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Preface

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IOP Conference Series: Earth and Environmental Science, Volume 907, Digital and Empathic Engagement in the New Era for Architecture and Civil Engineering 20-21 August 2021, Surabaya, Indonesia

Citation 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **907** 011001

https://doi.org/10.1088/1755-1315/907/1/011001

Abstract

The Proceeding contains papers based on invited keynote speeches and oral presentations at the International Conference on **Digital & Empathic Architecture & Civil Engineering (DEACE 2021)** and International Student Workshop. The event was organized by the Faculty of Civil Engineering & Planning, **Petra Christian University (PCU), Surabaya, Indonesia** on **August 20th-21st, 2021** for the international conference and August 12th-21st, 2021 for the workshop as a series of events celebrating the 60th Anniversary of Petra Christian University.

The event covered several topics: 'Structural Engineering and Materials', 'Building Science and Technology', 'Construction Management', and 'Architecture and Urban Development'. DEACE presented a theme: "Digital and Empathic Engagement in the New Era for Architecture and Civil Engineering". Digital engagement can revolutionize approach to design and engineering while supporting opportunities to accommodate the implementation of advanced technology. While empathic engagement reflects not only on effectively design and build infrastructure to meet safety and other regulatory requirements, but also understanding customer essential needs. DEACE aimed to gather researchers, scholars, and practitioners all over the world to share and exchange their knowledge and breakthrough in the fields of Architecture and Civil Engineering especially toward the new era.

As the event was approaching and there was no sign of the Covid-19 pandemic slowing down earlier that year, it was decided not to postpone the event but to hold it virtually instead. The conference started with plenary sessions with four keynote speakers, and followed by parallel sessions in two rooms with four sessions. Each keynote speech took 45 minutes and 30 minutes for presentation and discussion, respectively. While speakers in parallel sessions were given 15 minutes and 5 minutes for presentation and discussion. The were 30 presenters out of 159 participants in total, consist of both academicians and professionals. They came from Indonesia as well as some other countries such as China, Taiwan, Germany, Japan and Australia. Zoom video conferencing application was used in the event which served the event very well.

Editor of DEACE 2021,

Dr. Antoni Antoni

Dr. Pamuda Pudjisuryadi

List of Welcome Speech, DEACE 2021 Scientific Committee, DEACE 2021 Conference and Workshop Coordinator and DEACE 2021 Documentation are available in this pdf.

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Scopus coverage years: from 2010 to Present

Publisher: Institute of Physics Publishing

ISSN: 1755-1307 E-ISSN: 1755-1315

Subject area: Earth and Planetary Sciences: General Earth and Planetary Sciences

Environmental Science: General Environmental Science

Source type: Conference Proceeding

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Experimental study on ventilation using earth-to-air heat exchanger in Surabaya

To cite this article: A Juniwati *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **907** 012015

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Experimental study on ventilation using earth-to-air heat exchanger in Surabaya

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Abstract. The main problem related to thermal condition in Surabaya as a second-largest city in Indonesia is humid and hot. It is a typical condition of tropical climate. Ventilation in the hot day will bring warm and humid outdoor air into a room. It will increase the temperature of air in the room. One of some efforts to reduce the outdoor air temperature is using an earth to air heat exchanger (EAHE) to transfer heat from the air to the earth or ground. This paper will discuss about research done to study the effect of EAHE to a room temperature. The study used two model rooms which are similar and a model EAHE. One room called condition room will receive air flowing from the EAHE pipe and the other room is called the referent room. From the research, it is found that the air in condition room with EAHE is cooler in the daytime compared to the referent room. The temperature of the condition room with EAHE is more stable.

1. Introduction

Surabaya is the second-largest city in Indonesia which is in a humid and hot tropical area. The average temperature of Surabaya was 27.4°C throughout the year according to web Climatic-data.org [1]. The coolest month is February which climate conditions are 26.6°C and 84% for air temperature and humidity, respectively. The warmest happens on October which data are 28.4°C and 81% for air temperature and humidity, respectively. Those climate conditions are plotted on Olgyay–bioclimatic chart. Zsokolay [2] convert it to metric system, designed to meet the comfort zone in a warm climate. To obtain the comfortable thermal conditions, certain air flow is required. The conditions become more severe in Surabaya urban areas. More dense areas are covered with hard surface and lack of open space to generate air movement and cause the phenomenon of urban heat island. Jatayu and Cahyono [3] found that urban heat island condition in East Surabaya caused the air temperature in there rise 1-1.4% in the period 2011-2016.

