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# The Articulation of the High-Rise Residential Building Envelope: A Review from the Perspective of the Sustainability Concept

Tantarto Sugiman[1], Uras Siahaan[2,] Rumiati Rosaline Tobing[3]
[1]*Doctoral Candidate in Architecture at Parahyangan Catholic University, Indonesia*
[2]*Professors in Architecture at Indonesia Christian University (UKI)*
[3]*Doctor in Architecture at Parahyangan Catholic University*

***ABSTRACT :*** *The high-rise residential building emerges as a solution to overcome the problem of the housing needs in big cities. Its presence should also be taken into consideration from the perspective of sustainability concepts. Taking into account the life cycle of a building in the context of buildings as a product of the current architectural system is a wise consideration and recommended as the environment quality keeps on declining. This study discusses the correlation between the articulations of the high-rise building envelope with the approach of the life cycle of buildings as part of sustainable design thinking. The assessment has been made through the approach of library research as a stepping stone to attain understanding. The benefit obtained from this study will support the creation of high-rise residential buildings which in terms of life cycle is supporting the environmental quality provided it is assessed from the building envelope aspect.*

***Keywords -*** *articulation of form, building envelope, high-rise residential building, sustainable design thinking, building life cycle*

## I. INTRODUCTION

This paper describes the correlation between the articulations of the building envelope in high-rise residential buildings with the approach of building life-cycle concept as part of sustainable design thinking. The concept of sustainable development is a paradigm of thinking, that should be applied in a building, from the initial process until its completion. The phenomenon of high-rise residential buildings is inevitable due to the urgent need for housing, especially if it is related to its accessibility environmental capacity. Problems emerged when the articulations of the building form appear so similar without taking into account its environmental context (or its local content). The concept of sustainability itself is quite a complex issue involving many scientific disciplines, requiring the involvement of various parties or large scientific disciplines: environmental-social-economic ones. This paper attempts to juxtapose the concept of sustainability in an architectural approach that is more supportive of environmental problem.

Rapid population growth in Indonesia requires housing provision. On the other hand, there is land limitation, particularly in areas close to the workplace and the city center. In addition, the land is narrower and becomes more expensive. This condition results in the high price of property and makes it harder for the middle to lower strata of society to purchase houses that are close in terms of location.

Jakarta as a metropolite possesses a strong attraction for people to reside. No wonder that its population has grown rapidly. This certainly causes various problems such as the inefficient use of land, increase of slums, less organized housing areas and increase in water and air pollution. The increase in population has resulted in the increase of the need for appropriate housing with a strategic location, even though land availability is limited. Under these conditions, land will became more expensive and even unaffordable for the middle and lower classes that make up 65% of the urban population [1]. To respond to this problem, especially for the middle to lower strata, the government has launched 'Construction of 1000 privately owned and simple Apartments' or better known as 'Rusunami'[2]. The construction of high-rise residential buildings that leads to high rise building is inevitable for today's development. Its presence will be needed as an answer to the urgent need of housing. With the launching of 1000 towers based on Law No. 20 of 2011, Jakarta will certainly be followed by other major cities in Indonesia and be filled with housing towers in the future. Living in high-rise residential buildings will become a pattern of living for the major city population.

People used to experience difficulty in living in high-rise residential buildings for a number of reasons, but now, because of easy access to the city center, high-rise residential buildings have become a necessity inextricably linked with the urban population. High-rise residential buildings used to be limited to 4-5 floors, but now it has increased considerably, some building reaching over 50 floors.

## II. MATERIAL AND METHODS

The search for building envelope articulation begins with the establishment of parts of the building envelope. A building envelope covers all components forming the building shell or skin. This component separates the exterior and interior of a building. The building envelope should be designed well since it is related to climate, ventilation, and energy consumption inside the building. If the terminology 'façade' refers more to the site, then the building envelope refers more to the three dimensional shape since it is related to volume and performance.

The envelope consists of all building exterior components, including the wall, the roof, the foundation (base), the window, and the door [3,4]. If the façade takes into consideration decorative and ornamental aspects, the concept of building envelope does not include it in the envelope element. These envelope elements form a barrier separating the interior and exterior of a building. Figure 1 shows the variety of building envelopes.

