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Measurements of Thermal and Wind Environment of Vernacular Architecture made of Adobe in Morocco

Kiyotaka DEGUCHI* and Keiko SUGAWARA**

This paper deals with the field measurements on thermal and wind environment of a vernacular architecture made of adobe called "Kasbah" in Morocco. It has a courtyard and watch towers in corners. Investigation was carried out by measuring temperature, humidity, wind velocity, heat transfer, etc.

The thermal comfort was evaluated by the index of SET*. The courtyard is evaluated as comfort by SET* at the time of the shadow zone, and the central room at the first floor was almost comfort because of the absent of solar radiation all day long. In the environment where humidity is low, covering from strong solar radiation and well ventilation contribute greatly the thermal comfort.

Keywords: *Vernacular architecture, Morocco, Kasbah, adobe, SET**

1. INTRODUCTION

The architectural demands for the desert area of dray are asked for the technique coping with strong solar radiation and high temperature. The high thermal capacity and insulation with properties of adobe and ventilation through a courtyard are the traditional styles of the vernacular architecture in Morocco. Kasbah, a typical vernacular house in Morocco, is built by thick walls made of adobe with watch-towers in the corners. They are built in wide desert areas. It is thought that the thermal and wind environment is well protected against solar radiation and high temperature by high thermal insulation of adobe.

The purpose is to survey the thermal and wind environment of the traditional architecture, Kasbah, by means of measurements.

2. KASBAH

(1) Vernacular architecture made of adobe

Adobe is a natural building material made from soil or clay and straw, which is shaped into a mold and exposed under the natural sun. It is not necessary to burn to harden, and higher technology. Little energy is required. By such a reason, adobe has been used as building materials for many years. As the adobe will collapse if it gets wet by rain, the adobe houses are distributed over the high temperature arid region with little abundant rain of sunshine like a desert. An example of the distribution of vernacular architectures made of adobe is shown in Fig. 1. They are in many countries: Morocco, Niger, Mali, Algeria, Yemen, Iran, India, China and in U.S.A, etc [2]-[7]. The shape, the size, and the material of brick vary from region to region.

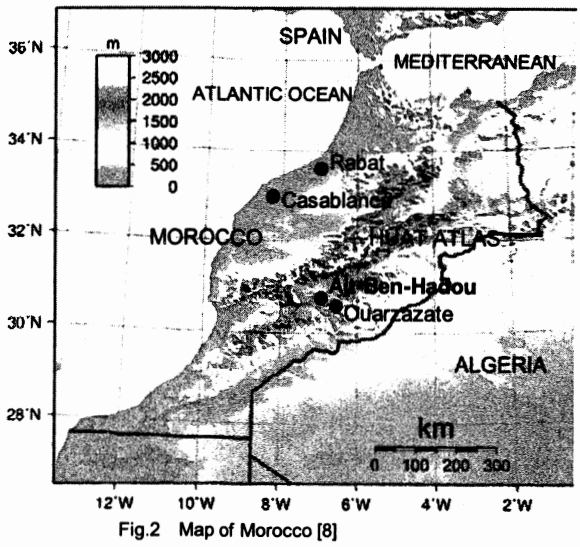


Fig.2 Map of Morocco [8]

(2) Kasbah in Morocco

The Kingdom of Morocco is famous for the typical adobe construction. In Morocco, the big cities of the capital Rabat or Casablanca are located in the Atlantic coast shown in Fig. 2. On the contrary, the south side areas of Haut Atlas Mountains in

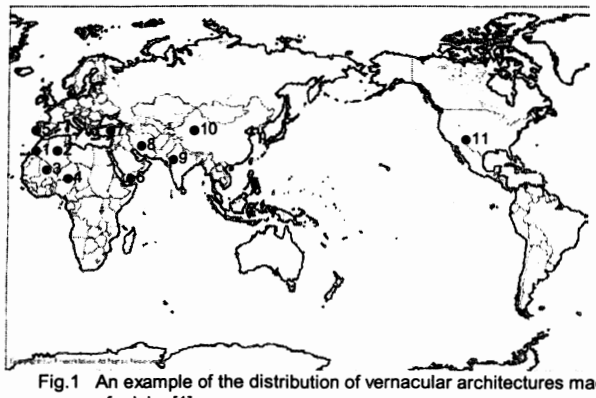


Fig.1 An example of the distribution of vernacular architectures made of adobe [1]

1: Morocco[2], 2: Algeria[3], 3: Mali[4], 4: Niger[5], 5: Portugal[5] 6: Yemen[3], 7: Turkey[5,6], 8: Iran[4,7], 9: India[4], 10: China[4], 11: USA[4]