In these conditions, many people who live in Surabaya use fans to circulate air in their active spaces. If the outdoor air that is warm is drawn into the room, then the room will get warm instead of cooled. Kusuma [4] said that the mean radiant temperature is the most influential factor in air temperature. Other factors are the relative humidity of air, the air velocity, human's activity, and the clothing. Those factors determine the thermal environment that will affect our productivity and our health. The thermal environment closely relates to our body thermoregulatory mechanisms and circulation system. According to Zsokolay [2], the dry-bulb temperature and speed of air flowing will affect the mean radiant temperature. This research focused to the dry-bulb air temperature or called room temperature only. The room temperature can be conditioned in many ways including by transferring heat from the outdoor air to the earth or ground in a heat exchanger called EAHE before entering the room. This research wants to study the effect of supplying air from the EAHE to the room temperature.

2. Theory and related studied

An earth to air heat exchanger (EAHE) is the exchange of heat between the air in the pipes buried within the earth or ground. The energy performance of an EAHE system can be influenced by three primary factors: the EAHE pipe material, the circulating fan, and the ground characteristics and its moisture content, according to Ozgener [5]. In general earth cooling ventilation can be illustrated in Figure 1.

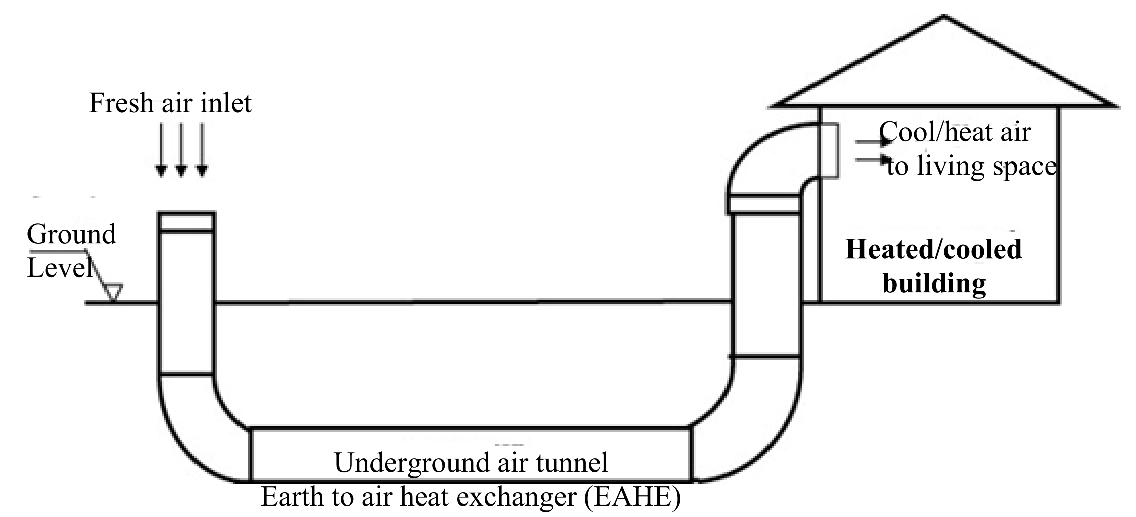

Figure 1. Earth to air heat exchanger (EAHE).

Suparwoko [6] studied the use of earth cooling tubes with and without stone on the ground surfaces at PT. Archi Link Consultant in Sleman, Yogyakarta. When stones cover the ground surface, the outside-air temperature will decrease from 33–35°C to 30-31°C at the outlet of earth cooling tubes. But, when no stones use on the ground surface, the outside-air temperature will decrease from 30–35°C to 29°C. Unfortunately, Suparwoko did not inform the depth, the length, and the diameter of the pipe used in his research. However, from this research, it is known that earth cooling tube can reduce the temperature of the outdoor air (ambient air). Meanwhile, Robert [7] found that the earth tubes can be installed at a minimum of 100 feet planted a few feet below the ground surface. This method can be used to condition the air naturally.