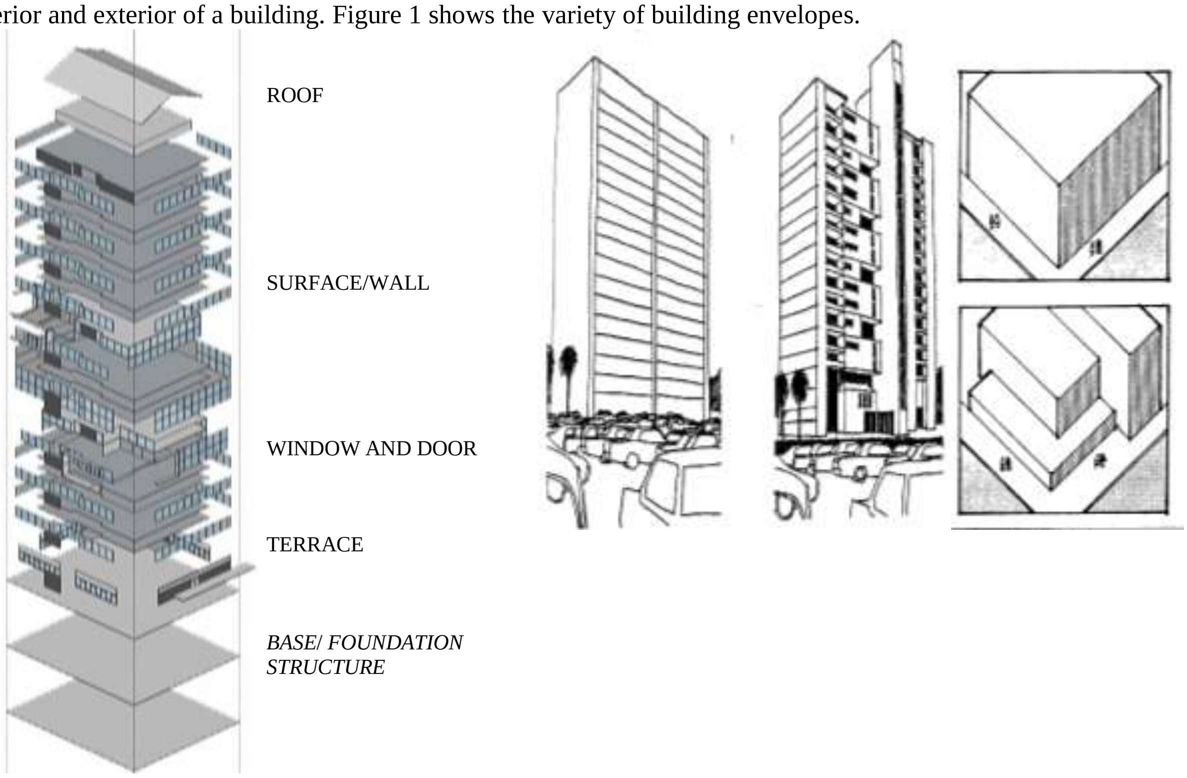



**Figure 1**. Part of Building Envelope and Its Variations
Source: *ririndina.files.wordpress.com. retrieved in November 2013*

The building envelope is influenced by the following factors [5]: 1) site, block, or superblock dimension; 2) street dimension; 3) boundary line building; 4) building height category; 5) building orientation; 6) local regulations. The discussion was conducted with the descriptive method based on the literature search for the building envelopes.

## III. DISCUSSION

### 3.1. Importance of the Building Envelope

There are five basic functions of the building envelope [6]: 1) to add structural support, 2) to control moisture and humidity, 3) to regulate temperature, and 4) to control changes in air pressure. The building envelope will also affect the ventilation and the use of energy inside the building, 5) reflection of the function inside the building. The building envelope determines the amount of energy needed to protect the environment inside the room to be comfortable in outdoor conditions. The design consideration of the building envelope [4]: 1) calculation of the capability of air insulation, 2) air-tight system, 3) wall and roof, 4) window, door and skylights, 5) local climate. The role of the building envelope is so significant that it is important to be taken into consideration. A building envelope that is not well articulated is bound to affect the building performance.

