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ADAPTING URBAN HEAT ISLAND MITIGATION STRATEGY ON BANDUNG DOWNTOWN AREA

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ABSTRACT

Urban Heat Island (UHI) mitigation research has been carried out for a long time but it requires to be sharpened to enrich mitigation strategies. In Bandung, maximum temperature has been increasing from 33^0C to 35^0C in 30 years. Bandung is getting hotter which can exaggerate the negative impact of UHI mainly in the downtown area. Suitable UHI mitigation strategies are needed to lower urban temperature. UHI mitigation has involved the use of heat-absorbing and covering man-made materials with vegetation such as green wall and roof system. Content analysis of UHI precedents and some preliminary studies are applied to assess prerequisites of UHI mitigation. The analysis showed adaptation opportunities of UHI mitigation strategy on buildings and environmental physical components. The mitigation strategies may vary depending on the typology of buildings (roof and wall) by using reflective materials, while outside the building by increasing vegetation to maximize evaporation to lower the temperature.

Keywords: Urban heat island; mitigation; Bandung.

INTRODUCTION

The increased in human activity as well as rapid development of built area causing the increasing temperature in urban area called urban heat island (UHI). UHI characterized as 'island' of hot air centered in urban areas, especially in the downtown area. UHI occurs because there is a dominance of artificial material that holds heat (heat storage) in urban areas which cause the increase of temperature. Hot temperatures in urban area are also triggered by the release of heat from anthropogenic activities such as industrial activities and urban transport. Akbari and Kolokotsa (2016) suggested that horizontal surfaces in urban areas (such as roofs and pavement) absorbed significantly solar radiation nearly 50% of this absorbed energy is convected to the air, leading to higher ambient air temperatures. There are two mitigation technologies to reduce the impact of urban warming, first by increasing solar reflectance and secondly by increasing evapotranspiration (Santamouris, 2014).

The main focus of UHI mitigation is to modify the surface of the city with a high heat absorption characteristics. UHI mitigation strategy must suitable with urban design elements especially mass and building form; green space; preservation area, and pedestrian walk. The application of UHI mitigation strategy will vary between cities according to the physical characteristics and the structure of the existing space in the city.

Although over the past three decades the mitigation research focus has been on developing materials, methods and policies to change the landscape and structure of urban buildings, research is still needed to sharpen studies in this field (Akbari and Kolokotsa, 2016). In Indonesia, research conducted generally looks at the macro context (Tursilowati, 2005; Tursilowati, et al., 2012; Manik and Syaukat, 2015; Rushayati et al., 2016), therefore, research related to strategic mitigation UHI on a micro/urban design scale is still required.

Bandung is a city with a fairly high population growth, reaching 2,503,710 inhabitants in 2018 with an average growth rate of 1.01% per year. High population growth rate contributed to the rapid development of the built environment leading to increase in temperature. Data measurement at Bandung Weather Station showed that the maximum temperature trends reached 35^0C in the 2001-2010 decade. Remote sensing study from LANDSAT data stated that the UHI areas (areas with surface temperatures above 30^0C) at the Bandung basin had been expanded in 1994 to 2001 due to the rapid changes in land cover (Tursilowati, 2005). Areas with high temperatures are located in the downtown area and expand to the suburbs due to widespread changes in land use. Bandung is also a city with a lot of tropical heat gain when compared to the subtropical city because of the large concentration of solar radiation at the equator so UHI can give more negative effects to thermal comfort of city residents.

UHI in Bandung is influenced by coefficient of mass and building form and building materials characteristic (Wonorahardjo, 2010). In general, buildings in Bandung also doesn't pay attention to the harmony of mass and form of the building with the surrounding. Beside, in certain areas, the building utilization likely to be multifunctional building and there are pockets of densely settlement that surrounded by commercial areas. Those problems emphasize that the implementation of UHI mitigation strategy in Bandung becomes more difficult when compared to the city with the uniform building mass and have good spatial planning.

Vegetation is lowering the temperature through evapotranspiration and shading (US EPA, 2012). The number of parks contributes to lower the temperature around the park and to mitigate urban heat (Spronken-Smith et al., 1998; Upmanis et al., 1998; Oke et al., 1989; Ca et al., 1998; Wattkins et al., 2002; Chen et al,. 2006; Hamada and Ohta, 2009; Skoulika et al., 2014; Bowler et al., 2010). Vegetation can reduce the air temperature by 0.2^{0}C - 1,2^{0}C around the land surface through evapotranspiration (Kleerekoper, 2009). However, trees require sufficient area so they can grow properly. Hot temperature mitigation in the dense areas can be implemented by combining vegetation on building facades through green roof and green wall. Building materials pavement have different albedo (the ability of a material to reflect heat). If a material have high albedo value, that material will stay cold when exposed to direct sunlight. In general, buildings and pavement in the city area are composed by heavy materials that easily absorb heat and have a low albedo value. Modification of pavement construction materials in order to provide thermal comfort can use cool roof and cool pavement. Narrow street and tall building also formed a canyon which trap solar radiation. Based on literature review preceding UHI mitigation research and theory of urban design elements, the study has obtained the requirements of mitigation strategy application as mentioned on Table 1.

