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Research and Design of Green Tropical Architecture

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ABSTRACT

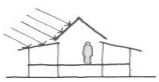
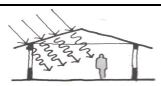
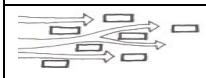
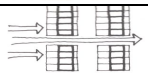
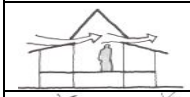
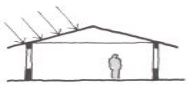
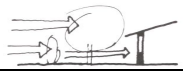
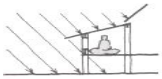
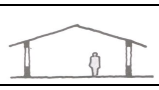
The common debate on traditional and nation architecture is always about projecting local identity on built form. The attempts are applauded especially against the western borrowed style, but the idea of architecture as befitting to the local climate is in question. This paper argues that climatic responsive design could directly be seen as significant architectural language for defining local architecture by research and design. The tropical principle illustrated an accurate prediction of controlling, filtering and responding to outdoor climate. This paper explains two research about traditional house to continuously sustain the fundamental nature that is the language of climatic understanding into contemporary solution. In the green architecture research must be evaluated local principle and purpose new tropical principle. Also in the green architecture design must be developed, justify, predicted and evaluated of design alternative with scientific reason.

Keywords: Green tropical architecture research

INTRODUCTION

The common debate on traditional and nation architecture is always about projecting local identity on built form. The architecture solution for achieving Nation identity in contemporary era commonly uses significant of cultural elements and Local artifacts to produce building as symbolic identity. The attempts are applauded especially against the western borrowed style, but the idea of architecture as befitting to the local climate is in question. This paper argues that climatic responsive design could directly be seen as significant architectural language for defining local architecture. Architecture can be described from various perspectives. The environmentalists see architecture from the environmental and bio-climatic angles. If one traces the evolution of architecture of a country that include change due to external influence, the architecture is still chiefly manifesting response to climate than the foreign cultural influence. In understanding llocal architecture, we can look from both the explicit and the implicit language. The explicit is easily understood as manifestation of shapes, patterns and forms whilst the implicit is about the soul, the spatial quality and the enjoyment of the whole architecture. Traditional architecture cleverly appreciate climate which in turn become part of the cultural understanding in creating built form. The construction technology depicted the available technology at that time but somehow illustrated an accurate prediction of controlling, filtering and responding to outdoor climate. We can put Traditional architecture into a frozen state or place into a protected inheritance for future generation to appreciate. But what is more important is to continuously sustain the fundamental nature that is the language of climatic understanding into contemporary solution. We cannot expect to duplicate, copy and blow-up the traditional scale into what we desire. It will not work. Architecture must be translate of some principle design from traditional building to modern building (Table 1).

Table 1 Design Principle of Local Tropical Architecture

Local Tropical Architecture	Design Principle	Modern Architecture
	Traditional building use lightweight construction of wood and natural materials (low thermal capacity)	
	Traditional houses are randomly his ensures that wind velocity in the houses in the latter path of the wind will not be substantially reduced	
	Roof space in the traditional house are properly ventilated by the provision of ventilation joints and panels in the roof construction	
	The use of coconut trees and other tall trees not only provides good shade but also does not block the passage of winds at house level	
	Large overhangs and the low exposed vertical area (wall, window) provide good shading	
	Lighting level give the psychological effect of coolness	

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Indonesian Traditional House

The field study is a Bena and Wogo traditional house in Flores Island, Nusa Tenggara Timur, Indonesia. The wogo traditional architecture is usually located at the foot of mountains (Fig. 1). Mountains have a great effect on the local climate. Through a suitable relation with mountains, architecture has been able to control the effect of climate. Wogo traditional architecture has utilized the effects of mountains and responded to the seasonal climate changes. Selecting the envelope material of buildings to utilize solar energy has been one of the most important elements in controlling the architectural environment. The wall of Wogo traditional architecture have had a variable and complex function so that the architectural space might have variability and adaptability. The spaces room to room, room to outside, could be easily divided as well as combined into one. This characteristic has made Wogo traditional architecture responsive of climate. As the wall of house are composed of double facade, on the outside made from bamboo trees and on the inside made from wood pairs. In Wogo's traditional architecture, a room accommodates everyday life, including sleep.

