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A Field Survey of Window-Opening Behavior and Thermal Conditions in Apartments of Surabaya, Indonesia

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Abstract: A field survey was conducted in apartments of Surabaya, Indonesia to investigate occupants' window-opening behavior and their thermal conditions. A total of 347 households were interviewed and about 30 houses were covered for measurements of thermal conditions. It was seen that occupants in the naturally ventilated apartments tend to open windows or doors as much as possible at least during daytime for satisfying air flow and ventilation in particular. The average duration of opening windows/doors was 16-17 hours/day in the naturally ventilated apartments, while the corresponding duration in air-conditioned private apartments was less than 5 hours/day. The results of measurement showed that generally indoor air temperatures was about 6°C lower than the outdoors during 11:00 to 19:00, while it was 3°C higher than the outdoors for the rest of the day, i.e. nighttime. The structural cooling effect was evident in these apartments.

1. Introduction

Indoor thermal comfort significantly affects the household energy consumption for HVAC systems. In air-conditioned houses in hot-humid climate, cooling was found to have a significant contribution to the total household energy consumption, unlike in naturally ventilated houses (Surahman and Kubota, 2012, and Kubota et al., 2013). In locations with high thermal stress such as Surabaya, the ownership of air conditioners is becoming less luxurious even in residential buildings (Ekasiwi et al., 2013). This indicates that there is an urgent need for passive-cooling strategies to reduce household energy consumption. In Indonesia, the housing demand for middle class has been growing due to the recent economic growth. Due to the limitation of available land and greenery, the development of apartments especially for the above middle-class is on the rise. Therefore, it is important to find possible energy-saving strategies for the future middle-class apartments.

Occupants' behavior is considered to be one of the adaptations in maintaining their thermal comfort in buildings. Humphreys et al. (2013) stated that: "If a change occurs such as to produce discomfort, people react in ways which tend to restore their comfort". In hot-humid climate, window-opening may be one of the major means for people to adjust their thermal comfort, especially for naturally ventilated houses. This is because those occupants have more opportunities to control their indoor thermal condition. Studies by Rijal et al. in UK and Japan (2007, 2013) showed that the highest usage of window-opening was found in summer and the lowest was in winter. People were most likely to open their windows when indoor and outdoor temperatures are high and tend to close them when the temperatures are low. In apartments, opening and closing windows can be even more significant since the number and size of openings are more limited compared to landed houses.

Since window-opening behavior significantly affects the thermal comfort, this may have an impact on energy consumption patterns. In fact, Fabi et al. (2012) argued that this behavior itself may have direct effects on energy consumption for cooling by changing air-flow rate inside the buildings. Therefore, the factors affecting people's behavior of opening or closing their windows are continuously studied. By finding these factors, architects may be able to create designs which can motivate people to actively open their windows.

To date, most of the relevant studies tried to relate the window-opening behavior with existing thermal conditions. This is because of assumptions that this behavior is most likely to be stimulated by people's reactions to discomfort for indoor thermal environment. The state of closing windows, on the other hand, is said to be happened only when the room's condition is too cool for people to open windows. When a room is equipped with air conditioners, the frequency and length of opening windows are said to be much less than those in naturally ventilated buildings. (Rijal et al., 2007, and Rijal et al., 2013). Nevertheless, Fabi et al. (2012) stated that the behavior of opening window is caused not only by thermal factors but also by various other factors. The possible factors include physical environmental, contextual, psychological, physiological, and social factors. However, studies involving social and psychological factors are mostly conducted not in the field of building science, but in psychology. Furthermore, most of the studies are focused only on drivers which motivate occupants to open their windows, but put little emphasis on the obstacles or reasons why they close their

windows.

This study aims to investigate patterns of window-opening behavior and their thermal conditions in apartments in the city of Surabaya, Indonesia. Thermal satisfaction and preferences, reasons for opening and closing windows are also discussed.

2. Methods

2.1. CASE STUDY HOUSES

Surabaya is geographically located on 7°9'21" South Latitude and 112°36'-57" East Longitude. It is the capital city of East Java Province and the second biggest city in Indonesia. Surabaya has a population of more than 3.1 million as of 2012, with density of 8,462 people/km². The city is located in the coastal area with elevation of about 3-6 meters above the sea level. Surabaya has a hot-humid climate, with monthly average temperature ranging from 27.2-29.0°C and monthly average relative humidity ranging from 65.9-80.9% (Fig.1). The city receives monthly average wind speeds of 2.12-3.10 m/s (NCDC, 2014). Although Surabaya has two seasons (dry and wet seasons), the monthly average temperatures and humidity of both seasons do not show significant differences.

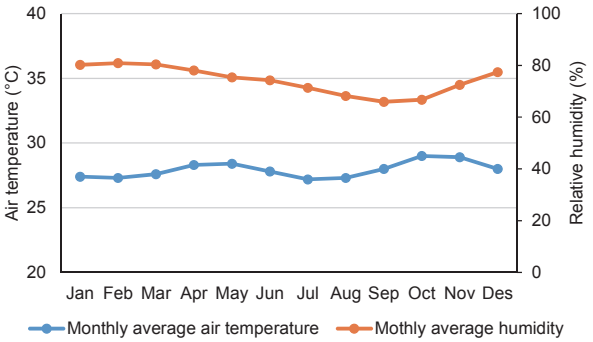

Fig. 1 Monthly average air temperature and humidity in the city of Surabaya (1993-2013)

Case study houses are apartments in Surabaya which are highly demanded by emerging middle-class market in Indonesia. There are four categories of apartments in Indonesia today. They are: private apartments, public apartments, special apartments, and state apartments (Indonesia, 2011). The first one is constructed and owned by private companies, whereas the rest is owned and managed by the government. Since the third and fourth categories are only built for special purposes, the number and development of those apartments are limited. Therefore, only the first and second categories (i.e. private apartments and public apartments) were addressed in this study (Fig. 2).

