

## 266: Improvement Proposal for Dome Houses in Indonesia

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### Abstract

This research is intended to propose an improvement on the design of housing relocation for Jogya Earthquake victims. The project was 80 domes consisted of 71 houses and 9 collective facilities, contributed by WANGO. The construction was under control of "Domes for the World". The superiorities are: affordable, quickly and easy to construct, more stable, and earthquake responsive building.

To be built in Indonesia the domes present serious problems. It is very hot inside. Occupants cannot stand to live in. As disaster victims occupants do not deserve to suffer further by living in uncomfortable dwelling. The design should at least consider the hot humid climatic design requirements such as: shading, opening for ventilation and other efforts for passive cooling.

Aim of this research is improving the dome house design particularly in indoor thermal quality. In principle the method used is simulation by CFD. Output of research is a new revised dome prototype accompanied by its ventilation airflow as well as its internal temperature. Contribution is design guidelines for related institution whenever the project will be realized in humid tropic areas.

**Key words:** passive cooling, thermal comfort, dome, Indonesia.

### 1. Introduction

What a pity if massive housing development including affordable housing either by government or private sector are erected without consideration of local climate condition, physical comfort requirements and energy saving. Simple houses for low income community including for disaster relocation built only for fulfilling their basic needs such as protecting from rain water, sun attack and privacy requirement. As a result many occupants feel thermally uncomfortable to live inside. Some of them who earned better cannot help to use Air Conditioner in their unit. This will increase energy use. Uncomfortable house might affect the occupants: decrease of work productivity, decrease of physical fitness. With the same cost the house can be designed more comfortable and better energy saving.

The basic shape of a dome is in principle considered as strong and stable construction. For disaster recovery as well as low cost houses, the requirements such as: cheap price, and easily and quickly constructed, are indeed very important. But some other requirements especially those influencing comfort living within the house during whole day and night is apparently more important as well. Moreover, according to sustainability principles, sustainable housing design should be considered under several points of view, not only economically, but should considered also socially and environmentally [2].

As hot humid dwelling the dome should meet the requirements climatically. Factors to be warned in hot humid are high temperature, strong radiation, high humidity, weak air movement, and high rain precipitation [1]. That is why the design of humid tropic house should mainly emphasized on its passive cooling: separated ceiling in which the roof

space is ventilated well to avoid heat transfer and storage; fluent cross ventilation to move trapped heat and vapor; shading devices on opening, glazing and external walls to protect building from radiant heat and rain water splash; and low heat thermal capacity building material [8]. Factually, the dome, due to its basic shape, almost misses all of those requirements, such as no separated ceiling, no fluent air movement, and no shading at all.

Moreover, in principle the basic shape of dome climatically contradict with the basic shape for humid tropic building [8, 9], as the criteria of passive cooling context principle of shading requires basic shape that larger at the top, smaller at the bottom, while the basic shape of dome is in the contrary: larger at the bottom smaller at the top.

### 2. Existing of Dome Ngelepen

Located at dusun Ngelepen (Sengir) Sumberharjo, kecamatan Prambanan, Sleman, the dome house project that worth 1 million USD was established by the Indonesian Housing Minister on April 30<sup>th</sup>, 2007. The mayor of Sleman declared that beside as monument of May 27<sup>th</sup> 2006 earthquake, the dome might also be as tourism object due to its distinct performance compared to other traditional houses. These 71 earthquake responsive houses and 9 public facilities (health centre, kinder garden, mosque, and 6 collective toilets) that shaped as domes were pilot project that were contributed by WANGO (World Organization of NGO) for Jogya earthquake victims. The single donator Muhammad Ali Alabbar is the owner of Dubai Emaar Property of Uni Arab Emirates. The secretary general of WANGO Taj Hamad in his speech said that after those 71 domes WANGO will continue develop

more domes in greater scale in Indonesia, there were already orders up to 200 units so far.

The construction of this dome only takes 2-3 days per unit. The diameter of each unit is 7 meters, consisted of: 2 bedrooms, reception room, kitchen or pantry, and family room up stair. The building construction uses no break at all, break is only as partition [4]. The price of this permanently modern and earthquake responsive house is only 35-40 million rupiah or 3500-4000 USD per unit. This is considered cheap.

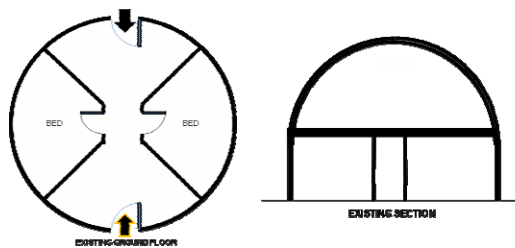


Fig 1. Plan and section of original dome

The construction process is under control of “Domes for the world” international institution which has built many in the entire world. To construct similar dimension and shape, they use big balloon as the dome basic shape. After a circle foundation buried, anchor utilized, then balloon blown. Next, is installed the reinforce concrete by following balloon shape. Finally like usual reinforced concrete, the concrete walls are made and finished by plastering and painting it.