In this study, the soil temperature has been determined from investigation in Jamshedpur, India by Singh [8]. That is employing finite numerical method which is validated against experimental value. Diurnal variation of soil temperature is found up to depth of 0.4m, whereas annual variation is up to 4 m of depth.

3. Methodology

This research used a model of EAHE made of steel pipes. The location of the research is at the northeast corner of Q – campus area of Petra Christian University. It is an open area covered where the ground is covered by paving stones and grasses. The type of the soil in the location is an alluvial soil mix with sand and gravel. The ground water could be found in some shallow depth, such as 100 cm. The model of EAHE used in experiment is shown on Figure 2. The fresh – outdoor air is drawn into

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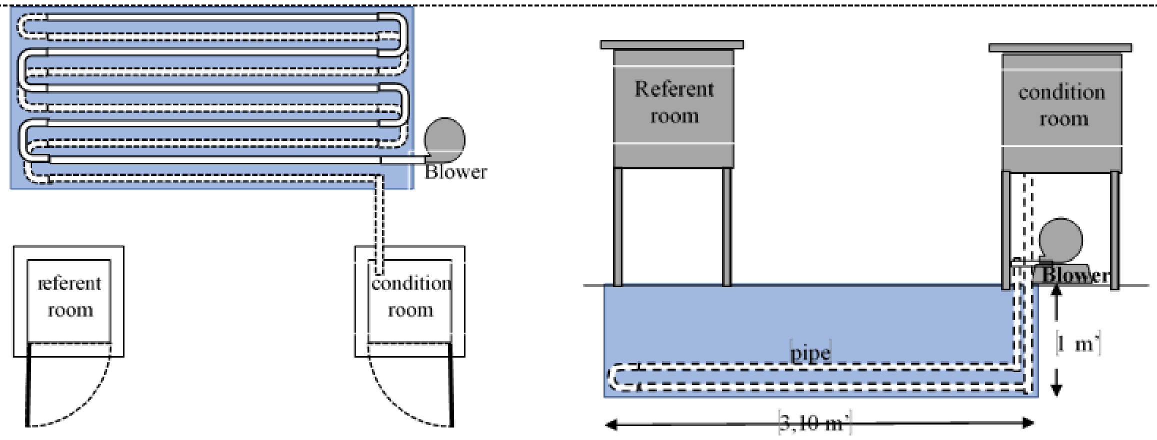
the pipe by a blower. The pipe used is black steel pipe with diameter is 2 inches and total length is 36 meters. The EAHE pipe in the ground is arranged in ten passes. To save the space, the pipe will have five passes in a certain depth (100 cm) and five passes more in different depth (80 cm) and the length of the pipes is 16.3 m. Inlet pipe length is 115 cm, where 80 cm is buried in vertical position as shown in Fig. 2 (a). Outlet pipe is 215 cm, where 100 cm is buried in vertical position, as well. To prevent heat transfer, the pipes connect with ambient will be insulated with bubble aluminum foil. Both rooms have the same dimension and volume of 1 m^3 each. All six sides of the room are covered with Styrofoam. There are two boxes. The first box is called condition room with EAHE air supply, and the other one is called referent room as shown in Fig. 2 (b). To minimize the effect of ground temperature to the room temperature, both boxes are raised 1 meter higher than the ground.



(a) Plan (b) Section

Figure2. The model experiment (a) Plan, (b) Section.

The photos of the blower, the EAHE, the condition room and the referent room are shown in Figure 3, Figure 4, and Figure 5 below.

Figure 3. The blower, that blows fresh air into pipe.

Figure 4. The bottom pipe is at 100 cm depth.

Figure 5. Two box rooms are condition room and referent room.