Private apartments are normally high-rise buildings and consist of 14-33 floor heights with floor area of 18-38 m² (Fig. 2c). Most of the houses in private apartments are equipped with air-conditioners. In this study, only middle-class private apartments are being considered. There are two typical types of unit in the private apartments: single room and family room. The single room contains only one room, functioning bedroom and

Fig. 2 Sample of apartments from each category and the typical unit plan: (a) Old public apartment; (b) New public apartment; and (c) Private apartment

Fig. 3 View of face-to-face interview

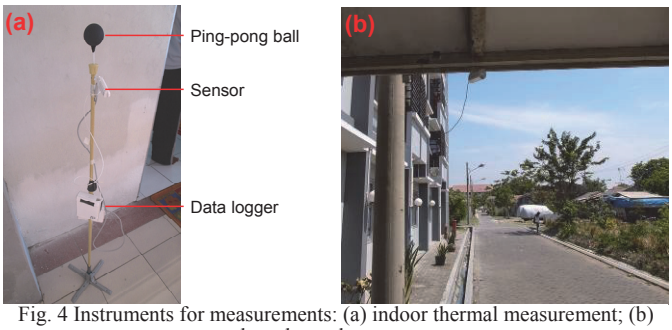

Fig. 4 Instruments for measurements: (a) indoor thermal measurement; (b) outdoor thermal measurement

kitchen, and one private bedroom. The family room has two bedrooms, one private bathroom, and one living room that is connected directly with kitchen and dining room.

On the other hand, public apartments can be broadly classified into two types: old public apartments and new public apartments (Fig. 2ab). The old public apartments were initially built to resettle slum squatters for providing better living environments (hereafter, 'old public apartment'). In the old public apartments, typical unit is one room with the floor areas of 18-21m². More than 70% of the units in those apartments have private bathroom, whereas the rest of units uses shared bathroom. The above purpose remained until 2008, when the government decided to extend the target to wider social classes, especially for low to middle income classes (hereafter, 'new public apartment'). In these new public apartments, we can also find the similar type of unit just like the one in the old public apartments with private bathroom. However, the newest type in these apartments has different room arrangement. The room is slightly larger (24-32m²) and divided by functions: a bathroom, a bedroom, a living room, and a kitchen. Both types of public apartments consist of 3-5 floor heights and almost all the houses are naturally ventilated. All of the units in both types of public apartments have one veranda which connects the indoor unit with outdoor environment.

Currently there are approximately a total of 48 housing estates in Surabaya. From these estates, 8 public and 8 private estates were selected through proportional stratified samplings (Table 1). A total of 347 households were chosen, comprising 209 respondents from old public apartments, 101 respondents from new public apartments, and 38 respondents from private apartments.

2.2 PROCEDURE OF SURVEY

The field survey was conducted during the hottest months of September to October 2013. The survey is composed of face-to-face interviews and one-week thermal measurements.

Face-to-face interviews were conducted by a number of university students. A group consisted of two students went to each respondent to do the interview using a questionnaire form (Fig. 3). The questionnaire covered: (1) socio-demographic profile of respondents (floor height, year of moving in, income, age, and occupation), (2) duration of occupancy in both weekdays and weekends, (3) thermal sensation and preference, (4) duration of opening and closing windows or doors, (5) reasons for opening and closing windows or doors, and (6) importance, expectation, and satisfaction for existing windows. In the interviews, all typical openings in the living room were considered. In most of the apartments, the front door (facing corridor space) is directly placed on one side of the living room, whereas the back door is normally placed on its rear side adjacent to the balcony. It should be noted that private apartments are not equipped with front window. However, the arrangement of the rest of the openings is similar with those in the public apartments.

One-week thermal measurements were conducted in 30 apartment houses: 11 houses for old public apartments, 9 houses for new public apartments, and 10 houses for private apartments, respectively. Two data-loggers were attached in a stand to measure globe temperature, indoor air temperature, and indoor humidity (Fig. 4a). Globe temperature was measured using TR-52i (T&D Corporation) by inserting the censor into a black-painted Ping-Pong ball. The Ping-Pong ball was then positioned at 110 cm height. Indoor air temperature and humidity were measured using TR-72ui (T&D Corporation). The above censor was placed slightly below the Ping-Pong ball. The equipment was installed in the living room and set to avoid direct sunlight. Outdoor air temperature and humidity were measured using TR-73Ui (T&D Corporation). The outdoor data logger was installed in a large open space at a certain height under the shade to prevent the effect of solar radiation (Fig. 4b).

3. Results and Discussion

3.1. PROFILE OF RESPONDENTS

The respondents were chosen to represent the residents who live in apartments of Surabaya (Table 1). The average household sizes are 3.5 to 3.6 for the public apartments and 1.9 for the private apartments. Age of respondents ranges from 20 to more than 60. The majority of respondents are housewives aged from 31-40 years old. Almost all of the respondents are Javanese (88.1%), although the respondents in the private apartments are much more diverse. The monthly average household income is the highest in the private apartments. More respondents in the new public apartments have a higher income than those in the old public apartments.

3.2 WINDOW-OPENING BEHAVIOR

Figs. 5 and 6 show the details of typical openings in the old and new public apartments, respectively. As previously mentioned, living room in most of the public apartments has two sides of opening: front and rear side. Each of them has one door and one window. For each opening, there is a small slit window (permanently opened) above them which is designed to allow the air to flow all day long. The size of the small windows varies from 20x40 cm to 50x152 cm, while the size of doors is from 80x200 cm to 80x220 cm for the old public apartments and 70x195 cm to 85x220 cm for the new public apartments. The size of the front window ranges from 120x60 cm to 120x116 cm for the old public apartments and 130x75 cm to 152x105 cm for the new public apartments. Back windows measured from

Table 1. Socio-demographic profile of respondents

	Whole sample	Old public	New public	Private
Sample size	347	209	101	38
Household size (persons)	3.5	3.6	3.5	1.9
Age (%)				
20-30 (years)	22.0	13.8	25.3	70.4
31-40	34.6	38.3	32.6	14.8
41-50	25.2	30.0	22.1	3.7
51-60	11.3	11.7	12.6	3.7
>60	7.0	6.6	7.4	7.4
Ethnic group (%)				
Javanese	88.1	92.8	85.7	59.3
Maduranese	6.0	4.8	9.2	3.7
Others	6.0	2.4	5.1	37.0
Monthly income (%)				
<1million (Rup.)	13.3	9.8	10.4	-
1-2million	39.8	50.2	25.0	20.0
2-3million	22.8	22.0	29.2	10.0
3-4million	13.0	11.7	15.6	30.0
>4million	11.1	6.3	19.8	40.0
No. of apartments				
Built before 2008	7	5	-	2
Built after 2008	9	-	3	6
Floor area (m²)	18-38	18-21	24-32	18-38

120x50 cm to 120x60 cm for the old public apartments and 50x35 cm to 130x80 cm for the new public apartments. In most of the public apartments, all of the openings are operable.

