Energy Saving Investigation on Undesignated Campus Mosques

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Abstract Mosque is a unique building by the function as Moslem prayer room. Indonesia as the world biggest moslem country has mandated each buildings to provide prayer room especially mosque by issuance of Ministry of Public Work-Housing Settlement decree no. 14/2017. Academic building like campus also mandated to have the campus mosque to facilitate the Moslem students or lecturers in performing their prayer. However the campus buildings commonly were not designed with mosque facility in purpose. Thus campus designer performed remodeling their building to meet this demand. The importance of thermal comfort in mosque to facilitate worshippers perform their prayer in profane room with minimum energy requirement, make energy saving investigation is critical for room performance, This study purpose is to assess and compare the energy saving over time on several type of undesignated campus mosques as a step towards comprehensive study about mosque and energy saving strategies. Literature study, Mosque "energy audit" evaluation on site observation, and edge building simulation were performed to investigate the energy saving. The study presents the analysis of several undesignated campus mosques type in tropical region's performance toward energy saving effort.

Keywords Energy saving · Building physics · Undesignated campus mosque · Edge buildings

1 Introduction

Mosques are unique building which having various frequency rates at different days and hours for Moslems gathering, resting and especially praying. The design and

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features of the mosques were varied by contextual site, cultural influence and geographical factors [1]. Mosques were simply designed to have prayer space scheme where the long edge is directing to qibla (the bait of Allah on Mecca) and ablution room to support the prayer [2]. Nowadays mosques has equipped with acoustic comfort by audio systems, visual comfort via lighting-visual arts and thermal comfort by air conditioning systems. Recently, many researches tried to improve thermal comfort and energy saving of various building types such as: office, mall, and not least mosque [3–7]. The energy should efficiently use to maintain the proper comfort area for the mosque users. In the literature there are limited number of studies about mosque and rarely also about the campus mosque which not designated to be mosque.

Almost a quarter of the world's people are Moslem. The Moslem community has built many mosques throughout the earth. Mosque is integral part of all Moslem community in the world and act as identity in Moslem majority countries as well as any other country with Moslem population [8]. Indonesia as the world biggest moslem country has mandated each buildings to provide prayer room especially mosque by issuance of Ministry of Public Work-Housing Settlement decree no. 14/2017. The decree also strictly stated that mushola must installs: clear direction to Qibla, distinctive separation between profane and common room, and proper thermal and lighting comfort [9].

Campus in Indonesia usually has central mosque. However the demand to pray right on prayer time brought every buildings to provide a space to perform prayer (undesignated mosque). The condition of undesignated mosque on campus usually fully equipped with ablution area and prayer area. Thus campus designer performed remodeling their building to meet this demand. The importance of thermal comfort in mosque to facilitate worshippers perform their prayer in profane room with minimum energy requirement, make energy saving investigation is critical for room performance.

Some Studies shown comparison of buildings of the same area and mosques have a higher energy usage and also higher energy expenditure for cooling purposes [10]. Moreover, there is fact that wall and roof thermal treatment and preventing air leakage, a maximum 25% of energy savings can be achieved [11]. There also methods for cooler (refrigerant) is not necessary risen the thermal comfort of the mosque users and thus the consumed energy proven to waste [12]. Through a comparison of several studies, occupancy zoning or building insulation is provided, more acceptable thermal comfort level will be achieved. The same time, the expenses reduced unto half of other mosques through less energy usage. Some studies also conclude that the existing scales for measuring thermal comfort levels were varied for the building typology of mosques [13].

This study purpose is to assess and compare the energy saving over time on several types of undesignated campus mosques as a step towards comprehensive study about mosque and energy saving strategies. Literature study, Mosque "energy audit" evaluation on site observation, and edge building simulation were performed to investigate the energy saving.

Fig. 1 Condition of Mosque in Pukyong National University, Busan, South Korea

2 Materials and Methods

2.1 South Korea Case

Pukyong National University is one of the campus in South Korea which having a mosque inside the education area. The condition of big number of Moslem students brought a mosque in 2014 and moved it into bigger room of 30 worshippers capacities in 2017 (see Fig. 1).

This mosque was underground bunker before being renovated to be class and now mosque, made this mosque is sample of undesignated mosque.

