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Ventilation Effect and Evaporation effect of Traditional Houses with Wind-Catcher in Iran

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This paper deals with the field measurements on thermal and air environment of traditional houses with a badgheer on hot arid regions in Iran. To know the effect of the badgheer, measurements were carried out on two houses with the different type badgheer. The house with a badgheer of one wind direction typed is mainly effective of the inflow of air. And the house with a badgheer of multi wind direction typed is effective of the inflow and outflow of air. Evan, a half outdoor space facing to the north, is thought to be comfortable in summer by findings of SET*.

KeyWords : Badgheer, Field measurement, thermal and air environment, humidifying cooling, ventilation

1. Introduction

Iran is in the sphere of Israrm, and from a religious reason there are many courtyard houses closed for the outside. Because rooms are thought to be poor ventilated, a wind-catcher called badgheer is necessary. The purposes of the badgheer are to take the wind in the building, and to make the room a comfortable space by ventilation. Yazd is famous city there are many traditional houses having the badgheer device and a pond in the courtyard to cooling effect against hot and dry summer.

This survey was carried out to clarify the effectiveness of the badgheer and verify comfort of the indoor and outdoor environment by measurements of the thermal and air environment on traditional houses with the badgheer.

2. Outline of the measurements

2-1 Measuring period and areas

Two areas were chosen for the measurements: Ardakan and Yazd in Iran. In Ardakan, measuring period was on Aug.4 to 5, 2005, while from Aug.6 to 8 in Yazd. These two cities are in Yazd state, and are located in the center part in Iran highlands. This state is enclosed surroundings by the desert, and the severe environment. Fig.1 shows the map of Iran.

Yazd is one of the traditional cities in Iran. There are the house built with the sundried brick and the badgheer of multi wind direction typed in the old city. Ardakan is at a position north of about 56km of Yazd. Their badgheers in this town face north. It is one of the most intereting subjects to verify the difference of effect of two types.

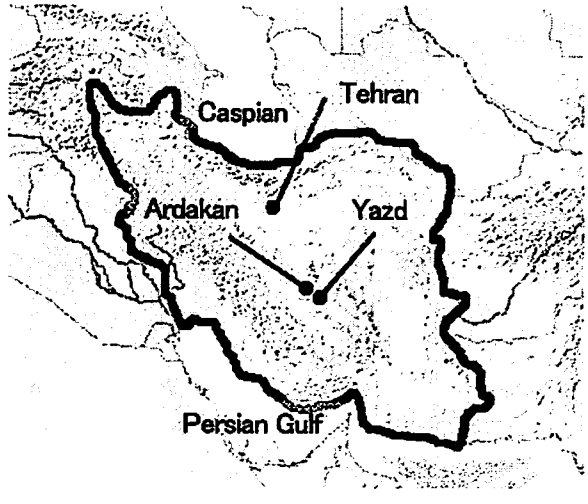


Fig.1 Map of Iran

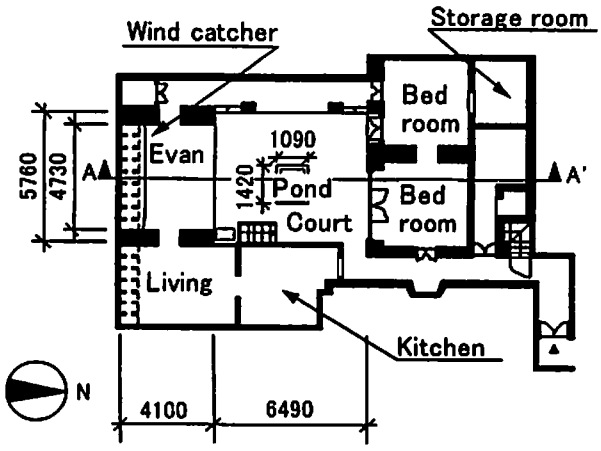
*Department of Architecture

2-2 Outline of measuring houses

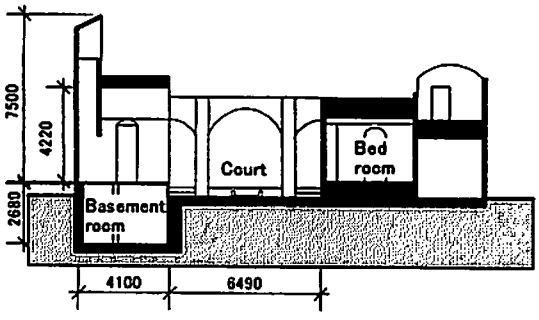
(1) Ardakan

Measurements were taken place at Hatefi's house in Ardakan where plan and section are showed in Fig.2. This house is the small-scale house with a badgheer of one wind direction typed. The house is built in the area where many buildings are crowded. All streets are narrow, and are covered in high wall.