There are six data loggers used to record data from thermocouple used to measure the air and ground temperature. The instruments used are the Onset – HD HOBO TMC Air/Water/Soil Temp Sensors which is for use with HOBO U-Series, UX120-006M external-channel data loggers. Three of them are used with probe sensors to measure the ground temperatures, air temperatures at the inlet and outlet pipe. And the other three data loggers are used to measure the outdoor air temperature, the referent room air temperature, and the condition room air temperature.

The experiment conducted in dry season with two environments. First, the ground surface was exposed to the Sun and ambient air directly. Second, the ground surface was shaded from the Sun using a tent above the ground where EAHE buried. The field-measurements for both environments were measured from July 17 to July 24, 2021. The field-experiment was conducted outdoor. Thus, it depends on the weather condition. From the three-day data obtained, the ambient air temperatures data of all systems are shown at Fig. 6 and Fig. 7.

4. Result and discussion

The results of measurements in two environments which are (1) exposed to the Sun and (2) shaded with a tent can be found in Table 1. Data given in the table are the average of three-day measurements of air temperature in referent room, condition room, outlet pipe, inlet pipe, temperature of outdoor air, and temperature of the ground where EAHE is buried.

Table 1. Hourly average temperature of outdoor air, referent room air, condition room air, outlet pipe air, inlet pipe air and soil of Exposed Ground Surface and Shaded Ground Surface.

Times	EXPOSED GROUND SURFCE						SHADED GROUND SURFACE					
	Out door air temp.	Ref. room air temp.	cond. room air temp.	outlet pipe air temp.	inlet pipe air temp.	soil temp.	Out door air temp.	ref. room air temp.	cond. room air temp.	outlet pipe air temp.	inlet pipe air temp.	soil temp.
06:00 AM	27.17	25.11	31.19	36.13	35.32	33.65	26.81	24.72	30.00	34.06	34.51	31.71
07:00 AM	27.25	25.22	31.33	36.11	35.69	33.65	27.00	25.19	30.29	34.06	34.85	31.73
08:00 AM	27.99	26.57	32.01	36.09	36.41	33.64	27.81	26.81	31.04	34.07	35.90	31.75
09:00 AM	29.12	28.49	32.81	36.09	37.51	33.63	28.92	28.97	31.90	34.08	36.80	31.76
10:00 AM	30.39	30.89	33.61	36.08	38.42	33.61	29.95	31.08	32.62	34.12	37.59	31.77
11:00 AM	31.83	35.22	34.92	36.09	39.47	33.59	31.14	35.33	33.68	34.15	38.47	31.78
12:00 AM	33.52	37.29	36.73	36.12	40.48	33.58	32.41	38.65	35.89	34.20	39.17	31.80
01:00 PM	34.68	38.83	37.72	36.16	41.28	33.57	33.62	40.34	36.94	34.27	39.86	31.81
02:00 PM	35.60	40.66	38.71	36.22	41.62	33.56	34.56	41.11	37.55	34.35	40.34	31.82
03:00 PM	35.94	40.46	38.28	35.93	41.39	33.76	34.48	40.28	36.79	33.53	39.62	31.50
04:00 PM	35.35	38.61	37.06	36.01	40.76	33.74	33.87	38.56	35.63	33.64	38.96	31.51
05:00 PM	33.93	35.27	35.28	36.08	39.64	33.74	32.87	35.21	33.90	33.72	38.10	31.53
06:00 PM	32.73	31.92	33.94	36.13	38.83	33.74	31.69	31.40	32.41	33.79	37.22	31.54
07:00 PM	32.01	30.19	33.42	36.16	38.41	33.71	30.94	29.56	31.86	33.85	36.89	31.55
08:00 PM	31.30	29.30	33.13	36.18	38.04	33.72	30.24	28.78	31.62	33.88	36.58	31.57
09:00 PM	30.76	28.63	32.90	36.20	37.65	33.72	29.79	28.39	31.49	33.93	36.41	31.60
10:00 PM	30.18	28.10	32.63	36.20	37.37	33.70	29.47	27.99	31.37	33.94	36.21	31.60
11:00 PM	29.72	27.74	32.47	36.20	37.06	33.70	29.13	27.61	31.20	33.98	36.03	31.62
12:00 PM	29.38	27.19	32.27	36.20	36.65	33.69	28.70	27.07	30.94	34.00	35.66	31.63
01:00 AM	28.98	26.48	31.98	36.18	36.39	33.67	28.18	26.40	30.59	34.01	35.28	31.65
02:00 AM	28.45	26.38	31.86	36.17	36.20	33.66	27.84	26.00	30.49	34.03	35.15	31.66
03:00 AM	27.94	26.19	31.61	36.17	35.92	33.67	27.56	25.84	30.42	34.04	34.91	31.68
04:00 AM	27.75	25.67	31.48	36.16	35.82	33.66	27.32	25.49	30.24	34.05	34.70	31.69
05:00 AM	27.42	25.43	31.29	36.14	35.62	33.66	27.04	25.00	30.11	34.05	34.53	31.71

