

BUILDING ORIENTATION ON TRADITIONAL BALINESE CULTURE

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Introduction

Traditional Balinese reasoning of zoning area follows the physics of microcosms (*bhuwana alit*) and macrocosms (*bhuwana agung*). According to four palm leaf manuscripts (named *Lontar*) the *Asta Kosala*, *Asta Kosali*, *Asta Patali* and *Swakarman* [anonymous], the housing area is divided into nine regions. The region is then named into three sub-areas called *nista*, *madya* and *utama* (poverty, middle, and primary areas, respectively).

In traditional Balinese architecture, people follow the *hulu* and *teben* (upward and downward directions, respectively). Upwards and downwards directions are defined following the movement of the sun or the mount - sea direction. Sunrise is upward and sunset is downward, or the mount is upwards and the sea is downwards. This traditional reason is presented in Figures 1 to 5.

A simple village in the southern part of Bali is shown in Figure 6. It consists of family compounds, each side of a wide well built avenue that runs in the direction of the cardinal points; from the mountain to the sea. The Balinese make a clear differentiation between the dwelling-grounds and the unlive parts of the village, those for public use such as temples, assembly halls and market. The village is a unified organism in which every individual is a body and every institution is an organ. The heart of the village is the central square, invariably located in the center of the village, at the intersection of the two main avenues. Consequently, the crossroads are the center of a rose of the winds formed by the entire village, the cardinal directions mean a great deal to the Balinese and the crossroads are a magic spot of great importance [Covarrubias, 1972].

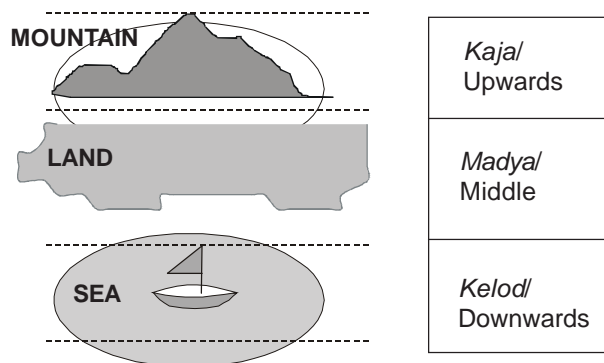


Figure 1 The Sanga Mandala concept following the mount-sea direction

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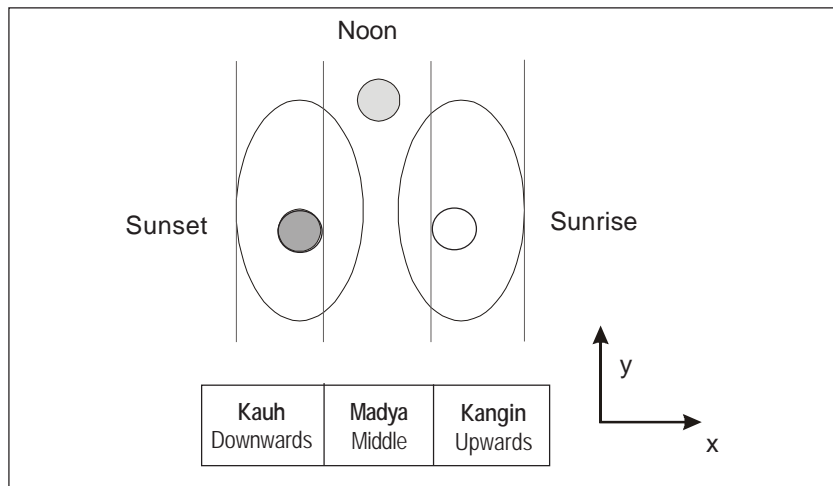