Figure 1 The Wogo housing at the foot of Mountains

Figure 2 Bamboo Wall of a Wogo Traditional House

Malaysian Traditional House

The field study is a Taman Tropika House with overall size of 10m length and 5 m width. The wall plate is about 3 m and the ridge plate at the center of the roof is about 4.2 m high from the floor surface. The Taman Tropika House represents a single space room without internal partitions. The house is surrounded by lush landscaping and lake at the rear of the house and the longitudinal axis of the house is oriented east-west. The roof is the most important building envelope component providing shelter from external climatic forces, such as solar radiation, rain and wind. Timber frames are used as roof structure covered with clay tile and timber panel underside of the tiles. The eave of the roof extends about 2.8 m from the external wall thus controls the solar penetration even at low solar angles. The middle zone is enclosed with 25 mm thick wooden horizontal louvered panels and 12 mm thick solid timber walls. The wooden horizontal louvered panels cover 80% of the wall area and positioned in all four cardinal orientations. The ventilation gaps between the horizontal louvers are about 25 mm and each panel is about 2.9 m high from floor surface. The design intentions of these horizontal louver panels are to provide cross ventilation while the openings are closed and for night ventilation. The floor is constructed with 25 mm and 150 mm wide wooden stripes. The height between the natural ground and the raised floor of the building differed from 1.4 m to 0.8 m.

Figure 3: A Taman Tropika House used for field measurements

The effectiveness of these horizontal louvers and the elevated floor in reducing the internal air temperatures needs to be explored before applying them in contemporary architectural design.

METHODOLOGY

Research Method of Indonesian Traditional House

The Wogo traditional house is surrounded by lush landscaping and the longitudinal axis of the house is oriented east-west. The roof component is providing shelter from external climatic forces, such as solar radiation, rain and wind. The eave of the roof extends about 1 m from the external wall thus controls the solar penetration even at low solar angles. The middle zone is enclosed with 80 mm bamboo horizontal louvered panels and 12 mm thick solid timber walls. The wooden horizontal panels cover 80% of the wall area and positioned in all two cardinal orientations. The design intentions of these horizontal bamboo louver panels are to provide secondary skin for passive heating. The floor is constructed with 25 mm and 150 mm wide bamboo stripes. The height between the natural ground and the raised floor of the building differed from 1 m and 0.8 m. The authors carried out a survey to determine the thermal parameters of a Wogo traditional timber house in Flores Island. The measurements were collected starting from 1 July to 2 July 2010. The instrumentation consisted of sensors with a data logger system. The sensors were setup to monitor outdoor and indoor climatic conditions. Fig. 4 shows the positions of the instrument installation within and outside the investigated house.

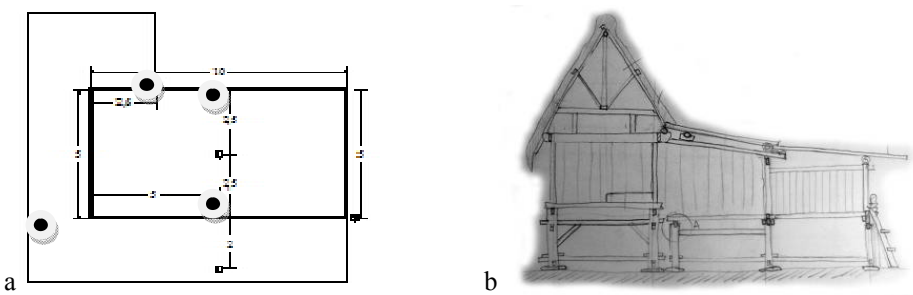

Figure 4: The positions of thermal data logger (○) a is plan and b is section

The physical measurements were carried out using air temperature and humidity data loggers. The temperatures for both internal and external were recorded at every 60 minutes interval. The data were averaged for every hour to obtain the hourly values. The temperature accuracy of the loggers ranged between 0.2°C to 0.5°C. The positions and the measured variables of the data loggers are described in table 2. The building was occupied during this period.