2.2 Indonesia Case

Architecture campus of Universitas Diponegoro is having three undesignated mosque in the building A, C and D as the result of majority academia are moslem that need to pray at least dzuhr and asr at campus and maybe maghrib, isya and shubh on campus off schedules. The room dimensions were varied according to the undesignated mosque conditions. Later on the conditions would be explained on discussion sections.

The condition of both countries is undesignated mosque on campus with ablution area and prayer area. Thus campus designer performed remodeling their building to meet these minimum requirements of mosque.

2.3 Literature Study

This method was included on introduction section as background of this scientific writing to set the research basis. Some research of refrigerant, heater which closely related to energy consumption to support thermal comfort inside mosque has been studied. Furthermore the energy consumption calculated by edge building simulation to predict the energy saving score.

2.4 Site Observation

This method was performed to gain data's from the mosques in Pukyong National University and Architecture campus of Undip, especially: dimension and energy consuming features. The measurements and documentation were taken using digital devices to make high precision.

2.5 Energy Evaluation Using Edge Building Simulation

Edge building simulation is an online building simulation by IFC sponsored by World Bank. The physical data obtained on site observation in this phase being filled on edgebuilding.com application to be calculated the energy saving prediction. The score of energy saving and water saving later on being reported as this study results.

3 Result and Discussion

3.1 South Korea Case

The condition of Al Pukyong in Daeyeon campus can be seen in Figs. 1 and 2. The capacities of 30 prayers taken by the direct counting while preparing communal jumat prayer. During the counting, more than 50 worshippers were came and performed their prayer until the ally between the mosque and ablution area. The dimension of 12 m * 5 m is not enough to fit the number above 30 users.

The features of centralized Air Conditioner with COP 3.5, undertile heater (ondol) and LED bulb were using the electricity as main power. Underground location of the mosque brought thermal comfort problems on the passive design analysis directly. However the energy saving simulation may show the other calculations.

The edge building simulation being input the data of mosque dimension with AC central (COP 3.5) bring score in energy saving: 5.2%, and undertile heater shown

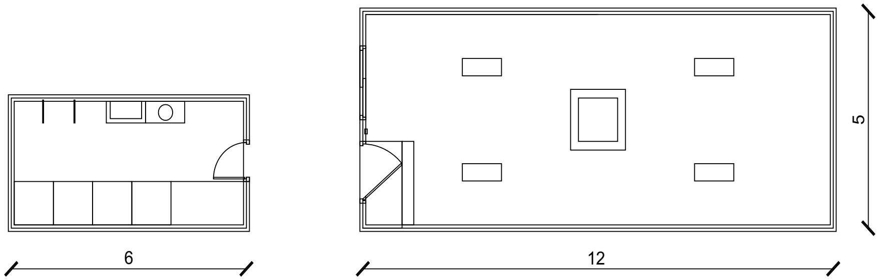

Fig. 2 Mosque-ablution plan in Computer Science Bld, Pukyong National University

0.02% of energy saving while application of LED bulb brought 0.21% saving. The total energy saving of this undesignated mosque is 5.44% (see Fig. 3).

The next phase of edge building simulation shown that water consumption on mosque Al Pukyong is 1.24% compared to the edge standard by using the low flow faucet 6L. This water devices consumed around 246 kL/unit/year according to the simulation result (see Fig. 4).