Figure 2 The Sanga Mandala concept following the sunrise and sunset

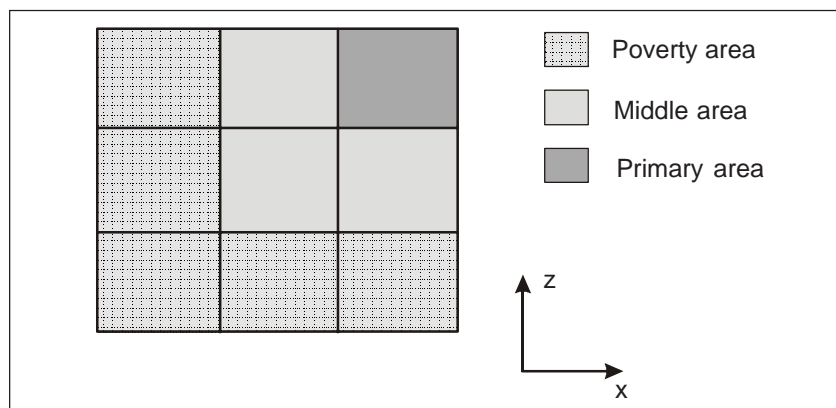


Figure 3 The Sanga Mandala concept, combination of Figures 1 and 2

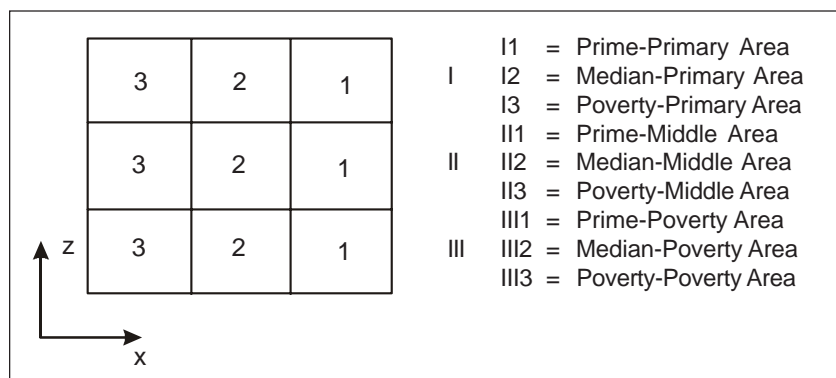


Figure 4 The zoning value of the Sanga Mandala concept

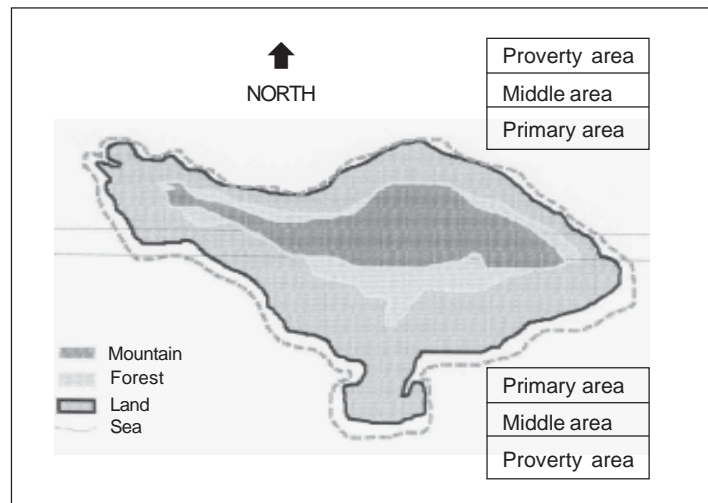


Figure 5 The Sanga Mandala concept of Bali island

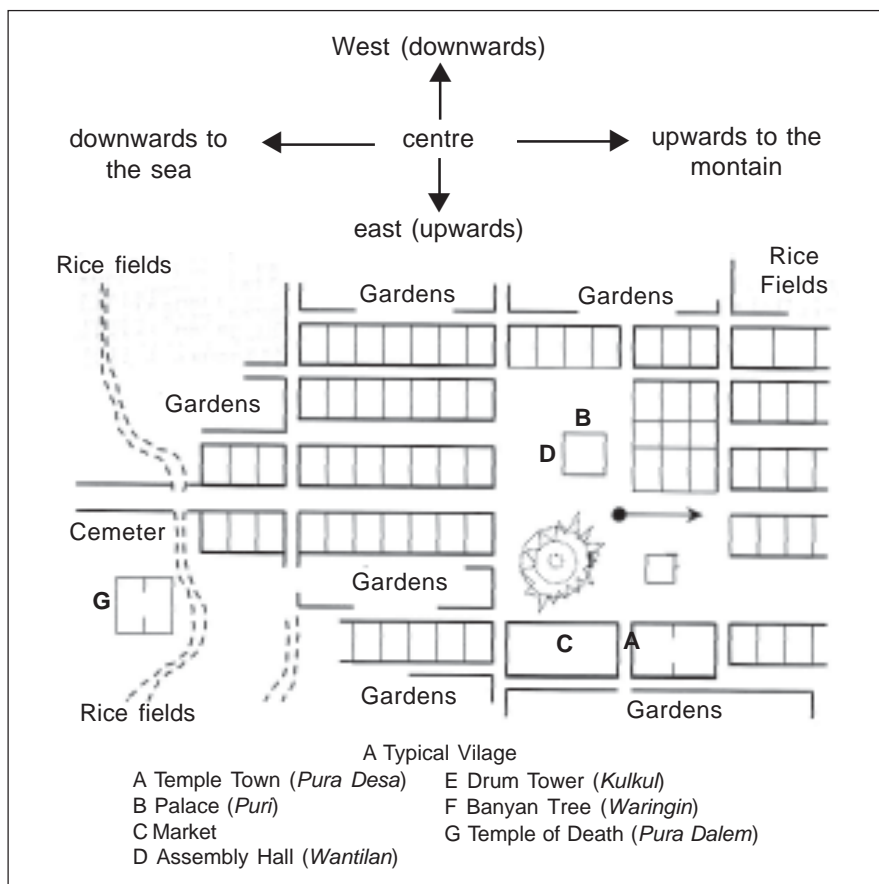


Figure 6 A typical village community

Problems

Culture does not simply constitute webs of significance, systems of meaning that orient humans to one another and their world. It may be depicted as neat and orderly and may be represented as being composed of constituent parts that articulate in a structure of logical and reassuring consistency. Culture tends to evolve with modern technology, and this often creates a conflict between the traditional and the modern. On the one hand one wants to keep traditional values, while on the other there is a tendency to change to a modern process. This statement indicates that culture can be assessed, reinvestigated, improved and developed in several manners. To resolve these conflicts, a research study is introduced in this paper that mixes modern technology in order to prove that traditional reasoning is valid and still relevant in the future.