As shown in Table 2, the respondents in public apartments tend to open their doors (12.8 hours for both old and new) for a longer period than to open windows (7.6 and 10.6 hours for old and new respectively). In contrast, the respondents in private apartments open doors for 1.4 hours and windows for 3.4 hours on average. Unlike those in public apartments, they tend to open their windows longer by 2 hours than doors. In the whole sample, the back door is used the longest (8.5 hours), whereas the back window is least used (2.9 hours). This tendency is found similarly among the respondents in both old and new public apartments. On the other hand, the respondents in private apartments tend to open their back windows longer than other openings (3.4 hours). The respondents in the old public apartments tend to open their front doors longer by 1.9 hours than the front windows, while those in new public apartments tend to open the front windows longer by 4.0 hours than the front doors.

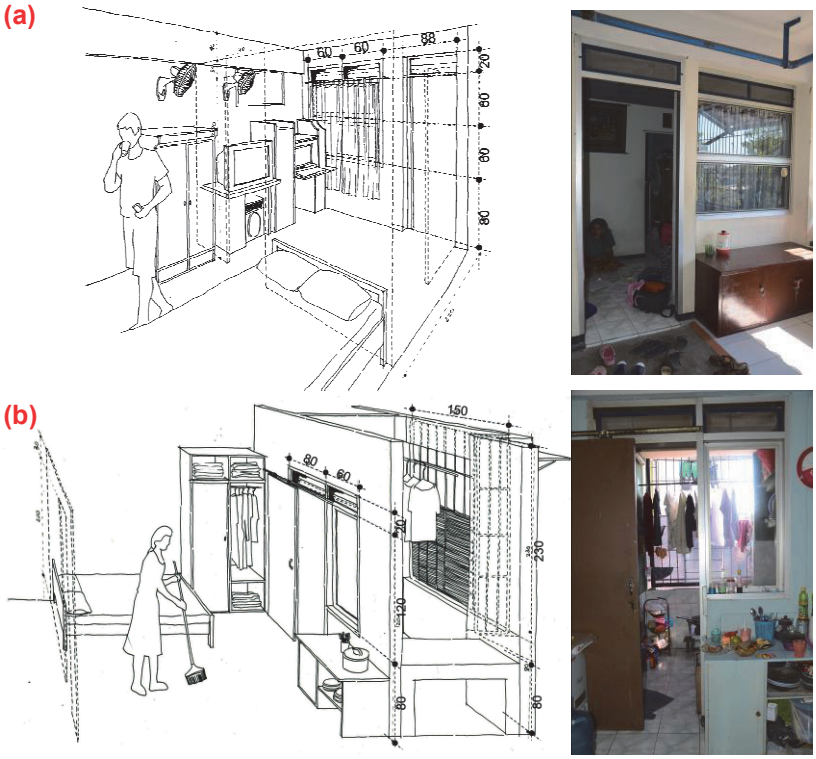

Fig. 5 Typical windows and doors in the old public apartments: (a) front side; (b) rear side

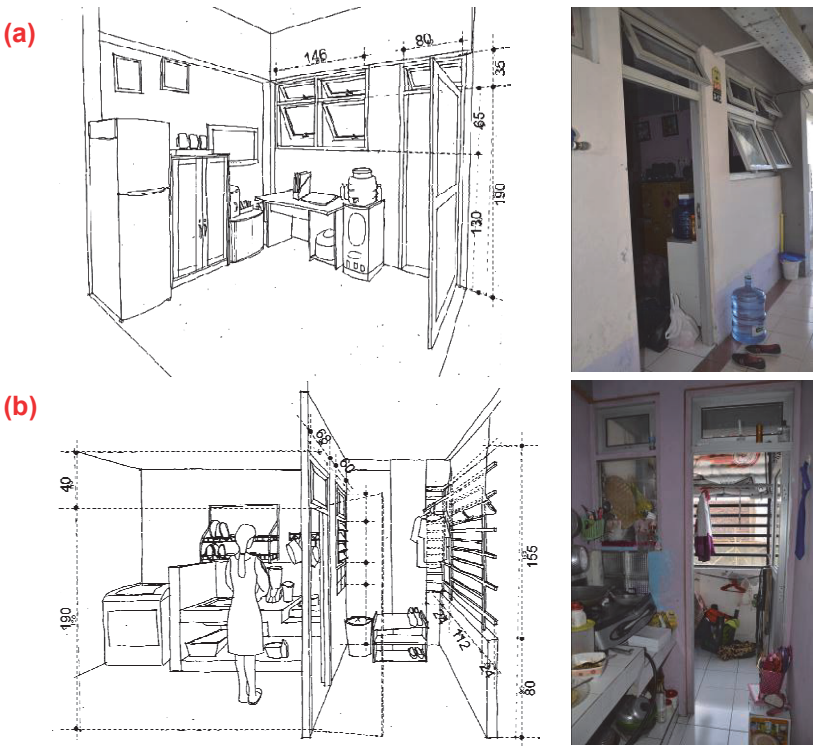

Fig. 6 Typical windows and doors in the new public apartments: (a) front side; (b) rear side

Fig. 7 shows the percentage of respondents who open each of the windows and doors during a day in old and new public apartments, and private apartments. First of all, the figure clearly shows that the occupants in the public apartments (both old and new) have a relatively high utilization of both front/ back doors and front window particularly during daytime (30-60%), while those in the private apartments rarely open doors or windows (0-30%). In general, most of the respondents in public apartments are likely to open only one opening for one side of units at one time. As indicated, less than 20% of the respondents open both windows and doors even during daytime in both public apartments for both front and back openings. In the case of old public apartments, the usage of front door (40-60%) was higher compared to the front window (30-40%). In contrast, the respondents in the new public apartments tend to open the front window (50-60%) more than the front door (20-40%). The usage patterns of back openings are similar between old and new public apartments. About 40-50% of the respondents open only the back door without opening the back window at the same time. In the nighttime, the respondents in both apartments tend to close their windows, except that 20-30% of the respondents continue to open the back door throughout the night.