METHODOLOGY

This study was using deductive and inductive approach. Deductive approach was used to conclude UHI mitigation prerequisites from literature review about UHI preliminary research, UHI mitigation precedents, and urban design elements using content analysis method. Inductive approach was applied by formulated the structure of the existing problems in the downtown area, formulate laws and regulations relating to the application form UHI mitigation, and to compare that existing problem structure with application prerequisites of UHI mitigation. Stuctural problems in the downtown area were formulated using exploratory analysis method that aimed to clarify the application of mitigating UHI issues in the downtown area. Comparative analysis method was used to compare the conditions in the study area with UHI mitigation prerequisites.

The study area is located in downtown area of Bandung specifically on *Kecamatan* (sub-district) Sumur Bandung. The area is affected by tropical climate condition with average temperature around 23.6ºC. Based on temperature measurement by local meteorological station, average temperature increases around 0.012ºC per year. There was an increase in maximum temperature around 0.95°C on 1980 to 2010. During the day, the temperature rises extremely, reached 35°C in the decade 2001 to 2010. Besides the lowest minimum temperature has been increased by 0.7°C, which indicated temperature is getting hotter. High surface temperatures contribute to high air temperatures although the surface temperature is more variable than the air temperature.

High surface temperatures contribute to high air temperatures although the surface temperature varies than the air temperature. The location of highest surface temperature in 2012 can be seen in Figure 1. Based on surface temperature distribution map, high surface temperatures (26-32ºC) tends to be on the western part of of Bandung. There are some areas with low surface temperatures on the eastern part of Bandung because land cover is dominated by rice fields and lack of built area. From these maps, it can be concluded that the downtown area and western part of Bandung has a higher temperature than other parts of Bandung.

Surface temperature on the study area (Figure 2) indicated that Urban Heat Island occurs. The surface temperature ranged from 21,3 - 32ºC. That temperature variation occured because there are differencies on urban morphology. Western part of study area is hotter than the eastern part because the buildings on that area are dense and lack of green space. The western area is consisted of commercial area (row of retail buildings) and densely residential area. Hot temperature on the western part also triggered with corrugated building materials that have low albedo values. The area around the river bank has low temperature (22ºC) because there are lot of trees that give shade effect to the pavement.

Table 1. UHI Mitigation Prerequisites

UHI Mitigation Strategy	Considered Factor	Component	Mitigation Method	Prerequsites
Green Roof	Safety	Building Structure	Extensive Green Roof Intensive Green Roof	Buildings have concrete structure (Bauder, tt; Wilkinson, S. and R. Reed, 2006).
		Roof in the load-bearing ability	Intensive Green Roof	Building structure can hold dead load 120-225 kg/m^2 (Peck, 2001).
			Extensive Green Roof	Building structure anc hold dead load 17-25 kg/m^2 (Peck, 2001)
		Roof material	Extensive Green Roof Intensive Green Roof	Have concrete roof (FLL, 1995).
		Electrical Utilities	Extensive Green Roof Intensive Green Roof	Green roof should not be placed near electrical utilities (Bauder, tt).
		Water drain pipe	Extensive Green Roof Intensive Green Roof	Building soul have rain drainage utilities (FLL, 1995).
		Roof pitch	Intensive Green Roof Extensive Green Roof	Roof pitch around 0^0-2^0 (US EPA, 2012). Rof pitch around 0^0-30^0 (US EPA, 2012).
		Age of building structure	Extensive Green Roof Intensive Green Roof	Building had been built 50 years ago (Castleton, et. al, 2010).
	Durability	Building Dimension	Intensive Green Roof	Wind breaker must be placed at roof of high rise building (Wanielista, et al., 2011; Hopkins, et al., 2010).
		Roof Material	Extensive Green Roof Intensive Green Roof	Roofing material preferred using concrete roof intstead galvanize roof or uncoated wood (Clark, et al., 2008).
	Accessibility	Stairs	Extensive Green Roof Intensive Green Roof	Roof can be acessed by stairs, both permanen and non-permanent (US EPA, 2012).
	Aesthetics	View of Facade Building	Extensive Green Roof Intensive Green Roof	At heritage buildings, green roof plants should not be visible from outside it can change the architectural caracter of building (Pestrela, 2009).
Green Wall	Safety	Building structure	Living Wall	Building structure must be strong, The building structure should not be made of wood (Hopkins, et al., 2010).
			Green Façade	Green facade can be applicated at every building (Mir. M. A.,2011).
		Massive Walls	Living Wall Green Façade	Green wall should be applicated on massive walls or load-bearing walls (Bjerre, 2011).
		Water drain pipe	Living Wall Green Façade	Building shoul have rain drainage utilities (Hopkins, et al., 2010).
	Efficiency	Building Orientation	Green Façade Living Wall	The wall surface area on the west side and east side are preferred to covered with green wall (Wonorahardjo, 2010).
	Durability	Wall materials	Living Wall	Wall material should be covered with a waterproof or water-resistant material (Mir. M. A.,2011).
	Aesthetics	View of Building Facade	Living Wall Green Façade	Placement green wall on heritage buildings must follow local building code (Mir. M. A.,2011).
Cool Pavement	Durability	Traffic Volume	Porous Asphalt, Permeable Pavement, Paving Block, Grass Block, White Cement	Pavement with high low traffic movements such as alleys, walkways, or parking lot (US EPA, 2012).
			Concrete Pavement, white topping aggregate on asphalts	Pavement with high traffic movements such as bus lane, roads, or, highways (US EPA, 2012).
Cool Roof	Efficiency	Roof area	all types of cool roof	Roof area is 25% of the surface area of the building (US EPA, 2012).
	Durability	Roof pitch	Coating cool roof Shingles or teckles cool roof	Roof pitch around 0-5% (US EPA, 2012). Roof pitch around 5%-30% (US EPA, 2012).
Albedo modification on building walls	Handling Priority	Wall surface area	Wall coated with high albedo color.	Building walls area is wider than lots area (Ferial, 2007).
		Wall orientation		The wall that faced east-west orientation walls should be covered with high albedo material (Wonorahardjo, 2010).
Trees and other plants	Safety	Private lot	Trees canopy have round or umbrella formaand have tight leaf mass. Canopy height should be 2-5 m above the ground. The root shoul not wide and extensive.	There is minimum space around ¼ or 1/3 of treess height beetween trees and buildings (Russ, 2002). Available space for the root around 1,5-3,6m^2 (Russ, 2002).
		The existence of cable network		Trees must not adjacent to the power grid, telephone network and underground utilities (Russ, 2002).
	Efficiency	Trees Placement		On west and east side of buildings (Russ, 2002).