Method

This paper examines traditional Balinese building arrangements by using numerical investigation. Three-dimensional building arrangements have been simulated in order to verify some traditional definitions such as *natar* (centre), orientation of all buildings to the *natar* and distance between buildings to the shrines of gods. To simulate traditional Balinese buildings, a complex arrangement is introduced in Figure 7. In the present study, no open surfaces at walls or roofs are considered, similar to traditional villages. A uniform distance equal to one building height, H , is used on the simulation.

In modern sites, the windward side of buildings faces the main street, but in traditional arrangements all buildings are oriented to the centre (*natar*). Therefore, in order to better understand the buildings orientation, all buildings are facing the

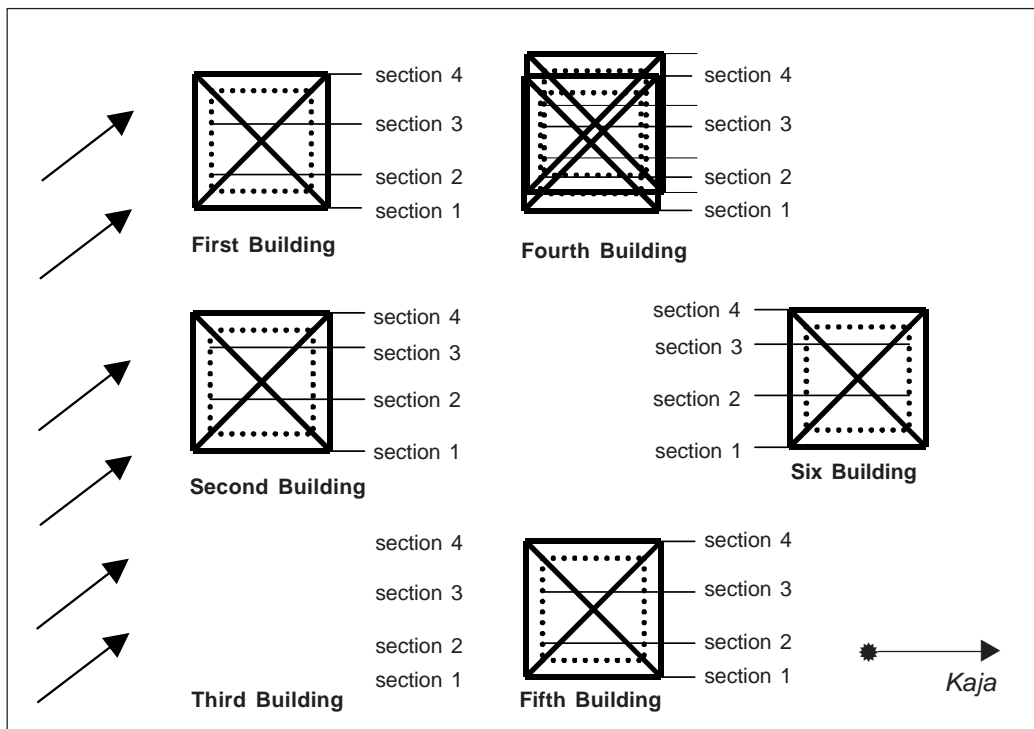


Figure 7 A top view of the buildings arrangement

windward side. Therefore, definition of *natar*, the place of honor and magic rules on traditional Balinese architecture can be understood from the simulations. None of the researchers has applied this technique, and this is a typically new method in order to find the meaning of traditional Balinese architecture.

Two reasons are considered in this paper. Firstly, to show that although housing complexes are built using modern techniques, the *Tri Hita Karana* concept should be taken into consideration. If the basic reason can be understood, the *Tri Hita Karana* concept should be adopted and applied in the urban and town planning of Bali. Secondly, this arrangement can also be applied to the original traditional Balinese buildings, since some features of traditional buildings may not be suitable for health and comfort conditions. By using similar arrangements to modern sites, the weakness of traditional architecture can be corrected, improved and developed without loss of its identity.

Results and Discussion

From streamline plots as shown in Figure 8, it can be seen that the building

arrangement produces very high velocity at the sixth building. Wind flows from the area between the first and second buildings merge with wind flows from the area between the second and third buildings, at the windward side of the sixth building. For three-dimensional problems, this distance is around one and two-thirds the building's height. Since the wind direction is at an angle, both flows merge near the windward side and deflect at the rear sides of the sixth building.