“Ngelepen village” that located at the bottom of mountainous place along Bantul to Klaten, was initially infamous and unlivable, this location is 7 kilometers from the main street of Solo-Jogya. Until then WANGO cheerfully developed their pilot project for Ngelepen housing relocation. Now the dome house complex has been erected, they said it is seen as a fantastic view as if scattered swan eggs from a distanced hill. Unfortunately these igloo shaped houses are indicated very hot inside. The occupants said that even in the night time when the 2 doors and windows are closed, it is extremely hot inside.



Fig 2. Domes of New Ngelepen Village

### 3. Problems

For Indonesia the dome houses are unique and interesting public intention. The house performance was amazed every visitor who happened to pass the location. But to be lived in a long duration, it needs discussion and evaluation especially for the basic shape and the performance either culturally

or climatically. Moreover, nowadays development although it is for low income people, it remains require deep considerations particularly related to comfort and sustainability. The domes are of course having its superiorities to be the contribution of WANGO, but at the same time the domes are having also disadvantages which should be discussed and evaluated well in order to keep the environment sustainable and the houses remain capable to be occupied in livable way. Following are discussions of the dome concern with negative things or disadvantages economically, socially, environmentally and architecturally.

#### 3.1. Economically

For the house price, it can be said relatively cheap or affordable. According to Presty Larasaty on her May 16<sup>th</sup>, 2007 report it is said that the house price is 15-20 million rupiah per unit [5], but signaled on Housing Resource Centre (HRC) discussion the house price is reaching 35 million rupiah.

For maintenance, concrete skin is strong, no need to maintain, no leaks, but the finish work is painted, the outer dome skin requires to be repainted periodically. Additionally, unprotected doors and windows tend to damage shortly [1].

For operational cost, due to basic shape and concrete as skin, the dome house needs extra energy for cooling the internal space. Further, overheat inside and glare or over-bright outside maybe happened and causing uncomfortable work which may diminish working capability.

#### 3.2. Socially

For public facilities availability, there are 9 units sufficiently served for public facility buildings: Health clinic, Kinder Garten, Mosque, and six for collective public toilets. For cultural consideration, there are traditional ways that require back terrace.

#### 3.3. Environmentally

For climatic reason, the dome basic shape contradicts the humid climate design principle, and the concrete mass skin is definitely disadvantaging for hot humid buildings [7], as it transmits very big heat-gain into internal space.

For ecological reasons, white color concrete with dome shape that tends to reflect to all direction, producing heat radiation as well as glare to the environment surround. Moreover, heat emitted from dome skin will be very big as the heat coefficient of concrete is the highest after metal [9].

#### 3.4. Architecturally

For structural reason, the basic shape is positively capable to support its own load and responsive to earthquake. The building components are made on field, and the construction process is quite simple. Although the materials are not locally delivered, but the works are practical, easy, and low cost to install or to construct.

For building design reason, dome shape is unique and interesting for Indonesia. There is a big chance

to be tourism object. Yet the basic shape is not responsive to local climate (humid tropic). The material selection (concrete) is either not a good choice for skin in hot humid environment. No ventilated roof space causing direct heat transfer to internal space. No protection (shading, devices, cantilever) on openings to respond local climate.

#### 4. Discussion

##### 4.1. Basic shape considered climatically

The basic shape of dome is in principle contradict the required basic shape for hot humid area, on which hot humid mass should be larger above and smaller at the bottom part in order to protect the lower part against radiation heat that comes from upper part. In contrarily the basic shape of dome is smaller at above and larger at the bottom, so that in principle it tends to catch or even trap sun heat. In other words it can be said that the dome shape is more appropriate for passive heating instead of passive cooling [8, 9].

##### 4.2. Concrete as the dome skin

Concrete is a kind of strong building material, but unfortunately it has great thermal capacity coefficient, meaning that it will keep greater amount of heat compared to those having smaller thermal capacity coefficient. The thickness of concrete is another and additional reasons that indicate the duration of the heat maybe kept in it. The thicker the concrete, the longer the heat will be kept within. To relieve the problem of heat storage, it can be removed by passing wind as much as possible to push the heat mass trapped inside the space or ventilate it, even in cross ventilation [9]. In fact the dome has no roof space on which ventilation should be conducted.

##### 4.3. Unavailability of roof space

The existence of roof space in a hot humid building is very important as the roof is the first building component that touched by the sun heat, in which the heat will be transmitted to internal space and heating internal space [1]. That is why this roof space is needed to be ventilated well in order to remove the heat, so that radiation transmitted to internal space below is already cooler since the heat has already pushed away by air movement in the roof space.