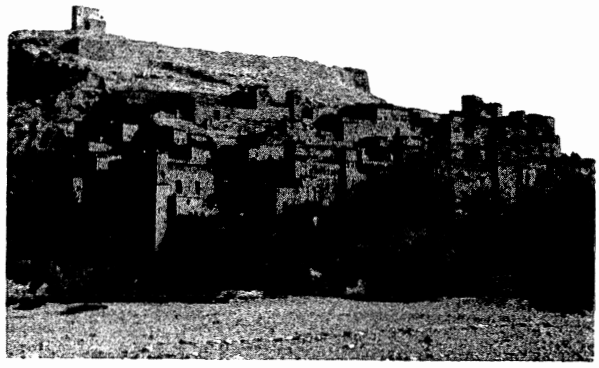


Fig. 3 A outside view of the vernacular architectures made of adobe with watch-towers at Ait-Ben-Haddou in Morocco, 2009

the center of Morocco have desert climate. They are connected with famous Sahara Desert. There are many adobe architectures in the Oasis beside several rivers on a large desert plain. The riverside way along with the river Oued Dades to the east of Ouarzazate is called the "Kasbah way" and dotted with the villages of the Adobe construction. Ait-Ben-Haddou located in the west of Ouarzazate is the village in which a group of fort like houses exists, shown in Fig. 3. These architectures are preserved finely than other areas. This area, Ksar of Ait-Ben Haddou, has been registered into the World Cultural Heritage of UNESCO in 1987.

"Kasba" was originally an African natives' storehouse of grain with watch-towers, which is equipped in the "Ksar" (fortified village), and was the fort against the nomad's attack.

(3) Climate

Fig. 4 shows the climatic data of Ouarzazate. Average monthly temperature reaches about 30 degrees in the months June, July and August, and the monthly rainfall does not exceed 50m at the maximum, September. Moreover, the annual value is only 109mm. It turns out that this area is suitable to adobe construction.

3. HOUSE FOR THE MEASUREMENT

(1) Outline of the house complex

At the village Ait-Ben-Haddou, located in west 33km of Ouarzazate, a complex of adobe made vernacular architectures stands on the slope of the hill facing a small river. It is said that the gravel portion of the previous photograph, Fig. 3, is the small river which water flows in winter and autumn, one can walk across for the low depth of water. Before the housing complex, irrigation channels have been pulled from the river,

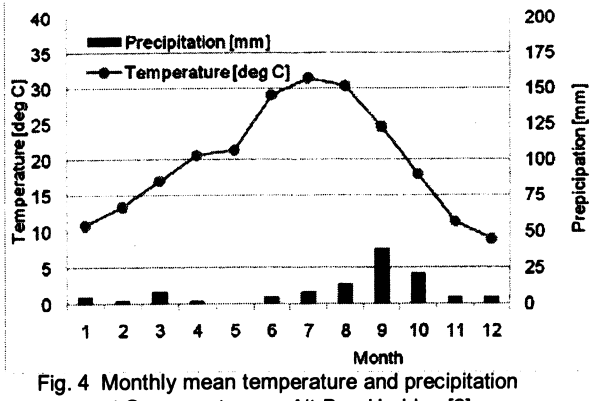


Fig. 4 Monthly mean temperature and precipitation at Ouarzazate near Ait-Ben-Haddou [9]

and crops were made in the field as oasis, shown in Fig 5. The crops mainly become the food for domestic animals such as cows and sheep. Olives and fruits are also cultivated.

The house complex is surrounded by a high rampart and the entrance is only one with a big gate. The narrow roads in the village become like a maze, and many watchtowers against the enemy's invasion are seen. Now, many residents have been moving in the flat ground by the opposite side of the river. Only about five families actually live inside the rampart. But the houses are open for tourists and used souvenir shops.

(2) Kasbah for the measurement

The measurement house faces the open space just beside the gate, and is a typical Kasbah. Kasbah is the house made of adobe with watchtowers in four corners shown in Fig. 5. The façade shown in Fig. 6 is covered with thick wall that has some small windows for watching an enemy. It has been used mainly as grain storage. The residents, an old couple and a employee, live in an adjoining housing building.