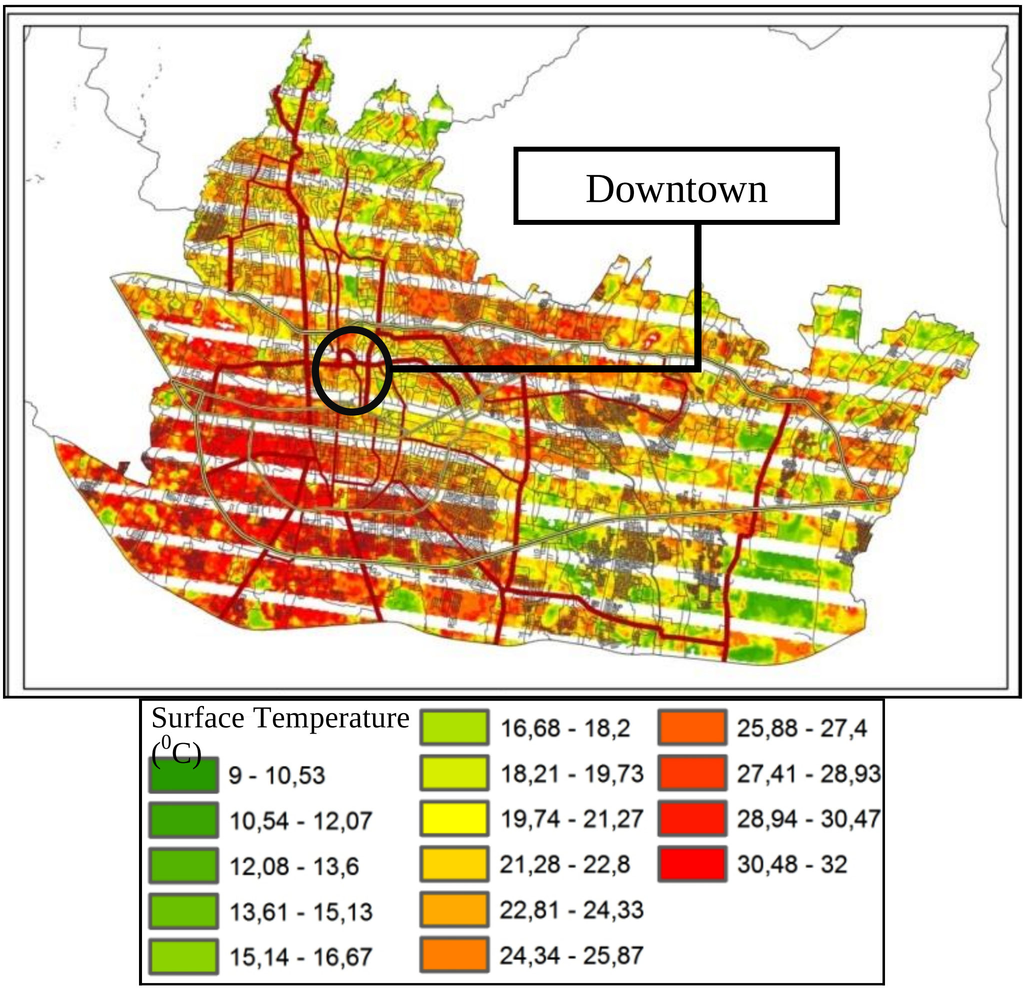

Fig. 1. Bandung Surface Temperature Map (August, 2012)