As shown in Fig. 8, when analyzing all the opening usages at the same time, it can be seen that approximately 80-90% of respondents in naturally ventilated apartments (i.e. public apartments) open at least one of the windows or doors during daytime (6:00 to 19:00). The percentages decrease after 19:00 and reach its bottom lines between 24:00 and 2:00. In the nighttime, about 30-50% still use their openings.

Table 2. Average hours of opening windows or doors

	Whole sample	Old public	New public	Private
All openings	14.8	15.5	17.0	4.8
Day	9.7	10.5	10.4	3.1
Night	5.1	4.9	6.6	1.7
Doors	11.5	12.8	12.8	1.4
Windows	8.1	7.6	10.6	3.4
Front door	5.8	7.5	4.6	0.7
Front window	6.2	5.6	8.6	-
Back door	8.5	9.1	10.2	1.0
Back window	2.9	2.8	3.5	3.4

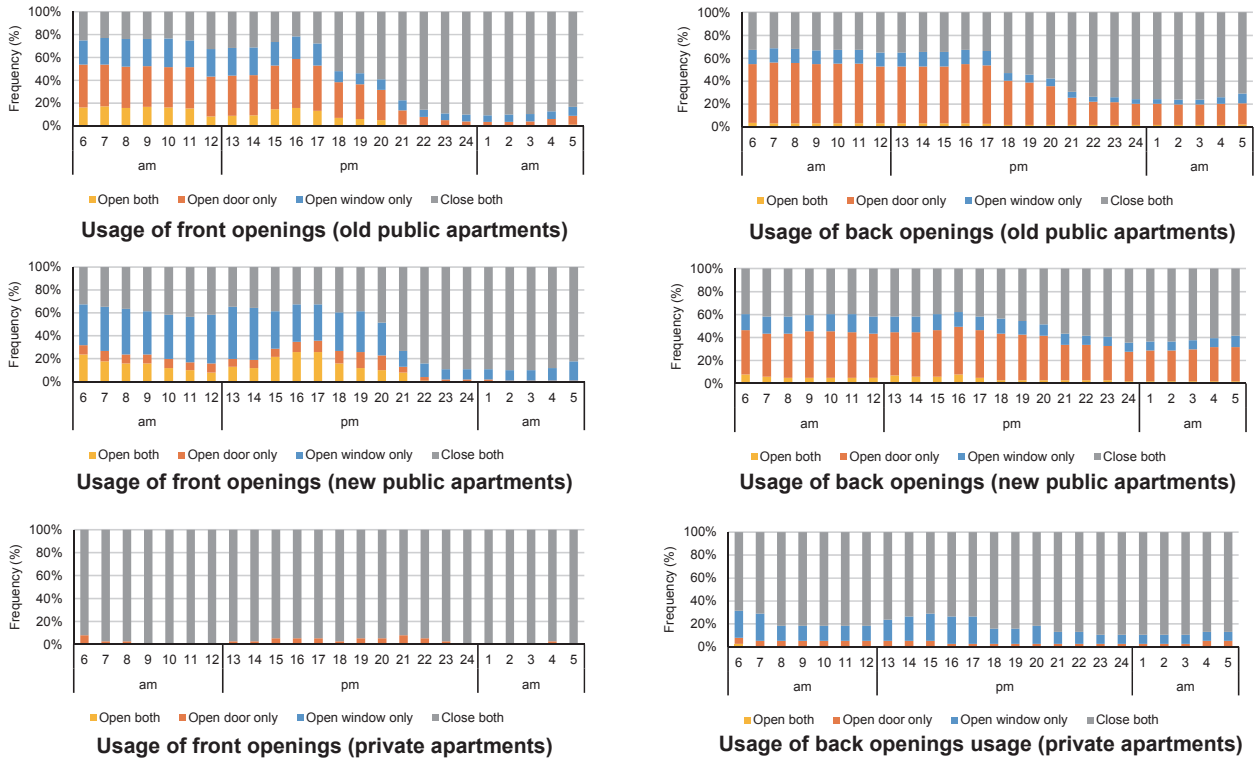

Fig. 7 Daily usage pattern of doors and windows for each category

In contrast, the opening usages are very low in air-conditioned apartments (i.e. private apartments) even during daytime (10-40%). Further, the results show that majority of respondents in the old public apartments open at least one door or window for both front and back sides of the units (40-50% during daytime). During nighttime, 20% of them open only their back opening(s), although majority of them (60-70%) close every opening. Meanwhile, in the new public apartments, about 30-40% of respondents open at least one door or window for both sides of their units during daytime, while 20% of them open a door or window on the front side only. Approximately 30% of the respondents continue to use at least one back opening even during nighttime.

As shown in Table 2, in the whole sample, the respondents use their openings more than half of a day (14.8 hours) on average. The average duration during daytime (6:00 to 18:00) (9.7 hours) was almost two times longer than that of nighttime (5.1 hours). This tendency is seen similarly for all the categories except for private apartments. In the private apartments, the average duration of opening windows or doors is very short, even in daytime (less than 5 hours).

3.3 REASONS FOR OPENING/CLOSING WINDOWS

Figs. 9 and 10 illustrate major reasons for respondents to open or close their windows or doors. The highest reasons for opening windows/doors are found to be 'obtaining fresh air' (74.3%), 'letting wind to enter' (66.2%), and 'to provide cooling' (45.4%) for the whole sample (Fig. 9). In each category, the order of the top two reasons remains the same. This implies that the respondents particularly expect ventilation and air flow through opening widows/doors.