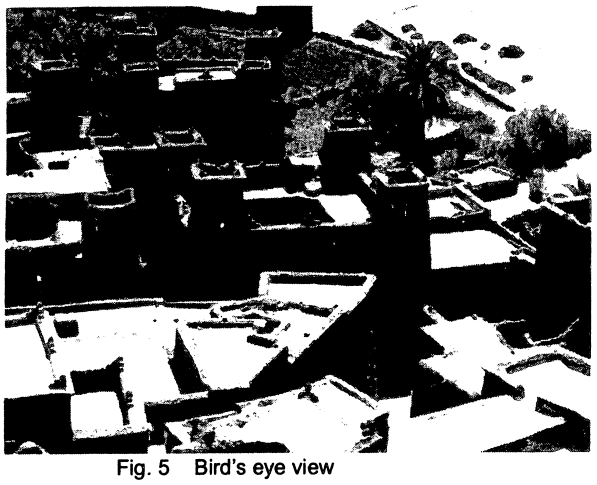


Fig. 5 Bird's eye view

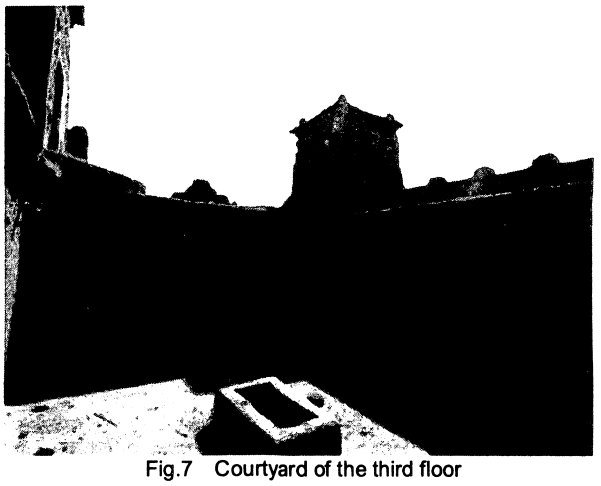


Fig.7 Courtyard of the third floor

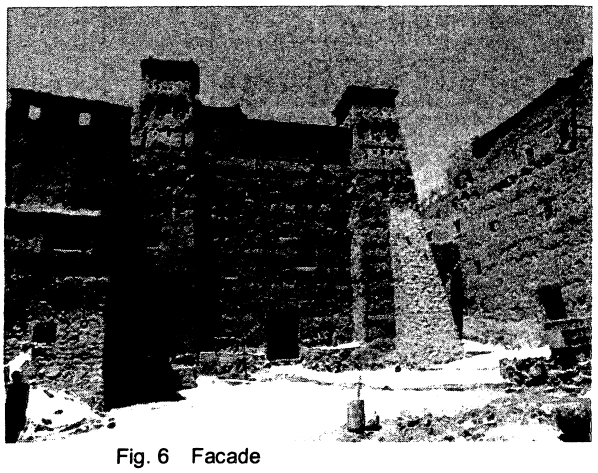


Fig. 6 Facade

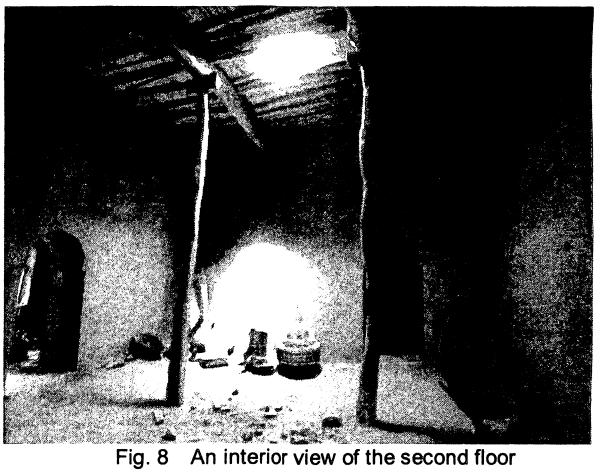
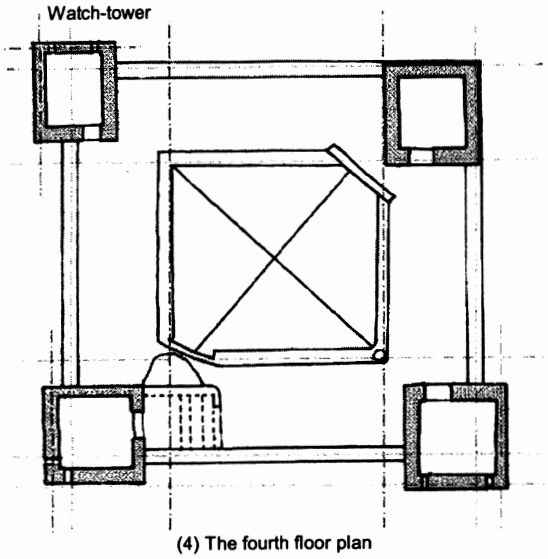
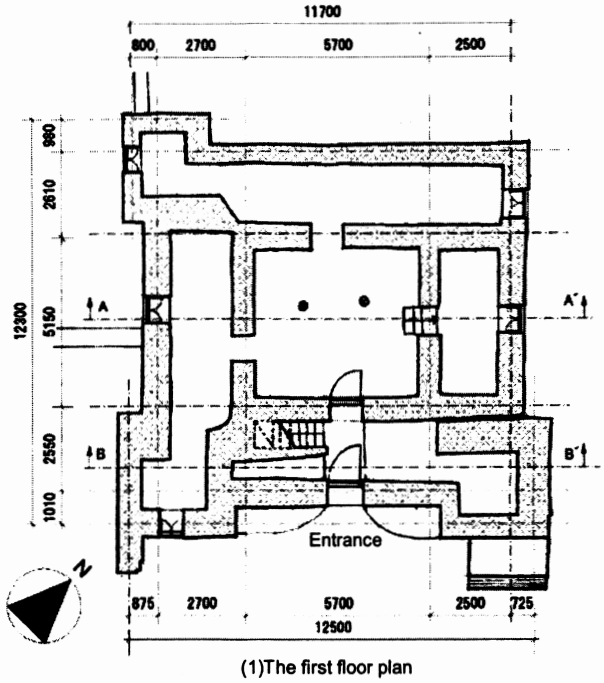