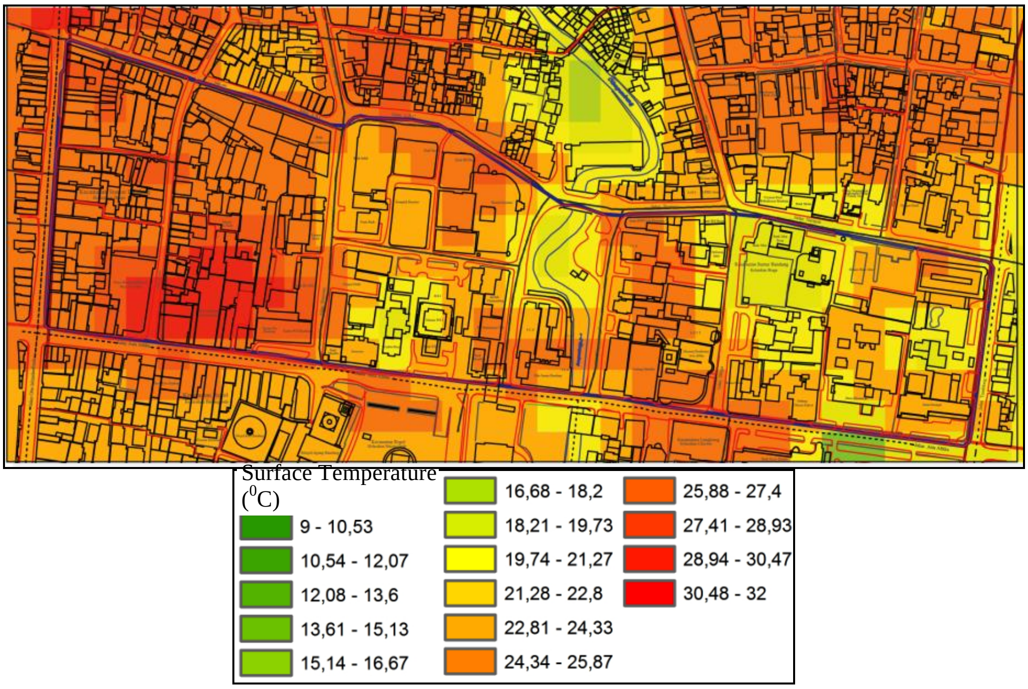

Fig. 2. Surface Temperature Distribution on Study Area (August, 2012)

RESULTS AND DISCUSSION

To facilitate observation of the study area, the study area is divided into five blocks of observations (Fig. 3). These divisions based of the numbers of blocks that exist in the study area and did not consider the similarity of building typologies or other physical characteristics. The components that are observed include physical components that should be intervened by implementation of UHI mitigation. The results of observations of the study area can be seen in Table 2. Both internal and external physical components in study area are compared with mitigation prequirements to determinate appropriate UHI mitigation strategy that can be adaptable with physical components of study area. Typologies of existing buildings in the study area include new and old shophouses, high rise buildings, one or two floors residential buildings, three and four floors residential building, and heritage building. The results from that comparison analyst is a form of UHI mitigation that adaptable with the typology of the building as well as the physical characteristics of the downtown area. The UHI mitigation principles and application on new shophouses, mentioned on Table 3.

After the study of UHI mitigation strategy on building typologies and external physical characteristics of each blocks the next stage is determining the location of the application UHI mitigation strategy that was discussed as well as the number of parcels and buildings that can be applied with mitigation strategy.