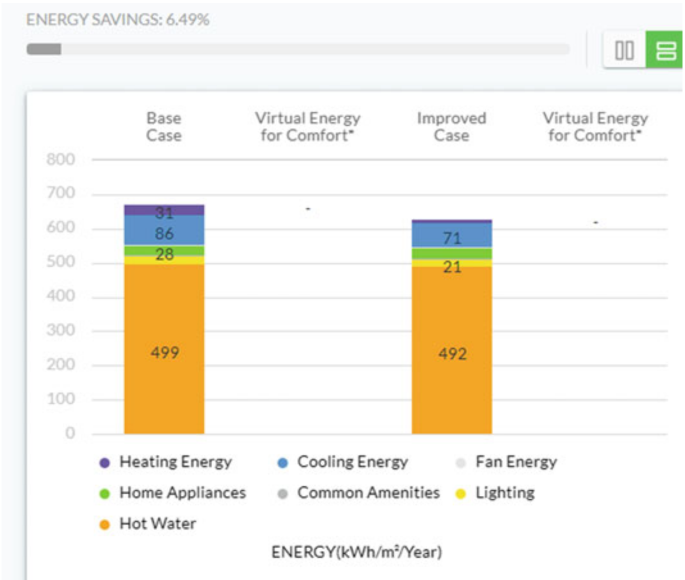

Fig. 3 Energy saving simulation on Pukyong National University Mosque

Fig. 4 Water saving simulation on Pukyong National University Mosque

3.2 *Indonesia Case*

3.2.1 Building a Mosque

Mosque in Building A Architecture Undip is functioned as lecturer mosque so that only this mosque equipped by air conditioner type split package with 0.5 PK installed on this 7.2 m * 2.1 m prayer area. However the ablution area is only 1.9 m * 1 m with three low flow faucets (see Fig. 5).

The installment of AC split with COP 3.5 brought result of 3.59% energy saving (see Fig. 6), while low flow faucets scored 11.85% water saving (see Fig. 7). Later on the low flow faucets also applied on other three architecture campus so that the water saving for each places were 11.85%. The situation of mosque that located inside room with no outside windows and ventilation worsen the energy consumption compared to the earlier Pukyong mosque.

This mosque was a lecturers/professors room that modified to meet the prayer demand amongst lecturers. The architecture lecturers itself reach 38 persons so that couldn't fit to perform prayer (salat) at the same time in this undesignated mosque. The maximum capacity is 9 worshippers with composition of 3 rows and 3 columns include imam (leader) who will take about 10 cm more forward than the follower (makmum).

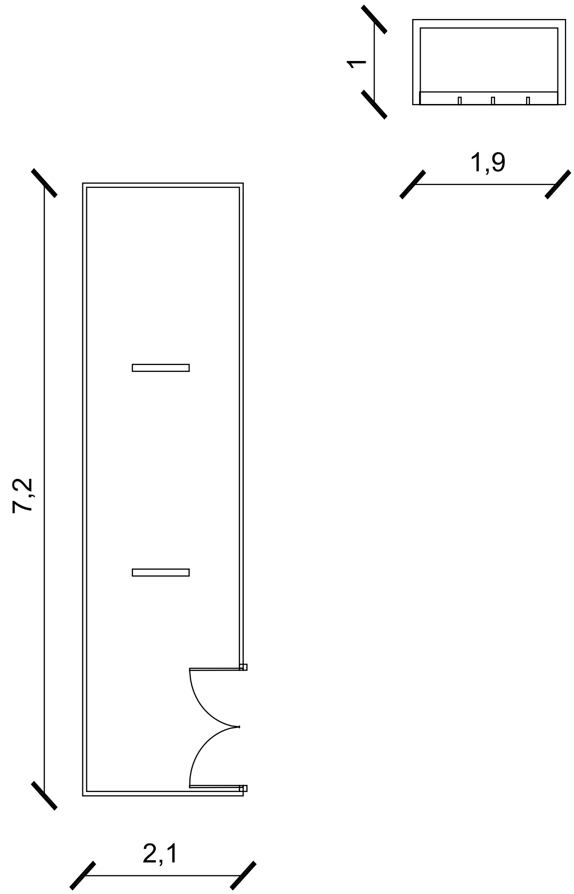

Fig. 5 Mosque-ablution plan in Building A Architecture Undip

3.2.2 Building C Mosque

Mosque in Building C Architecture Undip is located in 2nd floor of the building. This mosque is equipped by stand-wall fans and window panel installed on this 6 m * 3 m prayer area. However the ablution area is only 1 m * 1 m with three low flow faucets inside 2 m * 3.9 m lavatory (see Fig. 8). This mosque only fit for 12 caused by the 3 m of width which allow more person in a row rather than mosque in building A (Fig. 9).

The energy saving simulation result of ceiling fans installment is 7.59% and natural ventilation (windows) is 5.79%. So that the total energy saving was 9.21% with energy consumption of fans 14 kWH/m^2/year and lighting 8 kWH/m^2/year. Same with previous building A, the water saving with three low flow faucet resulted 11. 85% score (see Fig. 7).

