applied based on different intended architectural purposes. For example, it is used as a visual response (private) and not just a thermal problem. The secondary skin can also touch the sensitivity of technology that is usually raised to achieve sustainability. The place's identity through the philosophical concept of pattern transformation has also begun to be raised by the secondary skin even though it is on the scale of a residential building. In newer buildings, craftsmanship becomes one of the potentials developed to the secondary skin application in Indonesia.

Various housing designs from well-known Indonesian architects who apply the secondary skin technology show the various characteristics applied. The form that tends to be different is found in Issi
Villa's work (Budi Pradono), which applies an organic form, and the Betang House (Yu Sing), which transforms the akar betaup pattern. The existence of experimental materials used such as bricks in Omah Boto (Andy Rahman). Materials that tend to be new and different from other buildings are used at Issi Villa (Budi Pradono), a combination of GRC material and perforated metal sheets. Mechanical techniques have also begun to be applied, such as the Clay House (Budi Pradono) sliding system and the folding system at the Folding House (Andy Rahman). The response of the facade structure caused by secondary skin dominance also influences the technique. This can be seen in AS Residence (Andra Matin), which seems to be floating, Pori-Pori House (Budi Pradono), which uses a steel frame, and Omah Boto (Andy Rahman), which adds reinforcement with vertical iron. Other techniques relate to pre-construction, such as bamboo processing as in Yu Sing's work. Of all the case studies, natural texture and color is the dominant choice for the secondary skin. Natural textures and colors also reinforce concept and context.

The use of the secondary skin technology in the housing being studied is indeed quite varied. Still, it can be seen from the 12 case studies from four architects that they provide solutions that tend to do the repetition, respectively. Many innovations can still be extracted from the locality, material, and form, and idea abstraction. Besides, there are still many technological innovations that can be developed. There are still very few secondary skins that used mechanical and kinetic technology, especially facades integrated with new technologies.

This paper's study represents a definition of contemporary Indonesian residential architecture that displays elements of contextuality, locality, and appropriate technology. Previous theoretical studies explained that contemporary architecture should be able to develop from the idea that architecture should be able to achieve goals and solutions for tomorrow's and today's architecture, so the characteristics studied should answer these goals. This study is an initial observation related to several case studies in Indonesia. Further studies are expected to be deeper, with a larger number of cases.

References

[1] T. M. Boake, K. Harrison, D. Collins, A. Chatham, and R. Lee, "Understanding the Principles of the Double Façade System Terri Meyer Boake BES B.Arch M," no. November, pp. 1–18, 2003.
[2] Belgian Building Research Institute, Ventilated double façades – Classification and illustration of façade concepts. Department of Building Physics, Indoor Climate and Building Services, 2004.
[3] A. Ghaffarianhoseini et al., "Exploring the advantages and challenges of double-skin façades (DSFs)," Renew. Sustain. Energy Rev., vol. 60, pp. 1052–1065, 2016.
[4] T. İNAN and T. BASARAN, "A General Evaluation on Double Skin Facades," Megaron, vol. 9, no. 2, pp. 132–142, 2014.
[5] C. Liu, X. Chen, and Y. Wei, "Evolution : the Development of Intelligent Double-skin Facades," vol. 78, pp. 1546–1549, 2011.
[6] O. Kalyanova, "Double-Skin Facade: Modelling and Experimental Investigations of Thermal Performance," Aalborg University, 2008.
[7] C. Balas-Ramirez, J. J. Sendra, R. Suárez, E. D. Fernandez-Nieto, and G. Narbona-Reina, “The mure neutralisant as an active thermal system: Saint Gobain tests (1931) versus CFD simulation (2015),” Le Corbusier, 50 Years Later Int. Congr., no. 1931, pp. 708–722, 2015.
[8] C. Struck et al., "Adaptive facade systems – review of performance requirements, design approaches, use cases and market needs," in Conference Proceedings of the 10th ENERGY FORUM, 2015, no. October, pp. 1254–1264.
[9] U. Knaack, K. Tillmann, M. Bilow, and T. Auer, Façades Principles of Construction. Germany: Birkhäuser Verlag AG, 2007.
[10] C. M. Rodriguez and M. D'alessandro, "Climate and Context Adaptive Building Skins for Tropical Climates: a review centred on the context of Colombia," Conf. Adv. Build. Ski.
Bressanone, Italy, no. October 2014, 2014.