Table 2. Description of Internal and External Physical Components

Component	Block A	Block B	Block C	Block D	Block E
INTERNAL PHYSICAL COMPONENTS					
Number of Buildings	14	37	104	86	122
Building Height	1-11 floors	1-4 floors	1-8 floors	1-4 floors, formed urban canyon	1-4 floors, formed urban canyon
Building Coverage Ratio	50-60%	70-100%	50-70%	90-100%	90-100%
Roof Materials	44% of buildings use concrete roof	28.9% of buildings use terracotta roof 24.4 % of buildings use concrete roofs	70.17% of building use mix-materials roofs	57.5% of buildings use terracotta roofs 27 % of buildings use concrete roofs	52.9% of buildings use terracotta roofs 43.26% of buildings use concrete roofs
Building Structure	Almost all buildings have concrete structures	Almost all buildings have concrete structures	Almost all buildings have concrete structures	Almost all buildings have concrete structures	Almost all buildings have concrete structures
Drain Pipe	All buildings have drain pipe	All buildings have drain pipe	All buildings have drain pipe	All buildings have drain pipe	All buildings have drain pipe
Yard or Parking Lot	Almost all buildings lot have yard and parking area	Almost all buildings lot have yard and parking area	Almost all buildings lot have yard and parking area	Almost all buildings lot don’t have yard and parking area	Almost all buildings lot don’t have yard and parking area
EXTERNAL PHYSICAL COMPONENTS					
Width of Pedestrian Walk	1.5-3 m	1.5-5 m	1.5- 3 m	86	122
Green Belt	Potted medium trees and shrubs on pedestrian walk	Potted medium trees and shrubs on pedestrian walk	Potted medium trees and shrubs on pedestrian walk	Potted medium trees and shrubs on pedestrian walk	Medium trees on shoulder of the road.
Utilies Cable	Power network and telephone cable above the ground.	Power network and telephone cable above the ground.	Power network and telephone cable above the ground.	Power network and telephone cable above the ground.	Power network and telephone cable above the ground.
Parking Area	On street parking	On street parking parking and parking area beside the river bank	On street parking	On street parking	On street parking
River bank	-	The river bank width is around 10-22 m. There are some big trees on green belt beside the river bank.	-	-	-

Table 3. Application of Mitigation Strategy in Each Building Typology

Physical Components	Problem Characteristics	Handling Principles	Application of Mitigation Strategies
Building Dimension	• Buildings have long-shaped form with narrow front facade • The form of the row of buildings next to the inner wall of the building huddled together • Total walls surface area of is greater than the lots area • The adjacent buildings don't have uniform height. • Shophouses in the alley have narrow distance between front façade that is only 2 m. Comparison of building height and street width (the value of h / w) is about 3.5 to 5.25 and there are several hot exhaust AC condensers mounted on the wall of the building. These condensers placement can lead to urban canyon phenomenon.	• Building coincide with other buildings so the parts that exposed to direct sunlight are the roof and the front facade of the building. These parts should be covered by a material that can reflect the heat . • If there is a height differences at the adjacent building, the taller building's wall is also painted with reflective color to avoid absorption of the reflected heat from the roof of a lower building. • Avoid heat trapping in the building which located in the alley by coating the entire wall of the building with brightly colored paint or cover the walls with green wall.	*Green wall* • Green wall can only cover 20% of the building facade face. • Green wall can only install on second floor and above because the front facade of first floor is opened as display. • Green wall installed on buildings which use bricks as wall materials • Suggested to use green facade system with soil is placed on existing building structures such as floor balcony or at the space between the window and the wall. In building with flat roof, of soil media placed on roof. Plants used on a green facade is vines so the plants can cover most of the facade • Green wall should be placed on east and west facing wall. The facade side of the building that exposed to the sun is not installed with green roof by considering the possibility of the building next door will be elevated. • At building that is covered with aluminum billboards on the front facade, a green facade media placed on the space between the wall and the aluminum plate. Green facade uses climbing plants without supporting structure. The plants shouldn't have large-diameter leaf so the billboard message still can be seen. • Green wall structure can be placed on the front facade shop, precisely the structure is installed outside the plot or on the pedestrian walk. Construction is mounted on the column. The structure can be used as a propagation direction of the vines to the second floor of the building facade. Soil medium can be positioned just below the cantilever construction as in the shop porch, sidewalk, or on top of drainage. • Growing media can be installed over openings in the cantilever construction of first floor or placed on the edge of the roof (flat roof). Planting media should use the media as light as pumice with hydroponic system. • In building with a glass facade, green wall has limited installation. Green wall can only be installed at the structure parts that hold glass structure. The growing media placed on the sidewalk or on the flat roof. • It's difficult to place green wall media around the storefront at alley because the space is narrow and filled with street vendors. Growing media of green wall can be placed on the second-floor balcony. Other mitigation strategy. • The walls of the building that can't be installed with green wall should be repainted with bright colors that are reflective, prioritized on the eastern or western wall