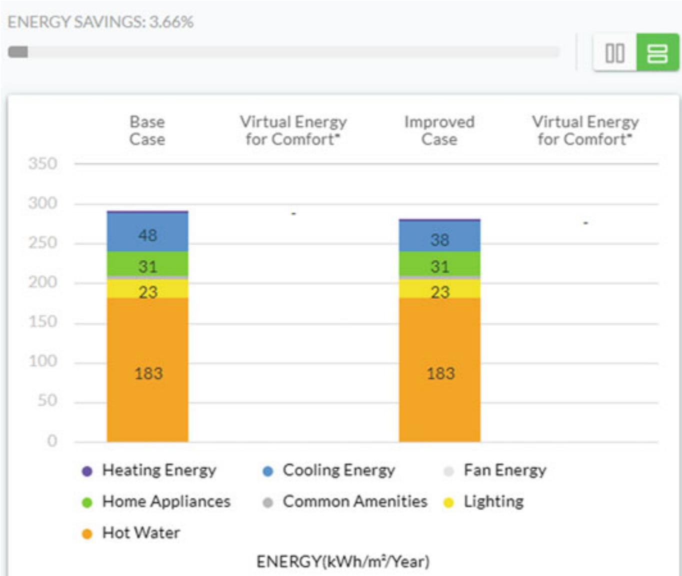

Fig. 6 Energy saving simulation on Building A Architecture Undip

Fig. 7 Water saving simulation on Building A, C and D Architecture Undip

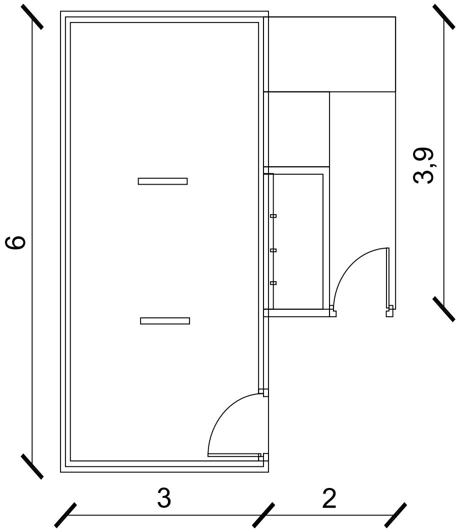

Fig. 8 Mosque-ablution plan in Building C Architecture Undip

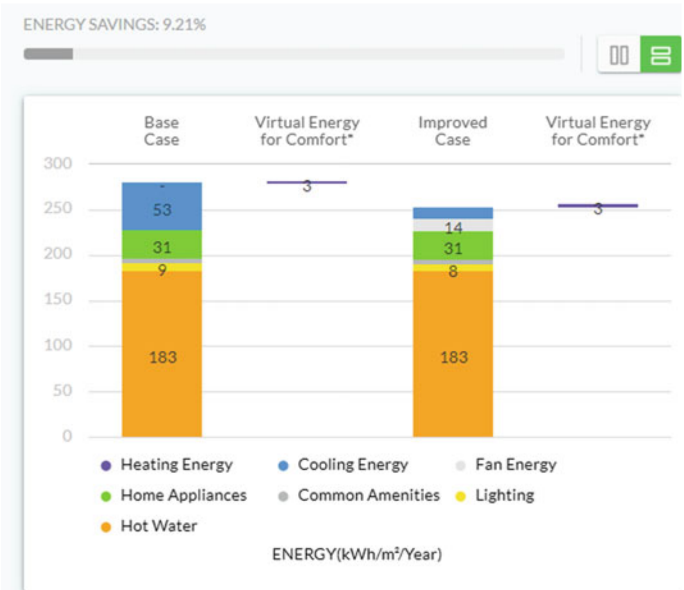

Fig. 9 Energy saving simulation in Building C Architecture Undip

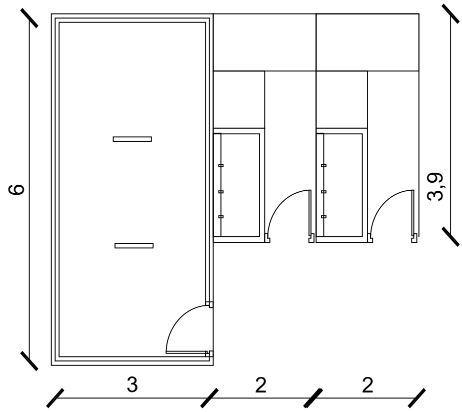

Fig. 10 Mosque-ablution plan in Building D Architecture Undip

3.2.3 Building D Mosque

The final mosque in Building D Architecture Undip is located in 1st floor of the post graduate building (plus vocational school). This mosque is installed a stand fan and window panel installed on this 6 m * 3 m prayer area which fit to 12 persons on 3 rows. However the ablution area is only 1 m * 1 m with three low flow faucets inside two of 2 m * 3.9 m lavatory (see Fig. 10). However in some occasion a lavatory on this building was being closed according to the plumbing and door problems. This mosque using natural ventilation as natural lighting source and air circulators so that can reduce the energy consumption for thermal and visual comforts during campus working hours of 7AM-5PM from Monday to Friday.

