ERGONOMIC INTERVENTION OF HOUSES TYPE 36/120 SAVES ELECTRICITY AND INCREASES COMFORT OF OCCUPANTS IN NUANSA KORI HOUSING SADING MENGWI BADUNG

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ABSTRACT

Development of the housing sector has now spread to the suburban areas of Denpasar; even some rural areas in Bali have become targets of housing developers. Designing and arranging of houses through ergonomic intervention comprises one of several efforts for improving the houses' quality in terms of their natural comfort. The ergonomic intervention should meet such criteria as to be technically applicable, less costly, energy saving especially that of electricity, socio-culturally convenience, and environment friendly. This experimental study being reported applied a treatment by subject design, in which eight houses were selected as sample, located in the housing complex of Perumahan Nuansa Kori Sading Mengwi Badung. Of the eight sampled houses, each two houses faced north, south, east and west, respectively. Twenty six occupants of the eight sampled houses were interviewed using a questionnaire. All samples were selected by stratified random sampling. The ergonomic intervention comprised remodeling of ventilation and windows of all the sampled houses. Data collecting of objective comfort was carried out before and after intervention i.e. at 8 am, 10 am, 12 pm, 2 pm, 4 pm and 8 pm, by measuring temperature, humidity, light intensity, and airflow. Data of subjective comfort were collected by questionnaire, which had been tested earlier for its validity and reliability. The results showed that (1) before intervention the average of wet temperature was 23.66 ± 1.36 ºC, after intervention was 23.09 ± 1.20 ºC; (2) before intervention the average of dry temperature was 28.76 ± 1.07 ºC, after intervention was 27.88 ± 0.73 ºC; (3) relative humidity before intervention was 73.44 ± 4.37 %, after intervention was 72.63 ± 2.73 %; (4) natural light intensity before intervention was 134.94 ± 71.69 lux, after intervention was 229.69 ± 114.53 lux; (5) the average of airflow before intervention was 0.10 ± 0.04 m/sc, after intervention was 0.31 ± 0.08 m/sc; and (6) electricity saving resulted in 11% as evidenced by decrease of electricity bill by 8%. The conclusions could be arawn are (1) that ergonomic intervention by remodeling ventilation and windows of houses type 36/120 could improve objective comfort by 12.4% ($p<0.05$), along with increase of subjective comfort of the occupants of the houses facing all directions; dan (2) moreover, electricity saving resulted in 11% ($p<0.05$) as evidenced by decrease of electricity bill by 8% ($p<0.05$). This study suggests that ergonomic intervention should be applied since early in the construction of houses in order to make them cheaper, healthier, and more comfortable.

Key words: *Ergonomic intervention, house type 36/120, comfort, electricity saving.*

1. Introduction

The development of housing sector was initiated in Indonesia in the 1970s. The development started to involve Bali in the 1980s and since then it had extended to suburban areas of Denpasar, even also to some rural areas in Bali. The increasing number of population is one of the factors that caused the high demand for housing.

The ever increasing demand for housing in the future needs to be anticipated by making a regulation on the use of land for housing, so developers, government and community have a legal reference and rule concerning management and use of land for housing. Increase of quantity in the housing development should parallel with improvement of the quality (Newmark and Thompson, 1977). The quality referred here is concerned with houses that are healthy and comfortable to live in.

Results of a study previously carried out in Nuansa Kori Housing Sading Mengwi in September 2006 showed: a) in living rooms of 15 m width, the average indoor wet temperature was 25 ºC, average natural light intensity 200 lux, bulb light intensity 250 lux, indoor airflow 0.3 m/sec, outdoor airflow 1.8 m/sec, outdoor light intensity 45,000 lux, outdoor wet temperature 26 ºC, outdoor dry temperature 31 ºC; b) in bedroom of 9 m^2 width, the average wet temperature was 25.5 ºC, dry temperature 30 ºC, natural light intensity 20 lux, bulb light intensity 50 lux, and indoor airflow 0 m/sec; c) in kitchens of 3 m^2 width, average indoor wet temperature was 24 ºC, dry temperature 29 ºC, natural light intensity 125 lux, bulb light intensity 200 lux, and indoor airflow 0 m/sec.

There were several causal factors of the inconvenience in the three rooms, such as outlay, model, size and location of ventilation, model and size of windows as well the lower opening direction (vertical). Thus, both factors result in the less optimum air circulation in the rooms (no cross ventilation) and limitation of lighting and natural air circulation into the rooms. These factors cause the rooms to become damp, stifled and electricity wasting.

The previous study on houses of type 36/120 at Nuansa Kori Housing Sading Mengwi Badung that involved 20 respondents showed: a) 55% respondents complained about comfort aspect such as air circulation and natural lighting in the rooms; b) 30% respondents complained about security aspect (placement of bars on ventilation and window); and c) 15% respondents complained about interior and furniture aspects such as concerning arrangement of facilities that are related to the pattern of indoor activities. Results of a questionnaire survey on the occupants' expectations done previously showed: a) 58% respondents expected improvement of the model and location of ventilation and windows; b) 31% respondents wished for more flexible furniture; and c) 11% respondents expected improvement of arrangement of facilities.

An ergonomic intervention by remodeling ventilation and windows of the livi ng rooms, bedrooms and kitchens of the houses of type 36/120 is thought to be able to save electricity as well as increase comfort of the occupants.

2. Materials and methods

This study was an experimental study using treatment by subject design. The study sample involved eight houses with two houses each facing North, South, East and West, respectively. The study also involved 26 respondents who were occupants of the sample houses of type 36/120 at Nuansa Kori Housing Sading Mengwi Bsdung. The samples were chosen by stratified random sampling method. The ergonomic intervention was remodeling of ventilation and windows done to all the sample houses. Objective data on convenience were collected before and after intervention i.e. at 8 am, 10 am, 12 pm, 2 pm, 4 pm and 8 pm Central Indonesian Time, by measuring temperature, humidity, light intensity and airflow. Subjective data were collected using a questionnaire, whose validity and reliability had been examined earlier.