Physical Components	Problem Characteristics	Handling Principles	Application of Mitigation Strategies
			• The rear of the building that is not attached to the other buildings was painted with white color to avoid heat absorption. • AC condensers can be mounted on the front of the building that leads to a major street or on the 3rd floor to the top so the heat emissions can be directly released into the sky. • The glass facade must be coated with reflective glass film.
Building Structure	The building structures use reinforced concrete.	The structure of the walls and columns that can withstand green wall required additional construction.	Almost all of shophouse buildings can be retrofitted with considering the availability of space for growing media as well as the existence of massive walls.
Building Roofs	• Most buildings use white flat concrete roof. Some buildings have additional roof with clay tile and aluminum plate. • The roofs functioned as a place to store the utility of air conditioners, water storage, complementary buildings and large-sized antenna • By law the building load of Indonesia 1983; all flat-roofed building is able to sustain additional live load with a total of 100 kg/m2. If the building is capable of supporting the load generators, large antennas, or building complement the building must be withstand load that exceed 100 kg/m^2 live load, reaching a maximum of 250 kg/m^2. • There are potted plants that placed on the roof in some buildings with flat roofs. • A number of buildings with flat roofs have dull conditions roof so the color is getting darker. • The buildings with steep-slopped roof use clay tile, ceramic tile, and aluminum plate. • Building with clay tile roofs have dull roof shape and experienced darkening of color while a number of buildings with metal roofs such as aluminum are rusty.	• The roof part of the building is most exposed to the hot sun so the building should use a roofing material that has a high albedo, so the direct heat is reflected back. • Installing a cool roof on a steep-sloped roof or shingle roof with high albedo value. • Installing a cool roof on a flat roof use a reflective coating.	<u>*Cool Roof*</u> • Installing a cool roof is prohibited for steep-sloped roofs because the roofs are vulnerable to support the added weight of the green roof. There is no permanent access to the steep-slope roof. • Cool roof can be installed to most flat roofs roof area functioned for people activities such as drying clothes. Installing a cool roof should also be applied to the flat roof with electricity were installation tool that occupies most of the roof area. This is to avoid the occurrence of a fire when the fire spillovers. • Buildings with steep-sloped roofs using terracotta clay tile or ceramic tile. The material suited to the tropical climate so that the mitigation strategy application is just repainted. Cool roof installation on steep-sloped roofs can also use metal roof painted with bright color • Flat roof buildings using cool roof coatings in the form of liquid spray that contain cement particle on the roof <u>*Green Roof*</u> • Green roof is applied if most of the building roof is a concrete flat roof. There should be a buffer zone (buffer) with a width of 1.5 m between the location of the green roof and electric utility tools to avoid spillovers fire. • Green roof that can be applied in the area is extensive green roof using lightweight media such as rock wool or pumice stones with a total weight of green roof installation should not exceed 10 kg/m2. This is to avoid excessive load because the existing roofs are not designed to accommodate a green roof. Plants used in the green roof are grasses or shrubs. • Green roof plants using media such low specific gravity pumice (0.6-0.7 kg/l) or synthetics material such as rock wool with a density from 0.04 to 0.05 kg/l. Plants need fertilizer and watering periodically through the custom installation of water drain

Physical Components	Problem Characteristics	Handling Principles	Application of Mitigation Strategies
Building yard	• Most of the buildings don't have a yard. • Cluster shaped buildings have green belt along the fence or wall. • In some building lot that does not have a yard; building owners put potted plants on the front porch or on the flat roof. • Building coverage area around 60-100%.	• On the limited plot area, the green yard can be made in the form of vertical garden (green roof or green wall). • Green belt in shophouse cluster used efficiently for planting trees.	• Placing potted plants around the patio or pedestrian walk. The placement of potted plants should not interfere with the circulation of visitors shop and pedestrians. • Potted plants can be placed on the balcony or by using hanging pots on the front facade if space is available.
Parking and Driveway Pavement	• Shophouses on Banceuy Cluster dan Braga Cluster have a parking area wider than green area. • Most of the parking lots using black asphalt as pavement. • Parking lots not covered by tree shading. • The road network on shophouse Cluster using black asphalt.	• Parking and driveway using porous pavement to prevent rainfall runoff so the water can flow into the ground under the pavement, thereby reducing the heat-absorbing pavement. • Parking lots pavement must have bright color so heat can be reflected.	*Cool Pavement* • Parking pavement on Braga Cluster can use porous paving or grass block. • Porous paving block should be brightly colored and have routine maintenance to avoid darkening of color. • Plants wide canopy tree around the parking lots so the pavement cannot absorb the sun heat. • Driveway and path in shophouse cluster should use a permeable paving block with light color.
Fences	• On Braga Cluster, plot is fenced with 5 m height brick wall. • On Banceuy Cluster, plot area is fenced with metal fence.	• Life fence system using green facade can reduce air temperature. • Wall fences can be used as the structure of living wall,	• Living wall system with a planter box or vertical growing media can be installed on wall fences of Braga Cluster. • Static metal fenced in Banceuy Cluster can be used as a green facade structure.