Fig. 8 An interior view of the second floor

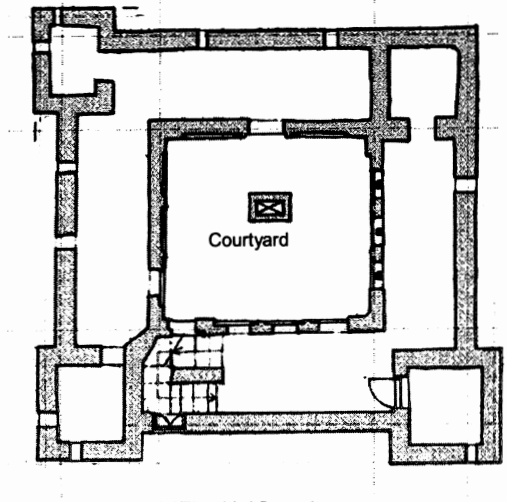


(4) The fourth floor plan

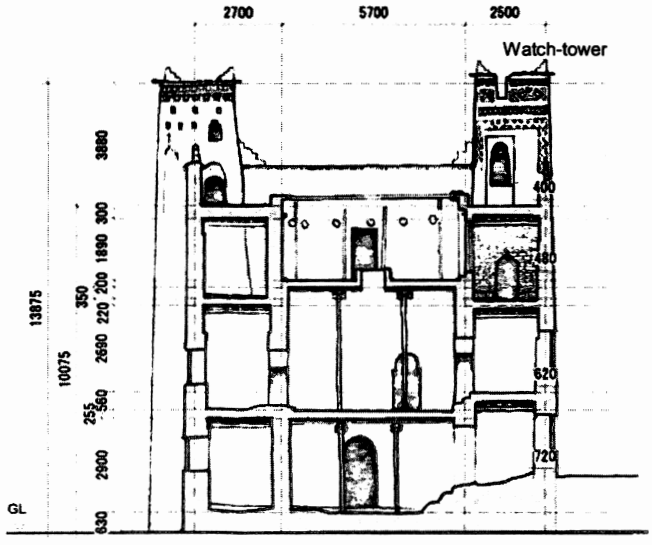


(1)The first floor plan

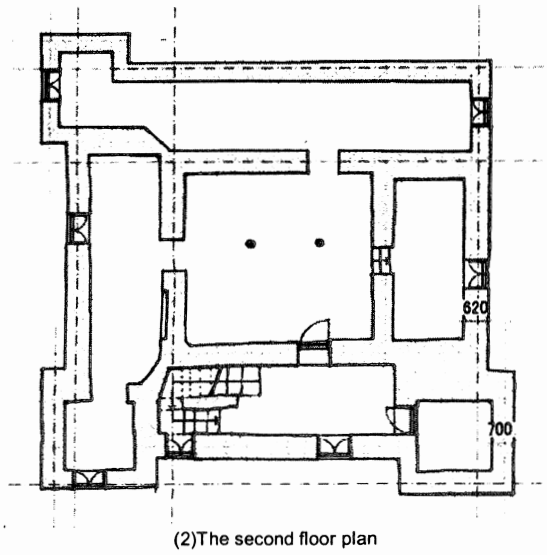
Fig. 9 Plans of the house for the measurement