Based on these data, two graphs of hourly temperature in three days are shown in Fig. 6 and Fig. 7. Figure 6 is for the exposed ground environment and Fig. 7 is for the shaded one. In Fig. 6 and Fig. 7, the temperature of air in referent and condition room is higher than outdoor air, because there is heat transfer from the roof and walls that absorb solar radiation in the daytime. The roof and walls are exposed to the Sun and receive heat gain from it. Then, this heat gain is transferred to the air by convection all the time, not only in daytime.

The air temperature at the inlet pipe is higher than outdoor temperature because the sensor is located after the blower. A blower will increase the temperature of discharged air as it uses energy to compress the air. But the outdoor air temperature still affects the air temperature at inlet. The air temperature at inlet fluctuates following the outdoor air temperature. The ground or soil temperature is almost constant compared to the outdoor air. When the temperature of inlet air is much higher than the soil, the air will release more heat to the soil as it passes the EAHE. Thus, the air temperature will be lower at the outlet than at the inlet. The outlet air temperature flowing out of EAHE is almost constant following the earth or soil temperature. The air flowing from the outlet of EAHE enters the condition room. Since the temperature of this incoming air is constant, the condition room temperature is almost stable, as well, compared to the referent room which has no EAHE air supply. However, the condition room temperature is lower than the incoming air temperature because the flowrate of the incoming air is small and there is outdoor air that infiltrates from small aperture in the walls or roof. The condition room is warmer in the night and cooler in daytime around noon.

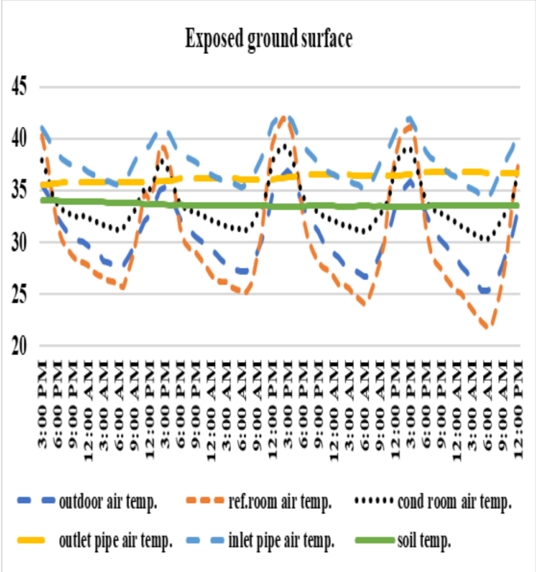


Figure 6. Hourly temperatures of outdoor air, referent room, condition room air, air in inlet pipe, air in outlet pipe and soil in exposed environment.