This house has a pond and roof-typed plants (Photo 1 - Photo 3) in the courtyard. There is the Evan in the south of the courtyard, and the badgheer is located. The fan wasn't used though it was installed in the ceiling of the Evan. There are the kitchen and the living room in the east side of the Evan, and the basement under the Evan. The room on the north side of the courtyard is made use of as a bedroom. The occupants have been spending indoors at hot time of daytime.



(1) floor plan



(2) section A-A'

Fig.2 Plan and section of Hatefi's house

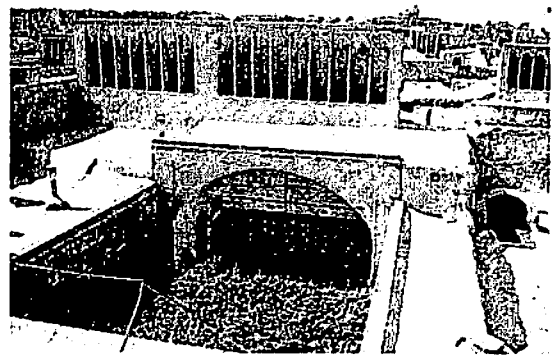


Photo 1 Exterior view of Hatefi's house

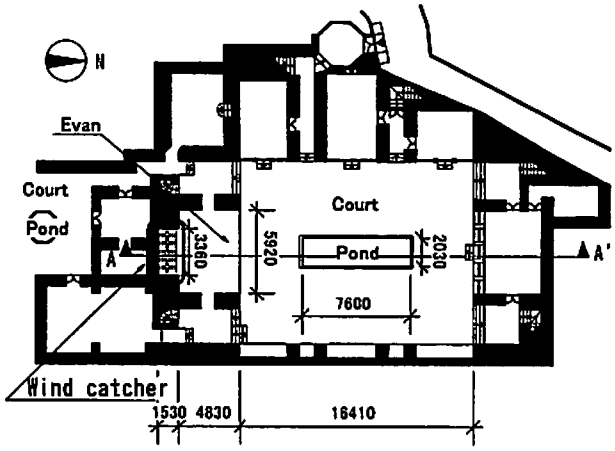
Photo 2 Courtyard

Photo 3 Evan through the coutyard

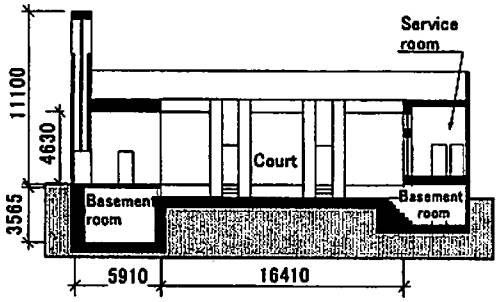
(2) Yazd

Measurements in Yazd were carried out at the Malek's house with a badgheer of four wind direction typed. Fig. 3 shows a plan and a section of this house. Malek's house is a large house having two courtyards. No person lives now and it is under a repair as the accommodations.

This house has two courtyards: the private one in the south called Andarlune, and the public one in the north called Belune.. There is the Evan in the south of the courtyard, and the badgheer is located on this. The southern room is decorated beautifully for the serving room. This house also has a basement. In addition, there is the safe under that.