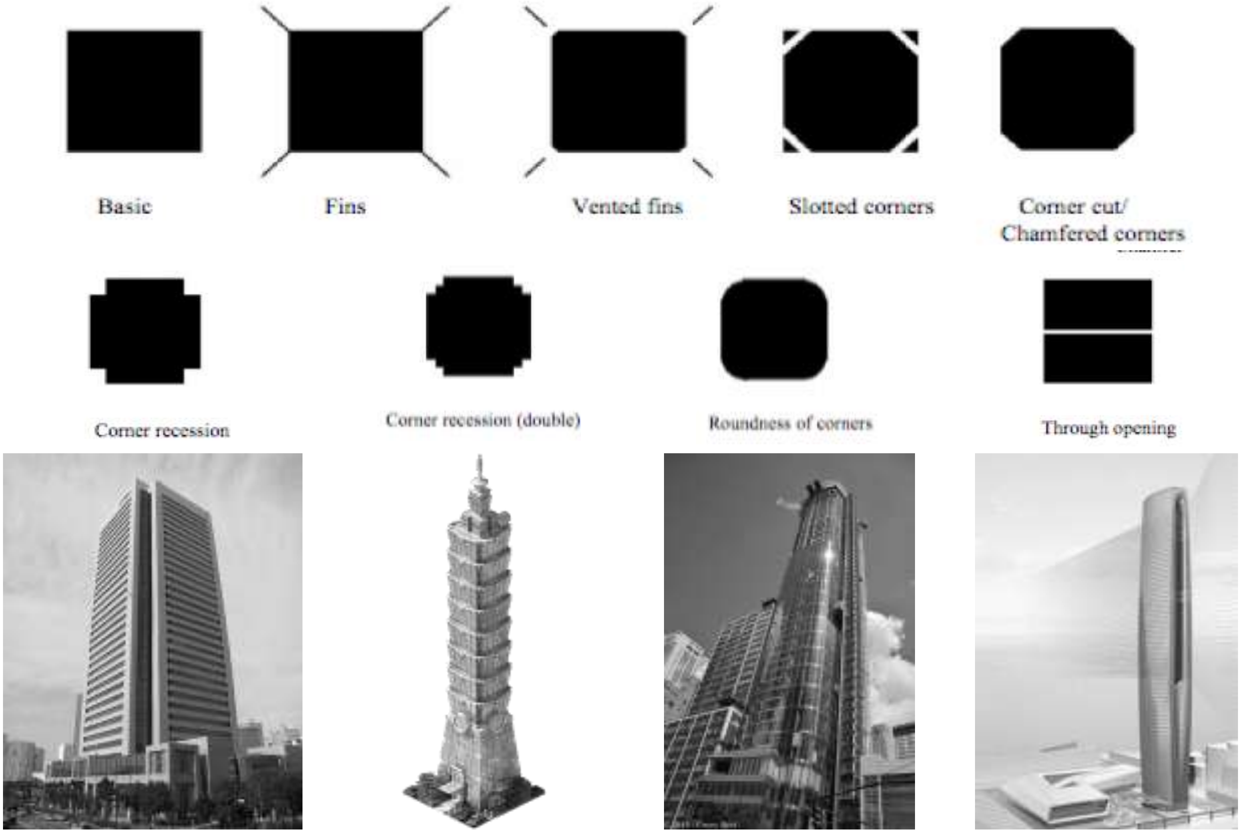
### 3.2. Building Envelope Articulation

Articulation in architecture refers to texture of the form [6]. The form of articulation can be stated as: 1) distinguishing planes with the composition of material, texture, and color, 2) developing angle as a linear element different from the boundary plane, 3) processed angle, and 4) lighting, to give a contrasting impression.

The building envelope articulation is aclarity of the building element in accordance with its function. One way to explain the form of articulation is through [7]: (1) the window, (2) the door opening, (3) the wall, (4) the roof and (5) the sun shading related to the creation of a harmonious unity between drafting, a good proportion, drafting vertical and horizontal structure, material, color and decorative elements.

### 3.3. Application of Building Articulation in High-Rise Building

Articulation in high-rise building architecture can be affected by various considerations [8]: 1) the thickness of building; 2) the level of lighting; 3) the building rigidity, considered through the existence of the core usually seen on the building façade; 4) the aerodynamic modification of building form, such as variation of a gap along the height, or even its measurement, significantly capable of reducing building response to wind pressure and wind direction by changing the wind pattern around the flow. Aerodynamic building modification in high-rise buildings can be classified into two groups: (1) Minor Modification: aerodynamic modification that does not deeply explore structural and architectural concepts. Examples of minor modification: the provision of fins, vented fins, slotted corners, chamfered corners, corner recession, roundness and building orientation that is more oriented toward wind direction with the strongest wind flow; (2) Major modification: aerodynamic modification with great impact on the structure and the concept of architecture. Examples of major modification: setback at every height, tapering effects, opening on top of the building, shape processing on top of the building, processing the entire shape of the building, setback, twisting the building, etc.[9, 10]. Figure 2 shows the layout as a result of aerodynamic modification.




MHI Yokohama Building | Taiwan 101 | 50 West Street, Manhattan | Greenland's Suzhou Center, Wujiang

**Figure 2.** The Shape of Layout and Façade Articulations

Along with technology, the shape of twisted buildings become an interesting approach in the current era, by twisting a building that can reduce the vortex effect from the wind. Twisting the shape of a building can reduce the wind pressure on the building [11]. It is also the most effective way for wind whose direction is difficult to determine (see figure 3a and 3b).

**Figure 3 a**. Twisting Effect on Chicago Spire
Source: Elnimeiri and Gupta. 2008

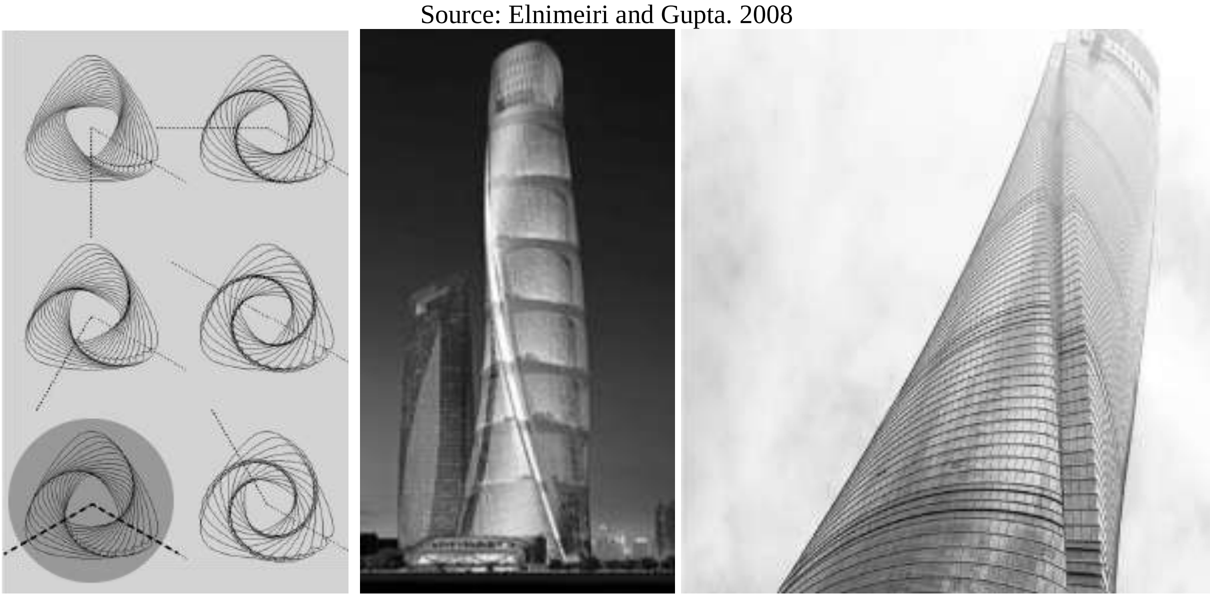


**Figure 3b.** Shanghai Center buildings for wind aerodynamic view
Source: archrecord.construction.com and http://du.gensler.com