Contrarily in reality the dome has no roof space, except the ceiling installed directly to the dome or even there is no ceiling installed. So that the sun heat radiation is transmitted directly by the dome skin to the internal space without any decrease effort. This may cause extremely hot inside the internal space especially during daytime. Further, if the concrete is thick enough [8] the time lag will worsen the internal thermal condition since the diurnal is small. The temperature difference between day and night in Indonesia is only 5-7 degree Celsius. So the night temperature is

incapable to cool the internal space since such night temperature is not cool enough [8]. This is the reason why the internal space especially upper floor is remain hot even in the night time. This bad condition may resolved better if there is ventilated roof space that enables to move the heat trapped. In hot humid area, the most problem factor that more causing uncomfortable is the height of relative humidity rather than the temperature [6, 8]. The relative humidity in reality is almost always reach 90% averagely, even the air saturated frequently, meaning that the air is incapable to accommodate vapor anymore as its relative humidity is reaching 100%. In fact, the way of removing the water vapor within internal space [6, 9] is only by passing air movement in order to throw the vapor away out of space. This means that cross ventilation in hot humid area is definitely needed, either horizontally through wall openings, or vertically through stack effect system. By stack effect, the air movement is not only based on pressure, but also temperature, and air density difference. That is why stack effect is usually more effective in dense area [3, 6].

##### 4.4. Unavailability of opening protection

Indonesia as hot humid area has very high temperature in hot season, and high precipitation in rainy season. In rainy season, rain water splash may enter the space through the opening frame if the opening is not protected well, as when strong rain comes it is often windy that causes rain water penetrate. Beside rain water, sun heat is also big problem to thermal comfort. Using devices, before entering the internal space, sun heat can be cooled first by the air movements outside the space. Otherwise direct sun heat which hits the internal space may cause overheated inside and resulting uncomfortable condition. In this case, protection meant must not always be devices, cantilever or screen, but it can also be realized by pulling the openings a bit (1 meter) to the inside from the dome skin line in order to give space for sun and rain protection as well as ventilation.

#### 5. Improvement proposal

##### 5.1. Pull space outer line inward to allow shading

It is important to pull the outer plan line in order to create protection for shading although this action causes the lessening of plan area. As a result, the total diameter 7 meters approximately left only 5 meters, but for stairs, pantry and terrace the outer plan line can be maximized. While the bed room, reception and dinning space can be shaded better.

##### 5.2. Orient the opening to minimize heat gain

Orientation of opening, although protected, should avoid the east-west to minimize direct radiation. To optimize air movement, orienting the opening 45 degree to wind direction is the best [6, 9].

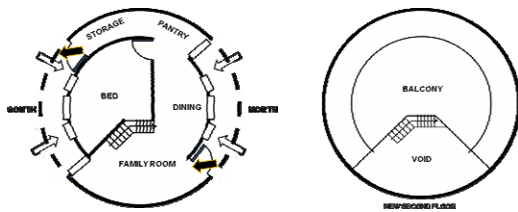


Fig 3. Proposed plan floor 1 and 2

### 5.3. Let pantry at the critical heated area

For pantry and storage, being heated is tolerable. But for family room, the disadvantaging position is resolved by the availability of permanent opening at the side wall and the roof top hole which capable to accelerate air flow assisting heat dissipation [3, 6].

### 5.4. Give hole at the roof top as an outlet to allow stack-effect works

To accelerate the wind flow, it is better to give lower ceiling which is perforated in the middle to allow stack effect principle running well. For better acceleration effort, it is required to make also a hole in the second floor, and the ceiling outside must be perforated as well. Additionally, the roof top should also be lifted to create upper side-lighting as well as roof ventilation. This air movement pattern is hoped to be able to pass the heat gain within the internal space, and capable to minimize the internal space temperature [3, 6].

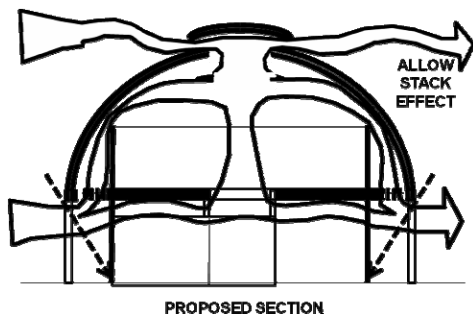


Fig 4. Proposed section of Dome

## 6. Result of CFD

The CFD simulation result shows that both the internal temperature and air movement on the proposed dome design are better than that at the existing or original dome.

## 7. Conclusion

From the color of CFD result it can be concluded that the proposed dome design indicates the improvement of internal thermal quality (more bluish) namely more air movements and lower temperature. Since the result should illustrate in color, so only few included in this paper, more illustration will be shown later in the presentation.

In order to present the improvement illustration following, is the comparison of axonometric section and CFD result between the original or existing and the proposed dome house design.

Original or existing	Proposed

Fig 5. Comparison of axonometric and CFD result between original and proposed dome house

From figure above it can be seen that the proposed dome has more holing and openings which conducted both on walls and roof. All of which are protected against sun heat and rain water.

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