3. Results and Discussion

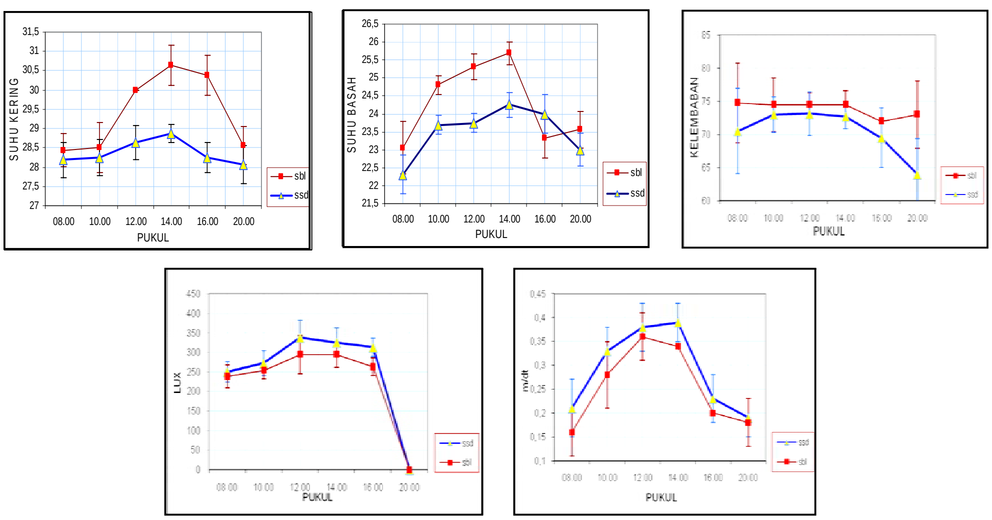

Figure 1 Condition of Living Rooms before and after improvement at Nuansa Kori Housing Sading Mengwi Badung

Figure 1 shows wet temperature, dry temperature, relative humidity, natural light intensity and airflow in the living rooms before and after improvement taken at 8 am, 10 am, 12 pm, 2 pm, 4 pm and 8 pm, Central Indonesian Time. All measurement values differed significantly ($p<0.05$). Wet temperature, dry temperature, relative humidity, natural light intensity and airflow of living rooms before and after improvement taken at 8 am, 10 am, 12 pm, 2 pm, 4 pm and 8 pm decreases wet temperature by 0,033%, dry temperature by 0,036% and decreases relative humidity by 0,048%, but increases natural light intensity by 0,11% and increases airflow by 0,13%. This means that ergonomic intervention by remodeling ventilation and windows of houses type 36/120 changed significantly the status of wet temperature, dry temperature, relative humidity, natural light intensity and airflow of living rooms.

Wet temperature, dry temperature, relative humidity, natural light intensity and airflow of living rooms before and after improvement in accordance with the orientation of the houses facing North, South, East, and West did not show any significant difference (p>0.05). This means that ergonomic intervention by remodeling ventilation and windows of living rooms could overcome the influence of the aspect of houses' orientation (facing North, South, East and West) to the level of comfort of the living rooms.

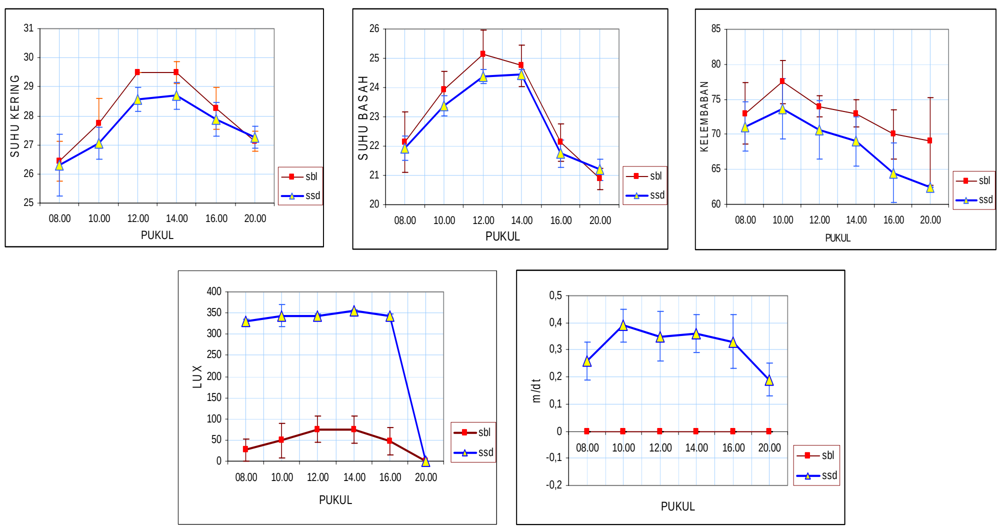

Figure 2 Condition of bedrooms before and after improvement at Nuansa Kori Housing Sading Mengwi Badung

Figure 2 shows significant difference (p<0.05) on the measurement values of wet temperature, dry temperature, relative humidity, natural light intensity and airflow in bedrooms before and after improvement collected at 8 am, 10 am, 12 pm, 2 pm, 4 pm and 8 pm, Central Indonesian Time. Wet temperature, dry temperature, relative humidity, natural light intensity and airflow of bedrooms before and after improvement taken at 8 am, 10 am, 12 pm, 2 pm, 4 pm and 8 pm decreases wet temperature by 0,013%, dry temperature by 0,017% and decreases relative humidity by 0,061%, but increases natural light intensity by 5,27% and increases airflow by 0,31%. This means that ergonomic intervention by remodeling ventilation and windows of houses type 36/120 changed significantly the status of wet temperature, dry temperature, relative humidity, natural light intensity and airflow of bedrooms.

Wet temperature, dry temperature, relative humidity, natural light intensity and airflow in in bedrooms before and after improvement according to front houses facing North, South, East and West did not show any significant difference (p>0.05). It signified that ergonomic intervention by remodeling ventilation and windows could overcome the influence of the houses' orientation (facing North, South, East and West) to the comfort of bedrooms.