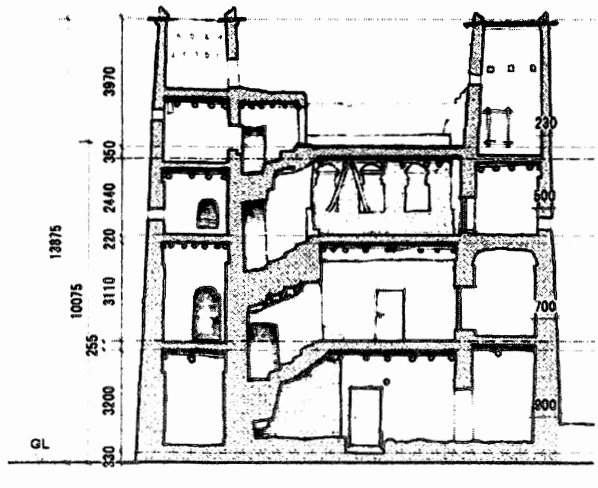
(3)The third floor plan



(1) A-A section



(2)The second floor plan



(2)B-B´ section

Fig. 10 Sections of the house for the measurement

There is a courtyard (Fig. 7) in the third floor of the building with 4 stories, and the house has a comparatively large room in the center (Fig. 8) and long rooms are arranged to surround it. The center room of the third floor has a small top light opening, as shown in Figs. 8 and 10.

The Kasbah building was built about 300 years ago and the house unit 250 years ago.

(3) Structure

The walls made of adobe block, whose sizes are 400×150×180 mm and 275×155×60 mm, have thickness of about 720 to 900 mm on the first floor and 230 mm the upper floor.

The floor is sustained on wood beams (60mm in diameter) over which is covered with plants like small bamboos (about 15-25mm in diameter) and the soil of about 60mm thickness. It shakes slightly by walking.

(4)Outline of environmental measurement

The survey for this Kasbah was carried out on Aug.12 to15, 2009.

As the external weather, wind speed and wind direction, solar radiation were measured by a three-cup anemometer (AF-750 and VF-016, Makino Sokki) and a pyrheliometer (ML-020VH, EKO Seiki) on the top of a pole installed in the south-east tower at height of 15.6m from the ground, where there is little influence of surrounding buildings. Outdoor temperature and humidity are also measured as a reference under the shade of sunlight.

As to the indoor environment, temperature, relative humidity and globe temperature were measured about the rooms of the third floor, the courtyard and the center rooms of the second and the first floor.

Wall surface temperature and floor surface temperature were measured by heat-flow meters (MF-180, EKO Seiki).

Indoor wind speed was measured by hand several times a day in some rooms.

These data were automatically recorded by data loggers (Thermic 2300A, ETO Denki).

4. THERMAL ENVIRONMENT

(1) Outdoor temperature and humidity

Solar radiation was obtained a maximum of 1073W/m^2, so that the measurement days were clear weather, and the sunrise and the sunset were recognized as 7:00 and 20:00 respectively.

The result of measurement of outdoor weather is shown in Fig. 11. Outdoor temperature reaches 43.5 degrees so that the weather was well fine through the measuring period. It is also remarkable that the temperature exceeding 40 degrees continues with about 14:00 to 18:00. The lowest temperature is 21.1 degrees around 7:00 before dawn. The daily range of temperature exceeds 20 degrees like a continental climate.

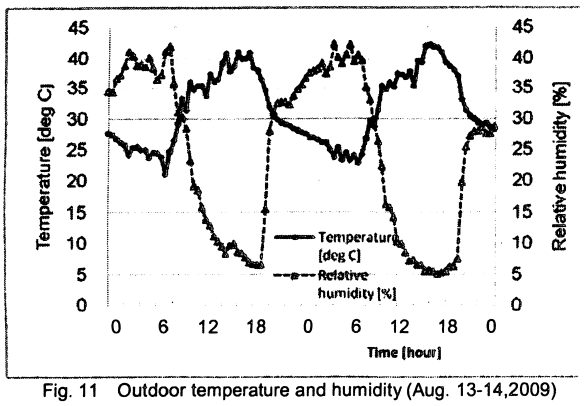


Fig. 11 Outdoor temperature and humidity (Aug. 13-14,2009)

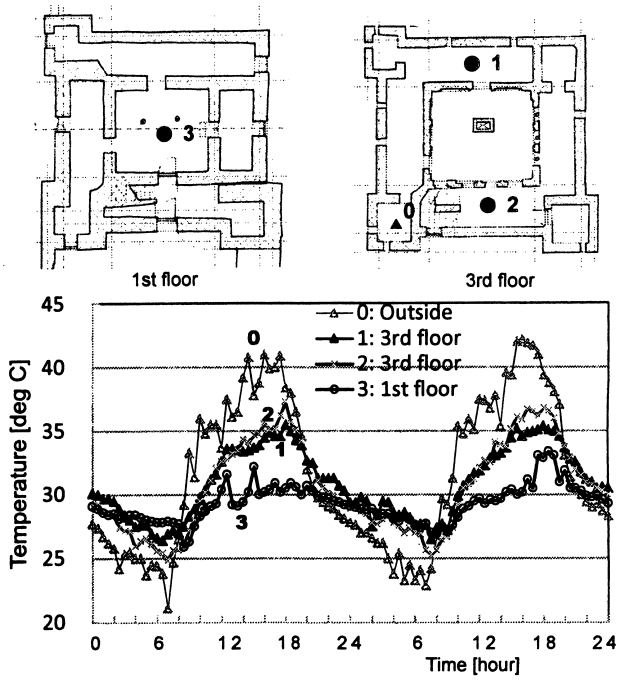


Fig. 12 Indoor temperature measured in the rooms on the 3rd floor, Aug. 13-14, 2009