From turbulent kinetic energy plots as presented in Figure 9, it is clear that its value is relatively high in the area between the first and fourth buildings and at the leeward side of the second building. The turbulent kinetic energy is also high at the corner between the fifth and sixth buildings. If the area at the leeward side of the second building (or the area between the second, fourth, fifth and sixth buildings) is named *natar*, then it can be seen that *natar* is the place where the streamlines merge and turbulent kinetic energy is reduced. The place of the shrines of gods (in the corner, between the fifth and sixth buildings) has relatively high turbulent kinetic energy.

From turbulent energy dissipation plots in Figure 10, it can be seen that energy

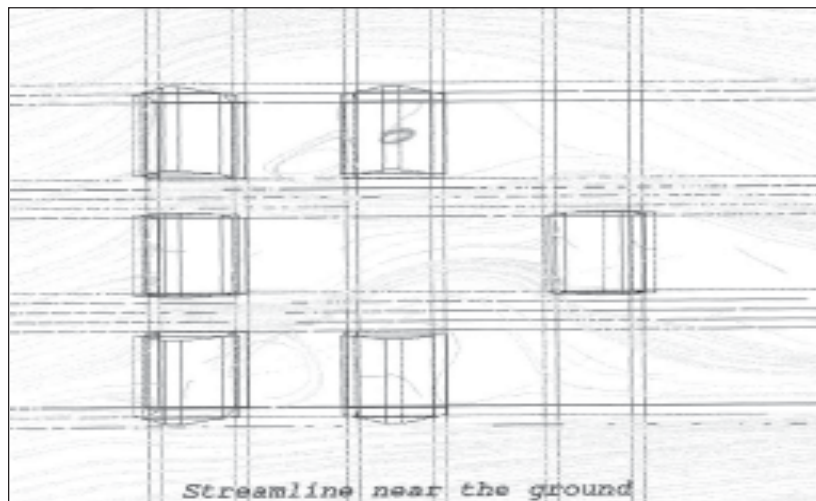


Figure 8 Streamline plot near the ground

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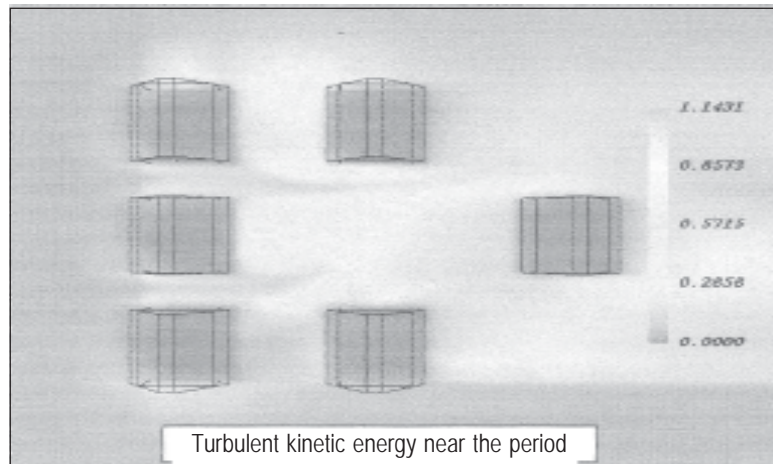


Figure 9 Turbulent kinetic energy plot near the ground

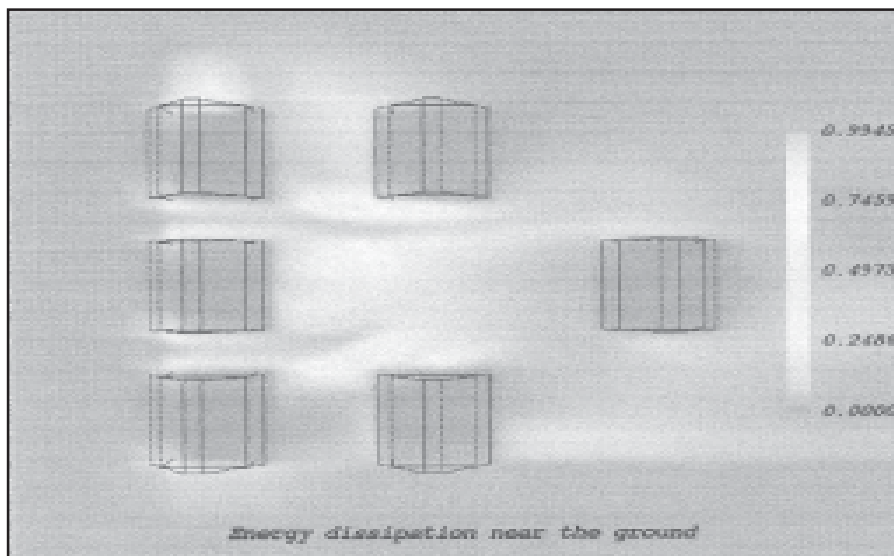


Figure 10 Turbulent energy dissipation plot near the ground

dissipation at the corner, between the third and fourth buildings, is relatively high as well as at the leeward side of the second building.

Pressure distribution around buildings is presented in Figure 11. The highest pressure distribution is received at the windward side of the first and second buildings. Therefore, drag forces at the windward side of these buildings should be

taken into consideration on the building design. Adding several posts at the windward side will minimize the wind load effects on the building surfaces.