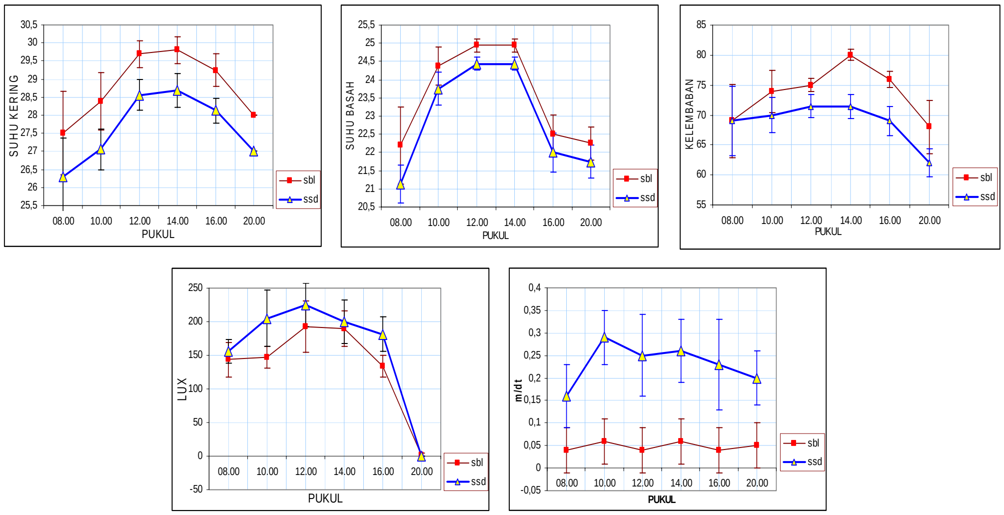

Figure 3 Condition of Kitchen before and after improvement
at Nuansa Kori Housing Sading Mengwi Badung

Figure 3 shows obvious changes that occurred to the wet temperature, dry temperature, relative humidity, natural light intensity, airflow in kitchens before and after remodeling which taken at 8 am, 10 am, 12 pm, 2 pm, 4 pm and 8 pm, Central Indonesian Time, showing a significant difference ($p<0.05$). Wet temperature, dry temperature, relative humidity, natural light intensity and airflow in the kitchens before and after improvement taken at 8 am, 10 am, 12 pm, 2 pm, 4 pm and 8 pm decreases wet temperature by 0,026%, dry temperature by 0,041% and decreases relative humidity by 0,070%, but increases natural light intensity by 0,19% and increases airflow by 3,79%. It indicates that ergonomic intervention by remodeling ventilation and windows of house type 36/120 gave significant changes to wet temperature, dry temperature, relative humidity, natural light intensity and airflow in the kitchens.

Wet temperature, dry temperature, relative humidity, natural light intensity and airflow in the kitchens before and after improvement according to front houses facing North, South, East and West did not show any significant difference ($p>0.05$). It signified that ergonomic intervention by remodeling ventilation and windows could overcome the influence of the houses' orientation (facing North, South, East and West) to the comfort of kitchens.

The average of temperature in the living rooms, bedrooms and kitchens was 27 ºC with interval 26 – 29 ºC. The result of this study matched with Manuaba's statement (1983) that satisfactory level of objective comfort of houses was that with a temperature between 24 - 28 ºC. In this study, the relative humidity average of living rooms, bedrooms and kitchens was 68% with interval 60 – 80%. The result was in accordance with Meijs (1983) who stated that satisfactory level of objective comfort of houses was at a humidity of 40% - 70%. On the other hand, examination on light intensity of living rooms, bedrooms and kitchens showed an average of 350 lux with interval 175 – 400 lux. The result was lower than that stated by Grandjean (1993) and Mangunwijaya (1997), in which satisfactory level of objective comfort of houses seen from light intensity aspect was 500 – 700 lux. Examination on airflow likewise gave result of 0.2 m/sec on average with interval 0.1 – 0.5 m/sec. The result of this study was in the range of comfortable airflow that is 0.1 – 0.5 m/sec (Mangunwijaya, 1997). The result was somewhat similar to that of Lippsmeier (1994), who stated that comfort standard of temperature in the equator areas was 22.5 ºC – 29.5 ºC with relative humidity 20 – 50%. Meanwhile, Sujadnja (1998) stated that in relation with the construction of *Bale Meten* in Bali, microclimate factors (lighting, temperature, humidity, and air circulation) affected the indoor comfort with relative contribution as follows: 8% from temperature and humidity, 0.41% from lighting and air circulation, with total relative contribution of 9.35%. Moreover, it can be explained that factors strongly influenced the microclimate were ventilation and windows. Windows had positive correlation to lighting with *weak classification* (r = 0.32). It was also correlated positively to air circulation with moderate classification (r = 0.41). While ventilation also had similar positive correlation to air circulation in moderate classification (r = 0.44). Next Darmawan (2005) did modification to the building of LPD Desa Pakraman Sibang kaja by choosing material that may decrease translocation efficiency of entire heat that the building received. The modification was replacing terrazzo with red bricks without using cement, replacing bricks of 115 mm to 220 mm, replacing glass from thickness of 3 mm to 8 mm and placing gypsum board on the wall of houses. The modification made significant decrease of heat acceptance value for 9.84% from 15602 Watt or 15.6 kW to 14122.49 Watt or 14.12 kW per day after modification. The study result of Nityasa (1999) also showed that improvement of houses type 36/100 by using rain drain of 1.30 meter width could increase comfort. Furthermore, it proved that South oriented houses were most comfortable, next were houses oriented to East, North and West.

The intervention also could make temperature, humidity, light intensity, and airflow remain in a comfort zone in which dry temperature was 25 ºC – 27 ºC, humidity 56% - 72%, light intensity 350 – 460 lux and airflow 0.22 m/sec – 0.34 m/sec. It means that ergonomic intervention by remodeling ventilation and windows can overcome the inconvenience effect caused by the difference of direction or orientation of the houses.