(1) floor plan



(2) section A-A'

Fig. 3 Plan and section of Malek's house

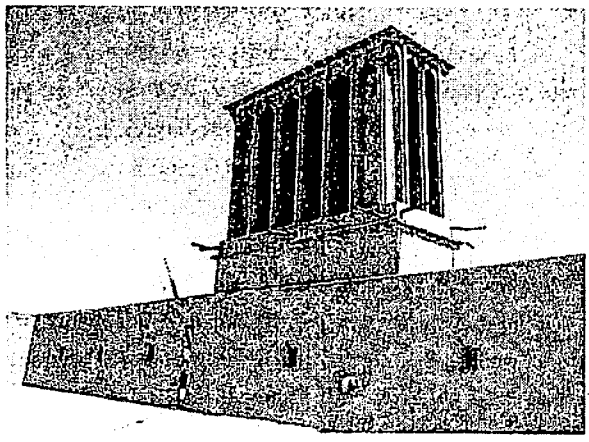


Photo 4 Close view of the badgheer at Malek's house

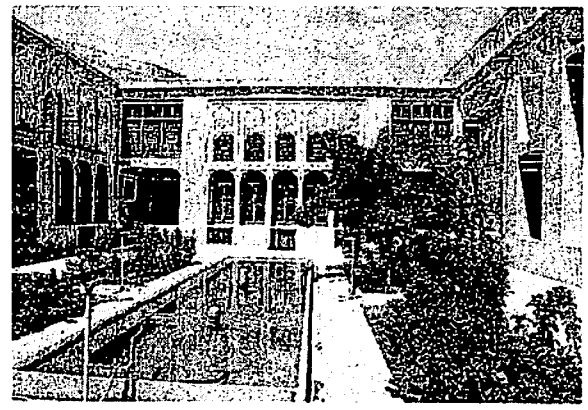


Photo 5 Cortyard (Belune)

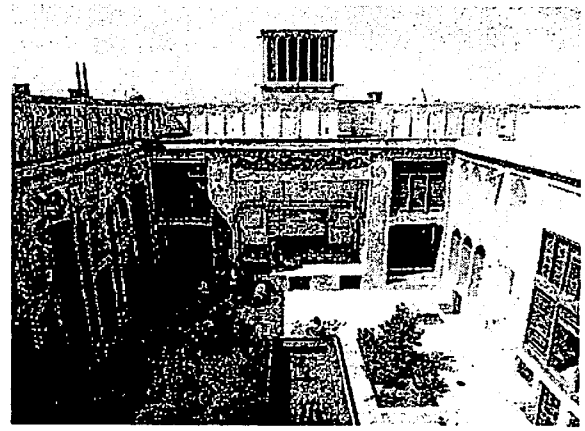


Photo 6 Evan of the Yazd house

2-3 Measuring points

At the center of Evan, each room and the basement in each house, temperature, humidity, globe temperature, wind velocity and directions were measured at height of 600mm from the floor. Vertical distributions of temperature were also measured in Evan and the basement. In the courtyard, they were measured at height of 1,100mm from the ground. Air flow with the smoke tester and wool the lower side of the badgheer were confirmed.

Table 1 shows the details of the measuring items.

Table 1 Measuring items and instruments

Items		Instruments (maker)
temperature and humidity		thermic 2300A (Eto denki) storage meter SK-L200TH (Sato)
temperature		thermo-couples
globe temperture		globe thermometer (Sibata)
wind velocity and direction	inside	climomaster 6541 (Kanomax)
	outside	three cup type anemometer AF750 anemoscope VF016 (Makino)
quantity of solar radiation		pyranometer MS-62 (Eko instruments)