In connection with the height effect, building articulation can also be modified as such (see figure 4). This aerodynamic modification was made by constructing the building to be more pointed from the base to the top, like cutting the building based on the received wind pressure with the increasing height of the building [9,10]. Examples of buildings applying tapering are: the Transamerica Pyramid, the Jin Mao Building, the Petronas Tower, the Burj Dubai, the Sears Tower, the Shanghai World Financial Center.

**Figure 4.** Articulation shape of Transamerica Pyramid, Jin Mao Building, Petronas Tower, Burj Dubai, Sears Tower, and Shanghai World Financial Center as an anticipation of building height factor

For the sake of energy use such as solar energy or wind (see figure 5 and 6), the shape of articulation will also have its own character [12] (Figure 7).

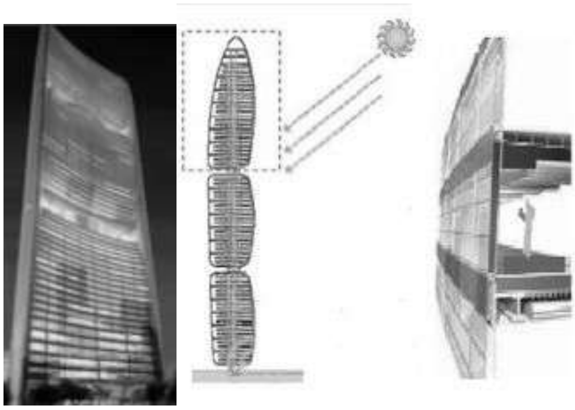


Figure 5. The shape of facade articulation due to solar energy consideration at Pearl River Tower

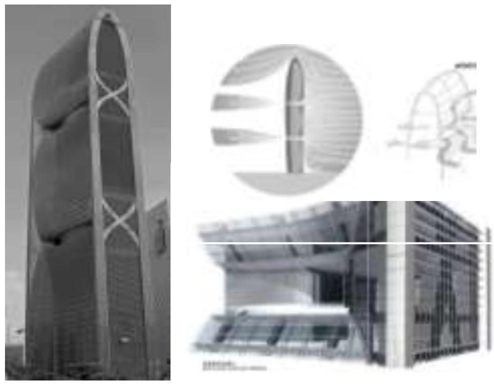


Figure 6. The shape of façade articulation due to wind energy consideration at Pearl River Tower, Guangzhou, China

The shaper of articulation can also be implemented through: the balcony, the canopy or the building detail (figure 7)

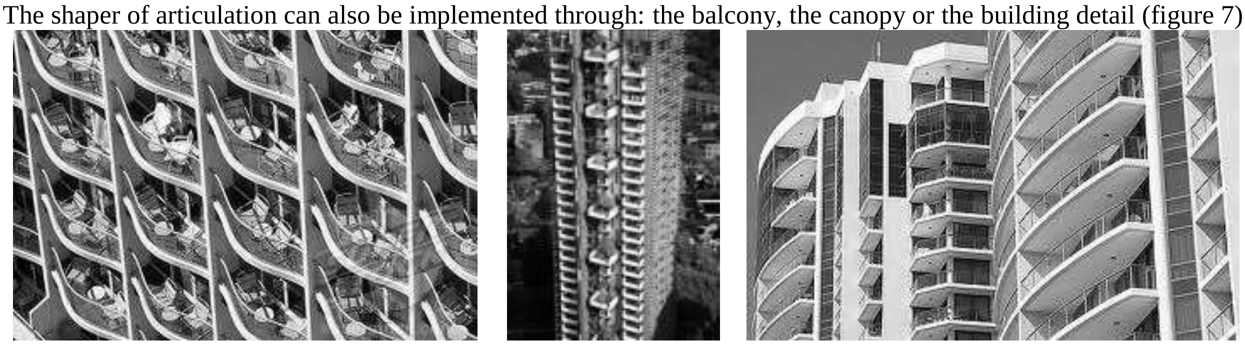


Figure 7. Shape of articulation through: balcony, canopy or building detail
Source: www.telegraph.co.uk

### 3.4. **The Effect of Plants on** the **Building Envelope, moving toward the Concept of Sustainability**

The greening of housing or buildings (multiple-storied) is actually beneficial, something that can be measured quantitatively in the form of financial benefit and qualitatively in the form of benefit from the environmental, social and aesthetic aspects. The effects are among others [13]:

3.4.1. Decrease in Temperature: The roof material of a building is usually made of hard and dark material with a low albedo value (low reflectivity value). Greening can reduce the canopy effect of fog/smoke directly above the city environment by shadowing the área that absorbs heat, and indirectly through evapo-transporational cooling. It also reduces heat as a result of re-radiation. Only around 20% of solar energy falling on the surface of the leaf will be reflected.