[11] J. A. Ibrahim and H. Z. Alibaba, "Kinetic Facade as a Tool for Energy Efficiency," *Int. J. Eng. Res. Rev.*, vol. 7, no. 4, pp. 1–7, 2019.

[12] Rob Krier, *Elements of Architecture*, Academy Ed. London: Architectural Design, 1983.

[13] T. Bryans, "Holding On to Our Principles. Why Manifestoes Matter," in *The Identity of The Architect: Culture & Communication*, L. Iloniemi, Ed. Architectural Design, 2019, pp. 116–121.

[14] Z. A. A. E. G. Elmoghazy and H. M. N. Afify, "Patterns: The crime that has become the haven in architectural practice," *Ain Shams Eng. J.*, vol. 11, no. 3, pp. 823–838, 2020.

[15] I. Ritchie, "The Public Role of the Architect. Architecture is the Medium – What is the Message?," in *The Identity of The Architect: Culture & Communication*, L. Iloniemi, Ed. Architectural Design, 2019, pp. 122–127.

[16] L. Iloniemi, *The Identity of The Architect: Culture & Communication*, no. 262. Architectural Design, 2019.

[17] M. N. U. R. Utami, K. Rizki, and S. Jatara, "Sistem Pemasangan Dan Pemeliharaan Selubung Kulit Bangunan Keramik Pada Daerah Tropis," vol. 3, no. 1, pp. 1–10, 2015.

[18] N. Khaira and A. M. Nugroho, "Pengaruh Desain Roster terhadap Kenyamanan Termal Bangunan ( Studi Kasus Kos Keputih Andy Rahman )," *J. Univ. BRAWIJAYA*, vol. 7, p. 2, 2019.

[19] R. M. B. Jati, J. Thojib, and C. B. Amiuza, “Secondary Skin Motif Batik Jawa Timur pada Hotel di Surabaya,” *J. Univ. Brawijaya*, vol. 3, no. 1, 2015.

[20] M. S. P. Nugroho, "Seni Ornamen Nusantara Sebagai Secondary Skin Bagi Sun Control Pada Bangunan,” in *Simposium Nasional RAPI XI FT UMS*, 2012, pp. 1–4.

[21] B. Budiman, “Perbandingan fasade kulit kedua antara arsitektur Walter Gropius dan arsitektur Indonesia masa kini,” Universitas Indonesia, 2006.

[22] J. W. Creswell, *Research Design: Qualitative, Quantitative, and Mixed Methods Approached*, 2nd ed. California: Sage Publications, Inc., 2003.

[23] I. Akmal, "Karakteristik Visual Arsitektur Dan Desain Interior Karya Andra Matin," Institut Seni Indonesia Yogyakarta, 2016.

[24] C. Kelly, "Working with Architects From Process to Identity," in *The Identity of The Architect: Culture & Communication*, L. Iloniemi, Ed. Architectural Design, 2019, pp. 64–67.

[25] A. Matin, "AS Residence," www.andramatin.com, 2013. [Online]. Available: https://www.andramatin.com/project/as-residence/.

[26] I. Akmal, *Archinesia 10: City, People and Architecture*. IMAJIbooks, 2016.

[27] I. Akmal, *Archinesia 07: The Architecture of South East Asia*. IMAJIbooks, 2015.

[28] A. N. Saputra and A. S. Ekomadyo, "Analisis Teori Desain Starchitect melalui Pendekatan Creativity Channels," in *TEMU ILMIAH IPLBI 2017*, 2017, p. 87.

[29] A. S. Asih, “Penerapan Konstruksi Bambu dan Arsitektur Berkelanjutan pada Bangunan Dancing Mountain House Karya Arsitek Budi Pradono,” in *SIAR 2020 : Seminar Ilmiah Arsitektur*, 2020, vol. 8686, pp. 421–429.

[30] I. Dwijayanti and S. Maulana, “Strategi Desain Bangunan Green Architecture oleh Arsitek Budi Pradono,” in *Prosidig Seminar Nasional Energi Efficient for Sustainable Living*, 2017, pp. 63–74.

[31] T. Ramadhan, H. Wibowo, R. R. Sukardi, and D. A. Hertoety, "Implementation of Green Architecture Concept in Mosque Design : A Face A nd Islamic Da' wah," vol. 1, no. 1, pp. 23–33, 2019.