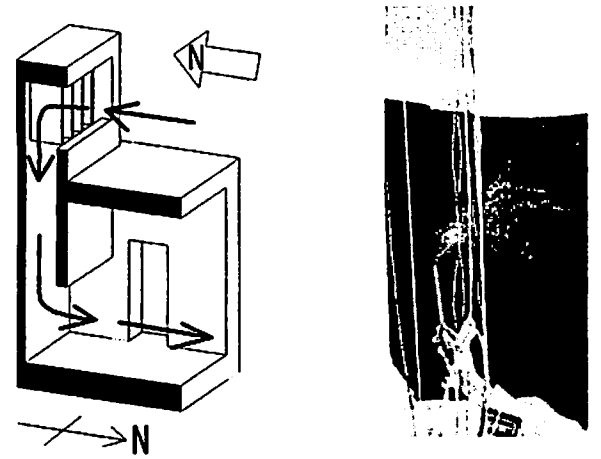
3. Results of measurements

3-1 Air flow around Badgheer

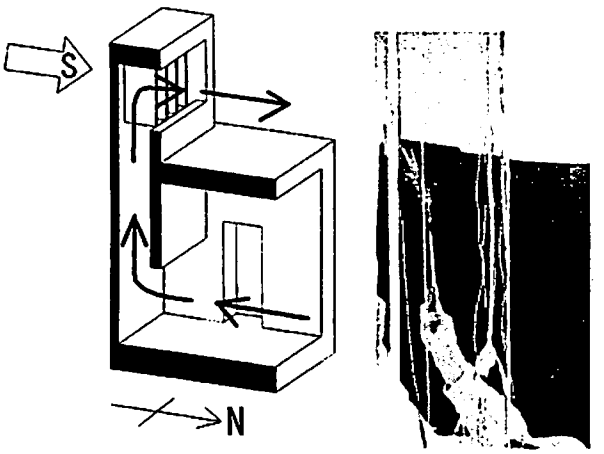
(1) Ardakan

Air flow around the badgheer was visualized with a smoke tester at height of 600mm from the floor at a lower end of the wind catcher duct.

In the case of external wind direction north, air flows from the tower to the courtyard, but vice versa in case of the south. Fig.4 shows the flow pattern around the badgheer.



(1) North Wind



(2) South Wind

Fig.4 Air flow of difference of the external wind

Fig.5 shows the ventilation rates of the badgheer by calculation. In case of the north wind, the ventilation rate increases as the wind velocity rises. But in case of the south wind such relation can't be seen.

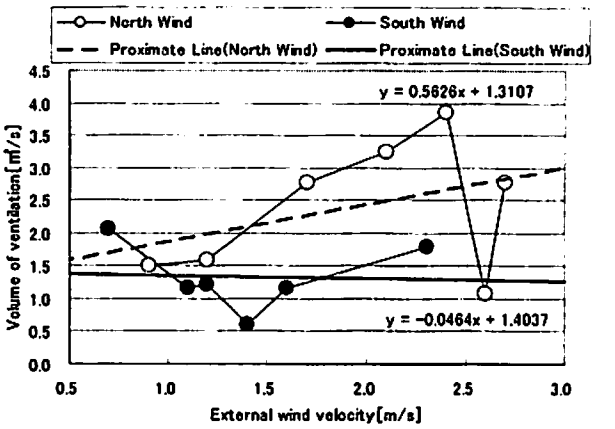


Fig.5 Ventilation volume

Fig.6 shows the percentage of appearance of external wind direction. The north wind direction is prevailing in the various directions. And, wind over 4 m/s is more abundant compared with other wind directions. Therefore it seems to be appropriate that the badgheer in Ardakan faces north direction.

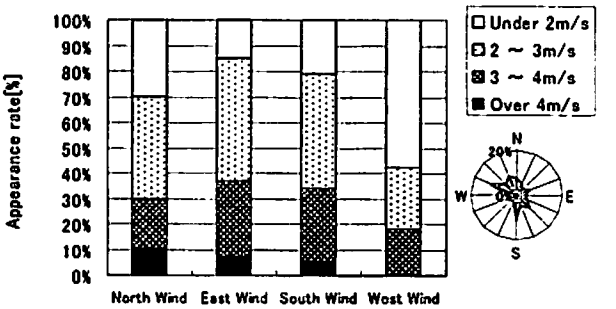


Fig.6 Appearance rate of difference of the external wind direction

(2) Yazd

The badgheer in Yazd is multi wind direction typed.

The wind speed was measured at the lower side of the badgheer of four wind direction in Yazd, at height of 600mm and 1,100mm from the floor. In most cases, air flow from the tower to the courtyard was observed in 600mm point, and in 1,100mm point, the reverse flow was observed

Air flow around the badgheer was also visualized by the movement of woolen yarn attached at the lower side of the badgheer duct. The wind was taken by the openings on the windward side, and exhausted from the openings on the leeward side. For example, when the external wind direction is the north and the east, the air flow pattern may be estimated shown in fig.7.

Average wind velocity was used for rooms, whole the average and the maximum were used for the space of Evan and the courtyard. The results of calculated SET* are shown in Fig.10 and 11.