Subjective comfort was measured by a questionnaire which consisted of 16 question items. These items related with the conditions of room such as temperature, humidity, light intensity, and airflow. The data collected by using the questionnaire showed increased score of comfort from 30.50 ± 1.16 to 62.80 ±1.46 (as shown in Table 5.25). Subjective comfort score after and before intervention significantly differed. It indicates that after ergonomic intervention by remodeling ventilation and windows of houses type 36/120, there was increase of subjective comfort score of occupants in living rooms, bedrooms and kitchens.

Average use of electricity before improvement was 85 KwH with electricity bill Rp 56,184. After improvement the amount decreased to Rp. 51,000 with use of 77KwH. According to calculation result, energy saving occurred in 11% and the bill decreased by 8% a month. Comparing the study result of Lumbantoruan (2008), this study showed there was electricity saving by 9.44 KwH a month, which means it reduced CO_2 to 5.37 kg a month or 0.015 ton a year.

Novelty in research that: (1) comfort of houses type 36/120 which measured by the wet temperature, dry temperature, relative humidity, natural light intensity, airflow can be achieved by the ergonomic intervention; (2) the objective comfort index of houses type 36/120 inherent with the subjective comfort of occupants; (3) comfort of houses type 36/120 with four orientations of houses ie. North, South, East and West could be achieved similarly by the ergonomic intervention; and (4) ergonomic intervention can dicrease electricity by remodeling ventilation and windows of houses type 36/120.

4. Conclusion

Based on the study result, analysis and discussion by ergonomic intervention of houses type 36/120 at Nuansa Kori Housing Sading Mengwi Badung, it can be concluded that: a) ergonomic intervention by remodeling ventilation and windows of houses type 36/120 increases objective comfort in 12.4% along with subjective comfort of occupants of four orientations of houses ie. North, South, East and West; b) ergonomic intervention by remodeling ventilation and windows of houses type 36/120 can save electricity by 11% and decreases electricity bill by 8%.

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INTERVENSI ERGONOMI MENINGKATKAN KENYAMANAN DAN MENGHEMAT ENERGI LISTRIK RUMAH TIPE 36/120 DI PERUMAHAN NUANSA KORI SADING MENGWI BADUNG

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ABSTRAK

Perkembangan sektor perumahan sudah merambah ke pinggiran wilayah kota Denpasar, bahkan beberapa wilayah pedesaan di Bali sudah menjadi sasaran para pengembang. Perencanaan dan penataan rumah melalui intervensi ergonomi merupakan salah satu upaya penyediaan kualitas rumah untuk meningkatkan kenyamanan di dalam rumah secara alami. Perencanaan rumah ergonomis hendaknya memenuhi kriteria yaitu secara teknis mudah dikerjakan, biaya lebih murah, hemat energi terutama energi listrik, nyaman sesuai dengan sosial budaya masyarakat, dan ramah lingkungan. Penelitian eksperimental ini menggunakan rancangan sama subjek (*treatment by subject design*). Dalam penelitian ini digunakan 8 rumah sebagai sampel yakni 2 rumah masing-masing menghadap Utara, Selatan, Timur dan Barat serta dilibatkan 26 orang responden yang merupakan penghuni dari 8 rumah tinggal tipe 36/120 di Perumahan Nuansa Kori Sading Mengwi Badung. Sampel dipilih secara acak berstrata (*stratified random sampling*). Intervensi ergonomi berupa perbaikan ventilasi dan jendela terhadap semua rumah yang terpilih sebagai sampel. Pengambilan data kenyamanan secara objektif dilakukan sebelum dan sesudah intervensi pada pukul 08.00 wita, 10.00 wita, 12.00 wita, 14.00 wita, 16.00 wita, dan 20.00 wita, dengan mengukur suhu, kelembaban, intensitas cahaya, dan gerakan udara. Sedangkan kenyamanan secara subjektif di data dengan kuesioner kenyamanan yang sudah diuji validitas dan reliabilitasnya. Hasil yang diperoleh dalam penelitian ini adalah: (1) sebelum perbaikan rerata suhu basah 23,66 ± 1,39 ºC dan sesudah perbaikan 23,09 ± 1,20 ºC; (2) sebelum perbaikan rerata suhu kering 28,76 ± 1,07 ºC dan sesudah perbaikan 27,88 ± 0,73 ºC; (3) rerata kelembaban sebelum perbaikan 73,44 ± 4,37 % dan sesudah perbaikan 72,63 ± 2,73 %; (4) rerata intensitas cahaya sebelum perbaikan 134,94 ± 71,69 lux dan sesudah perbaikan 229,69 ± 114,53 lux; (5) rerata gerakan udara sebelum perbaikan 0,10 ± 0,04 m/dt dan sesudah perbaikan 0,31 ± 0,08 m/dt; dan (6) terjadi penghematan energi listrik sebesar 11% dan penurunan tagihan rekening listrik sebesar 8%. Hasil analisis didapatkan bahwa intervensi ergonomi melalui perbaikan ventilasi dan jendela rumah tipe 36/120 dapat meningkatkan kenyamanan objektif sebesar 12,4% ($p<0,05$) yang didukung oleh peningkatan kenyamanan subjektif penghuninya pada semua arah hadapan bangunan. Disamping itu terjadi penghematan energi listrik sebesar 11% ($p<0,05$) dan disertai penurunan tagihan rekening listrik sebesar 8% ($p<0,05$).

Kata kunci: *intervensi ergonomi, rumah tipe 36/120, kenyamanan, penghematan listrik.*

1. Pendahuluan

Sektor perumahan mulai dikembangkan di Indonesia sejak tahun 1970an. Di Bali sektor ini mulai berkembang sekitar tahun 1980an. Perkembangan sektor perumahan di Bali sudah merambah ke pinggiran wilayah kota Denpasar, bahkan beberapa wilayah perdesaan di Bali sudah menjadi sasaran para pengembang. Meningkatnya jumlah penduduk merupakan salah satu penyebab tingginya permintaan terhadap perumahan.

Besarnya permintaan akan perumahan di masa yang akan datang perlu di antisipasi dengan usaha regulasi terhadap pemanfaatan ruang untuk perumahan, sehingga para pengembang, pemerintah dan masyarakat memiliki acuan dan aturan yang jelas mengenai tata guna lahan perumahan. Perkembangan kuantitas perumahan sebaiknya disertai dengan perbaikan kualitasnya (Newmark, dan Thompson, 1977). Kualitas yang dimaksudkan di sini adalah rumah yang sehat dan nyaman untuk ditempati.