On the other hand, the top reasons for not opening windows or doors are 'privacy' (43.1%), 'insects' (41.0%) and 'security' (30.4%) for the whole sample (Fig. 10). In each category, the top reasons for not opening windows are found to be different: 'AC

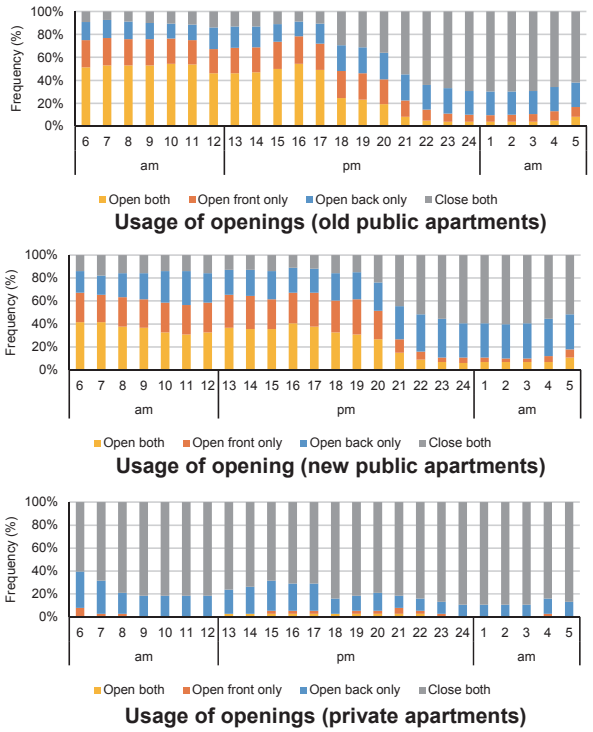

Fig. 8 Daily usage pattern of front and back opening for each category

usage' (52.6%) and 'dust/air pollution' (47.4%) for the private apartments, 'insects' (52.9%) and 'privacy' (42.8%) for the old public apartments, and 'privacy' (57.0%) and 'security' (44.0%) for the new public apartments. 'Security' reason may especially affect the closing behavior during nighttime. On the other hand, 'privacy' may be the major reason for the respondents not to open windows during daytime. As previously discussed, the pattern and average duration of opening front window and door were different between old and new public apartments, unlike the

back door and window (see Fig. 7). Further results showed that the respondents in the old public apartments who open their front door did not open their front windows. In contrast, in the new public apartments, most of them opened only front window but not front door. Fig. 10 implies that the occupants in new public apartments are more concerned about privacy and security than those in old public apartments. This means that when the occupants in the new public apartments cannot open their front door, they compensate it by opening front window instead. In the old public apartments, the concerns of privacy and security should be less because most of the residents were relocated from the same areas. This may be one of the reasons for opening front door more in the old public apartments.

3.4 IMPORTANCE, EXPECTATION, AND SATISFACTION FOR WINDOWS

Fig. 11 shows the importance, expectation, and satisfaction for existing windows by the respondents in the apartments. More than 80% of respondents acknowledge the importance of windows at home for all categories ('important' of 54.1% and 'very important' of 37.6% for the whole sample). They said that 'air flow' (73.1%), 'ventilation' (65.6%), and 'natural lighting' (46.5%) are the most important functions of windows. Accordingly, they regard the same functions as their major expectations for windows (52.9% for 'air flow', 47.4% for 'ventilation, and 46.0% for 'natural lighting'). Only the