Table4 Date to calculate SET*

(1) Hatefi's house

	Temp.[℃]			MRT[℃]			Humid[%]			Wind Velocity[m/s]		
	9:00	13:00	17:00	9:00	13:00	17:00	9:00	13:00	17:00	9:00	13:00	17:00
1)	34.1	39.0	39.5	37.2	38.7	38.7	15.2	11.6	12.9	0.33	0.29	0.60
				38.3	38.6	38.4				0.86	0.76	1.70
2)	33.6	36.9	37.2	34.1	38.3	37.5	18.3	14.3	14.1	0.02	0.02	0.05
3)	26.5	26.9	26.9	27.2	27.7	27.6	45.3	44.4	42.8	0.02	0.03	0.03
4)	33.1	39.3	39.0	35.7	41.1	38.2	16.8	11.9	12.7	0.15	0.07	0.33
				36.8	42.2	38.1				0.50	0.26	1.18

1) Evan 2) Southern Room 3) Basement Room 4) Court

(2) Males's house

	Temp.[℃]			MRT[℃]			Humid[%]			Wind Velocity[m/s]		
	11:00	15:00	19:00	11:00	15:00	19:00	11:00	15:00	19:00	11:00	15:00	19:00
1)	39.3	41.5	36.5	43.9	44.2	34.2	9.9	8.4	12.6	0.11	0.30	0.11
				45.0	45.6	33.5				0.27	1.17	0.34
2)	36.0	40.1	37.0	35.9	40.0	36.9	11.1	8.8	11.3	0.02	0.02	0.02
3)	38.6	38.7	37.0	39.1	38.8	36.9	10.7	10.7	11.2	0.05	0.05	0.05
4)	26.3	26.7	26.5	26.9	27.1	27.0	31.0	29.1	31.3	0.04	0.02	0.02

1) Evan 2) Southern Room 3) Eastern Room 4)Basement Room

※ [ ] means max wind velocity

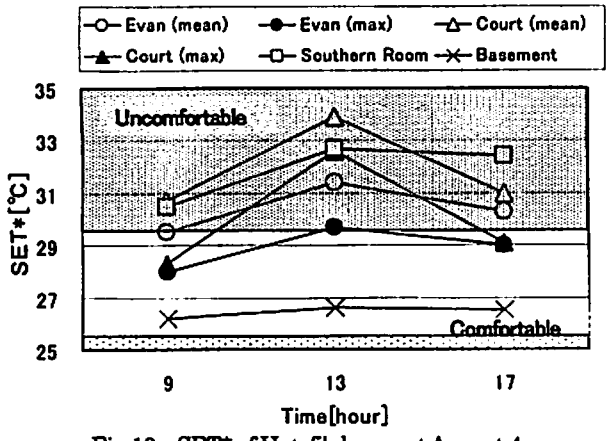
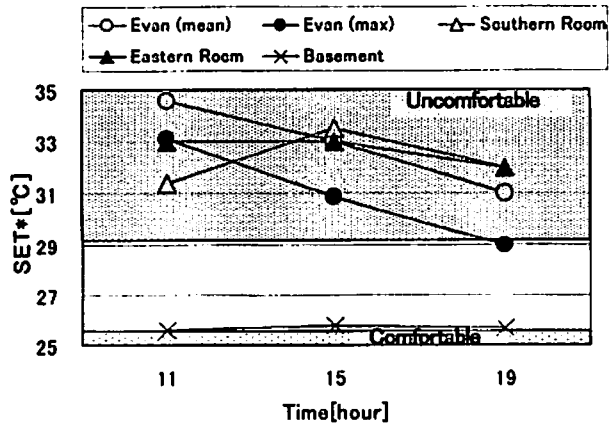


Fig.10 SET* of Hatefi's house at August 4



From Figs. 10, 11, the basement is the most comfortable space and Evan is easy to live on the grounds, by the reasons of sun-break effects, ventilation effects by the badger and the temperature characteristics of the soil.

4. Conclusions

The measurements of the traditional houses with a wind catcher in Iran were carried out, the following knowledges were obtained.

- The badgheer is effective for ventilation by the measurements of wind speed and the visualization of the airflow around the badgheer. In daytime, SET* of Evan is 3℃ lower than that of the southern room. The Evan is comfortable by sum break and the breeze from the badgheer.
- As the temperature of the basement room is about 10 ℃, it is a very comfortable space in summer.
- Humidification cooling power is expected with 7.6 ℃ in Yazd by calculation.