Hasil penelitian pendahuluan yang dilakukan di perumahan Nuansa Kori Sading Mengwi bulan September 2006, didapatkan data yaitu: (a) pada ruang keluarga dengan luas ruang 15 m^2, rerata suhu basah dalam ruangan 25 °C, rerata suhu keringnya 30,5 °C, rerata intensitas cahaya alami 200 lux, rerata intensitas cahaya lampu 250 lux, rerata gerakan udara dalam ruangan 0,3 m/dt, rerata gerakan udara di luar rumah 1,8 m/dt, rerata intensitas cahaya luar 45.000 lux, rerata suhu basah di luar rumah 26 °C dan rerata suhu kering di luar rumah 31 °C; (b) pada ruang tidur dengan luas 9 m^2, rerata suhu basahnya 25,5 °C, rerata suhu kering 30 °C, rerata intensitas cahaya alami 20 lux, rerata intensitas cahaya lampu 50 lux, dan rerata gerakan udara dalam ruangan 0 m/dt, dan (c) pada ruang dapur dengan luas ruang 3 m^2, rerata suhu basah dalam ruangan 24 °C, rerata suhu keringnya 29 °C, rerata intensitas cahaya alami 125 lux, rerata intensitas cahaya lampu 200 lux, dan rerata gerakan udara dalam ruangan 0 m/dt. Dari kuesioner yang disebarkan kepada penghuni menunjukkan bahwa kenyamanan ketiga ruangan ini belum memenuhi keinginan penghuni rumah tipe tersebut.

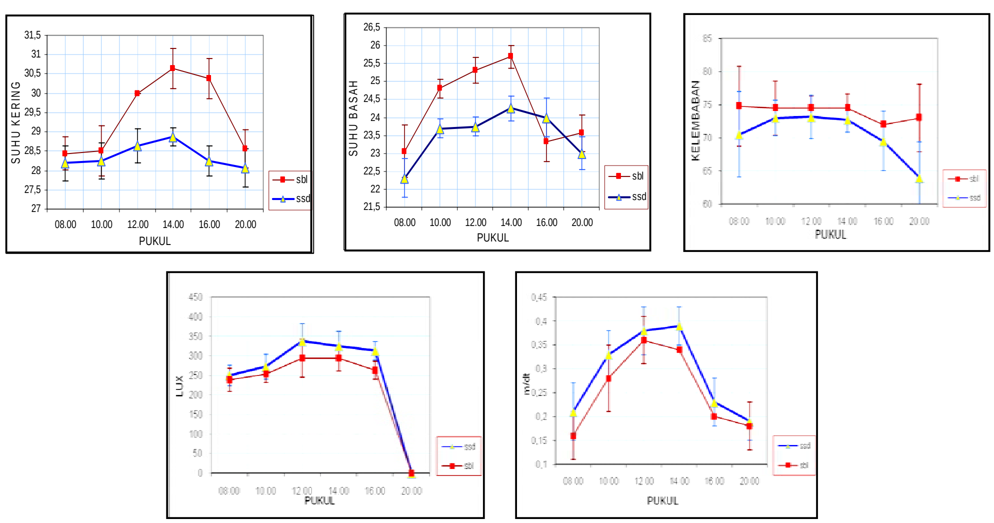
Ada beberapa faktor penyebab ketidaknyamanan ketiga ruang tersebut antara lain: tata letak, bentuk dan ukuran ventilasi dan tata letak, bentuk dan ukuran jendela serta arah bukaan bawah (vertikal). Kedua faktor tersebut akan berakibat pada tidak optimalnya sirkulasi udara dalam ruangan (tidak terjadi ventilasi silang) dan terbatasnya pencahayaan dan penghawaan alami yang masuk ke dalam ruangan. Hal tersebut mengakibatkan ruangan menjadi lembab, sumpek dan boros listrik.

Hasil penelitian pendahuluan pada rumah tipe 36/120 di Perumahan Nuansa Kori Sading Mengwi Badung yang melibatkan 20 responden, diperoleh hasil (a) 55% responden memasalahkan aspek kenyamanan seperti: penghawaan dan penerangan alami dalam ruangan; (b) 30% responden mengeluhkan aspek keamanan (pemasangan terali pada ventilasi dan jendela); dan (c) 15% responden mengeluhkan aspek tata ruang dan furnitur seperti penataan fasilitas ruangan terkait dengan pola kegiatan dalam ruangan. Hasil dari kuesioner daftar keinginan / harapan penghuni pada penelitian pendahuluan, adalah : (a) 58% responden mengharapkan perbaikan bentuk dan tata letak ventilasi dan jendela; (b) 31% responden mengharapkan perbaikan pada bentuk mebeler yang fleksibel; dan (c) 11% responden mengharapkan perbaikan pada penataan fasilitas ruangan.

Intervensi ergonomi melalui perbaikan ventilasi dan jendela pada ruang keluarga, ruang tidur dan dapur rumah tipe 36/120 diharapkan mampu menghemat listrik dan meningkatkan kenyamanan penghuni.