Relative humidity indicates a reverse change to the temperature. Relative humidity falls to 5 to 10% at daytime and is about 45 to 40% at night time. The characteristics of the desert c are seen clearly by the high temperature, a large daily range of temperature and low damp Humidity.

(2) Indoor temperature

Fig. 12 shows the results of temperature measured in the rooms on the third floor and the first floor at height of 1.1 from the floor, with the outdoor temperature. As mentioned above, since the measurement days were fine weather, outside temperature exceeds 40 degrees, but the temperature of the third floor (Points 1 and 2) shows a value low about 10 degrees from the outdoor temperature. Both points are in the rooms open to the courtyard, especially the room of the Point 2 has 6 openings face a courtyard. In the night time, the temperature of Points 2 and 2 is higher than the outdoor. Although the influence from outdoor is received easily to the rooms, it does not extent so large.

The Point 3 on the first floor is in the central room, the temperature in the daytime is kept low by about 20 degrees. Moreover the temperature in night is about 5 degrees higher than the open air, and it was kept almost constant because the room of Point 3 is covered doubly from outdoor high temperature and strong sunlight.

The daily ranges of temperature are obtained as about 12 degrees (Point 1) and 9 degrees (Point 2) at the third floor, and 6.5 degrees (Point 3) at the first floor.

(3)Wall surface temperature

Wall surface temperature was measured on both side at the third floor, the results are shown in Figs. 13 and 14. Outside surface temperature (Fig. 13), sunlight causes rise of the outside surface temperature. So, the temperature of the south-west side reaches over 55 degrees.

Although a sudden rise of the temperature by solar radiation is seen about the outside surface shown in Fig. 13 according to a direction of the wall, supposing there is no influence of sunlight, the wall surface temperature will change between the maximum value of 37 degrees and the minimum about 24 degrees.

As to the internal surface of four outer walls in Fig. 14, the difference by the direction of a wall has little, the wall

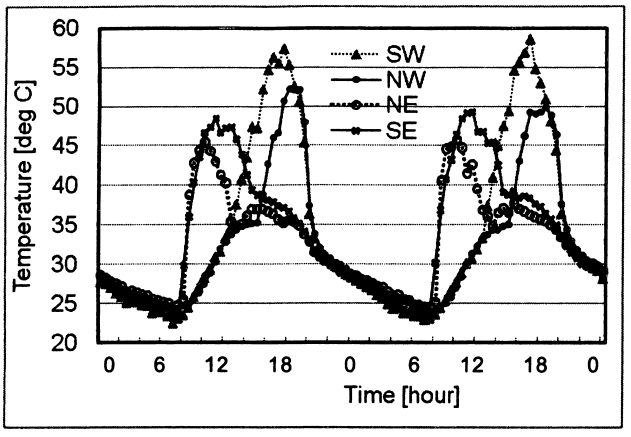


Fig. 13 Temperatures of outside Wall surface

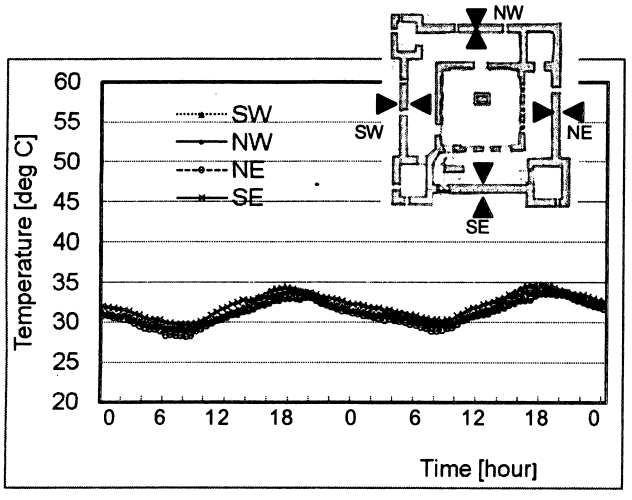


Fig. 14 Temperatures of inner side wall surface

surface temperature changes among 34 to 29 degrees, and a daily range becomes apparently small. Moreover, the time which shows the peak value is seen after 18:00, and has a time lag to which heat by sunlight from the outside surface reaches inside.