3.4.2. Improving Air Quality: A roof with plants is capable of directly improving the air quality by filtering particles flying in the air with leaves and branches. The increase of temperature on the roof surface influences a chemical reaction that causes the low content of ozone in the air, the most important factor in the formation of pollution. Therefore, by maintaining the air temperature to remain low, the greening of roof surface can improve air quality through ozone formation. A roof with a plant system can filter heavy metal and other hazardous substances from rain water, through a natural filtering mechanism that depends on the type of plant and the thickness of soil layer used on the roof with plants.

3.4.3. Improving Rain Water Absorption: One practical way to control the water run-off in urban areas is the use of roofs with plants because of their capability in storing rain water. From the environmental aspect, this has a positive effect such as reducing surface contamination from rain water, reducing soil erosion and improving the lives of plant and other living things (animals). Some exceptions found in the tropical climate can influence water absorption by roofs with plants. First, frequent heavy rain can cause erosion on recently built roofs with plants and the process of soil dissolution will take place faster. Second, the condition of daily temperature in tropical areas causes the high level of evaporation and the formation of biomass that will increase the level of water absorption. This process should be anticipated with a proper design.

3.4.4. Carbon Dioxide Reduction and Increasing the Amount of Oxygen : Plants can absorb carbon dioxide and release oxygen to the air in the photosynthetic process. Therefore, the stability of air composition will also be maintained by plants. Through thisphotosynthetic process, 155m$^2$ of plant area can produce enough oxygen for 1 person for 24 hours. A huge tree can produce enough oxygen for 10 persons per hour. The 'green' roof on high-rise buildings is proven capable of reducing the amount of energy needed for air cooling, and indirectly will reduce carbon dioxide emission from electricity generating machines.
3.4.5 Noise Reduction: Roofs with plants can reduce the noise level up to 50 dB. A soil layer of 12-20 cm can reduce noise level up to 40-46 dB. The soil layer tends to absorb a low frequency, whereas trees absorb a high frequency. The ability of roofs with plants to absorb noise is highly affected by the weight of the soil layer (its substrate and the level of leakage through other roof holes such as skylight, atrium, and others).
3.4.6 Reducing dust and smoke: Air pollution in the urban área can have seriously affect on the health of the citizens. Nitrogen oxide, carbon monoxide, and other hazardous gases can produce hazardous particles in free air. Plants can function to increase the air quality. Every 1 m$^2$ of roof garden can filter 0.2 kg of aerosol dust and smoke particles every year. In addition, nitrate and other hazardous materials in the air and from rain water can be deposited on the plant medium of roof gardens.
3.4.7 Beautifying the face of the city: Visually, roof gardens and vertical gardens can increase the quality of life of the urban citizens. A city that is monotonous with gloomy grey massive buildings can be changed astonishingly with the presence of beautiful roof gardens and vertical gardens adorned with flowers and green shady trees.

**3.5. The Issues of Building Envelope in Indonesia**

The problems of building envelope in Indonesia, particularly for high-rise residential buildings lie in: 1) the shape of articulation that is almost similar from one building to another. This seems to be influenced by economic factors that are still dominant, where developers seek more economical and rapid development solutions in the implementation; 2) Lack of attention paid to the orientation and location that fails to make the face of the building envelope distinguish between solar and wind factors in the location; 3) comfort and security factors which have not been seriously taken into consideration so that they have created discomfort, a high criminality level and occupants' accidents; 4) the face of building envelope that seems similar in the end raises the desire of the occupants to make it different, which will result in a non-aesthetic building face, if the building management is not good.

**3.6. Effort to Understand Building Envelope**

An effort is needed to understand the building envelope if it is viewed from different angles, by consistently emphasizing on the comfort for human beings as the users without damaging nature.

**Development Approach from the Sustainable Design Perspective as a Consideration**

When environmental damage has reached the surface of the earth, sustainable architecture emerged as a new paradigm of thinking that was considered as capable of fixing the environment. Many leading figures have tried to address the issue of sustainability although they often used different terminologies. James Steele (1997) used the term sustainable architecture, Ken Yeang (1994, 1995) coined the phrase ecological architecture and further elaborated on ecological high rise building and Brenda Vale (1991) presented her green architecture [14,15,16,17].
The involvement of architecture and architect was clearly stated by Steel (1997) that it is so important in dealing with sustainable development [14]. Practice in real conditions cannot escape from the problem of modern construction sweeping the world if it is not dealt with wisely, this will lead to environmental damage and waste of resources such as energy, land and other natural resources.
In principle, sustainable architecture will cover both physical and non-physical items, including institutional and financial ones, to maintain the existence of resources in fulfilling all basic needs and developing opportunities for the improvement of economic and social conditions for each generation, now and in the future [18,19].
Sustainable architecture is a consequence of the international commitment to sustainable development, since architecture is closely related to and focuses its attention on human factors by emphasizing the main pillar of the sustainable development concept which is the built environment with its environmental development, as well as economic and social developments.
As a product, sustainable architecture has a process ranging from the planning stage, design, construction to demolition. On the other hand, as a system, sustainable architecture should have a thinking pattern starting with the smallest aspects: material, system, building, site, until in its global level. The existing stage and system is still being explored and still offers an opportunity for various research domains. Architecture as a sustainable product seems to offer various interesting sides needed to be further explored.