The maximum turbulent kinetic energy occurred at the second building, followed by the third building. Therefore, the second row of buildings receives the highest turbulent kinetic energy, whatever the distance

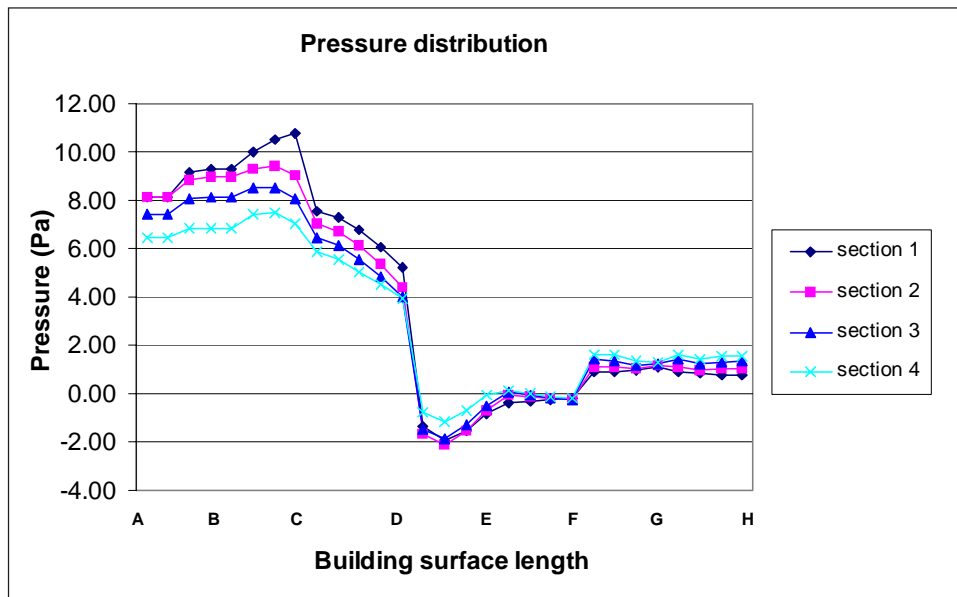


Figure 11 Pressure distributions on building

between buildings is. The results indicate that air momentum increases after separation. The separation point occurs at the first line of buildings (in this case at the second building), where the fluid near surfaces lacks sufficient momentum to overcome the pressure gradient and produces wakes at the separation regions. The interesting phenomenon is the maximum turbulent kinetic energy moves from the fourth to the sixth building, indicating the changes of direction at the separation region, especially at *natar*.

From the pressure distribution, turbulent kinetic energy and its dissipation rate, it can be stated that the distance to *natar* should be increased by moving the fourth building to a distance where the two flows -at *natar*-merge, the so-called reattachment point. At this point, the pressure distribution reaches the minimum and both turbulent kinetic energy and dissipation rate become very low. Therefore, by placing the fourth building after the reattachment point the effects of wind loads due to pressure distribution and energy can be minimized.

The fourth building does not need a floating foundation since these values become low.

Kaja (towards the mountain, upstream), leading to the sacred, is the area where momentum and energy transfer are relatively high. In Balinese world, these momentum and energy transfer are named evil spirit. Therefore, in order to reduce the negative effects of these parameters to the occupants, the sacred place should lie on this area. *Kelod* (towards the sea, downstream), leading to demons, is the area where momentum and energy are generated. This is understood since the wind is generated on the sea and moves to the land due to energy differences. Reducing the wind velocity reduces the pressure, turbulent kinetic energy and dissipation rate, or disposes of the evil spirit. Therefore, Balinese life is a constant movement between *kaja* and *kelod*, the main direction of orientation in Bali.

The *Sanga Mandala* concept is thus a concept relative to energy transfer. The wind moves from the sea to the mountain, and energy transfer (heat flux) increases proportionally to the sun-direction. Heat flux is very high at the sea and at 3 pm, but low at the mountain and in the morning. Therefore, the conditions when the heat flux is high and causes discomfort to the

populations are downstream. In opposition, the conditions when the heat (e.g. sun shine in the morning) causes are upstream.

Since the wind flows at an angle (from the south-east to the north-west in South of Bali island), the highest surface friction and drag force due to pressure occur at the south-western area, but the lowest is in the north-eastern area. The south-western (*kelod-kauh*) thus denotes the poverty-poverty area and the north-eastern (*kaja-kangin*) denotes the prime-primary area. Since the mountain lies in the middle of Bali island, the local wind in the north becomes opposite (due to eddy vortices) to that in the South of Bali island. By the same explanation relating to wind forces, the poverty and the primary areas in the North of Bali island are opposite to that in the South of Bali. This indicates that the *Sanga Mandala* concept has a strong relation to wind forces, where the lower the wind forces indicates the better area.