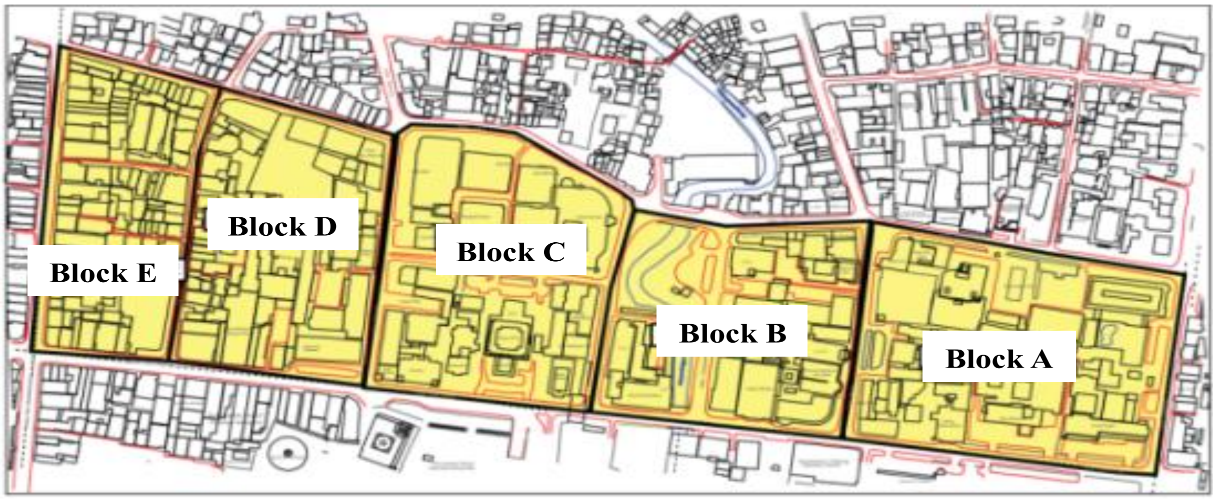

Fig. 3. Observation Blocks

Green Roof. Flat roof buildings in the study area have concrete roof, concrete columns, rain drainages, and permanent access. These criteria are usually owned by the new shophouses and high rise building typologies. In the study area, many buildings with flat roofs have been modified by the owner of the building so that the building has an additional building in the form of permanent or semi-permanent building on the roof with a roof covering of zinc, aluminum, or asbestos materials. That cause the buildings are vulnerable to additional dead load on the roof. In addition, the roof of these buildings only have limited space that is located at the edge of the roof therefore placing a green roof system might be vulnerable. Most of flat roof are used for drying clothes or other residents activities so it's difficult to install a green roof. Type of extensive green roof light with additional dead load of 10-25 kg/m^2 applied to a new shop building typology with criteria that refers to the National Building Load Regulation 1983. High rise buildings that were designed to accommodate a permanent building on the roof can accommodate the intensive green roof system using shrubs or small plants with soil as plants medium. Therefore, resulted the numerous buildings that can accomodate green roof which can be seen on Table 4 and Figure 4.

Table 4. The number of buildings that can accomodate green roof system

Block	Green Roof Types	Number of Buildings
Block A	Extensive Green Roof	2
	Intensive Green Roof	4
Block B	Extensive Green Roof	-
	Intensive Green Roof	1
Block C	Extensive Green Roof	11
	Intensive Green Roof	2
Block D	Extensive Green Roof	18
	Intensive Green Roof	-
Block E	Extensive Green Roof	15
	Green Roof	1
Total		**54**

Table 5. The number of buildings that can accomodate green roof system

Observation Blocks	Number of Buildings
Block A	8
Block B	37
Block C	104
Block D	80
Block E	97
Total	**326**

Green Wall.Green wall is a vertical placement of plants, either attached to the building wall or on a stand-alone structure. The purpose of green wall installation at UHI mitigation is to reduce the area of building walls that exposed to the sunlight. In order to accommodate green wall system must meet the requirements to have a solid wall structure that has enough space to put a green wall system. Green wall is difficult to be placed on the front facade of the building with a dominant form of unstructured wall such as aluminum plate for advertisement or glass material dominance. Green wall also can not be mounted on the walls of heritage buildings as it can be categorized as an additional ornament unrelated to the initial architecture of the heritage buildings. Buildings that were not built according to standards such as residential house can use simple green wall system with hanging potted plants. Buildings that have priority to install green wall in west and east faced buildings. Number of buildings and building locations that can accommodate the installation of a green roof can be seen in the Table 5. and Figure 5.