**3.7 Sustainable Design Principles in the Perspectives of Some Leading Figures.**

Some practitioners and theoreticians have written on the principles of sustainable design. There are basic principles that should be held on to in sustainable design [20]:1) Understanding Place: sustainable design requires architects to be willing to understand a place, be sensitive toward place, build without damaging, understand orientation, place naturalness, preservation and even transportation to and from the place; 2) Connecting with Nature: the correlation between a place and its natural characteristics although the building is located in an urban context; 3) Understanding the Natural Processes: understand the natural process that will happen, what the life cycle of environment and human beings is; 4) Understanding Environmental Impact: awareness of every impact of the developmental process by always conducting an evaluation of buildings, materials, and even frpm the stage of the construction process; 5) Embracing Co-creative Design Processes: listening to every input from various parties: collaboration with consultants, expertise from various scientific disciplines, the local neighborhood community, the prospective user; 6) Understanding People: a good sustainable design should be able to accommodate culture, race, ethnicity, religion and various human interests. The attitude of empathy should also be developed toward a powerless community (community with disabilities)

In the meantime, Thomas A. Fisher, proposed five principles of sustainable architecture [21]: 1) Salubrious Interior Environment: the use of safe material especially for the interior; 2) Energy Efficiency: Minimization of energy use; 3) Ecologically Benign Materials: material used does not come from material damaging to the natural environment. Wood was obtained without damaging the forest. Material was produced with a method that is safe for the environment; 4) Environmental Form: strict calculation between design and site, region and climate. All are considered based on the principle of harmony between man and environment that is friendly toward the life cycle and energy efficiency; 5) Good Design: increase in efficiency and sustainability taking into account area use, circulation, building shape, mechanical system and construction technology. Symbolic correlation is related to historical values, spiritual ones, and world view. A product should be built well, easy to use and beautiful.

Furthermore, Lennan (2004) offered some principles in sustainable development [22], i.e.: 1) Considering the wisdom of the natural system: The Biomimicry Principle; 2) Considering Human: The Human Vitality Principle; 3) Considering Place: The Ecosystem/Bio-Region Principle; 4) Considering the Life Cycle: The Seven Generations Principle; 5) Considering Energy and Natural Resources: The Conservation and Renewable Resources Principle; 6) Considering Process: The Holistic Thinking Principle.

Currently, tropical architecture designs, energy saving, the use of local natural materials, awareness of preservation efforts, revitalization, and renovation and designs as manifestations of traditional wisdom are part of architecture and architects in Indonesia that have intrinsically been in the spirit of sustainablity. This thinking process will be better if it is well-planned, systematic and holistic by taking into account intrinsicly building life cycle. The system began from raw materials collection until the end of the use of the building/or waste management. Holistic thinking should take place in every process of building provision in the context of building as architectural products.

The new paradigm in architecture has led architecture to the direction of eco-design. Eco-design in the context of architecture is one taking into account the building life cycle to make the building run efficiently. Eco-design directs the building to run effectively and efficiently in each stage of construction. The eco-design paradigm should not be in the level of idea that is hard to implement because it is considered as expensive. Each party involved in the building provision should start thinking at the level of the implementation of this ecological way of thinking.

## IV. EFFORT TO UNDERSTAND THE CORRELATION BETWEEN BUILDING ENVELOPE WITH THE APPROACH OF BUILDING LIFE CYCLE CONCEPT

### 4.1. The Concept of Building Life Cycle in Architecture

Previous research conducted by Abioso, obtained criteria of architecture design based on the concept of the building life cycle [19], i.e.: (1) Site: general, pedestrian concept, outdoor air conditioning, landscape; (2) Building: sun-oriented, room orientation and configuration, façade, structural system, construction and material, utility system, building automation system, and landscape.

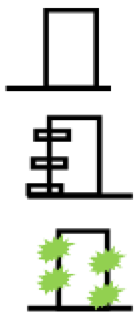
### 4.2. The Concept of Building Life Cycle in Vertical Housing

Thinking in the framework of building life cycle for vertical housing certainly should be thinking from the stage of the birth of the building until the end of the building's use. As an architect, at every planning stage, all cradle-to-grave aspects should always be considered. This thinking is absolutely necessary considering that housing is the primary function of human beings, where human daily lives occur around the housing circle, even until the end of their life. The thinking of building life cycle will be definitely needed for housing, particularly vertical housing.