Zoning of traditional Balinese architecture can be associated to wind engineering and heat transfer in order to produce better comfort for occupants. The primary zone is the area where the wind forces are relatively high but with the highest heat transfer rate. This area is suitable for convalescent homes and homes for the aged. In traditional Balinese architecture, this primary zone is for the parents' sleeping quarters. The middle zone is the area where the greatest wind forces occur with a relatively high heat transfer rate. This area is then convenient for conference rooms, meeting rooms or auditoriums. In traditional Balinese architecture, the middle area is for assembly halls and ritual places. The poverty zone is the area where the wind forces are relatively high but with the lowest heat transfer rate. This is adequate for kitchens, stores or garages. In traditional Balinese architecture, the granary lies on the poverty area. From the above explanations, it is clear that traditional Balinese arrangement has a strong relation to thermal comfort.

In traditional Balinese architecture, building orientation and air circulation is from the downstream to the upstream through the centre. Therefore, it is clear that the *Sanga Mandala* concept has a strong relation with

air motion around buildings. The use of pillars in buildings will minimise the momentum effects and protect from damage caused by turbulent kinetic energy. Therefore, there is a strong relation between buildings names, e.g., *Sakapat*, *Sakanem*, *Balé Tiang Sanga* and *Balé Sakutus* (the four posts building, the six posts building, the nine posts building and the eight posts building, respectively) and the need to protect against damage caused by turbulent kinetic energy. Therefore, building arrangement should be as follows; the four posts building at the front followed by the six posts building; the nine posts building at the middle; and the eight posts building at the rear. The use of pillars can also reduce wind forces by pressure (drag) on building surfaces.

Natar is the area where the flows reattach to the ground. The pressure, turbulent kinetic energy and dissipation rate decrease here. At the reattachment point, the shear stress becomes zero and the heat transfer to the surroundings is reduced. After the reattachment point, the pressure, turbulent kinetic energy, energy dissipation and heat transfer tend to increase. Therefore, the distance between the sixth building and *natar* plays an important role in order to reduce the wind effects at the sixth building (the parent's sleeping quarters). The reattachment length also depends on the distance between the front fence and the first row of buildings, with a shorter distance producing a shorter reattachment length. From the analyses, the reattachment length is around 1.7 times the first row building's height (**H**). A shorter distance between the sixth building and the centre produces a higher turbulent kinetic energy and dissipation rate. This is explainable since the air motions are not fully developed turbulent. Increasing the distance between the sixth building and *natar* will reduce those impact on the sixth building. Therefore, the distance between the sixth building and *natar* should be around 2.5-2.6 **H**, or a distance of 4.2-4.3 **H** between the first and sixth buildings, as presented in Figure 12.

At the separation region, the formation of eddy vortices affects the flow patterns. The

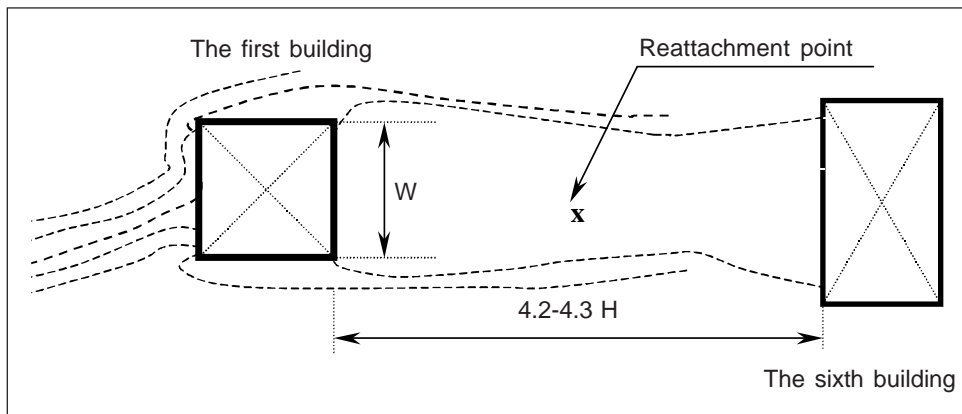


Figure 12 Design for the sixth building

separation width becomes important to adjacent structures since it becomes small at the reattachment point but enlarges thereafter. In order to reduce the wind effects, the second row of buildings (in this case the fourth and fifth buildings) should lie at the reattachment point, or $1.7 H$ times the first building height.

To reduce wind effects and cooling loads, the second row of buildings should be moved away from the reattachment point, at least 1.5 times the separation width (w) which depends on the first building width (W),

as shown in Figure 13 (a). A shorter distance between the second row and the first row of buildings results in a longer distance between the second row of buildings and the reattachment point, as presented in Figure 13 (b). Since the separation width increases after the reattachment point, the distance between the second row of buildings and the centre will also be increased, as presented in Figure 13 (c). We recommend that the second row (the fourth and fifth) of buildings should be placed at the reattachment point. Based on the above definition of *natar*, the