[32] Budi Pradono Architects, “pori pori house,” www.budipradono.com. [Online]. Available: https://budipradono.com/pori-pori-house.

[33] FURNIZING EDITOR, “Clay House: Rumah yang Terbangun di Area Perbukitan Lombok dengan Desain Unik Ala Budi Pradono,” www.furnizing.com, 2019. [Online]. Available: http://furnizing.com/article/clay-house-karya-budi-pradono-di-lombok--2.

[34] Budi Pradono Architects, “issi villa,” www.budipradono.com. [Online]. Available: 
[36] S. Winarni and Hamka, “Penerapan Unsur Arsitektur Nusantara pada Karya Desain Arsitek Yu-Sing,” *PAWON J. Arsit.*, vol. 01, no. 01, pp. 25–34, 2019.

[37] V. Indrawati, “Evaluasi Konsep Perencanaan Rumah Tradisi Lokal dan Masa Kini dalam Sistem Penilaian Greenship,” Pontianak, 2015.

[38] Y. Sing, “reinterpretasi rumah betang,” *http://rumah-yusing.blogspot.com/*, 2011. [Online]. Available: http://rumah-yusing.blogspot.com/2011/06/reinterpretasi-rumah-betang.html.

[39] P. Paluphi, "Profil Arsitek Yu Sing," 2017. [Online]. Available: https://docuri.com/download/profil-arsitek-yu-sing_59c1dc56f581710b2868962e_pdf.

[40] Y. Sing, "rumah puri cinere," *http://rumah-yusing.blogspot.com/*, 2010. [Online]. Available: http://rumah-yusing.blogspot.com/2010/08/rumah-puri-cinere.html.

[41] Y. Sing, "reintepretasi rumah nias," *rumah-yusing.blogspot.com*, 2011. [Online]. Available: http://rumah-yusing.blogspot.com/2011/06/reintepretasi-rumah-nias.html.

[42] R. D. Pangestu, N. K. Adelia, S. S. Az-Zahra, and A. S. Ekomadyo, “Andy Rahman: Menggali Esensi Arsitektur Nusantara dan Ketukangan dalam Berkarya,” in *Temu Ilmiah Ikatan Peneliti Lingkungan Binaan Indonesia (IPLBI)* 7, 2019, pp. B106–B112.

[43] A. R. Wijaya, Y. Kusumarini, and F. P. Suprobo, “Manifestasi Nusantara Mengkini pada Konsep Karya Interior Arsitektur Andy Rahman (Studi Kasus: Omah Boto),” *J. Intra*, vol. 7, no. 2, pp. 1–9, 2019.

[44] A. Rahman, “Rumah Berongga,” *www.andyrahmanarchitect.com*, 2011. [Online]. Available: http://www.andyrahmanarchitect.com/projects/?idpro=11&nf=Residential&pageload=detpro.

[45] A. Rahman, "Folding House," *www.andyrahmanarchitect.com*, 2012. [Online]. Available: http://www.andyrahmanarchitect.com/projects/?pageload=detpro&idpro=23&nf=Residential.

[46] A. Rahman, "Tes Lampu," *www.instagram.com/andyrahman/*, 2018. [Online]. Available: https://www.instagram.com/p/Bq4S15aFlGq/.

[47] A. Rahman, "In this project (Omah Boto)...," *www.instagram.com/andyrahman/*, 2018. [Online]. Available: https://www.instagram.com/p/BiQk3MCD4It/.

[48] A. Jahya, “Fasade Bangunan, Tinjauan Aspek Keselamatan Bangunan,” Jakarta, 2017.

[49] T. Ramadhan, D. Larasati, L. Widaningsih, and H. E. Kusuma, "Parameter of Green Concept Implementation in Residential Building: A Community Perspective," *KnE Soc. Sci.*, vol. 3, no. 21, pp. 847–861, 2019.

[50] T. Ramadhan, “Pemahaman Masyarakat Mengenai Dampak Pembangunan Hunian Terkait Global Warming dan Penerapan Green Building,” in *Prosiding Temu Ilmiah IPLBI 2017*, 2017, no. 8, p. G 035–42.

[51] N. D. Estika, Y. Kusuma, D. R. Prameswari, and I. Sudradjat, "The hedonistic sustainability concept in the works of Bjarke Ingels," *ARTEKS J. Tek. Arsit.*, vol. 5, no. 3, pp. 339–346, 2020.