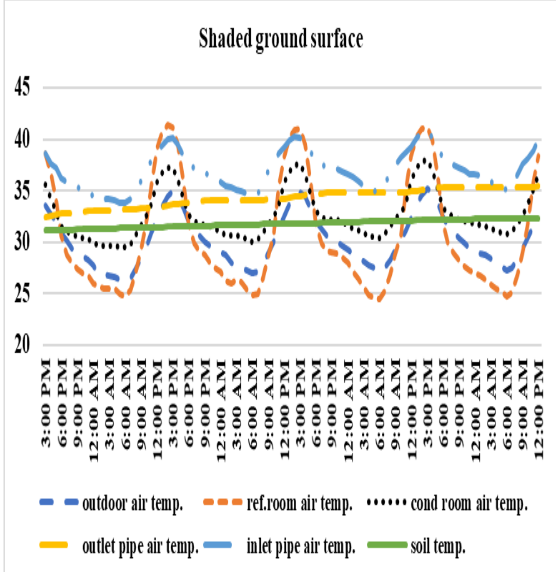


Figure 7. Hourly temperatures of outdoor air, referent room, condition room air, air in inlet pipe, air in outlet pipe and soil in shaded environment.

The result of using EAHE when the ground is exposed directly to the Sun is shown in Fig. 6. The lowest temperature occurred at 06.00 AM. The three-day average air temperature in condition room is 31.19°C. It is 4.02°C warmer than the outdoor air and 6.08°C warmer than the referent room. While the highest temperature occurred at 03.00 PM. The three-day average air temperature in condition room is 38.65°C. It is 2.1°C cooler than the referent room and 2.57°C warmer than the outdoor air. The condition room gets cooler than the referent room from 11:00 AM to 04:00 PM. Without EAHE, the referent room temperature reached 40.75°C and it was 2.1°C warmer than the condition room.

The result of using EAHE when the ground is not exposed but given shading over it is shown in Fig. 7. The lowest and highest temperature occurred at the same time, i.e., 06.00 AM and 03.00 PM, respectively. The lowest of average air temperature in condition room is 30.00°C. It is 3.19°C warmer than the outdoor air and 5.28°C warmer than the referent room. While the highest of average air temperature in condition room is 37.60°C. It is 2.60°C warmer than the outdoor air and 3.49°C cooler than the referent room. As in exposed ground, using EAHE in a shaded ground makes the condition room cooler compared to referent room, longer from 11:00 AM to 05:00 PM.

From Fig. 6 and Fig. 7, the soil temperature and the air temperature at the outlet pipe are cooler when there is shading over the ground. The soil temperature is 1.71°C cooler in shaded ground than exposed ground and the outlet air temperature is 1.85°C cooler. EAHE used in the shaded ground makes the condition room cooler than the exposed ground. At 03.00 PM, the warmest condition, the room condition is 1.36°C cooler when the ground is shaded and using EAHE.

The soil temperature is quite high all the time whatever the outdoor air temperature, i.e., 33.6°C and 32.0°C when the ground is exposed and shaded, respectively. The soil temperature does not change and seems not effected even though there is no solar radiation. So, it needs more observation to find this strange behavior.

The condition room temperature depends on temperature of outdoor air and incoming air from EAHE (or called the outlet air). But the referent room temperature depends on outdoor air temperature only. The referent room line in Fig. 6 and Fig. 7 is following the outdoor line and has higher deviation compared to the condition room line. Thus, EAHE is useful to reduce the room temperature whenever the day is hot and EAHE is better used with a shading over the ground.

5. Conclusion and recommendation

From the experiments, it is found that the use of EAHE with a blower as an air cooling ventilation system all day long is not effective when the soil temperature is high. The outlet air from EAHE is always higher than the outdoor air. But at noon, the condition room with EAHE air supply is cooler than the referent room without EAHE air supply. Thus, ventilation using EAHE air supply is suitable when the day is hot or around noon. In the evening and morning, it is better to use cross ventilation with outdoor air. Adding a shading over the ground where EAHE is installed is useful for air cooling ventilation systems.

Another benefit of using EAHE to supply air to the room is to stabilize the room temperature. The room with EAHE air supply is not too hot at noon, and not too cold during the night. This finding suggests that EAHE is suitable to be used in any location with high diurnal air temperature, such as in highland area.

Acknowledgment

We would like to thank Petra Christian University Research and Community Service Institution for financial support of this research. And the other, we would like to thank the Vice Rector for Administration and Finance Petra Christian University and Head of Campus Services and Maintenance Unit of Petra Christian University.

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