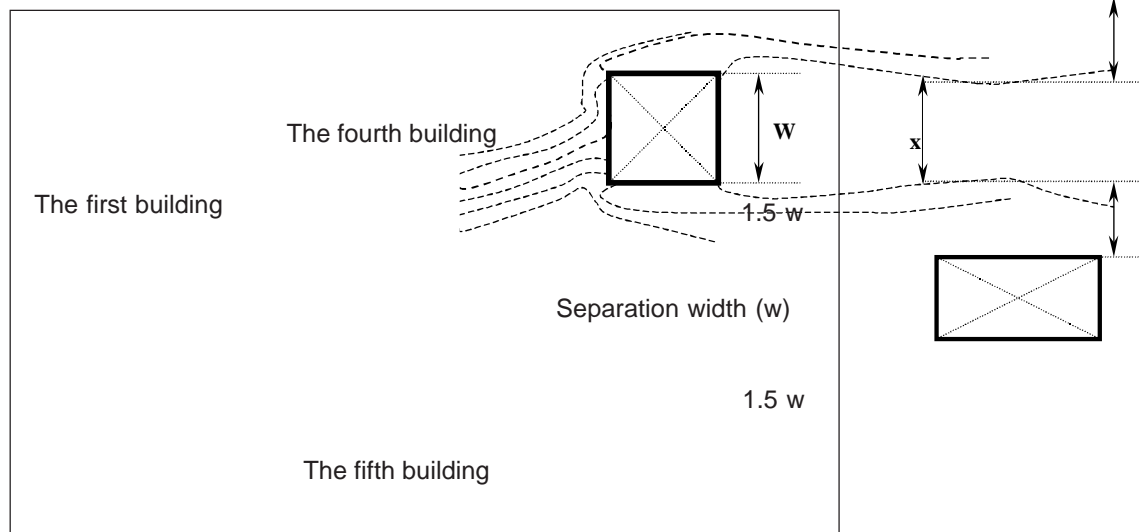


Figure 13 (a) Design for the fourth and fifth buildings, at the reattachment point

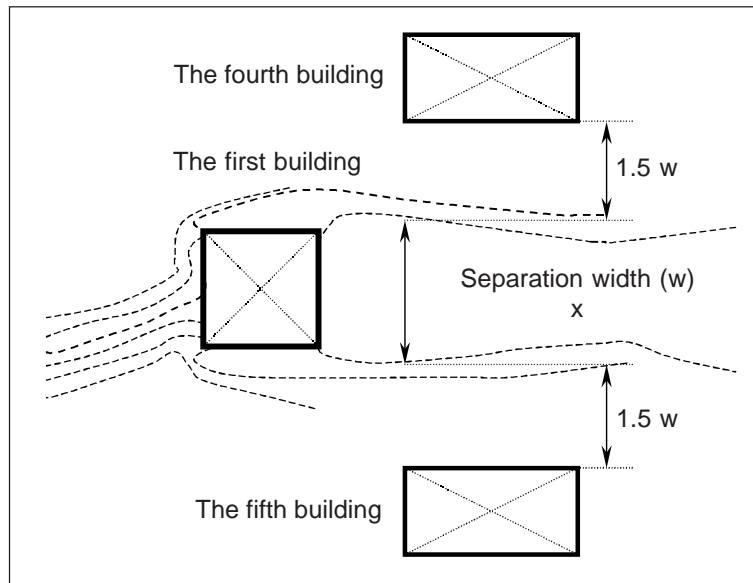


Figure 13 (b) Design for the fourth and fifth buildings, near the first building

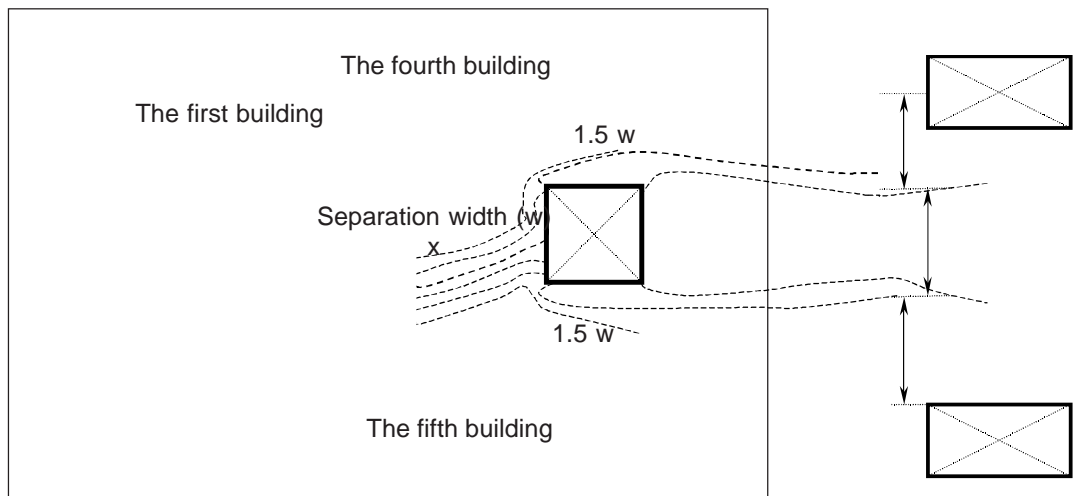


Figure 13 (c) Design for the fourth and fifth buildings, far from the first building

fourth and fifth buildings should be placed and faced to *natar*. This indicates that the reattachment length and separation width have been taken into consideration in traditional Balinese architecture, by reducing their width (**W**) and increase their length (**L**).