2. Meterial dan pembahasan

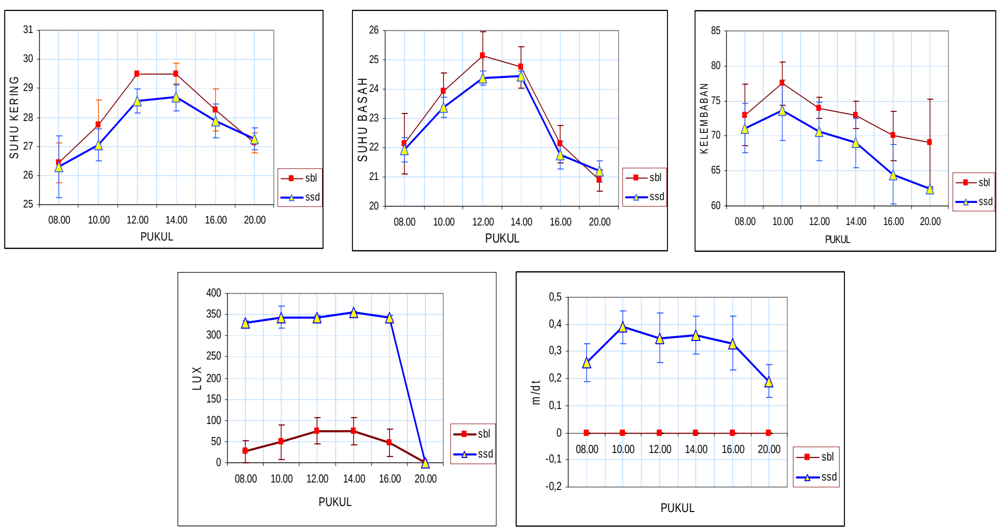
Rancangan penelitian yang digunakan adalah rancangan penelitian eksperimental yang menggunakan rancangan sama subjek (*treatment by subject design*). Dalam penelitian ini digunakan 8 rumah sebagai sampel yakni 2 rumah masing-masing menghadap Utara, Selatan, Timur dan Barat serta dilibatkan 26 orang responden yang merupakan penghuni dari 8 rumah tinggal tipe 36/120 di Perumahan Nuansa Kori Sading Mengwi Badung. Sampel dipilih secara acak berstrata (*stratified random sampling*). Intervensi ergonomi berupa perbaikan ventilasi dan jendela terhadap semua rumah yang terpilih sebagai sampel. Pengambilan data kenyamanan secara objektif dilakukan sebelum dan sesudah intervensi pada pukul 08.00 wita, 10.00 wita, 12.00 wita, 14.00 wita, 16.00 wita, dan 20.00 wita, dengan mengukur suhu, kelembaban, intensitas cahaya, dan gerakan udara. Sedangkan kenyamanan secara subjektif di data dengan kuesioner kenyamanan yang sudah diuji validitas dan reliabilitasnya.



Gambar 1 Kondisi Lingkungan Ruang Keluarga sebelum dan sesudah perbaikan di Perumahan Nuansa Kori Sading Mengwi Badung

Gambar 1 menunjukkan suhu basah, suhu kering, kelembaban relatif, intensitas cahaya alami dan gerakan udara di ruang keluarga sebelum dan sesudah perbaikan yang di data pukul 8.00; 10.00; 12.00; 14.00; 16.00; dan 20.00 WITA berbeda bermakna ($p<0,05$). Berdasarkan perhitungan rerata kondisi lingkungan (Suhu basah, suhu kering, kelembaban relatif, intensitas cahaya alami dan gerakan udara) sebelum dan sesudah perbaikan pukul 8.00; 10.00; 12.00; 14.00; 16.00; dan 20.00 WITA pada ruang keluarga terjadi penurunan suhu basah sebesar 0,033%, penurunan pada suhu kering sebesar 0,036% dan penurunan pada kelembaban sebesar 0,048%, tetapi dari intensitas cahaya terjadi peningkatan sebesar 0,11%, begitu pula pada gerakan udara terjadi peningkatan sebesar 0,13%. Hal ini berarti intervensi ergonomi melalui perbaikan ventilasi dan jendela rumah tipe 36/120 di ruang keluarga berpengaruh secara signifikan pada perubahan suhu basah, suhu kering, kelembaban relatif, intensitas cahaya alami dan gerakan udara.

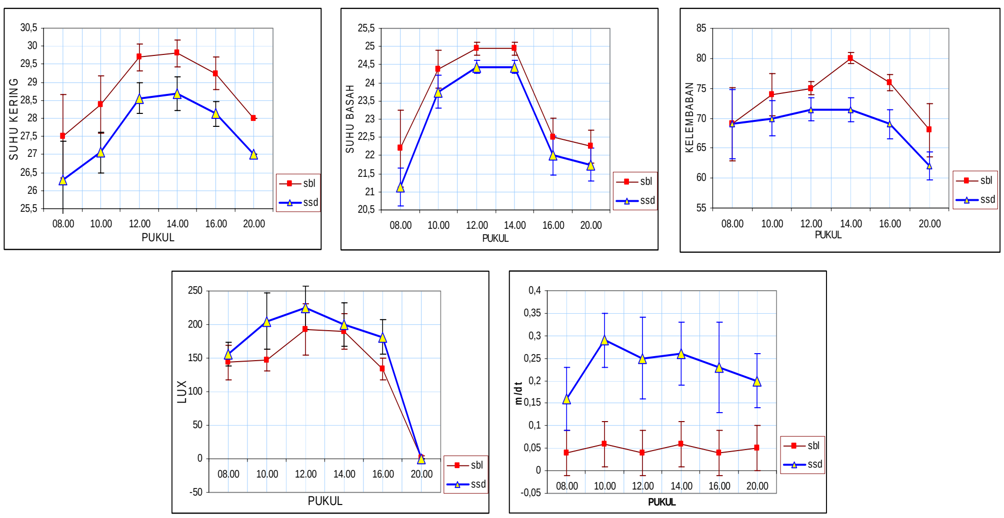
Suhu basah, suhu kering, kelembaban relatif, intensitas cahaya alami dan gerakan udara di ruang keluarga sebelum dan sesudah perbaikan berdasarkan orientasi bangunan antara rumah yang menghadap Utara, Selatan, Timur dan Barat tidak berbeda bermakna ($p>0,05$). itu berarti intervensi ergonomi melalui perbaikan ventilasi dan jendela di ruang keluarga mampu mengatasi pengaruh orientasi bangunan (menghadap Utara, Selatan, Timur dan Barat) terhadap kenyamanan ruang keluarga.