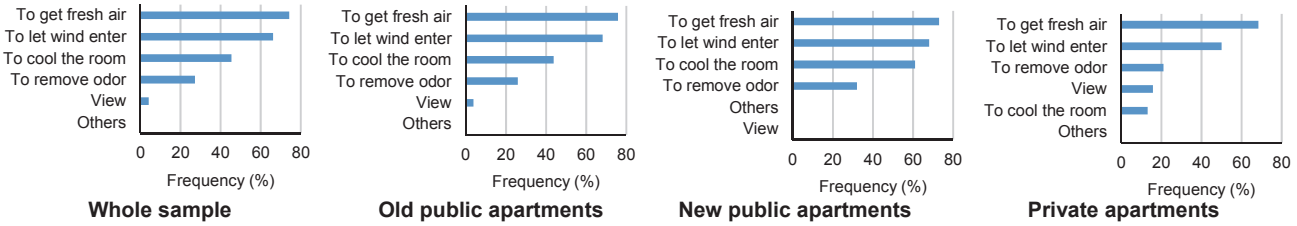

Fig. 9 Reasons for opening windows or doors

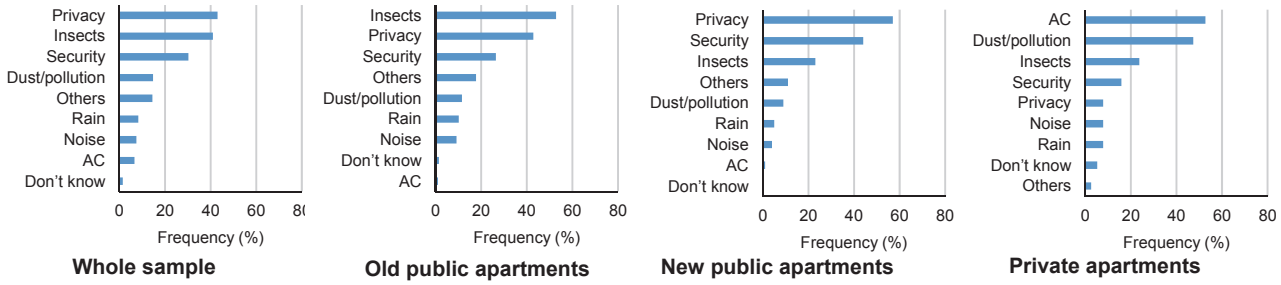

Fig. 10 Reasons for not opening windows or doors

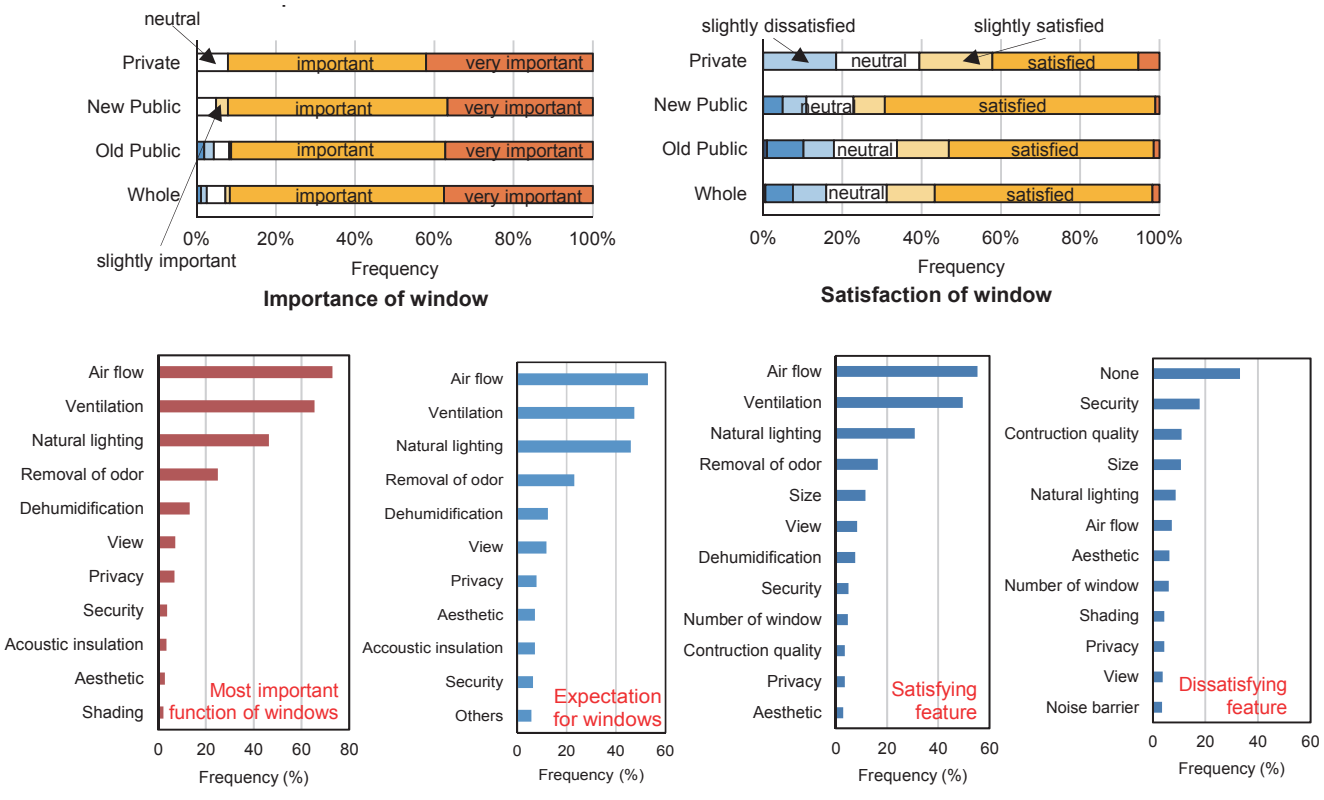

Fig. 11 Importance, expectation, and satisfaction for windows

respondents in the new public apartments chose 'natural lighting' as their top expectation for windows.

In terms of satisfaction level, majority of the respondents said they are 'satisfied' with the existing windows (68.8%), while 15.3% are 'neutral', and less than 15% are 'unsatisfied' for the whole sample. More respondents in the new public apartments are satisfied with their windows (77.2%) than those in the old public apartments (66.2%) and private apartments (60.5%). On average, the most satisfied features of the current windows include 'air flow' (55.5%), 'ventilation' (49.7%), and 'natural lighting' (31.0%). Very few respondents are dissatisfied by their current windows. More than 30% answered 'none' as dissatisfied features of windows, followed by 'security' (17.9%), 'quality of construction' (11.0%), and 'size of windows' (10.7%). It can be seen that occupants in apartments of Surabaya are generally satisfied with their windows particularly for their functions of air flow, ventilation and natural lighting. This result, particularly the priorities for air flow and ventilation, is consistent with their reasons for opening windows or doors that were analyzed in the section 3.3 (see Fig. 9).

3.5 ENVIRONMENTAL CONDITIONS

Fig. 12 shows the statistical summary of one-week thermal measurements in the selected houses (n=30). Figs. 13 and 14 present examples of one-week temporal variations of air temperature, globe temperature and relative humidity in a public apartment (naturally ventilated) and a private apartment (air-conditioned), respectively. As indicated in Fig. 12, the outdoor air temperature ranges from 25.6-36.7°C whereas the outdoor relative humidity ranges from 27-77% during the measurement periods. The mean globe temperature measured 29.7°C, while mean indoor air temperature is 30.5°C and mean humidity is 56.8% for the whole sample. Due to the use of air-conditioning, indoor air temperature in the private apartments is significantly lower (about 26°C) during its operation (Fig. 14). As a result, the mean indoor air temperature in the private apartments is lower by approximately 1.5°C than that in the public apartments (Fig. 12). Accordingly, the mean relative humidity in the private apartments is found to be slightly higher by 4% than that in the public apartments even though air conditioning was utilized. There are no significant differences for indoor air temperature, globe temperature, and relative humidity between samples in the old and new public apartments.

Even in the naturally ventilated apartments, the diurnal air temperature ranges are smaller than that of the outdoor temperature, though the mean indoor air temperatures in both old and new public apartments (30.9°C and 31.0°C) are slightly higher than the mean outdoor air temperature (30.3°C). As shown in Fig. 13, in general, daytime indoor air temperature is about 6°C lower than the outdoors, while nocturnal indoor air temperature is about 3°C higher than the outdoors in the naturally ventilated public apartments. The peak of indoor air temperature is delayed, which is found around 17:00 to 18:00, compared to the outdoors. Moreover, it is found that the measured globe temperatures are slightly lower than the corresponding air temperatures throughout the day in almost all the apartments. Therefore, it is apparent that indoor air temperature in these public apartments generally maintains lower daytime air temperature with the narrow range of about 28 to 31°C due to the structural cooling effects. Although most of the occupants (80-90%) open windows/doors during daytime (see Fig. 8), indoor air temperature does not follow the outdoor air temperature, except for a few hours during nighttime (24:00 to 9:00) in the private apartments (see Fig. 14). This indicates that air change rates in these public apartments are not necessarily sufficient to change the indoor air even when windows or doors are opened during daytime.