Table 2 The Measurement items and Method of Indonesian Traditional House

Position	Data Type	Equipment	Height
Middle of the space	Air temperature, humidity and air velocity	Lutron data logger	900 mm above the floor
Outdoor	Air temperature, humidity and air velocity	Lutron data logger	900 mm above the floor

Indonesian modern architecture ignores the natural material of building envelope. Therefore, modern architecture has a lower capacity to control its architectural environment arising from change in climate. However, all contemporary wall are different from the traditional wall, which consist of both bamboo and wood wall. A bamboo wall is not used. Therefore, there is less variability and adaptability than in traditional architecture.

Research Method of Malaysian Timber Traditional House

The authors carried out a survey to determine the thermal parameters of a prototype Indonesian traditional timber house in Universiti Teknologi Indonesia, Johor Bahru. The measurements were collected starting from 20 September to 10 October 2007. The instrumentation consisted of sensors with a data logger system. The sensors were setup to monitor outdoor and indoor climatic conditions. Fig. 5 shows the positions of the instrument installation within and outside the investigated house.

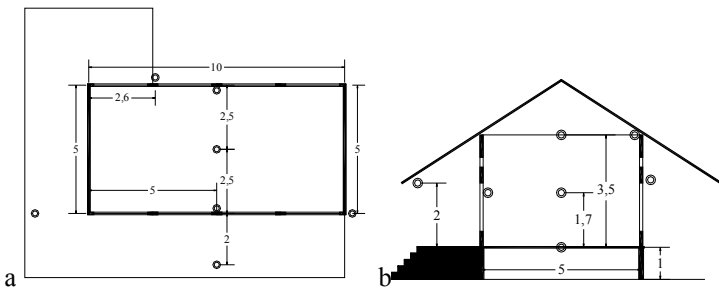

Figure 5 the positions of thermal data logger (○) a is plan and b is section

The physical measurements were carried out using air temperature and humidity data loggers and surface temperature data loggers. The temperatures for both internal and external were recorded at every 10 minutes interval. The data were averaged for every hour to obtain the hourly values. The temperature accuracy of the loggers ranged between 0.2°C to 0.5°C. The positions and the measured variables of the data loggers are described in table 3. The building was not occupied during this period.

Table 3 The Measurement items and Method of Malaysian Traditional House

Position	Data Type	Equipment	Height
Middle of the space on the floor surface	floor surface temperature	Dickson CHL	0m on the floor
Middle of the room space	air temperature & humidity	Dickson CHL	1.5m above the floor
Middle of the room space	air temperature & humidity	Dickson CHL	3m above the floor
Outdoor	**air temperature & humidity**	**Dickson CHL**	**3m above the floor**

RESULTS AND DISCUSSION

Indonesian Traditional House

The purpose of this paper is to assess the responsive wall technology for comfortable traditional house in Wogo Traditional House. The results are analysed by comparing the internal and external temperatures by the wall element. Figures 6 illustrate the results of the internal temperatures obtained at 0.9 m height from the floor level over the period of one day. This period was taken in order to establish the preliminary study the temperature over one period a day (24 hours).

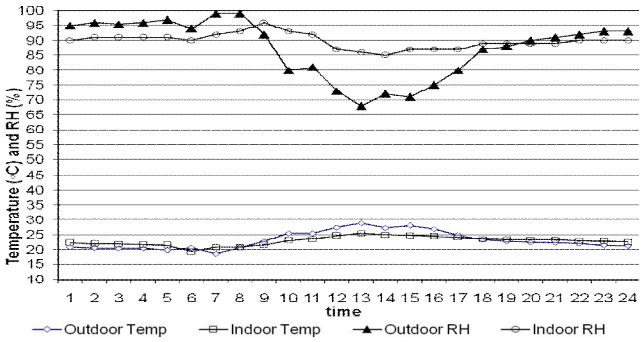

Figure 6. Comparison of internal-external temperature and relative humidity at 0.9 m height from floor level – 14 to 15 April 2009 at Wogo Traditional House

The indoor temperature showed higher value during night time, while lower value during daytime compared to the outdoor temperature. The review of maximum and minimum temperature data on each day indicated that the air temperature vary little between the day and night. The comparatively smaller temperature differences indicate that building envelope can cool down sufficiently in the day and warm up in the night therefore the responsive wall constructions are recommended. Both relative humidities indicated a higher value compared to outdoor and indoor in the night. During the daytime the indoor relative humidity measured higher temperature than the outdoor. The maximum relative humidity was indicated at 07:00h and 08:00h on respective days. However, the maximum indoor relative humidity was measured at 09:00h on both days. This means the indoor relative humidity measured high over 80% of hours within a day. This indicates that the iradiating temperature from the wall surface not influence on the indor humidity especially during the daytime. The use of bamboo as wall element had more effect on reducing the heat transfer from outside to inside during daytime compared to timber pairs. The elevated floor reduced the heat gains from the ground surface to the interior during daytime. However, the stored heat from the floor influenced the indoor air temperature to be higher than the outdoor air temperature during the night time.