Gambar 2 Kondisi Lingkungan Ruang Tidur sebelum dan sesudah perbaikan di Perumahan Nuansa Kori Sading Mengwi Badung

Gambar 2 menunjukkan suhu basah, suhu kering, kelembaban relatif, intensitas cahaya alami dan gerakan udara di ruang tidur sebelum dan sesudah perbaikan yang di data pukul 8.00; 10.00; 12.00; 14.00; 16.00; dan 20.00 WITA berbeda bermakna ($p<0,05$). Dari perhitungan rerata kondisi lingkungan (Suhu basah, suhu kering, kelembaban relatif, intensitas cahaya alami dan gerakan udara) sebelum dan sesudah perbaikan pukul 8.00; 10.00; 12.00; 14.00; 16.00; dan 20.00 WITA pada ruang tidur terjadi penurunan suhu basah sebesar 0,013%, penurunan pada suhu kering sebesar 0,017% dan penurunan pada kelembaban sebesar 0,061%, tetapi dari intensitas cahaya terjadi peningkatan sebesar 5,27%, begitu pula pada gerakan udara terjadi peningkatan sebesar 0,31%. Hal ini berarti intervensi ergonomi melalui perbaikan ventilasi dan jendela rumah tipe 36/120 berpengaruh secara signifikan pada perubahan suhu basah, suhu kering, kelembaban relatif, intensitas cahaya alami dan gerakan udara di ruang tidur.

Suhu basah, suhu kering, kelembaban relatif, intensitas cahaya alami dan gerakan udara di ruang tidur sebelum dan sesudah perbaikan berdasarkan hadapan rumah antara rumah yang menghadap Utara, Selatan, Timur dan Barat tidak berbeda bermakna (p>0,05). Ini berarti intervensi ergonomi melalui perbaikan ventilasi dan jendela di ruang tidur mampu mengatasi pengaruh orientasi bangunan (menghadap Utara, Selatan, Timur dan Barat) terhadap kenyamanan ruang tidur.



Gambar 3 Kondisi Lingkungan Ruang Dapur sebelum dan sesudah perbaikan di Perumahan Nuansa Kori Sading Mengwi Badung

Gambar 3 menunjukkan suhu basah, suhu kering, kelembaban relatif, intensitas cahaya alami dan gerakan udara di ruang dapur sebelum dan sesudah perbaikan yang di data pukul 8.00; 10.00; 12.00; 14.00; 16.00; dan 20.00 WITA berbeda bermakna (p<0,05). berdasarkan perhitungan rerata kondisi lingkungan (Suhu basah, suhu kering, kelembaban relatif, intensitas cahaya alami dan gerakan udara) sebelum dan sesudah perbaikan pukul 8.00; 10.00; 12.00; 14.00; 16.00; dan 20.00 WITA pada ruang dapur terjadi penurunan suhu basah sebesar 0,026%, penurunan pada suhu kering sebesar 0,041% dan penurunan pada kelembaban sebesar 0,070%, tetapi dari intensitas cahaya terjadi peningkatan sebesar 0,19%, begitu pula pada gerakan udara terjadi peningkatan sebesar 3,79%. Hal ini berarti intervensi ergonomi melalui perbaikan ventilasi dan jendela rumah tipe 36/120 berpengaruh secara signifikan pada perubahan suhu basah, suhu kering, kelembaban relatif, intensitas cahaya alami dan gerakan udara di ruang dapur.

Suhu basah, suhu kering, kelembaban relatif, intensitas cahaya alami dan gerakan udara di ruang dapur sebelum dan sesudah perbaikan berdasarkan hadapan rumah antara rumah yang menghadap Utara, Selatan, Timur dan Barat tidak berbeda ($p>0,05$). Itu berarti intervensi ergonomi melalui perbaikan ventilasi dan jendela di ruang dapur mampu mengatasi pengaruh orientasi bangunan (menghadap Utara, Selatan, Timur dan Barat) terhadap kenyamanan ruang dapur.

Rerata suhu udara dalam ruangan pada ruang keluarga, ruang tidur dan ruang dapur adalah 27 ^{o}C dengan rentangan 26 – 29 ^{o}C. Hasil penelitian ini sesuai dengan pernyataan Manuaba (1983), yang menyatakan bahwa tingkat kenyamanan objektif yang baik pada rumah berdasarkan suhu udara adalah 24^{o}C – 28^{o}C. Berdasarkan pada kelembaban relatif, dalam penelitian ini di ruang keluarga, ruang tidur dan ruang dapur diperoleh rerata kelembaban relatif 68% dengan rentangan 60 – 80%. Hasil penelitian ini sesuai dengan pendapat Meijs (1983), yang menyatakan bahwa tingkat kenyamanan obyektif yang baik pada rumah berdasarkan kelembaban udara adalah berada pada 40% - 70%. Sedangkan jika ditinjau berdasarkan intensitas cahaya, dalam penelitian ini di ruang keluarga, ruang tidur dan ruang dapur didapatkan rerata intensitas cahaya 350 Lux dengan rentangan 175 – 400 Lux. Hasil penelitian ini lebih rendah dari apa yang dikemukakan Grandjean (1988) dan Mangunwijaya (1997), yang menyatakan bahwa tingkat kenyamanan objektif yang baik pada rumah berdasarkan intensitas pencahayaan adalah 500 lux – 700 lux. Demikian juga jika ditinjau dari segi gerakan udara, dalam penelitian ini di ruang keluarga, ruang tidur dan ruang dapur didapatkan rerata gerakan udara 0,2 m/dt dengan rentangan antara 0.1 – 0.5 m/dt. Hasil penelitian ini berada dalam rentangan gerakan udara yang nyaman yakni 0.1 – 0.5 m/dt (Mangunwijaya, 1997). Hasil penelitian ini hampir sama dengan hasil penelitian Lippsmeier (1994), yang menyatakan bahwa batas kenyamanan di daerah khatulistiwa berkisar antara temperatur 22,58C s.d. 29,58C dengan kelembaban udara relatif sebesar 20-50%. Di samping itu, Sujadnja (1998) juga menyatakan bahwa pada bangunan *Bale Meten* di Bali, mikroklimat (penerangan, suhu, kelembaban dan sirkulasi udara) merupakan faktor yang berpengaruh terhadap kenyamanan dalam ruangan dengan perincian sumbangan relatif: suhu dan kelembaban sebesar 8%, penerangan dan sirkulasi udara 0,41%, dengan total sumbangan relatif sebesar 9,35%. Lebih lanjut disebutkan bahwa faktor yang berpengaruh kuat terhadap mikroklimat adalah jendela dan ventilasi. Jendela mempunyai korelasi positif terhadap penerangan dengan klasifikasi *lemah* ($r = 0,32$). Jendela mempunyai korelasi positif terhadap sirkulasi udara dengan klasifikasi *sedang* ($r = 0,41$). Sedangkan ventilasi mempunyai korelasi positif terhadap sirkulasi udara dengan klasifikasi *sedang* ($r = 0,44$). Selanjutnya Darmawan (2005), yang melakukan modifikasi terhadap Gedung LPD Desa Pakraman Sibangkaja, dengan memilih material yang dapat menurunkan nilai koefisien perpindahan kalor menyeluruh yang diterima oleh gedung. Modifikasinya antara lain dengan mengganti terrazzo dengan bata merah tanpa plesteran, mengganti bata 115 mm dengan bata 220 mm, mengganti kaca jendela dari kaca tebal 3 mm dengan kaca tebal 8 mm dan menambahkan papan gipsum pada lapisan dinding bangunan. Dengan cara tersebut dapat menurunkan nilai perolehan kalor dari gedung sebesar 9,84 %, dengan perincian nilai rerata awal perolehan kalor rata-rata seluruh bangunan adalah 15602 Watt atau 15,6 kW per hari dan setelah dilakukan modifikasi seperti tersebut didapat nilai perolehan kalor rata-rata seluruh bangunan lebih rendah yakni sebesar 14122,49 Watt atau

