（別紙様式６）
(Attached Form 6)

学位論文の要旨（論文の内容の要旨）
Summary of the Dissertation (Summary of Dissertation Contents)

論　文　題　目
Dissertation title
Fundamental Study on Indoor Thermal Environments in High-Rise Apartments in Hot-Humid Climates of Indonesia

広島大学大学院国際協力研究科
Graduate School for International Development and Cooperation, Hiroshima University
博士課程後期　開発科学専攻
Doctoral Program　Division of Development Science
学生番号　D140332
Student ID No.
氏　名　MUHAMMAD NUR FAJRI
Name　ALFATA　Seal

Currently, the number of high-rise apartments in Indonesia is increasing and it is projected to be further increasing in the future. As the increasing of high-rise apartments, the energy consumption particularly electricity consumption will be further increasing. The aims of this doctoral thesis are to gather all the fundamental data and information regarding current conditions of existing apartments in Indonesia particularly in the middle-class high-rise apartment and to propose the comprehensive cooling techniques for middle-class high-rise apartments in Indonesia towards energy-saving guidelines.

The review in Chapter 2 particularly focused on the development of passive cooling techniques for the high-rise apartments building in hot-humid climatic regions. As reviewed, there are few studies of passive cooling strategies in apartments in the tropics except for Singapore. Moreover, proper guidelines or regulations and practices of energy-saving apartments particularly through passive cooling strategies are still lack. The existing standards for energy-saving on buildings that rely on the single value of OTTV (for building envelope) alone are not enough in the case of hot-humid climatic regions since ventilation requirements are crucial and important aspect in determining thermal comfort.

Chapter 3 explained the current condition of existing apartments in Indonesia, particularly in the middle-class high-rise apartment. Three types of apartments were selected for in depth field experiments, they are: old public apartment, new public apartment and private apartment. Results of field measurements revealed that under unoccupied condition, old public apartment had better indoor thermal environment compared to two other apartment types. Newly constructed middle-class high-rise apartment are designed on the premise of using air-conditioning. Based on the generalization through computer simulation, it is concluded that it is difficult to achieve thermal comfort without relying on air-conditioning particularly in the middle-class high-rise apartment. Under occupied condition, nocturnal indoor air temperature in the public apartments were higher than that of under unoccupied condition, and even higher than the daytime indoor air temperature under same condition (i.e. unoccupied condition). By using multiple regression analysis, it is found that factors influencing indoor air temperature in occupied units were physical variables (such as orientation, floor level and window to wall ratio) at the daytime and windows/doors opening behavior at the night-time. Current problems particularly in the middle-class high-rise apartments are the absence of shading devices, lower ventilation rate due to single-side ventilation and uninsulated external wall. Furthermore, potential passive cooling techniques for the middle-class high-rise apartments are proper building orientation, proper shading devices and proper design of thermal buffer zones (such as balcony and corridor spaces).

Chapter 4 explained the some key findings extracted from the field investigation on the one of the vernacular buildings in Indonesia, Dutch colonial buildings. Three Dutch colonial buildings were selected in this study after carefully selecting from hundreds lists of Dutch colonial buildings in Bandung. It is found that daytime

indoor air temperatures in Dutch colonial buildings maintained lower than the corresponding outdoors. Indoor thermal comfort evaluation showed that operative temperature exceeded the 80% upper comfortable limit during the daytime. However, thermal comfort in those rooms was improved by increased wind speeds. Thermal comfort survey revealed that as the wind sensation increases due to stronger winds, occupants tend to feel cooler. Passive cooling strategies found in the Dutch colonial buildings are thermal mass, natural ventilation, corridor spaces, high ceiling and permanent openings above windows/doors. Corridor spaces played important roles as thermal buffer zone and shading device as well as encourage cross ventilation for improving wind speed. Meanwhile, high ceiling (5.3-5.7m) contributed in maintaining indoor air temperatures at occupied level (1.1m) at lower values even when windows/doors were open during the daytime.

Chapter 5 discussed the results of a numerical simulation study and proposal of passive cooling attempted guidelines for high-rise apartments. One of the field experiment apartment buildings, i.e. middle-class high-rise apartments, was modelled using the TRNSYS-COMIS and Computational Fluid Dynamics (CFD) STREAM programs. The main objectives of these simulations are to obtain the combination of some parameters including ventilation strategies in structural cooling (i.e night ventilation) and comfort ventilation (i.e. full-day ventilation). Parametric study under night ventilation and full-day conditions were carried out by varying thermal mass, ceiling height, window positions and ratio of openings area to the total floor area. The results showed that that daytime indoor air temperature would be reduced if thermal mass increased (i.e. 2,000 kg/m²). However, increasing thermal mass caused nocturnal indoor air temperature increasing as well. This increasing could be overcome by increasing ratio of opening area to floor area, in order to allow cool air enter the indoor space from the outdoor. Nevertheless, the window position should be further considered to reduce more indoor air temperature. Upper and lower window position significantly cooled the building structures (i.e. walls, floor and ceiling) and effectively reduced indoor air temperature even during the daytime. Although changing window position would not significantly affect the indoor air temperature, but it reduce indoor wind speed by more than half compared to the previous cases. This is important since some standards such as ASHRAE-55 allowed maximum indoor air velocity not exceeded to 1.2 m/s. Furthermore, ceiling height should be considered to optimize the indoor air temperature. From the simulation results, the optimum result was obtained when the applying thermal mass of 2,000 kg/m², ratio of opening area to floor area of 0.15, ceiling height of 5.0m, and upper/lower windows at back-side while maintaining central window at windward side (front-side).

Under full-day ventilation condition, simulation results showed that indoor air temperature at daytime are not significantly different amongst all cases. Instead, applying all parameters affected the nocturnal indoor air temperature. However, these effects were diminished due to the air infiltration during the daytime. Meanwhile, the significant results was found in wind speed profiles particularly when upper and lower windows are applied. It reduced more than half of wind speed compared to that when central windows are applied. It is obtained that the unit employing central windows and increasing window opening ratio to floor area significantly increased wind speed, and therefore lowered the SET* values. Hence, it is found that the unit with ratio of opening area to floor area of 0.10 and employing central windows at the both sides enjoyed lower SET* values and larger distribution area of these values during the peak hours regardless ceiling height. Furthermore, the cooling load in air-conditioned room (master bedroom) reduced almost half from the base model (around 43.9%) by applying the combined techniques, i.e. internal insulation and ceiling height of 2.2m. It should be noticed that the unit is facing North/South and the master bedroom applied daytime ventilation while living room applied night ventilation. Moreover, air-conditioning unit is turned on in the night-time only

Chapter 6 discussed recommendation of proposal for design guidelines of energy saving in the middle-class high-rise apartment. For final conclusions, Chapter 7 summarized the main findings of this study and recommended key areas for further studies based on the limitations of this thesis.