One of the design problems of recent houses is embodied in the space formation which neglects the environmental conditions [1]. In fact, the reinforced concrete structures reflect the general design approach in terms of the unawareness of material characteristics and the inappropriate solutions of materials in general. The interactions between the building materials and the climatic constraints are not properly interpreted. Together with correct precautions such as additional insulation materials and necessary constructional decisions, the climatic response of the new materials can be improved in comparison with the current ones. Additionally, the local traditional materials, such as bamboo, can be developed and adapted for today's conditions by considering their sustainable features. Today's modern building materials and techniques are being used in new architectural practices with the eclectic compositional character of past images. The consequent image conveys the ambiguity of the formal expressions. Series of reinforced concrete arches with different styles and dimensions are commonly observed in the modern built environments of Flores island. The buildings have to be designed according to the nature of the building materials for reflecting the structural honesty. At this point, the role of architecture can be emphasized in terms of providing livable and peaceful habitats. Proposing new buildings that are in harmony with the existing traditional environment is as important as the rehabilitation of the old fabric. The new buildings or contemporary additions in the historical settings should include cultural values in the new design concept. This can be achieved by using new technology and materials besides the traditional ones. The concept of cultural continuity in the traditional environments can only be realized by fulfilling current requirements by using today's tools and methods without losing the local original character and spirit.

Malaysian Timber Traditional House

As illustrated in fig. 7, 30th September and 5th October were selected to analyse the internal and external temperatures. These two days were selected as they indicated the minimum and maximum external temperatures respectively, during the experiment period. The external and internal temperatures illustrate a similar pattern during day and night time.

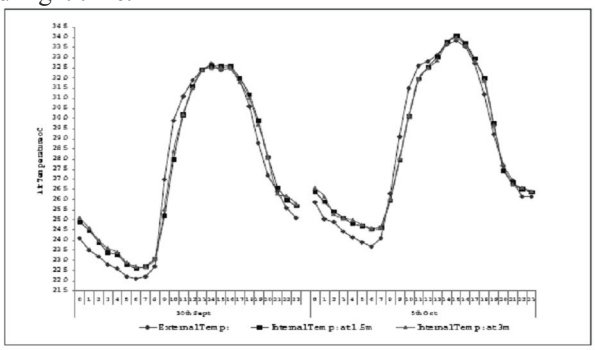

Figure 7: The external and internal temperature profile for the selected days

Similarly, the roof zone (3m height) and middle zone (1.5 m height) of the internal space indicated insignificant temperature difference. This may be due to the exposed nature with louvers of the external walls of the Taman Tropika House. This means that the effect of the wall design for cross ventilation with louvers had influence on the internal temperature to be similar as the external temperature during the day time. Further, the roof does not include any insulation materials. Therefore the heat transfer through the roof element is high. It is important to reflect or re-radiate the heat to outdoors as much as possible before entering to the space inside. Thus, the use of insulation material is inevitable with the roofing material. Use of dark colour surfaces for roof, wall, louvers and the floor also may have influenced on the high internal temperature. The external maximum temperatures were recorded as 32.7°C (14:00h) and 33.85°C (15:00h) on 30th September and 5th October respectively. The maximum internal temperatures at 1.5 m height were recorded as 32.6°C (14:00h-16:00h) and 34.1°C (15:00h) on respective days. The internal temperature recorded above the comfort range (28.5°C) between 10:00h-19:00h on both days. This emphasises that during daytime Taman Tropika House is uncomfortable with louvered openings. The minimum external and internal temperatures were indicated at 06:00h on both days. On 30th September, the minimum internal temperature indicated below the comfort limits at 1.5 m height between 03:00h – 08:00h. Although, the internal temperature increased above the external temperature during night hours (between 20:00h to 07:00h), the house is under comfort range between 20:00h at night to 09:00h next morning. Thus, uses of louvers are inadequate to control the hot air during daytime although it may control the glare and direct radiation. But during night time the louvers may help to reduce the internal air temperature through stack effect. Hence, the design principles for cross ventilation need to rethink considering the time of day and especially in areas with minimum ventilation. Further, the results emphasise the importance of the use of night ventilation in hot and humid climate.