Acknowledgement

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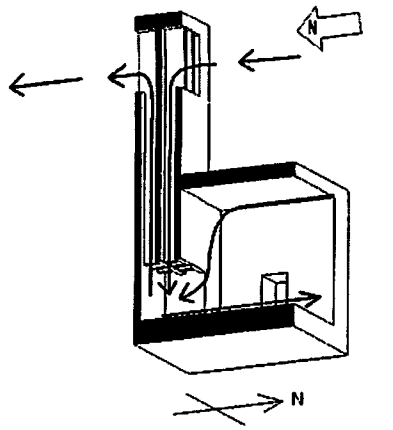
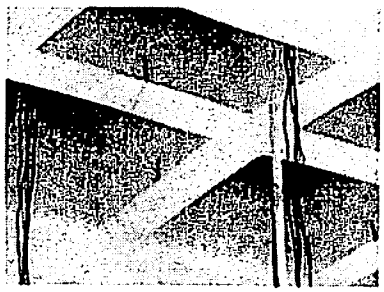
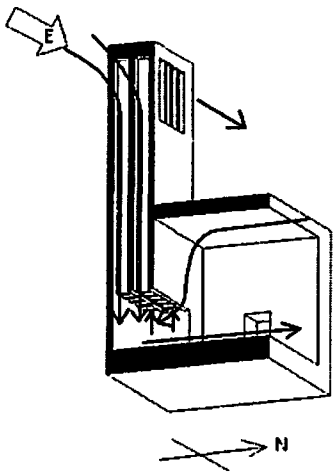
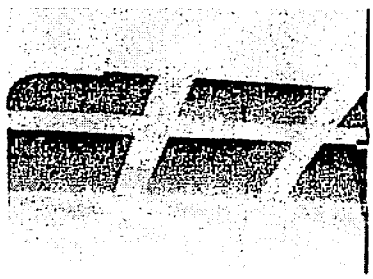




(1) North Wind





(2) East Wind

Fig.7 Air flow

Fig.8 is a wind rose of Yazd during year, based on weather data of Iranian Meteorological department. The west and south-east wind are prevailing.

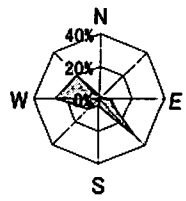


Fig.8 Wind rose in Yazd during year

3-2 Effect of humidifying cooling

As Yazd is hot arid regions, it is thought that the effect of the humidifying cooling may be large. The experiment data of Iran and Tokyo were compared, and the effect of cooling was examined. The installation situation of the water is shown in Table2, and the maximum value in the effect of the humidifying cooling of calculating is shown in table3. The effect of cooling was calculated by the following formula.

$$\theta_2=\theta_1-2.5(x_2-x_1)$$

where, the θ_1 : initial temperature, θ_2 : temperature after humidifying, x_1 : initial absolute humidity, x_2: absolute humidity after humidifying.

Table2 Installation situation of the water

	situation of the water		Other humidifying
	medium	area[㎡]	elements
Ardakan	pond	1.8	tree
Yazd	pond	18.2	watering
Tokyo	pool	1.6	—

Table3 Effect of humidifying cooling (maximum)

	date	time	absolute humidity [kg/kg']			Effect of cooling [℃]
			humidification			
			before	after	difference	
Ardakan	8/4	16:00	0.0038	0.0060	0.0022	5.50
Yazd	8/7	16:00	0.0037	0.0067	0.0030	7.60
Tokyo	7/18	12:00	0.0168	0.0170	0.0002	0.47

It has been understood that effect of cooling in Ardakan and Yazd of hot and arid region is better than Tokyo.

3-3 Thermal comfort by SET*

SET * of each space of two houses is calculated by using thermal residence of cloth, metabolism rate, MRT and measurement data of temperature, humidity, and wind velocity. MRT was calculated by using globe temperature. Thermal residence of cloth is estimated as 0.6 clo and metabolism rate is used 1.1 Met. comfortable zone of SET * is defined between 22.2℃ and 25.6℃ [D.A.McIntyre, 1980].

The table4 shows the basic data for calculation of each space obtained at Hatefi's house and Malek's house.