### 4.3. Articulation of High-Rise Residential Building Envelope in the Building Life Cycle Consideration

Thinking in the framework of building life cycle should be comprehensive, integrated, related to one another and inseparable. Beginning with its design context, all aspects of the birth of the building until the end of its use should be properly considered. Succinctly it can be seen in table 1 below:

Table 1. The Articulation of the Envelope in the context of Building Life Cycle

| | | | |
|---|---|---|---|
| **BUILDING ENVELOPE:**<br>▪ Window ,<br>▪ Door opening ,<br>▪ Wall,<br>▪ Roof surface and<br>▪ *Sun Shading*<br><br>ARTICULATION: CLARITY OF THE BUILDING CURVES IN ACCORDANCE WITH THE FUNCTION OF BUILDING ENVELOPE | ***Resource Extraction*** | How the material is extracted from the nature, distance aspect, energy produced | ▪ MATERIAL<br>▪ HUMAN RESOURCES |
| | ***Manufacturing*** | What is the production process of its envelope? Correlation with environmental damage and energy saving and human resources involved | ▪ PROCESS |
| | ***On-Site Construction*** | ▪Simple?<br>▪Inexpensive?<br>▪Damaging the environment? | ▪ PROCESS<br>▪ HUMAN RESOURCES<br>▪ ECONOMY |
| | ***Occupancy/ Maintenance*** | ▪Maintenance: expensive?<br>▪Requires a lot of human resources?<br>▪Often change the material?<br>▪Model is easily outdated?<br>▪Endanger the occupants?<br>▪Uncomfortable for the occupants? | ▪ SHAPE<br>▪ *SECURE*<br>▪ *SAFETY*<br>▪ COMFORT<br>▪ ECONOMY<br>▪ EASE OF USE |
| | ***Demolition*** | No harm to the surrounding during the demolition | ▪ PROCESS |
| | ***Recycling/Reuse/ Disposal*** **renovation** | ▪Inexpensive? → material availability<br>▪Simple? → execution<br>▪Damaging the environment? | ▪ MATERIAL |
|  | **Re-use** | ▪Simple? → time<br>▪Inexpensive? → re-use material that can still be used<br>▪Damaging the environment? | ▪ ECONOMY<br>▪ PROCESS |
| | **Conversion** | ▪Simple? → spatial flexibility<br>▪Inexpensive? → material availability<br>▪Damaging the environment? | ▪ SPATIAL FLEXIBILITY AND SHAPE |
| | | Sun-oriented<br>Spatial shape and configuration<br>Structural system<br>construction and material<br>utility system<br>building automation system<br>landscape | |

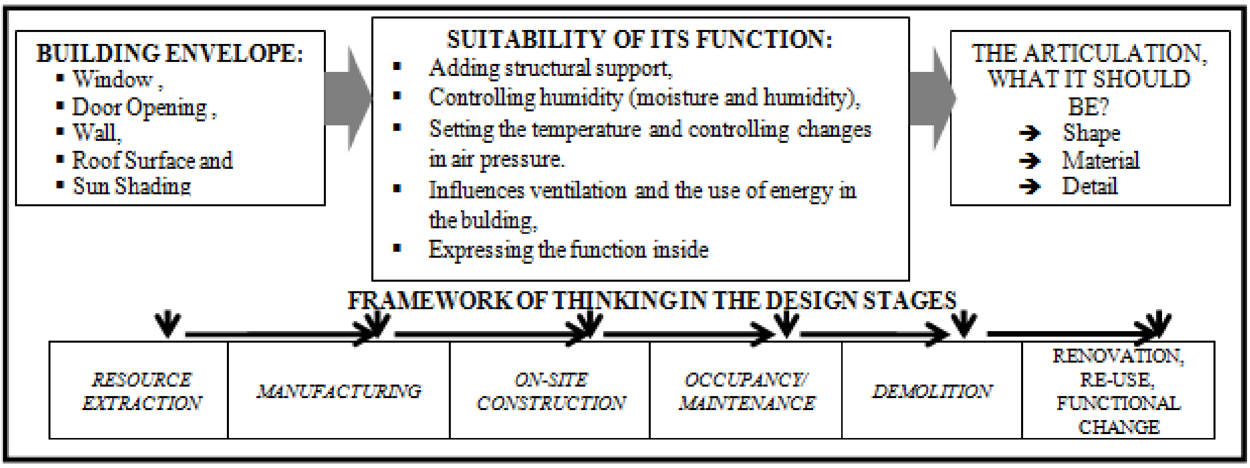
When we think from the perspective of the building life cycle about the building envelope, for example: the window. Windows have to have clear articulation, as their function: to look outside/inside, to distribute air circulation, and lighting [figure 8]. In accordance with its function, the articulation should be clear: if it is for a visual purpose, it should be affordable and ergonomic, enabling to see well, in accordance with the intended level of privacy. To distribute air circulation: the window can be opened. In the context of lighting, articulation of shape as light transporter should correspond: big, small, high, low, and so on.

In the context of its building life cycle, windows should have been considered since the material procurement: ease of use, distance, availability in nature and whether it is, easy to be executed by the available human resources. In the context of production, the system production should be considered: whether it is mass or custom-made, and its economic value. During the installment process in the field: easy execution, detail construction, time needed, human resources involved, etc. During the use period: easy maintenance, its economic value, its security aspect, especially for housing units on the upper floor, comfort aspects: such as causing heat inside, causing glare, and so on., feeling safe particularly related to crime, animals, rain, heat, wind, etc. An other thing is the aspect of shape if it is related to fashion trends. The building should be considered for its period of use so it won't look outdated. In the context of renovation, the aspects of convenience, material, and others. should also be considered. If there is a change of function in the future, the window design should be flexible and suitable for the new usage. Now, highrise building also care about the sun direction and the vegetation due to minimize the use of lighting and cooling temperature [figure 9].