3.6 THERMAL SENSATIONS

Fig. 15 shows the sensation and preference of respondents for thermal comfort, air flow, humidity, natural lighting, and general comfort in the living room during the day. The sensations were measured in 7-point scale while preferences were measured in 5-point scale. More than 57% of the respondents regard the thermal comfort in their living room as 'warm' to 'hot' even for those in the private apartments. Accordingly, the preferences for cooler environments are evident (more than 68%). Despite the use of air-conditioners, more than 97% of respondents in the private apartments prefer cooler indoor conditions. Meanwhile, more than 40% of the respondents found humidity in the living room to be 'slightly humid' to 'very humid'. Consistently, they prefer 'less humid' conditions (38.5%). However, almost 60% of the respondents do not prefer to change the conditions, though only 36% of them answer 'neutral' for their humidity sensation.

As for the indoor air flow, more than 70% of respondents consider it to be 'slightly high' to 'very high'. Despite the 'high' air flow conditions perceived by the respondents, more than half of the respondents do not prefer to change the current conditions, while about 30% prefer even higher air flow. This result also clearly indicates their high preference and priority for air flow conditions in their apartments. Similarly, in the case of natural lighting, although more than 50% of the respondents regard it as 'slightly bright' to 'very bright', about 61.7% of them do not prefer to change the conditions while 30% still prefer brighter condition.

In general, more than 60% of the respondents regard their thermal condition in the apartments as 'comfortable', even though they prefer cooler thermal condition. Only less than 10% of respondents answered 'uncomfortable', and no single answer of 'very uncomfortable' was found. This indicates that the respondents in these apartments already adapted towards the prevailing environmental conditions in their houses.

4. Conclusions

A field survey was conducted in apartments of Surabaya, Indonesia to investigate occupants' window-opening behavior and their thermal conditions. A total of 347 households were interviewed and about 30 houses were covered for measurements of thermal conditions. The major findings are summarized as follows:

(1) In most of the public apartments, the living room has two sizes of opening, i.e. front and rear side. Each of them has one door and one window. The results showed that 80-90% of the respondents open at least one of the windows and doors during daytime (6:00 to 19:00), while 30-50% still open one of the openings at night (19:00-6:00). The average duration of opening windows/doors is 16-17 hours/day in the naturally ventilated public apartments, while the corresponding duration in air-conditioned private apartments is less than 5 hours/day. More respondents in the old public apartments open the front door rather than the front window, while those in the new public apartments open the front window instead of the front door. The respondents in the both old and new public apartments tend to open either window or door on each side of the living room. Less than 20% of them open both door and window simultaneously on the same side.

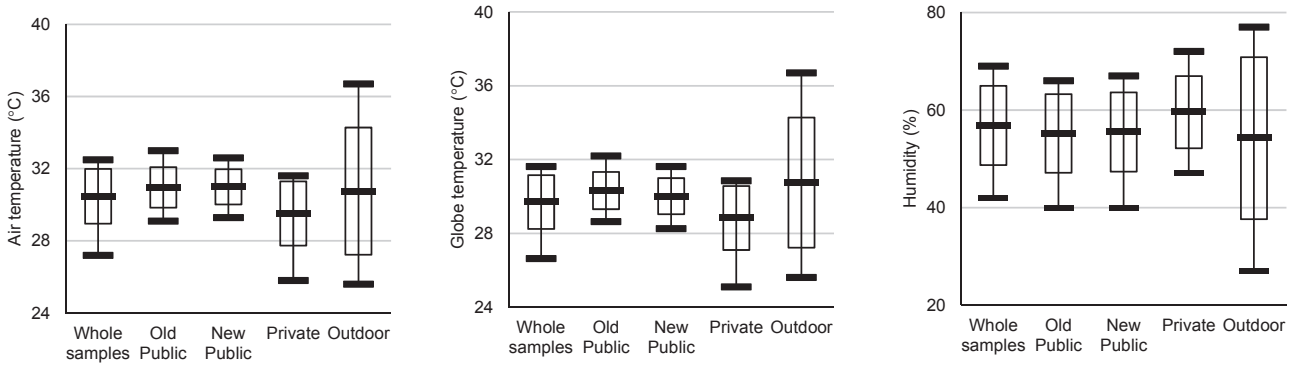

Fig. 12 Statistical summary of air temperature, globe temperature, and humidity (5th and 95th percentiles, mean and ± one standard deviation)

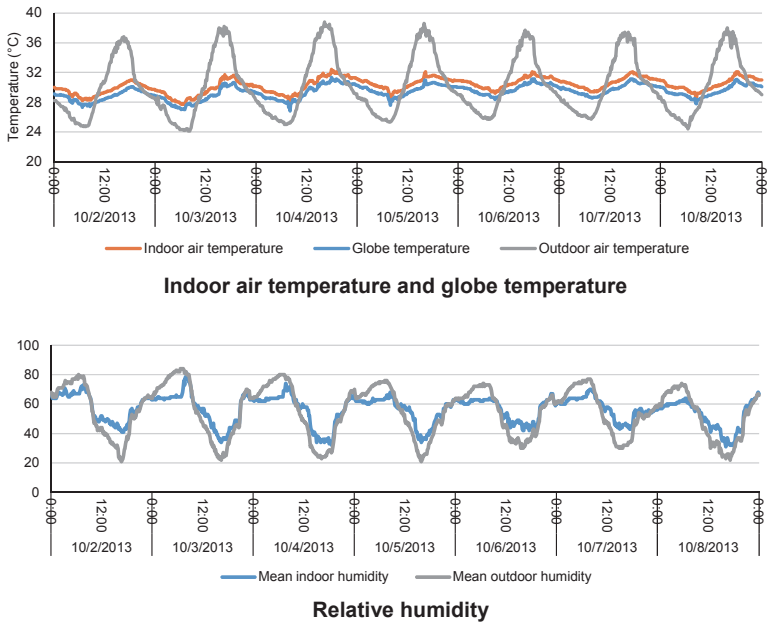

Fig. 13 Temporal variation of indoor air temperature, globe temperature, and relative humidity in the public apartments (i.e. naturally ventilated apartments)