The energy saving simulation result of stand fan installment is 7.79% and natural ventilation (windows) is 7.73%. So that the total energy saving was 9.38% with energy consumption of fans and lighting of 6 and 37 kWH/m^2/year (see Fig. 11). Same with previous building A, the water saving with three low flow faucet resulted 11. 85% score (see Fig. 7).

3.3 The Comparison Studies

The earlier discussion of each mosque cases on Pukyong National University and Architecture campus of Universitas Diponegoro can be resumed and compared into Table 1. The AC was attached on PKNU and building A, but wall/stand fan was installed non-permanent on building C and D. The windows exist on building C and D but not in building A (as result of space inside a room) and Al Pukyong (as result of underground space). The lowest energy saving is building A caused by the contextual location and the highest is building D with application of fan on the small room rather than AC and position which having windows on a side of it. However

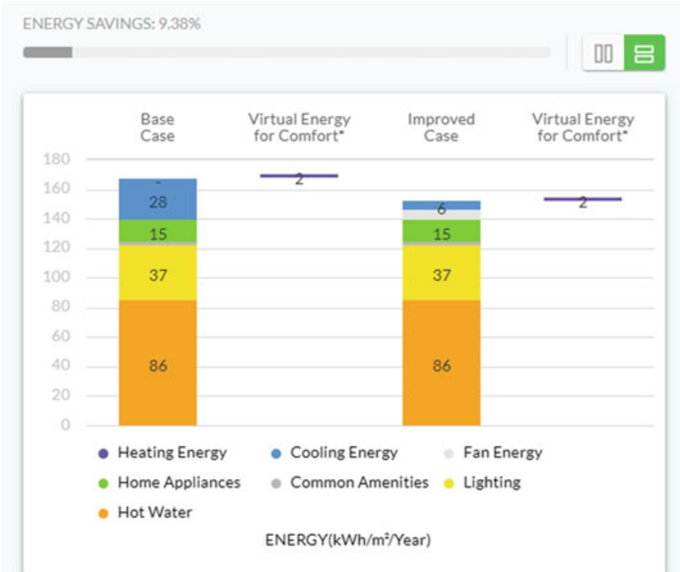

Fig. 11 Energy saving simulation in Building D Architecture Undip

Table 1 Comparison of the studied mosques

Location	Features	Energy saving (%)	Water saving (%)
PKNU	AC central + sub floor heater	5.44	6.49
A bld Undip	AC split-windows	3.59	11.85
C bld Undip	Windows + wall fan	9.21	11.85
D bld Undip	Windows + wall fan	9.38	11.85

the water saving of Al Pukyong is lowered than other since the area of ablution is bigger.

The passive design strategy had shown its effect on this study by evaluation of edge building simulations. The comfort standard on each place is incomparable [13] since Korea is subtropical area (demand AC and heater) while Indonesia is tropical area. However the mosque main space of prayer room and ablution [2] must be provided on this undesignated mosque.

Furthermore the thermal conditioner of AC and heater shall be more calculated since it cost highest energy consumption (see Figs. 3, 6, 9 and 11) and highly related to the area of the prayer space [10].

4 Conclusion

We can concluded that whether designated or undesignated, the mosque as communal space demand not only spacious room but also features that support space comforts. In subtropic campus mosque like al Pukyong in Busan, the effort in Air conditioning and sub floor heater made low energy saving but higher than tropical campus mosque with no natural and using only AC split for ventilating. The best saving energy in tropical is using the potential of passive design thermal comfort system like windows (natural ventilation) and installment of ceiling/stand fans in prayer rooms. In water saving, the efforts of low faucets in bathroom and ablution space were also depend to the area and the faucet quantities.

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