Modification of tropical opening design had been undertaken on selected climate condition (on 19 September) within same ambient conditions. It was simplified to make easier comparison between field study and the different design configuration due to similar climatic conditions used. However, general and subjective conclusions were formulated. In the field study, the louver of the Taman Tropika House is used as a ventilation controller. A combined opening modification between full opening (100% open), no opening (close) and small louvers (0.05m) should be employed and tested for same field study design elements (roof, wall, floor). Figure 8 shows the indoor temperature and outdoor temperature of the Taman Tropika House with different sizes of opening. Generally, decrease of the opening size will decrease the indoor temperature. Further, closed opening with good insulation and wall material can make indoor temperature cooler than outdoor temperature [2].

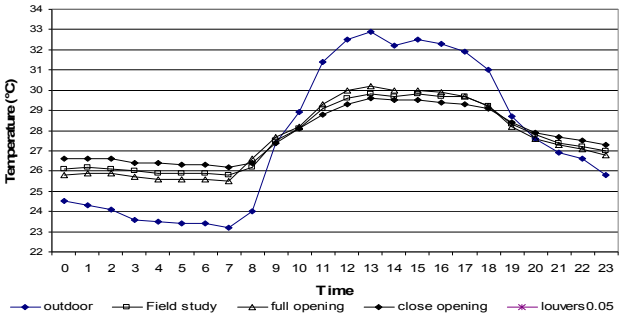

Figure 8: Indoor temperature in relation to the opening modification

However, as shown in figure 9, the temperature differences increased with reducing opening size of the Taman Tropika House model. Thus, the amount of indoor temperature without opening would be lower than that with full opening. Therefore, to anticipate the heat gain by the user (human body and equipment), the size of the opening should be smaller than Taman Tropika House louvers size. Figure 9 shows that the average indoor temperature was achieved for each correspondence of opening modifications and the upper target of neutral temperature (28.5°C) was achieved during all day except at 11:00h until 18:00h.

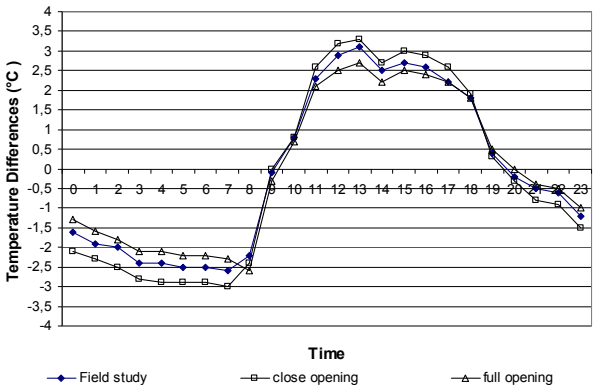

Figure 9: Temperature differences in relation to the opening modification

From Fig. 9, it is clear that when the sun is visible, the temperature reduction is higher when the opening size is minimal. The results are similar with Rosangela [3] and Prianto [4]. There is no requirement for much larger opening for the climatic conditions considered. Opening type and size should be chosen in accordance with the building passive cooling (lesser than outdoor temperature) for diurnal building operations. Small opening are advisable for night operation while for the building day operation, louver opening type should be adopted. The study is paralleled to Prianto [4] who examined various types of louver as having significant effect on the indoor comfort level. Further, Rosangela [3] also found that smaller opening for heavyweight construction provided better performance of indoor temperature

Indonesian traditional architecture has been based on the vision that it should coexist with nature. Natural phenomena were accepted and used. Therefore, the architectural environment could be controlled to manage the extreme differences in climate of the seasons and mountainous ground. In contrast, Indonesian contemporary architecture ignores the natural surroundings and relies solely on contemporary technology, which consumes a great deal of energy. Consequently, contemporary architecture has lost its ability to control its environment, and its environment is not necessarily better. Therefore, there is need for another direction for architecture. Architecture should coexist with nature. This does not mean that contemporary conveniences should be abandoned, but that they need to coexist with nature. For this purpose, there is a need to make architecture control its environment according to the natural environment. Indonesia traditional architecture and its architectural environment responsive can be applied to contemporary architecture. It is hoped that this paper will be useful to architects whose aim is to improve the architectural environment.