For better natural ventilation and beneficial air motion, inlet openings should be located to intercept prevailing winds and direct them towards the living room. Therefore, all buildings should be oriented to the *natar* in order to optimise the airflow

into buildings. This again indicates that building orientation to the centre (*natar*) in traditional Balinese architecture has a strong relation to natural ventilation and thermal comfort of occupants.

The place of honour, the higher north-east corner of the house towards the mountain, was occupied by the family temple (*sanggah kemulan*) for worshipping their ancestors. In our analyses, the place of honour is an area where the turbulent kinetic energy and dissipation rate are relatively high. According to the definition that an evil spirit has a strong relation to momentum and energy transfer, then the energy transfer in

of honour depends on the separation width at the fifth building, as presented in Figure 14.

Conclusions

Traditional Balinese architecture has always been followed by the people of Bali and contains exalted values which are considered eternal. Fluid is believed to circulate from the holy mountains to the sea, from where it returns to the mountain (as wind and rain). So, Balinese life is a constant movement between *kaja* and *kelod*, the main direction of orientation in Bali [Nordholt, 1986]. Temples and shrines follow a similar logic,

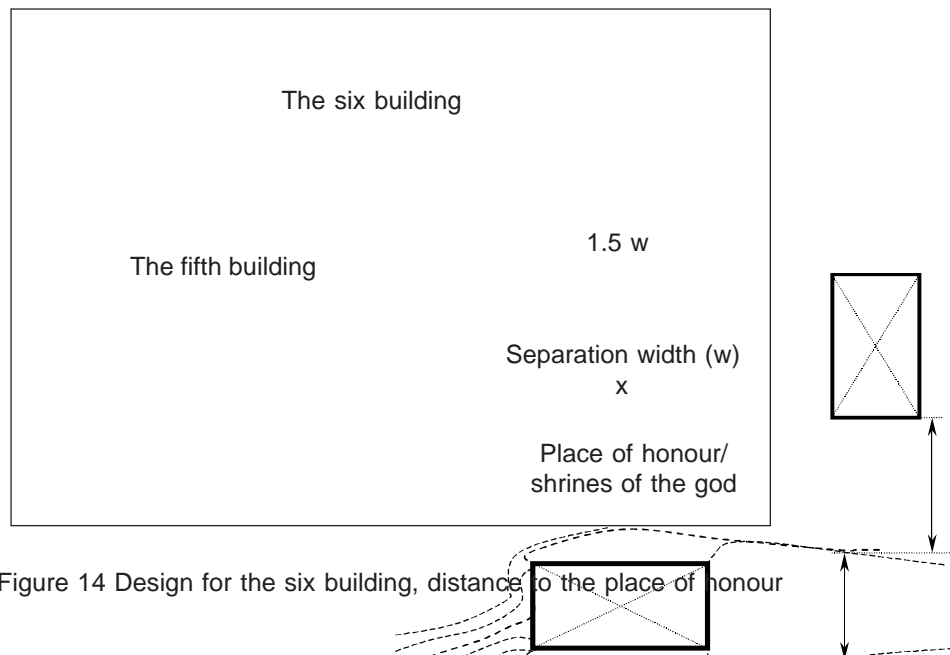


Figure 14 Design for the six building, distance to the place of honour

this area should be eliminated. The evil spirit can be contrasted with the gods. Therefore, the shrines of gods should be built in this area in order to reduce the evil spirits. We propose that the reason for building the family temple at the north-east (*kaja-kangin*) corner of the house towards the mountains is to dispose of the evil spirit around the buildings. This leads to an increased thermal comfort of occupants.

Based on this analysis, the distance between the sixth building and the place

where temples are physically located at the upstream edge of whatever system they purport to control [Lansing, 1991]. From the above description, we propose that the temples and shrines should be physically located in such a way to protect the buildings and occupants from natural disaster.

We conclude that traditional Balinese architecture is not only a traditional way of life, but also has a strong and significant correlation with several engineering fields such as wind engineering, architectural

aerodynamics, heat transfer, fluid dynamics and thermal comfort.

Traditional Balinese architecture does not only mean harmonisation between humans and their environment, but also giving protection to humans from environmental disasters. Therefore, new Balinese codes of building design should refer to the *Tri Hita Karana* concept in order to improve thermal comfort of occupants and reduce cooling loads with corresponding energy savings.

Suggestions for Future Work

It would also be advantageous if the use of numerical simulation could be extended to cover the details of the *Tri Hita Karana* concept in urban planning, such as shrines of gods and temples, especially when land occupation becomes a major problem in the future.

Given the above conditions, it would be interesting to explore the possibilities of combining the results derived herein with several fields of sciences, as a method of improving and developing the traditional Balinese communities and revising the Balinese code of building design.

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