In addition, in measurement of the heat flow, the thermal conductivity of the wall was calculated with about 0.96 W/m/K.

5. WIND ENVIRONMENT

For indoor ventilation effect, wind speed was measured in several rooms, as shown in Fig. 15. The measurement was performed for 5 minutes and wind direction was observed for every minute by a light paper tip. The results are expressed as the velocity ratio of the indoor wind velocity to the reference wind speed of over the house that was measured in the same time by 3-cup anemometer at the height of 15.6m from the ground.

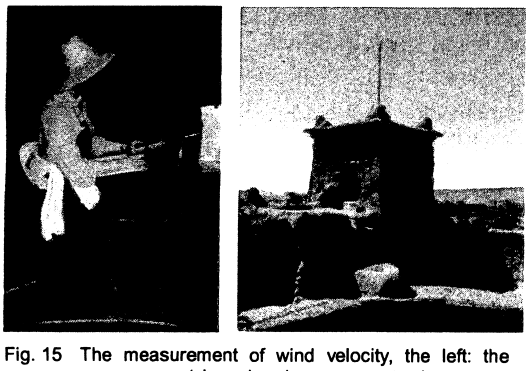


Fig. 15 The measurement of wind velocity, the left: the measurement by a handy anemometer in a room, the right: 3-cup anemometer as the reference.

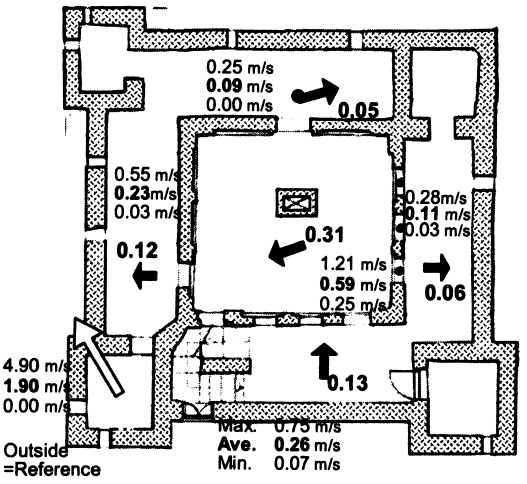


Fig. 16 Results of wind velocity, 14:00, Aug.13, 2009

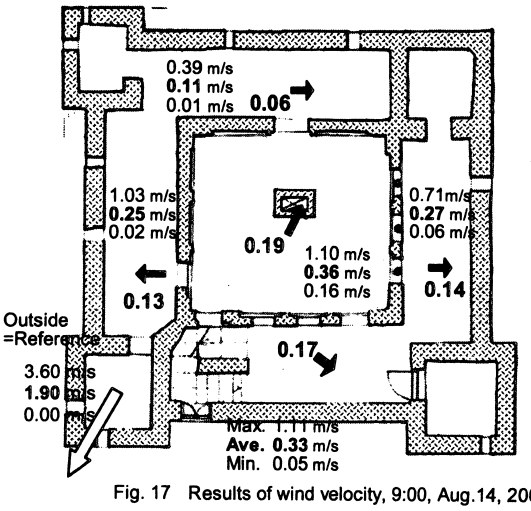


Fig. 17 Results of wind velocity, 9:00, Aug.14, 2009

Fig. 16 shows the result of the reference wind direction NWN measured at 14:00 on Aug. 13. The wind velocity ratio of the courtyard was a value of 0.31, and those in the surrounding rooms were around 0.1 of low values.

At the wind direction of N, shown in Fig. 17, the velocity ratio is as low as 0.19 at the reverse wind direction to the reference wind. Three rooms around the courtyard are somewhat larger than the wind direction NWN, and are a wind velocity ratio of 0.13 to 0.17. However, in the northwestern room, the north wind would be sheltered by the outer wall, the velocity ratio is low of 0.06.

6. EVALUATION BY SET*

SET* is the new Stand Effect Temperature for the thermal comfort in buildings, and is calculated by using thermal residence of cloth, metabolism rate, MRT, temperature, humidity, and wind velocity. SET* is defined as comfortable between 22.2 and 25.6 degrees [10].

In order to calculate SET*, the thermal residence of cloth was estimated as 0.6 clo, the metabolism rate was used 1.0 Met, the temperature, humidity and the mean wind velocity were used the measured values. The calculated result of SET* are shown in Fig. 18.

SET* of the outdoor air is the value more than 33 degrees and is evaluated as hot and unpleasant.

The central room at the first floor, Point 3 in the figure, is evaluated as the most comfortable because it is sheltered from the solar radiation by double wall and its large thermal capacity.