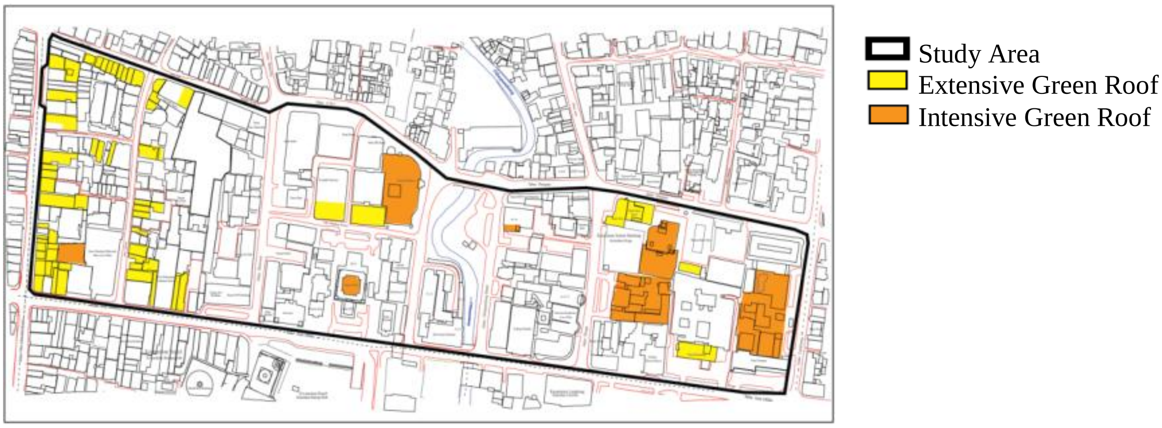

Fig. 4. Location of Buildings that can accomodate Green Roof System

Fig. 5. Location of Buildings that can Accomodate Green Wall System

Albedo Material Modification. Albedo modification can be applied on all buildings and pavement. Albedo modification with cool roof and wall coating material method can applied on any building, especially to the dull building. Albedo modification on the pavement based on the movement of the load passing on the pavement. Cool pavement in the form of porous paving or grass block applied to the parking lot and drive way in the plot. The total area of pavement parking that can be mitigated is about 8,256 m^2. Highway pavement that can be mitigated by using bright colored aggregate with a total area of pavement reach 12,700 m^2.

Trees Mitigation. The trees planting applied on plots of land that has enough space (Buildind Coverage Ratio below 70 %) but does not have a shade tree in the yard. The trees can be planted on a plot boundary with the pavement so the trees can provide shading to the sidewalk in front of him. The planting of trees in the plot can be applied to a BJB Tower, West Java Tourism Office, Commercial Complex Braga, Bank Training Center (Nedhandel), BRI Tower, PT Waskita, Cikapundung Pharmacy, Cikapundung Parking Area, Hotel Ibis, Banceuy Permai Cluster, Natraco, Panin Bank, Post Office, Hotel Golden Flower a parking lot at the shop. Green belt which located beside the sidewalk is maintained. Plants the trees on the pavement directly into the ground so that the roots have space to grow. Height and width of the tree canopy in green belt adjacent to the building is maintained to prevent damaging the building. The narrow sidewalk can use the pergola as a green line. A pergola can be placed on the sidewalk on the side of the river along Jl. Cikapundung Timur.

CONCLUSION

On this study, UHI mitigation strategy applied by manipulating the amount of heat energy that absorbed by the building and land cover materials. UHI mitigation strategies described in this paper aim to:

a. Decrease the absorption of thermal energy by raising the albedo in areas exposed to the sun
b. Lowering the heat radiation absorption by covering the physical building, sidewalks and parking lots with green roof and green wall system.

The mitigation strategy cannot be applied to every buildings dan physical environments in the downtown area because not all buildings have a same physical condition. In addition, each owner of buildings has modified the building form or changes some material parts so the buildings have changed from its original form. In contrast to European countries, Bandung does not have specific regulations regarding the criteria on building facade modification. This causes the application UHI mitigation strategy in a couple adjacent buildings may be different. A number of local regulations regarding the physical components and the configuration of the building mass has led of UHI intensity reduction. However, due to the lack of regulation enforcement, assumed the UHI phenomenon can not be handled properly. The reason that the lack of rules application is because the regulation is not equipped with complementary rules that contained a detailed form about application mitigation such as design guidelines.

Fig. 6. Location of Pavement that can be Mitigated by Cool Pavement

Comparison between UHI prerequisites and physical condition of the study area resulted UHI mitigation strategies that can be applied as follows,

a. There are 43 buildings or as much as 12.4% from total buildings that can accommodate extensive green roof system.
b. There are 46 buildings or as much as 13% from total buildings that can accommodate the application of extensive green roof.
c. There are 8 buildings or as much as 2.26% from total building that can accommodate the implementation of an intensive green roof.
d. There are 326 buildings or as much as 92.1% from total building that can accommodate green wall. Almost all buildings can accommodate green facade system.
e. All buildings can accommodate the application of cool roof and wall material and match the albedo modification.
f. The total area of parking pavement that can be mitigated by using porous paving or grass block is 8,256 m^2 or as much as 3.84% of the total area .
g. The total area of parking pavement that can be mitigated by using porous paving or grass block is 12,700 m^2 or about 5.9% of the total area of the study .
h. Planting more threes for shade trees on 18 plots.
i. Maximizing the green belt and the yard is difficult on block E because space is limited.

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