14,12 KwH per hari. Demikian juga hasil penelitian Nityasa (1999), yang menyatakan bahwa perbaikan rumah tipe T-36/100, dengan menggunakan lebar tritisan 1,30 meter berpengaruh terhadap peningkatan kenyamanan objektif. Lebih lanjut dinyatakan bahwa tingkat kenyamanan rumah yang berorientasi ke selatan adalah paling nyaman disusul kemudian rumah yang berorientasi ke timur, ke utara dan ke barat.

Di samping itu intervensi tersebut menyebabkan suhu, kelembaban, intensitas cahaya dan gerakan udara berada dalam wilayah kenyamanan (*Zone Comfort*) yakni suhu kering 25ºC - 27ºC, kelembaban 56% - 72%, intensitas cahaya 350 lux – 460 lux dan gerakan udara 0,22 m/dt – 0,34 m/dt. Hal ini berarti intervensi ergonomi melalui perbaikan ventilasi dan jendela mampu mengatasi efek ketidaknyamanan yang disebabkan oleh perbedaan orientasi arah bangunan.

Kenyamanan subjektif yang diukur menggunakan kuesioner kenyamanan yang terdiri dari 16 item. Keenam belas item tersebut mencerminkan kondisi lingkungan dalam ruangan, seperti suhu, kelembaban, intensitas cahaya, dan gerakan udara. Dengan menggunakan 16 item kuesioner kenyamanan subjektif sebelum perbaikan rerata skor kenyamanan subjektif penghuni rumah adalah 30,50 ± 1,16, sedangkan sesudah perbaikan reratanya adalah 62,80 ± 1,46 (lihat tabel 5.25). Skor kenyamanan subjektif antara sebelum dan sesudah perbaikan berbeda bermakna. Hal ini berarti bahwa setelah dilakukan intervensi ergonomi melalui perbaikan ventilasi dan jendela rumah tipe 36/120 terjadi peningkatan skor kenyamanan subjektif penghuni rumah baik pada ruang keluarga, ruang tidur, dan ruang dapur.

Dari rerata penggunaan energi listrik dalam rumah tangga sebelum perbaikan adalah 85 KwH dan rerata tagihan rekening listriknya adalah Rp. 56.184,-, dan rerata penggunaan energi listrik sesudah perbaikan adalah 77 KwH dan rerata tagihan rekening listrik Rp. 51.000,-. Berdasarkan hasil perhitungan terjadi penghematan jumlah energi listrik sebesar 11%, dan penghematan tagihan rekening sebesar 8% per bulan. Dengan membandingkan dari hasil penelitian Togar (2008) maka dalam penelitian ini terjadi penghematan penggunaan listrik sebesar 9,44 KwH perbulan berarti dapat mengurangi CO2 5,37 kg per bulan atau 0,015 ton per tahun.

Temuan baru dalam penelitian ini adalah (1) Kenyamanan rumah tipe 36/120 yang dipresentasikan oleh suhu, kelembaban, intensitas cahaya dan gerakan udara mampu diwujudkan melalui intervensi ergonomi; (2) Kenyamanan rumah tipe 36/120 yang ditunjukkan dengan data objektif (suhu, kelembaban, intensitas cahaya dan gerakan udara) ditunjang oleh kenyamanan subjektif; (3) Kenyamanan rumah tipe 36/120 dapat diwujudkan melalui intervensi ergonomi dan mampu mengatasi efek perbedaan orientasi bangunan baik secara *solar orientation* (Timur –Barat) maupun *geografical orientation* (Utara-Selatan); dan (4) ditemukan cara penghematan listrik melalui intervensi ergonomi melalui perbaikan ventilasi dan jendela rumah tipe 36/120.

3. Simpulan

Berdasarkan hasil penelitian, analisis dan pembahasan melalui intervensi ergonomi rumah tipe 36/120 di perumahan Nuansa Kori Sading Mengwi Badung dapat disimpulkan bahwa (a) intervensi ergonomi melalui perbaikan ventilasi dan jendela rumah tipe 36/120 meningkatkan kenyamanan objektif sebesar 12,4 % yang didukung oleh kenyamanan subjektif penghuninya pada semua arah orientasi bangunan baik arah Utara, Selatan, maupun Timur dan Barat; (b) intervensi ergonomi melalui perbaikan ventilasi dan jendela rumah tipe 36/120 mampu menghemat biaya listrik sebesar 11% dan terjadi penurunan tagihan rekening listrik sebesar 8%.

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