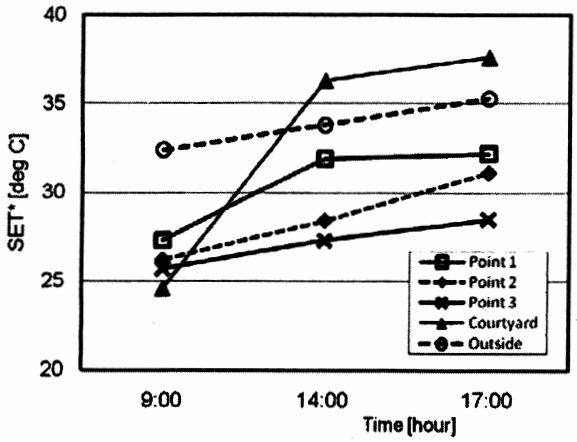


Fig.18 Results of the thermal comfort SET*, Aug 13, 2009

The room at the third floor(Point 2) is evaluated slightly higher than the central room of the first floor, by the effect of moderate ventilation. The room of Point 1 is estimated to be hotter than other rooms, in the afternoon under the influence of solar radiation.

In a courtyard, evaluation is roughly divided by the existence of the influence of solar radiation. At 9:00 a.m., SET* evaluation is comfort at 24 degrees because of well ventilation and shadow from the sunlight. But, SET*s are 36 - 37 degrees with the evaluation of "very hot" at 14:00 and 17:00 p.m., since the sunlight hits the courtyard.

In the environment where humidity is low, covering from strong solar radiation and well ventilation contribute greatly comfort.

CONCLUSIONS

The environmental measurement was carried out in summer about Kasbah, the typical Adobe made vernacular and following knowledge were acquired:

1) Outdoor temperature reaches 43.5 degrees, under the fine weather of the daily maximum solar radiation was 1073W/m^2.
2) The daily ranges of temperature are obtained as about 12 degrees (Point 1) and 9 degrees (Point 2) at the third floor, and 6.5 degrees (Point 3) at the first floor, as opposed to the daily range of outside temperature amounting to 20 degrees.
3) The courtyard was well ventilated as the velocity ratio of 0.19 – 0.31 and the surrounding rooms of the courtyard were the values of velocity ratio of 0.06 to 0.17.
4) The courtyard is evaluated as comfort by SET* at the time of the shadow zone, and the central room at the first floor was almost comfort because of the absent of solar radiation all day long. In the environment where humidity is low, covering from strong solar radiation and well ventilation contribute greatly comfort.

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Mr. Jamel Dine MOHUMED, the owner of Kasbah, was readily consented the survey. Ms. Ayaka AKIYAMA of Ksour Voyages aided us at the application of investigation and helped towards solution on the occasion of the trouble on a customhouse. Mr. MOHUMED took part as an interpreter.

Ms. Asuka HARADA and Ms. Nana HARADA, Students of Hosei Hosei University, volunteered to participate in this survey. The survey and data analysis were conducted by students: Yutaro IGARASHI, Keisuke MAMIYA, and Momoko YATOMI of Hosei University.

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REFFERENCES

[1] http://www.sekaichizu.jp/atlas/worldatlas/p800_worldatlas.html
[2] Paul Oliver, Dwellings, Toyo Shorin Publishing Co. Ltd., November 2004.
[3] Akira FUJII, Colony inquiry, Kenchiku Shiryo Kenkyusha CO., Ltd. 2000, p72-79.
[4] Shuji FUNO, World housing magazine, Showado, 2005, p140-141, p154-155, p186-187, p186-187, p276-277, p310-311.
[5] Yoshio KOMATU, LIVING ON EARTHnt of an earth life, Fukuinkan-Shoten Publishers Inc., Jun 1999, p50-51, p94, p192-193, p200, p284.
[6] Kiyotaka DEGUCHI, Kohei IGUCHI, Takashi ODAKA, Keisuke SAITO, and Rui MATSUZAWA, Thermal and Air Environments on Cave dwellings in Cappadocia, Turkey, Bulletin of the Faculty of Engineering, Hosei University, No.43, March 2007, pp.27-34.
[7] Kiyotaka DEGUCHI, Yoshihito UENO and Youhei KAWANO, Ventilation Effect and Evaporation effect of Traditional Houses with Wind-Catcher in Iran, Bulletin of the Faculty of Engineering, Hosei University, No.42, March 2006, 27-32.
[8] http://commons.wikimedia.org/wiki/Atlas
[9] Meteorological Agency, A terrestrial month climate value weather report 2008.
[10] The Society of heating , Air-conditioning and Sanitary Engineers of Japan, The mechanism of comfortable warm temperature environment, MARUZEN, 1997.

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