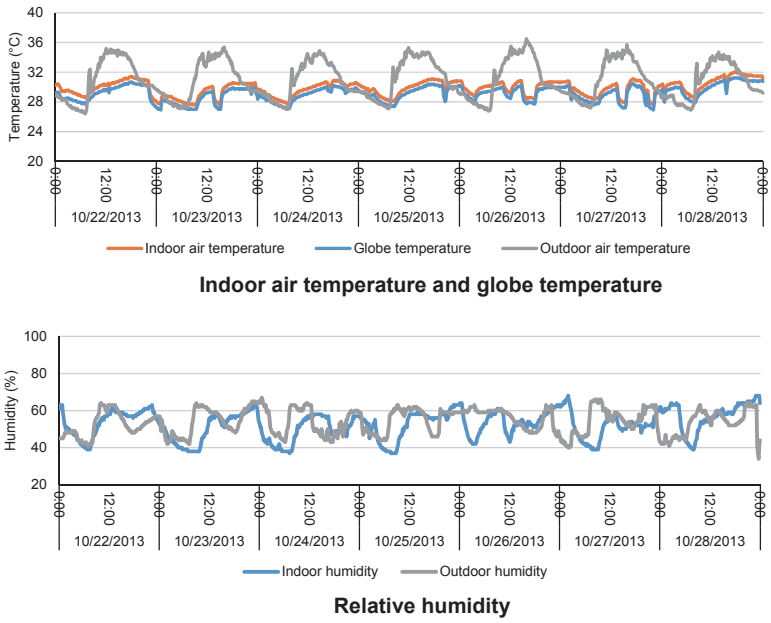

Fig. 14 Temporal variation of indoor air temperature, globe temperature, and relative humidity in the private apartments (i.e. air-conditioned apartments)

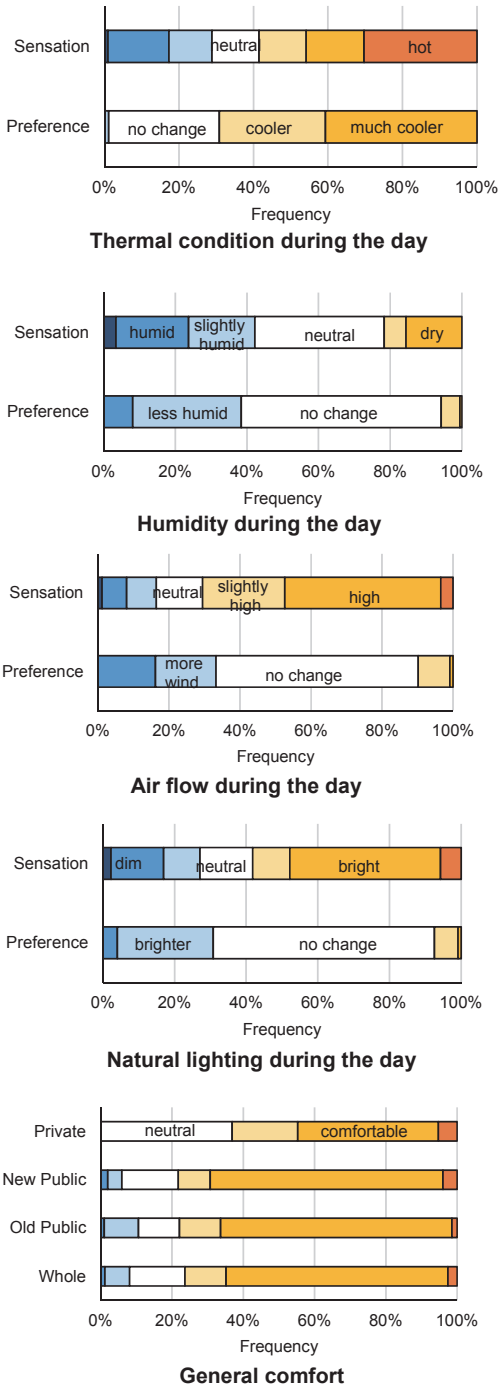

Fig. 15 Thermal sensations and preferences

(2) The survey results indicated that the occupants in new public apartments are more concerned about privacy and security than those in old public apartments. These are probably the main reasons why the occupants in the new public apartments tend to open the front window instead of the front door. Further, it could be seen that occupants in these apartments are generally satisfied with their windows especially for their functions of air flow, ventilation and natural lighting. In particular, air flow and ventilation are found to be the major reasons for them to open windows or doors.

(3) The results of measurement showed that even in the naturally ventilated apartments, the diurnal indoor air temperature ranges are smaller than that of the outdoor temperature, which is 25.6-36.7°C. In general, indoor air temperatures is about 6°C lower than the outdoors during 11:00 to 19:00, while it is 3°C higher than the outdoors for the rest of the day, i.e. nighttime. It is apparent that indoor air temperature in these public apartments generally maintains lower daytime air temperature with the narrow range due to the structural cooling effects. Although most of the occupants open windows/doors during daytime, indoor air temperature does not follow the outdoor air temperature in most cases. This indicates that air change rates in these public apartments are not necessarily sufficient to change the indoor air even when windows or doors are opened during daytime.

(4) More than 57% of the respondents regard the thermal comfort in the living room as 'warm' to 'hot', thus prefer cooler environment (more than 68%). As for the indoor air flow, more than 70% of respondents consider it to be 'slightly high' to 'very high', but more than half of the respondents do not prefer to change the current conditions, while about 30% prefer even higher air flow. This result also clearly indicates their high preference and priority for air flow conditions in their apartments.

Based on the above findings, it can be said that occupants in naturally ventilated apartments in hot-humid climate of Surabaya tend to open windows or doors as much as possible at least during daytime for satisfying air flow and ventilation in particular. The air change rates in these houses are, however, not necessarily sufficient to change the indoor air, and therefore the indoor air temperature maintains much lower values during daytime than the outdoors. This implies that a high air flow and a high air change rate that would increase indoor air temperature are not required in these apartments at least during daytime. Reducing indoor air temperature is probably not a trigger for opening windows or doors in the hot-humid climatic regions such as in Surabaya.

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