Figure 8. Window Articulation based on its opening and closing depend on its function
Source: fotodesainrumah.net

Figure 9. Window Articulation based on the design of sun direction and the vegetation
Source Yeang, 1994 and www.otakku.com

The Integration of the framework for the sustainable design thinking should be part of comprehensive thinking as follows:




## V. CONCLUSION

Thus far, the perspective of sustainable design, particularly in high-rise residential buildings has only been presented in theoretical discourses or “commercial” products of a marketing commodity whose application in reality does not necessarily meet the criteria of sustainable design. Therefore, it is important to conduct an analysis of the architectural design life cycle as a product, particularly if it is related to the context of high-rise residential building. The perspective here certainly will involve profound thought. Thinking in the framework of the building life cycle is a paradigm shift. This entails a change in the way of thinking. A paradigm shift occurs when the dominant paradigm is replaced with the new one. It is the time for the old ways of thinking in delivering a building to be replaced by the new one. When the 1000 towers are completed, they should be in the framework where the existence can make human beings properous, improve environmental quality and minimize the impact of environmental damage.

## REFERENCES

[1]. Marja, C. H-S. 2001. *Technical Assistance for Policy Development For Enabling The Housing Market To Work In Indonesia*. HOMI 2001.
[2]. Antara News.com. 2007. *Menpera: Pemerintah Segera Bangun 1000 Tower Rumah Susun*. Retrieved from http://www.antaranews.com/berita/55969/menpera-pemerintah-segera-mulai-bangun-1000-tower-rusun
[3]. Kirchhoff. H. 2013. *What is the Definition of a Building Envelope?. How Contributor*. Retrieved from http://www.ehow.com/about_6705189_definition-building-envelope_.html#ixzz2hPav1Oa1.
[4]. The Regulation of Jakarta‘s Governor number 38/2012. *Green Building’s Code*.
[5]. Sukawi. 2010. Kaitan Desain Selubung Bangunan terhadap Pemakaian Energi dalam Bangunan (Studi Kasus Perumahan Graha Padma Semarang). *Proceeding of Seminar Nasional Sains dan Teknologi, Fakultas Teknik Universitas Wachid Hasyim, Semarang..*
[6]. Ching, F.D.K. 3rd edition. 2007. *Architecture: Form, Space and Order* . New York: John Wiley & Sons, Inc.
[7]. Krier, R. et al. 1988. *Architectural Composition.* London: Academy Edition. London.
[8]. Brett. H. 2010. *Housing Strategy: Urban Design Analysis. 20 Storey Building*. Retrieved from www.hornsby.nsw.gov.au/building/housing-strategy/Housing-Strategy-Volume-1

[9]. Kwok and Bailey. (1987, 1988) in Günel, M.H & Ilgin, H.E. 2014. *Tall Buildings: Structural System and Aerodynamic Form* . Routledge, London and New York.
[10]. Amin, J.A and Ahuja, A.K. 2010. Aerodynamic Modification to the Shape of the Buildings: A review of the State of the Art. Asian Journal of Civil Engineering (Building and Housing) Vol. 11, No.4.2010, pp. 433-450.
[11]. Elnimeiri and Gupta. 2008. *The Structural Design of Tall and Special Buildings*. Special Issue: CTBUH 2nd Annual Special Edition: Tall Sustainability, December 2008, Volume 17, Issue 5, pp. 853–1002.
[12]. Frechette, R.E and Gilchrist, R. 2008. *'Towards Zero Energy' , A Case Study of the Pearl River Tower, Guangzhou, China*. CTBUH 2008 8th World Congress.
[13]. Feriadi, H and Frick, H. 2008. *Atap Bertanaman Ekologis dan Fungsional. Seri Pengetahuan Lingkungan-Manusia-Bangunan*. Penerbit Kanisius, Yogyakarta.
[14]. Steele, James. 1997. *Sustainable Architecture, Principles, Paradigms, and Case Studies.* New York: McGraw-Hill, Inc.
[15]. Yeang, Ken.1994. *Bioclimatic Skyscraper*. London: Artemis London Limite
[16]. Yeang, Ken.1995. *Designing With Nature, The Ecological Basis for Architectural Design*. New York: McGraw-Hill, Inc.
[17]. Vale, Brenda and Robert. 1991. *Green Architecture: Design for a Sustainable Future*. London: Thames & Hudson.
[18]. Abioso, W.S. 2007. Daur Hidup Gedung dalam Sistem Arsitektur. *Jurnal Dimensi Teknik Arsitektur, Vol. 35, No. 2, Desember 2007: 128 – 13.5*
[19]. Abioso, W.S. 1999. *Kriteria Rancangan Arsitektur Dalam Konteks Pembangunan Berkelanjutan* Thesis Magister ITB.
[20]. Hui, S.C.M. 2001. *Sustainable Architecture*. *Sustainable Architecture and Building Design (SABD).* Retrieved from http://www.arch. hku.hk/research/ BEER/sustain.htm
[21]. Fisher, T. A.. 1992. *Sustainable Design.* (AIA, November, 1992).
[22]. Lennan, J.F. Mc. 2004. *The Philosophy of Sustainable Design* (Kindle Edition). Kansas City: Ecotone Publishing,