The aim of the first research is to assess the responsive wall technology for comfortable traditional house in Wogo Traditional House with the actual data on a selected date. The Wogo Traditional House is within the comfort range during night time when the external environment is cooler. During the day time, efficiency of the wall and louvered bamboo panels are high in order to reduce the indoor air temperature in the day and to increase air temperature in the night. Louvered bamboo panels provide required night ventilation to bring the temperature within comfort range at night. The elevated floor reduced the heat gains from the floor surface to the interior during daytime. However, the stored heat from the wall and floor influenced the indoor air temperature to be higher than the external air temperature during the night time. The heat gain from the wall surface especially bamboo material enabled to maintain the internal temperature within the comfort temperatures.

The responsibility of designers is to find the ways of analyzing and interpreting the rural Wogo housing tradition for the continuity of the tried, developed and evolved design principals in the Indonesia traditional architecture. Hence, climatically responsive and environmentally sensitive can be created. Instead of merely copying the traditional architectural elements without questioning the concept behind them, the new designs have to surpass the existing ones in the light of a new understanding. The re-interpretation and re-use of shared images and values can transfer the regular houses to Wogo house.

The aim of the second research is to evaluate thermal performance of Taman Tropika House as prototype Malaysian traditional timber house with the actual data on a selected date. The thermal conditions were also

studied based on the climatic conditions on a selected date comparing the measured and simulated results. The study also emphasizes that modification of an opening tropical design can affect the indoor thermal condition in a hot humid climate. The results of the field study measurements of the air temperatures of the existing Taman Tropika house proved that the internal air temperature is similar to the external temperature. This is due to the low maximum and minimum temperature difference experienced in the warm humid zone and due to the use of lightweight materials for construction. The Taman Tropika House is within the comfort range during late night time and in the morning hours when the external environment is cooler, while during the daytime the air temperatures were above the comfort range. During the day time, efficiency of the roof, wall and louvered panels are low in order to reduce the internal air temperature than the external air temperature at Taman Tropika House. Louvered panels provide required night ventilation to bring the temperature within comfort range at night.

The design principles for cross ventilation need to rethink considering the time of day and especially in areas with minimum ventilation. The elevated floor reduced the heat gains from the floor surface to the interior during daytime. However, the stored heat from the floor influenced the indoor air temperature to be higher than the external air temperature during the night time. The heat gain from the floor surface enabled to maintain the internal temperature within the comfort temperatures. The air temperature in the existing Taman Tropika House is considered similar compare to the outdoor temperature. The results at mid day were higher than upper limit of neutral temperature. This proved that having large roof overhang that fully shaded the wall can provide conditions similar to like being under shaded trees. Simulations of the Taman Tropika House house were developed to predict the air temperature within similar condition. The resultant indoor temperature revealed that the simulation has a good agreement with field measurement result. Based on the measurement and simulation results, the indoor temperature during day time is above the neutral temperature for all selected conditions. The investigation of the indoor temperature also showed that this house on all correspondence months experienced some temperature value of uncomfortable conditions. Generally, the Taman Tropika House experienced highest indoor temperature in the mid afternoon.

CONCLUSION

It is important to consider further the cooling solution for the afternoon times where the roof design may need to be reviewed and experimented. The indoor temperature with respect to opening size modifications indicated lower indoor temperature with smaller opening size during the day. This may contradict conventional belief that larger opening is better for tropical area. The last evaluation shows that natural ventilation performances can be improved when ventilation is modified, by reducing an opening size in the existing timber houses. Therefore, further experiments are required to determine the modification of principle design to improve thermal performance in buildings in hot and humid tropical climates. In the green architecture research must be evaluate local principle and purpose new tropical principle. Also in the green architecture design must be develop, justify, predict and evaluate of design alternative with scientific reason.

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